RESTORATION APPALACHIA: A VISUAL AND LITERARY ANALYSIS OF ECOLOGICAL DISTURBANCE AND RESTORATION POTENTIALS IN THE CENTRAL APPALACHIAN COALFIELDS

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List of Abbreviations

AMD – Acid Mine Drainage

AML – Abandoned Mine Lands

AML Pilot – Abandoned Mine Land Reclamation Economic Development Pilot Program

AOC – Approximate Original Contour

ARRI – Appalachian Regional Reforestation Initiative

EPA – Environmental Protection Agency

FRA – Forestry Reclamation Approach

GFW – Green Forests Work

ICDP – Integrated Conservation Development Programs

MEA – Millennium Ecosystem Assessment

OSMRE – Office of Surface Mine Reclamation and Enforcement

SER – Society for Ecological Restoration

SMCRA – Surface Mine Control and Reclamation Act of 1977

UN – United Nations

Executive Summary

Appalachia follows the topographical boundary of the Appalachian Mountains which runs north-south along the Eastern Coast of the United States. This paper focuses on the Central Appalachia subregion of West Virginia, Eastern Kentucky, Southwestern Virginia, and Eastern Kentucky, as characterized by large-scale Mountaintop Removal Coal Mining operations. Indigenous nations reliant for subsistence on this region's ecological base were, over-time, increasingly displaced by communities dependent on resource extraction-oriented companies. This transition is chronicled through historical overviews and visual aids of Timber Harvest, Underground Mining, and Surface Mining processes. These resource extraction methods are then analyzed as ecological disturbances that damage, degrade and destroy ecosystems that previously served as an ecological base for subsistence communities. Following the overview of Restoration Ecology, potentials for ecological restoration of Appalachian minelands are presented through relevant policy initiatives and collaborative institutions that implement the Forestry Reclamation Approach. These concepts are applied through a case study of Bishop, West Virginia, whose immediate vicinity to a mountaintop removal coal mine raises concern about public health. In furthering current reclamation practices, I propose applying community-based conservation theory from international development agencies to Appalachian coalfield communities in order to benefit the present, and future generations by i) aiding in the ecological restoration of natural resources to post-surface mined landscapes, ii) providing socioeconomic development opportunities for local communities, and iii) creating sustainable eco-tourism opportunities in the region. In conclusion, I present the creation of *Uganost Cooperatives* to revitalize the ecological base as a public common to communities who were historically reliant upon the land for sustenance and survival.

1. Introduction

This manuscript used the field of Restoration Ecology as a lens to understand ecological disturbance and socio-environmental impacts in Central Appalachia with an emphasis on ecological restoration opportunities alongside visual and educational aids for Science Communication. Through a literature review compiled from journal publications, online databases, and informational interviews, potentials for ecological restoration in this region were presented as an applied collaborative practice to return ecosystem services to post-surface mined landscapes through the implementation and improvement of the Forestry Reclamation Approach. Included is a compilation of compelling and informative visual content generated through Google Earth Engine, ArcGIS software, LiDAR data, satellite imagery, aerial photography, along with archived film, maps, and botanical illustrations. Finally, a set of structured lesson plans were adapted from the long-standing West Virginian outdoor education institution, Experience Learning, and are presented with the visual content to bolster communication and dissemination of this science.

1.1 The Alleghanian Orogeny and the Great Alleghany Bituminous Coal Field

Approximately 500 million years ago, during the formation of Pangea, the present-day Appalachian Mountains began to take shape. These mountains first formed during the Ordovician period, when a dense oceanic tectonic plate sank beneath the North American plate, creating a subduction zone resulting in a mountain-building event known as an orogeny. Over the next 250 million years, a shallow inland sea formed and dying vegetation deposited along the sea bottom. The anaerobic conditions of this environment hindered the decomposition of the plant biomass. Over time, these carbon-rich deposits of peat were exposed to pressure and heat that metamorphosed into lignite, then bituminous and lastly anthracite coal seams. Finally, during the Mesozoic Era, the North American Plate separated and drifted away from Pangea. Since this separation, the Appalachian Mountains have weathered and eroded down to the iconic rolling hills, hidden hollows, and access to rich coal deposits of today (Figure 1.1) (Lutgens *et al*., 2012).

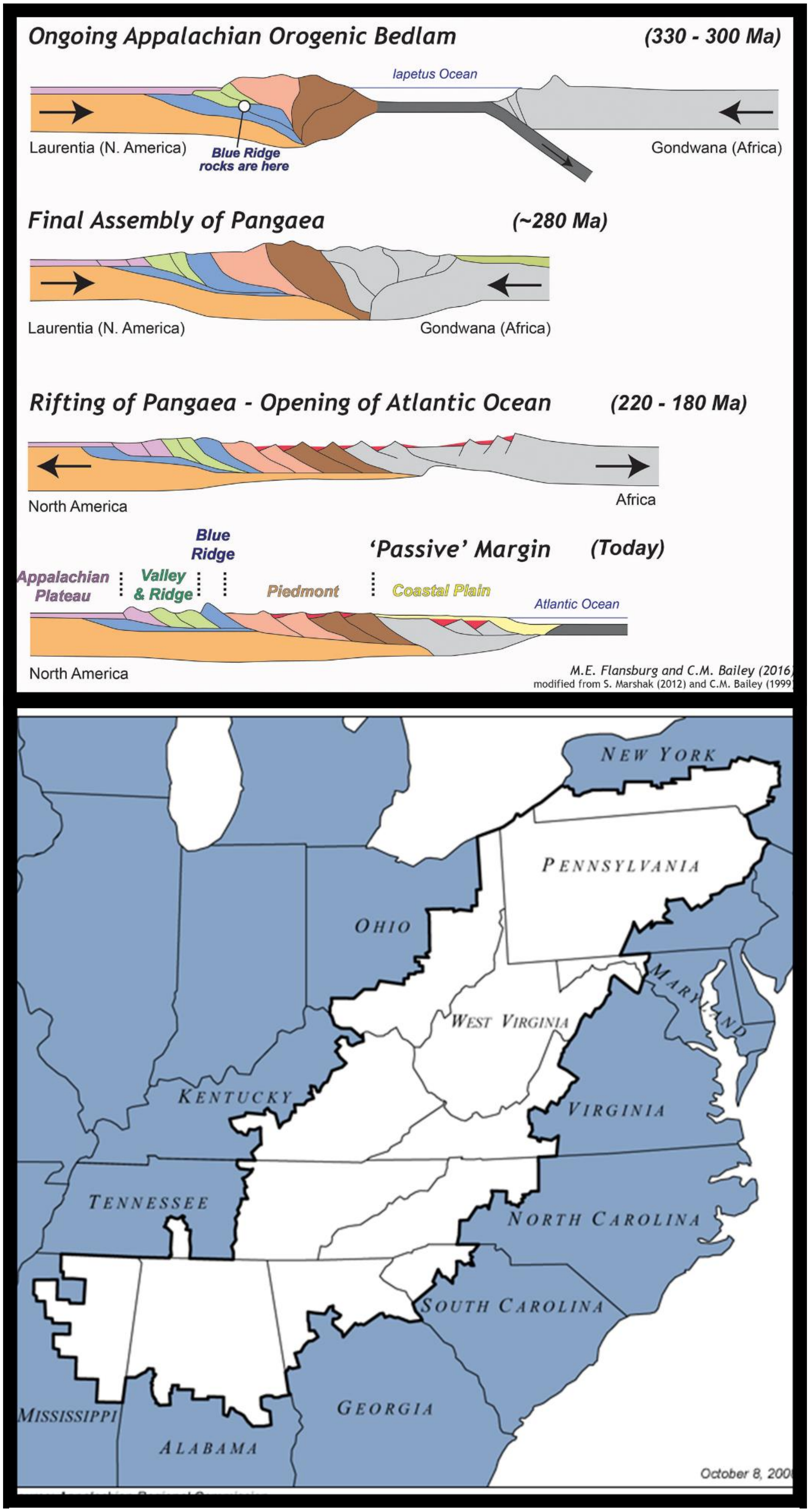

Figure 1: Above - Geologic formation of the Allegheny Mountains. Below - The Region of Appalachia as defined by the Appalachian Regional Commission.

1.2 Appalachia: Place and Space

Historians, geographers, and anthropologists still struggle to give Appalachia a formal boundary due to its expansive topography and diverse cultural characteristics (Stoll, 2017). For clarity, this paper will adopt the boundaries of Appalachia as defined by the Appalachian Regional Commission (Figure 1.2). This definition of Appalachia follows the topographical boundary of the Appalachian Mountains which runs north-south along the Eastern Coast of the United States. This region is distinctly defined by its culture which stretches from Pittsburgh, Pennsylvania southward to Birmingham, Alabama. Specifically, I will focus on the Central Appalachia subregion of West Virginia, Eastern Kentucky, Southwestern Virginia, and Eastern Kentucky, (Appendix A.1) which is the region most characterized by Mountaintop Removal Coal Mining.

During the 1800s, the invention of the Shay locomotive provided access to timber in Appalachia's remote valleys. This new technology would lead to the exhaustion of these virgin forest reserves. In the wake of Post-Civil War Industrialization, Appalachia's culture of resource extraction would shift from timber to coal. Tapping into 'Coal Country's' abundant resources provided stability to the region but created harsh working conditions that plagued laborers with health ailments such as black-lung disease. Throughout the mid-1900s, environmental regulations would cause a transition away from traditional shaft mining towards surface mining, resulting in a massive disturbance that destroys ecosystems and impacts the health of nearby communities. While resource extraction runs deep in Appalachian culture, its current impact on public and environmental health is undeniable. It is paramount that the ecological restoration of mine lands has a priority in all agendas focused on the revitalization and prosperity of this region.

In order to understand the history of the Appalachian region, it is best to look through the sociological lens of the American settler culture as acts of accumulation through a series of dispossessions. These actions transitioned the region from communities of indigenous nations to subsistence agrarians, and presently, to communities dependent on resource extraction-oriented enterprises. Following the colonization of the United States of America, the revolutionary elite claimed rights to immense tracts of native Cherokee, Choctaw, Chickasaw, Seminole, and Creek nations land as property. At the time these tracts of forested mountainous land were perceived as too steep and remote for commercial cultivation and were thus left alone by the elite. Between the Revolutionary (late 1700s) and Civil Wars (early 1800s), communities of Highlanders, mountaineers, and pioneers settled the Central Appalachian highlands and claimed household land through the act of squatting or tomahawk right (Scott, 1977; Stoll, 2017). The use of absentee holdings of land without proper ownership prevailed over remote state-recognized ownership during this time. These communities functioned as subsistence agrarian societies that were dependent on the surrounding forest's "ecological base" for sustenance and commodities (Stoll, 2017). I have amended the term "ecological base," as presented by historian Steven Stoll and define it as a functional ecosystem that provides a renewable fund of resources through habitat for native flora and fauna, from which a human community makes a living through sustainable foraging, farming, gardening, and hunting practices. Households in these communities externalize their needs to the surrounding landscape for necessary commodities such as fuel, lumber, tubers, nuts, fish, berries, and wild game at no fiscal cost. Over time, agrarians began to cultivate and distill rye into whiskey, commonly known as moonshine, and raise livestock. In turn, both livestock and moonshine could be brought to the market and used to barter and trade for commodities such as textiles and coffee (Steuart, 1767). Subsistence communities continued to squat on the holdings of absentee owners and make use of the ecological base until claims of property rights forced another dispossession (Scott, 1977). Absentee owners began to see economic value in their property after the Industrial Revolution gave rise to the Band Saw and Shay Locomotive which were catalysts for the industrial takeover of Appalachia (Figure 2.2) (Clarkson, 1964; Hiltz, 2019). The following section, titled "Resource Extraction," will focus on the effect that these land grabs had on the destruction of the region's ecological base and the communities that were reliant on them.

1.3 Resource Extraction

In presenting the history of resource extraction in Central Appalachia I would like to develop my definition of an "ecological base" to be a synonym of a "common" and its loss or destruction as a "tragedy" as is theorized by William Forster Lloyd and Garret Hardin (Lloyd, 1833; Hardin, 1968). Historically, the indigenous nations and the subsistence agrarians relied on Appalachian ecosystems as a communal unregulated resource or "common" (Lloyd, 1833). By the 1840s this ecological base was largely claimed by timber and coal companies in order to gain access to the common's resources. These companies' over-exploitation of the commons' resources destroyed the region's ecological base (Clarkson, 1964). Consequentially the tragedy of the Appalachian commons brought an end to subsistence agrarian lifestyles.

1.3.1 Timber: Logging and Fire

The Industrial Revolution defined an era in which humanity showcased its dominion over the natural world. Before the development of industrial machinery, early logging efforts of old-growth timber were completed using labor-intensive cross-cut saws and horsepower (Figure 2.1). The invention of the steam engine fostered the development of the band saw and the Shay geared locomotive which sparked commercial logging in the 1870s (Figure 2.2). These two machines operated in concert to enable access to and transport of timber in large volumes from remote and treacherous wilderness to lumber mills for efficient processing. In the forty years that commercial logging operated at full capacity, over 10 million acres of virgin old-growth forests were clear cut, and 30.4 billion board feet of wood (1 board ft = 1 ft^2 x 1in of wood) were produced (Ambler and Summers, 1958; Clarkson, 1964; McNeill, 1940). Deforestation of the Appalachian forests stripped away the region's ecological base that provided the foundation of indigenous nations' and subsistence agrarian livelihoods (Stoll, 2017). To make matters worse, the aftermath of logging left behind slash, or unwanted timber that was too small for marketable use, which easily caught fire from sparks produced by the steam-powered locomotives and sawmills (Clarkson, 1964).

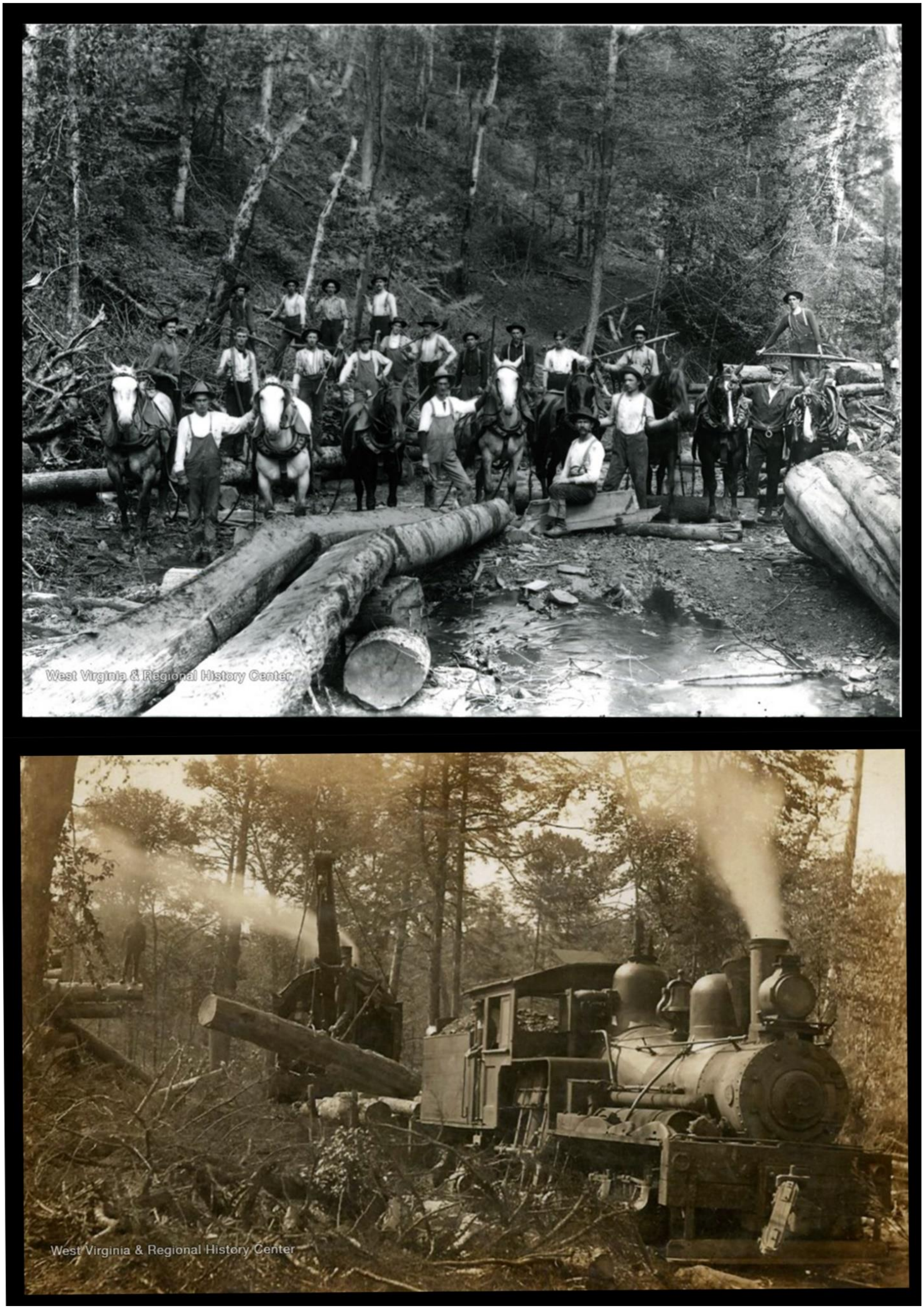

Figure 2: Above - Early Logging Crew and Their Team of Horses, Below - Use of the Shay Locomotive to Log Along Railroad Lines

1.3.2 Coal: Traditional Shaft Mining

The reconnaissance and cartography expeditions in Central Appalachia both before and during the Civil War gathered extensive amounts of geographical and geologic information (Breckinridge, 1861). As cartographers scouted out the hills and valleys into order to draw battle maps, they noticed extraordinarily rich outcroppings of coal seams throughout the region (Eller 1982). The synthesis of this geological and statistical information as visual maps was critical in conveying the prospects of this new energy frontier to potential commercial investors (Stoll, 2017). The most influential works were those of geologist Richard Cowling Taylor and Confederate cartographer, Jedediah Hotchkiss. Taylor and Hotchkiss' work increased public awareness of the abundance of Appalachia's coal reserves (Figure 3 and 4). The discovery of these reserves coincided with the boom of commercial logging and utilized the same railroad infrastructure to increase the accessibility to mining regions significantly. As a result, the railroads functioned as a conduit for parceling and dismantling the ecological base (Lewis, 1998).

Historically, miners accessed Appalachia's extensive coal seams through the underground mines (Figure 5 and 6). These mining practices bore vertical or sloping shafts into the ground, allowing miners to descend underground and access horizontal-lying coal beds which would be unattainable from the surface. Miners use a combination of hand tools and powered machinery to break up and extract coal. The loosened rock would be loaded into rail carts, brought to the surface and loaded into train cars for transportation throughout the country. Though profitable, this work was extremely dangerous, and since 1900 has caused more than 100,000 deaths (Goodell, 2007).

Additionally, the constant inhalation of coal dust by workers has caused a Black Lung epidemic and taken more than 200,000 lives (Goodell, 2007). As a result of advancement in heavy machinery and the formation of labor unions, which advocated for health regulations, the turn of the 1940s brought a shift from underground mining to surface mining methods (Fox, 1999). By 1971, four-fifths of American mined ore came from surface mines (Bradshaw & Chadwick, 1980)

Figure 3: Mapping of Appalachian Coal Reserves by Richard Cowling Taylor. Visual Representations of prospective resource reserves were critical in promoting extraction potentials to investors and the public

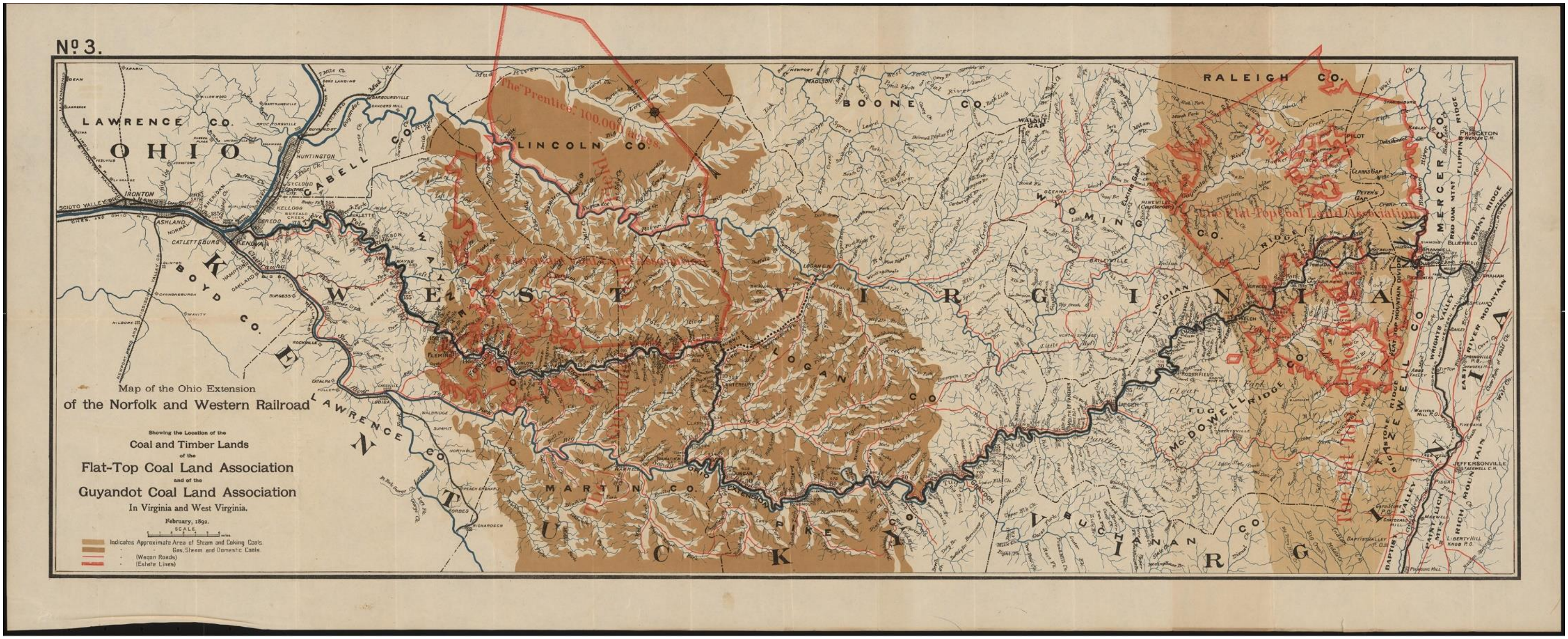

Figure 4: Jedediah Hotchkiss' map depicts the extension of the Norfolk and Western Railroad while highlighting the prospects of potential coal reserves in the region. By pairing prospects in resource extraction alongside the existing infrastructure of railways, investors, such as the Flat-Top Land Association and the Guyandot Coal Land Association, quickly realized the potential for profit and fuel for the recent Industrial Revolution.

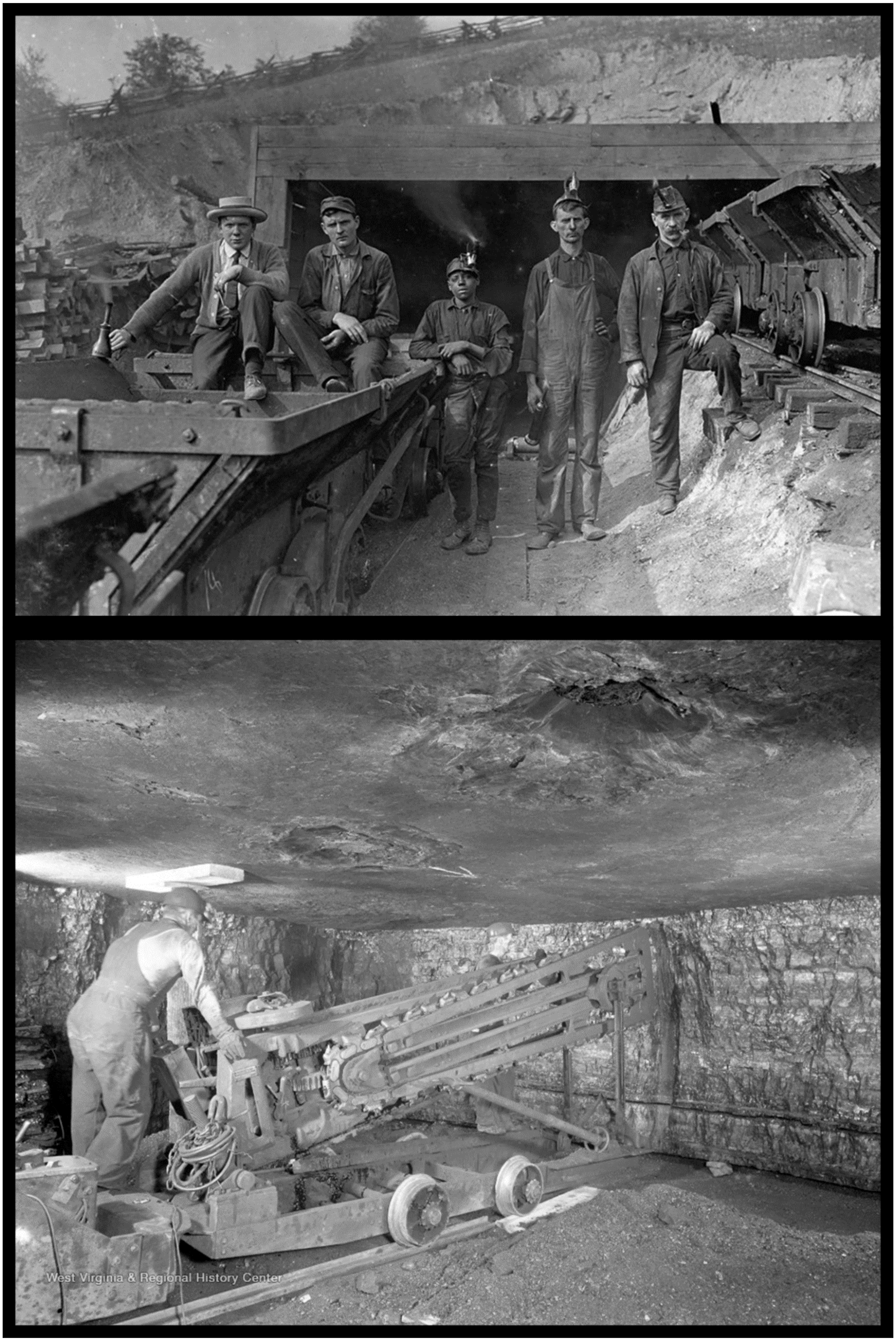

Figure 5: Above - Coal Miners of Red Star, West Virginia. Below - Miner Operating Heavy Machinery within a Shaft Mine.

1.3.3 Coal: Modern Surface Mining

Transitioning from shaft mining to surface mining with newly advanced heavy machinery enabled coal companies to increase the scale of their operations (Goodell, 2007; Hand, 2018). Advancements in heavy machinery, such as the development of the dragline, radically increased mining productivity and scale by enabling a few machinery operators to work at an immense scale (Figure 7) (Fox, 1997). Modern-day surface mining yields the highest cost-benefit for coal companies because they spend less money on labor while simultaneously meeting higher volumes of coal extraction (Fox, 1999).

Surface Mining is categorized into three different methods and is selected based on the topography of the mining area. These three methods are mountaintop removal, contour, and area mining (Figure 6) (Angel, 2008). While this paper primarily focuses on mountaintop removal methods and its effects, all three of these methods follow the same basic pattern of steps. They start by first stripping the land of forests and understory vegetation in order to expose the soil that is covering a coal deposit (Bernhardt *et al.*, 2012). These overlying layers of topsoil, subsoil, and bedrock material, known as overburden, is loosened through explosives and excavated by heavy machinery and discarded into piles called spoil (Fox, 1997). The underlying coal is excavated, and the mined area is reclaimed after mining operations have finished (Lima *et al.*, 2016; Bradshaw and Chadwick, 1980). Area mining methods are implemented in the rolling flats of America's Midwest and western states and use a dragline to dig repeating parallel rows (Figure 7). In contrast, contour and mountaintop removal mining methods are the most frequently used processes in the Appalachian coalfields because of the regions' steep and hilly terrain (Fox, 1999).

When coal is visible as an outcropping along the side of a mountain, contour mining methods are implemented to extract a long and narrow portion of the seam following its contour (Palmer *et al.*, 2010). This process begins with the removal of overburden, and the creation of a high wall over the coal seam and a bench beside it for the large-scale machinery to operate from (Figure 6). This process continues until it becomes too costly to remove any more overburden in comparison to the amount of coal that would be exposed underneath (Fox, 1997).

The adaptation of both Area and Contour mining methods results in Mountaintop Removal Mining (Angel, 2008). This process starts similarly to contour mining by removing the overburden near a coal outcropping on the side of a mountain (Palmer *et al*., 2010). However, mountaintop removal differs from contour mining by continuing to extract from the side of a mountain using the area mining technique of digging repeated parallel rows until the entire mountaintop has been removed down to the coal seam (Lima *et al.*, 2016).

The excavated overburden from contour and mountaintop removal mining is deposited in dedicated excess spoil disposal sites known as valley fills, durable rock fills, and head-of-hollow fills (Angel, 2008). The difference between these disposal sites is their place of construction and their composition of mining spoil (Fox, 1999). Valley and Head-of-hollow fills are unambiguous terms for spoil disposal sites that occur in valleys and at the head of a hollow, respectively (Welsh, 1991). A hollow is defined as a small sheltered valley and is synonymous with the word 'holler' in Appalachian English (Wolfram, 1977; Luu, 2018). Durable rock fills are either valley or head-of-hollow fills which are comprised of 80% durable rock (Welsh, 1991) A durable rock is classified as an aggregate of stone that does not easily erode or dissolve in water (Lutgens *et al.*, 2012). Over time, physical and chemical weathering causes these collection piles of overburden to release toxic leachate into watersheds, affecting aquatic, and human communities (Cook, 2015; Palmer, 2014).

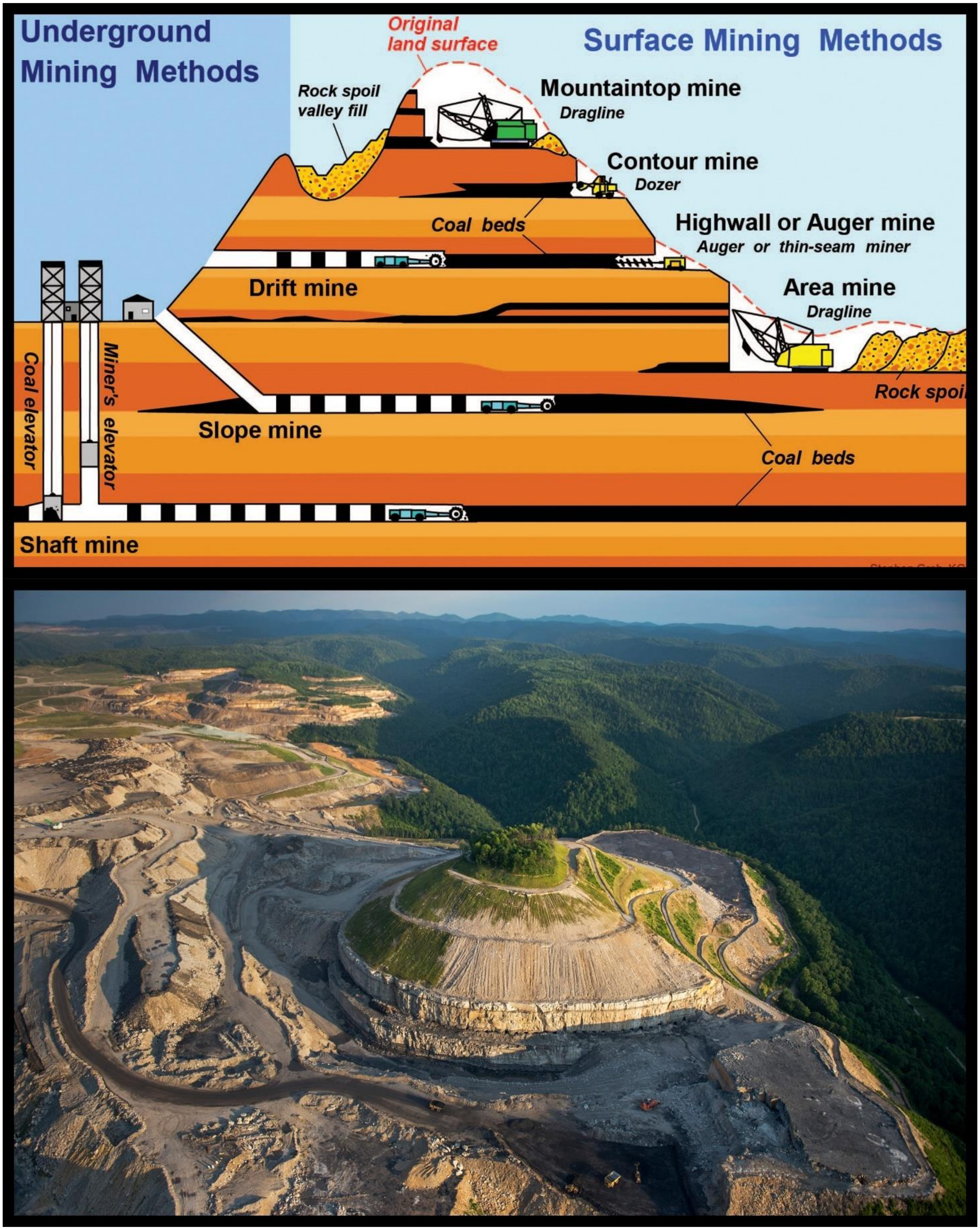

Figure 6: Above - Underground and Surface Mining Methods, Below - Aerial Photograph of a Mountaintop Removal Coal Mine. The island of trees in the center of the image is all that remains of a family cemetery that the mining operation worked around (McGlynn, 2012).

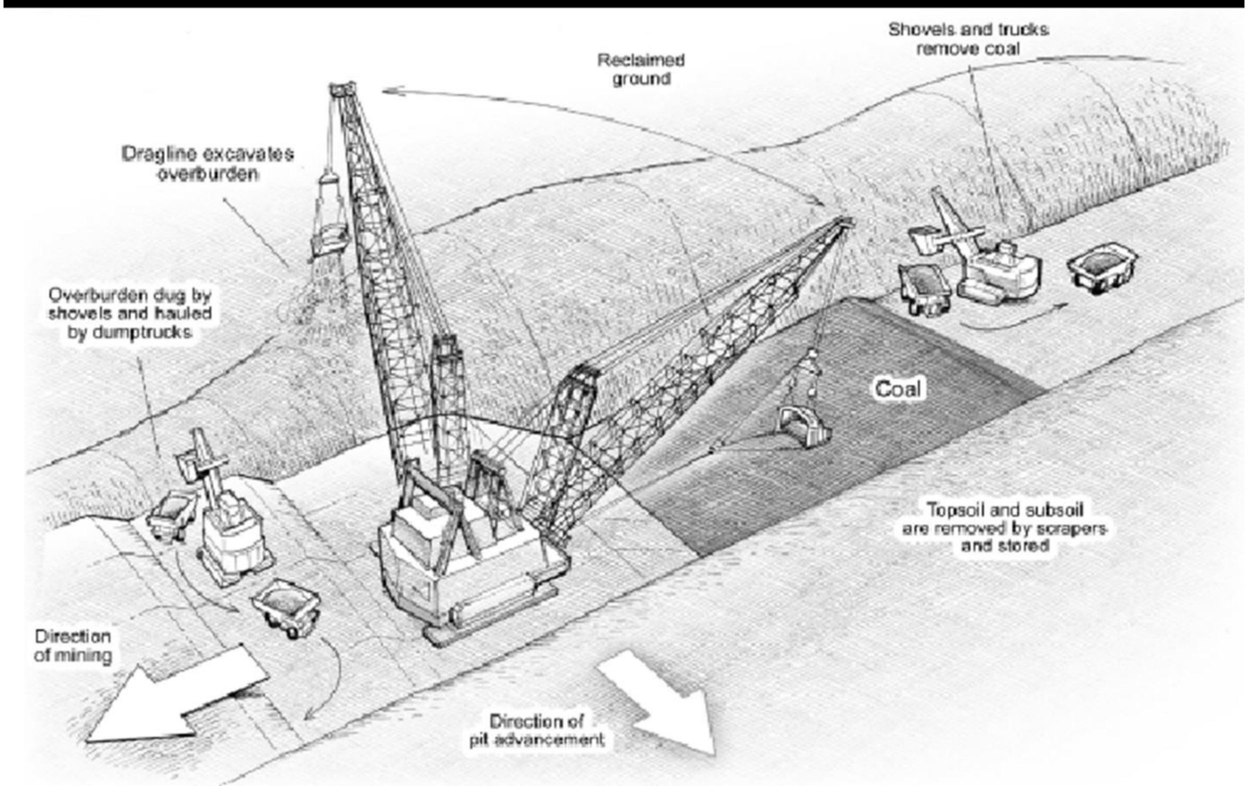

Figure 7: Above - Aerial Photography of a Dragline Removing Overburden to Access a Coal Bed, Below – An Illustration of How Draglines and other Heavy Machinery Operate in Area and Surface Mining Processes

2. Restoration Ecology

2.1 Restoration Ecology and Ecological Restoration

The field of Restoration Ecology is a scientific study rooted in the academic framework of Ecology that focuses on the process by which an ecosystem's structure, composition, and function responds to and recovers from a disturbance that has damaged, degraded or destroyed it (SER, 2004). This field of thought informs the practice of Ecological Restoration which is defined by the Society for Ecological Restoration (SER) as any "intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability" (SER, 2004). This implementation of theory and ideology as a response to a rapidly changing climate, increasing loss of habitat and biodiversity, and need for food and water security, has attracted international support from the United Nations (UN), who recently declared the upcoming span of years from 2021 to 2030 the Decade of Ecosystem Restoration (UN, 2019).

2.2 Pre-Anthropogenic Disturbance Ecosystem

The virgin mixed-mesophytic forests of Appalachia stretched well over 10 million acres and were a diverse swathe of "ash, aspen, beeches, and cottonwood; black oak, black walnut, and black locust; red maple, red oak, and red pines; along with chestnut, birches, buckeye, cedar, cherry, and hickory" (Stoll, 2017). Amid this range of canopy-forming trees was the climax species American Chestnut (*Castanea dentata*), whose rot-resistant wood was essential for timber construction, and its late blooming chestnuts provided an essential food resource for native fauna and subsistence agrarians into mid-summer. This ancient mountainous region which was an unglaciated refugium during the last ice age, is characterized by countless ridgelines and numerous hidden hollows and is among the most biodiverse ecosystems on Earth (Maigret *et al*., 2019; Hinkle *et al*., 1993; Ricketts *et al*., 1999). This biodiversity is the result of complex topography, comprised of narrow ridgelines with steep slopes on either side and countless streams and tributaries in-between. Elevation and topography are driving factors in the development of forest composition, function, and structure due to their influence on soil type, temperature, water availability, and solar radiation (Stephenson, 1998; McKenzie, 2013; Adams, 2014). The interplay of landform and biophysical variable across small spatial scales affects vegetation community composition and creates microhabitats that give rise to the unique and diverse flora and fauna of Appalachia.

The flora that flourished before widespread timber harvest decimated Appalachia and was a diverse suite of herbaceous, shrub, and tree species that had commonly reach a stable state as climax communities. These Central Appalachian ecosystems primarily existed as various climax communities because the region's historical disturbance regime, which was primarily windthrow events, was absent of stand replacing events (White *et al*., 2004). However, at high resolution and small spatial scales, canopy gap creation by these windthrow disturbance events would impact individually large canopy species and allow for the release of successional trees species from the understory (White *et al*., 1985). The specific wild plants that were of most importance to the indigenous nations of Appalachia, and the subsistence agrarians that followed them, were the charismatic herbaceous understory species that provided foragable sustenance. The Cherokee nations of Appalachia called these edible plants which leafed out in the spring after a long cold winter *uganost*, which stands for sweet wild greens (Figure 5) (Hammmet & Chamberlain, 1999). A select few of these species include; Indian cucumber-root (*Medeola virginiana*), corn salad (*Valerianella locusta*), cutleaf coneflower (*Rudbeckia laciniata*), pokeweed (*Phytolacca americana*), two-leaved toothwort (*Cardamine diphylla*), ginseng (*Panax quinquefolius*), wild leek or ramp (*Allium tricoccum*), and goldenseal (*Hydrastis canadensis*) (Krochmal *et al*., 1969).

Additionally, the tree canopy species of red spruce (*Picea rubens*) at high elevations, and the American chestnut (*Castanea dentata*) at lower elevations were essential in establishing stand dynamics that promoted the success of these *uganost* species in their understories (Figure 5).

Figure 5: Above - Archival Image of Virgin Red Spruce Forest Understory, Below – Definition and Compilation of Uganost Species which were foundational to the ecological base and provided essential sustenance to indigenous nations and agrarians. Clockwise from the 12 o'clock position, 1. Indian cucumber-root (Medeola virginiana) 2. red spruce (Picea rubens) 3. corn salad (Valerianella locusta) 4. cutleaf coneflower (Rudbeckia laciniate) 5. pokeweed (Phytolacca americana) 6. two-leaved toothwort (Cardamine diphylla) 7. ginseng (Panax quinquefolius) 8. ramp (Allium tricoccum) 9. American chestnut (Castanea dentata) 10. goldenseal (Hydrastis canadensis).

2.3 Disturbance:

Authors Peter White and Anke Jentsch define disturbance as “a relatively discrete event in time that disrupts ecosystem, community, or population structure and changes the resources, substrate availability, or physical environment” (White and Jentsch, 2004). The process of surface mining for coal extraction is an anthropogenic disturbance that exists outside of Appalachia’s historical disturbance regime. This anthropogenic disturbance creates ecological legacies that remain long after the disturbance, creating environmental conditions which impact succession. Specific examples of ecological legacies left behind by mountaintop removal include the loss of topsoil horizons, water holding capacity, and the exposure of heavy metals from un-weathered mining spoils (White and Jentsch, 2004). Beyond its impacts to the abiotic environment, this disturbance also impacts the structure, composition, and function of biodiversity on a landscape scale through deforestation, habitat fragmentation, water pollution, increased flooding and decreased erosion control (Carter, 2002; Palmer, 2014).

The following three subsections will consider an overview of anthropocentric ecosystem disturbance resulting from the extractive processes of timber harvest, underground coal mining, and surface coal mining as previously discussed in Section 1.3 “Resource Extraction”. Going beyond the direct sources of disturbance that are derived from resource extraction, these processes also have an indirect impact on global climate change and increased greenhouse gas emissions as a result of their end product use as fuel and fodder for energy production (Nash, 2004).

2.3.1 Timber Harvest

> “Where, in the other days, the boys had seen blue waves of spruce and hemlock, stretching away mile upon mile, the men now beheld desolation – bare hills, ribbed with shale, from which fire and erosion had swept every vestige of soil; long mountain ranges without a tree…a monotonous panorama of destruction as far as the eye could run”
> - Douglas McNeill, *The Last Forest: Tales of the Allegheny Woods* (1940)

The tale of the Allegheny Mountain forests after the Industrial Revolution is a story defined by landscape scale deforestation. As a result of humanity’s display of dominance over the natural world, 10 million acres of old-growth forest were clear cut between 1870 and 1910 (Stoll, 2018). The same steam engine that drove the rapid removal of forests from the region, was also the ignition source for the rampaging fires that ravaged the landscape following timber harvest. The steam-powered lumber mills and locomotives released sparks which fell onto the forest floor and ignited the slash that lay littered in the wake of recent timber harvesting. Because this region does not experience regular fire return intervals most species have no fire adaptations. Therefore, the seed bank that was present in the soil was scorched and washed away by increased erosion events as a result of decreased slope stability. Together the clear-cut timber harvest and subsequent fires created a stand replacing disturbance that was drastically outside the historical disturbance regime.

In the early 1900s, as the timber industry slowed down and early successional species began to re-establish and colonize clear-cut and burned sites, the iconic American Chestnut (*C. dentata*) was decimated by an alien species. The parasitic fungus known as the chestnut blight (*Cryphonectria parasitica*) is native to South East Asia and was first identified at the Bronx Zoo by Herman W. Merkel, and most likely introduced through the ornamental Japanese Chestnut (*Castanea crenata*) (Freinkel, 2009). The chestnut blight devastated most of the American chestnut (*C. dentata*) populations through the Appalachian Mountains, removing it from the canopy throughout its native range by the 1950s (Bauman *et al.*, 2013). In the years that followed, chestnut blight's removal of the American chestnut (*C. dentata*) as a canopy species from its native forests, ecologists would begin to notice drastic decreases in the squirrel, deer, cougar, bobcat, and Cooper's hawk (*Accipiter cooperi*) populations, along with the extinction of seven native moth species (Davis, 2006). The loss of this charismatic species which provided rot-resistant lumber and an abundant harvest in late summer would impact indigenous communities, agrarian livestock, and native fauna for whom it was essential for life. Since it was first clear-cut in the late 1800s, The American chestnut (*C. dentata*) species has yet to return return to the canopies of its native range.

Figure 6: Blackwater Canyon, West Virginia: (Top Left) View before Logging, (Top Right) View with half of the valley logged, (Bottom Left) view with the entire valley logged, (Bottom Right) view of a skidder atop the valley after logging and burning left the valley barren.

2.3.2 Traditional Shaft Mining

In contrast to the large-scale disturbance associated with timber harvest, underground mining creates minimal immediate disturbance in terrestrial ecosystems. This is primarily because operations occur below the surface where there is an absence of biotic systems. However, countless open mine portals scattered throughout the region have continue to release acid mine drainage into nearby waterways. Acid mine drainage (AMD) refers to the outflow of acidic water from a mine site as a result of the oxidation of pyrite minerals after exposure to air and water. As precipitation finds its way into shaft mines it interacts chemically with exposed metals, which dissolve and flow into downstream waterways. Highly toxic flows of AMD contain dissolved metals and low pH and commonly change bodies of water into a deep rusty orange color. Acid mine drainage is ecologically destructive to aquatic ecosystems and contaminates sources of human drinking-water with sulfuric acid and heavy metals, including arsenic, copper, and lead (Blodau, 2006).

Figure 7: Before and After Acid Mine Drainage into a River System

2.3.3 Modern Surface Mining

> "Is it wrong to love beauty; is it wrong to love nature? Is it wrong that we have only one earth and it will never be reclaimed- you can't reclaim a destroyed mountain – you can put something back there, but you can't put that topsoil back on – just try it. You never, never can walk through that little glade where the ferns are growing"
> - Julian Martin, *Wild Wonderful WV blog* (Stoll, 2017)

Surface Mining starts by first stripping the land of forests, understory vegetation, high productivity soil biota, and topsoil in order to expose the soil that is covering a coal deposit (Fox, 1999). This overlying soil material, known as overburden, is excavated by heavy machinery and discarded into piles called spoil. The underlying coal is extracted, and reclamation of the mined area begins after all mining operations have finished.

Surface mining is substantially altering the very topographic gradients that provide the foundation for elevated biodiversity in the mixed mesophytic forest. These drastic changes in topography effectively filter reclaimed sites from the ability to harbor ecological communities that were analogous to the biota defined by the pre-disturbance topography (Maigret *et al.*, 2019). An Environmental Protection Agency (EPA) report published in 2005 states that approximately 5700 km^2 of Appalachian forest has been disturbed by surface mines, and over 3200 km of streams were buried by overburden deposits (EPA, 2005). Ultimately, mountaintop removal is the most ecologically destructive form of surface mining as the extractive process removes all vegetation, soil biota, topsoil, and substrate heterogeneity and drastically changes the area's uniquely diverse topography.

2.4 Stand Succession

Mining sites reclaimed using SMCRA practices are often smoothly graded to stabilize the surface and prevent erosion. This compacted soil lacks substrate heterogeneity and topsoil traits characterized by the pre-disturbance ecosystem. This compacted landscape is revegetated through hydroseeding, which uses a mixture of competitive grass seeds, such as tall Festuca (*Festuca arundinacea*), and a nutrient-rich slurry of chemical fertilizer. This propagation concoction is applied across the soil substrate and forms a dense ground cover that has very weedy and competitive autecological traits, making it hostile to native woody and herbaceous species. Therefore, the natural succession of SMCRA reclaimed minelands is impeded and results in plant communities dominated by early successional, persistent, non-native, herbaceous species (Figure 8) (Burger, 2009; Burger, 2011; Zipper *et al*., 2011). The use of heavy machinery, such as bulldozers to grade the land leads to overly compacted soil are used to grade and compact the soil of reclaimed mine lands (Zipper *et al*., 2011). These practices impact the ability for the site to be re-colonized by native species from the landscape's surrounding matrix and progress through succession towards its climax community (Figure 8). Succession is defined by author Truman Young as "an orderly, more or less predictable turnover of species composition at a site that has been cleared of species or otherwise disturbed, often back toward a pre-disturbance state" (Young, 2001). The concept of Colonization-Competition Trade-Offs explains this halt in succession because the hydro-seeded herbaceous species outcompete the recruited native species for nutrient and water availability (Turnbull *et al*., 1999). The rampant growth of these species also encourages frequent browsing from herbivorous wildlife, which negatively impacts the development of newly recruited species (Zipper, 2011). In addition to this competition, the compacted soil from the grading inhibits wood species from establishing extensive root networks thus further impacting their ability to compete for nutrients against the herbaceous species (Suding and Gross, 2006).

Figure 8: Above - Aerial Photograph of a West Virginia Coal Mine in Arrested Succession as a result of being reclaimed using traditional SMCRA techniques. Below – Aerial Photograph of a Valley Fill Overburden Deposit Site with Distinct Ridgelines on Either Side.

2.5 Soil and Water Health

The removal of forest vegetation and soil horizons causes increases in erosion and runoff, ultimately impacting the propensity of flooding and landslides, the silting of rivers, and the pollution of aquifers and surface waters. The disturbed soil can cause toxic ingredients in clay-rich soils to mobilize and enter local watersheds (Fox, 1997). Two types of environmental damage can result from the improper management of mine tailings. This damage includes, Tailing Dam ruptures which cause catastrophic damage in downhill communities and ecosystems as well as the percolation of toxic water from slurry ponds into the local groundwater cause contamination and resulting in the need for costly remediation (Fox, 1997).

2.6 Ecosystem Services

Ecosystem Services are benefits which humans obtain from an ecosystem and is an accepted valuation method for conveying the importance of conservation. Ecosystem services are categorized by the Millennial Ecosystem Assessment (MEA) as either Supporting, Provisioning, Regulating, or Cultural (MEA, 2005). Supporting services are foundational elements that create a framework for proper ecological function and is attributable to soil substrates. Provisioning services relate to discrete harvestable products that are obtainable from an ecosystem such as timber. Regulating services are ongoing processes that result from interactions within an ecosystem such as water filtration. Lastly, cultural services are non-material, social-based pursuits that humans engage in, and include a suite of outdoor recreational activities. Before the disturbance of coal mining operations, Appalachian forests provide ecosystem services that include carbon sequestration through photosynthesis, carbon storage in plant biomass, watershed and water quality protection, habitat for native flora and fauna, and production of timber crop (Zipper *et al*., 2011). Specific Ecosystem Services that are provided by Central Appalachian forests within the presented categories will be discussed in greater details in section 4.5 titled “Restoring Ecosystem Services”.

3. Policy and Community Collaboration

3.1 Surface Mining Control and Reclamation Act of 1977

> The Surface Mining Control and Reclamation Act of 1977 is “an Act to provide for the cooperation between the Secretary of the Interior and the States with respect to the regulation of surface coal mining operations, and the acquisition and reclamation of abandoned mines, and for other purposes”
> - (Surface Mining and Control Reclamation Act of 1977)

This federal law is the primary legislating article for the environmental effects of coal mining and was enacted on August 3rd, 1977 by President Jimmy Carter. The signing of the Surface Mining Control and Reclamation Act (SMCRA) into law was a response to the widespread and unchecked coal mining operations of post-World War II-era America. The five major regulatory components (Standards of Performance, Permitting, Bonding, Inspection and Enforcement, and Land Restrictions) ensure that once mining operations are complete, minelands are reclaimed, and the environmental impacts that they caused are properly mitigated. Compliance with SMCRA requires that mining operators return the site to its “approximate original contour” (AOC) after mining operations are complete. However, accurately returning a post-mined landscape to its AOC is problematic due to soil stability issues and volume differences between fractured and intact bedrock and soil horizons (Copeland, 2015; Maigret *et al*., 2019). Alternatively, SMCRA will allow variance in AOC for situations where the proposed land use reclaims the land in a method that will compensate for the adverse effects associated with not returning the land to AOC (OSMRE, 2000).

3.2 Environmental Protection Agency: Clean Air and Water Acts

As a result of the National Environmental Policy Act of 1969, the EPA was established (Fox, 1997). The formation of this agency alongside the Council of Environmental Quality brought about the other legislative acts, such as the 1970 and 1990 Clean Air Acts, mandating larger ratios of low-sulfur coal and therefore, promoting further coal extraction within Appalachia in comparison to other states in the country (Loeb, 1997). This boost in Appalachian coal use is because the region contains high deposits of efficient Anthracite, which emit low levels of atmospheric sulfur upon combustion (Fox, 1999). The driving force behind the development of new mountaintop removal projects has been the increased demand for electricity produced from low sulfur-emitting fuel sources (Goodell, 2007). To meet these ever-growing energy demands, the West Virginia Division of Environmental Protection and other Appalachian federal agencies have continued to authorize thousands of acres for new mountaintop mining operations (Fox, 1999).

In addition to the 1990 Clean Air Act, the Clean Water Act of 1972 which mandated the creation of a regulatory body for the management of pollution in American waterways. Reports that monitor stream chemistry have shown significant increases in electrical conductivity, water hardness, acidity, and other chemical concentrations downstream of mountaintop removal operations (Bharti, 2013). A multitude of water pollutants currently found in Appalachia have been associated with mining activities, and include contaminants such as organic pollutants, metals (Iron, Copper, Aluminum, Cobalt, and Nickel), residues from explosives, and sediment to streams from mine site runoff and discharge from valley fills (Cook, 2015). The potential presence of these compounds in streams and rivers is a serious health concern due to their high toxicity and potentially cancer-causing effects (Duhigg, 2009). Lastly, these impacts extend beyond human health and impact the wildlife communities: mine-impacted streams have accelerated the disappearance of the native West Virginian Brook Trout (Bharti, 2011).

3.3 Collaboration of Stakeholders in Mining Restoration

The development of a shared vision for the restoration of Central Appalachian ecosystems involves a diverse array of stakeholders belonging to academic institutions, coal corporations, organizations, private landowners, and federal entities. The collaboration of these collective voices is essential to resolving conflict and achieving success in the field of ecological restoration

(Urgenson, 2016). This collective group of stakeholders agrees on accomplishing a set of desired conditions which range from socio-economic to ecological attributes. A collaborative "defines priorities, identify risks and negotiate trade-offs among these objectives to reach a 'zone of agreement' on desired conditions that serve as a form of collective input" (Urgenson, 2016). Collaboration crosses political, environmental, and private barriers through the equal valuation of social and scientific issues, thereby increasing the implementation of solutions in the real-world that is supported by an engaged and understanding community. Factors that contribute to effective collaboration are diverse and inclusive participation from all stakeholders, attainable goals, transparent operations, availability of funding, trust in leadership, and effective grassroots organization (Urgenson, 2016).

3.3.1 Office of Surface Mine Reclamation Enforcement

In order to properly implement and regulate the newly passed SMCRA, the Office of Surface Mining and Reclamation Enforcement (OSMRE) was created. The primary goal of the Federal inspectors was to increase site stability in order to stop landslides, control erosion, and clean the waterways from excess sedimentation derived from pre-SMCRA mines. Initially, the OSMRE focused on soil compaction and the use of aggressive groundcovers to quickly achieve their goals. Although OSMRE succeed at achieving their goals in water quality, site stability, and erosion control, it came at the expense of losing natural succession and the transition of ecosystems to climax communities.

3.3.2 Abandoned Mine Lands

As a result of SMCRA's Title IV, the OSMRE was tasked with the responsibility to reclaim abandoned mine lands (AML) that were decommissioned before the enactment of SMCRA in 1977. The AML program addresses coal mine-related problems that adversely impact public health, safety, and environmental degradation posed by legacy mine sites throughout the country. AML utilizes reclamation fees paid by the coal mining industry for each ton of coal produced to take inventory of legacy mines and promote the reclamation of hazards left behind by pre-regulatory coal mining. These hazards include unstable highwalls, frequent landslides, over sedimentation of streams, land subsidence, acid mine drainage, open mine portals, and hazardous structures (Division of Mined Land Reclamation, 2015). Over the course of its existence, the AML fund has collected $11.3 billion and redistributed the funds through state and tribe grants, United Mine Workers Association Health and Retirement Funds, and internal operating expenses. The AML Development Pilot Program (AML Pilot) awards their accrued funds as grants to encourage innovative economic developments that repurpose old mine land with economic and community development end uses. This collection of fees on the coal mining industry is scheduled to expire in 2021 pending no legislative extensions (OSMRE, 2019).

3.3.3 Appalachian Regional Reforestation Initiative

The Appalachian Regional Reforestation Initiative (ARRI) is the result of a collaborative effort in 2003 by coal country stakeholders that include multiple states within Appalachian and the US Department of Interior's Office of Surface Mining to "encourage the restoration of high-quality forests on reclaimed coal mines in Appalachia." ARRI's goals are to communicate and promote mine reforestation practices that 1) plant more high-value hardwood trees on reclaimed coal mined lands in Appalachia, 2) increase the survival rates and growth rates of planted trees, and 3) expedite the establishment of forest habitat through natural succession. ARRI intends to achieve these goals through reforesting abandoned and recently mined lands through the implementation of the Forestry Reclamation Approach (FRA) (Angel, 2005, 2009; Burger, 2005, 2009; Zipper *et al*., 2011). The ARRI Science Team is composed of professors and scientists engaged in research to help answer questions and solve problems related to restoration ecology and reclamation. They are always providing the public, reclamationists, and concerned citizens with the best available science and continually refine the FRA and communicate its science through new Advisories.

4. Restoration Techniques and Management Activities

4.1 Pre-SMCRA Reclamation

During the early 1900s when coal mining first began transitioning from underground to surface mining methods, there was no legal requirement in place to mandate mine operators to reclaim minelands after operations had ceased. As a result, coal companies made little to no effort towards reclaiming or stabilizing the land that had been stripped away. This was primarily due to economic demands for energy production independence during World War I, World War II and the 1973 oil crisis (Angel *et al*., 2008). As a result of economics taking precedence over environmental regulations, spoil piles were subjected to increased rates of chemical and physical weathering. This accelerated weathering greatly impacted local communities due to rapid erosion, slope instability, landslides, topsoil loss, groundwater contamination, and increased sedimentation in waterways. By the late 1900s events such as the publishing of Rachel Carson's *Silent Spring*, the formation of the Environmental Protection Agency, and the enactment of the Clean Air, Water, and Endangered Species Acts empowered the environmental movement. As a result of this movement and strong-willed political activism, Congress passed the Surface Mining Control and Reclamation Act on August 3rd, 1977 effectively enforcing the coal industry to reclaim minelands (SMCRA, 1997).

4.2 Post-SMCRA Reclamation

The SMCRA initially improved the surface-mine landscapes that were neglected by mandating actions to restore slope stability, improve water quality, and enhance human safety in coal country. The immediate process by which SMCRA's regulations focused primarily on the stability of mountain slopes and invested minimal, if any, resources in the act of restoring forest land. This focus derived from the desire to solve problems related to erosion, sedimentation, and landslides, which were frequent occurrences on pre-SMCRA surface mining sites (Burger *et al*., 2005; Burger *et al*., 2009; Burger *et al*., 2011). After a smooth grading a site, it is traditionally hydro-seeded with highly competitive herbaceous vegetation such as tall fescue (*Festuca arundinacea*) (Burger *et al*., 2009) (Figure 8). Not only does this create a barrier to the recruitment of native species from the surrounding matrix but can also inhibit the growth and survivability of planted trees. Additionally, because of the inherent legislative nature of the SMCRA, both regulators and mining companies face challenges in fully understanding the demands of the act. Thus, most stakeholders in this restoration project developed a false belief that restoring mining sites as pastureland was the most economically efficient means, further exacerbating deforestation in Appalachia by inhibiting succession changes (Angel *et al*., 2009).

The SMCRA requires that land be restored “to a condition capable of supporting the uses which it was capable of supporting before any mining, or higher or better use” (SMCRA, 1977). The SMCRA provides further instruction in that mining companies are to restore the land to “approximate original contour” (AOC). However, a report filed by OSMRE finds that the parameters used to define AOC “lack sufficient detail” in describing what accuracy (ex. elevation) to reclaim the mineland. Thus, allowing mine operators to place large quantities of overburden into valley fills (Ward, 1998). This lack of a precise definition is a significant loophole in mining law as it allows mining companies to ignore proper restoration of topography and soil substrate composition.

Figure 9: Above - Archival Print of Historical Restoration by Densely planting Red Spruce (Picea rubens) Saplings after Clearcutting and Fire-Ravaged the Landscape. Below – Digital Photograph of a Modern Restoration implementing the Forest Reclamation Approach after Surface Mining operations and Early SMCRA reclamation techniques.

4.3 The Forestry Reclamation Approach

The Forestry Reclamation Approach (FRA) is a prescription for effective post-coal-mine reforestation and restoration of ecosystem services that is applicable under the SMCRA. "The FRA is intended to establish site conditions suitable for survival and growth of planted trees while also enabling colonization by native vegetation whose seeds are dispersed by native fauna and wind" (Zipper *et al*., 2011). This approach is presented in its five steps as follows.

4.3.1 Step 1: Create Rooting Medium

The properties of soil atop reclaimed mining sites act as an environmental filter for the assembly of species to the site. Thus, the first step of the FRA is to properly select a growth medium that resembles spatial and temporal reference sites. Due to the scale of mountaintop removal, the properties for this growth medium depending on what is available from the surrounding landscape. Exposed soil material is the most desirable because chemical and physical weathering creates a substrate that supports the growth of native vegetation. Chemical weathering processes remove soluble minerals, causing reductions in conductivity and pH. Physical weathering processes break down coarse fragments into finer particles, which results in high soil nutrient and water holding capacities. Lastly, organic matter from the surrounding landscape is applied as the uppermost layer to contribute and promote the availability of essential nutrients (Zipper *et al*., 2011).

4.3.2 Step 2: Loosely Graded Topsoil

Traditional SMCRA reclamation methods promote the use of heavy mining equipment to smoothly grade the soil and return the land to its AOC. Ultimately this process creates a site characterized by compacted soil, resulting in lower overall ecological productivity. This compaction has negative effects on woody species as it inhibits root growth and water infiltration (Burger *et al.*, 2011; Angel *et al.*, 2005; Zipper *et al.*, 2011).

The second step of the FRA reduces soil compaction by removing the use of large-scale machinery in exchange for smaller equipment when grading soil surfaces. Additionally, the use of any heavy equipment should proceed only during dry conditions because of the susceptibility of saturated soils to increase compaction, and after the grading process, all further traffic of machinery should cease (Sweigard *et al.*, 2011). By minimizing the use of heavy machinery and implementing parameters for operation, soil porosity increases, bulk density decreases, and environmental conditions that promote root growth, water infiltration, and native species recruitment by providing shelter features for seeds improve (Zipper *et al*., 2011).

4.3.3 Step 3: Native and Non-competitive Groundcovers

As an alternative to hydroseeding, the third step prescribes using herbaceous species that supply enough plant cover to provide erosion regulation but also have non-weedy autecological traits to allow for succession. Examples of specific grass species that are successful for this step are redtop (*Agrostis gigantean*), timothy (*Phleum pretense*), and little bluestem (*Schizachyrum scoparium*) (Burger *et al*., 2009). In place of adding synthetic fertilizers, Nitrogen-fixing legumes such as birdsfoot trefoil (*Lotus corniculatus*) can be included in the seed mix to provide an alternative to the synthetic fertilizer found in hydroseeding mixtures (Burger *et al*., 2009). The incorporation of this step is essential for the successful transition of a site into a later stage successional community, as this step ensures the SMCRA's explicit demands for erosion control are met without compromising the potential for reforestation (Zipper *et al*., 2011).

4.3.4 Step 4: Early Succession and Commercially Valuable Trees

In progression of the successional pathway established in the FRA's third step, early successional trees such as eastern redbud (*Cercis canadensis*) are planted to function as nurse trees, facilitating the accumulation of organic matter while fruiting Dogwoods (*Cornus* spp.), which can provide food and habitat for wildlife (Groninger, 2009). Additionally, crop trees such as yellow poplar (*Liriodendron tulipifera*), maples (*Acer* spp.), ash (*Fraxinus* spp.), and oaks (*Quercus* spp.) are native climax community deciduous trees that can be harvested for a profitable timber crop (Angel *et al.*, 2009; Burger *et al.*, 2009; Berger *et al.*, 2013; Davis *et al.*, 2012).

4.3.5 Step 5: Proper Planting Techniques

The final step in the FRA is ensuring that species selected for the site are properly stored, transported, and planted within a hole deep enough to house the root system of a woody plant. When steps 1 and 2 are sufficiently implements, the effectiveness of Step 5 improves most. Special consideration should be given to the position and aspect of where to plant particular species, as environmental conditions can impact growth rate and survivability (Zipper *et al*., 2011).

4.4 Green Forest Works

The Green Forest Works (GFW) program is a small independent non-profit organization which implements a modified version of the FRA (McGowan, 2017). GFW has modified steps 1 and 2 of the FRA because they work on mines where the selection of growth medium, final grading, and revegetation of the mine were completed by mine operators under SMCRA law and are also limited in funding. Because their sites have already been compacted and hydroseeded, GFW modified steps 1 and 2 in order to control unwanted vegetation and mitigate soil compaction (M. French, personal communication, Feb. 5th, 2019). Their modified approach is as follows.

1. Control unwanted vegetation such as Fescue, Sericea, and Elaeagnus in order to provide trees with a competitive edge and allow the plant community to transition towards a community composition of goldenrod, ragweed, horseweed which are favorable for trees seedlings. In areas where either multiple herbicide applications are required or is prohibited, GFW implements a technique called "scraping". This technique uses a bulldozer to scrape away the upper few inches of topsoil in order to remove the seedbank (M. French, personal communication, Feb. 5th, 2019).

2. Mitigate compacted ground through deep ripping and cross ripping. This process utilizes bulldozers pulling rear-mounted 3-foot ripping shanks to create parallel rips on an 8' spacing across an entire site. The bulldozer operator then runs tracks perpendicular to the first rips and rips the entire site a second time, resulting in a grid like pattern with 8' x 8' "cross-ripped" intersections. The "cross ripping" technique can only be implemented on sites with slopes 0-20%. For sites that have a slope between 20-30%, deep ripping is done along the contour lines of the site. For all slopes over 30% there is no ripping to ensure safety of the machinery operators. However, it should be noted that the compaction on this steep of slopes tends to not be a problem and can usually be planted with bareroot plants (P. Angel, personal communication, February 5th, 2019).

3. Plant early succession and commercially valuable trees. The species selected for planting by GFW is dependent on the reference site, nativity, landowner desires, nursery availability, affordability, natural colonization, heavy seeded species unlikely to establish naturally, dollar value, habitat, and those known to be successful from previous experience (Burger *et al*., 2013).

4. GFW uses the same planting techniques that have been presented by the FRA (Figure 9).

4.5 Restoring Ecosystem Services

In the presence of modern environmental regulatory pressures, coal companies are being held accountable for their environmental impacts. By adopting the FRA's five-step method, the companies can provide Appalachia with more of the following ecosystem services 1. Forest Productivity 2. Carbon Sequestration 3. Habitat for Native Plant Communities, 4. Wildlife Habitat, 5. Watershed Protection, and 6. Improvement of Water Quality (Zipper *et al*., 2011). In reference to the previous Ecosystem Services section, the services that the FRA returns to minelands fulfills all four groups: Supporting, Provisioning, Regulating, and Cultural (MEA, 2005).

Supporting: Steps One and Two of the FRA ensure that supporting services are present on mine sites through the establishment of a healthy and low-compaction soil substrate.

Provisioning: The FRA’s Step 4, which is sequentially supported by those steps which precede it, creates a provisioning service through the cultivation of crop trees that can be harvested as timber product and sold on the market for a profit.

Regulating: The cumulative effect of the FRA promotes proper ecological function through ecosystem interactions as a result of increased structural, compositional, and functional Biodiversity, and the processes of carbon sequestration, erosion control, watershed protection and the successional development of native wildlife habitat.

Cultural: Throughout the literature associated with coal mine reclamation, there was an absence in the mention of Recreation as it relates to Hunting, Camping, Hiking, Biking. The absence of recreational opportunities is potentially due to mining properties being owned privately and not allowing these activities or any obligation to provide cultural ecosystem services.

5. Case Study – Bishop, West Virginia

5.1 Threat of Water Contamination from a Nearby Mountaintop Removal Coal Mine

There is cause for concern regarding the pollution of Horspen Creek and Jacobs Fork River due to the nearby mountaintop removal sites looming within a 1-mile radius of Bishop, West Virginia (Appendix A.9). These coal mining sites are situated directly above the community, leaching toxins into nearby rivers and streams, polluting local churches, schools, and homes. The potential presence of these compounds in Central Appalachia's streams and rivers is a serious health concern as they are highly toxic and potentially cancer-causing (Duhigg, 2009). Consequently, communities near mountaintop removal sites have reason to be concerned about the purity and availability of drinking water from natural and municipal sources. Lastly, these health impacts extend beyond humans and have resulted in the disappearance of entire communities of aquatic organisms (ex. West Virginian Brook Trout) from mine-impacted streams (Bharti, 2012).

In addition to water pollution, communities such as Bishop, which reside near mountaintop removal sites are exposed to a variety of environmental disturbances such as the increased frequency of flooding, which are traceable to coal companies stripping the land of its forests in preparation for mountaintop removal (Goodell, 2007). Without trees on steep mountain slopes, rainfall quickly flows downhill, endangering nearby communities to powerful flash floods. The absence of plants and their root systems in a communities' surrounding land exacerbates the movement of toxic pollutants from mountaintop to river valley.

While it may not be politically and economically feasible to shut down a coal mining operation completely, the magnitude of their public health and environmental impacts means that humans, plants, and animals will experience negative effects for years to come. However, there are still steps that landowners and townships can take through reclamation, remediation, and restoration of mining sites and their surrounding areas to ensure that the health of the public and the future of the environment prevails.

5.2 Phytoremediation and Riparian Buffers

Phytoremediation utilizes plants' natural, passive, solar-driven ability to extract, degrade, and stabilize soil pollutants. Unlike conventional engineering methods that would remove the fertile soil, phytoremediation would enhance the fertility of the soil and is also about ten times cheaper than traditional remediation technologies (Doty, 2008). Plants on a contaminated site would provide phytostabilization, minimizing the amount of contaminated material that could leave the site (either through water erosion or leachate) that could pollute neighboring communities, hence acting as buffer zones (Khan, 2011). According to recent scientific research and professional applications by Dr. Lou Licht, PE and his organization EcoloTree, it is possible for phytoremediation to be applied to water treatment as it relates to contaminated runoff from surface mining and acid mine drainage (Barac, 2004; Bharti, 2012, 2013; Cook, 2015; Cristaldi, 2017; Licht, 2017). Therefore, phytoremediating species (ex. *Salix* spp.) should be installed into riparian buffer zones, areas where a waterway and its banks meet and interact, to improve buffering capabilities. These zones are essential as they help to regulate water quality, manage flood waters, stabilize riverbanks, and provide essential habitats for plants and animals (Appendix B.7).

Appalachia contains some of the highest levels of biological diversity in the nation (Hinkle *et al*., 1993; Ricketts *et al*., 2009). This region's high elevation also means its mountains and valleys are the headwaters of the drinking water supplies for many major east coast cities. It is imperative that Coal Country communities manage polluted water runoff, not only for their local health but for those populations that live within their watersheds. In the progression of scientific research and successful professional projects, I recommend that phytoremediation species, such as poplar and willow, be planted along with native vegetation along community waterways to create

Phytoremediation Riparian Buffer Zones. Along with minimizing human exposure to toxic pollutants, these biological corridors would create wildlife habitat for animals and would provide community members with recreational services in the form of hiking, hunting, and fishing.

5.3 Science Communication: Environmental Education

Most limitations that have been highlighted by ARRI regarding the proper reclamation of minelands are tied to long standing cultural beliefs. This is because mine operators and state regulatory authorities are used to conventional reclamation and did not embrace the changes suggested by the FRA because it creates a rough and ugly landscape. These new methodologies also required new language in mining permits and getting these new instructions to the equipment operators who were performing the reclamation has been slow. Ultimately, everyone grew too accustomed to reclamation that converted the land into a manicured golf course look. It has taken time and training to educate all parties on the new methodologies and is a process that is still ongoing (Angel *et al*., 2005; M. French, personal communication, February 5th, 2019).

To actively engage community members in environmental education and increase public awareness to the proper reclamation of coal minelands I have developed an outdoor education curriculum. This material is comprised of four structured lessons plans (Appendix B) and a history lesson (Section 1) that would be implemented over the course of a normal 5-day school week. Conceptually, this curriculum has been structured for the Southside K-8 School in McDowell County, West Virginia, and North Tazewell Elementary School in Tazewell, Virginia because both schools are situated near the Bishop, West Virginia Surface Coal Mine.

Three of these lesson plans I have adapted from course material I implemented at Experience Learning; a long-standing outdoor education institute focused on developing effective community members through beyond-the-classroom, outdoor learning opportunities in West Virginia (Experience Learning Inc., 2017). The “It’s All Connected”, “Watershed Delineation”, and

“Riparian in a Pan” Lesson Plans lesson plans focus on engaging and teaching students about the impact that surface mining has on topography, ecosystems, and its inhabitants. These lessons are structured to be inclusive and presentable to individuals of any background in order to remain engaging and informative and can either be paired together in clusters or taught as independent modules. In addition to these lessons, I have also expanded upon a lesson that is currently being taught in public classrooms in order to ensure Central Appalachia receives current and up-to-date science communication. The “Digging for Coal in a Cupcake” Lesson Plan is as follows.

5.3.1 Coal in a Cupcake

Primary Schools throughout Central Appalachia have incorporated lesson plans on the history and importance of coal in Appalachia into their curriculum, with many of them being a part of the Coal in the Classroom program. This program receives funding and promotion by Friends of Coal, a long-standing industrial lobby group that has intentions to safeguard coal company profits. I want to highlight a specific lesson plan that presents a far-gone and romanticized version of coal mining to the region’s next generation of scholars. This lesson titled “Cupcake Core Sampling” (Appendix B.1) presents students with cut straws, called ‘drilling rigs,’ who are then told to locate and extract the chocolate chips “coal” from the center of the cupcake. This lesson conjures images of soot-covered men surfacing through a low-ceiling shaft after a hard-days’ work underground.

However, the reality is that coal does not come from traditional shaft mines. Instead, modern surface mining techniques are used to collect fossil fuel resource. Thus, to best simulate reality, I present an updated “Cupcake Core Sampling” lesson titled “Digging for Coal in a Cupcake” (Appendix B.2). This lesson expands on one of the most environmentally destructive processes occurring on Earth, Mountaintop Removal. For this analogy perceive a cupcake as a mountain, the brown icing as rich organic topsoil, the green sprinkles resting atop are dense forests, the chocolate center as energy-rich coal veins, and any attempt to recreate the original cupcake as reclamation. Mountaintop Removal strips the mountain (cupcake) of its topsoil (frosting) vegetation (green sprinkles) and uses explosives and large machinery (plastic knives) to loosen and scrape away all the overburden (top half of the cupcake) to provide access to the coal veins (chocolate center). Under SMCRA coal companies are mandated to return abandoned mining sites to their original form (teacher grading the recreated cupcake). The problem is that ecologically after coal extraction, the mountain's soil is compressed (compact ball) and it's extremely difficult to get large trees (sprinkles) to reestablish on the mining site. Therefore, it is common to find that reclaimed mining sites have not transitioned back to the old-growth forests that existed before the industrial revolution, but instead, are dominated by grass (rolling the compact dough ball on icing to make it look green).

6. Implications for the Field of Restoration Ecology

6.1 Barriers and Limitations

The initial goals of SMCRA aimed to address the problems of land instability and sedimentation loss associated with initial surface mining operations. It emphasized reclamation practices that inhibit ecosystems from transitioning through natural successional stages. The FRA is a restoration approach that amends and remedies the ecological downfalls of Pre-SMCRA processes by promoting the use of non-competitive ground cover seeded in loosely graded weathered soil. The implementation of this practice promotes an ecological trajectory towards a historically referenced Central Appalachia climax community. The application of this restoration approach is a viable alternative to traditional reclamation methods which operates within federal regulatory regulations. Continued maintenance and monitoring of FRA sites will aid in building a robust understanding of its implementation. I believe that it is critical for future research in the field of mineland reclamation to progress beyond mandatory reclamation by engaging with current Restoration Ecology theory, implementing best management practices in Ecological Restoration, and aligning goals with the upcoming UN Decade of Ecosystem Restoration (UN, 2019).

Despite the FRA taking a significant step towards the restoration of post-surface mining disturbed landscapes, there are still significant limitations and barriers to its proper implementation. For this reason, the establishment of ARRI has worked to disassemble cultural, technical, and regulatory barriers. Examples of these barriers include the cultural belief that traditional SMCRA mandated reclamation techniques such as smooth grading and hydroseeding are the most ecologically and economically efficient means of restoration (Angel, 2009; Burger, 2005; Zipper *et al*., 2011). As presented in section 5.3, in order to address the barriers associated with the dissemination of information regarding post-surface mined landscapes, I have compiled a comprehensive set of lesson plans available in Appendix B for use in educational settings.

Regulatory barriers such on the total percent ground cover during initial seeding, and technical barriers associated with toxic or unsuitable growth material commonly found on the surface of pre-SMCRA sites (i.e. AMLs primarily reclaimed by GFW). These sites tend to have acid-producing material, or leach metals, posing water quality concerns. Ripping these areas could create additional water quality problems. An additional technical barrier are steep slopes which limit the implementation of FRA techniques. These sites are commonly left unmanaged to ensure that safety is paramount, thus allowing loose material to cause landslide and water quality concerns (M. French, personal communication, February 5th, 2019)

6.2 The Anthropocene and Novel Ecosystems

Humanity has altered planet Earth at such an immense scale that civilization's impacts will be notable at geological timescales. Researchers have distinguished this shift in geological processes from the preceding Holocene epoch due to humanity's measurable geological, climatic, and biological signatures in sediments and ice cores (Waters *et al*., 2016). These signatures are the result of agriculture, resource extraction, and global colonization practices, along with the impact of the industrial revolution and its influence on modern technology (Kolbert, 2014). This new human-centered or anthropogenic era is called the Anthropocene epoch (Ellis, 2018).

A concept that developed in concert with the Anthropocene epoch is the novel ecosystem which was coined by lead author Richard Hobbs. These researchers define a novel ecosystem as new, non-historical arrangements of species, their interactions, and functions which arise as a result of changes at the local and global scale (Hobbs *et al*., 2009). These ecosystems derive from human-induced habitat loss, carbon emissions, non-native species introductions, and are comprised of ecosystem dynamics which have no naturally occurring equivalents (Hobbs *et al*., 2006).

I present these modern concepts in the context of Central Appalachia that has been damaged, degraded, and destroyed by the resource extraction industries of the timber and coal industries. This implementation of both the Anthropocene and Novel Ecosystem theories is a response, to Appalachia's immense landscape changes in habit and topography due to resource extraction and the resulting biodiversity loss, ecological community change, hydrological shifts, watershed pollution, all alongside a rapidly changing global climate (Nash, 2014).

6.3 Development Theory

Environmental conservation and poverty alleviation are two important agendas in the world today that apply to the Coalfield communities of Central Appalachia (Pollini, 2011). Historically, environmentalists have considered socioeconomic development in direct conflict with conservation (Brown, 2002). However, initiatives by international development agencies such as the World Wildlife Fund’s Integrated Conservation Development Programs (ICDP) have begun to pair economic and environmental efforts through the implementation of Community-based conservation (Mehta and Heinen, 2001). These programs attempt to ensure the conservation of biodiversity while reconciling the management of the environmental landscape with the social and economic needs of local community members (Wells, Brandon, and Hannah, 1992). This concept has begun to gain popularity due to their success in simultaneously addressing three critical areas of sustainable development: biodiversity conservation, public participation of locals, and economic development of the rural poor (Wells and McShane, 2004).

Empowerment depends on developing competencies by providing the skills and confidence necessary to exercise power through decision-making in participatory development. Participation is a process that enhances the capacity of individuals to improve their lives and facilitate social changes to the benefits of those who are disadvantaged (Cleaver, 2001). Development theorists often criticize participatory conservation for benefitting elite members of the society while excluding marginal communities (Cooke and Kothari, 2001; Robertson, 2019). A critical understanding of the complexities with participatory engagement is, therefore, essential to improving policies and practices (Senecah, 2004).

I propose applying community-based conservation theory from international development agencies to Appalachian coalfield communities in order to benefit the present, and future generations by i) aiding in the ecological restoration of natural resources to post-surface mined landscapes, ii) providing socioeconomic development opportunities for local communities, and iii) creating sustainable eco-tourism opportunities in the region.

6.4 Restoration Appalachia: *Uganost* Cooperatives

Since industry scale resource extraction first began in the late 1800s, the gap between the coal barons and local Appalachian community members has widened over time as a result of civilization's overemphasis on resource consumption. Currently these communities are struggling to redefine their identity in a world where global coal production is on the decline (Patzek & Croft, 2010). Viewing post-mining landscapes through the ideological lens of Novel Ecosystems provides this region with a canvas upon which there are opportunities to bring back the ecological base that indigenous and agrarian communities depended upon. This concept for the revitalization and ecological restoration of Appalachia is presented as follows.

1. Progress current reclamation by engaging with current Restoration Ecology theory, implementing best management practices from Ecological Restoration, and aligning goals with the upcoming UN Decade of Ecosystem Restoration. Advance methodology by transitioning away from planting commercially valuable timber crop as guided by Step 4 of the FRA which is a relic of historical overemphasis on resource extraction. In its place, focus on the restoration of *uganost* understory species which would facilitate the natural succession and community composition of these ecosystems to their historical state. Additionally, these wild edibles could be commercially marketable as agricultural crops if a fiscal replacement for timber crop is needed.

2. Engage local community members through Participatory Development as stewards of the land by returning minelands to public commons after proper reclamation has been completed. These community members would have access to the ecological base that is foundational to Appalachian culture. Further economic development prospects in the region by providing educational and management opportunities for individuals to propagate *uganost* species and FRA early successional species. These nurseries could contract grow native species for large scale ecological restoration and promote job posting and work party announcements for crew member and volunteer labor for the installation of nursery stock on reclamation sites.

3. Retrofit existing infrastructure to be more sustainable and where feasible, provide eco-tourism opportunities such as hiking and biking. The creation of green infrastructure in this region will provide green collar employment, facilitate increased tourism revenue and begin to hybridize the regional utility's fuel blend (Trabish, 2018).

4. Apply for AML Pilot grants to fund the creation of a local food cooperative which facilitates land stewards to harvest and forage *uganost* for the local community and tourism sector by marketing homecooked meals as a sustainable traditional forest-to-table experience. This collective, called *Uganost* Cooperatives, would further promote the previously presented initiatives of eco-tourism, green infrastructure, and sustainable development in Appalachia by effectively uniting them into a single entity.

6.5 Future Research

In reflection of my belief that future surface mine reclamation research should orient itself within the field of Restoration Ecology, I present three potential research topics that fill necessary gaps in the current literature and propose genuine research by implementing modern technologies. I propose these projects as a set that would be a typical structure for a doctoral dissertation.

The first proposed research, titled *Growth, Survival, and Edibility of Native Uganost Understory Species on Reclaimed Minelands*, is the most essential component in determining the success of *Uganost* Cooperatives. This research would aspire to determine if site conditions are favorable for the establishment of these species, and if so, whether they would be edible due to their growth in commonly toxic environments.

Depending on the results of the first project, the second focus of study, titled *Phytoremediation of Surface Mine Effluent by Hybrid Poplars and their Creation of Microhabitat for Uganost Understory Species*, would focus on the phytoremediation of toxic minelands and the creation of canopy structures for the facilitation of *uganost* understory species. If the first project determines that *uganost* understory species are not edible due to their phytoaccumulation of toxins, then the goal of this research is to present a novel symbiotic relationship between phytoremediating and edible species in hope that the later could be consumable.

The final project would, titled *Viability of Precision Pod Planting of Hybrid Poplars in Landscapes Restored through the Forestry Reclamation Approach* would focus on the implementation of modern drone technology. Considering the immense scale of surface mine reclamation operations, this technique could drastically cut down on plant installation costs. This research would attempt to work with technological systems already put in place by Biocarbon Engineering Ltd. and Droneseed (Biocarbon Engineering, 2019; Droneseed, 2019).

6.6 Conclusion

If surface mined coal remains a critical component in American energy production, Central Appalachia's biodiversity will be sacrificed due to the homogenization of physical landscape and the resulting loss of habitat drivers for topographically restricted vegetative communities (Adams *et al*., 2014). The ecological destructive process of surface mining has set reclaimed minelands on novel ecological trajectories, with certain habitats unlikely to progress naturally towards historical climax communities (Ross *et al*., 2016). Although reclamation methods such as the FRA are effective at mitigating long-term habitat loss, it is paramount that future ecological restoration focus on creating habitat for topographically restrictive species such as the red spruce (*Picea rubens*), Cheat Mountain salamander (*Plethodon nettingi*), northern Virginia flying squirrel (*Glaucomys sabrinus*), timber rattlesnake (*Crotalus horridus*), and West Virginia brook trout (*Salvelinus fontinalis*) (Rentch *et al*., 2010; Bulger, 2000; Maigret et al., 2019).

Most importantly, the communities that have been impacted for generations by resource extraction in Appalachia should be a primary focus in the ecological and economical restoration of this region. For this reason, I present the creation of *Uganost Cooperatives* to synergize Restoration Ecology and Development Theory aspirations. This proposal is in direct contrast with the variety of recent regional revival attempts in that it does not propose the creation of an entirely new industry. Instead, it presents the return of the ecological base as a public common to communities who first relied upon it for sustenance and survival. In addition to supporting Appalachian livelihoods, the return of fully functional ecosystems provides the region with essential ecosystem services.

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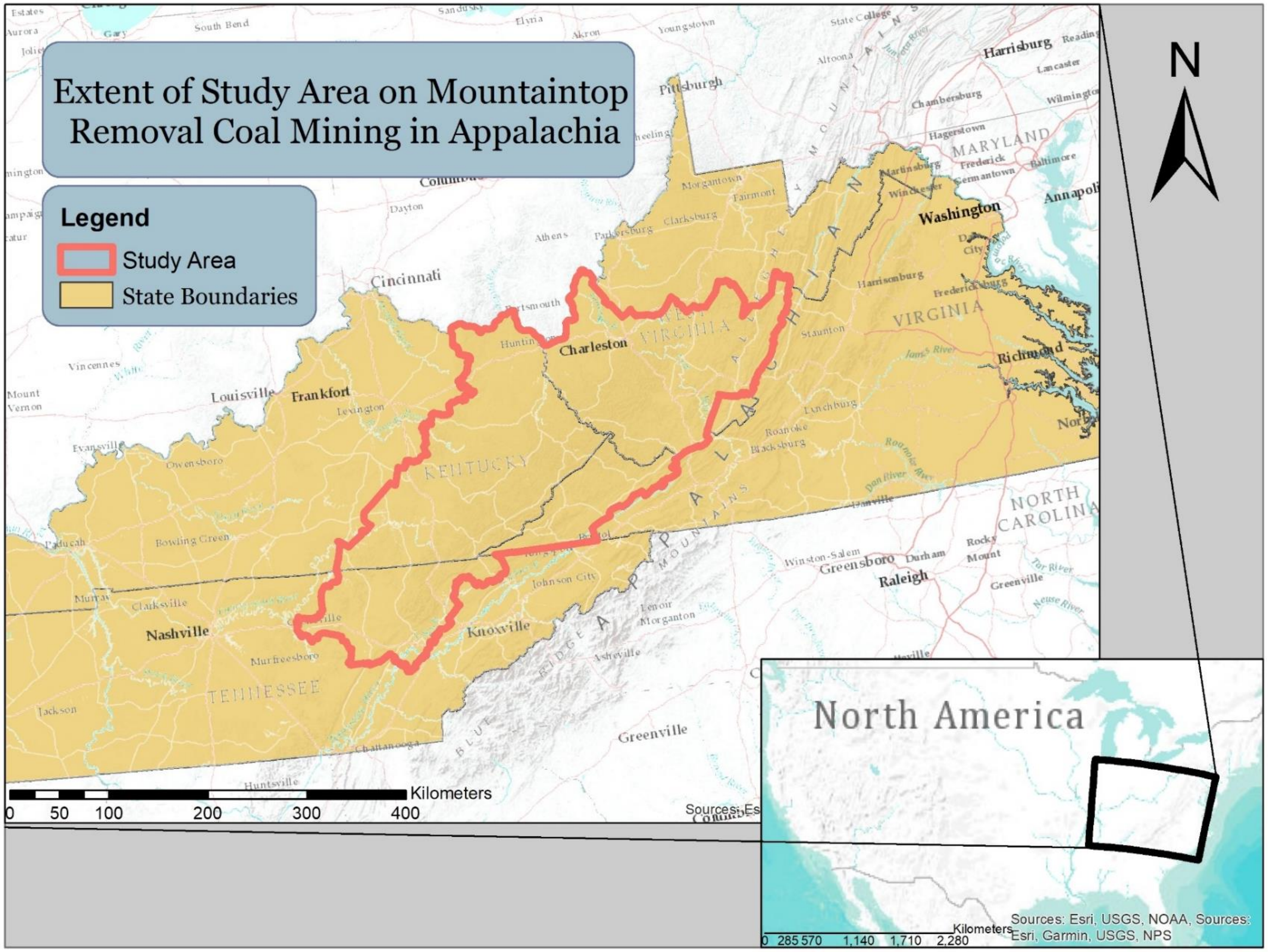
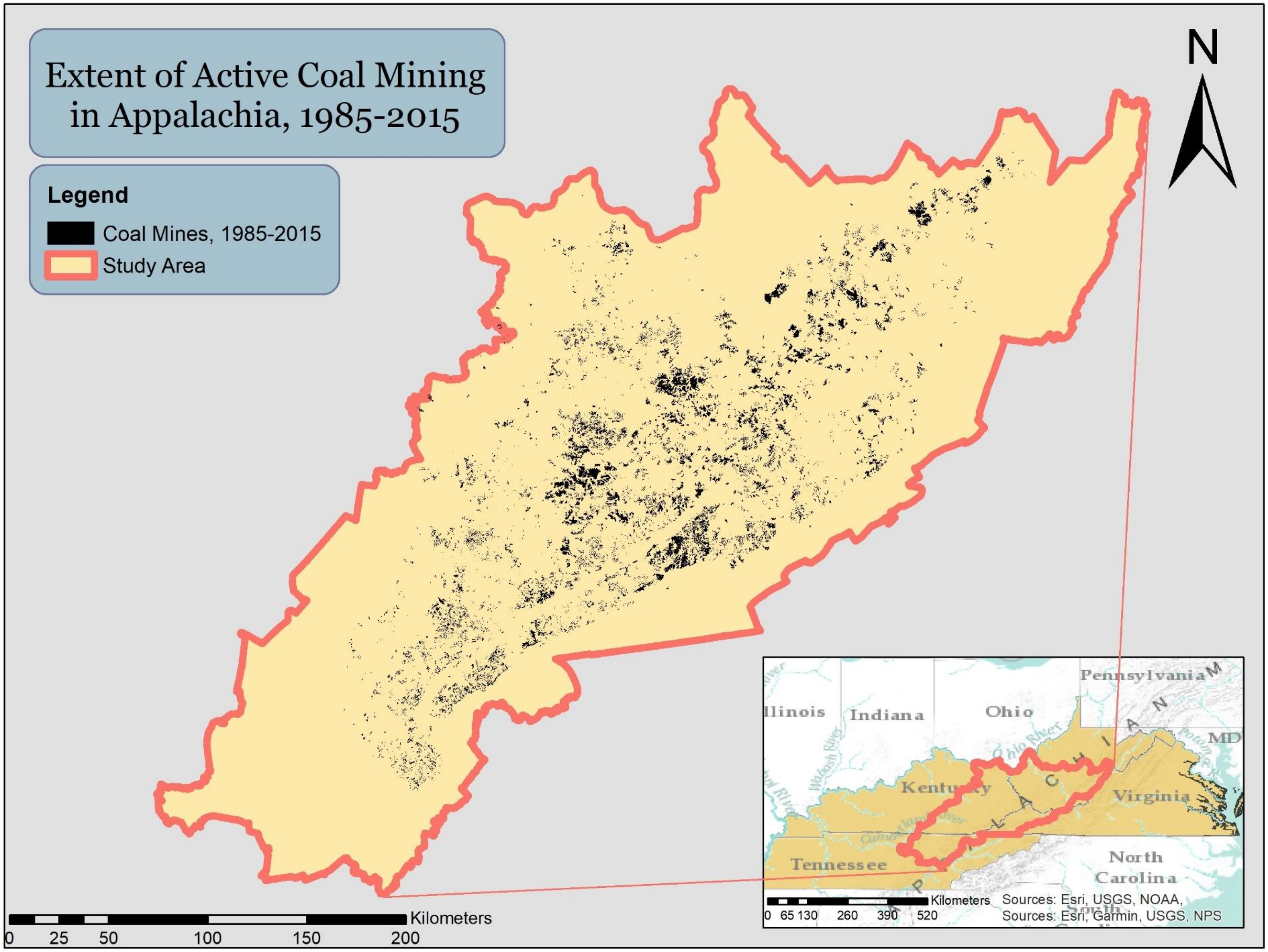
Appendix A: Visual Analysis Maps

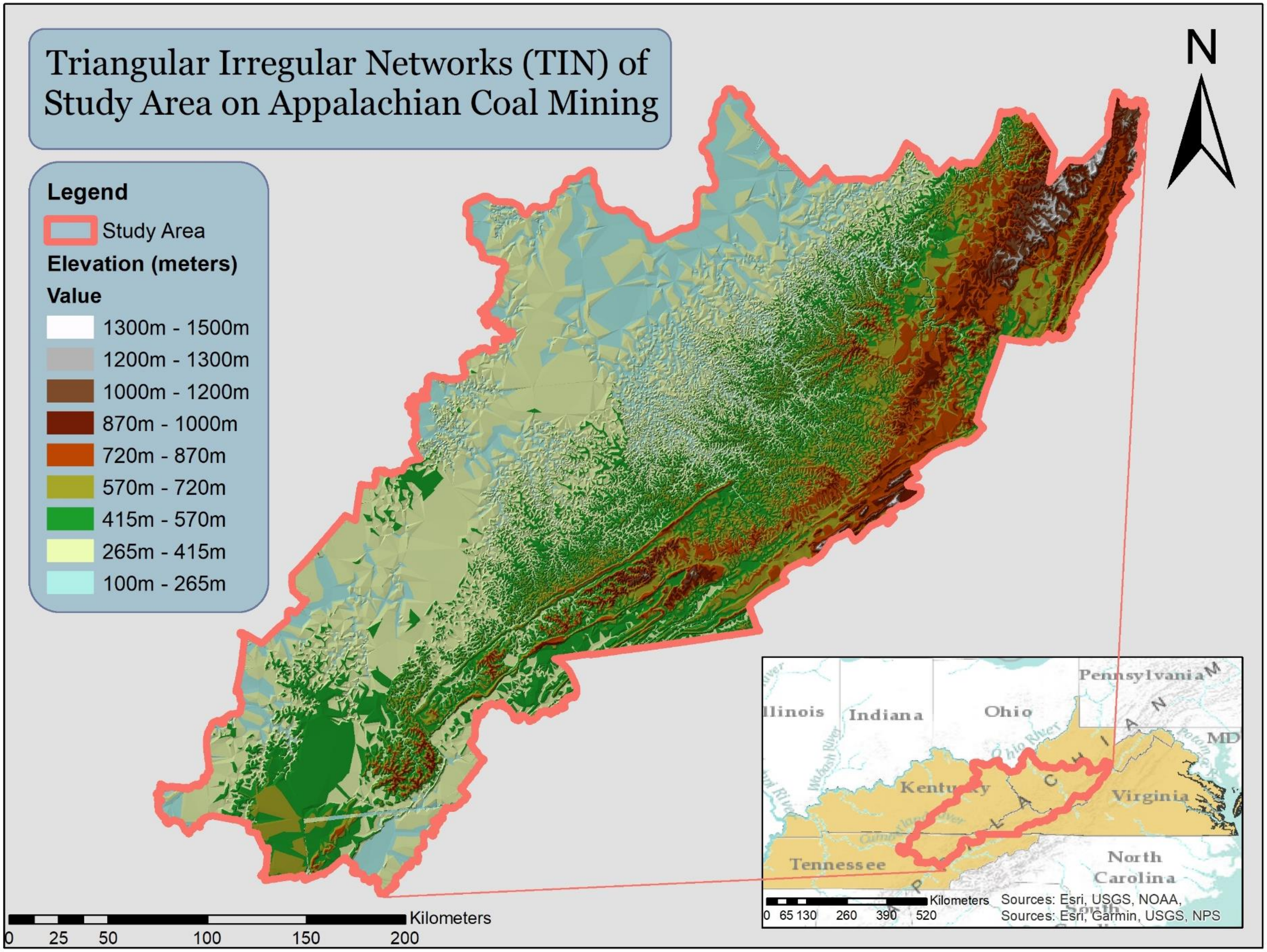
A.1: Extent of Study Area on Mountaintop Removal Coal Mining in Appalachia



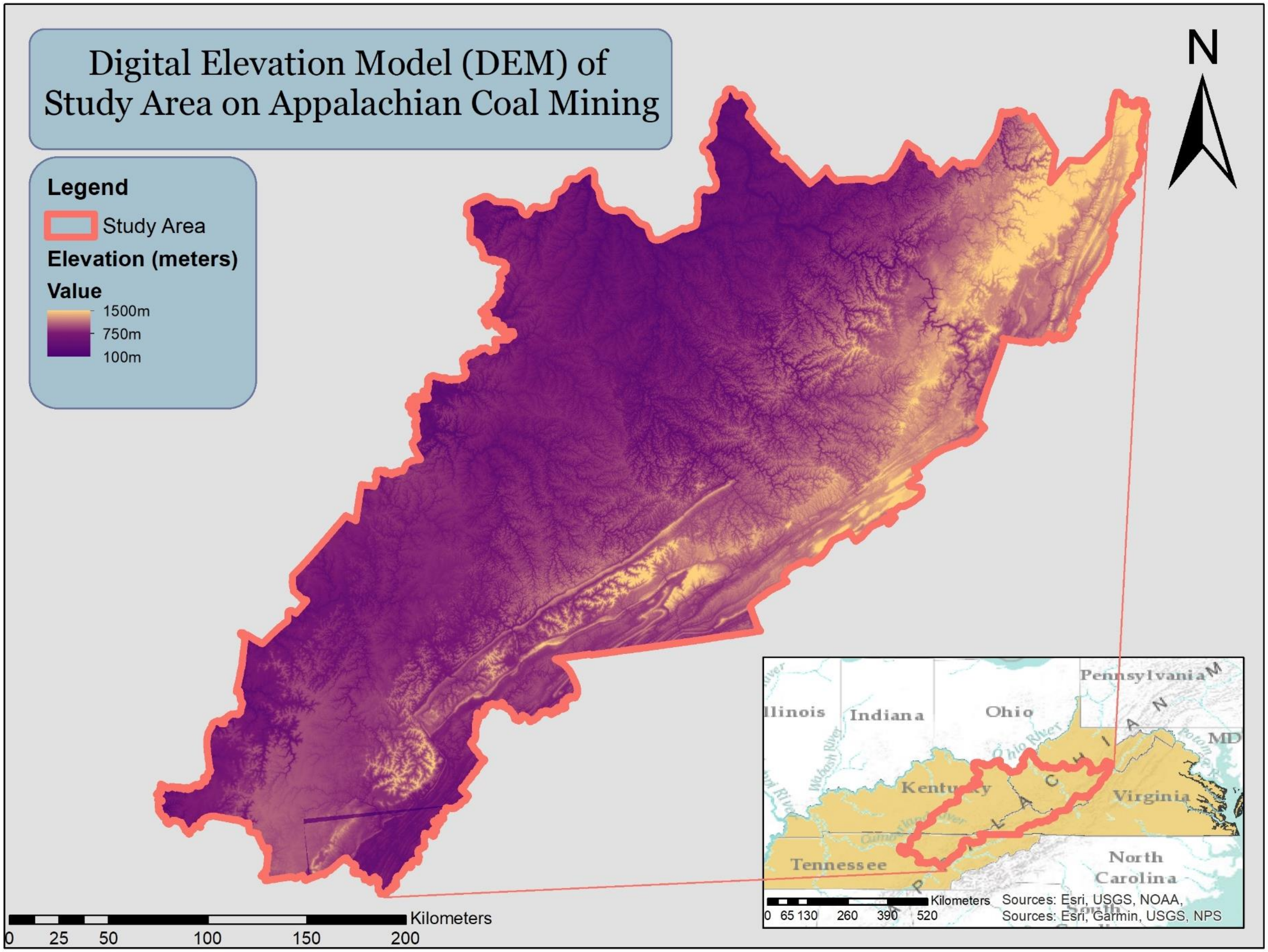
A.2: Extent of Active Coal Mining in Appalachia, 1985-2015



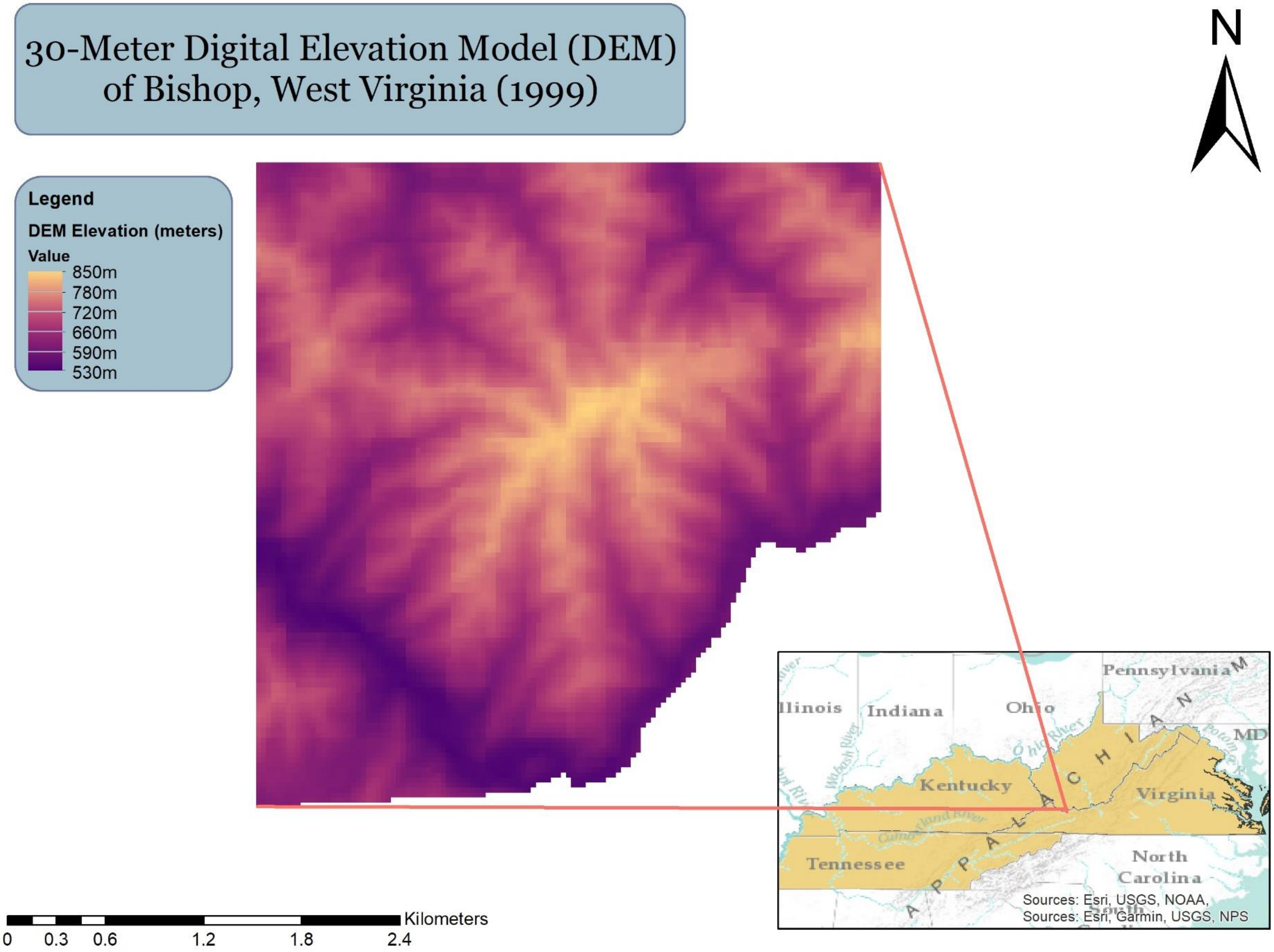
A.3: Triangular Irregular Networks (TIN) of Study Area on Appalachian Coal Mining



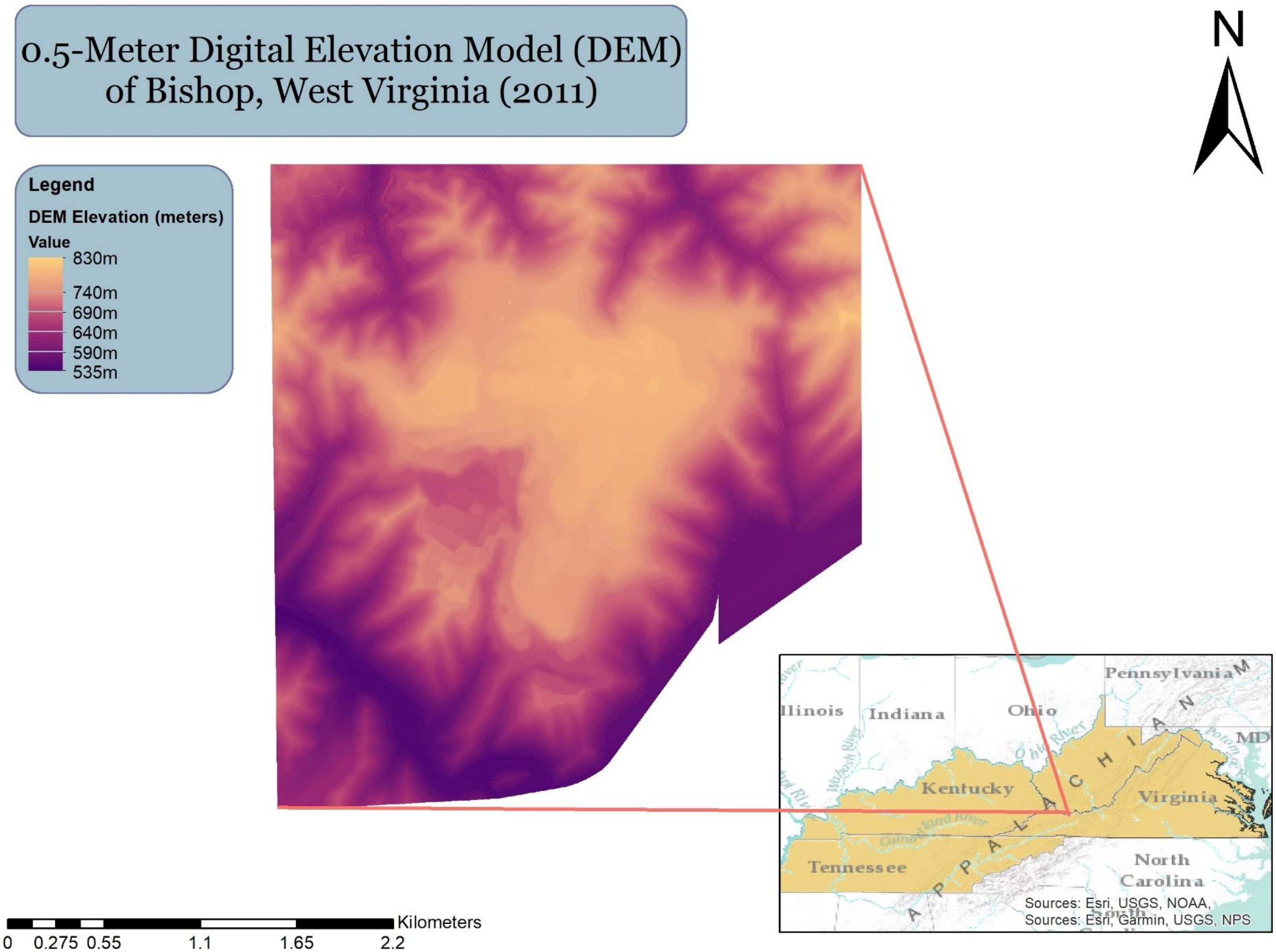
A.4: Digital Elevation Model (DEM) of Study Area on Appalachian Coal Mining



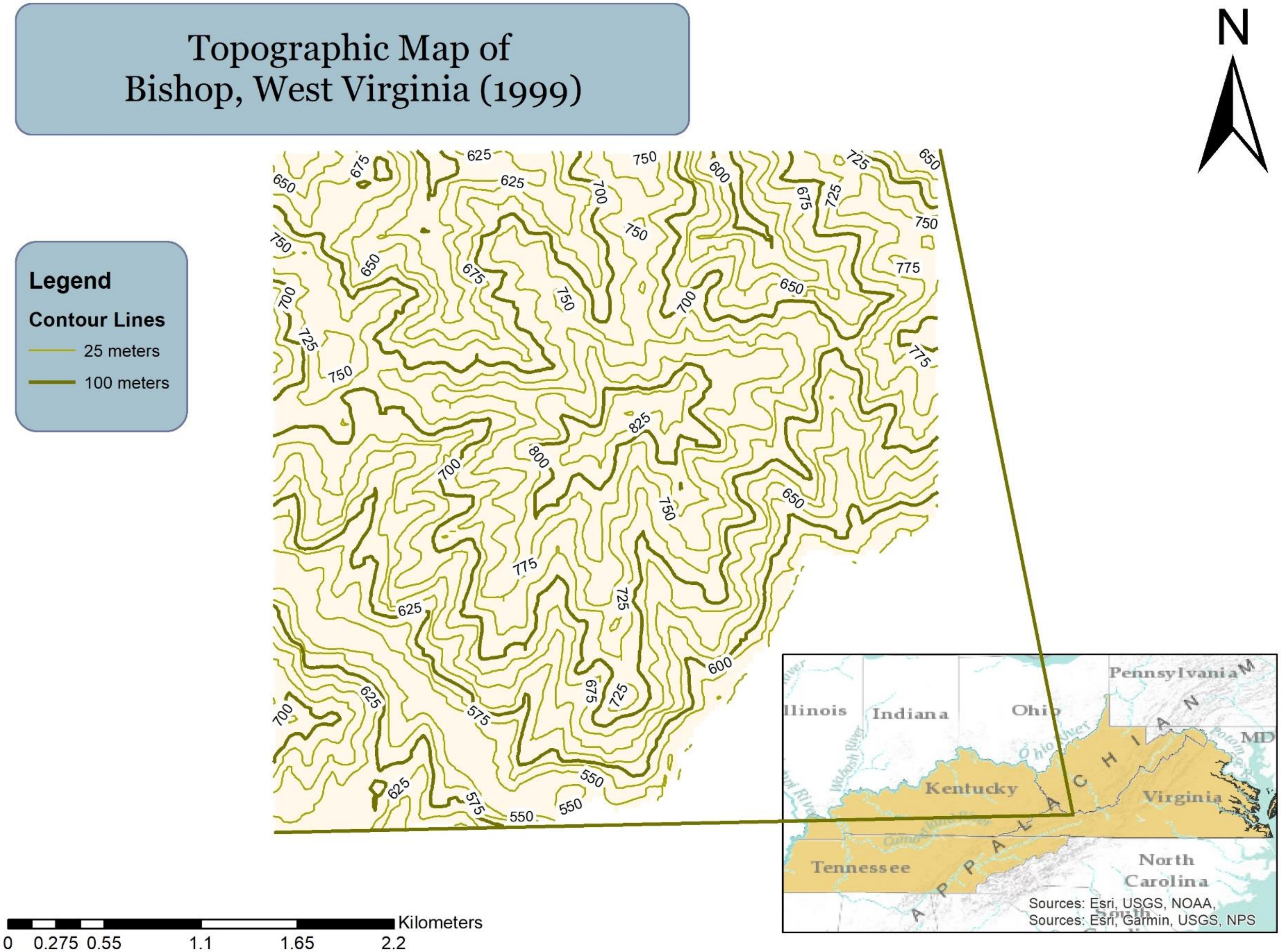
A.5: 30-Meter Digital Elevation Model (DEM) of Bishop, West Virginia (1999)



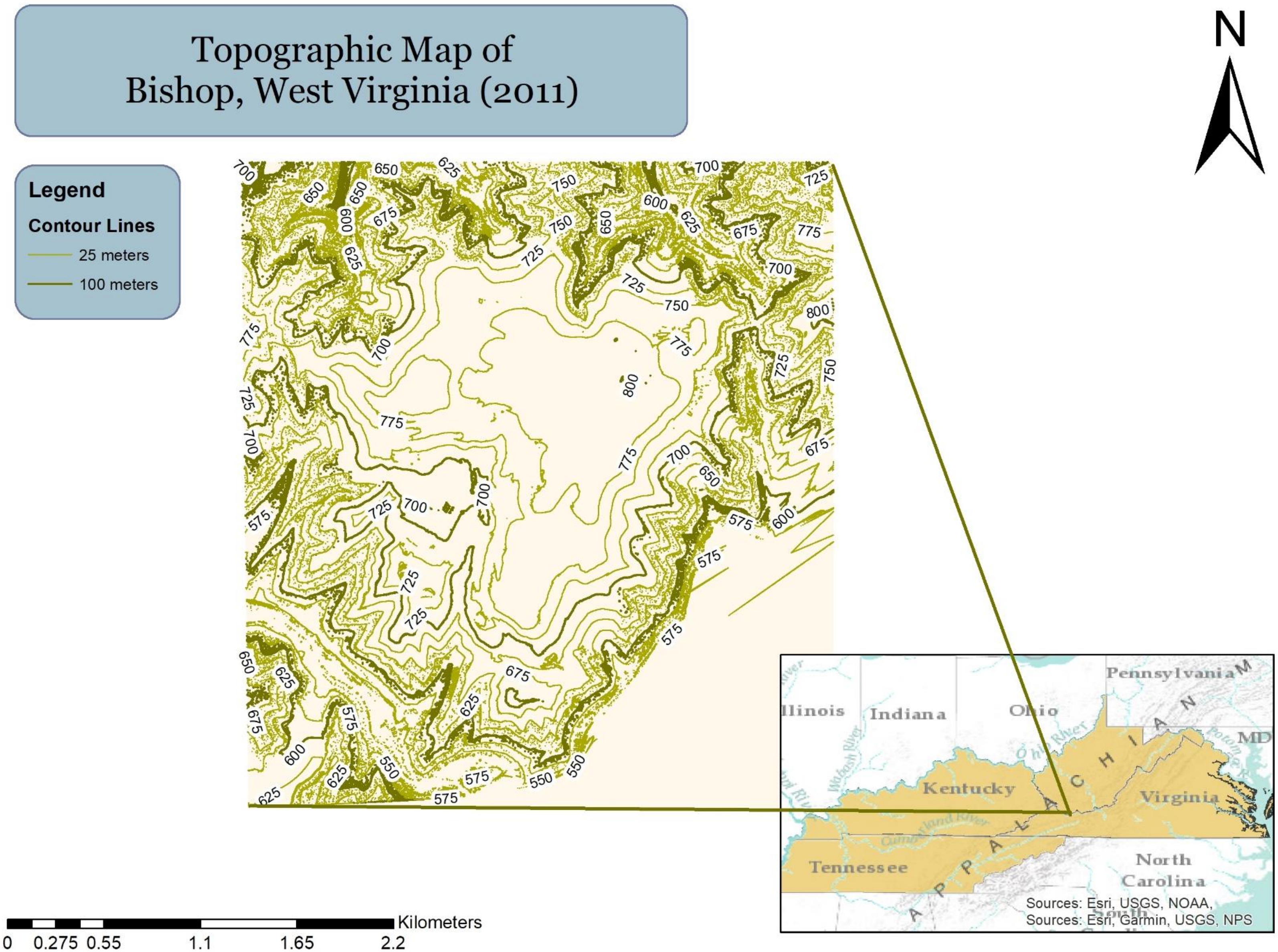
A.6: 0.5-Meter Digital Elevation Model (DEM) of Bishop, West Virginia (2011)



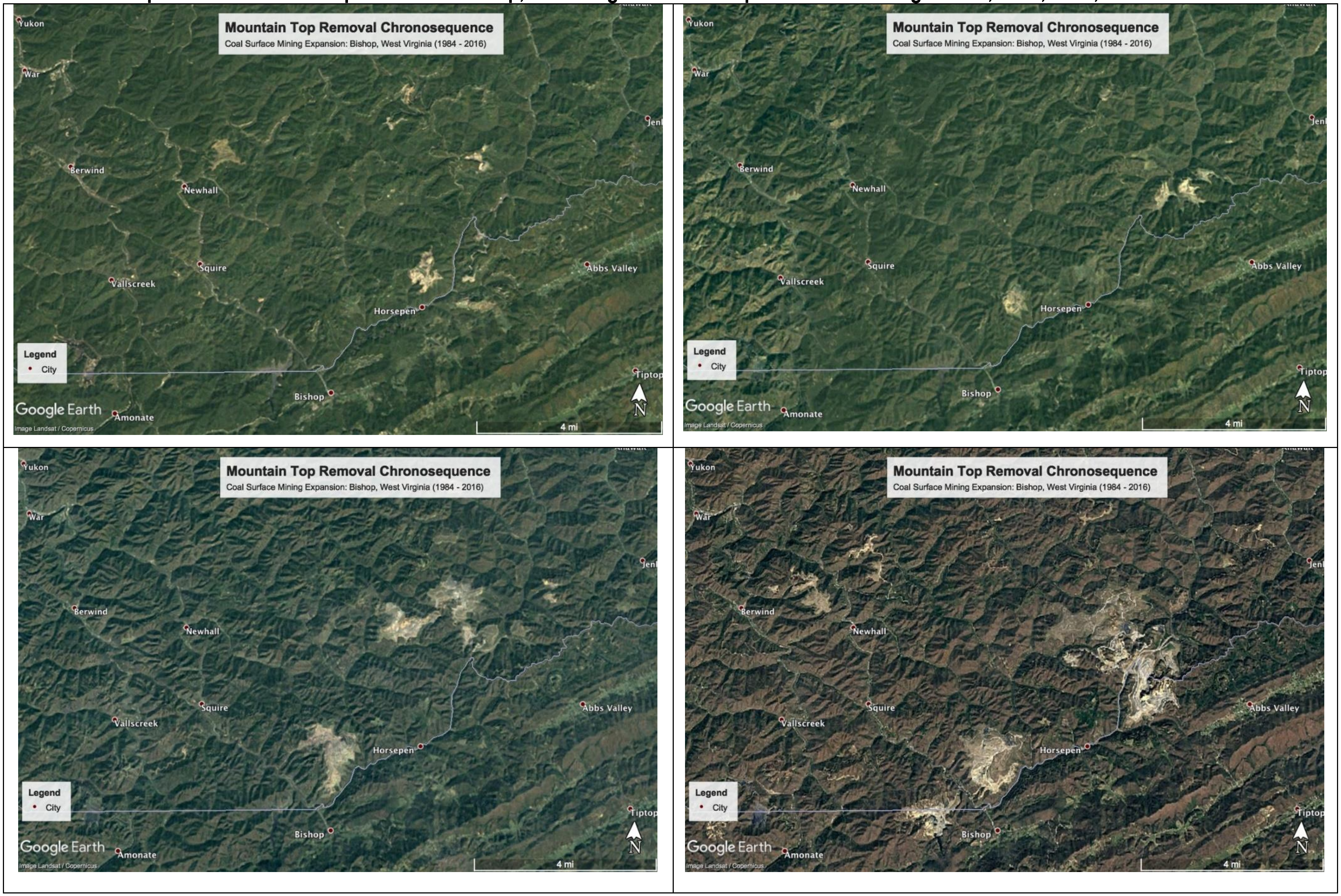
A.7: Topographic Map of Bishop, West Virginia (1999)



A.8: Topographic Map of Bishop, West Virginia (2011)



A.9: Mountaintop Removal Chronosequence near Bishop, West Virginia - From Top-left to Bottom Right 1984, 1994, 2004, 2016



Appendix B: Lesson Plans

B.1: Coal in a Cupcake: Traditional Cupcake Core Sampling Lesson

Women in Mining: Cupcake Core Sampling

GEOLOGY INTERMEDIATE 3-6, Earth Science & Math (Adaptable for K-12) PURPOSE:

Trying to "see" what is beneath the surface of the earth is one of the jobs of a geologist. Rather than digging up vast tracts of land to expose an oil field or to find some coal bearing strata, core samples can be taken and analyzed to determine the likely composition of the earth's interior. In this activity students model core sampling techniques to find out what sort of layers are in a cupcake.

Materials Needed:

Cupcake mix	Plastic knives
Foil baking cups	Food coloring
Drawing paper	Toothpicks
Frosting	Plastic transparent straws

Directions:

Make cupcakes with at least three layers of colored batter. Provide each student with a cupcake, straw, toothpick, and drawing paper. Foil baking cups and frosting will prevent the students from seeing the interior of the cupcakes in much the same way that a geologist cannot see the interior of the earth. If making cupcakes is not an option, purchased cakes with cream filling inside can be substituted.

Ask the students to fold a piece of drawing paper into four sections and in one of the sections draw what they think the inside of the cupcake would look like. Ask the students how they might get more information about the cupcake without peeling the foil or cutting it open with a knife.

Someone may suggest using the straw to take a core sample. If not, show them how to push the straw into the cupcake and pull out a sample (straws can be cut to a length slightly longer than the depth of the cupcake.) Fresh cupcakes do not work as well as cupcakes that are dryer.

The students should make a second drawing of the cross section of their cupcake based on the information from three core samples. Each new drawing should be carefully labeled and placed in a different section of the recording paper.

Finally, the students should cut open the cupcakes with a knife to compare them to the drawings.

Teacher Hints:

Keep relating what the students are doing to what real life geologists do. Nobody eats until the discussion is complete!

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B.2: Coal in a Cupcake: Updated Cupcake Removal Mining Lesson

This lesson plan has been adapted from the Lesson Plan titled “Cupcake Core Sampling” (Appendix 1B) developed by the Women in Mining Education Foundation in order to better represent the Ecological Disturbance of mountaintop removal coal mining.

Activity Title: Digging for Coal in a Cupcake

Time: 30 minutes

Age: Grade school through Collegiate

Materials: Cupcakes with a chocolate core center (see attached recipe), chocolate frosting (see attached recipe), green sprinkles, clear plastic straws cut in half, and wash cloths or napkins for clean-up.

Purpose: When talking about coal, it is easy for the mind to conjure images of soot covered men surfacing through a low-ceiling shaft after a hard-days’ work underground. Despite a recent transition towards more modern and machinery-centric surface mining techniques, this concept of coal mining persistent. The purpose of this lesson plan is to increase awareness to the amount of disturbance that is associated with modern mountaintop removal coal mining. By updating an existing lesson plan that instructs students to use straws to survey a cupcake, in reference to traditional shaft mining, students will be able to visualize the destructive force of more modern techniques. Essential to this lesson is an analogy of a cupcake being a mountain;

The cupcake’s soft and moist structure is the result of a combination of ingredients being blended together and baked in an oven at a high temperature (the equivalent of rock strata being subjected to millions of years of geologic forces eventually giving rise to mountains). Inside of the cupcake is a d,ense sugary sweet piece of chocolate (associated with a coal seam, rich in energy potential). Atop the cupcake is a delicately whipped layer of chocolate frosting which allows the vibrant green sprinkles to stick nicely atop the cupcake (This is the thin layer of organic topsoil that rests atop a mountain’s soil profile and provides the nutrients essential for vegetative forests to thrive).

Analogy:

Cupcake = An Appalachian Mountain

Chocolate Frosting = Organic Topsoil

Green Sprinkles = Forest Vegetation

Chocolate Center = Coal

Oven = Geologic Time (350 degrees is the equivalent of 350 million years, or roughly how long ago the Alleghany Orogeny was, the geologic event responsible for creating the Appalachian Mountains!)

Sugar = energy and nutrient rich substance

Plastic transparent straws = Traditional Shaft Mining

Knife = Heavy Machinery used to clear cut forests and move large volumes of earth.

Directions:

Create enough cupcakes for each student and one to demo. Provide each student with a cupcake, straw, plate and napkin. Foil baking cups and frosting will prevent the students from seeing the interior of the cupcakes in much the same way that a geologist cannot see the interior of the earth.

Present the analogy of the cupcakes to the students and make sure none of them start to eat it! Ask the students what they think the inside of the cupcake/mountain would look like and open the class to discussion. Someone should suggest using the straw to take a core sample. This will spur the analogy forward by talking about traditional shaft mining. Next, use the knife to scrap away the frosting and sprinkles and set it aside on your plate. Talk with the students about clear cutting and its impacts on an ecosystem. Continue by removing the top half of the cupcake with your knife, remembering to reinforce the analogy of the knife being heavy machinery which is removing the upper layers of the cupcake/mountain. Extract the chocolate core center and talk about society's dependence on fossil fuels in relation to the student's desire to immediately eat the chocolate piece once they have it in their hand.

Finally, using what they have left over, the students will need to put their cupcakes back together and have a competition to see who can best recreate the original cupcake. This final process resembles surface mine reclamation and the difficulties associated with restoring ecosystems to landscapes that have been disturbed by coal mining. After having an open discussion, let everyone eat what is left of their cupcakes and clean up their mess with the provided napkins.

Recipes: In order to increase the accessibility of this activity to be inclusive of all individuals who live a life with a restrictive diet a Vegan, Dairy-Free, and Gluten-Free Recipe for Chocolate Cupcakes is as follows. Note: This activity will work with all cupcakes that have a chocolate core center.

VEGAN GLUTEN-FREE CHOCOLATE CUPCAKES

INGREDIENTS **(**Serves: 10-12 cupcakes**)**

Dry Ingredients

1 ½ cups gluten free oat flour

⅔ cup unsweetened cocoa powder

1 teaspoon baking soda

¼ teaspoon salt

1 bag of Hershey Kisses

Or chocolate chunks of choice

Wet Ingredients

½ cup + 2 tablespoons water

½ cup non-dairy milk

3 tablespoons melted coconut oil

¼ cup coconut sugar

¼ cup pure maple syrup

1 teaspoon vanilla extract

INSTRUCTIONS

Preheat the oven to 350°F. Line a 12-cup muffin pan with cupcake liners. Set aside.

In a large bowl, sift together the dry ingredients: oat flour, cocoa powder, baking soda and salt.

Add water and non-dairy milk to a microwave-safe bowl. Heat in 10-second increments until just warm. This will prevent the melted coconut oil from solidifying once mixed with these liquids.

In a medium bowl, whisk together all wet ingredients: water, non-dairy milk, coconut oil, sugar, maple syrup and vanilla. Whisk until well incorporated.

Add wet ingredients to dry ingredients. Whisk until just incorporated, making sure no flour patches remain.

Pour batter evenly into prepared muffin pan—filling each cup about 1/4 of the way. Then place a single Hershey kiss in the middle. Top off until the cup is ¾ full. Bake for 16-20 minutes. Test for doneness with a toothpick. The toothpick should come out with a few dry bits of cake on it, but no liquidy batter. *Experienced bakers can simulate various rock strata by layering vanilla and chocolate cupcake batter during this phase. This will improve the analogy but is not essential to teaching the lesson.

Place muffin pan on a cooling rack to cool for 30 minutes. Remove cupcakes from muffin pan and continue cooling on a rack until completely cool before frosting.

Demeter. (2017, November 13). How to Make Vegan, Gluten Free Chocolate Cupcakes (Vegan, Paleo, Gluten-Free, Dairy-Free, Refined Sugar-Free) - Beaming Baker. Retrieved April 19, 2019, from https://beamingbaker.com/vegan-gluten-free-chocolate-cupcakes-v-gf-dairy-free-refined-sugar-free/

VEGAN GLUTEN-FREE FROSTING

INGREDIENTS

¾ cup coconut cream

1 ½ cups vegan chocolate chips or paleo-friendly chocolate chips

INSTRUCTIONS

1. The night before, place can of coconut cream into the refrigerator to chill. This will make it easier to scoop the firm cream out of the can--leaving behind any extra coconut juice.
2. Use the double boiler method to melt the chocolate and coconut cream or do the following: add coconut cream and chocolate chips to a large microwave-safe bowl. Heat in 30-second increments until melted and smooth. Stir between heating increments, until chocolate is melted. Once completely melted, whisk thoroughly until smooth.
3. Transfer to refrigerator to chill for 2-5 hours. It's done when the mixture is medium firm, similar to a very firm gel. It will be stiff enough to be solid, but lightly depresses when pressing a finger into it.
4. Using a spoon, scoop this mixture into a large, deep mixing bowl for whipping (or use the same bowl). You may also transfer to the mixing bowl of a stand mixer. If the texture is right, it won't be too hard to spoon.
5. Allow to soften and warm up a bit at room temperature, for about 10-15 minutes. It should be soft enough to whip, but firm enough to not become liquidy when whipping.
6. Using a hand mixer, or a stand mixer, fitted with a whisk attachment, beat the frosting mixture until fluffy. The color of the mixture will lighten to that of milk chocolate.
7. Frost completely cooled cake or cupcakes! Enjoy.

Demeter. (2017, November 9). How To Make Homemade Chocolate Frosting (Vegan, Paleo, Gluten Free, Dairy-Free, Refined Sugar-Free) - Beaming Baker. Retrieved April 19, 2019, from https://beamingbaker.com/make-homemade-chocolate-frosting-vegan-paleo-gluten-free-dairy-free-refined-sugar-free/

B.3: It’s All Connected

Based on the AWSM Classroom Activity created by Experience Learning, West Virginia https://experience-learning.org/ / info@experience-learning.org / 304-567-2632.

MATERIALS NEEDED

Several large sheets of paper

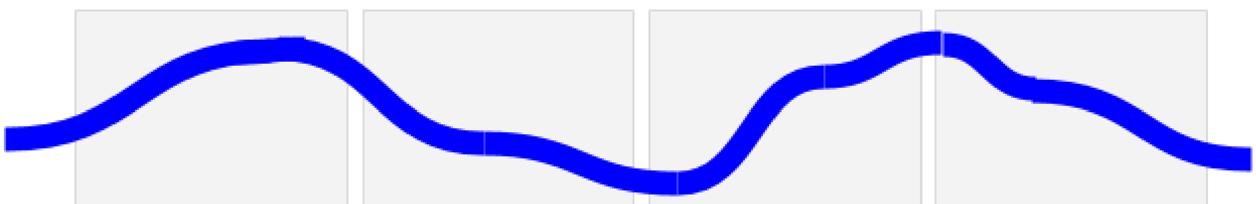
Markers/ colored pencils

Tape or magnets to hold up sheets of paper

*If available, a digital projector

PREPARATION

Prior to class, prepare several large sheets of paper with a continuous drawn river running through the pieces (# of sheets depend on group sizes). Familiarize yourself with area specific environmental codes and policies that may come up during this activity: water treatment facilities, sewage/trash disposal, etc. Incorporate geographic reference by knowing what watershed you are physically in when you are doing the activity.



ACTIVITY (Suitable for all Ages: K-Collegiate)

On the board, list the following criteria:

Name of Town

Population

Education

Homes

Employment

Entertainment

Transportation

Source of Energy

Waste Disposal

Food & Water Source

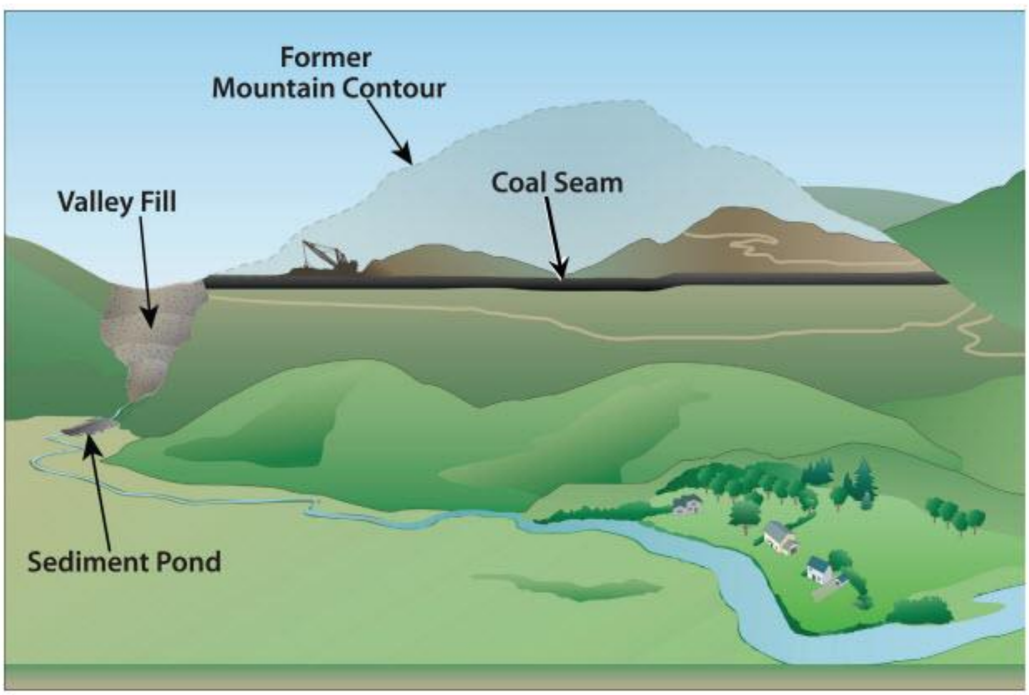
Instructor should mix-up the sheets of paper and hand one out to each group. Present the guiding question "Make an ideal community/ town/ city with your group… your community should include each of the listed criteria above.

IMPORTANT: Make sure to front load and encourage creativity, however, when town attributes get too *unrealistic* or *"make believe"* it can be challenging as the instructor to debrief and bring home the activity.

Collect each groups town and place them in the correct "order of the river" in front of the class. For a self-reminder, write the numerical order on the back of each paper with a pencil. Have each group present their town to the class. Have fun with this!

At this stage, ask them how it makes them feel to see their town's position: *Did they foresee this? How do you like your location in comparison to other neighboring towns… positives/negatives? Etc…*

It is time for the instructor to give some positive and constructive feedback on each town. Pick the order that would be the most meaningful: work upstream or downstream. After going through each community, introduce the following image of a mountaintop removal site and valley fill as the most upstream community. The easiest way to do this is to project the image onto the wall using a projector.



The new order should be as follows:

Use colored markers or pencil to identify certain pollutants and threats that come from either student's communities or the upstream mining operation: Examples include Phosphates, nitrates, erosion, heavy metals, acid mine drainage, flooding, water temperature, pH changes, surface runoff from non-permeable surfaces, community litter, neighbor conflict, and property rights, poor infrastructure, toxic waste, sewage, etc…

Take away:

IT'S ALL CONNECTED. What is a watershed? How does this activity relate to understanding the size of a watershed? What real-life examples can you relate to this activity too? As a community member of your town, what is your responsibility, what is out of your control? *Advanced Level Question*: What is the Tragedy of the Commons, and how could a waterway be considered common?

Depending on time, give the towns back to the students to correct. They can re-present to the class with the modifications they have made. The following question can then be revisited: *How do you like your location in comparison to other neighboring towns, positives/ negatives?*

Image Reference:

United States Environmental Protection Agency. (2017, January 19). A Watershed View of a Mountaintop Mine and Valley Fill [Digital image]. Retrieved February 27, 2018, from https://www.epa.gov/sc-mining/basic-information-about-surface-coal-mining-appalachia\

B.4: Watershed Delineation Lesson Plan: Elementary-Intermediate

Activity created by Experience Learning, West Virginia https://experience-learning.org/ / info@experience-learning.org / 304-567-2632.

Activity Title: Watershed Delineation
Time: 45 minutes
Age: Grades 2nd through 5th
Materials: chalkboard, old sheet, marbles or other small balls, washable markers, a spray bottle of water, miscellaneous objects that will be used to replicate topography

Description:

In this lesson, we will be exploring the concept of a watershed in depth by creating three dimensional maps of a landscape and outlining where one watershed ends and another begins. We will also be figuring out how waterways and the land surrounding them are connected to areas downstream.

First, I'm going to write the word "watershed" on the chalk board. Does anyone have a definition for this word? What is in a watershed? Rivers, right! I'll put that underneath. We can keep adding to our definition as we go.

Now let's create a landscape together. I've got all these fun bowls and other objects to use as mountains, ridges, and hills (we'll just have to imagine we're five inches tall). Help me arrange them in an area that can be covered by this sheet.

Once students are done arranging the objects, cover them with the sheet. Now we have some mountains and hills, what else does our landscape need (hint: we've been studying this a lot lately!). Right, we need some rivers! Where do rivers usually occur in the landscape? What direction does water always flow? Downhill, of course. The biggest rivers tend to be found in our valleys. Smaller tributary streams flow downhill into these larger rivers from the mountains. Let's draw some big rivers and some tributaries flowing downhill into them.

Okay, so we have mountains and hills and rivers and streams. What do you think happens when it rains on the sides of these mountains? Where does water flow? Downhill, of course. So, if it rained here (pick a mountain side and drop a marble), the water flows down into this river. But if it rained here (drop a marble on the opposite side of the mountain), the water flows down into this other river. Let's see if we can use these marbles to figure out where water will go once it falls on our landscape. Use these colored markers to trace the path of your marble after you drop it.

(Give everyone a marble or two to experiment with and have students go two or three at a time to trace their marbles path into the rivers. Once everyone has gone, the sheet should be covered with arrows pointing into the rivers and there should be an obvious divide where arrows point into different watersheds). Does anyone notice any patterns on our landscape? Do you think we can outline the drainage area of this river? What about this one? (Coach a student through drawing the line that distinguishes one watershed from another).

Let's look back for a moment at our definition of a watershed. Does anyone think that they can add to this definition after our experiments with raining marbles? The landscape is also a part of the watershed – all land that drains into a river or stream is also a part of that river's watershed.

We've just delineated an entire watershed!

So now that we understand how to delineate a watershed, what information have we gained and why is it valuable? We can now identify all of the tributaries and all of the land area that could be having an impact on our watershed at any given point. For example, if we got some weird results in our stream study, we could look at a map and think and figure out where we would need to go next to identify the source of the problem. We'd go upstream right? We could investigate what tributaries were flowing into our stream; we could see what kind of land use was occurring along those tributaries; and with all that information, we would be better informed to address our problem.

Notes: For advanced 4th and 5th graders, you can combine this lesson with the following lesson for older students. Use the miscellaneous objects, the sheet, and some rulers to make your own topographic map and explore drainage patterns. Then ask them to repeat the exercise of outlining watersheds on a real topographic map.

B.5: Watershed Delineation Lesson Plan: Intermediate-Advanced

Activity created by Experience Learning, West Virginia https://experience-learning.org/ / info@experience-learning.org / 304-567-2632

Activity Title: Watershed Delineation
Time: 1 hour
Age: Grades 6th through Collegiate
Materials: chalkboard, laminated topographic maps (either as referenced in Appendix 6A and 8A or from your local region), dry erase markers, paper towels or erasers for wiping down maps after the lesson

Description:

In this lesson, we will be exploring the concept of a watershed in depth by looking at real maps of our landscape and outlining where one watershed ends and another begins. We will also be figuring out how waterways and the land are connected to areas downstream. Before we can delve into watershed delineation though, we need to understand how to read topographic maps.

What are topographic maps? Topographic maps show the topography or the three- dimensional shape of the landscape in a two-dimensional map. They do that using contour lines. All those brown squiggles you see all over the map are contour lines.

Contour lines represent differences in elevation. The difference in elevation is noted by the contour interval, which can be found in the legend on the map. These maps have a contour interval of 40ft, which means that between each contour line on our map, there is a vertical (elevation) difference of 40ft. To determine the horizontal distance between points, we look at the scale of the map. We know a slope is steep when many contour lines (representing vertical distance) are close together on the map (over a short horizontal distance).

How do we know what is higher and lower elevation on a topographic map? There are a few ways to tell. You can look at the numbers on the bold contour lines (called index contours) to determine the elevation of that line and compare it to the next bold contour line. Another easy way to determine what is up and what is down is by searching for high points. High points are often obvious because they consist of concentric circles of contour lines, with the highest point being the smallest inner circle. These concentric circles represent the mountains. Mountains and ridgelines are the features of the landscape that most often separate one watershed from another. Let's draw some pictures on the board to practice reading our topographic maps.

Okay, now an easy question: How are waterways represented on this map? Right, all lakes, river, and streams are represented in blue. We're going to focus on our rivers and streams right now but remember that lakes are also a part of our watersheds. We'll explore how that works in a moment.

"Everyone please have a look at your topographic maps and see if you can find the location where we did our stream study yesterday. Mark that point on your maps with one of your markers." (Instructors should go around and see if all students have found the correct point – coach students with clues before you give them the answer – Do they remember the name of the stream? Do they remember a bridge or a gate? Do they remember traveling over dirt or paved roads?). To begin defining this watershed, lets first find all the tributaries of this stream that occur upstream of where we did our stream sample. Trace all the waterways that eventually flow through the point we studied. (Instructors should go around and see if all students have traced the correct waterways – again, coach students on how to distinguish upstream from downstream).

Okay, so now we have identified the rivers and streams that form a part of our watershed. What else is included in a watershed? All the land area that drains into those waterways that we have highlighted is also a part of this watershed. So how do we know where that land that is a part of our watershed ends and a different watershed begins? Visualize the three-dimensional landscape depicted by this topographic map and then imagine some rain falling on those hillsides surrounding our highlighted waterways. That rainfall would flow downhill, right? So, if the water falling on our landscape flows downhill towards and into our highlighted waterways, then that land is part of our watershed. If the water flows away from and into a different, un-highlighted waterway, it is not a part of our watershed.

Where does that divide between watersheds occur? Usually, the divide occurs at the tops of mountains and ridgelines. Identify all the high points surrounding our highlighted waterways with an “x” on your topographic maps. If you connect those “x”s, following the ridgelines (usually identifiable by their downhill pointing “u”s of contour lines), you will delineate our entire watershed. To check your work, again imagine that water falls somewhere just outside the area you outlined on the map. If that water flows downhill, away from your watershed, and into an entirely different waterway, the border you have drawn is correct. Be aware of false summits, though! Sometimes a high point exists that is higher than the high point nearest our waterways of interest and should be included in our watershed because the land area still drains into those same waterways. (Instructors should go around, and check students work – when you see an error, work with students to encourage them to correct themselves).

So now that we have delineated our watershed, what information have we gained and why is it valuable? We’ve now identified all the tributaries and all of the land area that could be having an impact on our stream where we did our stream study. If we got some weird results in our stream study, we could look at this map and think and figure out where we would need to go next to identify the source of the problem.

Up in the mountains, it is simple to draw watersheds because there are so many headwater streams. Can you imagine trying to delineate the entire Potomac watershed? Or trying to identify the source of a water quality problem on the Potomac River? There are so many more tributaries and so much more land that is a part of the Potomac Watershed! That doesn’t mean that we should be overwhelmed by water quality problems downstream, just that we need to be very conscious of where we are in a watershed. As citizens, we need to understand that whatever impacts water quality where we are also impacts water quality for all areas downstream of us in the watershed. As citizen scientists, we need to be strategic in how we approach the identification and management of water quality issues.

Journal Prompts

To what extent does topography influence hydrology? What are some major topographic features that provide information on how to best delineate a watershed?

What effect does surface mining have on the topography of a region? How would a sudden change in topography effect the hydrology of a region? What else may be affected by this change? (Hint: think about the sun, slope, and what plants might try and grow there.)

References

A useful explanation of watershed delineation using topographic maps can be found in the following Appendix 6B and accessed at:
http://www.geo.brown.edu/research/Hydrology/FTP_site_5099-05/maine_appD_watershed-delineate.pdf

Topographic Maps of areas within the United States can be accessed through USGS's topoView availabe at: https://ngmdb.usgs.gov/topoview/viewer/

Additionally, the topographic maps in Appendix A (6A and 8A) can be used to provide a tool for understanding the impact mining has on topology and watersheds.

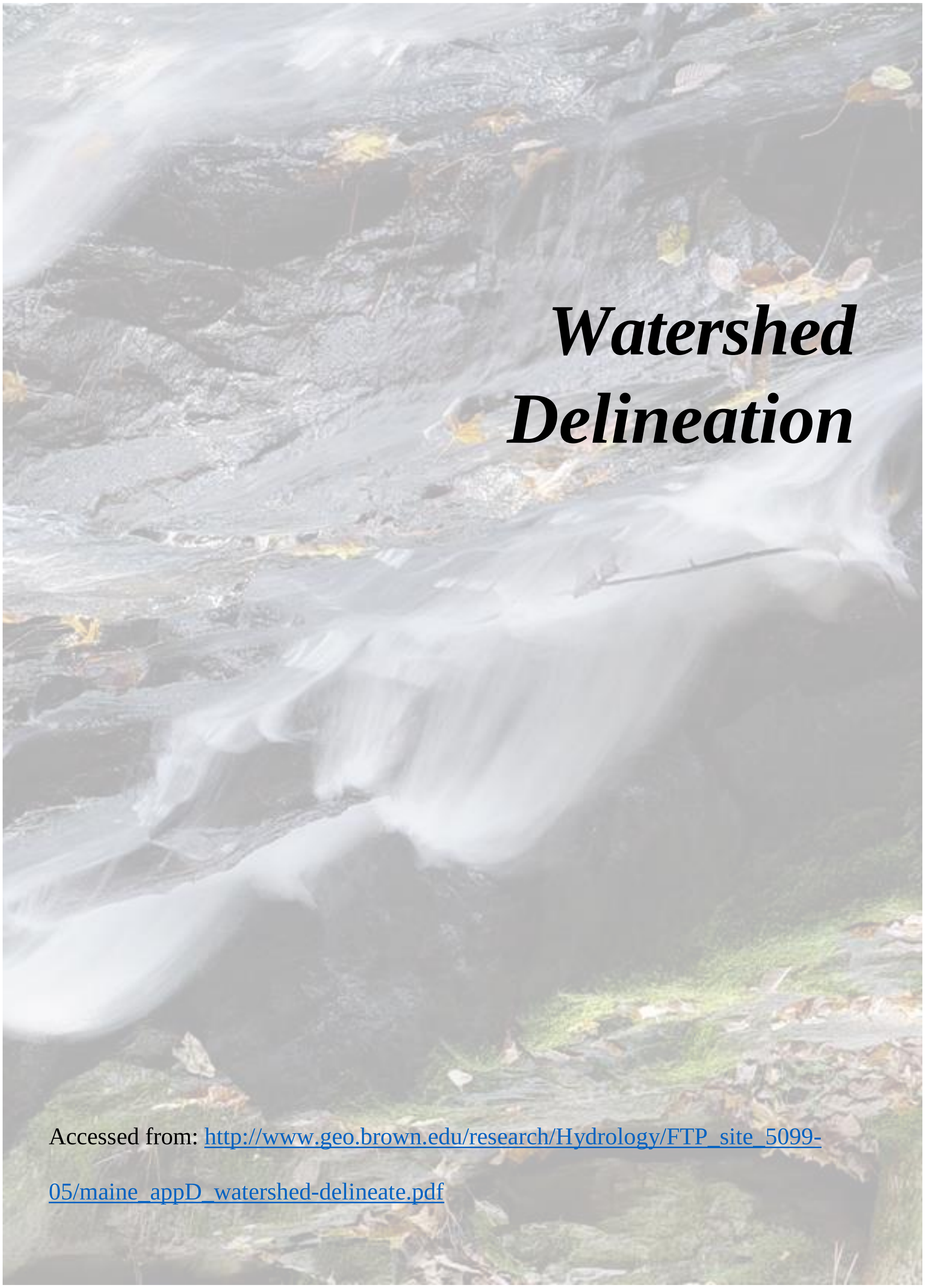
Goals

- Students will understand how to interpret and critically analyze data collected during our stream study

Objectives

- Students will review the data collected in our stream study and compare our results to the results we would expect from a healthy stream
- Students will gain practice analyzing quantitative data
- Students will gain practice analyzing qualitative data
- Students will think critically about our data collection methods and analysis and be able to give examples of how to obtain more accurate and/or precise results in future stream studies
- Students will be able to give examples of how to improve the overall stream rating based on their data analysis

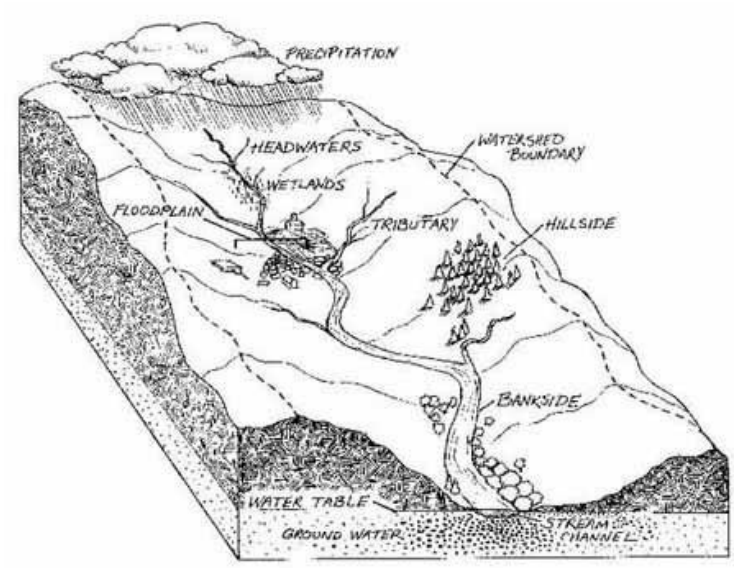
B.6: Watershed Delineation: Information Resource



Watershed Delineation

Accessed from: http://www.geo.brown.edu/research/Hydrology/FTP_site_5099-05/maine_appD_watershed-delineate.pdf

Watershed Delineation



Imagine a watershed as an enormous bowl. As water falls onto the bowl's rim, it either flows down the inside of the bowl or down the outside of the bowl.

The rim of the bowl or the watershed boundary is sometimes referred to as the ridgeline or watershed divide. This ridge line separates one watershed from another.

Topographic maps created by the United States Geological Survey (USGS 7.5 minute series) can help you to determine a watershed's boundaries.

Topographic maps have a **scale of 1:24,000** (which means that one inch measured on the map represents 24,000 inches [2000'] on the ground). They also have **contour lines** that are usually shown in increments of ten or twenty feet. ***Contour lines represent lines of equal elevation,*** which typically is expressed in terms of feet above mean sea level. As you imagine water flowing downhill, imagine it crossing the contour lines perpendicularly.

We describe basic topographic map concepts and symbols below, but more information can be found at the U. S. Geological Survey's website on Topographic Map Symbols:

- http://erg.usgs.gov/isb/pubs/booklets/symbols/index.html — or
- http://erg.usgs.gov/isb/pubs/booklets/symbols/topomapsymbols.pdf

Here's how you can delineate a watershed:

STEP 1:

Use a topographic map(s) to locate the river, lake, stream, wetland, or other waterbodies of interest. *(See the example, West Branch of Big River, in **Figure D-1.**)*

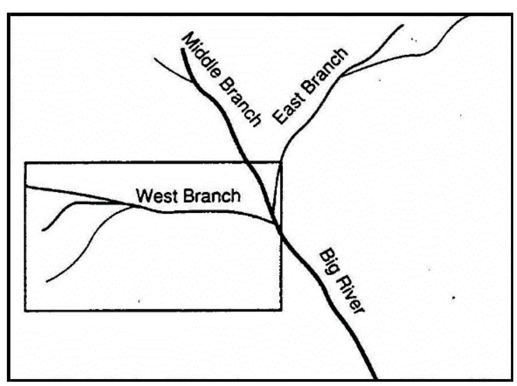


Figure D-1: West Branch of Big River

STEP 2:

Trace the watercourse from its source to its mouth, including the tributaries ***(Figure D-2).*** This step determines the general beginning and ending boundaries.

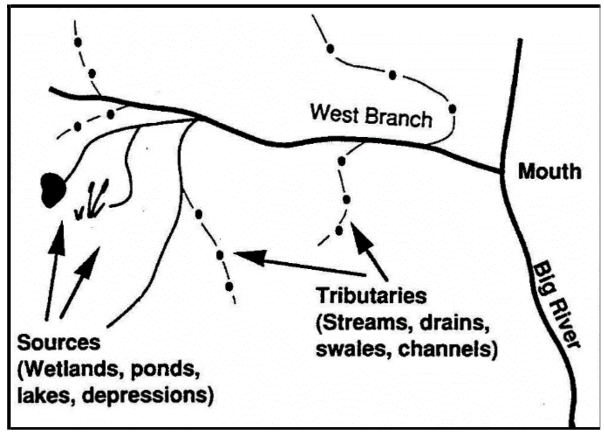


Figure D-2:West Branch subwatershed

STEP 3:

Examine the **brown lines** on the topographic map that are near the watercourse. These are referred to as contour lines. **Contour lines connect all points of equal elevation above or below a known reference elevation.**

• The dark brown contour lines (thick lines) will have a number associated with them, indicating the elevation.

• The light brown contour lines (thin lines) are usually mapped at 10 (or 20) foot intervals, and the dark brown (thick) lines are usually mapped at 50 (or 100) foot intervals. Be sure to check the map's legend for information on these intervals.

• To determine the final elevation of your location, simply add or subtract the appropriate contour interval for every light brown (thin) line, or the appropriate interval for every dark brown (thick) line. ***Figure D-3*** shows a point (X) at an elevation of 70 feet above mean sea level.

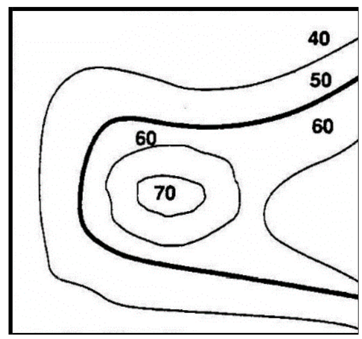


Figure D-3: Contour lines and an example point (X) at an elevation of 70 feet above sea level.

STEP 4:

• Contour lines spaced far apart indicate that the landscape is more level and gently sloping (i.e., they are flat areas). Contour lines spaced very close together indicate dramatic changes (rise or fall) in elevation over a short distance (i.e., they are steep areas) ***(Figure D-4)***.

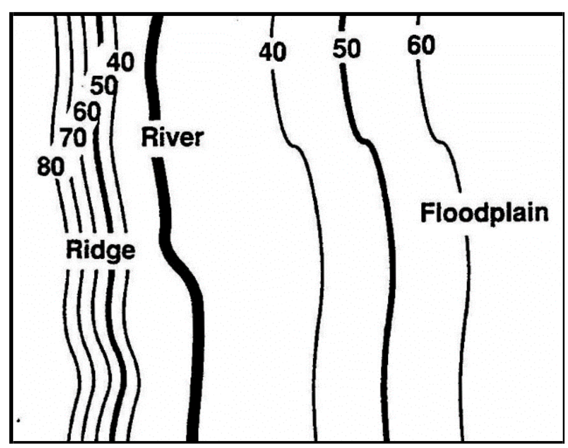


Figure D-4: Floodplains and ridges

STEP 5:

Check the slope of the landscape by locating two adjacent contour lines and determine their respective elevations. The slope is calculated as the change in elevation, along a straight line, divided by the distance between the endpoints of that line.

• A depressed area (valley, ravine, swale) is represented by a series of contour lines “pointing” towards the highest elevation ***(Figure D-5).***

• A higher area (ridge, hill) is represented by a series of contour lines “pointing” towards the lowest elevation ***(Figure D-6)***.

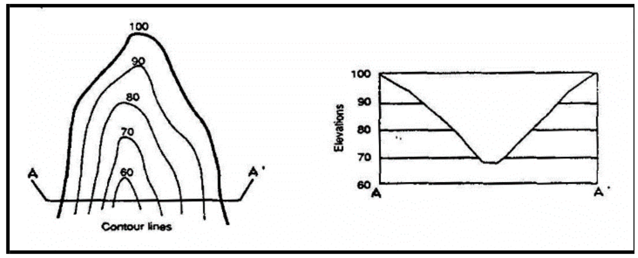


Figure D-5: Valley

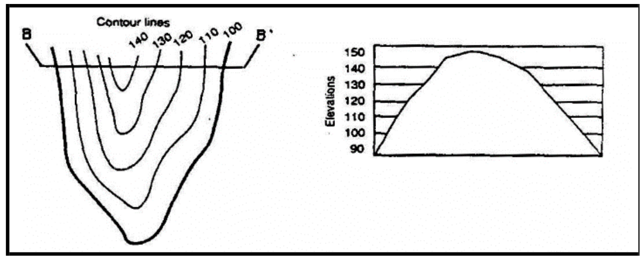


Figure D-6: Ridge

STEP 6:

Determine the direction of drainage in the area of the waterbody by drawing arrows perpendicular to a series of contour lines that decrease in elevation. Stormwater runoff seeks the path of least resistance as it travels downslope. The “path” is the shortest distance between contours, hence a perpendicular route ***(Figure D-7)***.

Mark the break points surrounding the waterbody. The “break points” are the highest elevations where half of the runoff would drain towards one body of water, and the other half would drain towards another body of water **(Figure D-8)**.

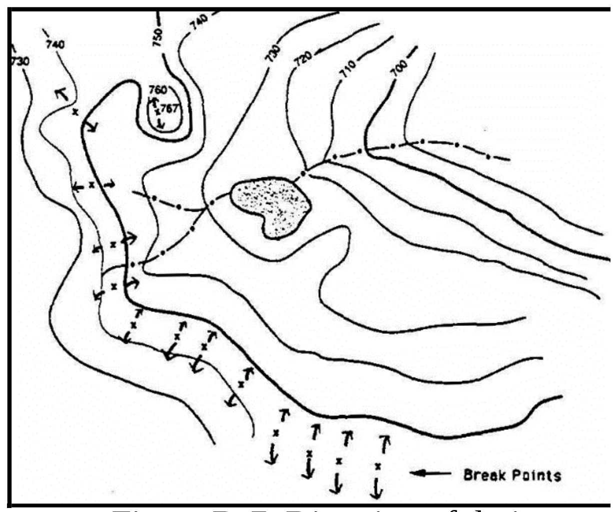


Figure D-7: Direction of drainage

STEP 8: IDENTIFY BREAK POINTS

Connect the break points with a line following the highest elevations in the area. The completed line represents the boundary of the watershed ***(Figures D-8 and D-9)***.

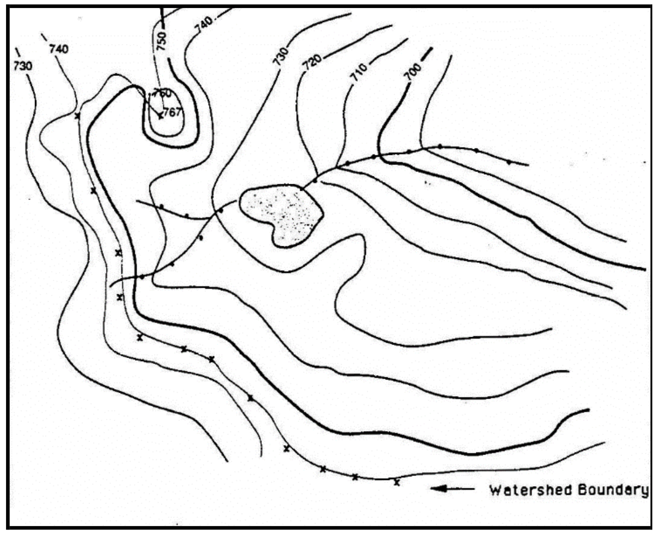


Figure D-8:Watershed Boundary

STEP 9:

Once you've outlined the watershed boundaries on your map, imagine a drop of rain falling on the surface of the map. Imagine the water flowing down the slopes as it crosses contour lines at right angles.

Follow its path to the nearest stream that flows to the water body you are studying. Imagine this water drop starting at different points on the watershed boundaries to verify that the boundaries are correct.

STEP 10:

Distribute copies of your watershed map to your group.

STEP 11:

Watersheds sometimes have what are termed subwatersheds within them. Rivers, large streams, lake, and wetland watershed often have more than one subwatershed (usually smaller tributary watersheds) within them.

Generally, the larger the waterbody you are examining, the more subwatersheds you will find. Your watershed map can be further divided into smaller sections or subwatersheds if it helps organize your study better.

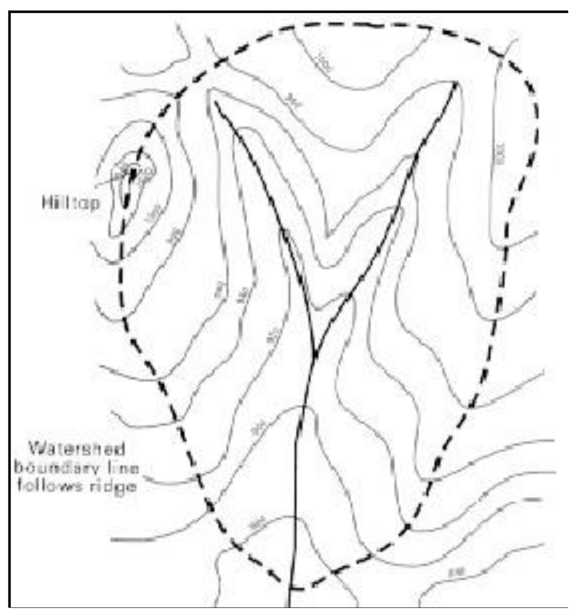


Figure D-9: Idealized Watershed Boundary

(Adapted from Ammann, Allen, and Amanda Lindley Stone, Method for the Comparative Evaluation of Nontidal Wetlands in New Hampshire. 1991, from New Hampshire Department of Environmental Service

STEP 12:

Once the watershed and subwatershed (optional) boundaries have been delineated on the map, your team can verify them in the field, if necessary.

B.7 Riparian in a Pan Lesson Plan

This activity should take place in a riparian buffer zone alongside a stream.
Introduction:

Ask the students where they are sitting? How would you describe this area? (the forest)

But what part of the forest? → Introduce the vocabulary of Riparian Buffer Zone

Break down the vocabulary → What is a buffer? What is a zone? What does Riparian mean?

Explain the definition in simple terms – ie: The area of plants next to streams that helps to protect them.

What do you think the plants (trees) do to protect the stream?

To help them figure out the answer to the above question, have them do a thought experiment: what would happen if a very large amount of pollutants (unwanted mining tailings) were dumped into the forest in a short amount of time (trees would absorb some of the pollution, preventing some erosion, holding the soil in place, etc)

what would happen if the trees were gone and the same toxic waste was poured in the riparian buffer zone? (flooding, acid mine drainage, toxic runoff, erosion, fish kill).

The Takeaway – Three Benefits of a Riparian Buffer Zone

1. Shade

2. Absorbing Pollutants

3.Preventing Erosion

Riparian in a Pan Visual:

This lesson requires the use of a model to demonstrate some of the ecosystem services provided by a riparian buffer zone in a very simplified way.

Materials: Plastic Painting Tray, Food Coloring, Spray bottle with water, toys (anything to represent built structures such as Legos, Hot Wheels, etc.), and Sponges cut into strips.

Convert a painting tray found from any hardware store into a learning tool. If you have some extra time, spray paint the basin a blue color to represent the river, and the sloped section green or brown to represent the river's watershed.

Have students come up with a hypothetical community (Similar to It's All Connected) and place different types of buildings throughout the watershed by using legos, or toys, or whatever is on hand to represent the buildings the students suggest.

Fit the sponges into a strip just above the paint tray basin. Ask the students what the sponges represent. the trees and plants that make up the riparian area along the edge of the waterways.

Ask students if any of their buildings produce any sort of pollutants. Use diluted food coloring to drop little puddles of pollution around their buildings in the pan.

Slowly sprinkle a little bit of water from a spray-bottle. Explain that the water represents rain. Students will observe as the pollutants run-off downhill and are absorbed by sponges.

Ask: What do you think will happen if the riparian buffer is removed? (The water will not be absorbed; it will flow more quickly into the body of water.) Remove the sponges and water. Pour the same amount of water on the model at the same spot and rate as before. Have the students note any differences? The pollutants should fill the body of water much more quickly and may eventually overflow and flood the land. That's because it is no longer retained by the riparian buffer.

Journal Prompts

If Mountaintop removal coal mining destroys a riparian zone by filling the valley with overburden, what might happen to the downstream community during a severe rainstorm?

How might muddy or polluted water affect fish or other life in the stream? (Makes it harder for them to see and breathe with clogged gills and could lead to their death.)

How might the muddy water affect other animals and plants? (Settling sediment smothers clams, plants do not get sunlight needed for growth, birds and other animals that eat fish or plants have less to eat if food sources die or cannot be seen in muddy water. This is called a trophic cascade.)

How might all of this affect you or someone living in a downstream community? (Decrease in natural resources and food sources; decline in quality of drinking water; impacts on recreation such as swimming and fishing; change in aesthetics; change in community economy, such as shipping problems that affect jobs and industry, etc.)

How can we prevent these undesirable effects? (By protecting riparian zones from the effects of coal mining and helping to make their benefits known!)

Appendix C: Final Presentation Slides

Restoration Appalachia

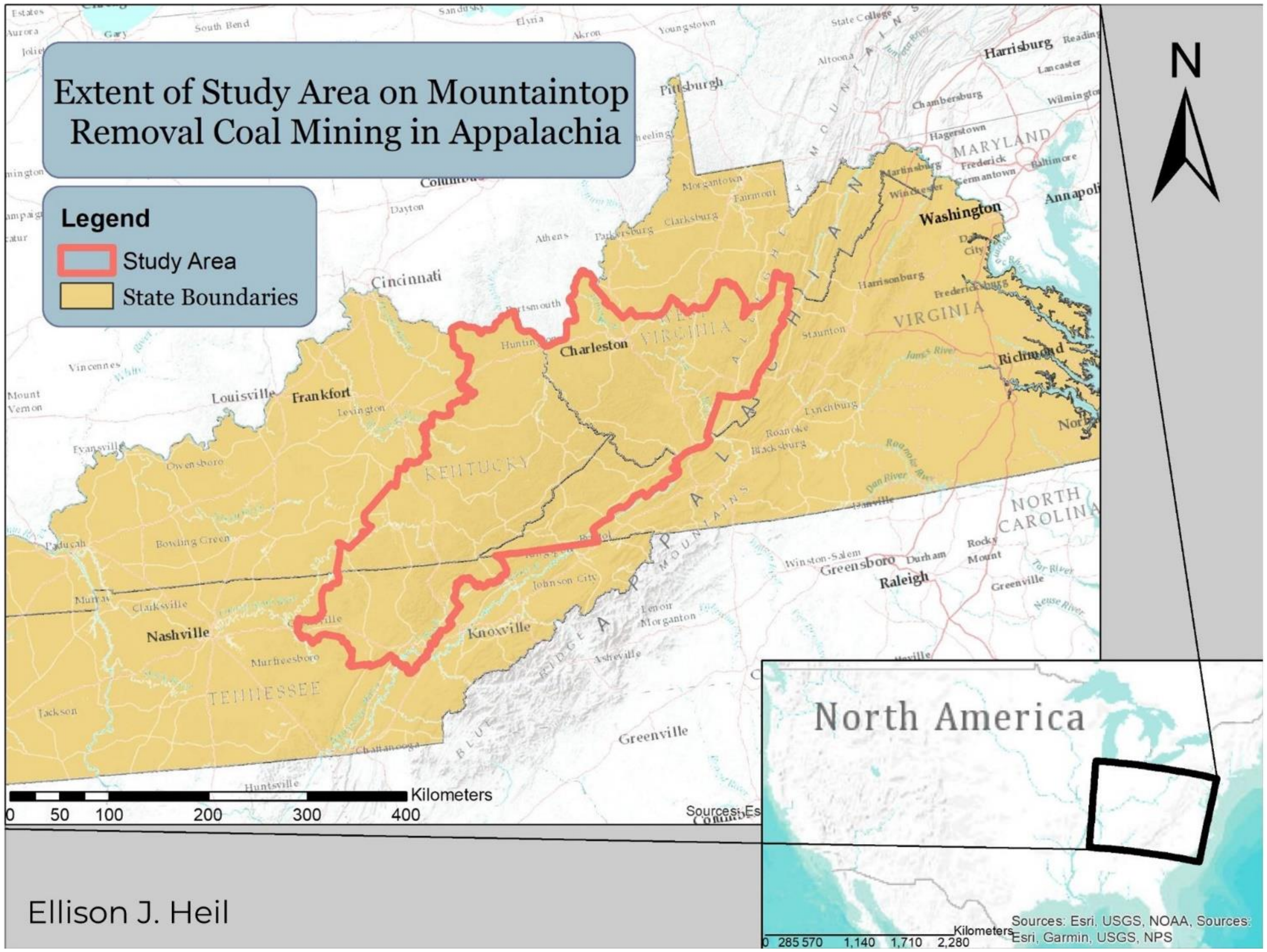
Ellison J. Heil

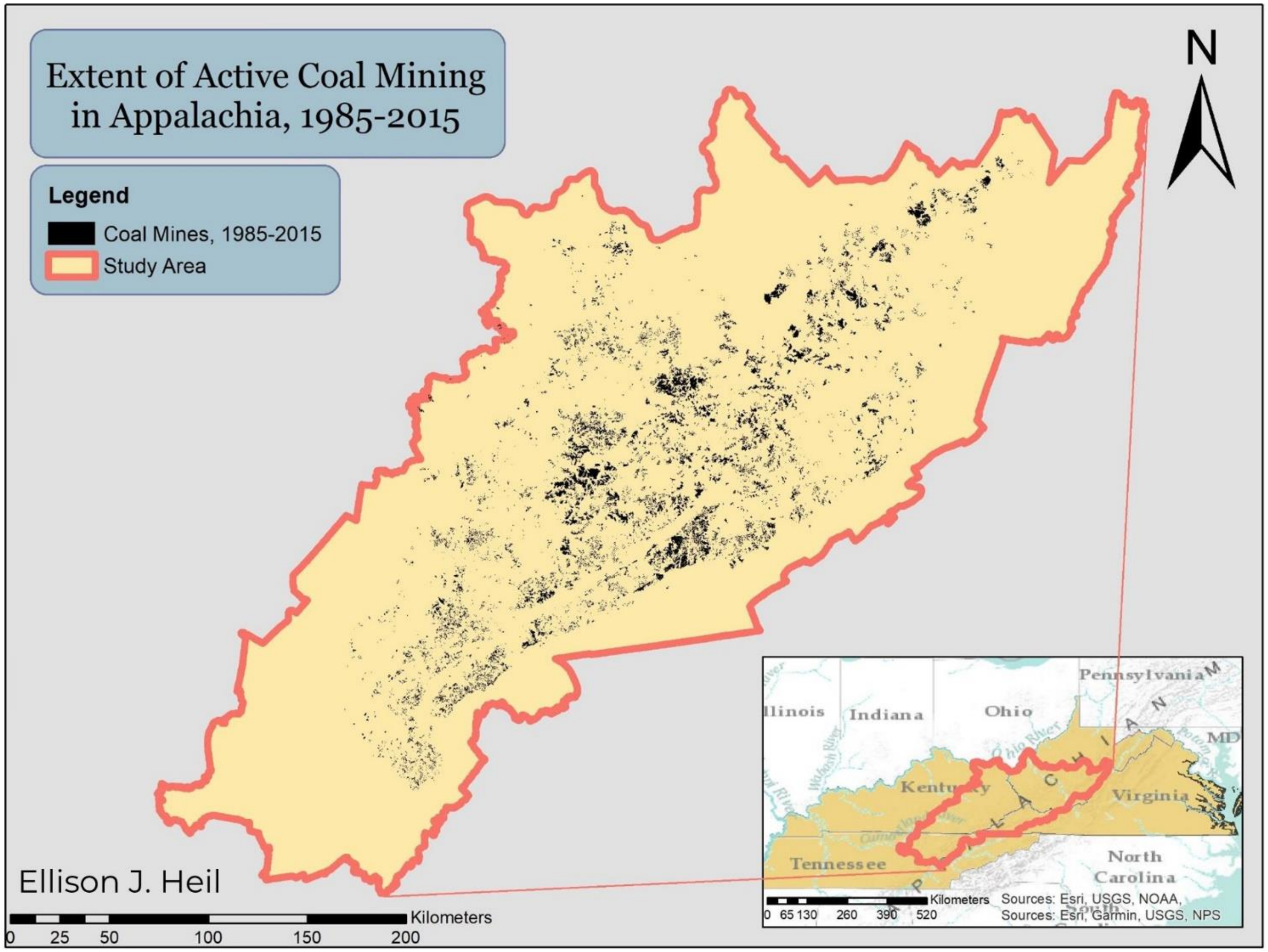
University of Washington

School of Environmental and Forest Sciences

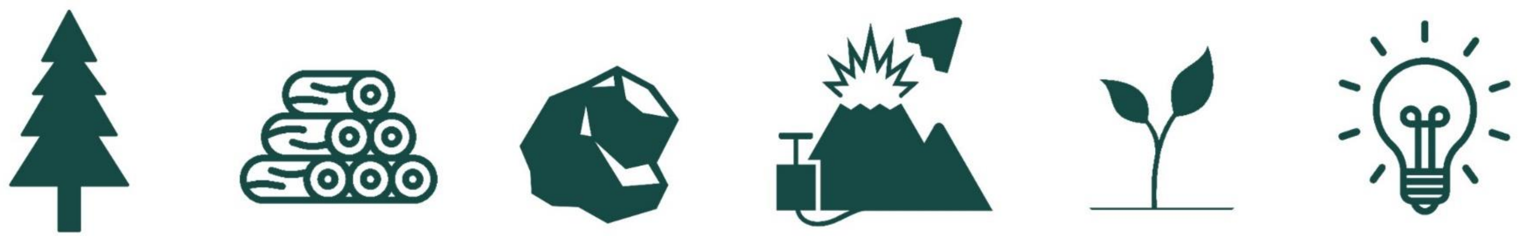
Master of Environmental Horticulture

Final Presentation May 24th, 2019


Extent of Study Area on Mountaintop Removal Coal Mining in Appalachia
Legend
Study Area
State Boundaries
N
North America
Kilometers
0 50 100 200 300 400
Ellison J. Heil
Sources: Esri, USGS, NOAA, Sources: Esri, Garmin, USGS, NPS


Extent of Active Coal Mining in Appalachia, 1985-2015
Legend
Coal Mines, 1985-2015
Study Area
N
Ellison J. Heil
Kilometers
0 25 50 100 150 200
Pennsylvania
Illinois
Indiana
Ohio
MD
Kentucky
Virginia
Tennessee
North Carolina
0 65 130 260 390 520 Kilometers
Sources: Esri, USGS, NOAA,
Sources: Esri, Garmin, USGS, NPS

Outline



OLD-GROWTH FOREST | TIMBER HARVEST | COAL MINING | MOUNTAINTOP REMOVAL | FOREST RECLAMATION | ECOLOGICAL RESTORATION

INDIGENOUS LAND

Ecological Base

The virgin mixed-mesophotic forests of Appalachia stretched well over 10 million acres and were characterized by rolling hills and numerous hollows, and were among the most biodiverse ecosystems on Earth. This biodiversity is the result of complex topography comprised of narrow ridgelines with steep slopes on either side and countless streams in-between.

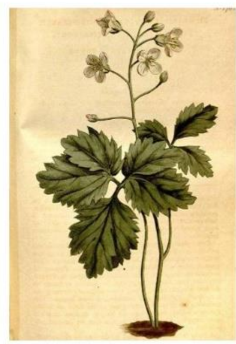




Uganost [ooh-guh-naw-s] *Cherokee*

noun wild sweet spring greens





Resource Extraction Timeline

1770s-1780s **Post Revolutionary War**

Following the colonization, the revolutionary elite claimed rights to immense tracts of native Cherokee, Choctaw, Chickasaw, Seminole, and Creek nations' land as property. At the time these tracts of forested mountainous land were perceived as too steep and remote for commercial cultivation and was thus left alone by the elite. Communities of highlanders and pioneers settled the region and claimed land through squatters right. These communities functioned as subsistence agrarian societies that were dependent on the surrounding forest's "**ecological base**" for sustenance and commodities

1800s-1840s **Industrial Revolution**

The Industrial Revolution defined an era in which humanity showcased its dominion over the natural world. The invention of the steam engine fostered the development of the band saw and the Shay geared Locomotive which sparked commercial logging. These two machines operated in concert to enable access to and transport of timber in large volumes from remote and treacherous wilderness to lumber mills for efficient processing.

1860s - 1870s **Civil War**

The reconnaissance and cartography expeditions in Central Appalachia both before and during the Civil War gathered extensive amounts of geographical and geologic information. As cartographers scouted out the hills and valleys into order to draw battle maps, they noticed extraordinarily rich outcroppings of coal seams all throughout the region. The synthesis of this geological and statistical information as visual maps was critical in conveying the prospects of this new energy frontier to potential commercial investors.

DEFORESTATION

Loss of the Ecological Base

In the forty years that commercial logging operated at full capacity, over 10 million acres of virgin old-growth forests were clear cut. Deforestation of the Appalachian forests stripped away the region's **ecological base** that provided the foundation of indigenous nations' and subsistence agrarian livelihoods. To make matters worse, the aftermath of logging left behind slash, which easily caught fire from sparks produced by the steam-powered locomotives and sawmills


Black Water Canyon,
W.Va.
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W.Va.
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UNDERGROUND MINES

Shaft and Slope

As Civil War era cartographers scouted Appalachia to draw battle maps, they noticed outcroppings of coal seams. The synthesis of this information as visual maps was critical in conveying this new energy frontier to potential investors. The discovery of these reserves coincided with the boom of commercial logging and utilized the same railroad infrastructure to significantly increase the accessibility to mining regions. As a result, railroads functioned as a conduit for parceling and dismantling the ecological base


MAP
illustrative of the
STATISTICS of the COAL TRADE
of Pennsylvania Showing the relative positions of the various Anthracite & Bituminous Coal Fields. Also the Railroads, Canals & navigable Waters, by which they are intersected, forming their respective Avenues to Market.
Prepared by R. C. Taylor, Esq. 1848.
Railroads in operation.
Railroads proposed or in progress
Canals.
THE GREAT ALLEGHANY BITUMINOUS COAL FIELD
Small detached Coal Fields
Bituminous Coal
Alleghany Mountains
PENNSYLVANIA
NEW YORK
NEW JERSEY
MARYLAND
VIRGINIA
MIDDLE COAL REGION
WYOMING COAL REGION
FIRST COAL REGION
Lackawanna
Carbondale
Broad Top
North or Blue Mountain
South Mountain
Conewago Hills
Blue Mountains
Schooleys Mountain
Region of Hamatite Iron Ore
Harrisburg
Huntingdon
Lewistown
Bedford
Frostburg
Cumberland
Greensburg
Connellsville
Clearfield
Philipsburg
Bellefonte
Hollidaysburg
Northumberland
Danville
Bloomsburg
Wilkesbarre
Plymouth
Honesdale
Middletown
Lebanon
Reading
Allentown
Easton
Lancaster
Columbia
York
Hagerstown
Winchester
Chambersburg
Carlisle
Juniata Canal
Union Canal
Morris Canal
Chenango Canal
New York & Erie Railroad

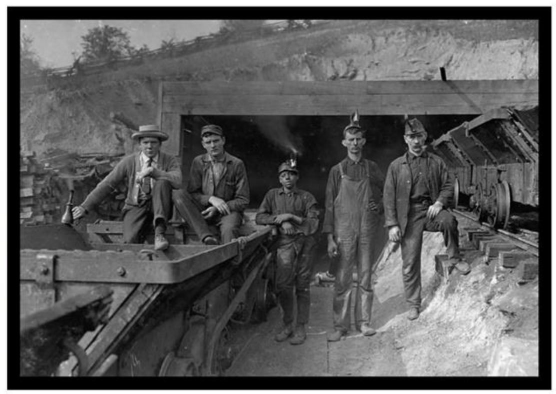
Traditional Shaft Mining

Extraction Process

Appalachia's extensive coal seams were initially harvested through underground shaft and slope mines. These practices send miners down shafts to access coal beds. Miners use a combination of hand tools and powered machinery to break up and extract coal. The loosened mineral is brought to the surface and loaded into train cars for transportation. This work is extremely dangerous and since 1900 has caused more than 100,000 deaths.

Disturbance: Acid Mine Drainage

Acid mine drainage (AMD) refers to the outflow of acidic water from a mining site. Exposed metals within the mine dissolve into water and flow into waterways and poison downstream waters. Acid mine drainage is a worldwide problem, leading to ecological destruction in watersheds and the contamination of human water sources by sulfuric acid and heavy metals, including arsenic, copper, and lead.


MOUNTAINTOP REMOVAL
Arrested Succession

Surface Mining starts by first stripping the land of forests and understory vegetation in order to expose the soil that is covering a coal deposit. This overlying soil material, known as overburden, is excavated by heavy machinery and discarded into piles called spoil. The underlying coal is then excavated, and the mined area is reclaimed after mining operations have finished. Mountaintop removal is the most ecologically destructive form of surface mining as the extractive process removes all vegetation and high productivity soil biota and topsoil and drastically changes the area's topography.

Modern Surface Mining

Heavy Machinery

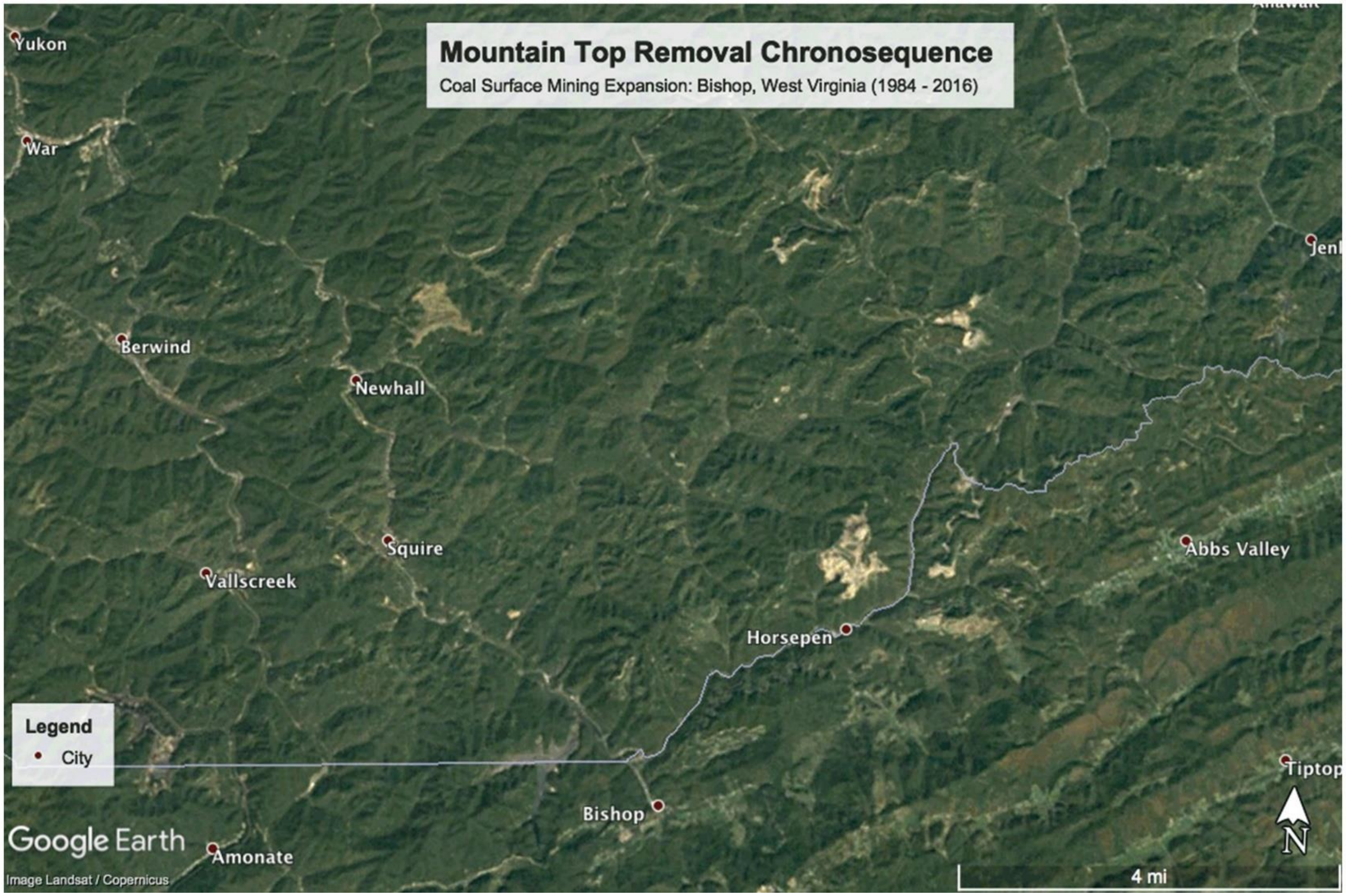
Advancements in heavy machinery, such as the development of the dragline, radically increased mining productivity and scale by enabling a few machinery operators to work at an immense scale.

Overburden and Spoil

The excavated overburden from mountaintop removal mining is dumped in dedicated excess spoil disposal sites known as valley fills, durable rock fills, and head-of-hollow fills.

Smooth Grading and Hydroseeding

After 1977 Federal law required sites to be smoothly graded and hydro-seeded with highly competitive herbaceous vegetation that creates a barrier to the recruitment of native species from the surrounding forest and also inhibits the growth and survivability of planted trees.


Mountain Top Removal Chronosequence
Coal Surface Mining Expansion: Bishop, West Virginia (1984 - 2016)
Yukon
War
Berwind
Newhall
Squire
Vallscreek
Horsepen
Abbs Valley
Bishop
Amonate
Tiptop
Legend
City
Google Earth
Image Landsat / Copernicus
4 mi
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FORESTRY RECLAMATION APPROACH

Return of Ecological Succession

The Forestry Reclamation Approach (FRA) is a prescription for effective post coal-mine reforestation and restoration of ecosystem services that can be applied under the Surface Mining Control and Reclamation Act.

"The FRA is intended to establish site conditions suitable for survival and growth of planted trees while also enabling colonization by native vegetation whose seeds are dispersed by native fauna and wind".

FORESTRY RECLAMATION APPROACH

Five Step Process

1. Create a Suitable Rooting Medium
2. Loosely Grade the Topsoil
3. Select Native and Non-competitive Groundcovers
4. Plant Early Succession and Commercially Valuable Trees
5. Use Proper Planting Techniques

UN DECADE OF ECOSYTEM RESTORATION 2021-2030

Novel Ecosystems

Ecological Restoration is any *intentional activity that aids an ecosystem in recovery*

Novel Ecosystems are *new, non-historical configurations of different species, interactions and functions owing to a variety of local and global changes.*

This implementation of theory is a response, to Appalachia's habit and biodiversity loss, drastic topography and resulting hydrology changes, watershed pollution, as well as a rapidly changing global climate.

RESTORATION APPALACHIA:
Uganost Cooperatives

The gap between Appalachian coal barons and local community members has widened overtime as a result of society's over emphasis on resource extraction. Post-mining landscapes provide an opportunity to bring back the ecological base.

1. Progress current methodology to focus on the restoration of **uganost understory plants** in place of crop trees.

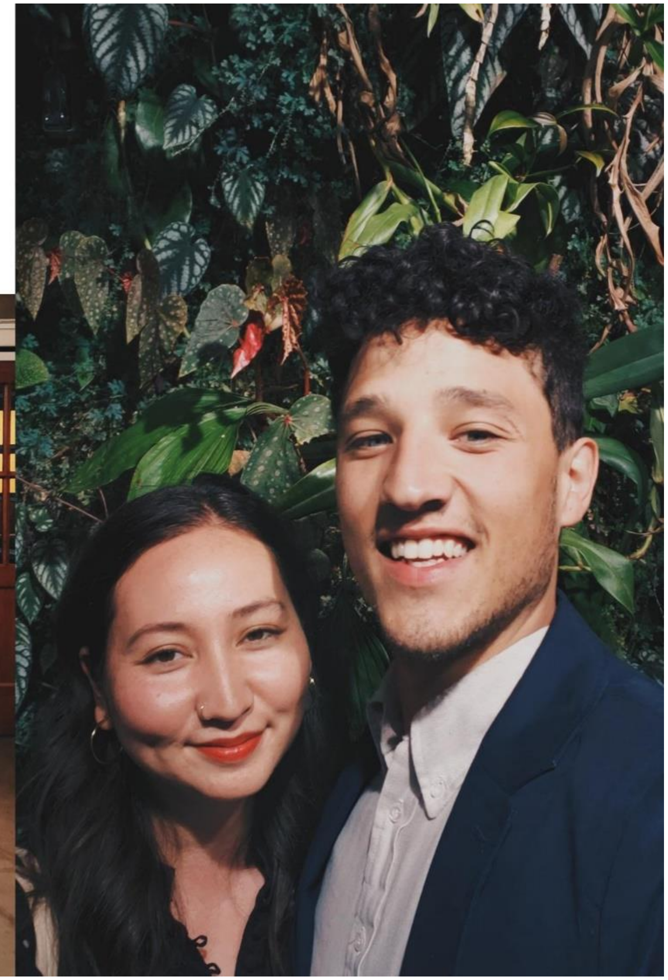
2. Engage local community members as stewards of the land by returning the landscape to a **public commons**.

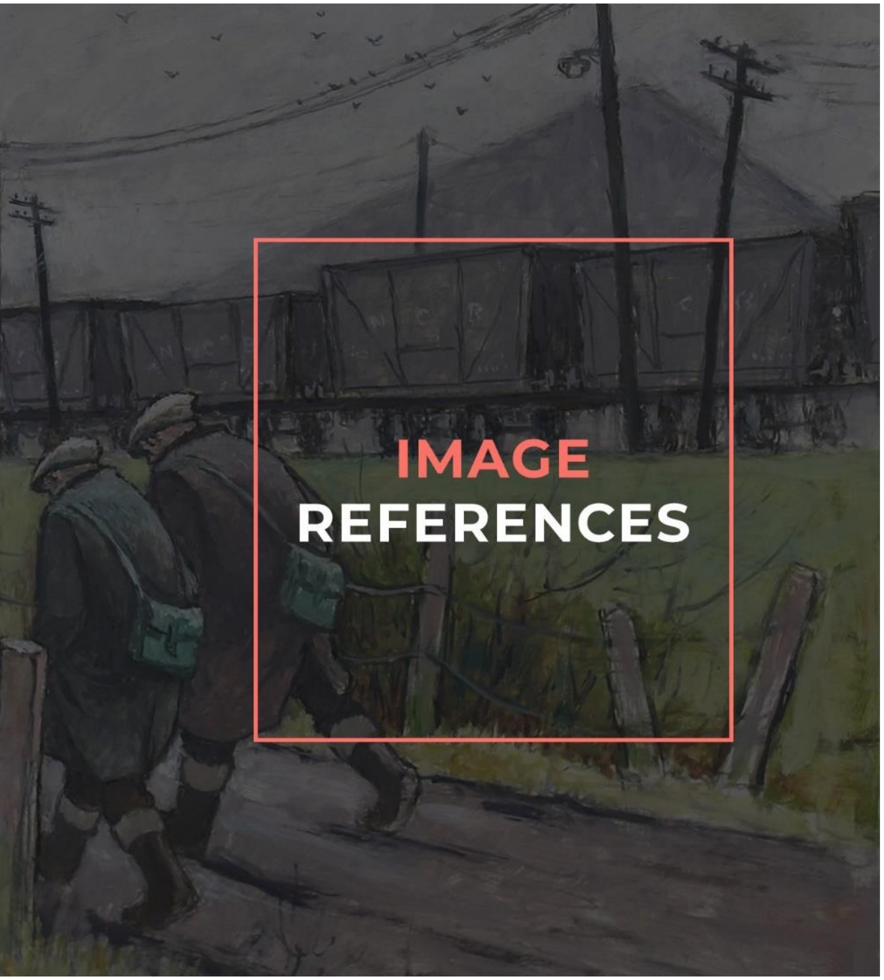
3. Retrofit existing infrastructure to be more sustainable and provide **eco-tourism opportunities** such as hiking and biking.

4. Apply for Abandoned Mine Land's Pilot Program grants to fund the creation of a local food cooperative which facilitates land stewards to harvest and forage uganost for the local community as tourism sector by marketing homecooked meals as a **sustainable traditional forest-to-table experience**.


Blackwater Canyon: Lindy Point

THANK YOU!
Acknowledgements & Questions





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Restoration Appalachia: Ellison Heil's Master of Environmental Horticulture Defense
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