CELF Summer Institute '10
Subject: Earth Science Grade: 7th-8th
School: Boston Latin School [public] MA Teacher: Margaret G
Unit Title: **Man, Mining and Sustainability**

Stage 1- Desired Results

Man, Mining and Sustainability

Summary/ Overview

The earth holds an abundance of minerals and fossil fuels, such as coal, oil, and natural gas. Sadly, these nonrenewable gifts from the earth are being slowly depleted through mining and drilling. With mining and drilling, the earth endures a continued assault for the needs of society. The assault on the environment starts with the extraction process and continues well beyond the end product. The need for minerals, and especially fossil fuels, will have a stronghold on our nation's economy for years to come. Fortunately, measures are being taken to help us reduce our carbon footprint and find alternative clean and renewable energy resources. With energy conservation, reuse, and recycling of materials, we can slow down the depletion of nonrenewable resources and help sustain the environment.

Massachusetts gets 84% of the state's electricity (based on 2009 data) from nonrenewable energy sources-- about 25% comes from coal, the dirtiest of fossil fuels. Nationally, about 50% of our electricity comes from coal, with Massachusetts ranking 37th in the nation use. As long as society has the need for products and the need for energy, the extraction of nonrenewable resources such as coal will continue. As long as mining continues, mining companies will owe it the environment and future generations to do their best to try and sustain it. Mining companies have a legal and moral responsibility to sustain the land by restoring it to its previous condition—or leaving it in better condition. Sustainable mining is an effective means to minimize the assault on the environment and still meet the needs of modern society. Sadly, though, the United States has close to 500,000 *abandoned* mines, some since the time of the gold rush, that pose a serious hazard to our environment. Although there is no coal mining in Massachusetts, *everyone* needs to be concerned about mining practices. Mining operations are not closed systems. When the environment and ecosystems are not sustained, there will be a ripple effect. Acid mine drainage from an abandoned mine in Colorado will leach heavy metals and make its way via the watershed to the Pacific and the Atlantic. One doesn't have to imagine the impact that will have.

The "Man, Mines, and Sustainability" lessons will enlighten students to the impact of mining. Ideally, when these lessons are implemented, students will be in the middle of a unit on "Resources and the Environment" and be somewhat familiar with the concepts of "input" and "output". These lessons will help tie together 'energy resources' and 'environmental issues'. Students will already be familiar with types of ores, as well as renewable and non-renewable energy resources. Most students will likely have the misconception that when it comes to mining these resources, it is all about the quantity of the resource that is extracted and the money it will bring. In most cases, very few will think about the cost paid by the environment and by future generations. The "Cookie Mining" activity acts as a hook to introduce the costs of mining, but this lesson and the one that follows give students insight to the price paid by the environment and ecosystems. They will understand importance of "reclamation". In the second lesson, they will understand at the effects of mining on both the environment and the ecosystem. The second lesson can be modified for different grade levels with the type of assigned reading and project rubric to make it more appropriate.

Adapted from *"The Big Ideas of UbD"* by Grant Wiggins and Jay McTighe, 2004.

Established Goal(s) (National and/or MA State and/or District goal):

Massachusetts State Frameworks :
(2.1) Renewable energy resources and nonrenewable energy resources.
(2.2) Effects on the environment and on the carbon cycle of using renewable and nonrenewable resources.
(3.4) Water flows into and through a watershed.

Massachusetts Scientific Inquiry Skills Standards:
SIS1. Make observations, raise questions, and formulate hypotheses.

- Observe the world from a scientific perspective.
- Pose questions and form hypotheses based on personal observations, scientific articles, experiments, and knowledge.

Alignment with National Standards for Sustainability for Grades 5-8:
1.1 Intergenerational responsibility
2.1 Interconnectedness
2.2 Ecological Systems
3.1 Personal Action
3.2 Collective Action

Enduring Understandings: *Students will understand that…* • Humans are not separate from the environment; their actions affect the environment and ecosystems. • The mining of natural resources disrupts the environment and ecosystems.	**Essential Questions:** • How does mining affect the environment? • How can reclamation reduce the impact of mining and help sustain the environment and ecosystems?
Students will know…	*Students will be able to…* • Students will understand the importance of reclamation. • Students will understand the effects of mining on the environment and ecosystems. • Students will understand why *everyone* should be concerned about the effects of mining. • Students will be able to role-play and brainstorm solutions to problems caused by mining in order to sustain the environment and ecosystems. • Students will be able to role-play and brainstorm solutions to problems caused by mining in order to sustain the environment and ecosystems.

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Stage 2 – Assessment Evidence	
Performance Task(s):	**Other evidence:**
Stage 3 – Learning Plan	

Learning Activities:

STAGE 3: Learning Plan

Learning activities (what will students do and what will you, the teacher do, to prepare the students to achieve the desired outcomes?

- Lesson on reclamation and mining: Cookie Mining Activity (hook activity)
- Reading assignments and accompanying questions.
- Class discussions
- Lesson on the effects of mining
- Develop a reclamation plan for fictional mine.
- Short PowerPoint presentation
- DVD: NOVA: Poison in the Rockies

COOKIE MINING ACTIVITY

Adapted from: http://www.womeninmining.org/activities/COOKIE_MINING.pdf

Note: This is a hook activity will introduce the process and problems involved in mining. The activity has been slightly modified in content from the original. The amount of paper required in this activity has also been reduced by *eliminating* the need to print out actual play money, and also by combining the Data and Grid sheets into one. It is helpful to have one class set (10 copies for a group of 30 students) of the Data/Grid sheet laminated so that they may be reused with *each class*, *each school year*. Post lab discussions, extensions, resources and vocabulary have also been added.

OBJECTIVE :
Students will participate in a simulated mining activity for the purpose of understanding the basic economics of mining: costs of permits, leasing the land, buying/leasing equipment. Student will learn about environmental responsibilities and the need for land reclamation.

ALIGNMENT WITH SUSTAINABILITY STANDARDS:
1.1 Intergenerational responsibility
3.1 Personal Action

INTRODUCTION: The introduction of the economics of mining is accomplished through the players' leasing their properties, leasing the mining equipment, paying for mining operations, paying fines, paying for the reclamation of the land. The objective of the game is to make as much money possible than any of the other mines.

MATERIALS:
Various chocolate chip cookies:
- Store Brand
- Chip Chips Ahoy
- Chips Deluxe

Mining Equipment:
- Flat toothpick
- Round toothpick
- Paper clip

Clock or timer
Laminated Cookie Mining Data/ Grid sheet
Overhead Projector markers

INSTRUCTIONS (for teacher, a.k.a., environmental police):
1) Use teams of three to plan and execute the mining of the ore.
2) Each mining team will be given a Cookie Mining Data/Grid sheet to record costs.
3) Each mining team must lease the "mining property," which is a cookie. One "mining property" allowed per team. Cookies for sale are:
- Cheap store brand chocolate chip cookies - $3.00
- Chips Ahoy - $5.00
- Chips Deluxe - $7.00

4) Once the cookie is bought, the cookie will be placed on the grid paper and, using the marker, traces the outline of the cookie. Count the number of grid squares inside circle. Count partial squares as a full square.

5) Each mining team must buy its own mining equipment. More than one piece of equipment may be purchased. Equipment may not be shared between miners. Mining equipment for sale is:
- Flat toothpick - $2.00 each
- Round toothpick - $4.00 each
- Paper clips - $6.00 each

6) Mining costs are: $1.00 per minute.
7) Sale of a chocolate chip mined from a cookie brings $2.00
(broken chocolate chips can be combined to make 1 whole chip).
8) Reclamation: After the cookie has been "mined," small crumbs need to be removed. This is waste material; the mining team will take the larger, more substantial pieces and place them back in the circled area on the grid paper, using the mining tools. No fingers or hands allowed.
9) Reclamation costs: Miners will count the number squares left exposed from the original outline of the cookie-- This is "un-reclaimed land". A fine of $1.00 per exposed square.

RULES:
1) No miner can use his/her fingers to hold the cookie. The only things that can touch the cookie are the mining tools and the paper on which the cookie is sitting.
2) Mining teams should be allowed a maximum of five minutes to mine their chocolate/ chip cookie. Teams that finish mining before the five minutes are up should only credit the time spent mining.
3) A Team can purchase as many mining tools desired and the tools can be of different types.

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4) If the mining tools break, they are not longer useable, and a new tool must be purchased.
If a mining team is caught using broken tools (i.e. breaking a paper clip in half to have to separate pieces to use), they will be assessed a fine for creating a hazardous workplace.
5) When the teams have finished, check the "local environment" for other possible violations. Crumbs on the floor or excessive crumbs in the workspace are considered as tailings.
It will be assumed that this waste material was been abandoned with the mine. A fine of $5 will be assessed.
6) The team that meets all of the following criteria wins:

a. They must show a profit.
b. the team that shows less than 20% un-reclaimed land
(the team has to find the difference the number of squares the cookie covered before and after mining, and divide by the original number X 100)
c. The team that has no fines assessed (not including reclamation costs)

POST LAB DISCUSSION:

- What is land reclamation and why is it important?
- If you were a resident of the area near a mine, what concerns would you have about the effects of mining?
- Explain the advantages and disadvantages of land reclamation from the viewpoint of the owner of a mining company and that of residents in nearby communities.
- If you had to do this activity over, keeping in mind to minimize the environmental impact, would profits be as high? Explain.

EXTENSION:
Students will be given a reading assignment for homework to prepare them for the follow up to the Cookie Mining activity. The reading will enlighten students to the environmental and ecological hazards of mining.

The first two reading are short and easy to understand. They are more appropriate for the middle school students. *Copies of the reading assignments are found below, following the "Data /Grid Sheet".*
"Coal Mining and the Environment"----- http://www.worldcoal.org/coal-the-environment/coal-mining-the-environment/ ;
"Effects of Mining on Environment"
http://www.buzzle.com/articles/how-does-mining-affect-the-environment.html

The next two reading are more appropriate for high school students.
"Issue Analysis - Mining and Its Effects on the Environment"
http://www.scribd.com/mobile/documents/103246
"Ecosystem Restoration"
http://ecorestoration.montana.edu/mineland/guide/problem/impacts/

OTHER RESOURCES USED:
Cookie Mining activity
http://www.womeninmining.org/activities/COOKIE_MINING.pdf

COOKIE MINING DATASHEET

1. Brand of cookie ....._____
2. Price of cookie....._____

("Store Brand" $3.00, Chips Ahoy $5.00, Chips Deluxe $7.00)

3. Size of cookie....._____squares covered
4. Equipment:
   - Flat toothpick _____ x $2.00 = _____
   - Round toothpick _____ x $4.00 = _____
   - Paper clip _____ x $6.00 = _____

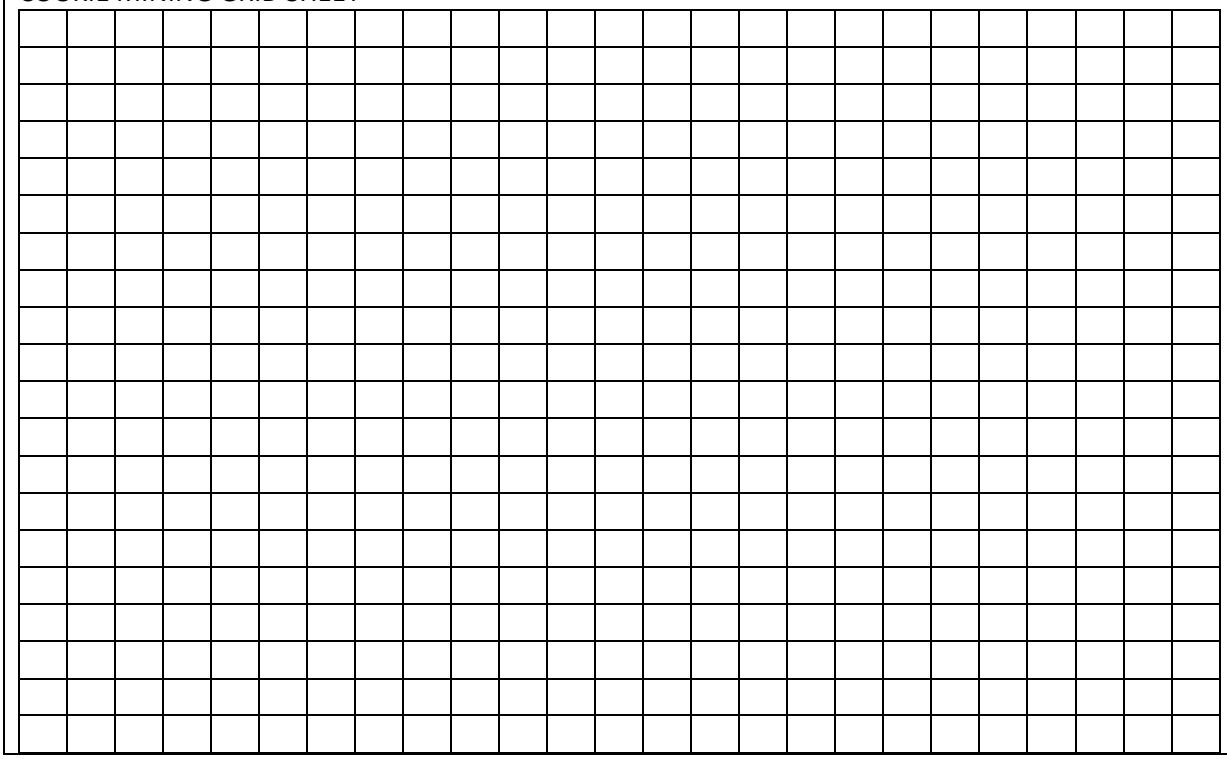
   TOTAL EQUIPMENT COST . . . . . _____
5. Mining: _____ minutes x $1.00 = Cost of removing chips = _____
6. TOTAL COST OF MINING (cookie + equipment + mining time) = _____
7. Income from chips:
   Number of chips _____ x $2.00 = VALUE OF CHIPS = _____

HOW MUCH DID I MAKE?

Value of chips . . . . . ( ) _____
Total cost of mining . . . . . (-) _____
*Worksite fines. . . . . (-) _____
($5 using faulty equipment; excessive pollution ; hazardous working conditions)
Reclamation _____ squares x $1.00 . . . . .(-) _____

PROFIT/LOSS . . . . . ( ) _____

COOKIE MINING GRID SHEET



Adapted from *"The Big Ideas of UbD"* by Grant Wiggins and Jay McTighe, 2004.

* modifications to original activity
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For Middle School Level:

COAL MINING & THE ENVIRONMENT

From: http://www.worldcoal.org/coal-the-environment/coal-mining-the-environment/
Coal mining, particularly surface mining, requires large areas of land to be temporarily disturbed. This raises a number of environmental challenges, including soil erosion, dust, noise and water pollution, and impacts on local biodiversity. Steps are taken in modern mining operations to minimize impacts on all aspects of the environment. By carefully pre-planning projects, implementing pollution control measures, monitoring the effects of mining and rehabilitating mined areas, the coal industry minimizes the impact of its activities on the neighboring community, the immediate environment and on long-term land capability.

Land Disturbance

In best practice, studies of the immediate environment are carried out several years before a coal mine opens in order to define the existing conditions and to identify potential problems. The studies look at the impact of mining on surface and ground water, soils, local land use, native vegetation and wildlife populations. Computer simulations can be undertaken to model impacts on the local environment. The findings are then reviewed as part of the process leading to the award of a mining permit by the relevant government authorities.

Mine Subsidence

Mine subsidence can be a problem with underground coal mining, whereby the ground level lowers as a result of coal having been mined beneath. A thorough understanding of subsistence patterns in a particular region allows the effects of underground mining on the surface to be quantified. The coal mining industry uses a range of engineering techniques to design the layout and dimensions of its underground mine workings so that surface subsidence can be anticipated and controlled. This ensures the safe, maximum recovery of a coal resource, while providing protection to other land uses.

Water Pollution

Mine operations work to improve their water management, aiming to reduce demand through efficiency, technology and the use of lower quality and recycled water. Water pollution is controlled by carefully separating the water runoff from undisturbed areas from water which contains sediments or salt from mine workings. Clean runoff can be discharged into surrounding water courses, while other water is treated and can be reused such as for dust suppression and in coal preparation plants.

Acid mine drainage

Acid mine drainage (AMD) can be a challenge at coal mining operations. AMD is metal-rich water formed from the chemical reaction between water and rocks containing sulfur-bearing minerals. The runoff formed is usually acidic and frequently comes from areas where ore- or coal mining activities have exposed rocks containing pyrite, a sulfur-bearing mineral. However, metal-rich drainage can also occur in mineralized areas that have not been mined. AMD is formed when the pyrite reacts with air and water to form sulfuric acid and dissolved iron. This acid run-off dissolves heavy metals such as copper, lead and mercury into ground and surface water.

There are mine management methods that can minimize the problem of AMD, and effective mine design can keep water away from acid generating materials and help prevent AMD occurring. AMD can be treated actively or passively.

- Active treatment involves installing a water treatment plant, where the AMD is first dosed with lime to neutralize the acid and then passed through settling tanks to remove the sediment and particulate metals.
- Passive treatment aims to develop a self-operating system that can treat the effluent without constant

human intervention.

Dust & Noise Pollution

Dust at mining operations can be caused by trucks being driven on unsealed roads, coal crushing operations, drilling operations and wind blowing over areas disturbed by mining.

Dust levels can be controlled by spraying water on roads, stockpiles and conveyors. Other steps can also be taken, including fitting drills with dust collection systems and purchasing additional land surrounding the mine to act as a buffer zone. Trees planted in these buffer zones can also minimize the visual impact of mining operations on local communities.

Noise can be controlled through the careful selection of equipment and insulation and sound enclosures around machinery.

Rehabilitation

Coal mining is only a temporary use of land, so it is vital that rehabilitation of land takes place once mining operations have stopped. In best practice a detailed rehabilitation or reclamation plan is designed and approved for each coal mine, covering the period from the start of operations until well after mining has finished. Where the mining is underground, the surface area can be simultaneously used for other uses - such as forests, cattle grazing and growing crops - with little of no disruption to the existing land use.

Mine reclamation activities are undertaken gradually – with the shaping and contouring of spoil piles, replacement of topsoil, seeding with grasses and planting of trees taking place on the mined-out areas. Care is taken to relocate streams, wildlife, and other valuable resources. As mining operations cease in one section of a surface mine, bulldozers and scrapers are used to reshape the disturbed area. Drainage within and off the site is carefully designed to make the new land surface as stable and resistant to soil erosion as the local environment allows. Based on the soil requirements, the land is suitably fertilized and re-vegetated. Reclaimed land can have many uses, including agriculture, forestry, wildlife habitation and recreation.

Companies carefully monitor the progress of rehabilitation and usually prohibit the use of the land until the vegetation is self-supporting. The cost of the rehabilitation of the mined land is factored into the mine's operating costs.

Using Methane from Coal Mines

Methane (CH_4) is a gas formed as part of the process of coal formation. It is released from the coal seam and the surrounding disturbed strata during mining operations. Methane is a potent greenhouse gas, with a global warming potential 23 times that of carbon dioxide. While coal is not the only source of methane emissions – agricultural activities are major emitters – methane from coal seams can be utilized rather than released to the atmosphere with a significant environmental benefit.

Effects of Mining on Environment

http://www.buzzle.com/articles/how-does-mining-affect-the-environment.html

Effect on Land

Deforestation: Mining requires large areas of land to be cleared so that the earth could be dug into by the miners. For this reason, large scale deforestation is required to be carried out in the areas where mining has to be done. Besides clearing the mining area, vegetation in the adjoining areas also needs to be cut in order to construct roads and residential facilities for the mine workers. The human population brings along with it other activities that harm the environment.

Loss of Biodiversity: The forests that are cleared for mining purposes are home to a large number of organisms. Indiscriminate clearing of the forests lead to loss of habitat of a large number of animals. This puts the survival of a large number of animal species at stake. The cutting down of trees in itself is a big threat to a number of plants and trees growing in the forests.

Pollution: Despite measures being taken to release the chemical waste into the nearby rivers through pipes, a large amount of chemicals still leak out onto the land. This changes the chemical composition of the land. Besides this, since the chemicals are poisonous, they make the soil unsuitable for plants to grow. Also, the organisms that live in the soil find the polluted environment hostile for their survival.

Effect on Water
Pollution: Chemicals like mercury, cyanide, sulfuric acid, arsenic and methyl mercury are used in various stages of mining. Most of the chemicals are released into nearby water bodies that leads to water pollution. In spite of tailings (pipes) being used to dispose these chemicals into the water bodies, possibilities of leakage are always there. When the leaked chemicals slowly percolate through the layers of the earth, they reach the groundwater and pollute it. Surface run-off of just soil and rock debris, although non-toxic, can be harmful for vegetation of the surrounding areas.

Loss of Aquatic Life: Release of toxic chemicals into the water is obviously harmful for the flora and fauna of the water bodies. Besides the pollution, mining processes use water from nearby water sources. The result is that the water content of the river or lake from which water is being used gets reduced. Organisms in these water bodies do not have enough water for their survival.

River dredging is a method adopted in case of gold mining. In this method, gravel and mud is suctioned from a particular area of the river. After the gold fragments are filtered out, the remaining mud and gravel is released back into the river, although, at a location different from where they had been taken. This disrupts the natural flow of the river that may cause fishes and other organisms to die.

Spread of Diseases
Sometimes the liquid waste that is generated after the metals or minerals have been extracted is disposed in a mining pit. As the pit gets filled up by the mine tailings, they become a stagnant pool of water. This becomes the breeding ground for water-borne diseases causing insects and organisms like mosquitoes to flourish.

For High School Level:

Issue Analysis - Mining and Its Effects on the Environment
http://www.scribd.com/mobile/documents/103246

General Impacts of mining on the environment:
Energy Consumption: Mining requires vast amounts of energy. The ore and rock has to be transported great distances by large vehicles, which require a large amount of energy in the form of gasoline. Underground mines need extensive hoisting systems to transport the minerals, which also require energy. Controlling the temperature of mines deep underground is very energy consuming as well. Pneumatic equipment, which is used a lot in the mining industry, also takes energy. Smelting ores and metal requires lots of energy.

Air: Mining has a great effect on the quality of the air. Since mines need to blast through rock to get to an ore, dust may be produced in the process. Coal mines release methane, which contributes to environmental issues because it is a greenhouse gas. The methane is sometimes captured, but only where it is economically feasible to do so. Some cooling plants may release ozone-depleting substances, but the amount released is very small. Non-vegetated or uncapped tailings dams release dust, and when radioactive elements are found in the ore, radiation is emitted. Heavy metals, such as sulfur dioxide, may be polluted into the air by unsafe smelter operations with insufficient safeguards.

The gold mining industry is one of the most destructive industries in the world, because of all of the toxins that are released into the air.
Acid rain and smog are also some side-effects of mining. Every year, 142 million tons of sulfur dioxide is emitted into the atmosphere because of smelting. That's 13% of total global emissions.

Water: Mines use a lot of water, though some of the water is reusable. Sulfide- containing minerals, when oxidized through contact with air, via mining, form sulfuric acid. This, when combined with trace elements, negatively impacts groundwater. This happens from both surface and underground mines. Another way surface and underground water are affected is through tailings dams and waste rock heaps, because they are a source of acidic drainage water. Leftover chemical deposits from explosives are usually toxic, and increase the salinity of mine water, as well as contaminating it. Groundwater can be directly contaminated through "in situ" mining, in which a solvent seeps into un-mined rock, leaching minerals. In the extraction of minerals, some toxins (for example cyanide and mercury) are used that can permanently pollute the water, making it hard for fishers to find fish. Spills into oceans and lakes add toxic heavy metals and sulfuric acid into the environment, which can take ages to fix. Also, Acid Mine Drainage lowers the pH of the water, making it more acidic (see Acid Mine Drainage section).

Land: There are many environmental concerns about the effects mining has on the land. Trees need to be cut down in order to have a mine built, and whole forests could be destroyed. Mining involves moving large quantities of rock, and in surface mining, overburden land impacts are immense. Overburden is the material that lies overtop of the desirable mineral deposits that must be removed before the mining process begins. Some mines make an effort to return the rock and land to its original appearance by returning the rock and overburden to the pit that they were taken out of. Copper mines sometimes extract ore that has very little copper actually in it (less than 1%). Almost all of the mined ore of non-ferrous metals becomes waste. A lot of areas are pock marked by thousands of small holes by people digging in search of precious minerals. Mining activities also may lead to erosion, which is dangerous and bad for the land. It destroys river banks, and changes how the river flows, where it flows, what lives in it, etc. Toxins used in the extraction of minerals (for example cyanide and byproducts like mercury) can permanently pollute the land, which makes people not able to farm in certain places. Open-pit mining leaves behind large craters that can be seen from outer-space.

Ecosystem Damage: Mines are highly damaging to the ecosystems surrounding them. Many different types of mines affect many different types of ecosystems. For example, deep-sea mines are at high risk of eliminating rare and potentially valuable organisms. Mining destroys animal habitats and ecosystems. Pits that mines create could have been home to some animals. Also, the activity that surrounds the mine, including people movement, explosions, road construction, transportation of the goods, the sounds made, etc. are harmful to the ecosystems and will change the way the animals have to live, because they will have to find a new way to cope with the mine and live around it. Spills of deadly substances obviously have a very negative effect on animals and ecosystems in general. Many of the toxins and tailings that are discharged from the mines can disrupt and disturb the way animals live, and their health. Mining can completely destroy ecosystems by adding or taking out something from the animals' everyday lives, therefore throwing the whole thing out of balance.

Health and Safety: Mining can be very safe, but often it is extremely dangerous. Underground mining is usually more unsafe than surface because of the poor ventilation and visibility, as well as the rock fall hazards. The biggest health risks are from dust, which can cause breathing problems. One example would be silicosis, which is when silica found in the rock gets into your lungs, and rip them apart. The silica gets you're your lungs when you blast the rock away to find the ore inside, and little fragments of silica arise as dust, which you then breathe in.

Another health issue is from exposure to radiation. People below poverty line in third-world countries are affected by mining. If the mining contaminates their fresh water supply, they will have to walk for miles to find more water.

Acid Mine Drainage: Acid mine drainage (AMD), or acid rock drainage (ARD), is when the pH of water is lowered and made more acidic. This usually happens in abandoned subsurface mines. The reason is because subsurface mines, when operational, have to keep pumping the water out of the mine. Once abandoned, however, the pumping stops and the mine floods. This flood is the initial step of AMD. Acidity is generated when metal sulfides are oxidized after being exposed to air and water. Bacteria and archaea decompose the metal ions faster. These microbes are found naturally in the rock, but their numbers are usually low due to limited oxygen and water. However, once they are in an environment with an abundance of water and oxygen, they flourish. …. When the ore is a sulfide or pyrite, the mine has a better chance of generating highly acidic discharges. … The water gets very acidic, which is unhealthy for the land and all the underwater creatures that it might come in contact with. Mines try to neutralize the water again by adding limestone chips, but they sometimes form a layer of calcium sulfate, which blinds the material and stops any further neutralization. Also, they use a method called Constructed Wetlands to try to neutralize the pH, but this is time-consuming and not enough to deal with heavily polluted discharge. Constructed wetlands use the products of bacterial processes to stabilize the pH, but said products are unstable when exposed to oxygen.

Ecosystem Restoration
http://ecorestoration.montana.edu/mineland/guide/problem/impacts/

Environmental Impacts of Mining: Acid Mine Drainage Formation

Why do we need to rehabilitate mine sites and what is causing the problem? As discussed in the previous section, the soil and rock (overburden) excavated to expose the materials of interest (i.e. coal, metal ores, non-metallic ores), in addition to the waste rock and tailings formed during the processing of valuable minerals, often contain sulfide minerals such a pyrite (FeS_2) that when exposed to air and water, will oxidize and release large quantities of iron and sulfate into solution. In addition, H^+ ions are liberated during the oxidation process producing an acidic solution that readily weathers and releases other trace minerals (i.e. copper and zinc) into solution. The acidic solution formed, characteristic of high metals and sulfate and low pH, is generally termed acid mine drainage (AMD).

Acid generation and drainage affect both surface and groundwater. The sources of surface water contamination are leachate (leached material) from mine openings, seepage and discharges from waste rock, tailings, groundwater seepage, and surface water runoff from waste rock and tailings piles. Mined materials such as waste rock or tailings use for construction or other purposes (i.e. road beds, rock drains, and fill material) can also produce acid mine drainage.

The environmental impact of AMD can be severe. High concentrations of metals and acidic conditions can have adverse effects on fish, aquatic plant communities and humans. Nationwide, over 19,300 km (12,000 miles) of rivers and streams and over 730 km^2 (180,000 acres) of lakes and reservoirs are adversely affected by contaminated water draining from abandoned mines. To remedy the problem, industry in the U.S. spends millions of dollars a day reclaiming mine sites to prevent the formation of acid mine drainage. However, despite the magnitude of the problem, the situation is much better than it was 30 years ago, when the number of stream miles adversely affected was 50% worse. The improvement can be attributed to the reclamation of many abandoned operations, and to the regulator.

Environmental Impacts of Mining: Erosion & Sedimentation

Erosion and sedimentation present another environmental issue for mine sites. When material is disturbed in significant quantities, as it is in the mining process, large quantities of sediment are transported by water erosion. The sediment eventually drops out of solution and sedimentation occurs at some point downstream from the erosive source. The degree of erosion and sedimentation depends on: the degree to which the surface has been disturbed, the prevalence of vegetative cover, the type of soil, the slope length, and the degree of the slope.

Erosion and sedimentation affect surface water and wetlands more than any other media. Erosion can adversely affect soil organisms, vegetation, and re-vegetation efforts because it results in the movement of soil, including topsoil and nutrients, from one location to another.

Environmental Impacts of Mining: Cyanide & Other Chemical Releases

Chemicals, such as cyanide, are used in the refining process to leach and separate valuable minerals from other unwanted minerals. Cyanide and other toxic chemicals such as oil, petroleum products, solvents, acids, and reagents used for processing can be released into the environment and can subsequently affect water, soil, aquatic organisms, wildlife, waterfowl, and humans. The cyanide-contaminated solution left after valuable minerals have been removed is placed in a tailings pond or solution retention basin. These ponds and basins have proven to attract unsuspecting waterfowl and wildlife that suffer both acute and chronic poisoning as a result of direct contact with and ingestion of cyanide-contaminated solution. Leakage from the piles of waste that are leached with cyanide can allow release cyanide and other toxic constituents directly into the environment via surface water and groundwater flow.

Environmental Impacts of Mining: Fugitive Dust Emissions

In the process of large-scale earthwork, dust emissions are inevitably a problem. These dust particles originate from the following potential sources: ore crushing, conveyance of crushed ore, loading bins, blasting, mine and motor vehicle traffic, use of hauling roads, waste rock piles, windblown tailings, and disturbed areas. Dust can contain toxic heavy metals such as arsenic, lead, and other. These toxic heavy metals, when incorporated with dust can contaminate the air. Dust can also deposit in surface water causing sedimentation and turbidity problems.

Environmental Impacts of Mining: Habitat Modification

The large disturbances caused by mining can disrupt environments, adversely affecting aquatic habitats (i.e. lakes, ponds, streams, rivers), terrestrial habitats (i.e. deserts, grasslands, forests), and wetlands that many organisms rely on for survival. The disruption of site hydrology by large consumption or release of water, manipulation of topography, and the release of particulates and chemicals can all have indirect impacts on various habitats.

Environmental Impacts of Mining: Surface & Groundwater

Contamination

Water becomes easily contaminated at mine sites when it comes into contact with waste rock and tailings. Surface water and groundwater can run off site contaminating downstream water bodies with highly acidic, metal laden wastewater…. Water can also become contaminated with toxic chemicals used for processing mine materials such as cyanide, petroleum products, oil, solvents, acids, and reagents.

Damming

Dams have gained much recent attention concerning their environmental and economic impacts on the land, animals, and humans. Dams tend to disrupt nature's equilibrium between the land and the rivers that are broken due to damming. This disruption of equilibrium is akin to the disruptions created by mining. The consequences of damming can not only affect the watershed where the dam is located but it can also affect the web of life it supports. Some of the environmental impacts are discussed in the following paragraphs and additional references are also given.

Dams have numerous environmental impacts. The reduction of water flow from a river can change the landscape downstream of the dam, which in turn can affect the ecosystem's flora and fauna. A dam holds back sediments, especially the heavy gravel and cobbles. The river, deprived of its sediment load, seeks to recapture it by eroding the downstream channel and banks, undermining bridges and other riverbank structures. The erosion effect deepens the channel which will in turn lower the groundwater table along a river, threatening vegetation and local wells in the floodplain and requiring crop irrigation in places where there was previously no need. The depletion of riverbed gravels reduces habitat for many fish that spawn in the gravelly river bottom, and for invertebrates such as insects, mollusks, and crustaceans.

The dammed sediments can also cause more far-reaching affects such as coastal erosion. In addition, dams alter the flow pattern of a river, both reducing its overall volume and changing its seasonal variations. The alteration of flows reaching a river's estuary, where fresh water meets the sea, is a major cause of the precipitous decline of sea fisheries.

Dams also prevent flooding events downstream which alter the river and floodplain ecosystems that have closely adapted to a river's flooding cycle. The native plants and animals depend on the river's variations for reproduction, hatching, migration, and other important lifecycle stages. Annual floods deposit nutrients on the land, flush out backwater channels, and replenish wetlands. It is generally recognized by biologists that dam building is the single most destructive element of many factors causing the rapid disappearance of river species. In addition, dams present a barrier for certain fish species, such as salmon, that migrate upstream to spawn. These environmental consequences should be closely reviewed before damming projects are initiated. The environmental problems they create could negate the environmental problems we are attempting to solve by reclaiming mine lands.

High Consumption

Massive quantities of water are often necessary on mine sites for many operations. The most significant of these, water use for processing minerals, along with the other water consuming processes can cause drawdown of the groundwater table. Drawdown can reduce the amount of water available for recharging wetlands and surface water bodies, thereby affecting any organisms that depend on those waters.

LESSON: THE EFFECTS OF MINING AND THE ENVIRONMENT
(Adapted from lesson from http://www.teachcoal.org/lessonplans/reclamation.html)

OBJECTIVE: Students will understand that surface mining disrupts the environment and ecosystems; Students will be able develop a plan for sustainability of the environment and ecosystems after mining.

Alignment with National Standards for Sustainability for Grades 5-8:
1.1 Intergenerational responsibility
2.1 Interconnectedness
2.2 Ecological Systems
3.1 Personal Action
3.2 Collective Action

INTRODUCTION: This activity can be done as a demonstration or as a class activity with groups of students. Students will have been given a reading assignment the night before to prepare them for the follow up to the Cookie Mining activity. The reading addresses some of the environmental hazards of mining a nonrenewable energy resource such as coal.

MATERIALS:
Clear shoebox
coal (or substitute a piece of charcoal)
gravel, sand, potting soil
small plants (or substitute a variety of artificial flowers)
plastic cup (cut down to about 1-2 inches deep)
small plastic toys animals
spoon

INSTRUCTIONS FOR SETTING UP THE MINE:
- Place a piece of coal in a clear shoebox
- Cover the coal with layers of sand, soil, and gravel
- Create a surface terrain that includes a hill (over the piece of coal) and a low-lying area.
- Next to the low-lying area, place the plastic cup into the soil.
- Fill the shallow cup with water. This will represent a body of water such as a lake or pond.
- Place the plants and the animals atop the terrain.

STUDENT INSTRUCTIONS:
1. Students will record their observations regarding the environment surrounding the shoebox mine.
2. Ask a student to excavate the coal using the plastic spoon. Conduct the excavation with as little disruption to the plant life or existing ecosystems.
3. After the coal has been recovered, have the student demonstrate the reclamation of the 'shoebox mine' to its pre-excavation condition.
4. Have students will record and share their observations from before and after reclamation. Follow up with the questions:
   - Who/what was impacted by the mining?
   - Is the mine restored to its previous condition?
   - How was the plant and animal life affected?
   - Did the lake become polluted by the tailings?
   (Be sure to point out any soil that accidentally fell into the cup.)

5. Students will break into small groups. Each group will represent a team of mining engineers who are in the planning stage of a mining operation. Students will develop a plan for a fictional surface mine (or plans for an abandoned mine). They will develop a reclamation plan that will meet the needs of the mining company, but allow for the sustainability of the environment and surrounding ecosystems

6. Use the "River Drainage Map of the U.S." to find a location for their mine.
Who will be directly affected by the mines runoff? What states will be in the watershed area of the mine? What will be done to protect the watershed?

7. Each group will address how each of the problems below is affected by coal mining.
- Human health hazards
- Land/ soil
- Pollution
- Ecosystems
- Vegetation

8. Before any excavating occurs, the mining company has to have a plan of action in place regarding reclamation of the land. Assign each team, one of the problems listed above. Student teams will propose possible solutions to the problem in order to sustain the environment and ecosystems.

9. Each group will break down mining by "input and output".

10. Each group will also decide how the land might be 're-used' afterward: Agriculture? Recreation? Commercial use?

11. Each group will either create a poster, PowerPoint, video or any other method for presentation of their plan of action for sustainability.

Groups will be evaluated based on the extent they addressed each problem, i.e.:
- Black lung, silicosis, ventilation, cave-ins, mine explosions, contamination of fresh water supply,….
- Land subsidence, topography, change in drainage pattern, tailings, erosion
- Air, noise, water pollution
- Water contamination, acid mine drainage, water tables, damming
- Wildlife, habitats, biodiversity, aquatic life
- Deforestation, native species

EXTENSION:
- Follow-up with a short PowerPoint presentation using the pictures and diagrams found below.
- Follow up with the DVD:

NOVA: Poison in the Rockies - the threats to water quality in the Rockies -mining, acid precipitation and recreational development.

Follow up with questions:
- Why should we be concerned about abandoned mines in Colorado, West Virginia, or Pennsylvania?
- Why is sustaining watersheds vital?

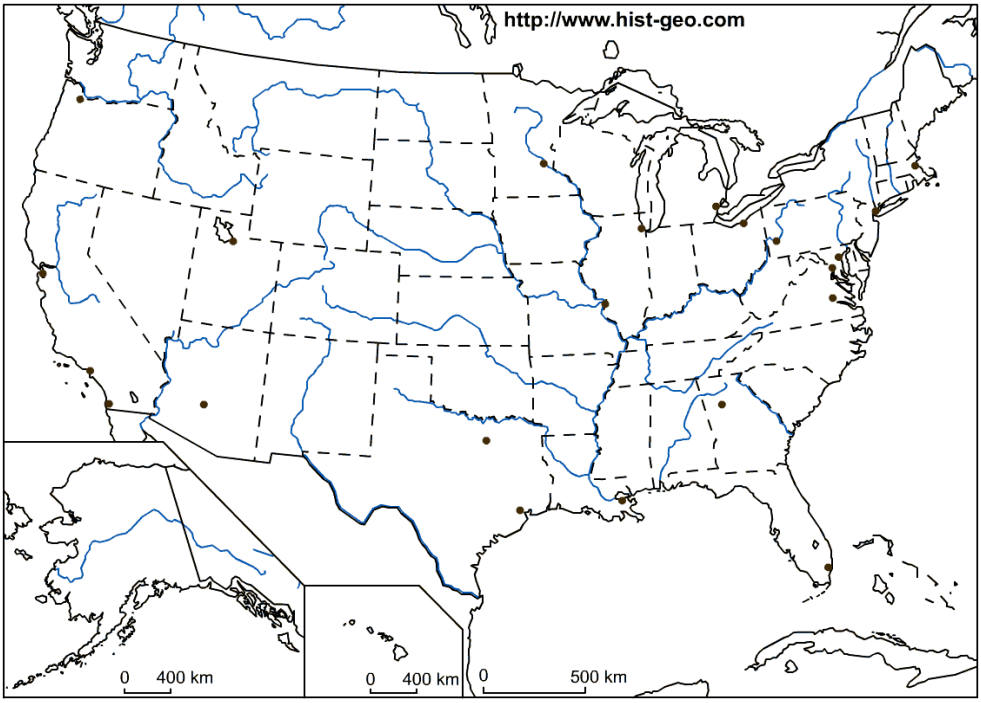
STUDENT ACTION:
(1) Report an Environmental Crime
http://www.mass.gov/dep/about/callnow.htm
"If you see, hear about or even suspect activity which you believe is against the law and placing people's health or natural resources at risk.

- Call the Environmental Strike Force 617-556-1000 (Boston Area) 1-888-VIOLATE (1-888-846-5283) (toll free from elsewhere in Massachusetts)
- Email the Environmental Strike Force (ESF.Hotline@state.ma.us)

Your call or email will be handled confidentially and you won't be asked to give your name if you don't want to. The Strike Force takes the tips it receives very seriously, and follows up on every one."

(2) Reduce your ecological footprint. Reduce the need for fossil fuels such as coal.
http://www.myfootprint.org/

RIVER DRAINAGE PATTERNS-CONTINENTAL U.S.
Source: http://www.hist-geo.co.uk/usa/outline-50/usa-50-states-rivers-cities-1.php

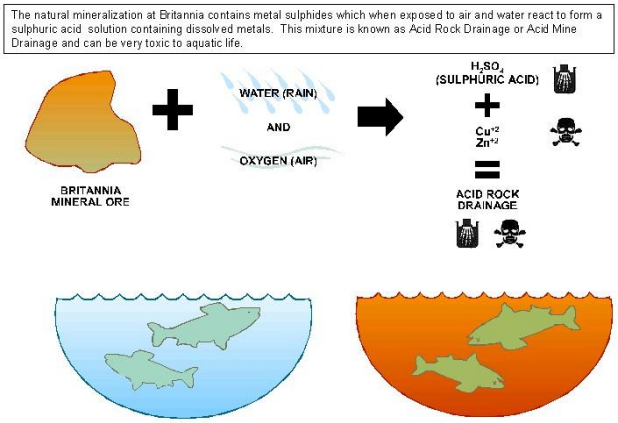


Another helpful site:

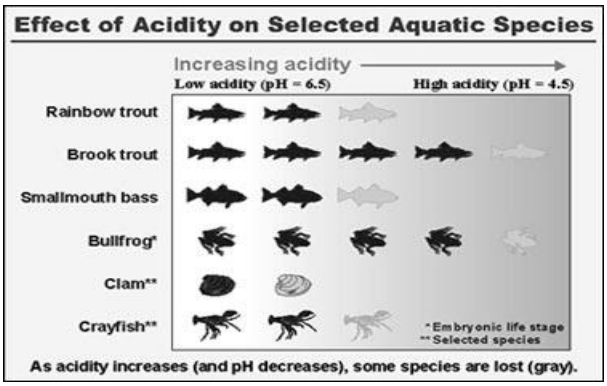
How to find your watershed: http://www.epa.gov/owow/watershed/whatis.html

What Is Acid Mine Drainage?
Source:
http://www.google.com/imgres?imgurl=http://maps.grida.no/library/files/mining_effects_on_rainfall_drainage_001.jpg&imgrefurl=http://earth2care.blogspot.com/2008/07/acid-mine-drainage.html&h=856&w=518&sz=143&tbnid=wh_eygEJpCa4-M:&tbnh=145&tbnw=88&prev=/images%3Fq%3Dacid%2Bmine%2Bdrainage&usg=__4qGDamkGUtUFdT1rz5MoRVAPhQk=&sa=X&ei=mndXTPOFJoL58Ab2qpCTBQ&ved=0CDwQ9QEwBw

Figure 1: Britannia Mine - What is Acid Mine Drainage?



Source: http://www.google.com/imgres?imgurl=http://www.agf.gov.bc.ca/clad/britannia/images/acid_mine_fig1.jpg&imgrefurl=http://www.agf.gov.bc.ca/clad/britannia/background.html&h=528&w=713&sz=81&tbnid=vmtpI4IKqqn-6M:&tbnh=104&tbnw=140&prev=/images%3Fq%3DAcid%2Bmine%2Bdrainage&usg=__g1HWMXG6FPTrJM0_BC27ZVzJpiM=&sa=X&ei=MppPTNGfK8PSnAerpMCPBw&ved=0CDQQ9QEwAw



"Over 400,000 abandoned mines are found on Federal lands. Defunct mines have contaminated public and private lands with more than 50 billion tons of untreated mine waste. In the Appalachian coal region, acid mine drainage (AMD) has degraded more than 8,000 miles of streams and has left some aquatic habitats virtually lifeless. The cleanup and remediation of abandoned mine sites will require a huge investment of taxpayers' dollars. In West Virginia alone, the coal industry is spending approximately $1 million each day to treat acid mine drainage."
Source: http://pubs.usgs.gov/98financial/resources.html

"Many of the abandoned mine workings have partially flooded with water. Pyrite (FeS2) is a common mineral that is often found in association with coal seams. When the pyrite in these mine voids comes into contact with water and oxygen; acidic mine water often results."
Source: http://www.google.com/imgres?imgurl=http://www.peterscreek.org/PetersCreekWatershed/BaratiTrib/LickRunTribBarati.jpg&imgrefurl=http://www.peterscreek.org/PetersCreekWatershed/pcwaAMD1.html&h=962&w=793&sz=420&tbnid=P7Qh5X2gfekfGM:&tbnh=148&tbnw=122&prev=/images%3Fq%3Dacid%2Bmine%2Bdrainage&usg=__3yJ2LnDpFeCym9calkQFUk5dXcI=&sa=X&ei=pXRXTILhOIyenAeF_JDoAw&ved=0CD4Q9QEwBQ

Source: http://www.google.com/imgres?imgurl=http://www.raccooncreek.org/editor/brushy%2520creek.jpg&imgrefurl=http://www.raccooncreek.org/ATWstreamhealth.aspx&usg=__ut7ovQhQx_GIqJ3ikvXuRPIpm6E=&h=272&w=364&sz=27&hl=en&start=0&tbnid=gxmkX5yHuHICsM:&tbnh=127&tbnw=167&prev=/images%3Fq%3Dacid%2Bmine%2Bdrainage%26um%3D1%26hl%3Den%26client%3Dsafari%26sa%3DN%26rls%3Den%26biw%3D1730%26bih%3D982%26tbs%3Disch:1&um=1&itbs=1&iact=hc&vpx=301&vpy=383&dur=7821&hovh=194&hovw=260&tx=98&ty=89&ei=E3pXTI6jNNOmnQfq1_nyAg&page=1&ndsp=29&ved=1t:429,r:20,s:0

Source: http://www.google.com/imgres?imgurl=http://www.ija.csic.es/gt/hidro/amd_Mora.jpg&imgrefurl=http://www.ija.csic.es/gt/hidro/Drama.html&usg=__BybA4jW5-iP8i2pyFN3vYphAy3U=&h=1200&w=1600&sz=456&hl=en&start=0&tbnid=TTwKrl0bruu1YM:&tbnh=127&tbnw=168&prev=/images%3Fq%3Dacid%2Bmine%2Bdrainage%26um%3D1%26hl%3Den%26client%3Dsafari%26sa%3DN%26rls%3Den%26biw%3D1730%26bih%3D982%26tbs%3Disch:1&um=1&itbs=1&iact=rc&dur=622&ei=eXpXTNPGEoa0nAfw5dGGAw&page=1&ndsp=29&ved=1t:429,r:21,s:0&tx=54&ty=58

VOCABULARY:

Acid Mine Drainage (AMD) or Acid Mine Runoff : Acidic drainage (most commonly, sulfuric acid) that is produced when sulfur-bearing coal/rocks/ minerals react with rainwater that flows through the mines .

Biodiversity: the variation of plant and animal life within a given ecosystem.

Ecosystem: A community of organisms and their with relationship the surrounding environment; an area that supports a certain community of organisms

Environment: Abiotic conditions that surround an organism or organisms.

Input: resources, materials, energy needed to do or produce something

Reclamation: measures taken to protect and restore the environment during all phases of mining; the land is preserved, nature is protected, water and soil are conserved; the land can be turned into productive farmland, forests, and lakes.

Nonrenewable resources: Natural resources such as minerals and fossil fuels (coal, oil, and natural gas) that cannot be replaced once they are used. They cannot sustain the rate of use.

Ore: a mineral rich rock deposit containing useable amounts of a metal or non-metal that can be mined and processed at a profit.

Output: pollution or wastes that occur when something is done or produced

Reclamation: Measures taken to protect and restore the environment during all phases of mining; the process of protecting, restoring, and possibly even improving the land before, during, and after surface mining.

Surface Mining: type of mining in which soil and rock overlying material is removed in order to extract the mineral deposit.

Tailings: Waste material that remains after an ore is separated from the host rock during mining.

Topography: shape of surface features

Watershed: an area of land where water drains downhill into a body of water, such as a river, lake, estuary, or ocean

RESOURCES :

Reading assignments:
"Coal Mining and the Environment"-----
http://www.worldcoal.org/coal-the-environment/coal-mining-the-environment/ ;

"Effects of Mining on Environment"
http://www.buzzle.com/articles/how-does-mining-affect-the-environment.html

The next two reading are more appropriate for high school students.
"Issue Analysis - Mining and Its Effects on the Environment"
http://www.scribd.com/mobile/documents/103246

"Ecosystem Restoration"
http://ecorestoration.montana.edu/mineland/guide/problem/impacts/

Lessons:
Cookie Mining activity
http://www.womeninmining.org/activities/COOKIE_MINING.pdf

Coal Mining and the Environment
Mining lessons
http://www.teachcoal.org/lessonplans/reclamation.html

Videos/DVD:
NOVA: Poison in the Rockies - the threats to water quality in the Rockies (Video/DVD)-mining, acid precipitation and recreational development.

Mining - "no significant environmental effects"? http://www.youtube.com/watch?v=TXC28jZgJWg
Coal Mining Effects-http://www.youtube.com/watch?v=a0S8iayJDhQ&feature=related

Mine Site Restoration
http://www.youtube.com/watch?v=Absuv4Y3F4U&feature=related

Information Sources:
Mining Reclamation and Enforcement
http://www.osmre.gov/

Map of mines and mineral resources in Massachusetts:
http://minerals.usgs.gov/minerals/pubs/state/ma.html

America's Power
http://www.americaspower.org/The-Facts/

Map of River drainage patterns United States
http://www.hist-geo.co.uk/usa/outline-50/usa-50-states-rivers-cities-1.php

Environmental Protection Agency http://www.epa.gov/

Report an Environmental Crime
http://www.mass.gov/dep/about/callnow.htm

How to find your watershed: http://www.epa.gov/owow/watershed/whatis.html

FUTURE PLANS FOR THE UNIT IN PROGRESS:
Preferably before these two lessons, I would include the life cycle of coal: from formation to combustion, the input and output. The lessons above, whereby, would focus on only one aspect of the cycle—the extraction component.
Eventually, I would like to develop a full unit, one that would include a more detailed lesson plan on watersheds.