January 2012

Proposed Uranium Mine and Mill, Coles Hill Virginia: An Assessment of Possible Socioeconomic Impacts

Final Report

Prepared for

Danville Regional Foundation
512 Bridge St., Suite 100
Danville, VA 24541

Prepared by
RTI International
3040 Cornwallis Road
Research Triangle Park, NC 27709

RTI Project Number 0212843.000

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Larry Campbell, Danville City Council

Laurie Moran, President, Danville Pittsylvania County Chamber of Commerce

Jeff Liverman, Director, Danville Science Center

Martha Walker, Community Viability Specialist, Virginia Cooperative Extension Service

Their insights into the values, aspirations, and concerns of the stakeholders of the study region provided invaluable help in shaping our study.

RTI would also like to thank residents of the study region, especially those who participated in stakeholder interviews and focus groups.

Table of Contents

Chapter **Page**

Appendixes

List of Figures

Number **Page**

List of Tables

1

Introduction and Approach Overview

1.1 Background

In late 2009, the Danville Regional Foundation (DRF) decided to fund a comprehensive, independent assessment of the possible impacts of establishing a uranium mine and mill at Coles Hill, near the towns of Gretna and Chatham in Pittsylvania County, Virginia. Virginia Uranium, Inc. (VUI) has recently begun assessments in the hope that it will be able to mine a deposit of an estimated 119 million pounds of uranium ore that had initially been discovered and evaluated approximately 30 years ago. At that time, the Commonwealth of Virginia established a moratorium on uranium mining in Virginia; because of declining market prices for uranium, interest in developing the resource waned and the moratorium remains in effect today. Conditions in the uranium market have strengthened and VUI has begun additional assessments of the ore body in hopes of being able to mine and mill the ore. Today, the Commonwealth is considering lifting its moratorium on uranium mining,[1] which has been in effect for nearly 30 years. This statewide consideration is under the jurisdiction of the Coal and Energy Commission of the Virginia Legislature.

Established in 2005, DRF is a nonprofit organization serving a region including the city of Danville and Pittsylvania County in Virginia, and Caswell County, North Carolina. Its mission includes development, promotion, and support of activities, programs, and organizations that address the region’s health, education, and well-being, with a focus on economic transformation, educational attainment, health and wellness, and civic engagement. In keeping with this mission, DRF’s Request for Proposals requested a comprehensive, independent study to provide area decision-makers and residents with sound, scientific information on potential environmental impacts regarding differing mining, milling, and waste management technologies and extraction methods and how pollutants might move through the environment. In addition, DRF requested an objective assessment of potential positive and negative socioeconomic impacts, including impacts on employment, regional business development and competitiveness, and reputation from the development and operation of Coles Hill. Finally, DRF requested information on possible impacts the mine and mill might place on county and local government services, and on county and local government finances.

1.2 Study Scope and Purpose

The purpose of this year-long socioeconomic study is to evaluate the potential impacts of developing and operating a uranium mine and mill on a region within 50 miles of Coles Hill. Figure 1-1 shows areas included within the study region. This report is intended to serve as a resource for all

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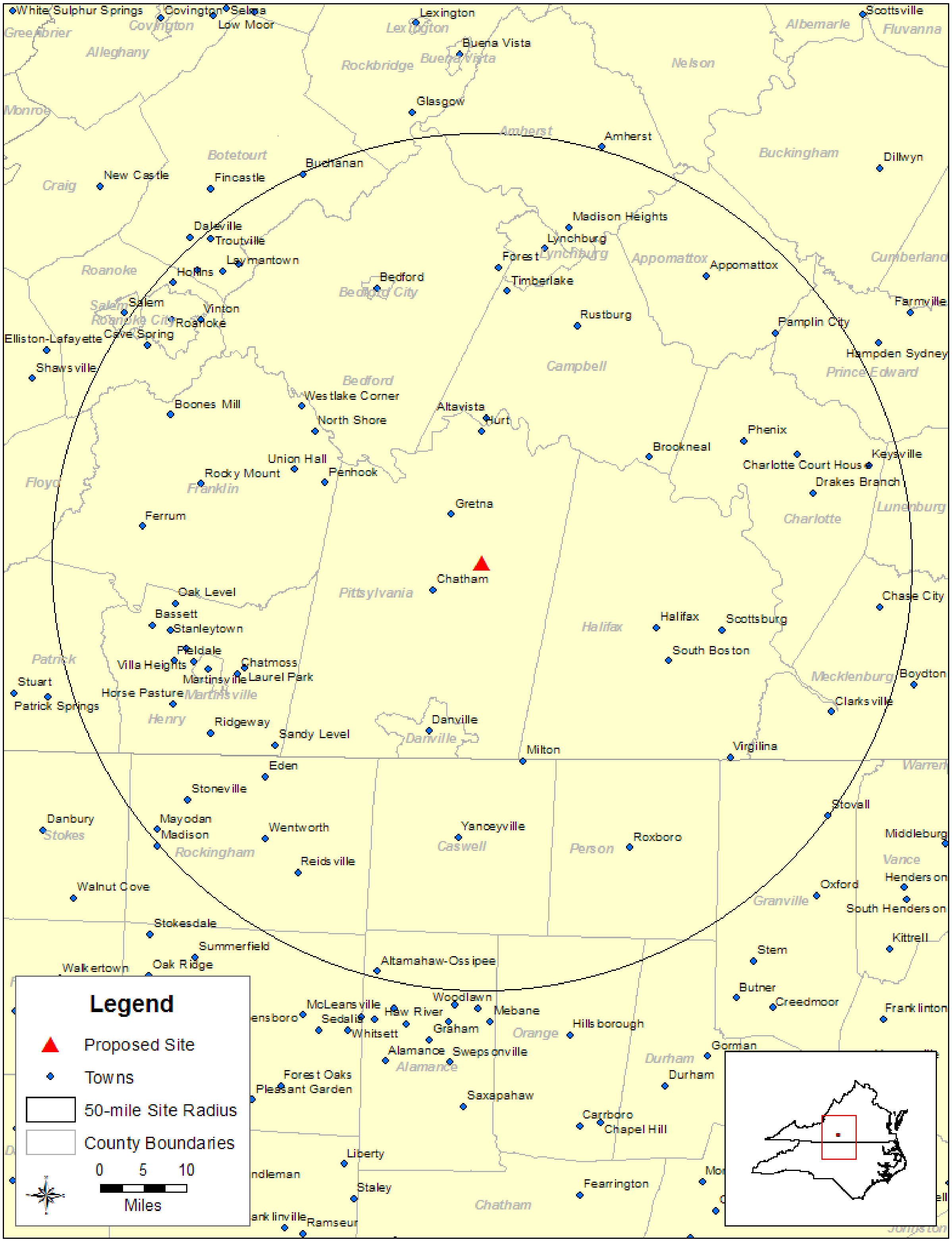
[1] In 1982, the Virginia General Assembly passed Statute 45.1-283, which states that “permit applications for uranium mining shall not be accepted by any agency of the Commonwealth prior to July 1, 1984, and until a program for permitting uranium mining is established by statute.”

Figure 1-1. The Study Region, a 50-mile Radius Around Coles Hill, Virginia



interested parties as they consider the variety of ways that this potential development may affect their communities and environment. As such, the goal of the study is to enable stakeholders

- to formulate informed opinions;
- to make the best collective decision possible; and
- in the case of an eventual mine and mill project, to be aware of questions and concerns they may want to investigate further or monitor going forward.

The focus of RTI International's study is on anticipating what might be entailed in the proposed mining and milling project, and on identifying possible ramifications of the project in social, economic, and environmental terms. To do this, our efforts are targeted toward providing accurate information about the types of possible impacts and which important factors of the project will drive these impacts, as opposed to providing extensive mathematical projections of specific metrics. Some modeling and projections will be used to describe the upper and lower bounds of potential impacts across a number of parameters. However, it should be noted that these numerical forecasts are intended to illustrate the relative scale of possible impacts, place the qualitative assessments in context, and allow this report to serve as a useful reference document for the stakeholders of the region.

The study does not reach any conclusions or make any recommendations as to the advisability of lifting the moratorium and allowing mining and milling of uranium in Virginia. Instead, the study is designed to provide a repository of information about the various types of impacts that may be experienced if the mine and mill are developed.

1.3 Study Framework

To ensure that our study meets the goal of serving as a reference document for the residents of the region, our approach must (1) identify and address the interests and concerns of regional residents and (2) provide as much well-documented, defensible information as feasible (subject to assumptions and data availability). Thus, our study combines an assessment of possible impacts predicted by environmental and social sciences, with an investigation of stakeholder interests and concerns within the study region. Our qualitative research into residents' interests and concerns helps us to specify the environmental and economic impact assessments. In addition, we provide illustrative information based on case studies of other mines and mills (U.S. and international) along with their surrounding regions.

1.3.1 Overall Analytical Framework

Our analysis is structured on a model of the interactions between households, firms, and the environment. Where the objective is to make the region the best place to live that it can be, the outcome depends not only on production, consumption, employment, and income, but also on other nonmarket conditions such as environmental quality, the availability of high-quality public services, and recreation. In this sense the assessment of the environmental impacts of the proposed mine and mill is a part of the overall assessment of socioeconomic impacts. Broadly speaking, conditions in the region's economy can be represented by the characteristics of the set of households and firms in that region. The other major components characterizing an economy consist of environmental amenities and other public amenities such as education, health care, safety, and transportation. In the event that a mine or mill is established at Coles Hill, these are the different parts of the regional economy that may be impacted. Changes in the condition of the region result from numerous interactions and feedback mechanisms among these different entities. This is illustrated in Figure 1-2. Within each box is a set of variables that could be affected by the establishment of the mine and mill. Characteristics of the mine include not only the mining, milling, and tailings management methods, but also production rate, hiring decisions, applicable regulations, and the extent of compliance with regulations. These all combine to determine likely pollutant releases to the environment, which combined with baseline environmental conditions in the region surrounding the mine, determine likely environmental impacts. Narrowly defined socioeconomic impacts (employment, income, output levels within the region) are determined by operations at the mine and mill and socioeconomic characteristics of the region, which include not only characteristics of households and firms, but also tax rates, provision of public services, and other market and nonmarket characteristics. Finally, the overall impact of the proposed Coles Hill uranium mine and mill on the region's quality of life and reputation depend on both the socioeconomic and environmental impacts of the project.

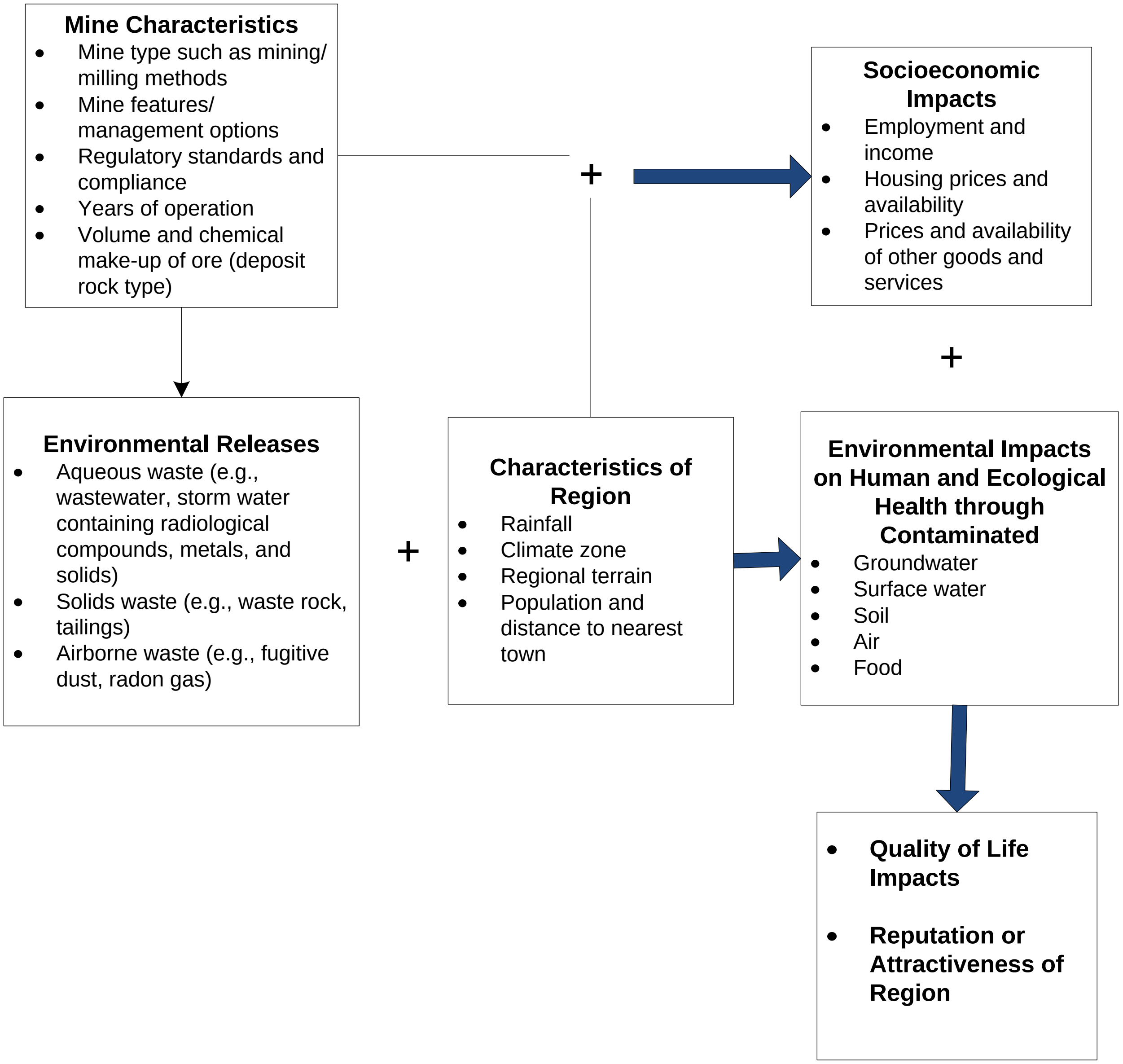
1.3.2 Understanding Interests and Concerns of the Region's Residents

Borrowing a framework from the field of decision analysis, our study draws on the interests of the community to help define the fundamental structure of the analysis, ensuring that the questions pursued and impacts assessed will address the questions and reflect the values of the affected communities. A decision analysis approach was chosen to guide information collection, facilitate the involvement of multiple stakeholders, and help us understand the characteristics of the linkages identified in Figure 1-2.

Unlike a decision-making approach that begins by identifying alternatives (e.g., to develop the mine vs. to take steps to ban the development of the mine), a decision analytic approach steps back to first identify the values underlying the decision and translate those values into objectives that the ultimate decision should support. Alternative decisions can then be evaluated with respect to how well they will meet these stakeholder-defined objectives. By then considering alternatives with respect to their effects on the objectives at hand, tradeoffs between the alternatives can be more clearly understood. Often, more alternatives are identified than were originally under consideration, because the focus on objectives allows for creative thinking.

In pursuit of this values-based approach, we sought out the opinions and viewpoints of multiple stakeholders as we structured the analysis. The concerns and interests of those affected by this decision were gathered and organized into a hierarchy of objectives articulated by the community (the methods for collecting these concerns and interests are discussed in Section 1.4.1). A hierarchy of regional objectives was assembled based on an amalgamation of opinions from across a wide range of stakeholders, including community leaders, business owners, and a broad spectrum of citizens in multiple counties and communities. In addition to serving as a facilitative tool for incorporating the views and communication desires of multiple stakeholders, this hierarchy of community objectives (the decision analytic framework) highlights the interconnectivity of many of the decisions facing the community, and can be used to explore and possibly uncover alternative steps the affected communities could take to achieve their objectives.

Figure 1-2. Analytical Framework for Assessing Socioeconomic Impacts



1.4 What Does the Community Care About?

This study was commissioned to address the region-wide impacts of a potential uranium mine and mill, and its content was guided by viewpoints of stakeholders across the Danville region. This differs from other approaches such as classical environmental impact studies, which follow predetermined formats and devote considerable resources to gathering and processing site-specific physical data. Instead, this socioeconomic study draws on what matters to the stakeholders who will be affected by the decision to pursue or deny the development of a uranium mine and mill in the region. These interests shape the direction of the research, along with insight drawn from the experiences of other communities that have faced similar choices, and along with RTI subject matter expertise.

1.4.1 Methods for Gathering Stakeholder Concerns and Viewpoints

To better understand the views and concerns of the people of the study region on the proposed uranium mine and mill, RTI formed a Community Advisory Panel (CAP) to help guide and focus the conduct of its research activities and engaged in qualitative and ethnographic research, involving key stakeholder interviews and focus group discussions, with community members to identify knowledge, perceptions, and attitudes related to the proposed mine and mill. Provided below is further detail on the approach and methods used in developing an understanding of community concerns.

1.4.1.1 Community Advisory Panel

The CAP provided critical guidance and information about the region's strengths, challenges, and concerns. The CAP initially included five leaders from the region:

- Lawrence Campbell, City Councilman and minister, Danville, Virginia
- Jeff Liverman, Director of the Danville Science Center
- Laurie Moran, President of the Danville-Pittsylvania County Chamber of Commerce
- Dan Sleeper, County Administrator of Pittsylvania County
- Martha Walker, Community Viability Specialist with the Virginia Cooperative Extension Service

During the course of the project, Mr. Sleeper was directed by the Board of Supervisors to step down from the panel, so the panel consisted of four members during the final few months of the project. RTI researchers met with the CAP approximately every 2 months during the course of the study, so the CAP provided an ongoing source of insight into the attitudes, priorities, and concerns of the region. The first meeting with the CAP focused on identifying key values and concerns in the region; the CAP also reviewed the draft interview guides developed by RTI researchers and suggested leaders from within the region to interview.

1.4.1.2 Key Stakeholder Interviews

Key stakeholders are individuals who because of their knowledge, previous experiences, or position in a community have the potential to offer unique or specialized perspectives on a topic. Participants in such key stakeholder interviews are selected purposely by the researcher, generally guided by some a priori criterion to ensure a range and balance of perspectives.

In the research on community perspectives and concerns related to Coles Hill mine and mill, we conducted 29 key stakeholder interviews with community leaders and representatives from different areas of civic life, based on categories of business, community development, community advocacy, education, environment, health, religion, and government. Table 1-1 provides an enumeration of the interview participants by these categories. The larger number of interviews among community development stakeholders reflects a specific interest in this aspect of the community that was identified for further analysis.

Table 1-1. Stakeholder Representation

Stakeholder Category	N
Business	4
Economic development	10
Community leader/advocacy	3
Education	2
Environment	4
Health	1
Religion	2
Government	3
Total	**29**

Recruitment started with recommendations from the CAP as to potential participants from each of the aforementioned categories. This list was then vetted internally and prioritized based on the individual’s involvement in the community and area of representation. In conducting the interviews, two RTI project team members placed telephone calls to stakeholders, provided an explanation of the purpose of the study, and invited them to participate in a 60-minute interview. Interviews were scheduled according to the stakeholder’s availability and took place in person and at locations convenient to participants.

Prior to the interview, participants were provided a description of the study and informed of their rights as a participant. Participants had the opportunity to ask questions or choose not to participate. Informed consent was obtained from each individual. The interviews were conducted by an experienced interviewer, following a semistructured interview guide (see Appendix A). A note taker attended each interview and recorded the substance of the discussions.

Following the interviews, participants were also asked to complete the structured questionnaire (see Appendix A). This questionnaire asked participants to rate the impact of the mine and mill on specific qualities or features in the domains of economy, environmental, and community issues. To rate the impact on these items, participants were asked to use an 11-point scale that featured a balance of positive and negative values, (e.g., negative five indicated a highly negative impact to the economy, environment, or community, and a positive five indicated a highly positive impact to the community). In addition, participants were asked to rank which was most important to them among economy, environment, and community, when considering the mine and mill. Fifteen of the key stakeholder participants completed the questionnaires.

1.4.1.3 Community Focus Groups

Focus groups are facilitated group discussions usually concerning a single topic of interest (Morgan 1989). They are a common method in qualitative studies and used to rapidly produce data concerning participants’ knowledge, attitudes, perceptions, and opinions on a range of topics.

A total of seven focus group discussions were conducted in Martinsville, Danville, South Boston, Gretna (two groups), and Chatham (two groups), Virginia, with a total of 51 community members. The purpose of the focus groups was to develop a more nuanced understanding of the values and concerns of individuals in each of the selected communities within the study area.

Participants in the focus groups were recruited through a local recruitment firm that placed telephone calls to households in the targeted areas. The recruitment firm used screening questions developed by RTI to determine eligibility and ensure diverse representation in each group. Communication between the firm and RTI took place on a daily basis during the process to ensure proper screening of participants and even representation across groups.

Prior to the start of the discussion, a moderator explained the purpose of the focus groups and their rights as participants. Participants had the opportunity to ask questions prior to consenting their participation or to choose not to participate. Informed consent was obtained from each participant. Discussions were led by an experienced moderator who facilitated the discussion using a semistructured question guide framed by several key domains. A note taker was present and systematically captured information shared in the discussions and the groups were audio recorded to aid analysis. These discussions lasted approximately 2 hours and following completion, each participant received a $50 honorarium. Providing an honorarium is an accepted practice in focus groups research and done in part to ensure that a diverse set of individuals are able to participate in the research.

Participants in the focus groups were also asked to independently complete the same structured questionnaire used in the key stakeholder interviews prior to the start of the discussion. This yielded 49 completed questionnaires among the focus group participants.

Participation in each of the focus group was balanced for the most part in terms of sex, with a total of 29 males and 22 female participating. The average age of participants was 50. The majority (71%) of those who participated in the focus groups were white or Caucasian and 24% were African American. Twenty-seven participants reported having achieved a high school education or less. Most participants (41%) had attended some college or had received technical education or training. Thirty-nine percent of participants reported full-time employment followed by 27% who indicated they were presently retired. The remaining participants were students (12%), unemployed (8%), and an equal number were homemakers or reported part-time employment (6%). Forty-one percent of focus group participants reported a household income of less than $20,000 per year; 22% reported earning between $20,000 and $30,000 and 25% reported an annual household income between $30,000 and $40,000. The majority (61%) were lifelong residents while others had resided in the area for most or a large portion of their lives. Few had lived in the area for a short period of time relative to their age.

1.4.2 Stakeholder and Community Interests and Concerns

To inform RTI’s decision analysis approach, we conducted qualitative research into what communities around the mine see as potential concerns for the introduction of uranium mining and milling in the region and any questions they have about the proposed mine and mill. This research involved focus groups and interviews, where interview participants were asked to share concerns and questions about the proposed mine and mill. Presented here is the broad set of concerns shared by participants and a summary of their main questions.

1.4.2.1 Environmental Concerns

Concern for the impact of the mine and mill on the environment was both the most frequent concern and the one most spontaneously expressed by participants in the focus groups and interviews. Participants' comments included both general statements about concerns for potential pollution or damage to the environment and more specific consideration of the mine and mill's potential impacts on water contamination, air quality, and management of waste materials. Potential contamination of water was the most common concern mentioned by participants. In particular, people cited concerns for the mine and mill contaminating local water used for drinking and agriculture. Several participants described scenarios where contamination would potentially come from seeping or leakage of materials from the mine and mill into groundwater. Another water contamination scenario participants expressed concern for was a failure or breach of the containment basins used to store mine waste. A failure of this type was thought to be a potential if the technology used to contain the water were to fail (e.g., crack in the lining) or if it were overwhelmed by a natural or human disaster, like a hurricane, flood, tornado, earthquake, or terrorism. Although quite a few participants in the research also mentioned air and air quality as an area of environmental concern, participants were less able to provide detail about potential impacts. A few individuals described uranium-contaminated dust from the mine as having the potential to be transported in the air to surrounding areas.

1.4.2.2 Concerns About Health

Almost all of the participants in the research shared some concern about impacts to people's health from the mine and mill. Many of these concerns were nonspecific statements about concerns (e.g., I am concerned that the mine will affect people's health) or the importance of health in relation to the mine (e.g., protecting people's health would be the most important thing about the mine). When participants expressed more detailed health concerns, aspects of the mine and mill that were linked directly to potential negative health impacts included exposure to the tailings and water used to wash or store them, increased dust and other pollutants affecting air quality, and ingestion of uranium through food products. Participants identified cancer as the illness most likely to occur from exposure to any pollutants from the mine and mill. Several participants expressed concern that the area around the mine would experience increased rates of cancer as a result of the project. The immediacy of the threat of cancer varied. A few individuals expressed concern for people getting cancer from it in a matter of months. Others said it could take many years, anywhere from 20 to 40, for the community to understand the impact on health and rates of cancer. Participants, particularly in the focus groups, also discussed concerns for the health of future generations in the community. Some participants expressed worry that exposure of adults to increased radiation would result in increases in incidents of birth defects and deformities in children. Two individuals also cited a risk for people with asthma and other respiratory issues if the mine were to decrease local air quality.

1.4.2.3 Views on Jobs and the Economy

Both interviews and focus groups revealed uncertainty about the proposed project's potential impact to jobs and the regional economy. This was shown as participants often argued about potential benefits and challenges to the economy. Most participants recognized that the region is facing economic challenges. With the collapse of the textile and furniture manufacturing industries in the region, and decreased tobacco farming, there are fewer well-paying jobs. The region needs new industries and businesses to employ its citizens. Further, many people commute long distances to find work. Given these challenges, the promise of new jobs, both those related directly to mine and milling operations and those created by other businesses supporting the mine, is appealing. However, some participants felt few jobs would go to local residents, or the jobs would be low paying.

Participants also expressed that any benefit from new jobs from the uranium mine and mill would be offset by potential losses of jobs in other economic sectors that would be negatively affected by the introduction of the mine and mill. In particular, participants in the research stated that the agriculture industry, which includes several large dairy and produce farms located in close proximity to the mine site, is an important aspect of the local and regional economy. Also, many participants saw the presence of the mine and mill as putting the region at a disadvantage in attracting new business, potentially limiting the overall growth of the region. Participants questioned whether new businesses would want to locate employees in an area with a uranium mine. They felt the area had many good things to offer in terms of attracting business—a workforce, nice communities, good schools, and affordable housing—but the negative impact of the mine on the community would be enough to stop new business from locating to the area.

1.4.2.4 Government-Related Concerns

Most people felt it was the role of state and federal government to protect the people through regulating and monitoring the activities at the mine and mill. Participants also expressed some skepticism as to the ability of the government to execute these tasks fully. A few participants suggested that the effectiveness of government's oversight depends on knowing which regulations need to be in place and having the resources available to effectively monitor and enforce any regulations. A few participants cited incidents like the Gulf Coast oil spill, however, as evidence that regulation is not always effective.

1.4.2.5 Community Concerns

Participants in the research expressed some concerns for the effect of the mine on the organization and functioning of the local communities. Participants' most frequent concern was that population would decline if the mine were to open. Several participants said they had heard people say they would move away from the area if the mine opened, potentially leading to further decreases in home values near the mine. Potentially countering this concern were suggestions that new workers would be coming into the community to support the mine. This could increase the number of educated and high-income families in the community.

1.4.3 Hierarchy of Study Region's Objectives

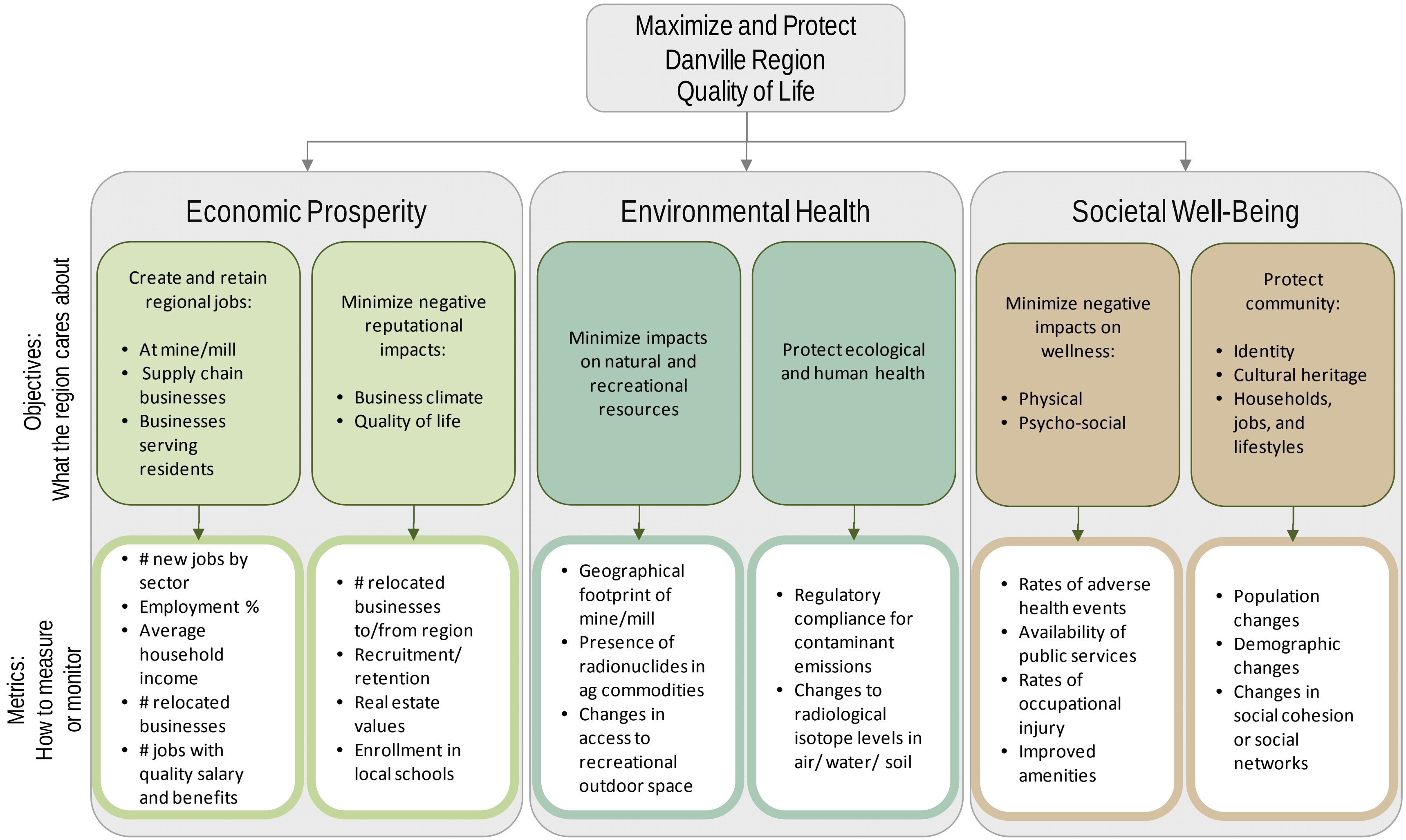
Interests and values expressed by residents were analyzed to reveal that residents wish to preserve and enhance the region's economic prosperity, human and ecological health, and community well-being. A graphical representation of this hierarchy of community values can be found in Figure 1-3. This schematic depicts the collective values articulated by the many individuals whose input was gathered via CAP meetings, focus groups, interviews, and individually provided feedback from concerned citizens, as well as identifying metrics that could be used to measure or monitor how well objectives are achieved.

Using these frameworks, we gathered information to characterize the region's current conditions and the planned operations at the mine and mill. These data were used to quantitatively or qualitatively simulate the potential effect of the mine and mill on the environment, human and ecological health, and the economy of the region. Scenarios were developed based in part on insights gathered by examining the experience of regions with existing and closed mines around the world, and used to illustrate a range of potential impacts.

1.5 Structure of the Report

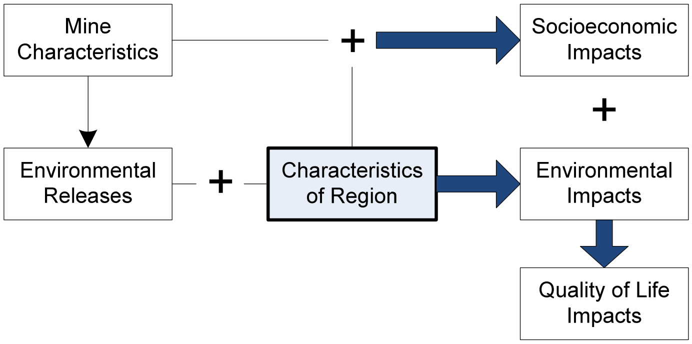
The report that follows provides background information on existing socioeconomic conditions in the study region (Section 2); gives a technical description of the proposed uranium mine and mill, and identifies potential environmental releases (Section 3); summarizes information gathered by conducting case studies of other mines and mills in Section 4; characterizes potential environmental impacts in Section 5; presents estimated socioeconomic and community impacts in Section 6; and summarizes findings in Section 7. In addition, there are several appendices that provide greater detail on some aspects of the study.

Figure 1-3. Objectives identified by Region's Stakeholders



2

The Coles Hill Region



This section summarizes existing and projected baseline conditions (without the impact of the mine and mill or other new employers) in the study region surrounding the Coles Hill site of the proposed uranium mine and mill. The area has many positive aspects but also faces challenges. The region has a beautiful and productive natural environment, providing many opportunities for outdoor recreation. Agriculture is important to the region: the region leads the state in production of tobacco and is important in production of beef cattle and dairy products, hogs, and hay and forage. Residents hope to revitalize the economy, damaged by declining traditional manufacturing, to offer increased opportunity to residents while retaining its environmental quality and small-town quality of life. However, the region has a smaller share of residents with education beyond high school, which may be needed for high-skill, high-wage employment. Over the next 20 years, the population of most area jurisdictions is projected to increase, and employment overall is projected to increase by more than 20%. However, manufacturing (which is currently more central to the region's economy than it is nationally) is projected to continue to decline. Although the region has more than 20 employers with more than 1,000 employees, examination of growth in employment by size category shows that the smallest two sizes of firms (sole proprietorships and companies with fewer than 10 employees) provide most of the growth in jobs.

This section presents a characterization of the study region, an area within a 50-mile radius of the site of the proposed Coles Hill uranium mine and mill. The region's population, land use, and economy are described; Appendix B provides additional details about the region. The purpose of this section is to provide a context for the subsequent sections, which discuss the proposed mine and mill project and its potential environmental and socioeconomic impacts. The data presented here are generally for existing conditions in the region. The mine and mill, if approved, would be in operation for an estimated 35 years. Thus, the "baseline" conditions against which the impacts would be measured are socioeconomic and environmental conditions that would exist over the 35-year life of the proposed project, if the proposed mine and mill did not exist.

We have little data to enable us to project future environmental, land use, and socioeconomic conditions; thus, our analyses generally rely on existing conditions as a baseline. However, the reader should bear in mind that without the mine and mill project, other things will change over the next 35 years. Thus, actual baseline conditions at some future time would likely be different from existing conditions.

2.1 Background

The approximately 7,850-square mile study region lies partly in Virginia and partly in North Carolina, including all or part of 28 counties and six independent cities. The proposed mine and mill site is located between the towns of Chatham and Gretna, in Pittsylvania County, Virginia. This is a rural area within a relatively rural county. The nearest cities are Danville, approximately 25 miles to the south, and Lynchburg, approximately 45 miles to the north. Chatham, a town of about 1,300, has served as the county seat of Pittsylvania County since 1777. In addition to county offices and courts, it is home to two private boarding schools, Hargrave Military Academy (founded 1909) and Chatham Hall girls' school (founded 1894). Gretna, the next nearest town to the proposed site, is also a town of approximately 1,300. It was incorporated in 1909, but the community existed as a railroad stop and post office during the mid-1800s. It is also home to historic Yates Tavern, built in the mid-1700s.

In terms of land use, the majority of the land in the study region is used for agriculture or is forested. However, several cities and many small towns in the study region are home to a population long tied to the land and associated commerce in agricultural-based products. Figure 2-1 shows the land use in the region in 2006, based on the National Land Cover Dataset (NLCD). In addition to the cities, the region includes small developed areas (shown in pink and red). It is possible to trace U.S. 29 from Danville north through the region to Lynchburg and beyond using the string of small towns and developed areas. In general, however, the predominant land uses are deciduous forest, grassland, and pasture and hay.

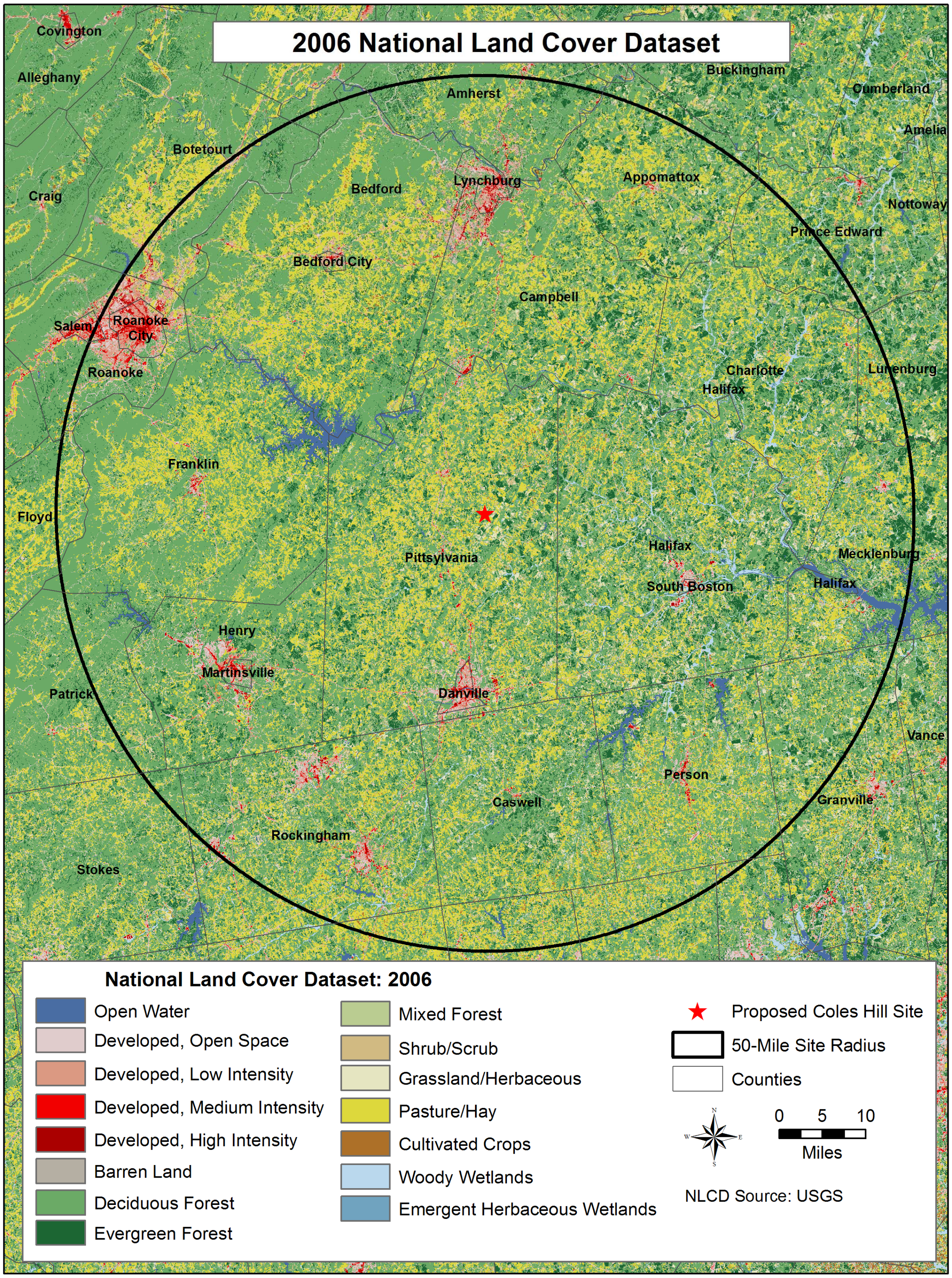
2.2 Stakeholder Perspectives on the Region

To better understand conditions in the study region, RTI interviewed more than 30 local leaders of business, education, the faith community, and local government and conducted seven focus groups of randomly selected local residents. From these qualitative interviews, it was possible to identify common themes. All the stakeholders interviewed recognize that the region's current quality of life benefits strongly from its culture, history, and natural environment but that the region faces economic challenges.

In the key stakeholder interviews and focus group discussions, we asked participants to share what they value about the region (what its current strengths are), current challenges they see facing the region, and their hopes and aspirations for the region. Table 2-1 summarizes participants' responses to these questions. Overall, they see the small-town lifestyle and natural environment as valuable; most challenges are related to the decline in traditional manufacturing industries over the past several decades, resulting in fewer opportunities. Residents hope to revitalize the economy while preserving the region's strengths.

In terms of the region's economic development, culture, and concerns, the 50-mile radius study area is not regarded as unified or homogeneous. Rather, stakeholders consider that the study region is in reality divided into two or more separate economies—one in the north with Roanoke and Lynchburg as anchors, one in the south with Danville and Chatham as anchors, and possibly a separate one for northern North Carolina. As one interviewee mentioned, Smith Mountain Lake, and associated tourism from it, is the only "big connector" between the two Virginia sections of the study region. Furthermore, the economies of some counties are strongly influenced by economic activity outside the study region; for example, southern Person County is closely tied to Durham and the Research Triangle, and southern Rockingham County is tied to the Triad; northern Person County, northern Rockingham County, and Caswell County, however, are closely tied to Danville and Martinsville.

Figure 2-1. Map of Land Use in the Study Region, 2006



Source: Multi-Resolution Land Characteristics Consortium. 2006. National Land Cover Dataset. http://www.mrlc.gov/nlcd2006.php.

Table 2-1. Summary of Stakeholder Perspectives on the Study Region

Positive Aspects of Life in the Study Region	Challenges Facing the Study Region	Hopes for the Study Region
People stick together, care for each other in times of need, are friendly	Unappealing to young adults because of lack of good jobs and entertainment; population decline as young people leave or do not return after college	Jobs and new businesses in information technology, data management, automotive industry, or green industries
Peaceful, quiet, small-town feel	Aging population; inadequate services or employment opportunities for older adults	Improved and diversified adult education and training to make the workforce more competitive
Natural environment—beautiful, productive, and provides many opportunities for outdoor recreation	Lack of a plan for the region’s future	Revitalization of communities with better entertainment, recreation facilities, and other amenities
Quality schools, both public and private	“Mill mentality,” including low self-esteem	Improvements to the region’s infrastructure (roads, water, sewer)
Sports programs (football and baseball)	Education a low priority, low literacy levels	More comprehensive planning policies
Safety and lack of crime	Economic downturn over past 30 years; few jobs available, and those that exist have low pay and few benefits	Preservation of the region’s natural beauty, historical resources, relaxing small-town lifestyle
Low cost of living, reasonable real estate prices	Local work force underqualified for the changing job market	Increasing ecotourism
Importance of churches and faith community	Lack of good local jobs leads to long commutes to work	Need more large industrial or mill employers
Strong health care system, including hospitals and nursing homes	Declines in manufacturing, plant closures, job loss	Need strong local leadership providing incentives and advocating for change
Small businesses such as restaurants and wineries/vineyards	High tax rates, low priority for state funding	
Strong agricultural industry	People are resistant to change	
Several large corporate employers	Concerns with land and property values	
Proximity to larger metropolitan areas (Lynchburg, Danville, Roanoke, and Richmond; Triangle and Triad regions)		

Just as the economies are not homogeneous across the entire region, the level of concern about the proposed uranium mine and mill varies from one part of the study region to another. Generally, residents closest to the mine and mill are more interested in the issue than those farther away; in addition, those south and east of the proposed site, or downstream, expressed much more concern about the impacts of the mine and mill than those north of the site or upstream. Furthermore, those generally north and northeast described positive experiences working with the companies in the nuclear industry in and around Lynchburg. According to them, dedicated commitment to the region by leadership at these companies plays a role in this positive relationship. Others stated that the region has had positive experiences with these companies for two main reasons. First, they came in as companies with employment opportunities, not as “the nuclear industry.” Second, they are manufacturing facilities and do not have mining and milling components, which are viewed as more threatening to the land and its residents.

2.3 Population and Projected Population Growth

In 2010, the population of the study region was approximately 889,000, based on summing population of all areas within the 50-mile radius using Geographic Information System tools. Table 2-2 shows population by county in 2000 and 2010, for the 15 counties (3 in North Carolina and 12 in Virginia) and six cities whose populations are largely within the 50-mile radius (omitting counties for which only a small share of the population falls within the 50-mile radius; U.S. Census Bureau, 2011). These counties, which comprise the core study area, were examined in detail because they are thought to be the most representative of the study region. Many of the counties include some areas that are outside the 50-mile radius of the study region; data in all tables are shown for entire counties, including the areas outside of the 50-mile radius. For this core region, the population in 2010 was approximately 954,000, an increase of approximately 37,000 (or 4%) from the population in 2000. This overall growth obscures considerable variability in population growth among the counties and cities. Over the 10-year period, 3 counties and one city experienced greater than 10% increases in population, while 3 counties and three cities experienced decreases in population.

As mentioned above, discussions with stakeholders in the study area revealed a sense that the Virginia section of the study region could be divided into northern and southern areas and that the two have experienced different economic and population trends over the past 20 or more years. These two areas, in turn, have experiences that differ from the three northern North Carolina counties. Thus, the table also shows summed populations for Person, Caswell, and Rockingham Counties in North Carolina; for Amherst, Appomattox, Bedford, Campbell, and Roanoke Counties and the cities of Lynchburg, Bedford, Roanoke, and Salem (the northern area of the Virginia study region); and for Charlotte, Franklin, Halifax, Henry, Patrick, Pittsylvania, and Mecklenburg Counties, plus the cities of Danville and Martinsville (the southern area of the Virginia study region). The North Carolina area population grew by about 3.8% over the 10 years; in Virginia, the northern area grew by about 7.6%, and the southern area’s population declined by about 0.5%.

Population density affects the availability of nearby workers for the proposed project, as well as determining how many residents might be exposed to environmental contamination if any occurs. Figure 2-2 shows population density across the same area and reveals considerable variation among the jurisdictions. Charlotte and Patrick Counties, Virginia, are sparsely populated, with fewer than 40 people per square mile. On the other hand, Rockingham County, North Carolina, and Henry and Roanoke Counties, Virginia, have considerably more than 100 people per square mile. Among the cities, Bedford has fewer than 1,000 people per square mile and Roanoke has more than 2,300. The counties in the region have a population density much lower than the state of Virginia as a whole but similar to that of the United States. Figure 2-2 shows that, even within counties or cities, population density can vary considerably among census block groups. See Table B-2 in Appendix B for population density at the county and city levels (U.S. Census Bureau, American Community Survey [ACS], 2005–2009).

Table 2-2. Population 2000 and 2010 by County

Jurisdiction	2000 Population	2010 Population	2001–2010 Change	Percentage Change
United States	281,421,906	308,745,538	27,323,632	9.7%
Virginia	7,078,515	8,001,024	922,509	13.0%
Caswell County, North Carolina	23,501	23,719	218	0.9%
Person County, North Carolina	35,623	39,464	3,841	10.8%
Rockingham County, North Carolina	91,932	93,643	1,711	1.9%
Amherst County, Virginia	31,894	32,353	459	1.4%
Appomattox County, Virginia	13,705	14,973	1,268	9.3%
Bedford County, Virginia	60,371	68,676	8,305	13.8%
Campbell County, Virginia	51,078	54,842	3,764	7.4%
Charlotte County, Virginia	12,471	12,586	115	0.9%
Franklin County, Virginia	47,280	56,159	8,879	18.8%
Halifax County, Virginia	37,350	36,241	−1,109	−3.0%
Henry County, Virginia	57,933	54,151	−3,782	−6.5%
Mecklenburg County, Virginia	32,380	32,727	347	1.1%
Patrick County, Virginia	19,407	18,490	−917	−4.7%
Pittsylvania County, Virginia	61,747	63,506	1,759	2.8%
Roanoke County, Virginia	85,776	92,376	6,600	7.7%
Bedford, Virginia	6,299	6,222	−77	−1.2%
Danville, Virginia	48,411	43,055	−5,356	−11.1%
Lynchburg, Virginia	65,269	75,568	10,299	15.8%
Martinsville, Virginia	15,416	13,821	−1,595	−10.3%
Roanoke, Virginia	94,911	97,032	2,121	2.2%
Salem, Virginia	24,747	24,802	55	0.2%
Total for 15 counties, 6 cities	**917,501**	**954,406**	**36,905**	**4.0%**
NC[a]	151,056	156,826	5,770	3.8%
VA-N[b]	434,050	466,844	32,794	7.6%
VA-S[c]	332,395	330,736	−1,659	−0.5%

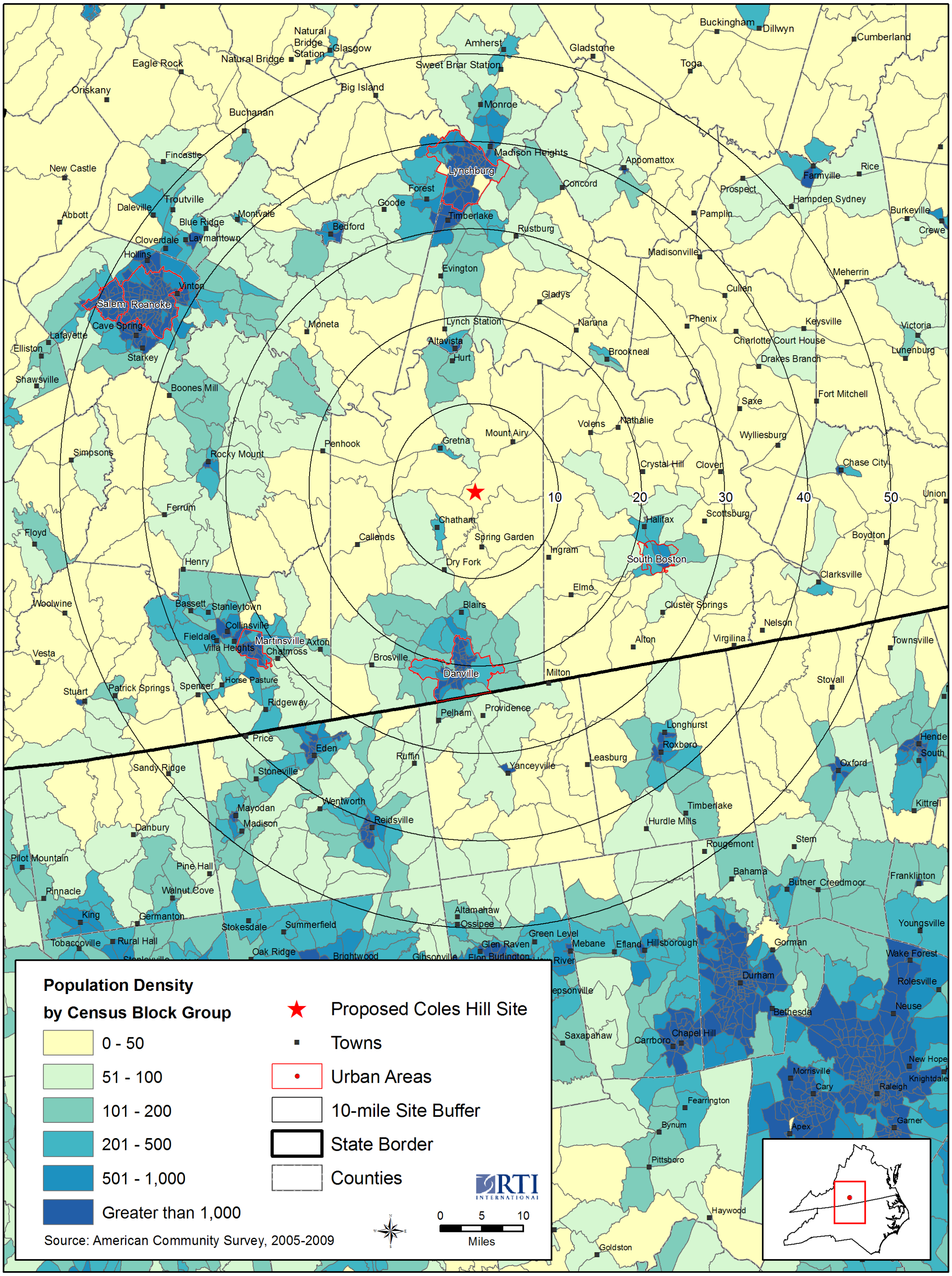
Source: 2010 census (http://www.census.gov/popfinder/)

[a] Includes Person, Caswell, and Rockingham Counties in North Carolina.

[b] Includes Amherst, Appomattox, Bedford, Campbell, and Roanoke Counties and cities of Lynchburg, Bedford, Roanoke, and Salem in Virginia.

[c] Includes Franklin, Patrick, Henry, Pittsylvania, Halifax, Charlotte, and Mecklenburg Counties in Virginia and cities of Danville and Martinsville.

Figure 2-2. Population Density in the Study Region, 2005–2009



Source: American Community Survey, 2005-2009

2.3.1 Projected Population Growth

Demographic projections made by the states of North Carolina and Virginia are shown in Table 2-3, for 2020 and 2030 (NCOSBM, 2011; VASDC, 2011). For the core region as a whole, the population is projected to grow by approximately 50,600 (5.3%) over the period 2010 to 2030, topping 1 million by 2030. Five counties, however, are projected to incur double-digit population growth rates over the period, while three counties and three cities are projected to experience population declines.

The differences in growth are projected to persist on a regional basis, as shown in Table 2-3, as projected by the state demographers of North Carolina and Virginia. The population of the three North Carolina counties is projected to grow by 12% between 2010 and 2030; in Virginia, the northern portion of the study area is projected to grow by 5.4%, while the population of the southern portion is projected to grow by only 1.9%. Within each region, however, the experience of individual counties and cities also varies considerably.

2.3.2 Characteristics of the Study Region Population

This section summarizes characteristics of the study region's current population, including ethnicity, poverty, and educational attainment. Minority or high-poverty populations have historically been economically vulnerable and have also on occasion been more vulnerable to environmental harms, giving rise to the environmental justice movement. Similarly, less-educated residents may have fewer employment options, again making them somewhat more vulnerable to environmental or economic risks.

The population of the core region is relatively diverse in terms of race and ethnicity, as shown in Table B-4 in Appendix B (U.S. Census Bureau, ACS, 2011). All the jurisdictions have majority white populations, although Danville and Martinsville have populations that are almost 50% minority. Overall, the region's population is approximately 25% minority; most of the nonwhite population is African American. The cities in general have populations with larger proportions of minorities, although several counties (Caswell and Person in North Carolina and Charlotte, Halifax, and Mecklenburg in Virginia) are more than 30% minority. Figure 2-3 presents minority shares of the population by census block group for the 50-mile radius surrounding the proposed site of the mine and mill. The block group within which the proposed mine site is located is characterized by a population that is 33% minority, while the entire area within 10 miles of Coles Hill is approximately 29% minority.

The core study region population has rates of poverty (14.8% of residents with income below the poverty level) slightly higher than the population of the country as a whole (13.5%) and considerably higher than the state of Virginia (10.1%). For individual jurisdictions, the region shows a range of poverty rates (shown in Table B-5 in Appendix B) from 5.3% in Roanoke County to 20.9% in Caswell County. Pittsylvania County, where the proposed mine would be located, has 15% of the population with income below poverty, very similar to the region as a whole. Similarly, the area within 10 miles of Coles Hill has 15% of the population below poverty. Figure 2-4 shows population with income below the poverty level by census tract, revealing considerable variation in poverty rates within counties and cities. The census tract within which Coles Hill is located has more than 22.0% of the population below poverty.

Table 2-3. Population Projections for Region

County or City	2010	2020	2030	Percentage Change, 2010–2030
Caswell County, North Carolina	23,719	23,944	24,171	1.9%
Person County, North Carolina	39,464	43,931	48,308	22.4%
Rockingham County, North Carolina	93,643	98,664	103,563	10.6%
Amherst County, Virginia	32,353	33,166	33,923	4.9%
Appomattox County, Virginia	14,973	14,713	15,254	1.9%
Bedford County, Virginia	68,676	76,731	84,858	23.6%
Campbell County, Virginia	54,842	54,948	57,023	4.0%
Charlotte County, Virginia	12,586	12,170	12,170	−3.3%
Franklin County, Virginia	56,159	57,347	62,443	11.2%
Halifax County, Virginia	36,241	33,836	33,821	−6.7%
Henry County, Virginia	54,151	52,979	52,977	−2.2%
Mecklenburg County, Virginia	32,727	32,511	32,755	0.1%
Patrick County, Virginia	18,490	18,895	18,885	2.1%
Pittsylvania County, Virginia	63,506	63,057	63,901	0.6%
Roanoke County, Virginia	92,376	99,048	105,889	14.6%
Bedford , Virginia	6,222	5,966	5,965	−4.1%
Danville , Virginia	43,055	45,711	46,025	6.9%
Lynchburg , Virginia	75,568	72,615	76,499	1.2%
Martinsville , Virginia	13,821	13,952	13,954	1.0%
Roanoke , Virginia	97,032	88,503	88,495	−8.8%
Salem , Virginia	24,802	24,145	24,143	−2.7%
Total for 15 counties, 6 cities	**954,406**	**966,832**	**1,005,022**	5.3%
NC[a]	156,826	166,539	176,042	12.3%
VA-N[b]	466,844	469,835	492,049	5.4%
VA-S[c]	330,736	330,458	336,931	1.9%

Sources: Virginia State Data Center. 2011. http://www.vawc.virginia.gov/analyzer/populatchoice.asp?cat=HST_DEMOG_POP&session=populat&time=&geo=.

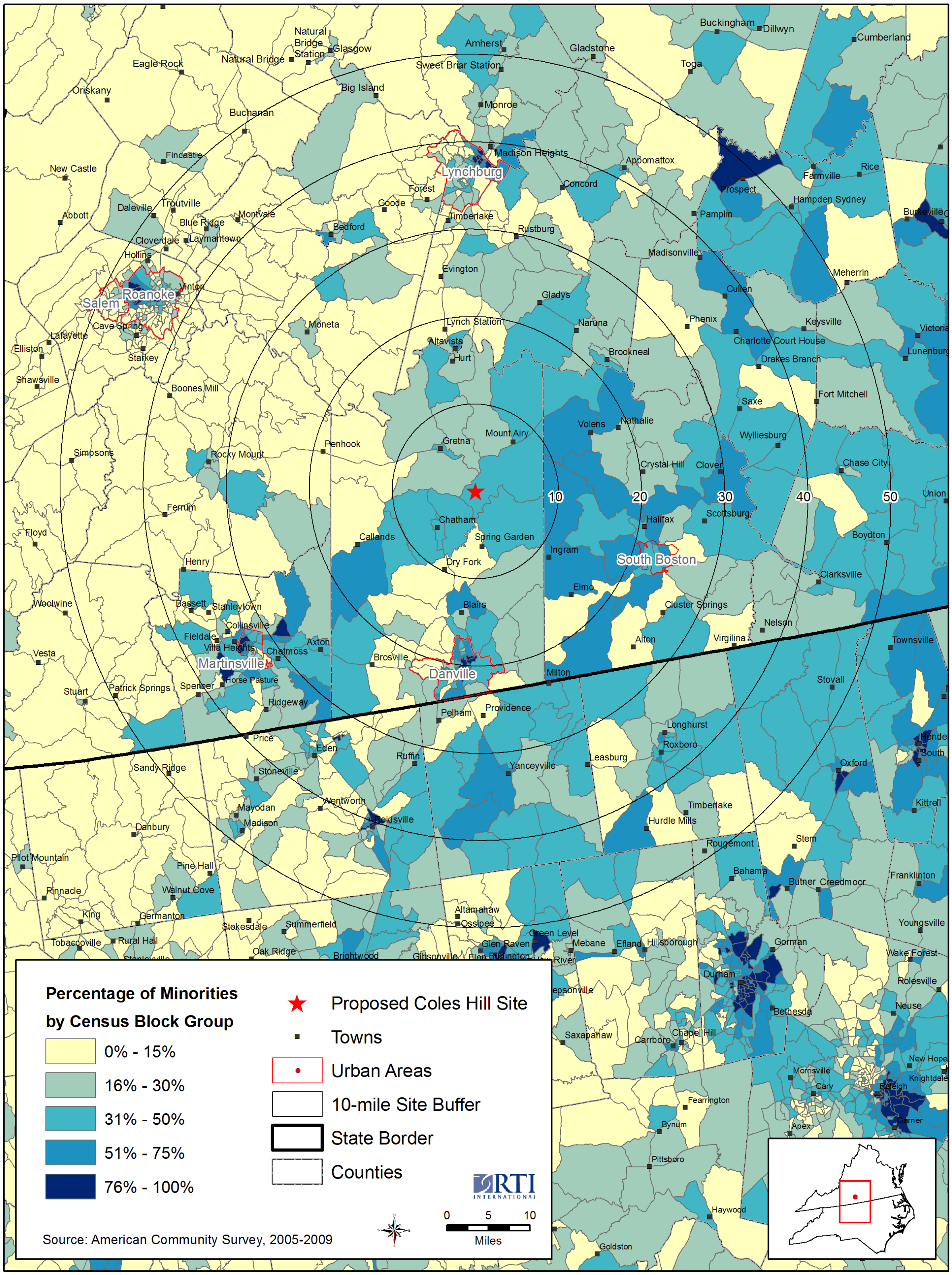
North Carolina Office of State Budget and Management. 2011. http://www.osbm.state.nc.us/ncosbm/facts_and_figures/socioeconomic_data/population_estimates/county_projections.shtm.

[a] Includes Person, Caswell, and Rockingham Counties in North Carolina.

[b] Includes Amherst, Appomattox, Bedford, Campbell, and Roanoke Counties and cities of Lynchburg, Bedford, Roanoke, and Salem.

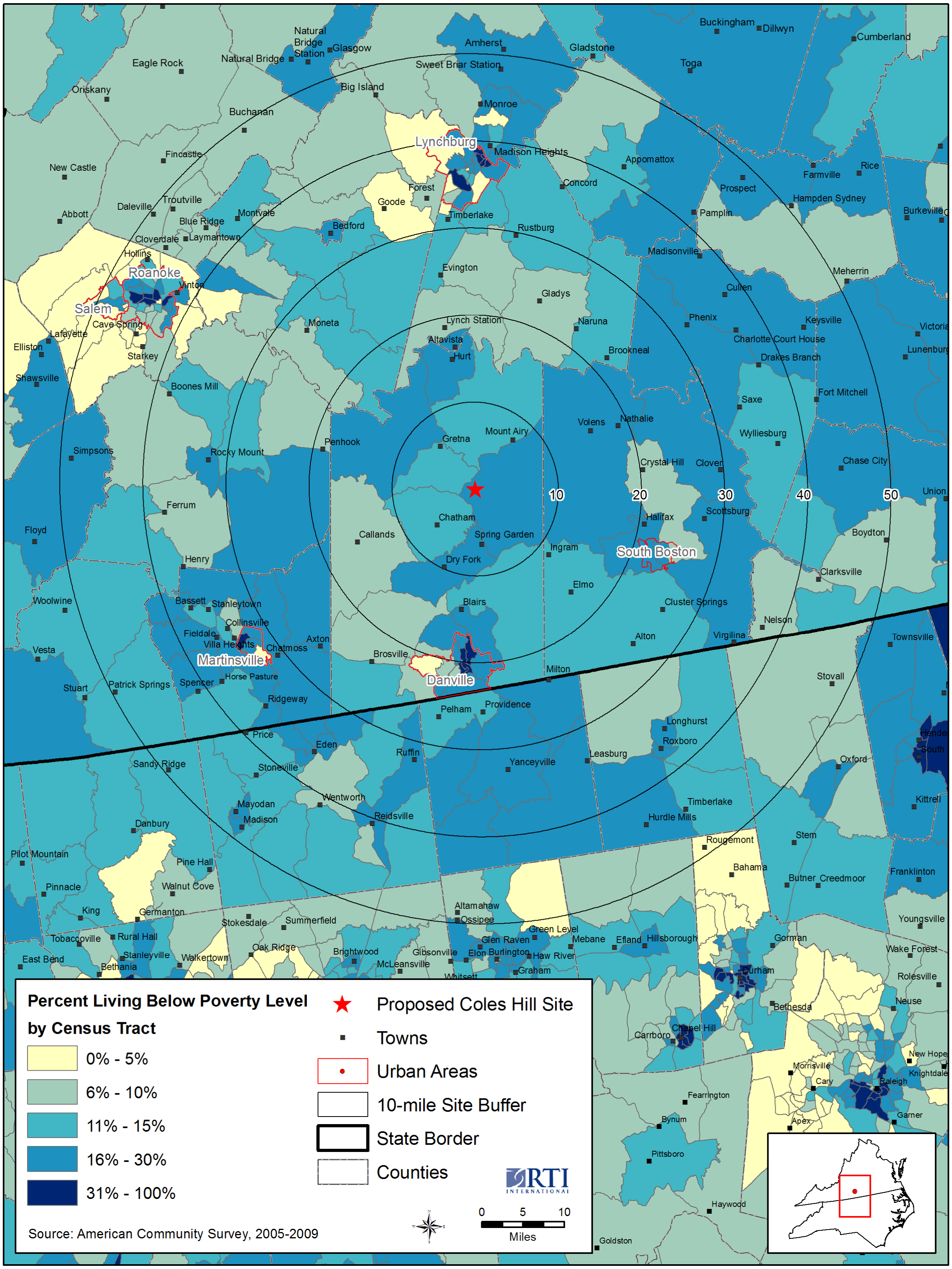
[c] Includes Franklin, Patrick, Henry, Pittsylvania, Halifax, Charlotte, and Mecklenburg Counties in Virginia and cities of Danville and Martinsville.

Figure 2-3. Minority Share of the Population by Census Block Group, 2005–2009



Source: American Community Survey, 2005-2009

Figure 2-4. Share of the Population Living in Poverty, 2005–2009



Source: American Community Survey, 2005-2009

Specialized education or training beyond a high school diploma is generally helpful in preparing workers for higher-skill and higher-paying professions. Overall, educational attainment in the core study region is somewhat lower than for the state or the nation. Averaging across all the jurisdictions in the core study area, we see that approximately 20% of the population over the age of 25 do not have a high school diploma, compared with approximately 14% for the state of Virginia and 15% for the United States. More than 33% of the population in the core region have a high school diploma as their highest degree, compared with 26% for Virginia and 29% for the United States. Conversely, only 12% of the population in the study region have a bachelor's degree, and only 6% have a graduate or professional degree. (See Table B-6 in Appendix B for jurisdiction-specific data.) Figure 2-5 illustrates the relatively low level of educational attainment in the study region; the figure shows the share of the population in the 50-mile radius study region with an associate's degree or higher and illustrates that in most of the region (excluding the areas around Lynchburg and Roanoke and a few other towns), relatively few residents have any post-secondary degrees. The shares of Virginia and U.S. populations with bachelor's or advanced degrees are considerably higher. This lower educational attainment may hamper the region's ability to convert from an economy based on manufacturing and agriculture to one based in other sectors, such as technology and information.

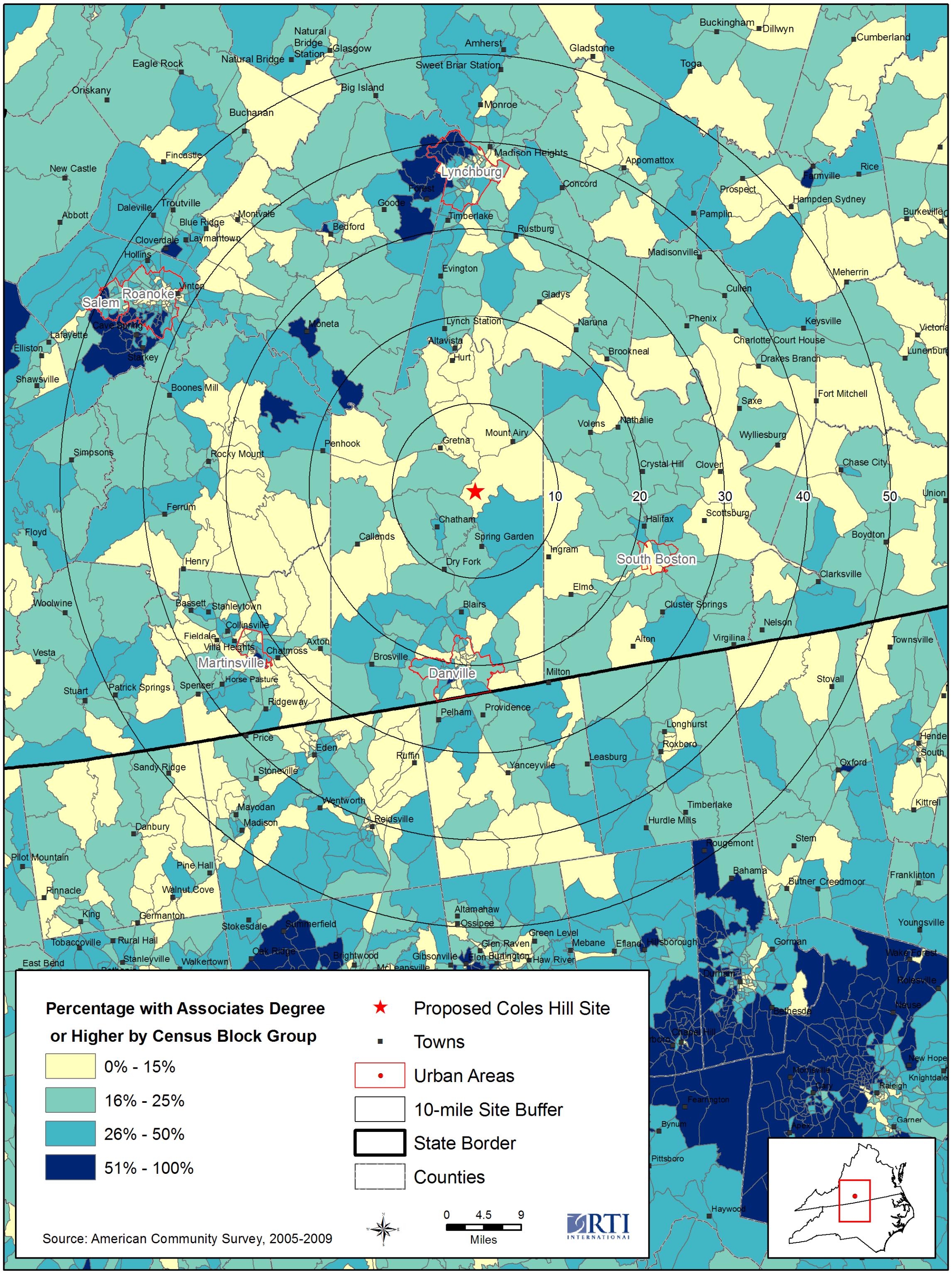
2.4 Economic Characteristics

This section examines the economy of the study region, including employment, wages, key industry sectors, and leading employers. In addition, projected future levels of economic activity are presented, because the project would continue to affect the region for at least 30 years. The data presented in this section come largely from two federal sources: the economic census and the Bureau of Labor Statistics (BLS), showing economic conditions for the present or recent past. In both of these sources, data may be suppressed for sectors with relatively few establishments to ensure that company-specific data are not revealed. Examination of the tables shows which sectors in which counties have data that are suppressed. Because of this, the study region totals (which are derived by summing county- and city-specific data) are underestimates for some sectors.

2.4.1 Employment and Occupational Patterns

Data from BLS for 2001, 2005, and 2009 (BLS, 2011), shown in Table B-7 in Appendix B, indicate that the study area has experienced greater economic challenges over the period than has the nation as a whole. For example, employment nationwide increased from 2001 to 2005, then declined by 2009 to 0.8% less than 2001 levels. In the study region, employment fell throughout the period 2001 to 2009, and employment in 2009 was 8.8% lower than it was in 2001. Public-sector employment grew by slightly over 2% in both the nation and the study region, while private employment fell. Nationwide, private employment fell by 2.2% between 2001 and 2009, while private employment in the study region fell by 11.2% over the same period. Sectors that were particularly hard hit in the study region include construction and manufacturing, both of which declined throughout the period. Construction employment declined by approximately 30% in the study region between 2001 and 2009, while manufacturing employment fell by 43% over that period. In the nation as a whole, employment in these sectors also declined between 2001 and 2009, although the rates of decline were smaller. It should be noted that there

Figure 2-5. Share of the Population With an Associate's Degree or Higher Educational Attainment, 2005–2009



Source: American Community Survey, 2005-2009

are counties within the study region whose manufacturing employment declined even more significantly, including Caswell and Person Counties in North Carolina and Charlotte, Henry, and Pittsylvania Counties in Virginia.

Conversely, the study region fared considerably better than the nation as a whole over the period 2001 to 2009 in some other sectors. For example, employment in wholesale trade fell in the nation as a whole but increased by more than 30% in the study region. Health care employment grew by 22% nationwide but grew by more than 34% in the study region.

Table 2-4 shows projected employment for the period 2015 through 2035 for the state of Virginia, by sector (I H S Global Insight, 2010). This commercially available forecast by the economic analysis firm I H S Global Insight predicts that, overall, employment in Virginia is projected to increase by more than 28%, with some sectors—such as information, scientific, and technical services; administrative support services; educational services; and health care services—increasing by more than 40%. Meanwhile, employment in manufacturing is projected to decline by more than 15% over the period. During the same period, I H S Global Insight projects that manufacturing output will increase by 28%, indicating that the historic trend of increasing labor productivity in manufacturing (and declining employment per dollar of output) is expected to continue.

Unemployment in the region averaged 7.2% during the period 2005 to 2009, as shown in Table 2-5 (U.S. Census Bureau, ACS, 2011). This rate corresponded very closely to the unemployment rate for the United States but was almost two percentage points worse than that for the state of Virginia as a whole. Details for counties and cities are shown in Table B-9 in Appendix B. Within the core study region, the North Carolina counties had unemployment of 9.3%, the northern section of the Virginia region had unemployment of 5.5%, and the southern section of the Virginia region averaged unemployment of 8.8%. Three jurisdictions— Caswell County, Danville, and Martinsville—had unemployment rates exceeding 12%. Thus, parts of the region are in especially dire need of increased employment opportunities.

Figure 2-6 shows unemployment by census tract based on Census Bureau ACS data for the years 2005 through 2009. During that period, unemployment ranged from 0% to 14.7% in the study region, with a median value of slightly less than 4%. The census tract within which the proposed mine and mill will be located experienced 6.6% unemployment during that period. It should be noted that unemployment rates increased after 2009. For example, in Pittsylvania County, the unemployment rate climbed to more than 11% in August 2010 and in August 2011 was estimated at 8.7% (BLS, 2011).

2.4.2 Industry and Business Data

Overall, the number of establishments increased both nationwide and within the study region over the period 2001 to 2009. Table B-10 in Appendix B presents the number of establishments by sector for the nation, study region, and individual counties and cities, on the basis of BLS data for 2001, 2005, and 2009. However, the rate of growth was higher in the nation as a whole (over 12%) than in the study region (over 7%). The combination of declining employment and increasing numbers of establishments may be indicative of increased labor productivity, both nationwide and within the study region. The only

Table 2-4. Projected Employment in Virginia, 2015–2035 (thousand employees)

Sector	2015	2020	2025	2030	2035	Percentage Change, 2015–2035
Total nonfarm	4,010.72	4,249.70	4,500.00	4,789.58	5,141.82	28.2%
Nonmanufacturing	3,759.27	4,002.77	4,269.74	4,569.04	4,928.10	31.1%
Natural resources & mining	9.98	10.22	10.47	10.87	11.03	10.4%
Construction	220.11	227.97	247.88	243.59	251.31	14.2%
Manufacturing	251.44	246.92	230.27	220.55	213.73	−15.0%
Wholesale trade	119.84	122.85	127.73	133.86	137.03	14.3%
Retail trade	427.23	434.46	454.19	477.07	504.24	18.0%
Transportation and warehousing	103.35	107.55	113.39	117.63	119.97	16.1%
Utilities	11.96	12.05	11.83	11.47	11.58	−3.2%
Information	84.65	91.02	99.01	113.81	129.94	53.5%
Financial activities	191.40	193.81	203.08	218.72	239.52	25.1%
Professional & business services	806.05	945.07	1,062.28	1,202.93	1,384.26	71.7%
Professional, scientific, and technical services	460.57	540.49	626.13	733.22	862.98	87.4%
Management of companies and enterprises	79.53	87.44	95.65	105.11	115.76	45.6%
Administrative and support and waste management and remediation services	265.95	317.14	340.51	364.60	405.52	52.5%
Educational services	93.80	101.63	111.48	121.24	134.43	43.3%
Health care and social assistance	405.04	446.04	483.93	528.33	576.69	42.4%
Leisure & hospitality	362.28	375.01	386.88	404.63	429.50	18.6%
Arts, entertainment, and recreation	47.37	48.31	51.11	53.91	56.27	18.8%
Accommodation and food services	314.91	326.70	335.77	350.72	373.24	18.5%
Other services	224.63	216.50	224.20	229.37	232.29	3.4%
Government	698.93	718.59	733.36	755.51	766.30	9.6%
Federal government	164.39	165.03	158.65	161.62	156.34	−4.9%
State & local government	534.54	553.56	574.71	593.89	609.96	14.1%
Agriculture, forestry, & fishing	15.55	16.23	16.14	16.25	15.30	−1.6%
Military	163.25	163.78	164.35	164.92	165.49	1.4%

Source: I H S Global Insight—U.S. Regional Service March 2010 Long-Term Forecast.

Table 2-5. Unemployment

	Total Population	Labor Force	Unemployed	Percentage of Labor Force Unemployed
United States	235,871,704	152,802,402	10,969,884	7.2%
Virginia	6,097,997	4,096,902	216,714	5.3%
Study region	751,115	457,824	32,953	7.2%

Source: U.S. Census Bureau. 2005–2009 American Community Survey 5-Year Estimates.

sector experiencing more than 10% reduction in the number of establishments was manufacturing, both nationwide and within the study region. The study region had historically relied on manufacturing to provide relatively high-paying jobs for residents with only (at most) a high school diploma. The decline in manufacturing establishments reflects a trend cited by many residents as a key source of the region's economic challenges.

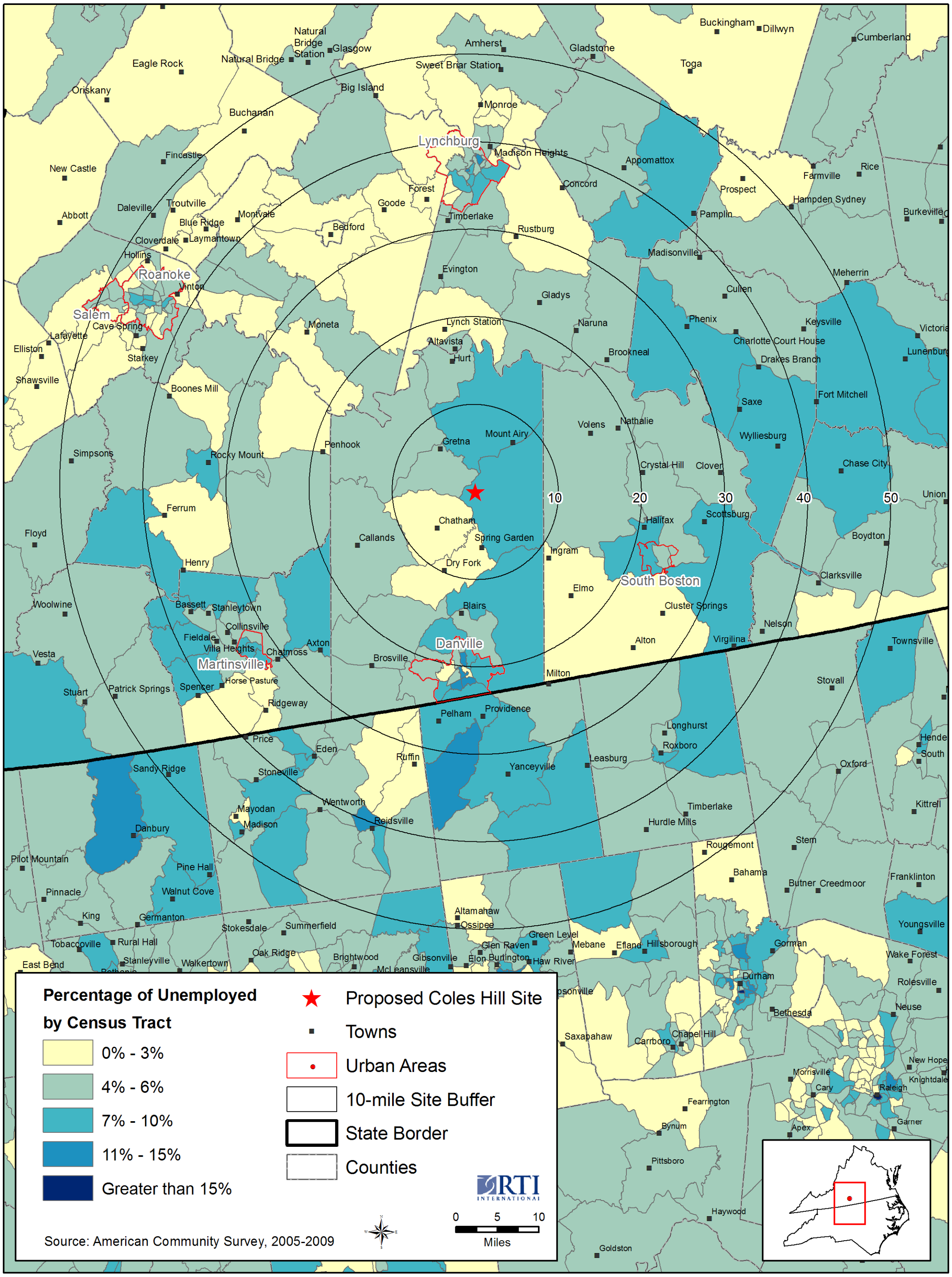
2.4.2.1 Largest Employers

Table 2-6 shows the 24 employers in the core study region with 1,000 or more employees in 2010 (VA Workforce Connection, 2010; NC Employment Security Commission, 2010). Many counties have either no employers with more than 1,000 employees or only one: the county school system. Only 12 jurisdictions in the region have any employers with more than 1,000 employees. Of the 24 employers listed, 9 are school systems, 4 are hospitals, 3 are insurance companies, 2 are municipal governments, 2 are tire manufacturers, and 2 (Babcock & Wilcox and Framatome) are nuclear fuel manufacturers. The remaining 3 employers with more than 1,000 employees are the J. Crew Outfitters warehouse and the GE Controls & Power Electronics plant. The cities of Lynchburg, Danville, Roanoke, and Salem are home to 15 of the 24 largest employers.

2.4.2.2 Important Economic Sectors in the Region

To identify sectors that are especially important to the study region, we examined location quotients (LQs) for the region. The LQ for a sector compares the share of the region's employment accounted for by a sector to the share of the nation's employment accounted for by that sector. Sectors with LQs near 1 are neither more nor less concentrated in the region. Sectors with LQs above 1 are more important to the region than they are to the nation; sectors with LQs below 1 are less important to the region than to the nation as a whole. Table 2-7 shows LQs by industry for the study area (BLS, 2011). Agriculture, forestry, fishing, hunting, mining, utilities, and educational services represent a smaller share of the region's employment than they do of the nation's employment; conversely, manufacturing, retail trade, and management of companies represent a larger share of the region's employment than of the nation's employment.

Figure 2-6. Unemployment by Census Tract, Based on Census Bureau's American Community Survey Data for the Years 2005–2009



Source: American Community Survey, 2005-2009

Table 2-6. Employers in the Core Study Region With 1,000 or More Employees in 2010

Area	Employer	NAICS Code	Industry Sector
Bedford County	Bedford County School Board	611	Educational services
Campbell County	Campbell County Schools	611	Educational services
Campbell County	Babcock & Wilcox Nuclear	332	Fabricated metal product manufacturing
Danville	Danville City Public Schools	611	Educational services
Danville	City of Danville	921	Executive, legislative, and other general government support
Danville	Danville Regional Medical	622	Hospitals
Danville	Goodyear Tire & Rubber Company	326	Tire manufacturing
Franklin County, VA	Franklin County School Board	611	Educational services
Halifax County, VA	Halifax County School Board	611	Educational services
Henry County	Henry County School Board	611	Educational services
Lynchburg	Lynchburg City Schools	611	Educational services
Lynchburg	City of Lynchburg	921	Executive, legislative, and other general government support
Lynchburg	Centra Health	622	Hospitals
Lynchburg	GNA Corporation	524	Insurance carriers and related activities
Lynchburg	J. Crew Outfitters	454	Nonstore retailers
Lynchburg	Framatome	541	Professional, scientific, and technical services
Pittsylvania County	Pittsylvania County School Board	611	Educational services
Roanoke	Carilion Roanoke Memorial Hospital	622	Hospitals
Roanoke	Anthem Blue Cross Blue Shield	524	Insurance carriers and related activities
Roanoke County	Allstate Insurance Customer Service	524	Insurance carriers and related activities
Rockingham County, NC	Rockingham County Schools	611	Educational services
Salem	VA Medical Center–Salem	622	Hospitals
Salem	GE Controls & Power Electronics	334	Industrial controls manufacturing
Salem	Yokohama Tire Corp.	326	Tire manufacturing

NAICS, North American Industry Classification System (U.S. Census Bureau).

Table 2-7. Location Quotient Identifying Important Sectors in the Region's Economy

NAICS Code	Sector Description	Location Quotient			2001–2005	2005–2009	2001–2009
		2001	2005	2009			
10	Total	1.00	1.00	1.00	0.00	0.00	0.00
10	Public-sector total	0.96	1.01	1.04	0.05	0.03	0.08
10	Private-sector total	1.01	1.00	0.99	−0.01	−0.01	−0.01
11	Agriculture, forestry, fishing, and hunting	0.27	0.20	0.17	−0.07	−0.03	−0.10
21	Mining, quarrying, and oil and gas extraction	0.10	0.05	0.00	−0.05	−0.05	−0.10
22	Utilities	0.32	0.44	0.39	0.13	−0.06	0.07
23	Construction	0.82	0.72	0.74	−0.10	0.02	−0.08
31–33	Manufacturing	1.78	1.68	1.55	−0.10	−0.13	−0.23
42	Wholesale trade	0.45	0.62	0.64	0.17	0.02	0.20
44–45	Retail trade	1.12	1.12	1.12	0.00	0.00	0.00
48–49	Transportation and warehousing	0.81	0.84	0.76	0.03	−0.08	−0.05
51	Information	0.49	0.51	0.54	0.02	0.03	0.06
52	Finance and insurance	0.70	0.71	0.68	0.00	−0.03	−0.03
53	Real estate and rental and leasing	0.66	0.69	0.74	0.03	0.05	0.07
54	Professional, scientific, and technical services	0.56	0.52	0.60	−0.04	0.08	0.04
55	Management of companies and enterprises	1.24	1.18	1.19	−0.06	0.01	−0.05
56	Administrative and support and waste management and remediation services	0.71	0.78	0.93	0.07	0.15	0.22
61	Educational services	0.51	0.49	0.52	−0.01	0.03	0.02
62	Health care and social assistance	0.74	0.82	0.87	0.08	0.06	0.13
71	Arts, entertainment, and recreation	0.64	0.66	0.62	0.02	−0.05	−0.02
72	Accommodation and food services	0.87	0.89	0.94	0.02	0.05	0.07
81	Other services (except public administration)	0.82	0.84	0.83	0.02	−0.01	0.01
99	Unclassified	0.00	0.09	0.11	0.09	0.02	0.11

NAICS, North American Industry Classification System (U.S. Census Bureau).

The combination of information provided by the LQ analysis and data shown in Tables B-7 and Table B-10 on employment and number of establishments provide further evidence of the challenge that the decline in traditional manufacturing industries poses for the study region. The LQ analysis indicates that manufacturing is more important to the region's economy than to the national economy, while Tables B-7 and B-10 show that both employment in manufacturing and number of manufacturing establishments have fallen in the study region, with employment falling 43% between 2001 and 2009. Because manufacturing is a key sector in the region's economy, the region is particularly sensitive to this reduction in employment and establishments.

2.4.2.3 The Role of Small Businesses and Entrepreneurial Start-Ups

Although large businesses often claim more attention, small businesses and entrepreneurial start-ups are important components of a region's economy. As recruitment of new industry becomes increasingly competitive, small business start-ups and growth are often important sources of job creation and economic growth. Data from the Edward Lowe Foundation help characterize the traits of small businesses and their growth in the study region. These data show the number of establishments and job creation by size of business, as defined by number of employees.

Over a 5-year period, 2002–2007, the study region experienced a net opening of over 10,679 establishments, as shown in Table B-13 in Appendix B. The data presented show net opened (number opened minus number closed), net expanded (number expanded minus number contracted), and net moved in (number moving in minus number moving out). Roughly equal numbers of net openings occurred in the smallest two size categories; all other categories experienced net closings. The smallest category of businesses, self-employed businesses, experienced net expansions, with every other size of business experiencing contraction over this 5-year period. On the whole, more small businesses moved in to the study region than moved out (a net of 650 businesses). Relocation to Roanoke explains most of this activity—469 net new small businesses moved there.

For the study region as a whole, almost all net new openings of business establishments were done by the smallest businesses. Figure 2-7 indicates that self-employed businesses were responsible for 49% of the openings, and those businesses with 2–9 employees comprised 48% of net openings. The larger businesses, with 10 to over 500 employees, all contracted during this period.

Small business can also be an important source for jobs. As indicated in Table 2-8, the study region lost 2,795 jobs during this 5-year period, less than a 0.01% change. Net job creation has remained fairly stagnant; some of the study region's losses have canceled out other parts of the region's growth. Most of the losses were experienced by nonresidents, while resident businesses with 2–9 employees created the bulk of the jobs (11,222). Businesses with 500 or more employees lost the most jobs (10,291) over this time period. Table B-14 shows county- and city-level detail on jobs created by business size category.

Figure 2-7. Net New Businesses by Number of Employees

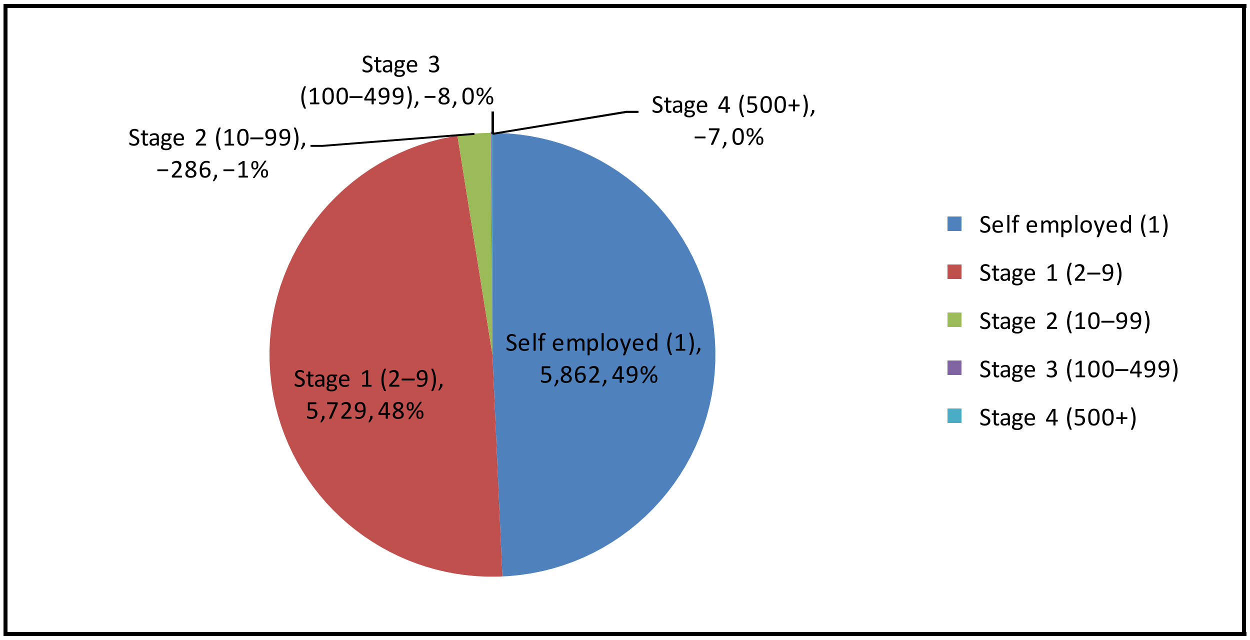


Table 2-8. Study Area Jobs Created by Size of Businesses

Study Area Jobs	2002	2007	Change	%
Total	468,441	465,646	−2,795	−0.006
Noncommercial	94,404	97,085	2,681	0.027615
Nonresident	117,797	103,591	−14,206	−0.13714
Resident	256,240	264,970	8,730	0.032947
Self-employed (1 employee)	10,520	16,199	5,679	0.350577
2–9 employees	73,002	84,224	11,222	0.13324
10–99 employees	93,892	96,154	2,262	0.023525
100–499 employees	40,812	40,670	−142	−0.00349
500 or more employees	38,014	27,723	−10,291	−0.37121

2.4.3 Employer Revenues

Table B-15 in Appendix B shows sales revenues by sector for the United States, Virginia, the core study region, and counties in the core study region from the economic census in 2002 and 2007 (U.S. Census Bureau, economic census, 2002 and 2007). Note that because data for individual counties may be suppressed or not available for some sectors, the study region totals (which are sums of county data) underestimate the actual values for the study region. When all available data are summed across the counties in the core study region, only one sector shows a decline from 2002 to 2007: professional, scientific, and technical services. Revenues for all other sectors increased over the period 2002–2007. Manufacturing revenues grew only slightly (2.6%) in the core study region, increased by more than 10% in Virginia, and increased by more than 30% in the United States. For individual cities and counties, the change in manufacturing revenues from 2002 to 2007 varied from a loss of more than 50% to an increase of more than 66%.

2.4.4 Income and Wages

Table 2-9 presents per capita income (PCI) data for 2009 for the core region (U.S. Census Bureau, ACS, 2005–2009). Across the 21 jurisdictions, the average value for PCI was approximately $21,400, ranging from $17,400 in Caswell County, North Carolina, to $30,300 in Roanoke County, Virginia (see Table B-16 in Appendix B for county-level detail). The region's PCI is lower than PCI for the state of Virginia as a whole (approximately $31,600) and PCI for the United States (approximately $27,000). Within the core study region, the northern section of the Virginia region has the highest average PCI, approximately $23,800; the North Carolina section and the southern Virginia section both have average PCI between $19,500 and $20,000. No jurisdiction in the study region has a PCI as high as the state as a whole, although Roanoke County comes close.

Table 2-9. Per Capita Income in the Past 12 Months

Location	Per Capita Income
United States	27,041
Virginia	31,606
Average, core study region	21,421

Source: U.S. Census Bureau, 2005–2009 American Community Survey.

Average weekly wages in the study region were generally lower and grew more slowly than for the nation as a whole over the period 2001–2009. Table 2-10 presents average weekly wages by sector in each jurisdiction, in current-year dollars (not adjusted for inflation). County-level detail is provided in Table B-17 in Appendix B. For all sectors and for the region as a whole, wages rose throughout the period from 2001 to 2009. Nationwide, wages increased during the period by 25.7%; for the core study region overall, average weekly wages increased by 21.6%. This pattern is repeated in 12 of the individual sectors; wages in these sectors grew an average of more than 6 percentage points faster nationally than they did in the region; the difference ranges from less than 1 percentage point for wholesale trade to more than 20 percentage points for educational services. Conversely, for 7 sectors, average weekly wages grew more rapidly in the study region than in the nation as a whole. These differences range from less than 1 percentage point to more than 9 percentage points for the agriculture, forestry, and fisheries sector. This sector is also the only sector for which average weekly wages in the core study region exceeded the national average weekly wage.

Table 2-10. Trends in Agriculture, 1997–2007

				Percentage Change		
	1997	2002	2007	1997–2002	2002–2007	1997–2002
Number of farms, core counties	11,296	10,177	10,399	−9.9%	2.2%	−7.9%
Acreage in farm operations, core counties	2,110,760	2,030,106	1,912,265	−3.8%	−5.8%	−9.4%
Commodity sales ($1,000), core counties	369,236	303,560	365,247	−17.8%	20.3%	−1.1%

Source: U.S. Department of Agriculture, National Agricultural Statistics Service. Agricultural census 1997, 2002, 2007.

2.4.5 Agriculture

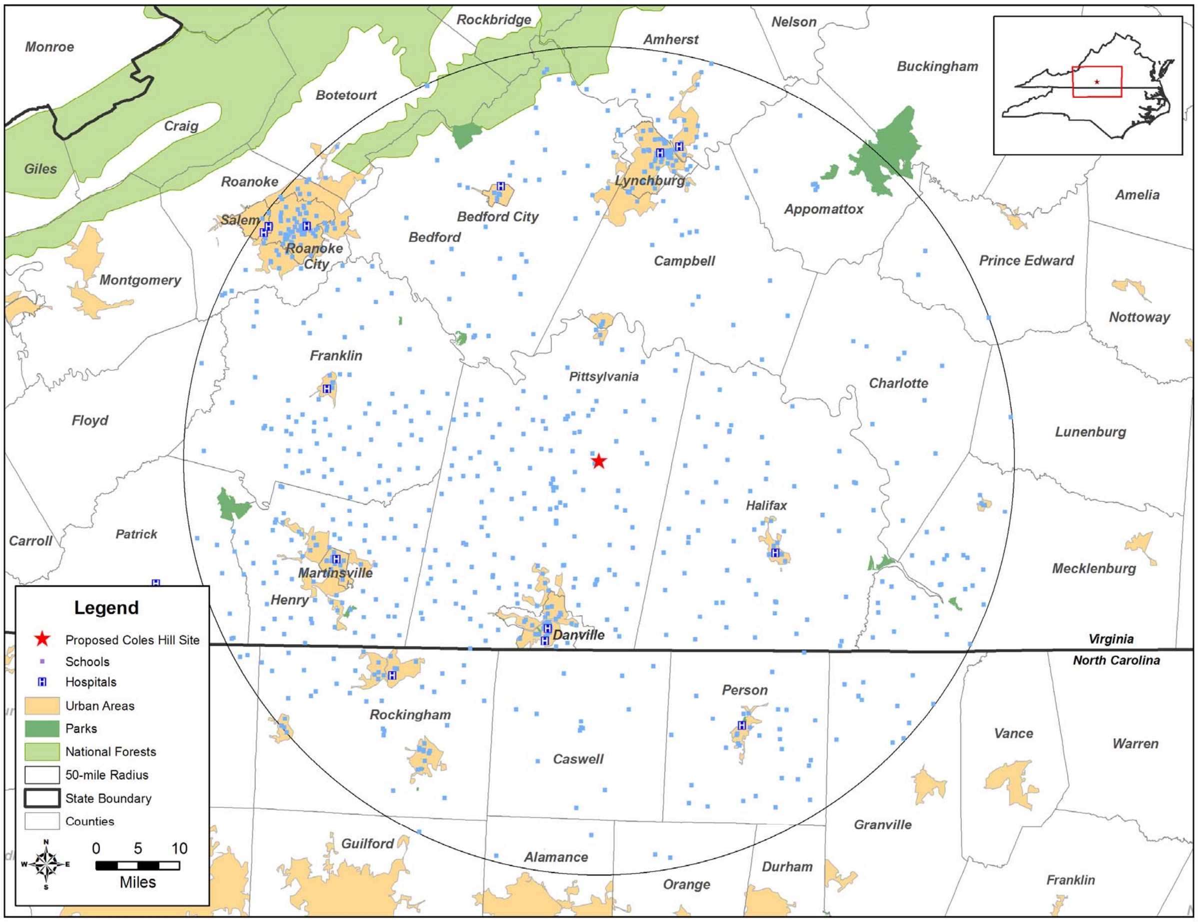
The core study region has a long history of agricultural production and continues to produce substantial quantities of agricultural commodities today. Although revenue earned from agriculture (approximately $365 million in 2007) is far less than that earned from manufacturing ($16 billion in 2007) or retail trade ($11 billion in 2007), agriculture remains important to the region, both culturally and economically. Table 2-10 shows trends in agriculture for the core study region over the period 1997 to 2007, including number of acres in farm operation, the number of farms, and commodity sales (U.S. Department of Agriculture [USDA], 1997, 2002, 2007). (County-level detail is shown in Table B-18.) Over the period 1997–2002, the number of farms fell in all the core study region counties, for an overall decline of 1,100 farms, almost 10%. The number of acres in farm operations also fell in most counties, with Person and Caswell Counties in North Carolina experiencing the largest percentage reductions. Commodity sales fell in all but three counties, for a total decline of more than $65 million. From 2002 to 2007, however, the number of farms increased by 222, and commodity sales increased by almost $62 million. Acreage in farm operations, however, continued to decline.

The 2007 Census of Agriculture also provides county profiles that identify key commodities in each county (USDA, 2007). Tobacco is the leading agricultural commodity, in dollar terms, in most counties in the core study region. Several counties in the region (Virginia) are also leading tobacco producers statewide, including Pittsylvania (#1), Mecklenburg (#2), and Halifax (#3). Other important commodities include cattle and calves, hogs and pigs, and dairy products. Pittsylvania County is the fourth largest producer of dairy products in Virginia (2007 Census of Agriculture), and it also has more than 47,000 acres of land devoted to production of forage for consumption by dairy and beef cattle, horses, and other farm animals. Clearly, agriculture is important to the region, and the region’s agriculture is important to the state.

2.5 Other Community Characteristics

Figure 2-8 illustrates the study region, showing hospitals and schools, parks, national forests, and urbanized areas. Among other items of interest, the figure shows that schools are located within less than 5 miles of the site of the proposed mine and mill. In addition, the figure indicates that the nearest hospitals are located in Danville. The nearest park is Smith Mountain Lake State Park.

Figure 2-8. Schools, Hospitals, Parks, and Urban Areas in the Study Region



2.5.1 Housing

Virginia Uranium plans to hire as many local residents as possible and estimates that up to 90% of their labor force will be local. This means that perhaps 10%, or approximately 33 employees, will move into the area from outside the region. As shown in Table B-19 in Appendix B, Pittsylvania County alone has more than 4,000 vacant residences. Thus, we do not expect workers moving to the area to work in the proposed mine and mill to have a noticeable impact on housing availability in the region. In the area within 10 miles of the proposed mine and mill site, 917 of 6,912 housing units (13.2%) were vacant during the period 2005–2009. Again, available housing is ample to provide housing for any incoming employees without significantly affecting the housing markets. Construction employment is projected to be between 250 and 350 for a short period of time. Depending on how many of the construction workers are local, there may be some noticeable increase in demand for rental housing in Pittsylvania County during the short construction period.

Table B-20 shows housing types available in the core study region (U.S. Census Bureau, ACS, 2005–2009). Throughout the region, approximately 70% of the housing stock is single-unit dwellings.

Within the cities, more than 20% of the housing is duplex or multifamily, and, in many counties, more than 20% of the housing stock is mobile homes.

2.5.2 Health Care and Public Safety

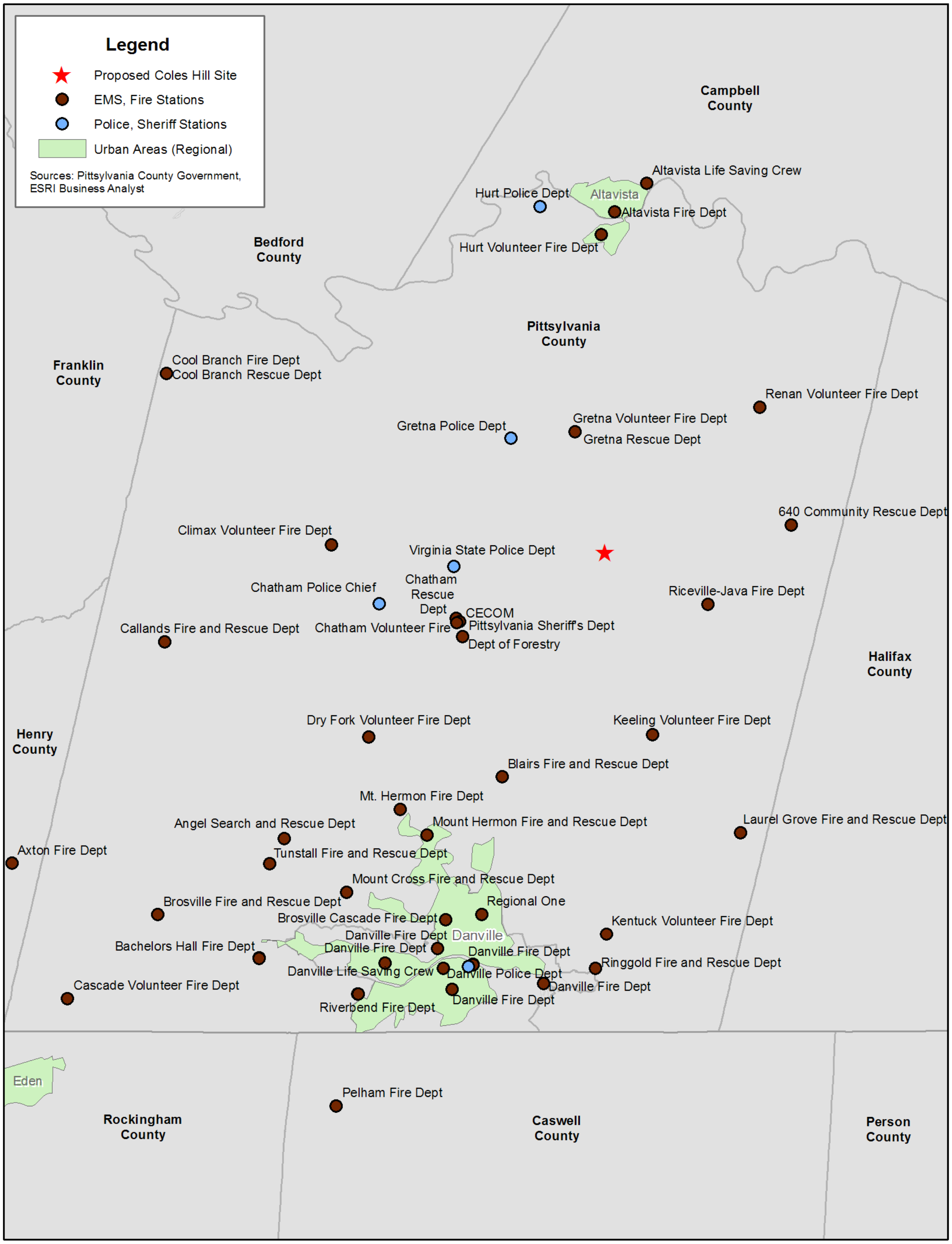
As noted above, the nearest hospital in the region is the Danville Regional Medical Center in Danville. Other nearby hospitals include Halifax Regional Medical Center in South Boston and Virginia Baptist Hospital and Lynchburg General Hospital in Lynchburg. In the event of an accident at the proposed mine and mill, patients would most likely be transported to Danville Regional Medical Center.

Figure 2-9 shows fire departments, rescue squads, police and sheriff stations, and other public safety locations within Pittsylvania County. Particularly those within 5 miles of the proposed mine and mill may be called on to respond to any incidents that occur at the proposed mine and mill.

2.6 Summary

The study region, comprising an approximately 7,850-square-mile area surrounding the Coles Hill location of the proposed uranium mine and mill, includes part or all of 28 counties and cities. Focusing on 15 counties and six cities, this section examined existing and projected conditions in the absence of the mine and mill. The region is rural, and pasture and hay and deciduous forest dominate land use. Agriculture has historically been important, and counties in the region are important producers of tobacco, beef cattle, dairy products, hogs and pigs, and hay and forage. Manufacturing is more central to the region’s economy than it is for the national economy, and the decline of traditional manufacturing industries such as textiles and furniture has hurt the local economy. Average weekly wages in the region are lower and have grown more slowly than national wages. Relatively low levels of educational attainment, acceptable for agriculture and traditional manufacturing, may hamper residents’ ability to obtain higher-skill, higher-paying jobs. The region has 24 employers with over 1,000 employees, but small businesses create the majority of jobs in the region. Although the region faces economic challenges, residents interviewed see many positive aspects to life here. They would like to see more economic opportunity and greater recreational and other amenities without sacrificing the region’s current small-town lifestyle.

Figure 2-9. Fire Departments, Rescue Squads, Police and Sheriff Stations, and Other Public Safety Locations Near Proposed Project Site



Sources: Pittsylvania County Government, ESRI Business Analyst

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3

Potential Environmental Releases

The potential of the proposed Coles Hill mine to emit pollutants is directly related to the chemical makeup of the host ore and surrounding earth, mining method, milling method, management options, and regulatory limitations, among others. Based on the geology of the site, conventional aboveground or underground mining and alkaline extraction will most likely be used. It is anticipated that the mine would produce 1 million tons of ore per year and have an operating life of 35 years. Pollutants from the site during operation and after closure will be regulated by a host of federal and state regulatory entities. This section identifies potential significant waste streams and estimates a range of emissions based on available data and mitigation options during normal operating conditions. Wastewater discharge rates and characteristics were estimated from previous studies and anticipated regulatory limits. Additionally, air emissions were estimated with proven U.S. Environmental Protection Agency (EPA) methods and were based on preliminary data and available control options. Based on an estimated water balance and regulatory concentration limits, wastewater discharges would emit at most 9 kg/day total uranium and 189 pCi/s total radium as well as other conventional pollutants. Estimated dust emission (PM_{30})s from the mine and mill conducting open-pit mining range between 379.8 – 2,138 kg/yr, while an underground operation would range between 302.1 – 1,544 kg/yr. Estimated radon emission rates based on the open-pit mining scenario for the overburden storage area ranged between 5.46×10^6 – 1.64×10^8 pCi/s and 1.59×10^6 – 1.59×10^7 pCi/s from the tailings management area.

3.1 Coles Hill Ore Reserve

The uranium deposit at Coles Hill (also referred to as the Swanson uranium deposit) has been studied extensively for more than 30 years. The deposit is made up of two large ore bodies located along the northwest margin of the Danville Triassic Basin in Pittsylvania County, Virginia, and is a hydrothermal hard-rock uranium deposit. The deposit was discovered in 1978 by the Marline Uranium Corporation, who subsequently did significant work on characterizing this ore body. More recent estimates put the total uranium ore deposit at about 60,000 tons for a cut-off grade of 0.025%, of which about 32,000 tons are minable at a cutoff grade of 0.06% (Lyntek/BRS, 2010a, 2010b). The difference between the total uranium deposit present and that which is considered "minable" is dictated by economics, because the cost to recover uranium increases as its concentration in the ore decreases. The uranium concentration at Coles Hill is lower than some other deposits, ores of which contain up to 21% U_3O_8 (Cigar Lake, Canada), but higher grade than some other uranium mines, such as a 0.03% cutoff grade in Copper Mountain, Wyoming. A preliminary scoping study prepared for VUI in 2010 estimates that the mine will be productive for 35 years, assuming approximately 1 million tons of ore production per year.

Coles Hill Uranium Deposit Facts

*Discovered—**1978***

*Estimated total uranium—**60,000 tons** as U_3O_8*

*Estimated minable uranium—**32,000 tons** as U_3O_8*

*Proposed duration of mining activity—**35 years***

3.1.1 Uranium-Related Site Features

RTI met with VUI on September 16, 2011, to become familiar with the environmental components of the proposed uranium mine and the surrounding land use, ecosystems, and ore body locations. The following is a brief summary of the information provided by VUI during the site visit. VUI has drilled more than 70,000 sample cores to better quantify the ore and surrounding host rock. VUI has also evaluated the baseline conditions of Mill Creek, which is located near the southern edge of the site (and southern ore body). The Chatham Fault runs parallel to the road near the core shed and Mill Creek. There are several small human-made ponds located at and near the site. There are also multiple springs on the site, including one located on Coles Road just south of the site. According to VUI, the springs appear to maintain similar flow regardless of precipitation. It may be possible that the water for the springs emanates from relic fractures in the underlying bedrock. VUI also noted that leatherwood granite in the area typically corresponds with rolling hills.

The discovery outcrop is southwest of the Coles Hill house and is the location of highest surface ore concentrations. West of the house, surface water drains to Mill Creek. East of the house, surface water drains toward Whitethorn Creek (see Figures 3-1, 5-1, 5-2, and 5-3) for details of all the features of the site and the immediate surrounding area. The ore body is divided into a southern and northern area based on concentration data. A part of the northern ore body is located beneath the house, approximately 400 feet below ground surface (ft-bgs). Based on the location at the site, the ore is expected to be present to a maximum depth of approximately 1,500 ft-bgs. Uranium concentrations at the surface can reach approximately 0.1% in the immediate surrounding area. The two deposits are approximately 1,150 ft long and 800 ft wide. Figure 3-2 displays a 3-D cross-sectional view of both the north and south ore bodies, generated using geological modeling software (Lyntek/BRS, 2010b).

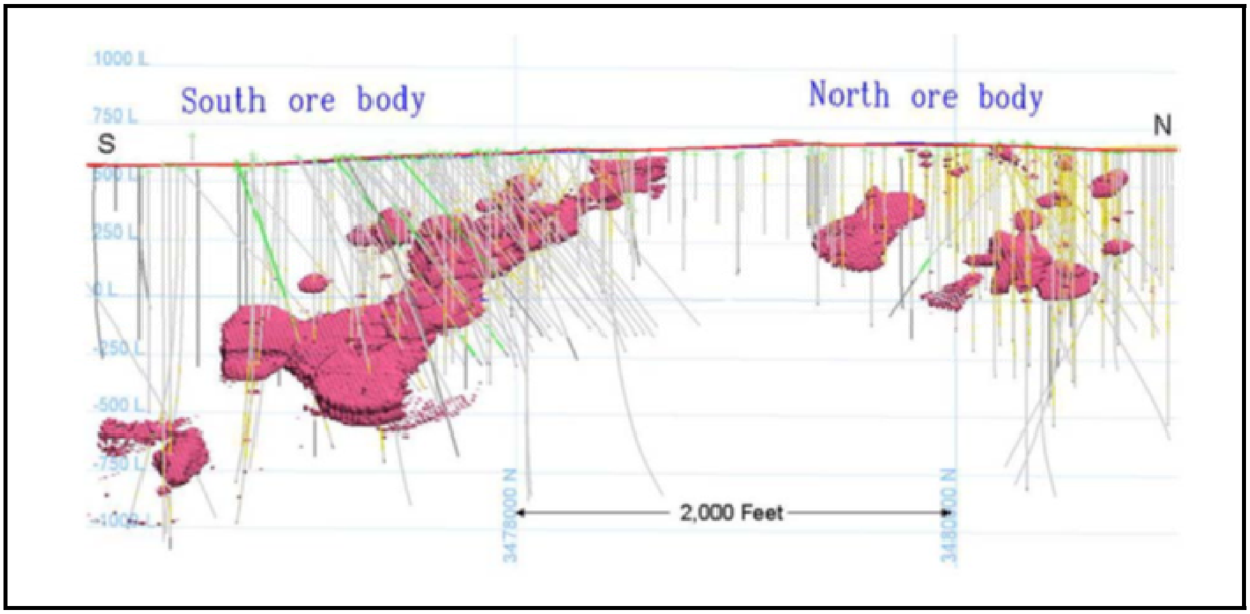
3.1.2 Chemical Makeup of Ore and Host Rock

As part of his doctoral dissertation, Jerden (2001) interpreted results from U.S. Geological Survey (USGS) analyses of 47 core samples. Five distinct rock types were identified to have played the major roles in the development of the uranium ore bodies: augen gneisses, interlayered amphilbolites, cataclasite zone, Triassic sediments, and diabase intrusions. Major elements that constitute the bulk ore formation are the associated oxides of silicon, aluminum, iron, calcium, sodium, magnesium, and titanium, as well as sulfates and phosphates (Jerden, 2001).

The primary uranium-containing ore minerals contained within the host rock to be mined are coffinite ($USiO_4$) and uraninite (UO_2, UO_3), with coffinite estimated to dominate by a factor of 2 to 3 times. Often, fractions of uranium present in the ore body of <1% are considered rich deposits. The ore rock may contain trace amounts of a wide variety of other elements in addition to uranium that may be concentrated and subsequently released during mining, processing, and disposal. As part of the Marline exploration and characterization of the Coles Hill site, numerous core samples have been drilled and analyzed with a variety of chemical analyses performed by the Colorado School of Mines Research

Figure 3-1. Satellite Image of Both the North and South Uranium Deposit Sites

Figure 3-2. Cross-Sectional 3-D View of the 0.1 wt% Grade Uranium Shell for Both the North and South Ore Bodies, Facing West



Lyntek, Inc. and BRS Engineering, December 2010 (2010b), *NI 43 – 101 Preliminary Economic Assessment, Coles Hill Uranium Property, Pittsylvania County, Virginia, USA.*

Institute, Barringer Magenta Corporation, and Hazen Research Inc. Although it cannot be said with certainty that these results represent the overall ore content, they provide one of the most comprehensive analyses of the uranium ore. Table 3-1 summarizes the results from these analyses.

Table 3-1. Selected Metallic Constituents of Interest Identified within the Ore Body

Element (Symbol)	% in Ore Sample	Element (Symbol)	% in Ore Sample
Uranium (U)	0.025–0.5	Copper (Cu)	0.00971–0.012
Zinc (Zn)	0.023–0.0030	Tin (Sn)	0.0003–0.003
Lead (Pb)	0–0.025	Barium (Ba)	0.0733–0.11
Strontium (Sr)	0.0427–0.073	Zirconium (Zr)	0.0065–0.046
Molybdenum (Mo)	0.0004–0.01	Manganese (Mn)	0.029–0.0525
Yttrium (Y)	0.002	Nickel (Ni)	0–0.0008
Arsenic (As)	0–0.001	Cobalt (Co)	0–0.0015
Silver (Ag)	0–0.0005	Vanadium (V)	0–0.0102
Thorium (Th)	0–0.005	Beryllium (Be)	0.000197
Chromium (Cr)	0–0.0039	Cadmium (Cd)	0–0.0001

Source: Marline, 1983. Ranges given show variability observed from different ore samples.

The elemental content in geological formations can vary widely between samples, so Table 3-1 provides the range observed, with zero values indicating that the element was not found within some of the samples analyzed. Single values without ranges indicate that only one result was available from a single laboratory, but it is unclear whether the other labs tested for the metal or found zero or nondetectable values. The table provides some insight into the metals that may be concentrated during processing and require treatment prior to disposal. It has been reported that the fractions of metals (listed in Table 3-1) in the Coles Hill ore are low relative to uranium deposits located in the southwestern United States and that none of the other metals are present at concentrations that make their extraction economically viable (Dolbear and Company, 2009; Marline, 1983).

3.2 Uranium Mining

The primary steps in producing commercial uranium products are mining, milling, and processing. Mining and milling are typically conducted at the mine site, while processing is performed at an off-site facility. Therefore, the focus of this section is mining and milling processes that would occur at the Coles Hill mine site location. Mining processes include all operations prior to milling and involve mining and handling the ore. Milling includes crushing, grinding, and leaching the ore, as well as producing the end-product precipitate known as yellowcake (U_3O_8). All of these processes will be conducted at the proposed Coles Hill site, although specifics have to be determined.

Uranium is typically mined by one or a combination of three methods: (1) surface (open-pit) mining, (2) underground mining, or (3) solution mining. Ore leaching typically uses an acid or alkaline solution to extract the uranium from the ore. Several factors are evaluated when determining which extraction methods to select for a particular ore and include among others:

- concentration of uranium in the ore
- geology
- location
- costs of extraction
- costs of processing
- waste management
- market price
- social/community acceptance

Based on preliminary evaluations, VUI has indicated that underground mining and chemical extraction of the uranium by alkaline leaching will most likely be the methods selected for the proposed site. However, a more detailed evaluation will be conducted prior to making the final determinations. Therefore, this section describes each potential extraction and beneficiation method.

3.2.1 Conventional Mining Methods

The mechanical process of removing host ore from the earth is considered conventional mining in this document and includes open-pit and underground methods. These practices produce various streams of material that may require different management practices. For example, the term “ore” implies economic viability given the current market price and the costs of production and is thus sent to the mill for processing. Protore is a term applied to mined ore deemed economically unviable and is often stockpiled for future processing when economical conditions become favorable. Additional materials generated during conventional mining that are not necessarily associated with the host ore include overburden and waste rock. Overburden is the mass of non-uranium-bearing country rock that must be removed to reach the rock containing the ore material. Rock that contains typically low non-viable concentrations of uranium or associated metals is considered waste rock and is managed separately from overburden and protore.

3.2.1.1 Open-Pit Mining

Open-pit mining involves the removal of the soil and rock overburden by large, open excavations that narrow toward the bottom of the ore reserve. This mining practice is typically employed in extracting shallow ore deposits with a typical maximum depth in the United States reported as about 550 feet below the surface (EPA, 2008). For comparison, the depth of the ore deposit at the proposed Coles Hill mine is approximately 1,500 feet below the surface (Lyntek, 2010a). Figure 3-3 shows a uranium surface mining operation where the ore is excavated and trucked to the adjacent mill. Although typical operational costs are lower than for underground mining, open-pit mining generates tremendous amounts of overburden that require removal and management. The ratio of the amount of overburden needing removal to extract one unit of ore is referred to as the stripping ratio, and uranium mines in the United States have typically ranged from 10:1 to 80:1 with an average of 30:1 (EPA, 2008). The overburden and waste rock can be stockpiled adjacent to the mine or used as backfill material in previously mined sections in the reclamation process.

Figure 3-3. Photograph of an Open-Pit Uranium Mine and Mill in Australia

Source: Australian Government, Department of Sustainability, Environment, Water, Population and Communities.

3.2.1.2 Underground Mining

Underground mining typically involves installing a shaft alongside the ore body with horizontal shafts extending into the ore for subsequent removal. A variety of excavation methods can be employed to remove the ore and include the following (EPA, 2008):

- longwall retreat—The ore-bearing rock is removed along a working face or wall and the mined-out space is sometimes allowed to collapse or filled with waste rock.
- room and pillar—Also known as open stoping, small unmined sections are allowed to stand and act as support pillars.
- panels—Mined sections are left surrounded by solid strata except for necessary entry points.

Ore and waste rock are typically removed to the surface through shafts with the use of elevators, conveyors, trains, or trucks. Although some waste rock may be used underground as backfill material in mined-out areas, the remainder needs to be managed on the surface in the same manner as practiced for surface mines. However, underground mining is a more targeted approach than open-pit mining with much lower stripping ratios than for surface mining operations, ranging from 1.5:1 to 16:1 (EPA, 1983b, Vol. 2).

Preliminary mining plans at Coles Hill include using sublevel open stoping (SLOPS) and include connecting the North and South ore bodies underground, thus only requiring one mine opening. The ore and waste rock would be trucked to the surface using low-profile front-end loaders and from the mine opening to the nearby mill with trucks. Cemented tailings material will be used as fill and the remaining pillars will be mined by the cut-and-fill method.

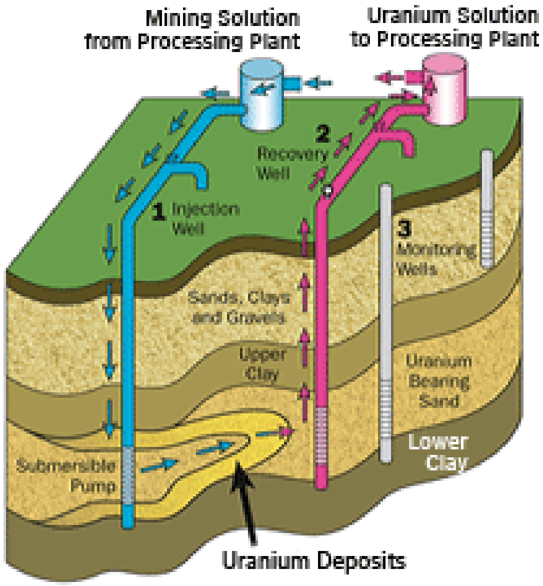
3.2.2 Unconventional Mining Methods

Unlike conventional mining methods that rely on mechanical means to extract the uranium host ore, unconventional mining methods rely on chemical reactions or other means. The most common unconventional method used in the uranium industry is in situ leaching (ISL). However, it is unlikely this mining method would be used at the Coles Hill site because of the type of ore (i.e., hard rock). ISL is typically used to recover uranium from sedimentary deposits.

3.2.2.1 ISL

ISL involves leaching the uranium host ore underground using injection and production wells. The leaching solution (i.e., lixiviant) most commonly comprises water containing added oxygen and carbon dioxide or sodium bicarbonate. The lixiviant is injected into the ore body through a series of wells, liberating the uranium and other metals into solution that is then pumped to the surface by production wells. The uranium-bearing (pregnant) leach solution is typically processed by ion exchange or solvent extraction to remove and concentrate the uranium. Presented in Figure 3-4 is a simplified schematic of the typical ISL operation. This method has been used for mining copper and uranium in the United States but on a limited scale. Copper ore dumps around formerly active underground copper mines have also been mined using similar techniques. Additionally, the hydrogeologic conditions must be suitable for solution mining to be successful and also environmentally safe. Because solution mining does not cause the level of ground disturbance that either aboveground or underground mining does, and because of the lack of waste piles and ore stockpiles, it is often initially considered as an alternative in the mine development stage. However, use of injection chemicals and the drilling wastes would need to be managed.

Figure 3-4. Typical Layout of an ISL Operation



Source: U.S. Nuclear Regulatory Commission (NRC).

3.3 Milling

Milling in the uranium mining industry includes ore crushing, grinding, screening, and sizing (e.g., liberation steps) and chemical leaching and precipitation steps to concentrate the uranium into the production of yellowcake (EPA, 1995). In this process, the ore is first crushed and ground to increase the surface area and improve the recovery potential of the leaching step. Next, depending on the characteristics of the host ore, a strong acid or alkaline solution is used to extract the uranium from the ore. The spent ore (or raffinate) is then separated from the pregnant leaching solution typically using gravimetric separation and sent as tailings for disposal. The uranium in the solution is typically concentrated with either an ion exchange or solvent extraction process followed by precipitation and drying. The resulting uranium oxide concentrate yellowcake is typically 85% uranium by mass.

Based on a preliminary investigation, the alkaline leaching circuit is the most likely process to be used at the Coles Hill site. Presented in Figure 3-5 is a block-flow-diagram of both the acidic and alkaline leaching circuits, and Figure 3-6 is a typical layout of a uranium mill.

3.4 Potential Waste Streams

EPA (2008) published a comprehensive list of all potential waste streams associated with the extraction and beneficiation of uranium (Table 3-2). Although information is provided for unconventional mining, preliminary plans indicate that conventional mining and milling practices will be used at the Coles Hill site. Presented in Figure 3-7 is a block flow diagram of the mining and milling process and identified waste stream and pollutants of concern. In general, the waste streams can be grouped into three categories: (1) solid wastes, (2) aqueous wastes (water), and (3) airborne wastes (air emissions).

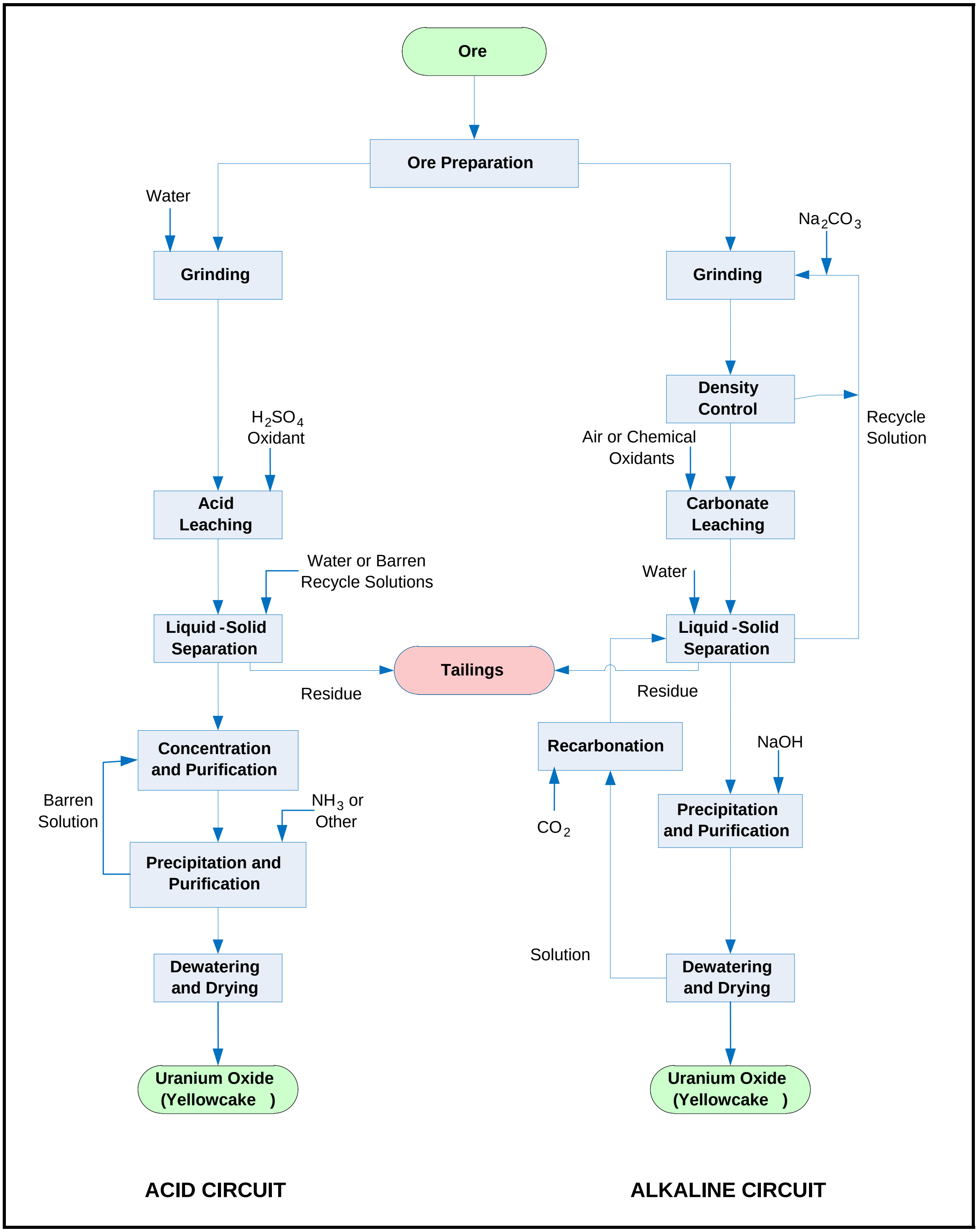
3.4.1 Solid Wastes

The primary solid wastes generated during the mining and milling of uranium are (1) overburden, (2) waste rock, and (3) tailings. In some situations, ore and protore may be stored on site for future processing, but this practice is managed differently than the waste materials.

Overburden and waste rock are the largest amounts of solid waste typically generated during the mining process. Based on the stripping ratios presented in Sections 3.2.1.1 and 3.2.1.2 and an average annual ore production rate of 1 million tons per year, the waste material from surface and underground mines is an estimated 30 million tons and 1.5 to 16 million tons per year, respectively. Associated with this amount of waste is a potential for air contamination as a result of dust and radon emissions and potential water contaminated with radiological elements, metals, and solids. However, proper management of these materials can greatly reduce potential contaminant releases.

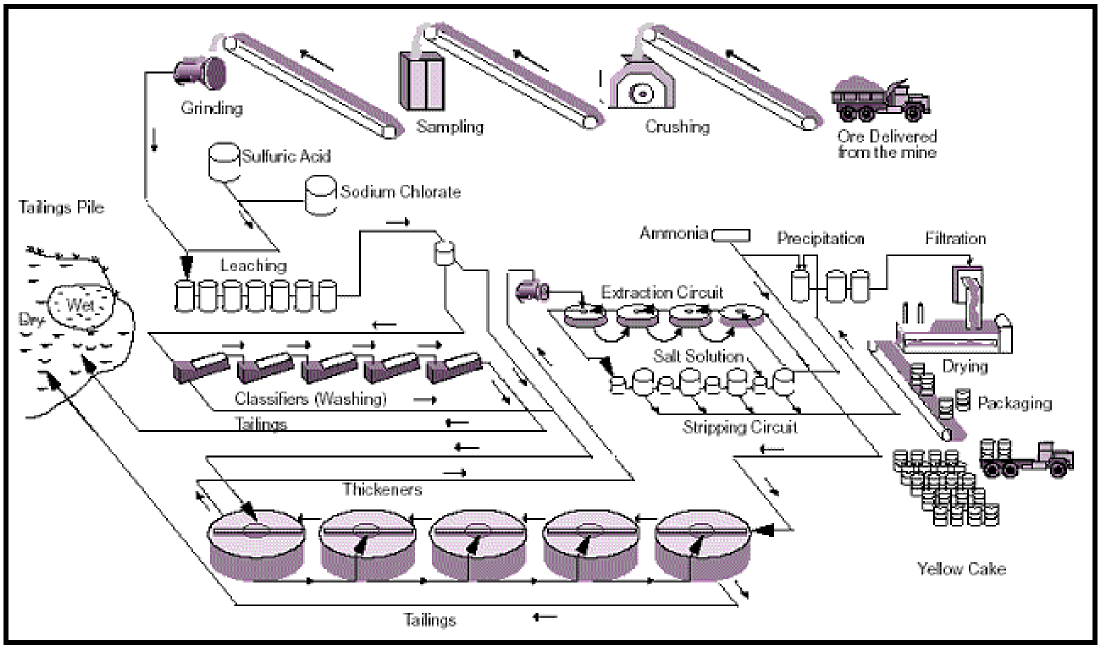
Tailings (or tails) are a by-product of the milling process comprising a mixture of spent ore, water, and extraction solution. Tailings are typically managed on site by tailings impoundments or used as backfill material. Projected tailings production at the Coles Hill site is approximately 2,833 tons/day and will require at least six 40-acre tailings impoundments that receive paste tailings (Lyntek, 2010 and VUI personal communication, 2011). Paste tailings have been augmented with cement to stabilize the material and contain contaminants. The primary pollutants of concern associated with air emissions from tailings

Figure 3-5. Block Flow Diagrams of the Acid and Alkaline Uranium Leaching Circuits



Adapted from U.S. Environmental Agency (EPA), 1995.

Figure 3-6. Typical Conventional Uranium Milling Operation



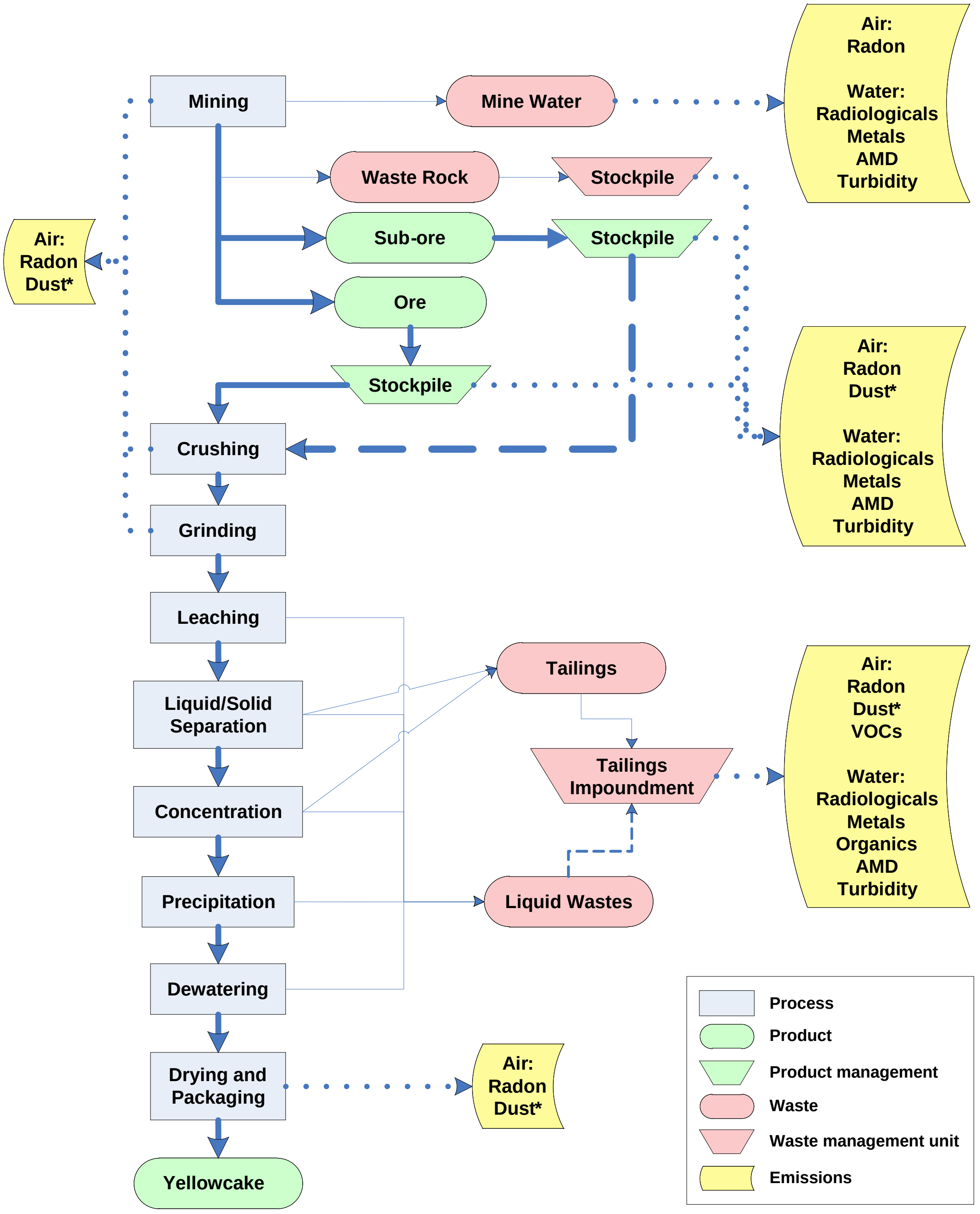
Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels.

Table 3-2. Identified Wastes Generated by Conventional Uranium Mining and Milling and Potential Regulatory Authority.

Conventional Open-Pit and Underground Mines (EPA, Federal Land Management, and Tribal and State Agencies Jurisdiction)	Uranium Mills (By-product Material Subject to NRC or Its Agreement State Jurisdiction)
Protore	
Overburden	
Barren or waste rock	
Top soils	
Drill cuttings and drilling wastes	
Wastewater	Wastewater
Wastewater treatment sludge	Wastewater treatment sludge
Lab wastes	Lab wastes
Pit water	
Mine water	
Evaporates	Evaporates
	Mill tailings
Refuse (if radioactive)	Refuse (if radioactive)

Adapted from EPA, 2008.

Figure 3-7. Block Flow Diagram of Uranium Processing and Associated Air and Water Potential Emissions



* In addition to airborne particulate hazards (e.g., respiratory impacts), dust may include radiological and metals contamination sorbed to the particulates

impoundments include dust, radon, and volatile organic compounds (VOCs). Additionally, tailings have the potential to contaminate water with radiological compounds, metals, organics, and solids when not managed properly.

3.4.2 Potential Aqueous Wastes (Water)

Potential sources of water that could be discharged from the proposed Coles Hill site that may be contaminated include the following:

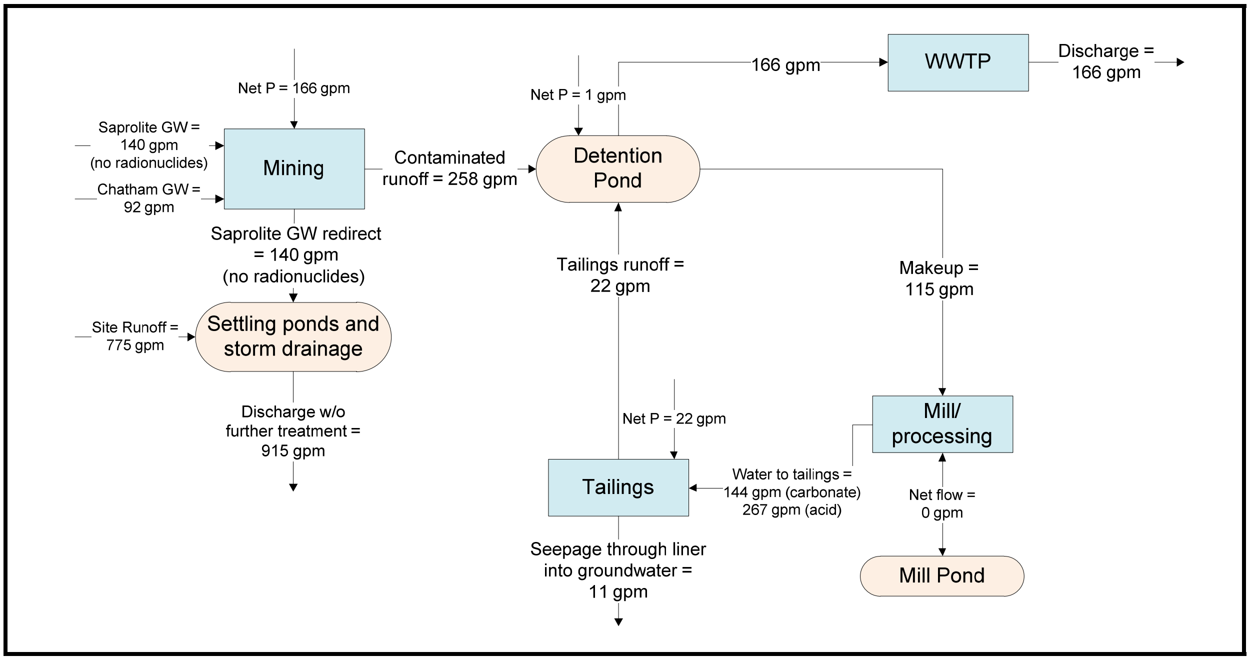
- Mine water—includes both precipitation and groundwater infiltration into the mine
- Process water—water used during uranium milling activity
- Tailings water—water used for dust suppression in tailings pits
- Site runoff water (storm drainage)—all other site runoff due to precipitation that is collected and discharged

Of these sources, the process water is most likely to contain the highest level of contamination, followed by tailings water, mine water, and site runoff water. Proposed plans from both the original Marline study, as well as recent material from VUI, indicate that the milling process will be designed so that it is a net consumer of water; therefore, no water will be discharged from milling activity. Both contaminated mine water and any tailings water drainage are expected to require treatment for radionuclides before being discharged. Although site runoff will be monitored prior to discharge, it is not expected to be reach contamination levels that require treatment before discharge. A water balance is an accounting tool used to identify and quantify all water inputs/outputs for a given site or region; the development of a water balance is a key regulatory requirement that must be submitted by a prospective discharger prior to permitting approval. Figure 3-8 summarizes the 1984 Marline study water balance for their proposed mining/milling activity, while Figure 3-9 provides a more recent possible/probable water balance updated using information provided by VUI.

The Marline water balance was generated assuming a processing value of 1,050,000 tons of ore per year, precipitation of 42 in/year, and evaporation of 9.5 in/yr. An overall value of site runoff and discharge was not explicitly provided in the study but is shown in Figure 3-8 using the site area and rainfall data provided in the study to give a complete picture of the water balance. Detailed assumptions used to generate the water balance are provided in Appendix C.

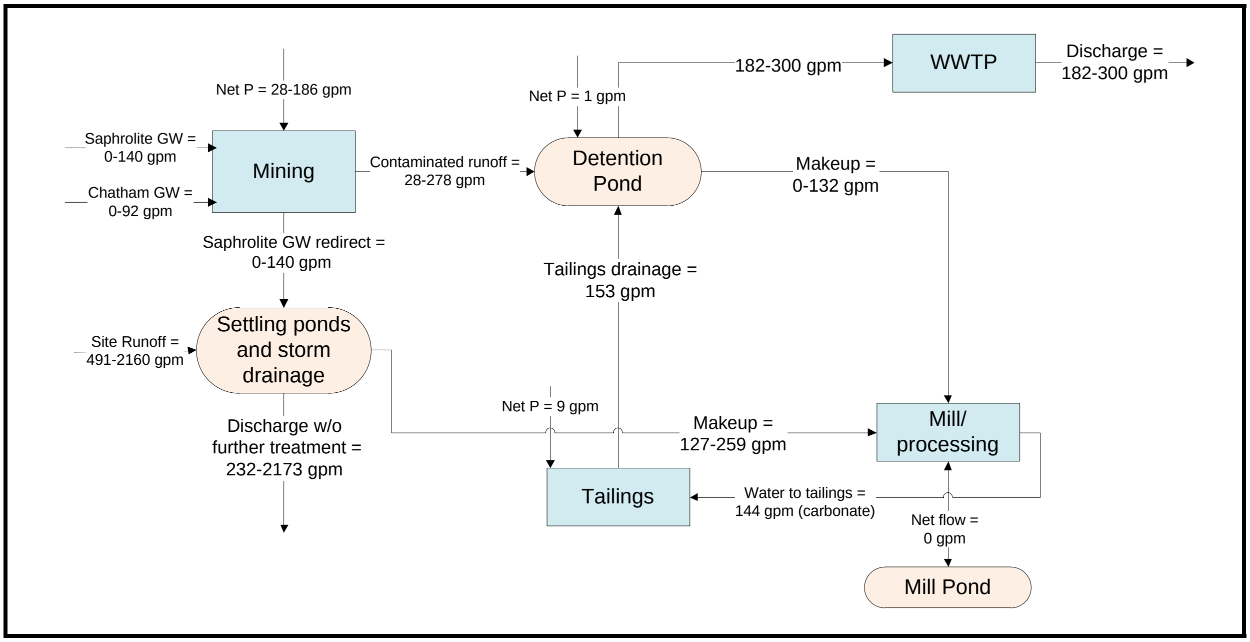
Precipitation, evaporation, and soil percolation were estimated using the Generalized Watershed Loading Function (GWLF), and historical climate data available from the National Climatic Data Center (NCDC) covering the period 1976 to 2006 were used to compute the site runoff water component for an updated water balance. To provide the range of water precipitation/runoff values used in the water balance, minimum and maximum averages from the historical data were used. A detailed description of the assumptions used for the revised water balance is provided in Appendix C. The discharge point will be finalized during the National Pollutant Discharge Elimination System (NPDES) permitting process, but it is likely that water will be discharged into Mill Creek.

Figure 3-8. Coles Hill Mining/Milling Water Balance Adapted from the Marline Study



Source: Marline, 1983.

Figure 3-9. Potential Coles Hill Water Balance Updated Using Water Usage Projections from 2010 VUI Scoping Study and Historical Rainfall Data



Although VUI has not provided an explicit water balance for the proposed mine, Figure 3-9 displays a revised Coles Hill water balance, which was estimated using historical data (Marline) and updated using information from the 2010 VUI scoping study and historical rainfall values in an attempt to capture the flow variability that will exist in this type of site. Although production is still estimated to be 1,050,000 million tons of ore, VUI has stated that they expect to treat contaminated effluent at a rate of 300 gpm, which is nearly double that proposed in the Marline study (166 gpm) (Lyntek/BRS, 2010a; Marline, 1983).

The biggest change to the updated balance is that the rainwater infiltration to groundwater and site runoff values are treated as ranges rather than explicit values to account for the large variability in weather, as well as the unknown behavior of groundwater infiltration into the mine. In addition, the tailings pond regulations have been updated since 1983 to incorporate an underdrain to prevent excess seepage into the groundwater. This is the primary reason why the wastewater treatment plant (WWTP) capacity has increased from the 1983 Marline projections.

3.5 Emissions Estimates

3.5.1 Mine Water

Water discharged from mining and milling activities must meet requirements set forth by the following federal statutes: the Clean Water Act (CWA) and the Safe Drinking Water Act (SDWA). In addition, mining/milling facilities must comply with any specific state regulations. Section 402 of the CWA states that all point-source discharges[1] of pollutants to waters of the United States must be permitted under the NPDES. NPDES permits are issued by either EPA or a state regulatory agency and are site specific. The effluent limits on NPDES permits are either technology or water-quality based. For uranium mines, technology-based effluent guidelines have been established for water discharges and are provided in Table 3-3.

Table 3-3. Effluent Discharge Guidelines for Mine Drainage of New Uranium Mines and Mills[a,b]

Effluent Characteristic	1-Day Maximum	30-Day Average
Chemical Oxygen Demand (COD)	200 mg/L	100 mg/L
Zinc (Zn)	1.0 mg/L	0.5 mg/L
Radium (Ra 226 -dissolved)	10.0 pCi/L	3.0 pCi/L
Radium (Ra 226 -total)	30.0 pCi/L	10.0 pCi/L
Uranium (U)	4.0 mg/L	2.0 mg/L
pH	6.0–9.0	6.0–9.0
Total Suspended Solids (TSS)	30.0	20.0

[a] Source: 40 CFR 440 Subpart C.

[b] Actual effluent discharge limits are site specific and determined during the NPDES permitting process.

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[1] A point source is defined as any discrete liquid conveyance, natural or man-made, including pipes, ditches, and channels (EPA, 1995).

Based on the anticipated regulatory effluent limits, mass load discharge estimations of contaminants can be made for the proposed mine and mill site. The mass loads are preliminary and can be refined once specific permits have been issued and treatment technologies with their associated discharge goals have been established. However, pollutant mass loads were estimated based on the 30-day average effluent concentration guidelines presented in Table 3-3 and the high/low impact scenario range of discharge volumes estimated in Section 5 of 166 to 830 gpm. These estimations are presented in Table 3-4.

Table 3-4. Mining and Milling Effluent Emission Estimates

Effluent Characteristic	Low-Impact Scenario	High-Impact Scenario
COD	90 kg/day	452 kg/day
Zn	0.9 kg/day	4.5 kg/day
Ra 226 (dissolved)	31 pCi/s	57 pCi/s
Ra 226 (total)	105 pCi/s	189 pCi/s
U	1.8 kg/day	9 kg/day
TSS	18 kg/day	90 kg/day

3.5.2 Process Water

40 CFR 440 states that discharges of wastewater from milling activities are not allowed, except in cases where annual net precipitation exceeds evaporation over the treatment facility and drainage area, in which case this volume difference may be discharged. The Coles Hill site is in an area with greater precipitation than evaporation, so any milling facility could potentially treat and dispose of milling process water. It is important to note that milling plans (both the carbonate and acid approaches) incorporate high internal water recycling resulting in a water deficit to the milling process. In addition, all indications from VUI suggest that process liquids discharge will not occur; the discharge of process liquids used directly in the milling, therefore, does not appear likely for the Coles Hill project. However, in the event that process liquids must be released, they would be subject to the same discharge limitations as presented in Table 3-3.

3.5.3 Nonpoint Source Water Discharges

Nonpoint source water discharges from the mine and mill would include any seepage from tailings and water retention ponds into the groundwater and percolation of precipitation (rain or melting snow) falling on site and seeping into surface soils, which may possibly bring with it contamination contained within any deposited dust. Although these discharge points are not specifically regulated by the CWA, they are accounted for through regulatory mechanisms. Because the majority of environmental releases have historically occurred because of failed tailings management/operation, the 1995 Final Rule on Groundwater Standards set forth new design standards. The new rule states that tailings facilities will have bottom liners, which can be natural or synthetic. All synthetic liners must have a leakage detection system installed just below the liner to ensure the detection of major failures that might occur. If clay liners are used to control seepage, tests must be conducted using representative tailings solutions to demonstrate that no significant loss of permeability will occur and must be conducted over a significant period of time to demonstrate such effectiveness. The second mechanism for controlling nonpoint discharges is the implantation of groundwater standards and monitoring. Table 3-5 displays the maximum concentration of constituents of concern for groundwater. Increases in contaminant concentration will trigger a cleanup corrective action, within a maximum of 18 months from the time of exceedance.

Table 3-5. Maximum Concentration of Constituents for Groundwater Protection[a]

Contaminant	Concentration
Arsenic	0.05 mg/L
Barium	1.0 mg/L
Cadmium	0.01 mg/L
Chromium	0.05 mg/L
Lead	0.05 mg/L
Mercury	0.002 mg/L
Selenium	0.01 mg/L
Silver	0.05 mg/L
Nitrate (as N)	10 mg/L
Molybdenum	0.1 mg/L
Combined radium-226 and radium-228	5 pCi/L
Combined uranium-234 and uranium-238	30 pCi/L
Gross alpha particle activity (excluding radon and uranium)	15 pCi/L
Endrin	0.0002 mg/L
Lindane	0.004 mg/L
Methoxychlor(1,1,1-trichloro-2,2’-bis(p-methoxyphenylethan)	0.1 mg/L
Toxaphene	0.005 mg/L
2,4-D (2,4-dichlorophenoxyacetic acid)	0.1 mg/L
2,4,5-TP Silvex (2,4,5-trichlorophenoxypropionic acid)	0.01 mg/L

[a] EPA 40 CFR Part 92.

3.5.4 Air Emissions

This section presents the air emissions of particulate matter (i.e., dust) and radon gas that were estimated from the proposed uranium mine and mill at the Coles Hill site. Because VUI is in the preliminary stage of the mining and milling development, many of the operational details remain undetermined. Therefore, the presented emissions estimates cannot be considered directly predictive but were developed using the best available information. Low- and high-range emissions were estimated to account for the high levels of uncertainly related to the proposed mining and milling activities.

As noted earlier, Figure 3-7 displays the general uranium mining process and expected emission types. The extraction of the ore during mining, crushing, and grinding processes will be responsible for emitting the largest amount of dust. The waste rock and stockpile are also sources of dust emissions, as is the transport of rock and ore via bulldozers and dump trucks. The two potential mining scenarios proposed for the site are open-pit and closed-pit methods; in situ mining emissions are, therefore, not estimated. The beneficiation process will be the same regardless of whether aboveground or underground mining methods are used at Coles Hill. The beneficiation of uranium is a less significant source of air emissions. The leaching, separation, concentration and precipitation, and drying and packaging processes involve much smaller volumes of uranium material than the large volumes of waste rock generated during mining. In addition, this material is generally enclosed within vessels and process equipment, because of the higher uranium concentration of the extracted material. In addition to beneficiation, dust and radon emissions are associated with the drying and packaging of the yellowcake.

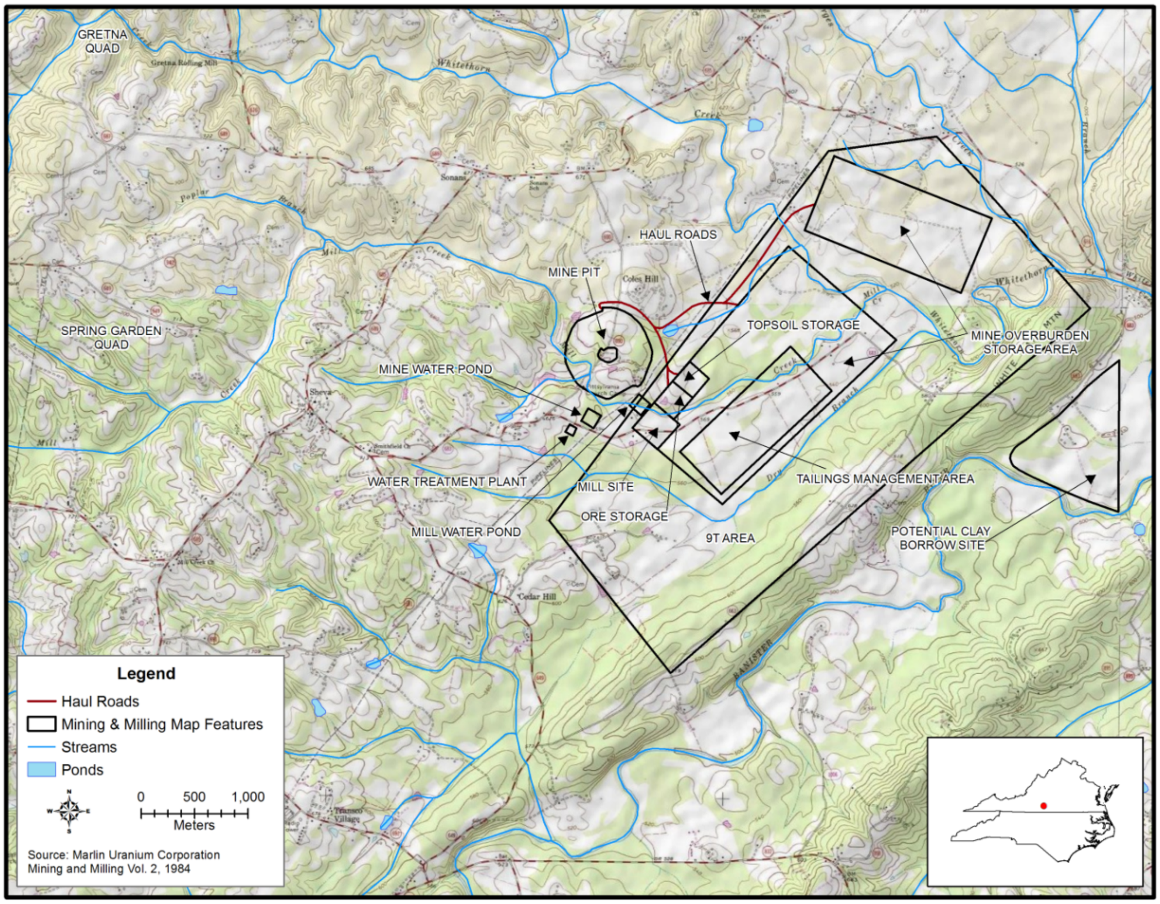
Detailed descriptions of the expected processes and operations are provided in Sections 3.2 and 3.3. The inputs used to estimate emissions for the potential uranium mine are displayed in Table 3-6. Additionally, the surface areas of potential “area” sources of air emissions were derived from a digital reproduction of a map presented in Marline (1983). Presented in Figure 3-10 is a map showing the Marline (1983) mine and mill layout and in Table 3-7 are the projected surface areas. It is recognized that the mine and mill layout likely would be modified to reflect current engineering and environmental regulatory requirements; nevertheless, this preliminary layout provides reasonable approximate surface areas upon which to base the air emission estimates.

EPA’s AP-42, a set of widely used emission factors to estimate the quantity of pollutants released during certain processes within industry sectors, was applied to estimate air emissions from the Coles Hill uranium mine and mill site. This compilation has been used for decades to provide representative and reliable emission estimates from industrial operations. Although many of the estimation methods applied are not specific to the uranium mining and milling industry, these operational processes are the same for mining processes in general. The selected AP-42 estimates used in this study are provided in Table 3-8. The presented air emissions represent realistic operational situations that may vary depending on a range of choices by VUI. These ranges were accounted for by selecting different technologies, climate, and operating conditions. Low and high emissions were estimated for both open-pit and underground mining. The emissions were estimated for particulate matter (PM) less than 30 micrometers (PM_{30}).

Table 3-6. Potential Mining and Milling Operations for Emission Estimation Equation Inputs

Input Operation	Value	Units	Source
Rock removal/overburden	8,400,000	Ton/yr	Marline, 1983
Blasts	1,000	Blasts/yr	Marline, 1983
Underground mining	0.02	Gr PM/dscf	Stricklin and Haney, MSHA
Blasting area	225	Ft^2	Marline, 1983
Daily production hours	24	Hr/day	Lyntek, 2010b
Annually production days	350	Day/yr	Lyntek, 2010b
Average U_3O_8 grade	0.19	%	Lyntek, 2010b
Alkaline recovery	84	%	Lyntek, 2010b
Processing recovery	83	%	Lyntek, 2010b
Ore production rate	3,000	Ton/day ore	Lyntek, 2010b
Uranium production rate	1,000	Ton U_3O_8/yr	Lyntek, 2010b
Exhaust air flow rate	300,000	cfm	Lyntek, 2010b
Radon emission rate	25.3	Ci/ton U_3O_8	EPA, 1985

Figure 3-10. Map of Uranium Mine and Mill Layout from Marline (1983)



Source: Marlin Uranium Corporation Mining and Milling Vol. 2, 1984

Table 3-7. Coles Hill Mine and Mill Production Areas

Description	Surface Area, m^2
Mine pit (large)	514,005
Mine pit (small)	19,084
Water treatment plant	6,179
Mine water pond	18,551
Mill water pond	18,943
Mill site	97,284
Ore storage	65,182
Topsoil storage	58,291
Tailings management area	795,056
Mine overburden storage area	2,729,440
Mine overburden storage area	1,188,680
9T area	11,779,342
Potential clay borrow site	791,386

Table 3-8. Emission Estimation Source and Correlating AP-42 Equation References

Emission Source	EPA AP-42 Reference
Blasting	11.9-1
Bulldozing	11.9-1
Dragline	11.9-1
Crushing	11.24-2
Grinding	11.24-2
Material handling and transfer	11.24-2
Plant road	13.2.2-1
Haul road to/from pit	13.2.2-1
Quarrying and processing	13.2.4-1

The emission estimate results for PM_{30} and radon are presented in Tables 3-9, 3-10, and 3-11. PM_{30} emissions were estimated from the following operations: open-pit blasting, open-pit bulldozing, underground ventilation, haul roads, handling and transfer areas, stockpiles, overburden, and processing. The ranges of the effectiveness of control technologies applied to reducing PM ranged between 10% and 80%, depending on the control. For example, a dust suppressant spray may provide 30% to 50% control, while a dust collector could provide up to 75% to 80% control; a detailed discussion of mitigation technologies is provided in Section 3.6.

Table 3-9. Emission Estimates of Ore and Nonore-Related PM_{30} from Open-Pit and Underground Mining Methods at the Proposed Coles Hill Site

Mining Method	Ore-related PM_{30}, kg/yr		Nonore-Related PM_{30}, kg/yr		Total PM_{30}, kg/yr	
	Low	High	Low	High	Low	High
Open Pit	245.3	1,119.1	134.4	1,019.2	379.8	2,138.3
Underground	244.3	1,107.1	57.8	437.2	302.1	1,544.3

Table 3-10. Radon Emission Estimate Results

Description	Square Meters	Low Radon Flux Rate, pCi/m2-s	High Radon Flux Rate, pCi/m2-s	Low Radon Emission Rate, pCi/s	High Radon Emission Rate, pCi/s
Mine overburden storage area (open-pit mine)	2,729,440	2[a]	60[a]	5.46×10^6	1.64×10^8
Tailings management area	795,056	2[b]	20[b]	1.59×10^6	1.59×10^7

[a] EPA, 2008.

[b] Golder Associates, 2010.

Table 3-11. Underground Mine Vent Radon Emission Rate Estimates at the Proposed Coles Hill Mine

Description	Ore Mining Rate, Tons/day[a]	Average U_3O_8 Content in Ore, %[a]	Radon Flux Rate, Ci/ton Mined Ore[b]	Uncontrolled Radon Emission Rate, pCi/s	Controlled (84%) Radon Emission Rate, pCi/s
Underground mine vent	3,000	0.19	25.3	1.61×10^9	2.57×10^8

[a] Lyntek, 2010b.

[b] EPA, 1985.

3.6 Mitigation and Control Options

3.6.1 Marline Study Wastewater Treatment Approach

The mining/milling facility proposed in the Marline study was designed with high levels of internal recycle and zero liquid discharge (ZLD) of the high pollutant concentration mill process water. VUI has also indicated that their milling design would require water. Although the design plans specified ZLD from the mill processing plant, they did provide a high-level technology review of treatment alternatives in the event that treatment of the higher concentration mill water became necessary. They noted that enhanced pond evaporation, chemical precipitation, electrodialysis, and ion exchange were potential treatment technology options, but that both further studies and a demonstrated need would be required before exploring the feasibility/performance of these options (Marline, 1983).

The Marline WWTP approach was, therefore, designed to treat the contaminated mine/tailings runoff. The proposed plant was designed to meet the then-current EPA mining discharge standards (40 CFR 440, 1982). The treatment plant was designed assuming a 100 piC/L radium concentration as the influent to the WWTP. This concentration is noted to be a conservatively high estimation, because the Marline Study estimates that undiluted tailings solutions are expected to range between 14 and 105 piC/L, and some dilution from rainfall will likely lower the concentration (Marline, 1983). The conceptualized treatment plant is provided in Figure 3-11.

Although today the treatment technologies for radionuclide removal are similar to those available 30 years ago, the addition of reverse osmosis (RO) and electrodialysis (ED) membrane processes provides high levels of removal and increases the available water treatment options. Table 3-12 provides a summary of available EPA-approved treatment technologies for radium/uranium removal from contaminated water. Although VUI has not yet generated current water treatment plans, the economics of radium and uranium removal make it likely that any proposed WWTP will have a similar structure. That is, the primary removal method is likely to be barium/sulfate coprecipitation, coagulation, and filtration, followed by a finishing treatment to ensure that regulations are met prior to discharge. The choice of the finishing treatment could be an adsorption, ion exchange, or membrane process like RO or ED and will depend on treatability studies and economics.

Figure 3-11. WWTP Scheme Proposed in the Marline Study to Treat Mine/Tailings Runoff for Discharge

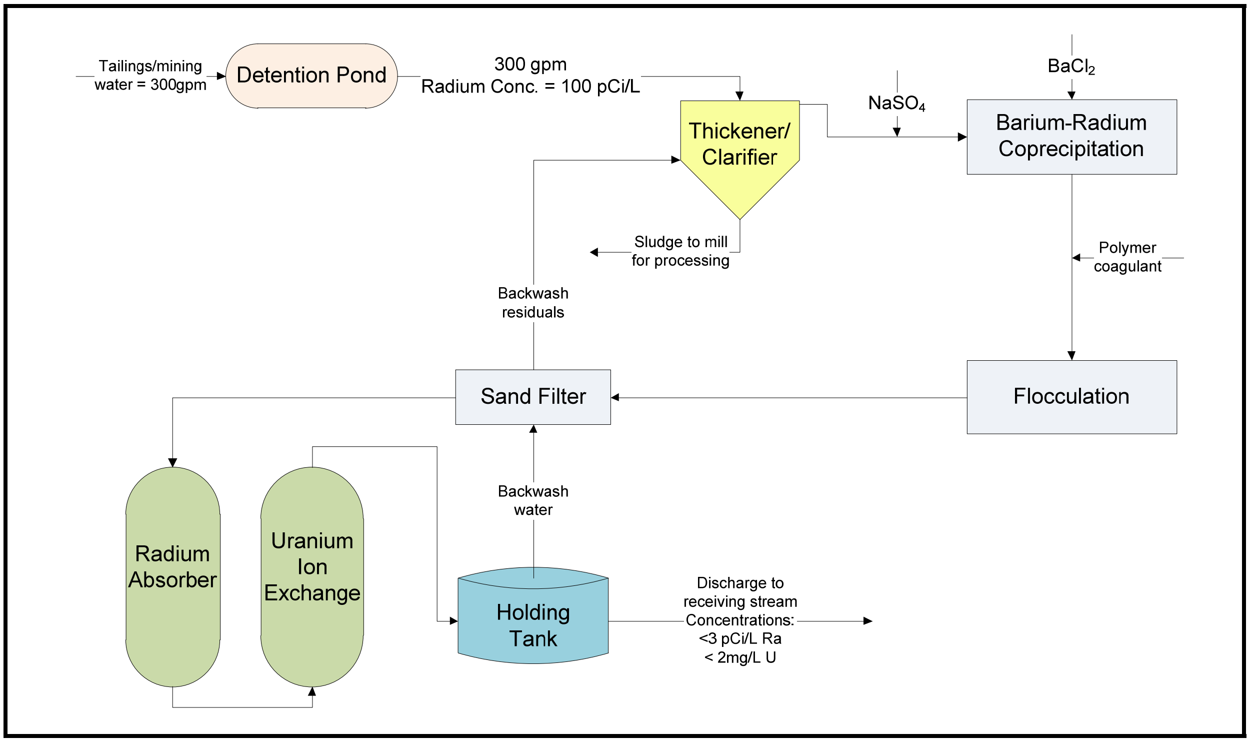


Table 3-12. Summary of Radium/Uranium Water Treatment Technologies and Associated Removal Efficiencies[a,d]

Treatment Technology	Contaminants Removed	Typical Removal Efficiency	Brief Technology Description
Coprecipitation with barium sulfate[b]	Radium	50%–95%	$BaCl_2$ followed by $NaSO_4$ to coprecipitate $Ba(Ra)SO_4$ sludge, followed by sedimentation and filtration.
Ion exchange[b,c]	Radium, uranium	>95%	Radium—cation exchange with sodium. Uranium—anion exchange with chloride.
MnO_2 adsorption[b]	Radium	50%–95%	Adsorption onto activated media for divalent cation removal.
Reverse osmosis (RO)[b,c]	Radium, uranium	>99%	High-pressure membrane system effective at removal of high percentage of ions in feed water.
Coagulation with Fe/Al[b,c]	Uranium	50%–90%	Coagulation with either alum or ferric followed by sedimentation and filtration.
Lime softening[b,c]	Radium, uranium	80%–99%	Lime/soda ash precipitates ions, and sedimentation and filtration steps facilitate removal. Removal is more effective at higher pH.
Electrodialysis[b]	Radium, uranium	95%	Electrical potential applied across alternating anion/cation exchange membranes removes ions in water.

[a] Note that removal efficiencies vary widely and are highly dependent on the source water concentration and composition. Accurate estimates of achievable removal efficiencies must be determined experimentally for the specific water.

[b] EPA, 2006

[c] EPA, 2007

[d] Dennis, 2004

3.6.2 Air Emission Controls

The dust and radon emissions can be controlled using different technologies and practices. Radon emissions from mining can be controlled or reduced by preventing diffusion of radon and containing radon in a confined space until it has decayed to less reactive products. Three suggested and more commonly used methods for reducing radon are application of sealants, backfilling, and bulkheading.

The use of sealants places a barrier over the ore pores and surface to prevent the release of radon. The cost of sealants is relatively high, and they can provide about 50% to 70% reduction in radon emissions (Proposed Standard 6-10). Backfilling is the practice of placing waste materials, such as tailings, back into the mine to fill the stope. This is used to stabilize the mine but also helps reduce radon emissions. This is also a costly process. It has been shown that backfilling can reduce emissions up to 84% (Proposed Standard 6-13). Bulkheading involves creating a barrier to restrain the air in a worked-out section of the mine, which allows the radon emissions to decay into less active products. In theory, a bulkhead could be 100% effective in reducing emissions.

Dust emissions can be reduced from the mine by different control devices. Control alternatives depend on the conditions at a mine and the amount of control necessary. Dust control devices such as sprayers or mechanical collectors can improve reduction effectiveness from 10% to about 75%. Table 3-13 shows a variety of effective dust control options for mining (CDC Handbook).

Table 3-13. Particulate Matter Emission Control Methods and their Removal Efficiencies

Dust Control Method	Treatment Effectiveness Low is 10%–30% Moderate is 30%–50% High is 50%–75%
Dilution ventilation	Moderate
Displacement ventilation, including enclosure with extraction of dusty air	Moderate to high
Wetting by sprays	Moderate
Airborne capture by sprays	Low
Airborne capture by high pressure sprays	Moderate
Foam	Moderate
Wetting agents	Zero to low
Dust collectors	Moderate to high
Reducing generated dust	Low to moderate
Enclosure with sprays	Low to moderate
Dust avoidance	Moderate

3.7 Regulations

Uranium mines and mills are regulated by federal and state agencies. EPA, the Nuclear Regulatory Commission (NRC), and the Department of Energy (DOE) are each responsible for different aspects of uranium mining and milling activities. Currently, the Commonwealth of Virginia does not have any regulations for uranium mining and milling. A moratorium is in place, which until lifted and regulations are established, disallows uranium mining in Virginia.

The Atomic Energy Act (AEA), Uranium Mill Tailings Radiation Control Act (UMTRCA), Clean Air Act (CAA), CWA, and SDWA are the statutes in place to regulate emissions, wastes, and water from uranium mining and milling. Each set of regulations is set to protect the health and welfare of the mine employees, the surrounding population, and the environment.

3.7.1 Air Regulations

The air regulations applicable to this process are the National Ambient Air Quality Standards (NAAQS), the New Source Performance Standards (NSPS), and the National Emission Standards for Hazardous Air Pollutants (NESHAPs). The pollutants of greatest concern and concentration are particulate matter and radionuclide emissions. For particulate matter emissions, most states will implement dust suppression work practices, and the federal government has set standards for any point-source emissions from the facility. The regulations for the radionuclide emissions are more stringent because of the nature of the pollutant. Subpart B of 40 CFR 61 sets standards for active mines and requires that no member of the public can be exposed to an effective annual dose higher than 10 mrem/yr. This requires multiple monitoring sites and equipment throughout the facility and community.

3.7.2 Tailings

Appendix A to 10 CFR Part 40 details the criteria related to operating and maintaining uranium tailings facilities. The overall objective of the criteria is to ensure that tailings facility designs have minimal impact both short and long term on human health and the surrounding environment. The document covers financial responsibility, design guidelines to minimize erosion, groundwater protection standards, monitoring protocol, and clean up requirements in the event of release/contamination. The final rule of 40 CFR Part 192 states that “Implementation of the disposal standard for protection of groundwater will require a judgment that the method chosen provides a reasonable expectation that the provisions of the standard will be met, to the text reasonably achievable, for up to 1,000 years and, in any case, for at least 200 years.” This is less than the NRC time frame of 10,000 years of protection and was lowered because of the lower radiation content in uranium tailings wastes. Typical radioactivity of uranium tailings is 0.4 to 1.0 nCi/g, whereas process wastes are always >100 nCi/g and typically much more than this.

There are two phases of tailings management, during operation and then closure once mining operations have ceased. Groundwater protection is addressed through the requirement of a monitoring plan (see Table 3-4), as well as actionable concentration levels.

3.7.3 Pile and Liner Design

Installation of a monitoring system upgradient of the point of compliance (the uppermost aquifer upgradient of the edge of the disposal site) to determine the background levels of any contaminants is required per 10 CFR Part 40. This background information along with information on the receiving water body/discharge point will be taken into account when specific NPDES permitting is issued for the site.

Regulatory boundary: Boundary to meet standards is on site or within 500 meters, whichever is closer. The point of compliance is chosen to provide the earliest reasonable warning in the event of groundwater contamination.

3.8 Post-closure Releases

3.8.1 Uranium Site Decommissioning Overview

Environmental, financial, and political issues are all important aspects of uranium site closure. The 1978 Uranium Mill Tailings and Radiation Control Act (UMTRCA) designates EPA with the overall responsibility of determining environmental standards for uranium production facilities, while the NRC is charged with licensing and regulating uranium production activities. Uranium site decommissioning plans must be submitted and approved as part of the NRC licensing process. Upon approval of the plan, the licensee must post a surety bond to ensure that sufficient funds will be available for tailings reclamation, groundwater restoration, site dismantling, and long-term monitoring of the decommissioned site.

3.8.2 Mill Dismantling

The decommissioning of a mill site includes multiple steps, which are outlined in detail in a 1995 report from the Energy Information Administration titled “Decommissioning of U.S. Uranium Production Facilities.” Equipment and buildings from mining and milling machinery and equipment must be cleaned and decontaminated. The equipment and building materials must be reviewed so that determinations on salvageability can be made. Unsalvageable materials are then cut up if necessary and buried nearby (usually in a tailings pile). All debris and contaminated soil must also be removed from the site, including roads and parking lots. Finally, the site area must be regraded, resoiled, and fertilized to reestablish fresh vegetation. Because this process involves the cleaning and remediation of the site, anticipated releases during mill dismantling are likely to be minimal to nonexistent as long as accidents are prevented.

3.8.3 Tailings Impoundments

Once mining and milling activity have ceased operation, many of the associated exposure pathways (e.g., dust from mining, treated effluent discharge) also cease to be a source for contaminant release. The remaining tailings impoundments is the chief operation of concern for potential environmental releases. Potential sources from tailings facilities include

- radiation from the pile into the atmosphere,
- groundwater contamination via seepage through the liner, and
- surface water runoff or flooding of the facility resulting in tailings impoundment erosion.

NRC regulation 10 CFR Appendix A to part 40 provides tailings design constraints that must be met during the permitting process. These regulations specify that tailings facilities must have bottom liners installed to prevent seepage into the groundwater, as well as a leakage detection system to identify any leaks. Once a pile is closed, the edges must be reinforced to prevent long-term erosion and covered with a radon barrier material. Any drainage into the tailings area must be redirected away from the impoundment. The entire impoundment must be covered with a radon barrier to prevent atmospheric releases, as well as a final pile cover to include vegetation (where possible) to prevent against erosion and limit water infiltration. The site remains the responsibility of the licensee until the NRC approves all aspects of the construction, design, and monitoring, at which time it will transfer over to the DOE or state entity for long-term maintenance and monitoring.

3.9 References

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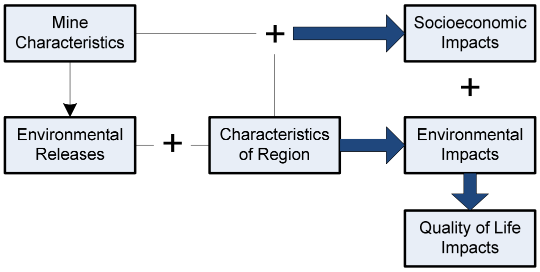
4

Insights from Case Studies



After screening more than 50 locations with possibly comparable mines, we selected 18 to profile in greater detail, including 11 uranium mines and mills and 7 non-uranium metal mines. We then interviewed stakeholders and examined data for 4 locations with operating mines and mills. While the settings of the uranium mines are different from Coles Hill, they offer useful insights, including the following. (1) Older mines typically had inadequate tailings management, resulting in serious contamination of the local environment and, in some cases, adverse health impacts for local residents. (2) Currently operating mines have better waste management technologies and more stringent regulations. Violations still occur at certain mines, especially those that fail to follow mandated procedures, but engineering and management improvements and regulatory reform have led to an apparently lower occurrence of environmental impacts above regulatory limits and fewer adverse health impacts associated with operating mines and mills. (3) Stakeholders generally did not report serious environmental concerns, although some did question whether such concerns would become more prevalent as mining and milling continued over time. (4) Economic impacts were reported as generally positive, but social and community impacts were reported as both positive and negative.

4.1 Introduction

Case studies provide information on what has happened in other communities with uranium and other metal mines and mills. As we gathered information about other mines, it became clear that no mines and mills are similar in all respects to the proposed site at Coles Hill. However, the experience of other communities can still provide useful insights into the potential environmental and economic impacts associated with uranium mines and mills, and it can help identify factors that may be correlated with these impacts. In addition, this information helps provide context for assumptions used by RTI in economic and environmental modeling (Sections 5 and 6). In this section, we present insights from case studies of uranium and other metal mines; we point out where similarities to and differences from Coles Hill exist to help clarify where connections can be made. For greater detail about the case study process, please see Appendix D.

Many different factors interact to determine how the presence of a mine or mill in a community can contribute to environmental and socioeconomic impacts and thereby affect quality of life. Examples of these factors include the following.

- **Characteristics of the mine and mill** (such as mining and milling methods, management methods, and volume and chemical makeup of ore), along with regulatory standards, determine pollutant releases, which are then transported through environmental media such as soil, air, and water.

- **Geographical characteristics of the region** (such as rainfall, climate zone, and regional terrain) determine the extent of transport of pollutants.

- The extent of transport of pollutants, along with distance to population centers and population density, consequently determines **human and ecological exposures**.[1]

Below, we present tables that characterize the case study mines, mills, and locations and compare them with the proposed Coles Hill project and location so that differences and similarities can be borne in mind as environmental and socioeconomic impacts of the case study mines and mills are discussed.

4.1.1 Case Study Methodology

To conduct our case studies, we used a tiered approach, starting with screening a large number of mines and mills, selecting a subset that appeared to offer useful examples, and then delving deeply into the data and stakeholder perceptions for four locations with operating uranium mines or mills.

1. The case study methodology began with data collection for more than 50 mines and mills in the United States and internationally. Table D-1 in Appendix D shows the initial screening list of mines and mills, along with some key characteristics such as location, mine type, years of operation, temperature, precipitation, and population density in surrounding areas. [2].

2. In the second step of the methodology, we down-selected cases to more thoroughly examine 18 mines and mills (listed in Table 4-1) that were of most relevance to Coles Hill. Location, mineral, mine type, and years of operation are presented for each of the 18 mines.

The selected mines share certain characteristics with the proposed mine in Virginia. Similarities and dissimilarities to the proposed mine and mill at Coles Hill are highlighted in Table 4-2. Data on a more exhaustive list of factors affecting environmental releases and transport are summarized for the 18 mines and mills in the following section (Section 4.2). We included uranium mines for comparison, because examples of environmental impacts associated with uranium mining are of great interest to the region's stakeholders. However, none of the areas in which uranium mines are located closely resemble Coles Hill in terms of geography, population, and other related community factors. We therefore included other metal mines that are in more similar settings. Metal mines provide useful examples, because the mining methods, waste management methods, and potential pollutants (except for uranium and its daughters) and pathways are similar to those for uranium mines.

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[1] See Sections 3 and 5 for a more detailed description of these processes and mechanisms.

[2] Sources with detailed information have been identified and are included as references.

Table 4-1. List of Mines and Mills Selected for Detailed Examination

	Mine Name	Mine Location	Mineral/ Mine Type	Mine Type	Years of Operation
	Proposed VUI Mine and Mill	Pittsylvania County, VA	Uranium	Underground or open pit/ underground	2013–2048
1	White King & Lucky Lass Uranium Mines	Lakeview, OR	Uranium	Open pit	~1955–1965
2	Midnite Mine	Wellpinit, WA	Uranium	Open pit	1954–1965, 1969–1981
3	Canyonlands Uranium Mines	Lathrop Canyon, Moab, UT	Uranium	Underground	Not available
4	Orphan Uranium Mine	Grand Canyon Village, AZ	Uranium	Underground	1956–1969
5	Bluewater Uranium Mines	Bluewater, NM	Uranium	Underground	1952–1966
6	Yazzie-312 Mine	Cameron, AZ	Uranium	Open pit	1956–1961
7	Arizona 1 Mine	Fredonia, AZ	Uranium	Underground	~1988–standby until 2009
8	White Mesa Mill	Blanding, UT	Uranium	Mill	1980–current
9	McArthur River Mine	La Ronge, SK, Canada	Uranium	Underground	1999–current
10	Rabbit Lake Mine	NE Saskatchewan, Canada	Uranium	Underground (former open pit)	1975–2017 (projected)
11	Ranger Mine	Jabiru, Australia	Uranium	Open pit	1980–2020 (projected)
12	Brewer Gold Mine	Jefferson, SC	Gold	Open pit	1828–1995
13	Cherokee County (Galena)	Galena, KS	Metals	Open pit, underground	Pre-1970s
14	Oronogo-Duenweg Mining Belt	Joplin, MO	Metals	Underground	Mid-1800s to 1970
15	Tar Creek	Miami, OK	Metals	Underground	Early 1900s to 1970s
16	San Manuel Copper Mine	San Manuel, AZ	Copper	Underground	1953
17	Henderson Molybdenum Mine	Empire, CO	Molybdenum	Underground	Ceased 1989; operated 3 mo/3 yrs
18	Geita District	Tanzania	Hard rock Metals	Open pit and underground	2000–current

Table 4-2. Comparison with VUI

	Mine Name	Mine Type (Underground/ Open Pit/Both)	Mineral Type Is Uranium?	Mine Adjacent to Mill?	Operating?	Precipitation (inches/year)	Distance to Population Center (Similar/ Higher/Lower)	Similar Population Density (Y/N)
	Proposed VUI Mine and Mill	UG/OP	Y	Y	2013–2048	45.4		13,600 (10 mi)
1	White King & Lucky Lass Uranium Mines	OP	Y	Y	N	12–16	Similar	N
2	Midnite Mine	OP	Y	Y	N	18.5	Similar	N
3	Canyonlands Uranium Mines	UG	Y	Y	N	5.59	Similar	N
4	Orphan Uranium Mine	UG	Y	Y	N	8.44	Similar	N
5	Bluewater Uranium Mines	UG	Y	Y	N	12.79	Similar	N
6	Yazzie-312 Mine	OP	Y	Y	N	13.87		N
7	Arizona 1 Mine	UG	Y	N	Y	10.5	Similar	N
8	White Mesa Mill	Mill	Y	N	Y	12	Similar	N
9	McArthur River Mine	UG	Y	Y	Y	14	Higher	N
10	Rabbit Lake Mine	UG (former OP)	Y	Y	Y	13.4 rain, 110 snow	Higher	N
11	Ranger Mine	OP	Y	Y	Y	60.63		N
12	Brewer Gold Mine	OP	N	Y	N	48.6	Higher	N
13	Cherokee County (Galena)	Both	N	Y	N	45.6	Higher	N
14	Oronogo-Duenweg Mining Belt	UG	N	Y	N	46.1	Higher	N
15	Tar Creek	UG	N	Y	N	43.1	Higher	Y
16	San Manuel Copper Mine	UG	N	Y	N	12	Higher	N
17	Henderson Molybdenum Mine	UG	N	Y	N	18.1	Higher	N
18	Geita District		N			Not available	Not available	N

3. In the third step, we use socioeconomic data and phone interviews to provide more in-depth information on four locations that are home to three mines and mills to draw out the socioeconomic characteristics and experiences of the region (Section 4.3). Arizona 1 (Arizona, USA) and White Mesa Mill (Utah, USA), Ranger (Australia), and Rabbit Lake (Canada) were selected for this additional review. These locations were selected because they represent communities that have operating uranium mines and mills and they had an existing population and industry base nearby, a climate similar to that of the Coles Hill location, or both. Local government representatives, community organizations, area newspapers, and other community representatives were contacted by telephone for interviews. Publically available reports were also used to glean socioeconomic information about mining and milling in these locations.

4.2 Environmental Impacts of Mines and Mills

Environmental impacts are a result of specific technologies, management practices, and local conditions. A brief summary of the documented impacts across all 18 mines and mills and a description of the factors that have potentially played a role in them are included in Section 4.2.1. A more detailed description of impacts for each selected mine and mill and summary data on factors affecting environmental releases and transport are presented for the 11 uranium and the 7 non-uranium mines and mills in Sections 4.2.2 and 4.2.3, respectively.

4.2.1 Summary of Impacts and Key Contributing Factors

Chemicals associated with the mining and milling process may be of concern if quantities are released to the environment, migrate in environmental media (e.g., air, water), and lead to potential undesired exposures to humans, ecosystems, or both. The potential constituents of concern (COCs) released during uranium mining and milling at the site for both human and ecological health can be classified as radiologicals, metals, particulate matter, and other chemicals used in the milling process (e.g., acidic or alkaline leaching chemicals). Possible COCs that may be encountered during mining, milling, treatment, disposal, or hauling include uranium, radioactive uranium daughter products (e.g., polonium, thorium, radium, and radon gas) and associated ionizing radiation (alpha particles, beta particles, and gamma rays), heavy metals present in the ore and overburden (e.g., arsenic, chromium), leachate with a pH outside of typical waters (i.e., acidic water with a $pH < 6$; alkaline water with a $pH > 8$), particulates (including the potential for chemicals such as metals and radiologicals to be bound to particulates), and additional chemicals required for the mining and milling process (e.g., blasting chemicals, leaching chemicals).[3]

Broadly speaking, documented potential environmental impacts from other mines and mills include the following:

- groundwater/surface water contaminated with radionuclides/ heavy metals
- radon gas concentrations in air

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[3] Section 5 provides an overview of the types of chemicals used and released during uranium mining and milling, which may become COCs.

- gamma/alpha radiation[4]
- radioactive wastes in soil
- subsidence issues[5]

These environmental impacts, along with the potential human and ecological risks, are identified for each of the mines in Table 4-3. The table also indicates whether there is potential contamination of water, air, and soils or sediment associated with the areas surrounding each of the mines and mills and whether the sites are classified as Superfund sites. Superfund sites tend to indicate worst-case scenarios and are thus not representative of an average mine or mill. It is nonetheless instructive to examine the factors and documented impacts of these sites. More specific details are provided in Sections 4.2.2.1 and 4.2.3.1 for uranium and non-uranium mines, respectively.

Table 4-3. Summary of Environmental Impacts

	Mine Name	Mine Location	Releases/ Subsidence Issues	Superfund Site (Y/N)
1	White King & Lucky Lass Uranium Mines	Lakeview, OR	Heavy metals and radionuclides, gamma radiation, and radon gas concentrations	Y
2	Midnite Mine	Wellpinit, WA	Exposed uranium-bearing rock, acid rock drainage, and radioactive decay	Y
3	Canyonlands Uranium Mines	Lathrop Canyon, Moab, UT	Metals leaching from waste rock piles	N
4	Orphan Uranium Mine	Grand Canyon Village, AZ	Radioactive wastes	N
5	Bluewater Uranium Mines	Bluewater, NM	No information	N
6	Yazzie-312 Mine	Cameron, AZ	Heavy metals and radionuclides	N
7	Arizona 1 Mine	Fredonia, AZ	No information	N
8	White Mesa Mill	Blanding, UT	No information	N

(continued)

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[4] Radiation results in removal of electrons from atoms (called “ionization); these atoms are then chemically reactive and may lead to biological damage. Alpha, beta, and gamma radiation are three types of ionizing radiation. For a description of radioactive decay and more detailed definitions, see Section 5.2.

[5] Subsidence issues refer to sinking or collapsing of landforms.

Table 4-3. Summary of Environmental Impacts (continued)

	Mine Name	Mine Location	Releases/ Subsidence Issues	Superfund Site (Y/N)
9	McArthur River Mine	La Ronge, SK, Canada	Uranium released but below regulatory levels	N
10	Rabbit Lake Mine	NE Saskatchewan, Canada	Greatest uranium emitter but below regulatory levels	N
11	Ranger Mine	Jabiru, Australia	Met water quality protection standards in general but over 120 publicly documented accidental leaks, contaminations and operating breaches. At least one of these instances of accidental releases was severe.	N
12	Brewer Gold Mine	Jefferson, SC	Acid rock drainage	Y
13	Cherokee County (Galena)	Galena, KS	Heavy metal contamination; surface subsidence	Y
14	Oronogo-Duenweg Mining Belt	Joplin, MO	Heavy metal contamination	Y
15	Tar Creek	Miami, OK	Heavy metal contamination, subsidence from underground mine workings, and acid mine drainage	Y
16	San Manuel Copper Mine	San Manuel, AZ	Subsidence issues; consequently, possible modifications to hydrologic flow	N
17	Henderson Molybdenum Mine	Empire, CO	Subsidence areas and consequent unstable conditions such as avalanches and increased chance of flooding	N

As illustrated in Figure 4-1, environmental impacts tend to depend in large part on the interplay of different factors. (Detailed data on these factors for all the uranium mines are provided in Sections 4.2.2.2 and 4.2.2.3. Sections 4.2.3.2 and 4.2.3.3 present corresponding data for non-uranium mines.) Some of these factors are listed below:[6]

1. Characteristics of the mine/site

    a) Mine type/features:[7] Mine type typically determines the amount of waste rock and overburden generation[8] and thus also has a bearing on management of releases. Open pit or surface mines generate much greater quantities of waste rock and overburden than do underground mines.

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[6] For a more detailed description of the relationships between these factors, please see Sections 3 and 5.

[7] Mine types include underground, open pit, and in situ leaching (ISL) mines. ISL mining is considerably different in practice from the other two types of mining, given a lack of excavation and the volume of chemicals injected into the subsurface to leach out uranium. ISL is not a viable technology given the fractured rock geology associated with the Coles Hill facility; thus, only open pit and underground mines were selected for the case studies.

[8] Overburden is the mass of non-uranium-bearing country rock that must be removed to reach the rock containing the ore material. Rock that contains typically low, nonviable concentrations of uranium or associated metals is considered waste rock and is managed separately from overburden. Please see Section 3 for a more thorough discussion of the different mining types.

   b) Years of operation: These serve as indicators for technologies being used for mining/milling and pollution control, level of regulatory stringency in effect for the mines and mills, and voluntary best management practices. They also indicate whether a mine is open or closed.

   c) Chemical makeup and volume of ore: All other characteristics equal, larger mines have the potential for larger environmental impacts. Greater iron content of the ore increases chance for acid mine drainage, while lower pH would make certain metals more soluble or leachable.

   d) Deposit rock type: Different rock types have variable densities, fractures, subsidence potential, and ability to transmit groundwater.

2. Characteristics of region

   a) Climate/rainfall: Areas with high average rainfall (or highly variable rainfall) may experience greater runoff than more arid settings; this may mean that they are more likely to experience pollution of groundwater or surface water, but less likely to experience particulate matter pollution.

   b) Geology/terrain: Different types of geological settings are best suited to specific mining or milling technologies. Geology affects the potential for subsurface hydrological changes and subsidence, as well as the COCs present in the subsurface. Terrain is an important factor when considering surface and groundwater hydrology (groundwater flow, the cone of depression that could be created surrounding the mine from dewatering, etc.). Thus, it determines transport of contaminants through various media. For example, a hilly area may result in contaminated sediments being carried further downstream than a flat area. Additionally, terrain can affect subsidence issues (i.e., there may be more subsidence in a mountainous area) and the potential for dam failures.

   c) Distance to population center/population density: The location of a population center downstream may raise potential exposure risks. Population density may also potentially play a big role. This is because higher populations or population densities in close proximity to the site imply that more people could incur both the costs and benefits of the mine and mill project.

   d) Other factors such as onsite or nearby presence of previous mining operations and other nearby non-mining operations.

4.2.2 Uranium Mines and Mills

Eleven closed or operating uranium mines and mills (some locations having both mine and mill) were profiled by mine and mill characteristics, regional characteristics, and environmental impacts. In the following section we provide a summary of environmental impacts and the factors that contribute to these impacts.[9]

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[9] For more information on a selected mine, please see the reference list.

4.2.2.1 Environmental Impacts

The selected uranium mines caused varying amounts of environmental impacts and potential for human exposure. The major environmental impacts for each site are described in general terms below.

White King & Lucky Lass Uranium Mines, Oregon, Northwest United States (closed)

The open pit sites were designated as a Superfund site (No. 7122307658) by the EPA. Environmental impacts include heavy metals and radionuclides in surface water and groundwater, as well as gamma radiation and radon gas concentrations in air. Mine releases caused creek and shoreline sediment contamination. Individuals with the highest potential of exposure include recreational visitors (EPA, 1995, 2001, 2008).

Midnite Mine, Wellpinit, Washington, Northwest United States (closed)

The open pit site, which is located within the Spokane Indian Reservation, was designated as a Superfund site (No. 980978753) by the EPA. Environmental impacts include exposed uranium-bearing rock, acid rock drainage, and radioactive decay. Mine releases caused surface water, groundwater, soil, sediment, and air contamination. Highest risk receptors include recreational, commercial, or subsistence visitors, as well as Native Americans. Approximately 33 million tons of waste rock are estimated to be located at the site, which closed 30 years ago. A $193 million agreement between regulators and the mining company was reached in 2011 and reclamation activities are scheduled to begin at the site. Reclamation activities will include (1) filling in two open pits with waste rock, followed by a cover to inhibit radon gas exposure and prevent precipitation from entering the pits, and (2) decreasing the amount of groundwater that contacts COCs and treating water that is affected before it enters the Spokane River (EPA, 2006, 2008, 2011; *Seattle Times*, 2011).

Canyonlands Uranium Mines, Lathrop Canyon, Moab, Utah, Western United States (closed)

Environmental impacts include metals leaching from waste rock piles at these underground mines. Depending on local geology and climate, leaching or remobilization of metals could contaminate the surrounding land and water bodies (EPA, 2008).

Orphan Uranium Mine, Grand Canyon Village, Arizona, Western United States (closed)

Environmental impacts from the underground mine include radioactive wastes, which have contaminated surface water and soils. Local creek discharges exceeded the MCL for gross alpha radiation in drinking water (EPA, 2008).

Bluewater Uranium Mines, Bluewater, Cibola County, New Mexico, Western United States (closed)

Environmental impacts from the underground mine include contaminated well water and houses constructed of mine waste. COCs include uranium, radium, thorium, bismuth, lead, radon gas, arsenic, barium, manganese, molybdenum, selenium, strontium, and vanadium. Contaminant samples were collected before and after the completion of reclamation activities (EPA, 2008).

Yazzie-312 Mines, Cameron, Arizona, Western United States (closed)

Environmental impacts from the open pit mine include heavy metals and radionuclides in mine pit water, groundwater, and a local river system (EPA, 2008).

Arizona 1 Mine, Fredonia, Mohave County, Arizona, Western United States (operational)

The Arizona 1 mine began underground uranium mining operations in December 2009. The site was cited for Clean Air Act violations by the EPA in May 2010 (EPA, 2010). In a May 3, 2010, letter, the EPA states that a Finding of Violation has been issued because the mining company failed to apply for and obtain approval for mine ventilation, start-up of the mine, and testing methods for emissions compliance (EPA, 2010). The Arizona Department of Environmental Quality (ADEQ) also cited the mine for four major violations during its first inspection of the mine, 9 months after mining began, in December 2009 (ADEQ, 2009). The violations included a lack of pumps in the mine to eliminate water, a lack of rock permeability testing before mining, penetration of a lined waste pond by a pipe, and a different mining layout from previously submitted plans. The Mine Safety and Health Administration also cited the mine for 38 potential safety violations in 2010, including air quality and equipment safety violations, mislabeled power switches, and lack of firefighting equipment inspections (Jordan, 2010; Wise Uranium, 2011). Prior studies also reported that uranium and associated radioactive contaminants affected the survival, growth, and reproduction of nearby plants and animals (USGS, 2011).

White Mesa Mill, Blanding, Utah, Western United States (operational)

The uranium ore from the Arizona 1 uranium mine is transported to the White Mesa Mill in Utah for processing. The U.S. Fish and Wildlife Service identified 10 threatened or endangered species that may reside in the mill area. Springs and shallow and deeper groundwater aquifers surrounding the mill are used for drinking by Ute Mountain tribal members, farm animals, and hunted wildlife. Additionally, a deeper water well is the main source of drinking water for tribal members living approximately 3 miles from the mill in White Mesa, Utah. As the well is located lower than the mill, the tribe and tribe regulatory officials are concerned about possible groundwater contamination via tailing ponds leakage, as well as potential health effects from atmospheric deposition of uranium during day-to-day mill operations and storage (NRC, 2002; USGS, 2011).

McArthur River Mine, La Ronge, Saskatchewan, Canada (operational)

Although measurable uranium is released, concentrations at the largest underground mine in the world are below Canadian regulatory levels. During 2009, monthly effluent uranium concentrations did not exceed Canada’s screening objective of 0.1 mg/L. Furthermore, the mine released a total load of 20 kg of uranium in 2009, which comprised only approximately 30% of the load released in 2008 of 68.7 kg uranium (Environment Canada, 2009; World Nuclear Association, 2011).

Rabbit Lake Mine, Northeast Saskatchewan, Canada (operational)

In July 2008, the underground mine identified that a release from the containment area was captured by the excavated sump, with potential contamination from other areas contained in the drainage system surrounding Rabbit Lake. Groundwater wells were monitored for contaminant concentrations surrounding the mine.

Substantial reductions in effluent uranium concentrations and loadings were achieved by facility modifications and upgrades during 2007 and 2008. The mass of uranium discharged into the environment was approximately 45% lower than in 2008 (240 kg instead of 610 kg) and did not exceed Canada's screening objective of 0.1 mg/L uranium. However, 2009 results indicate that this Canadian mine still is the greatest uranium emitter. Continued improvements to the mining treatment process are expected to further reduce uranium emissions to the environment.

Canada's 2009 *Annual Report on Uranium Management Activities* stated that uranium effluent from all licensed facilities (including McArthur River and Rabbit Lake Mines) did not result in significant risk to the environment during 2009. Uranium effluent concentrations from all operating uranium mines and mills were below Canada's 0.1 mg/L screening level. Furthermore, total uranium loading to the environment in 2009 was reduced by 36% compared with the prior year. Canada notes that continued work in limiting hazardous substances in effluent includes the use of both pollution prevention strategies and appropriate pollution control technologies (Dagbert, 2008; Environment Canada, 2009).

Ranger Mine, Jabiru, Australia (operational)

The Ranger Mine is an open pit mine located in an ecologically valuable area in the Alligator Rivers Region of northern Australia, which is a World Heritage and Ramsar listed area. Indigenous populations in the area may also consume foods near the mine. Overall, the mine has met water quality protection standards, although certain aspects have not been assessed, such as the potential for COC concentrations that are below regulatory levels but still cause a potential risk to sensitive ecological receptors. Another concern is the sharp increase in precipitation during the region's monsoon season. Heavy rainfall could lead to increased mining discharge into waterways and to flooding in the surrounding area. Indigenous residents are concerned about mine discharges increasing COCs above their natural variability in the environment (Ferguson and Mudd, 2011; World Nuclear Association, 2011).

4.2.2.2 Mine and Mill Characteristics

After reviewing inactive, abandoned, and operational uranium mines in the United States, Canada, and Australia, we included characteristics of 11 uranium mines (listed in Table 4-1) in Table 4-4 for comparison with the proposed mine. These included 2 uranium mining areas in the northwest United States, 5 uranium mines and 1 mill in the western United States, and 3 international uranium mines (2 in Canada and 1 in Australia). Mining information was obtained from various sources, which are separated by site and provided in the reference section for this chapter.

Table 4-4. Characteristics of Selected Uranium Mines

Mine Name	Mine Location	Mine Type	Deposit Rock Type	Years of Operation	Mine Features	Total Ore or Waste Volume (tons per year)
Proposed VUI Mine and Mill	Pittsylvania County, VA	Underground or open pit/ underground	Igneous	2013–2048	Some tailings returned to mine as paste tailings, alkaline process mill, 8 (9?) 40-acre tailing storage areas	1,050,000 (years 2–21); 350,000 (yrs 22–35)
White King & Lucky Lass Uranium Mines	OR	Open pit	Igneous	~1955–1965	Excavation pit water, ponds, & stockpiles	138,146 (WK); 5,450 (LL)
Midnite Mine	WA	Open pit	Igneous	1954–1965, 1969–1981	Ore/protore stockpiles, 2 open pits, waste rock piles, backfilled pits	2.4 M U3O8 & 33 M waste rock; 2.9 M processed
Canyonlands Uranium Mines	UT	Underground	Sandstone	Not available	Waste rock piles	Not available
Orphan Uranium Mine	AZ	Underground	Sandstone & claystone	1956–1969	Mine buildings, hoist headframe, ore loadout area, & waste rock piles	Not available
Bluewater Uranium Mines	NM	Underground	Sandstone	1952–1966	Open pits, exposed overburden, waste rock & protore	Not available
Yazzie-312 Mine	AZ	Open pit	Not available	1956–1961	Water-filled open pit	Not available
Arizona 1 Mine	AZ	Underground	Breccia pipe	~1988–standby until 2009	Mine access shaft & headframe, warehouse, equipment washpad, septic system, impoundment; no ore processing on-site	~109,500 ore/yr
White Mesa Mill	UT	Mill	Not available	1980–current	Tailings ponds, ore piles; process ore from Arizona 1	4,000 milled/yr when open
McArthur River Mine	Canada	Underground	Sandstone	1999–current	Slurry loadout building, mined-out pit	9,350 yellowcake/yr
Rabbit Lake Mine	Canada	Underground (former open pit)	Gneiss	1975–2017 (projected)	Waste rock, lake tailings	1,900 U3O8/yr (2010)
Ranger Mine	Australia	Open pit	Unconformity	1980–2020 (projected)	Open pit, tailing pond (former open pit), ore stockpiles	6,000 U3O8/yr (2009)

4.2.2.3 Characteristics of Region

Table 4-5 presents factors used to describe the geography and characteristics of each location, including climate, terrain, and proximity to population centers. Data in the table show that the proposed Coles Hill location is wetter than all other uranium mines in the United States and warmer than the ones in Canada. Its nearby towns are of comparable size to those in other locations; however, the overall population density is generally higher than that surrounding other mines on the list.

Table 4-5. Geographic Characteristics of Selected Uranium Mines

Mine Name	Mine Location	Rainfall, Average in/yr	Climate Zone	Regional Terrain	Population (miles to town)
Proposed VUI Mine and Mill	Pittsylvania County, VA	45.4	Humid subtropical	Rolling hills	13,600 within 10 miles Chatham: 1,300 (9 miles)
White King & Lucky Lass Uranium Mines	Lakeview, OR	12–16	Highland (alpine)	Mountainous	2,785 (17)
Midnite Mine	Wellpinit, WA	18.5	Semiarid steppe	Mountainous	930 (8)
Canyonlands Uranium Mines	Lathrop Canyon, Moab, UT	5.59	Midlatitude desert	Rocky	5,046 (20)
Orphan Uranium Mine	Grand Canyon Village, AZ	8.44	Semiarid Steppe	Rocky	1,460 (2)
Bluewater Uranium Mines	Bluewater, NM	12.79	Highland (alpine)	Flat to rocky	918 (3)
Yazzie-312 Mine	Cameron, AZ	13.87	Semiarid steppe	Rocky	978
Arizona 1 Mine	Fredonia, AZ	10.5	Midlatitude desert	Flat to rocky	1,048 (35)
White Mesa Mill	Blanding, UT	12	Arid	Flat to rocky	3,162 (6)
McArthur River Mine	La Ronge, SK, Canada	14	Subarctic	Glaciated	1,076 (Pinehouse 186)
Rabbit Lake Mine	NE Saskatchewan, Canada	13.4 rain; 110 snow	Subarctic	Glaciated	1,216 (Wollaston Lake 25)
Ranger Mine	Jabiru, Australia	60.63	Tropical savannah	Flat to rocky	1,521

4.2.3 Selected Non-uranium Hard Rock Mines

Examples of non-uranium hard rock mines and mills are also included. A large number of minerals and metals are recovered from hard rock mines. The term hard rock mining simply implies that the economic deposit is part of an igneous or metamorphic geologic setting in which metals and minerals typically accumulate during rock formation. Similar metal and mineral deposits are also found in softer sedimentary rock, such as sandstone or loose sediments and soil; however, in general, these sedimentary metal and mineral deposits are derived from the erosion of igneous and metamorphic rocks. There are general similarities in the geochemistry of igneous rock types and the sediments derived from them, and for this reason metals and some minerals recovered from sediments are generally grouped in the hard rock category. The mining methods used for sedimentary deposits are very different from those used for igneous and metamorphic rock environments, but the milling and processing methods are generally similar. Many of the same metals and minerals can be present in different igneous rocks and in rocks formed in different locations, but these metals and minerals will occur in varying amounts. For example, the amount of uranium present in an igneous rock may not be enough to be economically viable for the purposes of mining, but small amounts may occur in an economically viable deposit of another metal, such as rare earths; in this case the uranium would be considered as a nuisance metal in the ore or it might be recovered as a byproduct.

It is reasonable to compare the environmental impacts (e.g., acid mine drainage or the release of metals to the aquatic environment) between mines, even those producing different commodities, which result from the geochemistry of the host rocks. Likewise, hard rock mining methods used are similar because of the geotechnical engineering properties of hard rock (igneous and metamorphic) deposits, and the environmental impacts of these activities can generally be compared between mines. However, although general similarities can be identified and related for hard rock mines and related mine processors, the geologic and geomorphologic environment at each mining site is unique; the examples and discussion presented herein can be considered only broadly in comparison to Coles Hill.

4.2.3.1 Non-uranium Environmental Impacts

The selected non-uranium hard rock mines caused varying amounts of environmental impacts and potential for human exposure. The major environmental impacts for each site are described in general terms below. These mines are all closed (see above), and some were operational during a period when environmental regulation was less stringent. Several are Superfund sites, indicating that they resulted in serious contamination. Their characteristics are summarized in Table 4-6.

Brewer Gold Mine, Jefferson, South Carolina, Southeast United States

The open pit gold mine was designated as a Superfund site (No. SCD987577913) by the EPA. Environmental impacts include acid rock drainage from several seeps that contaminated local drinking water sources. A treatment plant was opened in 1995 to treat discharge. Highest-risk receptors include recreational visitors to local creeks and nearby wetlands (EPA, 2005).

Galena, Cherokee County, Kansas, Midwest United States

The underground mining site was designated as a Superfund site (No. KSD980741862) by the EPA. Environmental impacts include heavy metal contamination in residential soils, shallow groundwater contamination in a residential drinking water source zone, and surface water impacts. Surface subsidence is also a major safety and hydrologic concern, with more than 1,500 open shafts and nearly 500 subsidence collapses in the tristate underground mining area (EPA, 2010; Kansas State University, 2009).

Oronogo-Duenweg Mining Belt, Joplin, Missouri, Midwest United States

The underground mining site was designated as a Superfund site (No. MOD98068281) by the EPA. Environmental impacts include heavy metal contamination in residential soils, groundwater, and surface water. Stream sediment exceeds sediment toxicity criteria, indicating significant aquatic risk. Approximately 200 local homes were supplied bottled water from the EPA because of contaminated private wells from December 1993 until 2006, when a public water system was completed (EPA, 1990, 2010).

Tar Creek, Miami, Oklahoma, Midwest United States

The underground mining site was designated as a Superfund site (No. OKD980629844) by the EPA. Environmental impacts include heavy metal contamination in off-site soil, groundwater, and surface water. Current and future residential populations may be at increased risk of exposure due to chat piles and mine waste tailings on residential properties and certain building foundations built on chat piles or waste rock. Additional public health concerns include mine subsidence from underground mine workings, acid mine drainage, consumption of fish and other wild food near the site, and contamination of the Neosho River and Spring River watershed (EPA, 2011; Kansas State University, 2011).

San Manuel Copper Mine, San Manuel, Arizona, Western United States

Environmental impacts from the former underground mine include unstable subsidence areas, which comprise multiple acres and are a long-term safety risk. Furthermore, two subsidence pits at San Manuel are also highly transmissive precipitation pathways, which may have modified hydrologic flow in the region. There are also cattle ranches near the tailings impoundments, which could pose a risk to the farm animals and food supply chain if the cattle are used for dairy or meat. There do not appear to be any protected species near the mine (Blodgett & Kuipers, 2002).

Henderson Molybdenum Mine, Empire, Colorado, Western United States

Environmental impacts from the former underground mine include two large subsidence areas at the base of Red Mountain. The subsidence areas caused unstable conditions on Red Mountain itself, with frequent avalanches due to the subsidence areas. Furthermore, the subsidence areas cause precipitation to flow into underground mine workings and increase the chance of flooding. Both large subsidence areas expanded to merge into one large zone along the western side of Red Mountain in 2001. It is anticipated that the effects of the subsidence affect the entire mountain from the base to the peak (Blodgett & Kuipers, 2002; Freeport-McMoRan Copper & Gold Inc., 2008).

Table 4-6. Characteristics of Selected Non-uranium Hard Rock Mines

Mine Name	Mine Location	Mine Type	Deposit Rock Type	Years of Operation	Mine Features	Total Ore or Waste Volume (tons per year)
Proposed VUI Uranium Mine/Mill	Pittsylvania County, VA	Underground or open pit/ underground	Igneous	2013–2038	Plan to return paste tailing to mine, multiple mill tailings storage units, alkaline processing	Estimated 1,050,000, years 2–21; 350,000, years 22–35
Brewer Gold Mine	SC	Gold open pit	Igneous & metamorphic	1828–1995	Open pits, ore heaps, waste rock pile, sediment control pond, plastic-lined pond	12 M (ore & waste rock)
Cherokee County (Galena)	KS	Metals open pit, underground	Not available	pre-1970s	Mine and mill wastes, water-filled craters, open shafts & pits	~650,000 (lead); ~2.9 M zinc
Oronogo-Duenweg Mining Belt	MO	Metals underground	Not available	Mid-1800s to 1970	Remnants from hundreds of mines & 17 smelters	~10 M (waste)
Tar Creek	OK	Metals underground	Not available	Early 1900s to 1970s	Heap piles & tailing ponds	~75 M (chat)
San Manuel Copper Mine	AZ	Copper underground	Quartz monzonite & granodiorite	1953	Open pit mines, heap leach, tailings ponds, smelter facilities & train line	> 700 M ore
Henderson Molybdenum Mine	CO	Molybdenum underground	Igneous (rhyolite & granite)	Ceased 1989; operated 3 mo/3 yrs	Mill site, 9 mi. of railroad track & tunnel	20,000 (Molybdenum–2007)
Geita District	Tanzania	Metals hard rock open pit & underground	Not available	2000–current	Open pits, waste piles, subsidence areas	~13 M (2003–2009 gold average)

4.3 Socioeconomic and Quality-of-Life Experiences

After characterizing the environmental impacts of mines and mills, we now consider socioeconomic factors that show relevance for the wider community living and working in the region around the Coles Hill location. Some of the more important factors for gaining potential comparable insights for Coles Hill are mines' and mills' proximity to an existing population center with an existing industry base not reliant on mining and milling. As shown, few mines have a nearby population similar to Coles Hill. .

Table 4-7. Geographical Characteristics of Selected Non-uranium Hard Rock Mines

Mine Name	Mine Location	Mine Type	Rainfall, Average in/yr	Climate Zone	Regional Terrain	Population
Proposed VUI Mine and Mill	Pittsylvania County, VA	Uranium underground or open pit/ underground	45.4	Humid subtropical	Rolling hills	13,600 within 10 miles Chatham: 1,300
Brewer Gold Mine	Jefferson, SC	Gold open pit	48.6	Humid subtropical	Coastal	704
Cherokee County (Galena)	Galena, KS	Metals open pit, underground	45.6	Humid subtropical	Plains	3,200
Oronogo-Duenweg Mining Belt	Joplin, MO	Metals underground	46.1	Humid subtropical	Plains	~50,000
Tar Creek	Miami, OK	Metals underground	43.1	Humid subtropical	Plains	14,437
San Manuel Copper Mine	San Manuel, AZ	Copper underground	12	Midlatitude desert	Flat to rocky	4,375
Henderson Molybdenum Mine	Empire, CO	Molybdenum underground	18.1	Highland (alpine)	Flat to rocky	355

As shown in Table 4-8, the mines included for comparison in this section are the Arizona 1, White Mesa Mill, Rabbit Lake, and Ranger Mines.[10] These mines and mills are listed in Table 4-8 with key descriptors. Much of the information in this section is gleaned from publically available research and interviews with stakeholders near these mines. Information from interviews has been incorporated as perspectives from other communities; their insights, however, have not been verified with research. The mines most similar to Coles Hill are Arizona 1, White Mesa Mill, and Ranger. The other mines and mills are, in many instances, either closed (and have used old technologies under very different regulatory conditions) or in towns in very remote locations in which communities were essentially created around the operations of the mine and mill. For example, in Rabbit Lake in Saskatchewan, workers are flown to the location to work; they leave the area to return to the communities in which they actually reside and participate in civic life. In these instances, community and economic development impacts are less relevant because the community's origin and purpose is completely dependent on the mine. Coles Hill, on the other hand, has an existing social, economic, and cultural base that will likely change in some fashion as a result of mining and milling operations.

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[10] For more detailed information on these mines and mills, please see Table D.3 in the Appendix.

Table 4-8. Mines and Mills for Socioeconomic Consideration

	Mine Name	Mine Location	Mineral Type Is Uranium?	Mine Adjacent to Mill?	Operating/ Closed	Population Density
	Proposed VUI Mine and Mill	Pittsylvania County, VA	Y	Y	2013–2048	13,600 (within 10 mi)
7	Arizona 1 Mine	Fredonia, AZ	Y	N	operating	1,048 (35 mi)
8	White Mesa Mill	Blanding, UT	Y	N	operating	3,162 (6 mi)
10	Rabbit Lake Mine	NE Saskatchewan, Canada	Y	Y	operating	1,216 (Wolloston Lake 25 miles)
11	Ranger Mine	Jabiru, Australia	Y	Y	operating	1,521

Social and economic impacts are mixed in these cases, and many of the impacts experienced are difficult to attribute to the presence of the mining and milling. There are seven themes pertaining to social and economic impacts that may provide useful insights for the communities within the study area to understand. They are the experiences related to

- job creation,
- environmental and community health,
- revenues to local governments,
- industry spillovers and local business growth,
- community reaction,
- lessons learned,
- socioeconomic trends, and
- community development and quality of life.

4.3.1 Jobs

Employment impacts from these mines range from 60 to more than 500, depending on the size of the mine and mill and fluctuations resulting from changes in the value of uranium and related production rates. One interviewee[11] reported that the management of the mine and mill works diligently to maintain as stable an employment as possible during down times, but fluctuations are inevitable.

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[11] All responses from interviews conducted by RTI are clearly noted in this text. None of these statements have been validated.

For the Arizona 1 Mine in Arizona near the Grand Canyon, companies currently mine only two sites in the county. Associated impacts on the local economy were described by interview participants as minimal (60–80 jobs). Uranium mining was more widespread in the area in the 1980s, but most of the mines closed in that same period. One participant reported that the closing resulted from a collapse in the uranium market during that period. All of the individuals we talked with, however, were encouraged by the projected economic benefits that would come with the potential opening of six new mines that would be worked for the next 42 years. One interview participant suggested these openings could bring up to 900 well-paying jobs to the area. Several individuals described mining jobs as good, well-paying jobs ($25 an hour) that can support families, in contrast to tourism-related work, which does not pay well ($8 an hour) and requires workers to hold multiple jobs to make ends meet. They also expected economic growth in some other sectors should the new mines open, such as in manufacturing (heavy equipment), mine engineering, and transportation. One individual also reported that a study had been done and that no drop in tourism was found after the mines were originally opened in the area in the 1980s.

When White Mesa Mill is operating at full capacity, it employs up to 150 people, and 65% of these employees are local Native Americans (Tetra Tech, 2009). According to a member of the community, White Mesa Mill is considered a major employer in the area. He claimed employment peaks at 120–150 employees at times of high production. During retooling periods, he relayed that the mill employed 50–60 people. He estimated that 80% of jobs tend to be local; 20% of employees are from outside the area. Another interviewee said there was no other significant industry there and mill is viewed positively because it is the main employer.

At Ranger Mill it appears that the Energy Resources of Australia (ERA) has positively affected the economy by creating 523 jobs as of 2010 (ERA, 2010). It is unclear how many of those positions are filled by individuals from the area. The company has attempted to provide a significant number of Aborigines with employment; 81 currently work at the mine. ERA has also developed an Aborigine Employment and Training Plan, which includes apprentices, clerical and lab assistants, and mill services personnel (Collins, 2000).

For Rabbit Lake in Saskatchewan, the region was described to have had a positive experience with uranium mining in the region, but it has come with social costs. Also, Rabbit Lake is in a very remote location, where the town was created to support the operations and employees of the mine.

4.3.2 Reported Community Impacts on the Environment and Health

Of the currently operating mines and mills selected for deeper social and economic insights, only one has reported leaks into the environment—Ranger Mine in Australia. Health effects have mainly occurred from water contamination in 2004. Contaminated water from a holding tank was accidentally discharged into the environment. Uranium levels were 400 times greater than the Australian maximum. Employees at the mine experienced issues such as skin irritations, nausea, and headaches due to the spill (ENS, 2004).

Other potential concerns at Ranger Mine are about the consumption of water by native plants and animals around the mine site, which leads to greater levels of radiation. Much of the Aboriginal population consumes a significant percentage of their diet from these native plants and animals. This issue has been flagged by the Office of the Supervising Scientist (OSS) to be one that needs reassessment (Supervising Scientist, 2010). At Rabbit Lake, there was also concern that cancer rates may have increased in nearby communities. Also, water quality was another concern among the First Nations people.

In the other locations, there was no documentation of environmental or health-related incidents. Interviewees from these communities confirmed this. In Utah, community leaders attribute this to the fact that they sat with national security and regulatory agency representatives to ensure that safety practices at the mill would be held to the highest standards. Because of negative experiences during the 1940s and 1950s with uranium mining, interviewees stated that they are very strict with environmental standards at White Mesa, especially in regards to the tailings and the aquifer. Thus, they report, today these concerns are not an issue in the community. One interviewee claimed it only becomes an issue when national environmental groups get involved. However, while some interviewees had little to no concern about mining and milling with modern technology and regulation, other interviewees thought it was only a matter of time before potential negative impacts were experienced.

For example, in Arizona, the U.S. Department of the Interior has halted new uranium mining in the region and is considering putting a moratorium on mining because of concern over its environmental impact on the Grand Canyon and neighboring tourist areas, despite little reported documentation of adverse effects. An engineering firm, Tetra Tech, studied the issue and found no environmental problems from uranium there. A few interviewees suggested that water from mines can leach into nearby Colorado River, but they also said that this was not a threat to the environment or health. None of the interview participants had heard of any direct health issues from the mines. However, one health official reported that a few people in the county, not living near the mines, had found higher levels of uranium in their system than would normally be expected. These findings were not connected to the mines because of the individuals' distance from the mine. Trucks coming from the mine are required to be covered. However, mineworkers were reported as not needing special clothes when working in the mine.

Some of the reported community and economic development impacts related to the environment are complicated by the fact that, in regions that have had a history of uranium mining dating back to the 1940s, it is hard for community representatives familiar with these experiences to disentangle environmental issues between the old mines and the current mining. Previous mining was described as being done hastily with limited technology; as a result, either waste products were abandoned at these mines and the government is now working to remove the waste (Rabbit Lake) or the experiences were detrimental at the time (Northern Arizona and Southern Utah) and significant public health and environmental impacts were experienced.

A final general concern expressed in an interview was for mine reclamation. This was said to be not often thought about, but is important to consider given some of the costs that can occur later if more cleanup is needed. Also, there was concern that the mining companies were increasingly managing more aspects of environmental impact statements and public consultations, which was seen as a conflict of interest that could lead to failures.

4.3.3 Impacts to Local Government and Public Service

From the U.S. mines, local governments reported positive impacts from mining and milling in the form of property taxes and income taxes. At White Mesa Mill, the county experiences most of the benefits from property taxes on the mill itself. The towns tend to see benefits through increases in payroll and sales taxes. In nearby towns it is the employees, not the mine or mill, that generate the most positive impact on local finances. Representatives from towns and counties did report fluctuations in their revenues depending on the price of uranium and how the mine or mill responds in terms of production. One interviewee thought this happened roughly in 5-year cycles. When there is a dip in the value of uranium, the interviewee stated, employment can go down to about 50 from a high of 200. In Arizona, from a tax and revenue standpoint, the fluctuation is harder for the nearby town because the county has a diverse enough source of revenues to cushion any fluctuation.

In Australia at Ranger Mine, the surrounding communities benefit from a community foundation. An interviewee stated that the community nets 1.275% of total production from the mine in the form of community services such as socioeconomic reforms, schools, and substance abuse prevention.

4.3.4 Spillover Impacts From Additional Industry and Business

Most communities reported additional business and industry impacts in two ways: through an increase to their service industry and through additional mines located nearby. The White Mesa Mill is the only slight exception. It receives uranium ore from nearby U.S. uranium mines and is situated in Blanding, Utah, for the purpose of being centrally located to these nearby mines. The mill also processes vanadium (V_2O_5) and processes vanadium ore from mines as far away as Saskatchewan, Canada. Most of the other communities interviewed did not attract other industries or businesses as part of the uranium mining and milling supply chain.

Others stated that the mines and mills were not a factor for attracting other businesses and that they had, in fact, experienced growth in the service sector. That said, representatives from these communities noted that there was not a significant employment base outside of mining and milling for the most part. Like many rural communities, the mines and mills with nearby towns are in an economic downturn. Many of the manufacturing and construction businesses in the region have closed. An interviewee in Arizona noted that tourism seems to be the only constant sector for employment—the Grand Canyon is nearby. Nonetheless, the areas around the mine are not destinations for tourism, so they do not necessarily get the major benefits from it. As one person described his town as a “windshield town” that people pass through on their way from one destination to another. In the town of Fredona, near the mine, one indication of this downturn is the decreased enrollment in schools.

4.3.5 Community Responses to Uranium Mining and Milling

Communities we examined had a mixed response in terms of how they embraced or rejected uranium mining operations. In some communities, mining seems to have created a culture and tradition that brings citizens together, while in Australia it has reportedly left parts of the community feeling disenfranchised and disempowered. At the Arizona 1 Mine, just 10 miles north of the Grand Canyon, these issues are hotly contested, mostly because of the mine’s proximity to the national park. The U.S. Department of the Interior is currently finalizing an environmental impact statement and will make a decision by December 2011 on whether it will place a 20-year moratorium on uranium mining in the region.

Near White Mesa Mill, interviewees reported deep community pride in their history of uranium mining during World War II, despite the negative environmental and health impacts at the time. Others claimed that local community members tend to be highly supportive or mining and milling, but fractures in the discourse occur when outside groups enter local discussions about mining and milling.

In Australia, the overall community perception of the Ranger Mine is uncertain, but some groups are very concerned about the long-term environmental effects. Some groups are calling for permanent closure of the mine. It appears that the most immediate concern for residents and indigenous groups is water contamination and waste management issues (MacPherson, 2011). Conversely, some are in favor of the mine because of the financial resources the operations supply for residents. No agreement has been reached about which opinion prevails in the area. It was reported that the local community near the mine never really had a voice in the decision because the region is very remote and thus underrepresented in the national government. This caused feelings of disenfranchisement.

4.3.6 Other Insights and Reported Lessons Learned

Interviewees were asked about insights they would offer to other communities considering uranium mining and milling. Below are points shared by these community stakeholders to their counterparts in the surrounding region of Coles Hill.

Two interviewees stated that it is important for owners and managers of the mine to be local to the community. In their opinion, the quality of the mining operations depends on who runs the mine; when the mines and mills are owned and operated by companies or the federal government, operations and community members are disconnected from each other. Local owners and operators, in their experience, tend to be more transparent and responsive to community needs. Distant owners provide a lot less information about related activities. When owners are relatively nearby, operations are more likely to done correctly. These interviewees stated that good, local management ensures proper operations and upholding of environmental quality and standards.

Another interviewee said that it was very helpful in his community when residents and stakeholders take the emotion out of the issue and really focus on the facts and risks instead. In these kinds of issues, community members can tend to listen to and feed misinformation. He strongly recommended that the community identify facts and risks and base decisions on those facts.

A strong advocate and supporter for mining and milling in another community recommended that those in the Coles Hill region never discount the environment. The participant said the community should set up the mechanisms and monitor air and water quality itself to satisfy itself with the facts about any changes to the local environment. Even though the interviewee has full confidence in the National Regulatory Commission, he strongly stated that self-monitoring is important to community.

4.3.7 Socioeconomic Impacts of the Mine

Analysts at RTI also reviewed trend data for socioeconomic conditions in some of the mining and milling communities to track what these areas have experienced in terms of data points such as housing costs, population change, and employment rates. The data reported in this section cannot be attributed in any way to mining and milling in these communities. Instead, the section describes socioeconomic trends in these communities over a time period in which mining and milling has occurred. Many other factors, such as the recent recession, local economic-impact events such as a plant closing, and other ongoing occurrences, feed into a community's socioeconomic trends. Nonetheless, this section describes these trends for other mining and milling communities.

For the Arizona 1 mine in Mohave County, population increased slightly at 2% from 2008 to 2010 (Tetra Tech, 2009). Home prices have seen a significant 51% increase from $118,393 in 2000 (2009 dollars) to $179,300 in 2009 (Tetra Tech, 2009). This time frame also coincides with the surge in housing prices in the United States. However, according to BLS (2007 & 2011) data, the number of established businesses and total employment have fallen from 2007 to 2010 by 15% and 4%, respectively. The average weekly wage here has remained stagnant since 2007 when inflation is accounted for. In real dollars, weekly wages increased by 4% from $599 to $623. It is important to note, though, that this time frame also coincides with the recent economic recession.

At White Mesa Mill, housing prices have almost tripled since 1970 (using constant 2009 dollars), before the White Mesa Mill was constructed. In 1970 the median home price was $38,106, in 2009 dollars, for San Juan County. In 2009, after the mill had been in operation intermittently for several years, the median home price was $100,500 in 2009 dollars (Tetra Tech, 2009; U.S. Census, 1970). Again, this time frame coincides with national trends in housing value increases. Population has also increased somewhat. There were 9,606 inhabitants in 1970; as of the 2010 U.S. Census, 14,746 people called San Juan County home. Economic data for the county from the BLS were accessed back to 2001, and the region seems to be experiencing economic growth. Even adjusting for inflation, the average weekly wage has increased by 16%. While the population has increased by only 2.3% since 2000, the number of total persons employed has increased by 10% and the number of firms in the county has also risen (BLS, 2001, 2010).

4.3.8 Community Development and Quality of Life

This section described community and quality-of-life factors that were revealed in publically available reports and interviews. In many instances it is not possible to attribute these reported impacts to mining or milling. Nonetheless, we report experiences that these communities have faced in recent years that relate to the quality of life of those living near the mining and milling operations.

In several of the mine and mill locations, indigenous populations are most affected by the mining and milling. In Saskatchewan, the First Nations groups were said to live in closest proximity to Rabbit Lake Mine. An interviewee stated that the First Nations peoples are also some of the population segments least well equipped to deal with these issues because of reported higher incidences of social and economic difficulties compared with national averages. It was reported that the mine has brought jobs to the indigenous population in nearby communities, but many workers commute from towns and cities farther south of Rabbit Lake. The First Nations peoples expressed some concerns, such as how mining affects traplining (catching animals), an economic mainstay for their families and for local commerce.

At Ranger Mine, the Aboriginal populations also live nearby. The people who have been displaced by the mine’s operations receive annual land rental payments, and about $800,000 is also donated for the purpose of sponsorships in the local community (Collins, 2000). Major social issues, such as alcoholism, continue to persist today for the Aborigines. These issues were present before the mine opened as well. This is also supported by the 1977 Fox Report, which was the initial impact study commissioned to assess the impacts of the Ranger Mine (Collins, 2000). Alcohol abuse has led to a variety of other issues, including low education attainment and substantial health issues. These issues cannot be linked with the existence of the mine, of course. On a different note, according to a social impact study completed several years ago, the mine’s operations have contributed to the local economy, but overall employment has not increased even though greater opportunities exist now (Collins, 2000).

In terms of social impact, according to interviewees in Saskatchewan, the mining lifestyles in the region were said to be disruptive to communities. It was described as somewhat erratic, with many workers scheduled for two weeks on the job followed by two weeks off. In the off time, workers were said to be flush with cash and perhaps indulging in heavy or binge drinking.

In other U.S. communities, community experiences have generally been viewed more positively, with increased civic engagement in activities like Little League coaching and other kinds of volunteering. It was reported that this involvement can have a significant positive impact on a community with a relatively small population. There were also no reported issues or negative impacts on the nearby tourism or agriculture industries. One interviewee said, “There is so much uranium around that if you are walking around you’ll get it anyway.” The participant stated that management just needed to make sure the dust from the mine was managed, “but if it is in the ground, it is in the ground.”

Near the White Mesa Mill, the town of Blanding, Arizona, has had a significant increase in nonviolent crime since 2005, according to the FBI’s Uniform Crime Reports (FBI, 2005, 2010). Of course, determining the root causes of this increase in crime is outside the scope of this report. Community stakeholders here shared that one of their biggest community challenges as a result of the mill is managing the housing supply and stability in the housing market. Fluctuations in uranium prices can affect this market significantly and swiftly.

4.4 Summary

The potential impacts of developing and operating a uranium mine and mill include a combination of environmental and socioeconomic effects, and both of these affect residents’ quality of life. These impacts result from the complex interplay of various factors. Case studies can provide valuable insights into the experiences of other communities with uranium and other hard rock mines. They can also be useful in providing context for assumptions used by RTI in economic and environmental modeling.

Key factors contributing to environmental impacts include characteristics of the mine, such as mining and milling methods, management options, and volume and chemical makeup of ore. Regulatory standards affect pollutant releases, ands geographical characteristics of the region—such as rainfall, climate zone, and regional terrain—shape how the pollutants are dispersed through the environment. Distance to population centers and population density consequently determine human and ecological exposures to constituents of concern (contaminants are chemically reactive and can potentially cause cell damage). Common environmental impacts include presence of particulate matter and radon gas concentrations in the air, groundwater and surface water contaminated with radionuclides and heavy metals and associated radiation, and subsidence issues and contaminated soils and sediments.

Some of the more important factors for gaining potential comparable insights for Coles Hill are operational mines' and mills' proximity to an existing population center that has an existing industry base other than mining and milling. Although no uranium mine or mill compared with the Coles Hill location in terms of its population and existing industry, four mines and mills were determined to be most relevant for comparison. They are the Arizona 1 Mine (United States), White Mesa Mill (United States), Rabbit Lake Mine (Canada), and Ranger Mine (Australia).

On the whole, social and economic impacts are mixed in these cases. Furthermore, many of the impacts experienced cannot be directly attributed to the presence of mining and milling. This case study review did reveal seven themes pertaining to social and economic impacts relevant to other communities' experiences: job creation, environmental and community health, community development and quality of life, revenues to local governments, industry spillovers and local business growth, community reaction, lessons learned, and socioeconomic data-driven trends.

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Section 4.1.1

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5

Environmental, Human, and Ecological Health Impacts

Minimizing impacts to human and ecological health is clearly an important objective for the community and was identified as one of their key values (Section 1). In this chapter, we evaluate potential implications of the proposed Coles Hill uranium mine and mill for human and ecological health. The general environmental setting is discussed along with its importance in controlling contaminant mobility from the mine and mill and possible resulting environmental impacts. We next consider chemicals of potential concern such as radiological elements and heavy metals that may be released as a result of mine/mill activities. The following section examines the potential transport of these chemicals away from the facility in the various environmental media, including air, soil, surface water, and groundwater. The last section considers possible impacts to human health and ecosystems that might result from such contaminant releases and transport.

Analyses presented in this section are necessarily preliminary. Limited site-specific information is available to characterize many of the controlling environmental processes. Furthermore, the facility configuration and processes are as yet undetermined. If Virginia allows uranium mining in the state, comprehensive environmental and risk assessments will be needed to quantify potential risks and impacts associated with the proposed facility. These assessments will need to be based on additional site characterization data and site-specific analyses. Nevertheless, evaluations in this section provide a general characterization of potential contaminants and their mobility in the Coles Hill environmental setting and possible human and ecological health impacts. The results identify possible environmental concerns for the community to consider in their evaluation of the proposed mine and mill. This section also provides suggestions for additional site characterization and analyses that will increase the ability to predict and monitor the potential for negative environmental outcomes associated with the facility.

The Coles Hill ore body was discovered in the late 1970s, and Marline Uranium Corporation conducted a series of environmental studies documented in Marline (1983). Data from these studies have been used in this section where available and appropriate. In addition, Virginia Uranium, Inc. (VUI) has implemented more recent environmental studies, data from some of which were provided to RTI and are presented here. Other VUI studies are ongoing and listed herein; results from these studies are anticipated in 2012. Additional information in this section was derived from literature sources as referenced or was based on independent RTI analyses.

5.1 Environmental Setting

This overview of the environmental setting for the proposed mine and mill includes discussion of the site location, topography, geology, uranium ore configuration, climate, hydrology, hydrogeology, and land use. Characteristics of the environment such as rainfall, wind patterns, surface water runoff, and surface water flow largely control the migration of contaminants away from the proposed mine and mill.

5.1.1 Location

The proposed uranium mining and milling site is at approximate latitude and longitude coordinates of 36°52′34″N, 79°18′02″W and near the address of 644 Coles Road in Chatham, Pittsylvania County, Virginia. As shown in Figure 5-1, the site is about 6 to 7 miles from the towns of Chatham (to the southwest) and Gretna (to the northwest). These relatively rural towns have populations between 1,000 and 1,500 people (2000 Census). The area is within the Danville, Virginia, Metropolitan Statistical Area; the city of Danville with a 2000 population of about 43,000 is approximately 20 miles south of the site.

The Coles family and their ascendants have lived on the land overlying the uranium deposit since the late 1700s. Several distinctive historic structures are on the property, including a schoolhouse and the Coles family home, where the VUI president and CEO resides. Conservation easements protect more than 600 acres around the family estate and prevent surface disturbance of the land, including exploratory drilling and mining (Figure 5-2). The protected area is located between known north and south uranium deposits, which have been determined by VUI to have economic value. Deposits underlying the protected area (between the north and south deposits) have not been assessed; if these deposits are economically viable, it would be possible to mine them through the subsurface as long as disturbance to the areas under conservation easements can be avoided. Several areas of the property are still used for agriculture, predominantly for cattle and hay. Coles Road is gravel and passes through the property (Figure 5-2); the road is an easement of the State of Virginia. The surrounding area is rural and contains farmland, woodland, and sparsely populated residential and commercial properties. White Oak Mountain Wildlife Management Area is located approximately 5 miles south of the site.

5.1.2 Topography

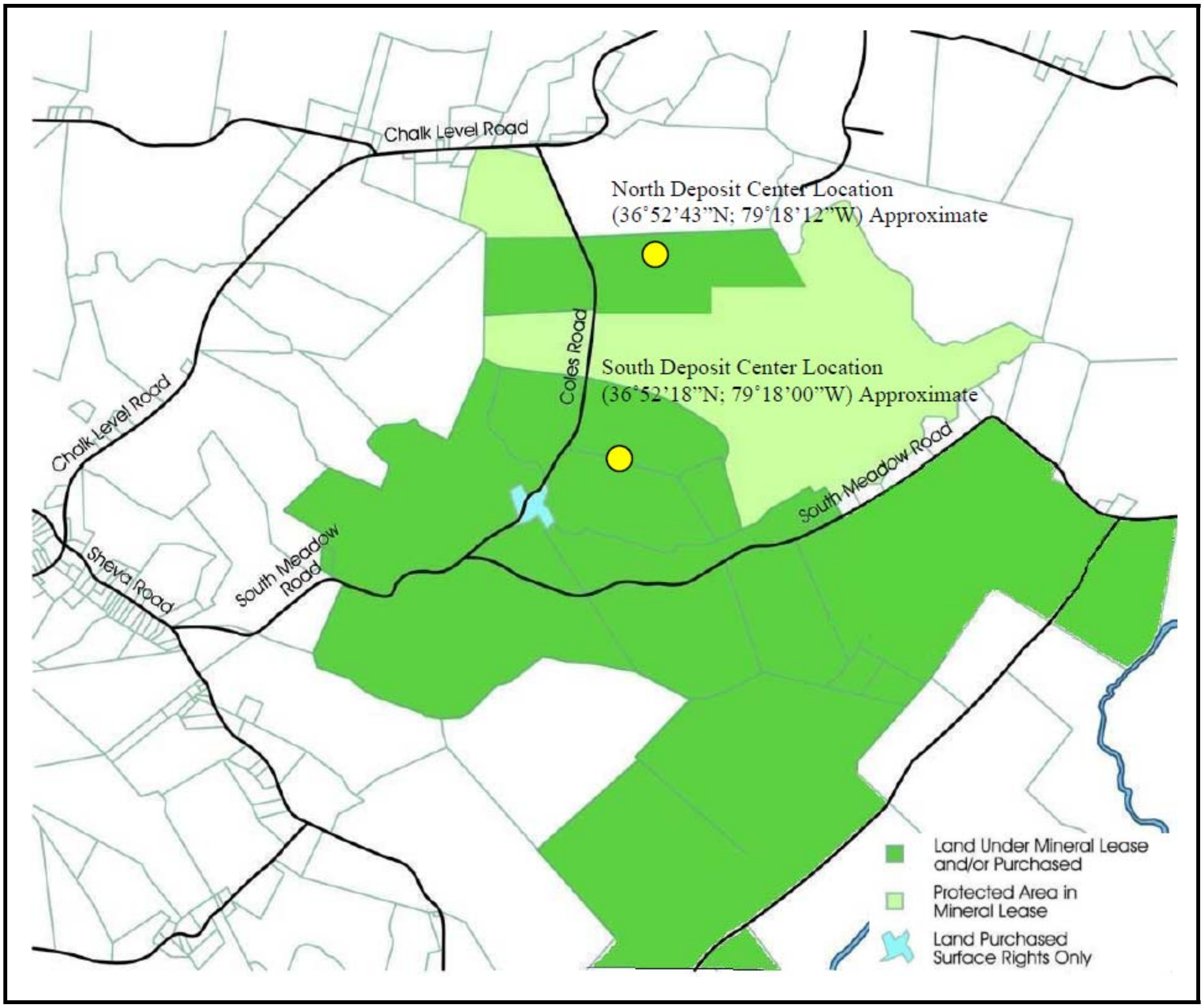
The site ranges in elevation from a low of approximately 560 feet above mean sea level (MSL) at Mill Creek to approximately 680 feet above MSL at the top of Coles Hill. Figure 5-3 provides a topographic map of the site. The topographic contour lines in brown represent elevations in 20-ft increments, state roads are solid double lines in black, streams and lakes are solid lines in blue, and vegetated and forested areas are shaded. This figure also shows the approximate surface outline of the known ore bodies.

5.1.3 Physiography, Geology, and the Uranium Ore Deposit

The proposed mine and mill are located within the Piedmont geologic province of Virginia, which consists primarily of igneous and metamorphic rocks between the coastal plain to the east and the Blue Ridge to the west (Figure 5-4). Several Triassic basins, also shown in Figure 5-4, are found within the Piedmont and originated as sedimentary deposits formed in basins deeply faulted into the igneous and metamorphic rocks during the Triassic period (around 200 million years ago). The Coles Hill deposit is on the edge of the Danville Triassic Basin and on the margins of the Chatham Fault, which defines the local boundary between igneous and metamorphic rocks of the Piedmont and metamorphosed sedimentary deposits of the Triassic basin.

Figure 5-1. The Proposed Uranium Mine and Mill Area

Figure 5-2. Site Property and VUI Land Holdings



Source: Lyntek Inc., 2010.

Figure 5-3. U.S. Geological Survey Topographic Map Surrounding Site

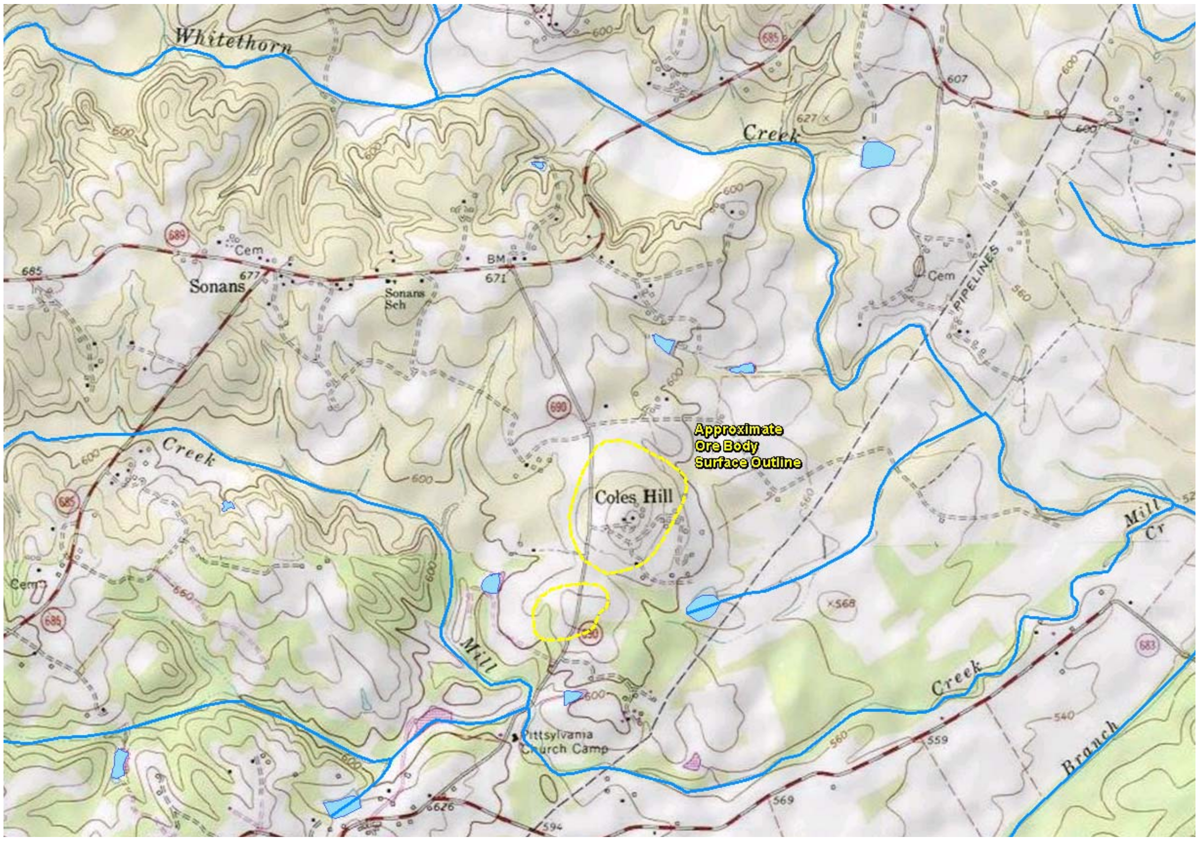
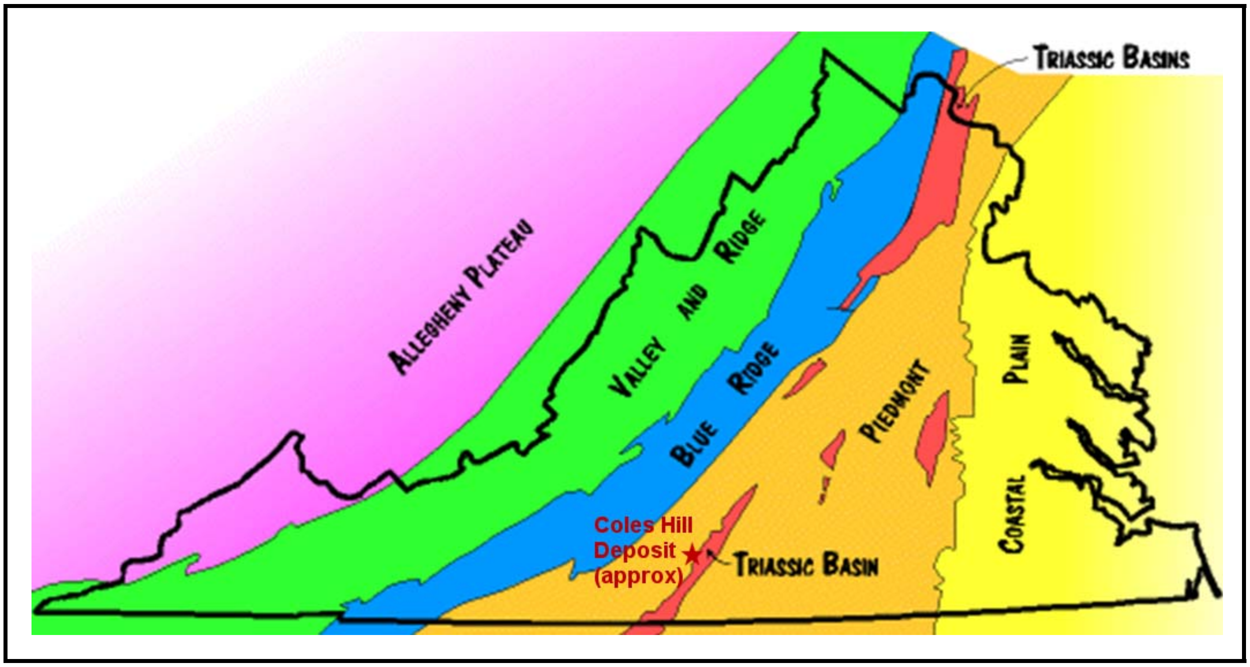


Figure 5-4. Physiographic Regions of Virginia



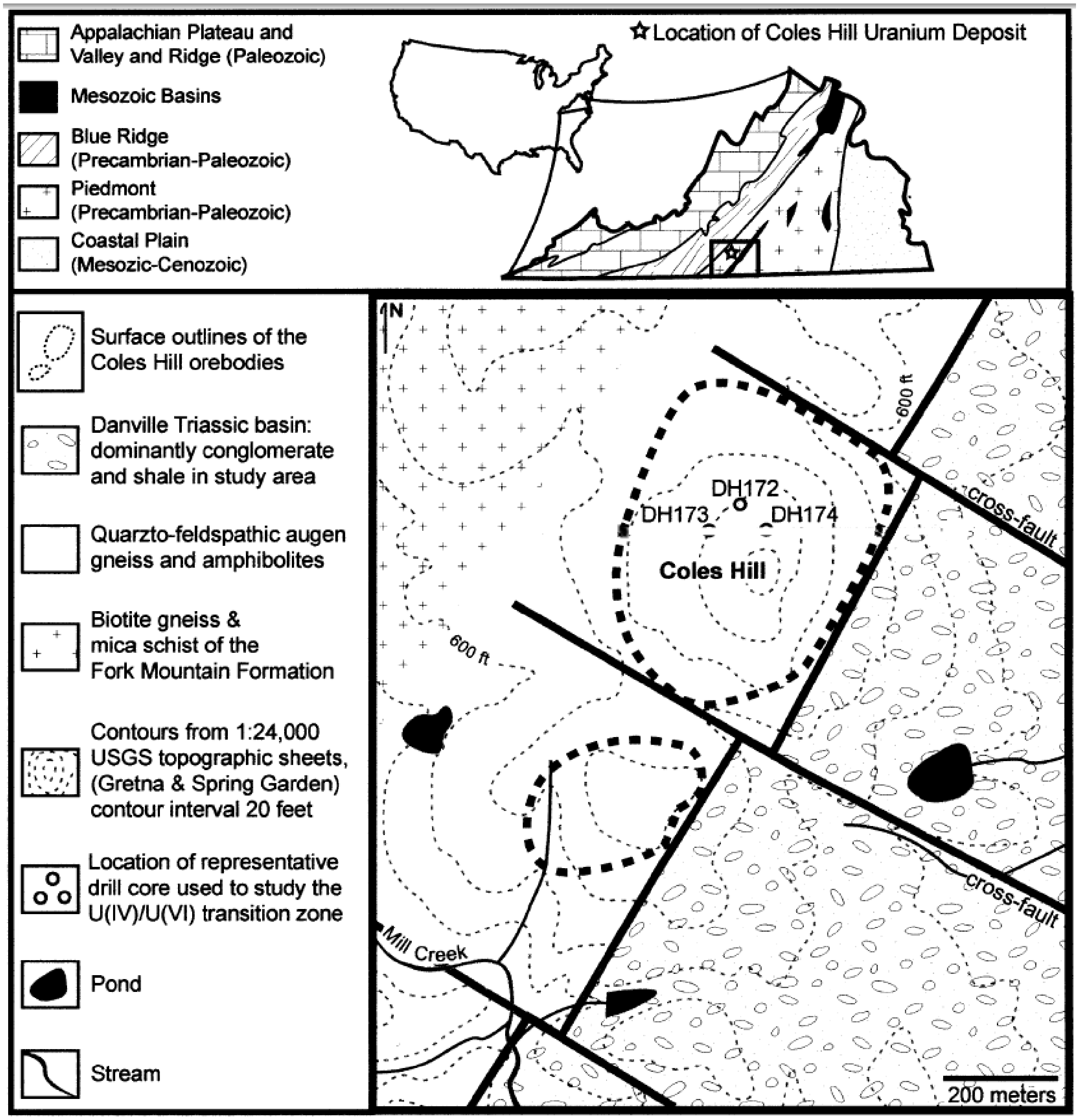
Source: http://csmres.jmu.edu/geollab/vageol/vahist/.

As shown in Figure 5-5, the Chatham Fault divides Precambrian granitic rocks to the west from the metasedimentary Triassic deposits to the east. Figure 5-5 also shows the approximate surface outline of the defined ore deposit. The ore bodies plunge downward approximately 60 degrees to the southeast and extend to depths greater than 980 ft (Jerden and Sinha, 2003). The north and south ore bodies may connect at depth; however, the potential ore underlying protected lands has not been assessed (Figure 5-2). The ore body is defined as rock exceeding a uranium concentration of 0.025% U_3O_8 (Lyntek, 2010). The extent of the ore body depends on the assumed economically viable concentration. Figure 5-6 provides a vertical cross-section showing the approximate ore body location and the surrounding geologic setting. Should the mine be permitted, the Coles Hill ore bodies (the known economic reserves) shown in Figures 5-5 and 5-6 would be extracted from the subsurface.

Example bedrock samples from exploratory drilling cores are shown in Figure 5-7, a photograph taken at VUI during a September 2011 site visit. The bedrock layers shown in these samples (from left to right) are as follows:

1. Upper layer—Triassic conglomerate, sandstones and shales
2. Chatham Fault
3. Footwall of ore body
4. Main ore body—Gneiss mylonitic leatherwood granite with amphibolites
5. Leatherwood biotite gneiss with pink feldspar, below main ore body
6. Fork mountain schist

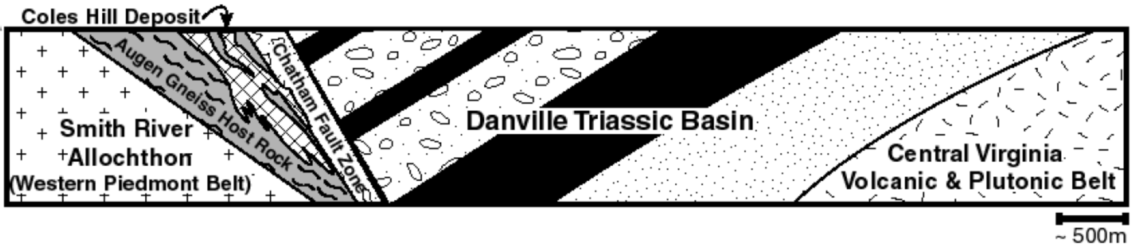
Figure 5-5. Surficial Geology and Ore Body Outline



Note: The Chatham Fault and associated cross faults are shown in straight, solid black lines.

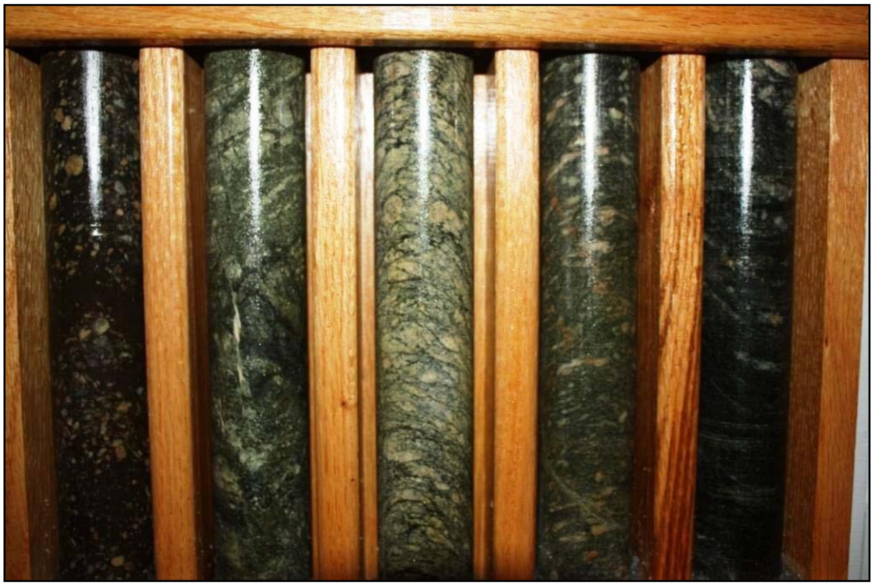
Source: Jerden and Sinha, 2003.

Figure 5-6. Vertical Cross-Section Showing Surrounding Geology and Approximate Ore Body Configuration



Source: Jerden and Sinha, 2003.

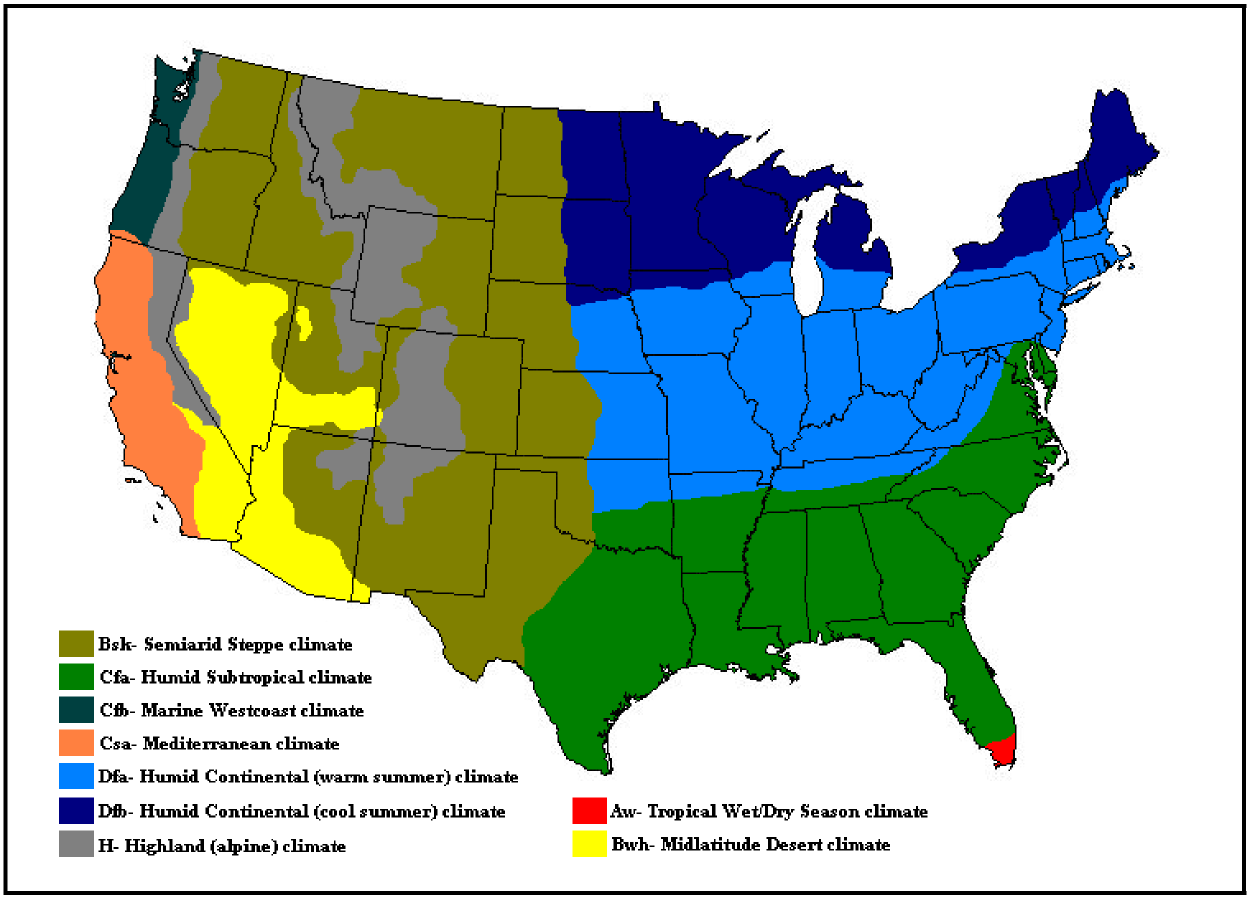
Figure 5-7. Photograph of an Example Rock Core at VUI Ranging from the Upper Layer on Left to the Lower Layer on the Right



5.1.4 Climate

The Köppen-Geiger climate classification (Figure 5-8) identifies the site as humid subtropical (Cfa) with hot, humid summers and mild to cool winters (Encyclopedia Britannica, 2011). Based on climate summary information available at http://www.usclimatedata.com, the average low temperature in January, the coldest month of the year, is 23°F, and the average high temperature in July, the hottest month of the year, is 87°F. Monthly precipitation ranges from an average high of 4.4 inches in March to an average low of 3.3 inches in February, November, and December (Figure 5-9). Based on climate summaries available at http://www.sercc.com/ for the period from 1922 through 2010, snowfall is greatest in January with an average of 3.8 inches. The number of days of precipitation in an average month ranges from a high of 11 days in May and July to a low of 8 days September through November. Average annual precipitation totals 44 inches.

Figure 5-8. Climate Zones of the Continental United States

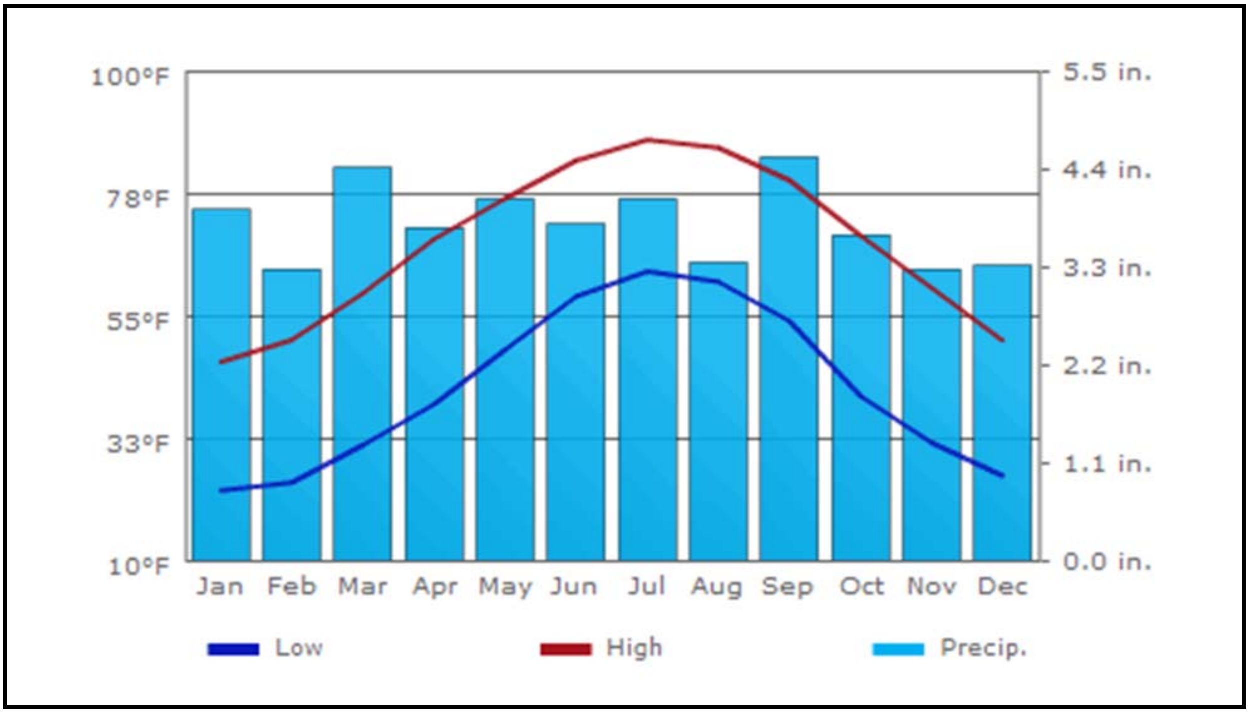


Source: Wikipedia, 2009.

Figure 5-10 shows the maximum recorded daily rainfall over the historical record (1922 to 2010) compared with the average. Table 5-1 lists the daily precipitation frequency for Danville, Virginia. Based on this table, the daily precipitation likely to occur once every 100 and 1,000 years are 7.9 and 11.9 in/day, respectively. Figure 5-10 indicates that two events have exceeded the 100-year event (7.9 in) over the 88-year measurement period. A more complete precipitation frequency table that provides precipitation frequencies for other time spans (e.g., 1 hour) is available in Appendix E.

Wind speed ranges from an average high of 9.0 mph in March to an average low of 5.8 mph in August (Town of Chatham, 2011). The predominant wind and storm movement in the area is from southwest to northeast. Tropical storms emanating from the Atlantic Ocean or Gulf of Mexico cause occasional extreme winds and precipitation (Connors, 2008).

Figure 5-9. Average Temperature and Precipitation in Chatham, Virginia



Source: U.S. Climate Data, 2011

Figure 5-10. Historical Extreme Daily Precipitation Events Compared with Average

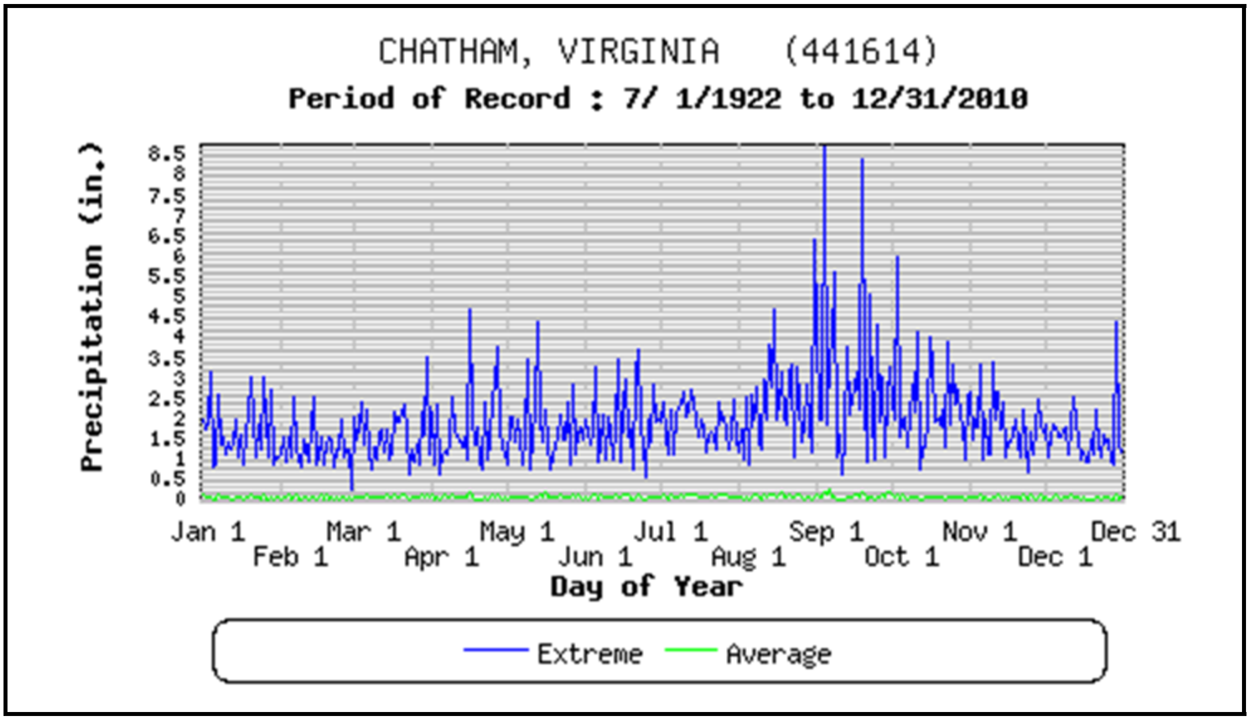


Table 5-1. Daily Precipitation Frequency Table for Danville, Virginia

Years	Daily Precipitation (in)
1	2.75
2	3.33
5	4.23
10	4.97
25	6.05
50	6.96
100	7.94
200	9.01
500	10.57
1,000	11.88

Source: http://hdsc.nws.noaa.gov/

5.1.5 Hydrology

Surface water originating from the site area flows regionally to the southeast and ultimately to the Atlantic Ocean. The ore body is located within watersheds for Mill Creek and Whitethorn Creek to the south and north of the ore body, respectively (Figure 5-11). Waters from these watersheds flow into Banister River approximately 3 miles east of the ore body. The mineral lease land parcels extend into watersheds for Dry Branch (in red on Figure 5-11) and land that slopes directly to Banister River. Banister River flows into Banister Lake and subsequently into Kerr Reservoir. This river system exits Kerr Reservoir, enters Lake Gaston, crosses into North Carolina, and continues to flow to the southeast into Albemarle Sound and the tidewaters of coastal North Carolina. Several small, human-made ponds are also located at and near the site. Multiple springs are also present, including adjacent to Coles Road just south of Mill Creek.

The proposed mine and mill are in a climatic region with relatively greater rainfall than many other uranium mines in the United States, particularly mines located in the southwest (see Section 4). This characteristic has raised concerns among several community and environmental groups about the potential for flooding and accidental releases and possible challenges in containing wastes and other contaminants on the site. Figure 5-10 provides the extreme daily precipitation events over the historical record. Figure 5-12 shows the extent of the 100-year (1% probability) flood zone in the area. Any facilities that handle potential contaminants would clearly need to be located at elevations greater than the area of potential flooding. Furthermore, stormwater management facilities would need to be designed to minimize runoff and erosion across the facility, particularly areas where ore byproducts and wastes are handled.

Figure 5-11. Surface Water Drainage Systems, Including Whitethorn Creek (Purple), Mill Creek (Green), and Dry Branch (Red)

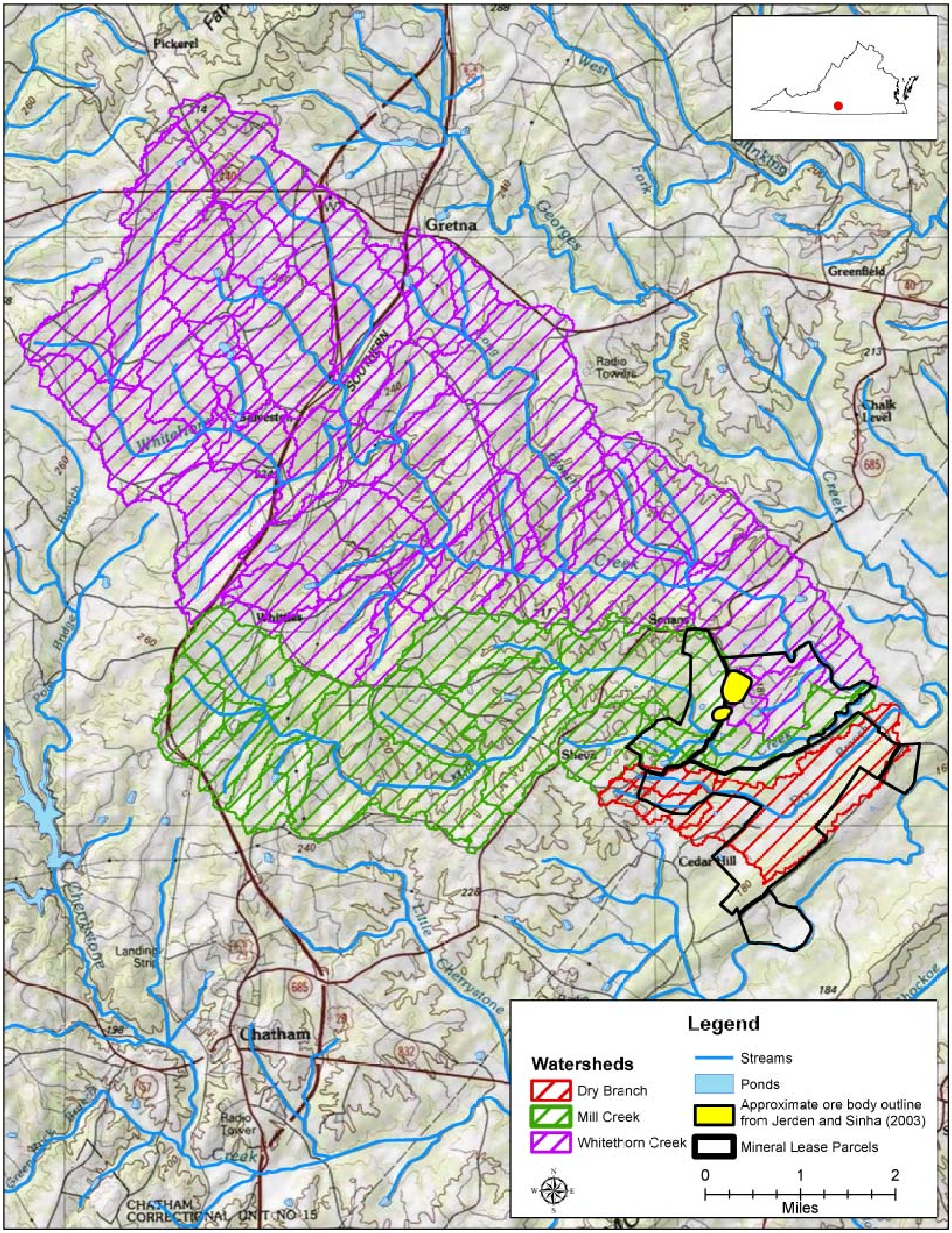
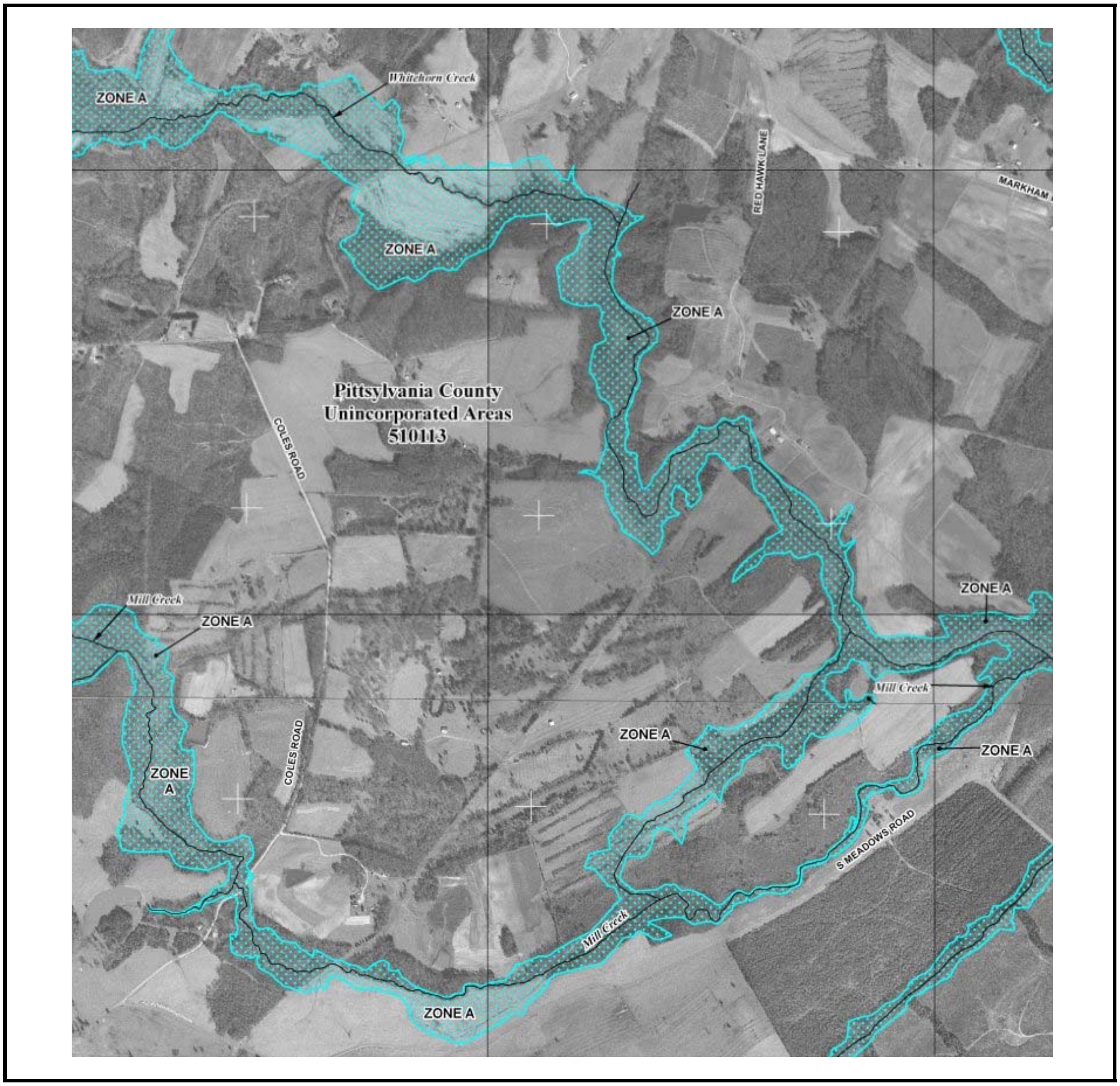


Figure 5-12. Extent of 100-Year Flood Zone in the Site Area



Source: http://www.fema.gov/

5.1.6 Hydrogeology

Groundwater systems of the Piedmont can generally be described as having three layers: (1) soil; (2) weathered rock, also called saprolite; and (3) fractured bedrock. In most areas, soils are formed from the weathering of underlying bedrock, and there is a transition zone of saprolite between intact rock and fully formed soil (Daniel, 1996). The upper zones supply groundwater originating from infiltrating precipitation to the bedrock fracture system. The saprolite and soils overlying fractured bedrock often maintain relict features of the underlying rock such as fractures or foliation. Such relict features can influence groundwater flow patterns, leading in some cases to preferential flows aligned with the orientation of relict features (i.e., anisotropy). According to Marline (1983), depths to groundwater in upland areas such as in the vicinity of the ore body range approximately from 30 to 78 ft below the surface. Depths to groundwater decrease and reach the land surface at streams and springs.

Fractures in the bedrock occur with highly variable density and geometric configurations. In general, fractures occur with lower frequency at depth as the weight of overlying rocks and sediments increases. Significant flow can nevertheless occur at deeper and shallower depths within less weathered fractures (weathering can tend to close the fractures). Fracture density generally increases in areas with faults (Seaton and Burbey, 2005). Patterns of groundwater flow in fracture systems can be very difficult to predict because of the variable interconnectivity of individual fractures. This variability accounts for the fact that water wells installed in fractured bedrock can have widely divergent productivities even when located in close proximity (because some wells intersect more productive fractures). Indeed, some relatively deep wells installed at the site (>100 ft deep) have essentially been dry, because they did not intersect productive fractures (Marline, 1983).

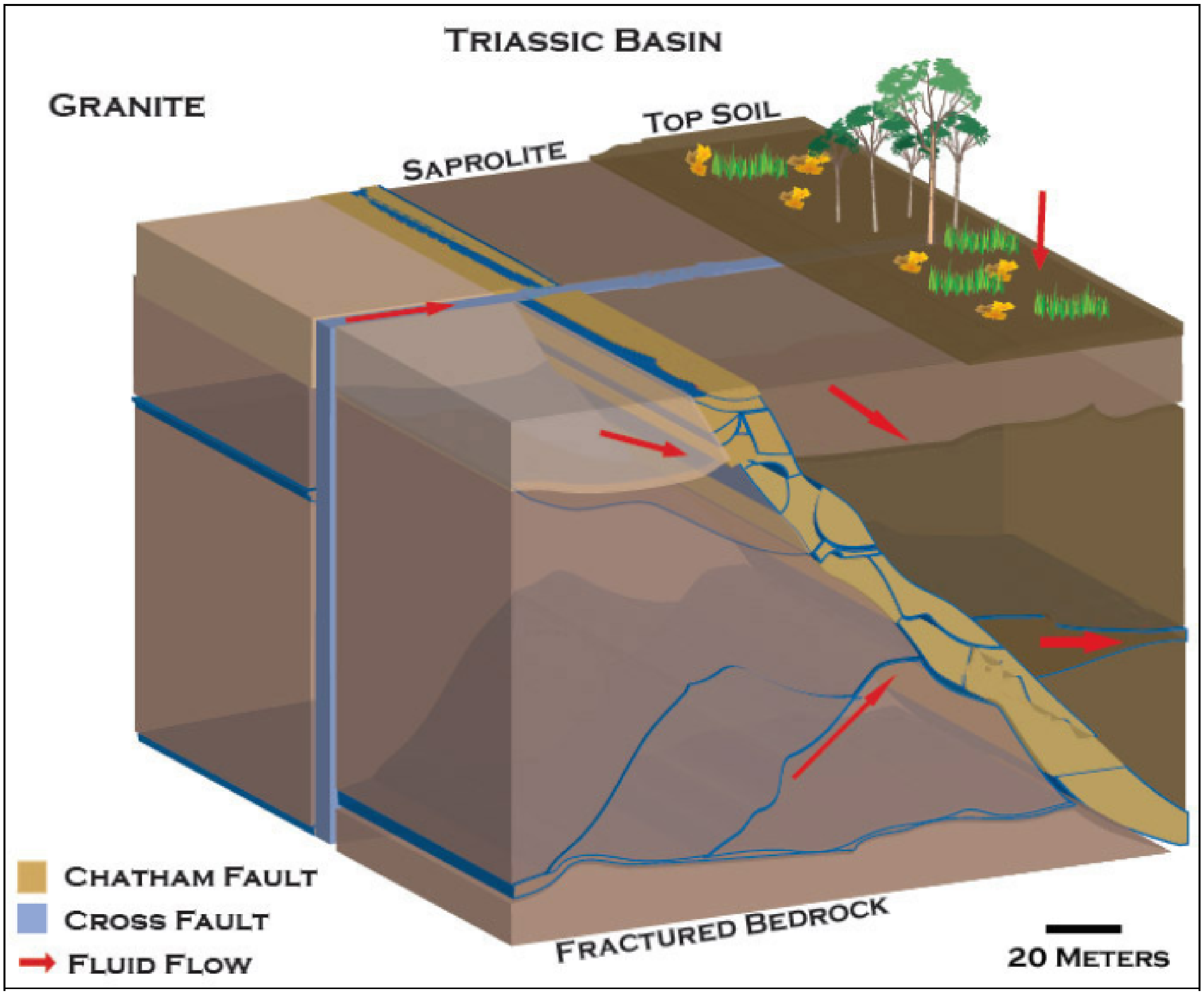
As previously indicated, the Chatham Fault forms a boundary between the igneous and metamorphic Piedmont formations and the Triassic basin metasediments. This fault zone is expected to have a greater density of fractures. Fractures may be sealed through the precipitation of minerals after the fracture forms (secondary mineralization/weathering). Therefore, it is currently unknown whether this fracture zone transmits relatively greater volumes of water than much of the surrounding area. A series of cross faults intersects the Chatham Fault and may provide further pathways for groundwater flow. Figure 5-13 provides a schematic illustration of the groundwater system at Coles Hill (Gannon, 2009).

Groundwater flow in the Piedmont generally occurs from upland recharge areas toward discharge points, including streams and springs. Groundwater usually flows within catchments defined by surface water bodies such as those depicted in Figure 5-11 for the Coles Hill setting. Accordingly, there is likely a groundwater divide somewhere in the ore body vicinity; north of this divide, groundwater flows to Whitethorn Creek, while south of this divide groundwater flows to Mill Creek. It is possible but not common in the Piedmont setting for groundwater to flow between surface water catchments. Groundwater flows can deviate from these typical patterns, for example, in the presence of significant groundwater extraction. Groundwater recovery for typical residential use is in most cases insufficient to greatly alter groundwater flow patterns. However, groundwater recovery to dewater a mine will result in substantial withdrawals and have a significant impact on groundwater flow regimes.

5.1.6.1 Estimated Mine Dewatering Rates

Depths to groundwater at the Coles Hill ore body location range approximately from 16 ft to 43 ft (Jerden, 2001). Considering that ore depths extend approximately to 1500 ft (Lyntek, 2010), the subsurface would need to be dewatered either for an underground or an open pit mine. Recovered groundwater would be used to support the mine and mill industrial processes. Any excess groundwater recovered beyond the facility demand would need to be managed as described in Section 3. Groundwater levels in the area around the mine would lower as a result of the dewatering, which could impact nearby wells, springs, and surface water bodies. Wells and springs in the affected area could decrease in capacity or go dry. Groundwater flow to surface water could decrease, or surface water could flow back into the

Figure 5-13. Hydrogeologic Conceptual Model for the Coles Hill Area



Source: Gannon, 2009

groundwater system in areas of lowered groundwater elevations, thus decreasing the surface water flows.

As described above, groundwater flow in fractured bedrock systems can be highly variable and difficult to predict. Therefore, estimating the potential rates of groundwater recovery required to dewater the mine is challenging. The Marline (1983) assessment estimated groundwater recovery rates of 232 gpm needed to dewater an open pit mine (140 gpm from saprolite and 92 gpm from bedrock) based on aquifer testing in the area. Gannon (2009) also characterized groundwater flow in the area through additional aquifer tests. The Marline (1983) and Gannon (2009) tests were relatively short in duration and only dewatered the system to relatively shallow depths (i.e., <15 m) and over relatively small lateral extents. Therefore, the potential dewatering rates and the extent of groundwater lowering that may result from mine dewatering remain uncertain. RTI has developed independent estimates of dewatering rates as discussed below; these predictions are preliminary and should be refined with additional site knowledge.

The required dewatering is fundamentally a function of the area's water balance (i.e., the amount of groundwater that would need to be recovered is equal to the precipitation that infiltrates to groundwater within the area under influence from dewatering). Section 5.2.2 and Appendix E describe a watershed-scale water balance model developed by RTI for the local watersheds. Results from this water balance model can be used to develop order-of-magnitude estimates of the groundwater recovery required to dewater the mine. Using this model, daily groundwater recharge rates in the area were estimated to range from 2.3 to 34.4 in/yr,[1] reflecting the climate and weather variability as well as the uncertainty in the estimates. A circular area encompassing the ore body (the smallest circular area shown in Figure 5-14) extends over an area of 0.68 km^2. Applying the estimated range of infiltration rates over this area would lead to groundwater recovery rates from 20 to 300 gpm. Table 5-2 provides the recovery rates based on areas extending 2 and 3 times the area encompassing the ore body (Figure 5-14). Results of this analysis lead to the following general conclusions:

- The rate of groundwater recovery necessary to dewater the mine may vary significantly over time because of climate and weather trends (i.e., wet periods leading to increased dewatering requirements; dry periods leading to less water availability).
- The estimated groundwater recovery required to dewater the mine varies over a relatively large range. For estimates in the current document (the facility water balance in Section 3), we assumed a range between 150 and 1,500 gpm.

Table 5-2. Estimated Recharge Rates to Groundwater

Area Description	Area (km^2)	Recharge Inflow (gal/min)	
		Low Estimate	High Estimate
Circle encompassing ore body	0.68	20	300
2X circle encompassing ore body	2.7	80	1,190
3X circle encompassing ore body	6.1	180	2,680

Given the complex fracture flow environment, the area of recharge from which dewatering might draw is unknown. For comparison purposes, the area for the Mill Creek watershed is 28.7 km^2 (Figure 5-11). Isotopic analyses by Gannon (2009) show that some of the groundwater in the bedrock exceeds 60 years in age, suggesting that the water may be drawn from a relatively broader area. Additional hydrogeologic testing is needed to refine the estimates of groundwater recovery necessary to dewater the mine and the potential extent of groundwater lowering. If the required dewatering rates are large, technical mitigation options such as grouting highly productive fractures may be possible. If limited, dewatering rates may be insufficient to supply all of the facilities' water demand; in this case, additional groundwater pumping (with a larger area of lowered water levels) or supplemental water sources could be required.

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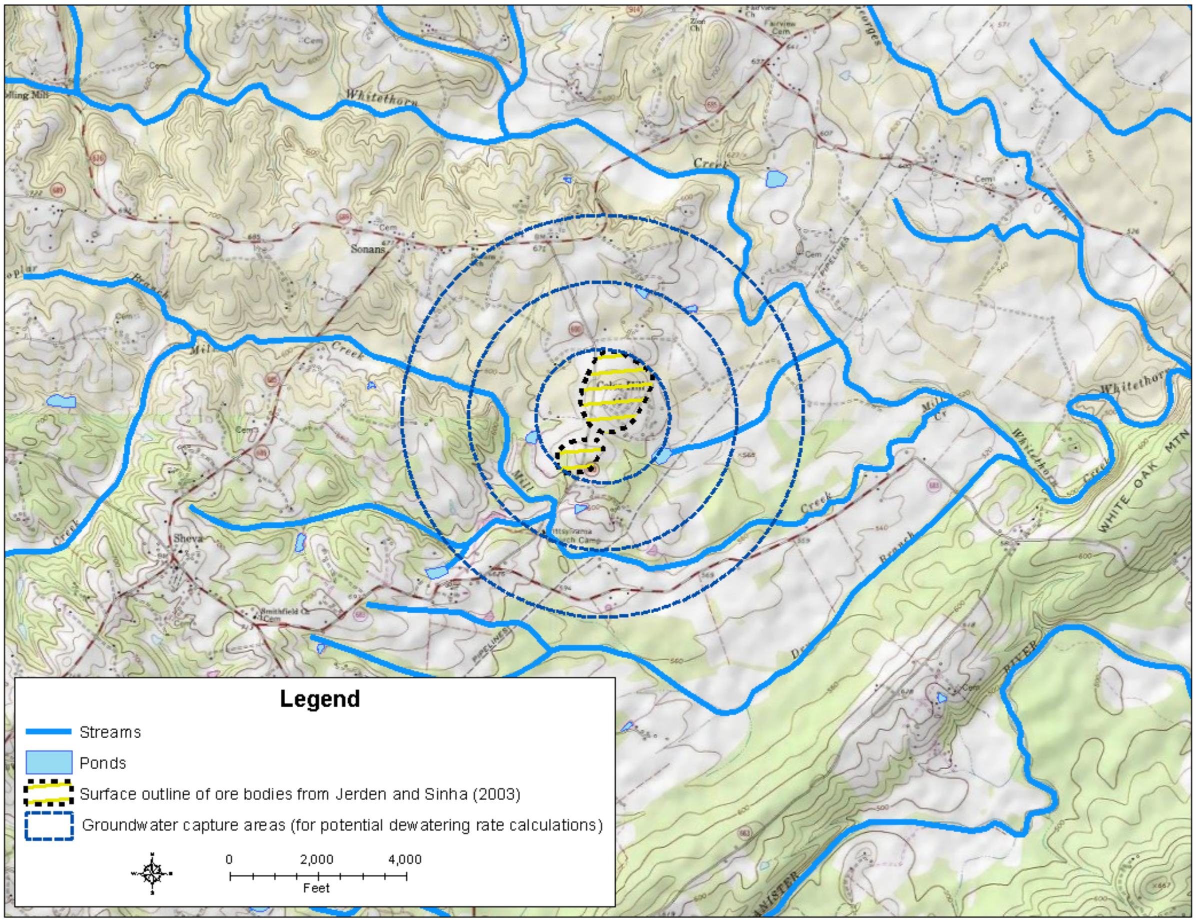
[1] Recharge rates are provided in inches per year. To calculate the associated volumetric flow, this rate is multiplied by the area.

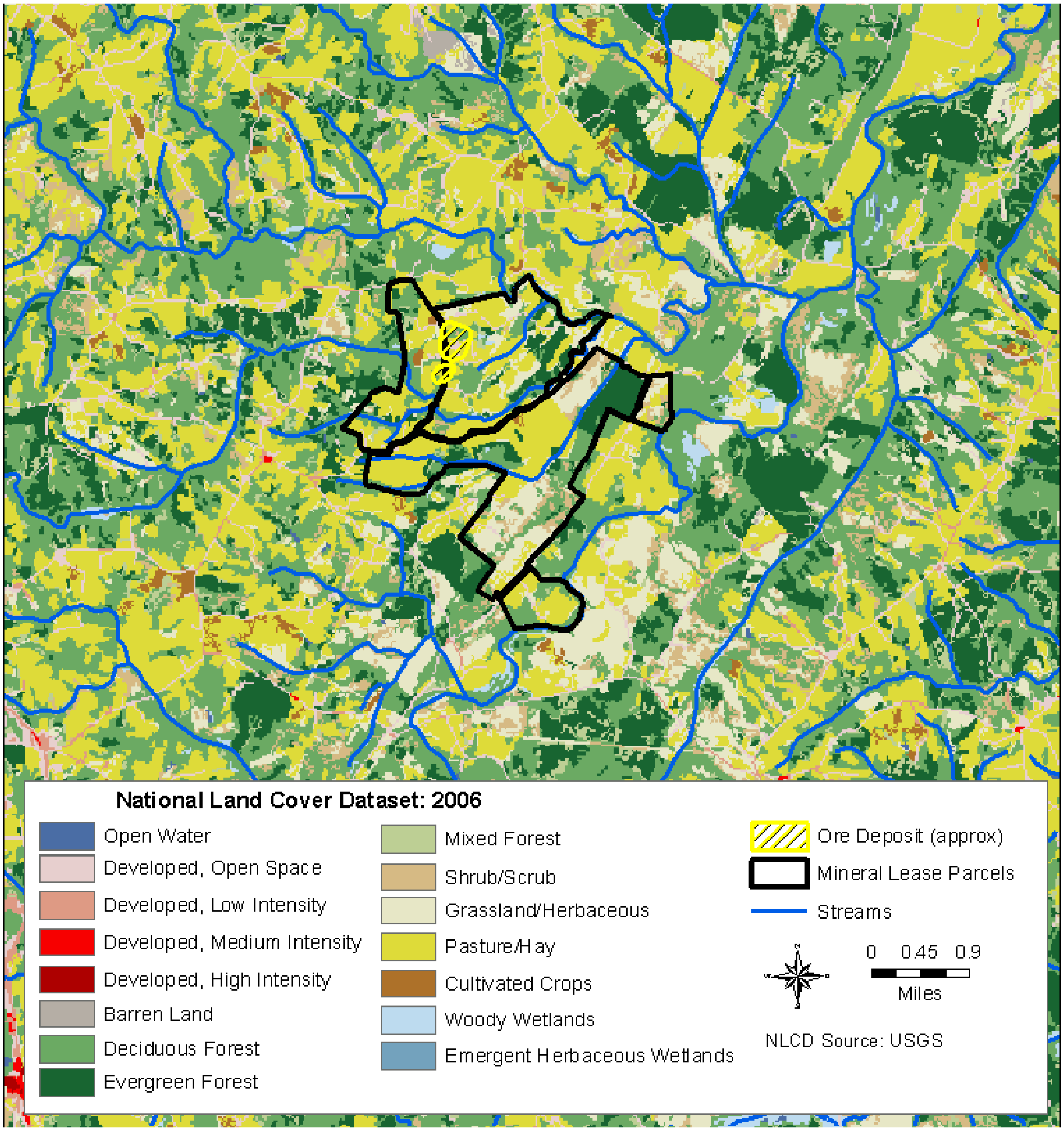
Figure 5-14. Groundwater Capture Areas for Potential Dewatering Rate Estimates



5.1.7 Land Use

Land use in the area of the site is predominantly agricultural or forested, with a relatively low density of residential, commercial, and industrial properties. As shown in Figure 5-15, the agricultural lands mainly comprise pasture and hay (yellow) or grassland and herbaceous (light beige) farming. A broader, regional view of land use can be found in Figure 2-1.

Figure 5-15. Land Cover in the Vicinity of the Mine and Mill



5.2 Potential Constituents of Concern

Chemicals associated with the mining and milling process may be of concern if quantities are released to the environment, migrate in environmental media (e.g., air, water), and lead to potential undesired exposures to humans or ecosystems. This section provides an overview of the types of chemicals used or released during uranium mining and milling, which may become constituents of concern (COCs). The potential COCs at the site for both human and ecological health can be classified as radiologicals, metals, particulate matter, and other chemicals used in the milling process (e.g., acidic or alkaline leaching chemicals). Possible COCs that may be encountered during mining, milling, treatment, disposal, or hauling include

- uranium,
- radioactive uranium daughter products (e.g., polonium, thorium, radium, and radon gas) and associated ionizing radiation (alpha particles, beta particles, and gamma rays),
- heavy metals present in the ore or overburden (e.g., arsenic, chromium),
- leachate with a pH outside of typical waters (i.e., acidic water with a pH < 6; alkaline water with a pH > 8),
- particulates (including the potential for chemicals such as metals and radiologicals to be bound to particulates), and
- additional chemicals required for the mining/milling process (e.g., blasting chemicals, leaching chemicals).

Contamination from metals that may present in the ore or overburden has been an issue at several historical uranium mines (see Section 4). The potential for metals contamination depends on a variety of factors including the ore and overburden chemistry, concentrations in waste materials (particularly tailings), geochemical conditions (e.g., pH, oxidation reduction potential), and waste management practices. Table 5-3 provides concentrations of various metals in ore samples from Coles Hill (Jerden, 2001) along with a comparison to EPA residential soil screening levels. With the exception of uranium, none of the reported elements exceed these screening levels; however, several notable elements of potential concern are not included (e.g., arsenic, chromium). A summary assessment in Marline (1983) states the following: “Heavy metals do not represent a problem in the study area. The total amount of metals present in the soil is low because the parent material is low in metals.” This statement appears to be supported in general by data in Table 5-3 and results in Table 3-1. However, the determination should be verified through more comprehensive sampling and analysis of rock and leachate samples from the site.

Table 5-4 gives concentrations of metals and radiologicals in an aqueous solution in direct contact with tailings from treatability studies conducted by Marline (1983). Values are provided for acid and alkaline (carbonate) leach scenarios. VUI is currently planning to adopt an alkaline leaching process. Comparing tailings leachate concentrations with the regulatory screening levels (also in the table) shows that the tailings leachate has concentrations above tapwater screening levels for most of the cited chemicals of potential concern. This comparison underscores the requirement for proper management and isolation of tailings materials—because of the associated metals concentrations in addition to the elevated radiation levels.

Table 5-3. Example Whole Rock Geochemistry of the Ore (Concentrations in Parts Per Million)

	DH 174	DH 174	DH 174	DH 173	DH 173	DH 173	DH 172	DH 172	Average	Residential Soil RSL[a]
Depth (m)	30.8	29	28.4	29	28.7	28.4	28	27.7	—	
V	99.6	94.4	58.6	104.9	92.7	95.7	112.9	91.5	93.8	390
Rb	7.2	6.1	2.2	7	6.5	9.4	8.7	6.1	6.6	NA
Sr	181.9	245.3	147.2	1210	183.9	208.5	67.1	256.6	312.6	47,000
Y	10.7	14.1	14.5	37.1	21.4	22.7	9.4	12.8	17.8	NA
Zr	214.3	263.2	140.1	182.1	220.1	235.2	285.3	146.6	210.9	NA
Nb	14	15.8	12.2	18.2	20.5	22.8	13.3	10.7	15.9	NA
Ba	164.5	196.3	126.1	171.9	790.9	1,150	232.2	543	421.9	15,000
La	47.8	63.4	27.9	156.6	54.6	60.1	20.3	77.2	63.5	NA
Ce	78	100.4	47.6	255	92.1	100.2	41.8	129.9	105.6	NA
Pr	7	9.4	4.6	24.3	8.6	9.8	4.2	11.1	9.9	NA
Nd	24.1	32.4	16.9	79.6	30.6	33.3	14.9	35.4	33.4	NA
Sm	3.6	4.6	3.1	9.5	5.3	5.5	2.5	4.5	4.8	NA
Eu	1.1	1.3	0.8	2.6	1.1	0.9	0.7	1	1.2	NA
Gd	2.6	3.5	2.6	7.3	4	5	1.8	2.7	3.7	NA
Tb	0.4	0.5	0.4	1	0.7	0.8	0.3	0.4	0.6	NA
Dy	2	2.8	2.4	6	3.8	4.5	1.5	2.1	3.1	NA
Ho	0.4	0.5	0.5	1.2	0.7	0.9	0.3	0.4	0.6	NA
Er	1.1	1.5	1.7	3.4	2.1	2.7	1	1.2	1.8	NA
Tm	0.2	0.2	0.3	0.4	0.3	0.4	0.2	0.2	0.3	NA
Yb	1.3	1.6	1.5	2.3	2.3	2.5	1.2	1.3	1.7	NA
Lu	0.2	0.2	0.2	0.3	0.3	0.4	0.2	0.2	0.3	NA
Hf	5.8	6.4	3.9	0.8	5.7	6.3	6.9	1.3	4.6	NA
Pb	10	19.5	10.1	16	14.4	23.1	13.2	23	16.2	400
Th	13.8	14	31.5	22	20	31.4	7.5	18.1	19.8	NA
U	138.2	521	211.2	706.4	1,030	955.5	496.3	459.9	564.8	230

[a] The cited RSL is the regional screening level allowable for residential soils (http://www.epa.gov/region09/superfund/prg/); this level is considered safe for residential land use (based on conservative exposure assumptions). The top row of the table provides the boring sample identifier.

Source: Jerden, 2001

Table 5-4. Chemical and Radiological Concentrations in Undiluted Tailings Solutions from Coles Hill Ore

Undil	Acid Leach	Acid Leach (pH Neutralized)	Carbonate Leach	MCL (mg/L)[a]
General Parameters				
TDS (g/l)	28.9	13.1	7.34	
pH	1.9	4.2	9.8	
Chemical Profile	**Concentration, mg/L**			
SO4	20,300	9,380	1,200	
HCO3	<5	<5	446	
CO3	<1	<1	2,370	
Cl	251	165	396	
F	54	2	1,1.6	4
Na	424	322	2,700	
Ca	396	436	9	
Mg	1,650	1,300	17	
As	0.18	<0.01	0.08	0.01
Ba	0.1	0.1	<0.1	2
Cd	0.18	0.03	0.01	0.005
Cr	1.17	0.01	<0.01	0.1
Cu	4.66	0.07	0.17	1.3
Fe	1,700	220	0.51	
Hg	0.0021	0.0004	<0.0003	0.002
Mo	0.5	0.1	2.2	
Pb	4.3	0.4	4.9	0.015
Se	<0.01	<0.01	<0.01	0.05
V	19.3	<0.1	0.5	
Zn	40	2.6	0.02	
PO4-P	0.01	0.01	1.09	
NH3-N	1.16	413	1.61	
NO3-N	0.1	0.3	<0.1	10
NO2-N	0.04	<0.01	0.01	1
Radioactive Profile	**Concentration, pCi/L**			
U3O8 (in mg/l)	44	0.7	35	30
Gross alpha	14,117 ± 382	391 ± 40	19,817 ± 280	15
Gross beta	28,085 ± 319	531 ± 33	7,719 ± 124	
Th 230	6,681 ± 1,569	502 ± 33	162 ± 88	
Ra 226	105 ± 6	14 ± 2	22 ± 2	5
Pb 210	23 ± 14	2.9 ± 1.3	6.7 ± 1.1	
Po 210	833 ± 25	0.2 ± 0.2	0.8 ± 0.4	

[a] The MCL is EPA's maximum contaminant level.

Source: Marline, 1983

Acid mine drainage (AMD) occurs when acidic waters are released from a mine site. A typical scenario involves leachate seeping through stockpiles and flowing to surface water or infiltrating to the subsurface. In addition to low pH values, acidic water can carry high concentrations of metals such as arsenic. AMD has been an issue at many hard rock mines (see Section 4). Based on communications with VUI, the ore appears to have significant buffering capacity, which partially accounts for VUI's current plan to adopt an alkaline rather than an acid leach process. If the buffering capacity is sufficient, it may mitigate AMD concerns. Nevertheless, specific leachate testing of the ore and other potentially stockpiled materials (e.g., overburden, subore) is necessary to confirm whether AMD would be an issue at this site.

It is also expected that petroleum products would be on site, at least to support vehicle usage, and it is possible that there would be an on-site generator or storage tank. Milling chemicals would presumably be stored on site as well and could include acidic or alkaline solution for uranium ore leaching or organic carriers such as kerosene or alcohol. In addition, rock blasting chemicals will be used with the potential for residual chemicals, including nitrates and ammonia.

Many of the chemicals of potential concern are present naturally in the environment. For example, metals such as arsenic and lead and radiological elements such as uranium and radon exist naturally at a wide range of background concentrations. Their environmental concentrations depend on a variety of factors such as local geology, geochemistry, and weathering rates. Natural background concentrations can sometimes exceed health-based guidelines. Background radiologicals are known as NORM (naturally occurring radioactive materials) and include uranium, thorium, and potassium. Technologically enhanced naturally occurring radioactive materials (TENORM) refers to radioactive materials with relatively increased concentrations resulting from human processes such as milling. Uranium tailings are an example of TENORM with elevated radioactivity relative to baseline conditions.

Given the presence of many of the COCs in the background environment, it can be challenging to distinguish between natural and anthropogenic concentrations of these chemicals. Therefore, characterization of baseline conditions before a facility is built is important to understand future environmental concentrations and potential impacts resulting from operations. It is important to recognize that baseline refers to the regional conditions in an environmental medium (e.g., water, soil, sediment) that has not been increased by a local source of contamination but may have been increased by regional contamination (e.g., elevated mercury levels across a region because of coal-fired power plant emissions). Available baseline characterization data are reviewed in the media-specific discussions in Section 5.3.

Given its prevalence as a possible COC associated with the mine and mill, uranium is further described below. In addition, key concepts about radioactivity are explored, providing a basis through which to understand potential radiological issues associated with the site.

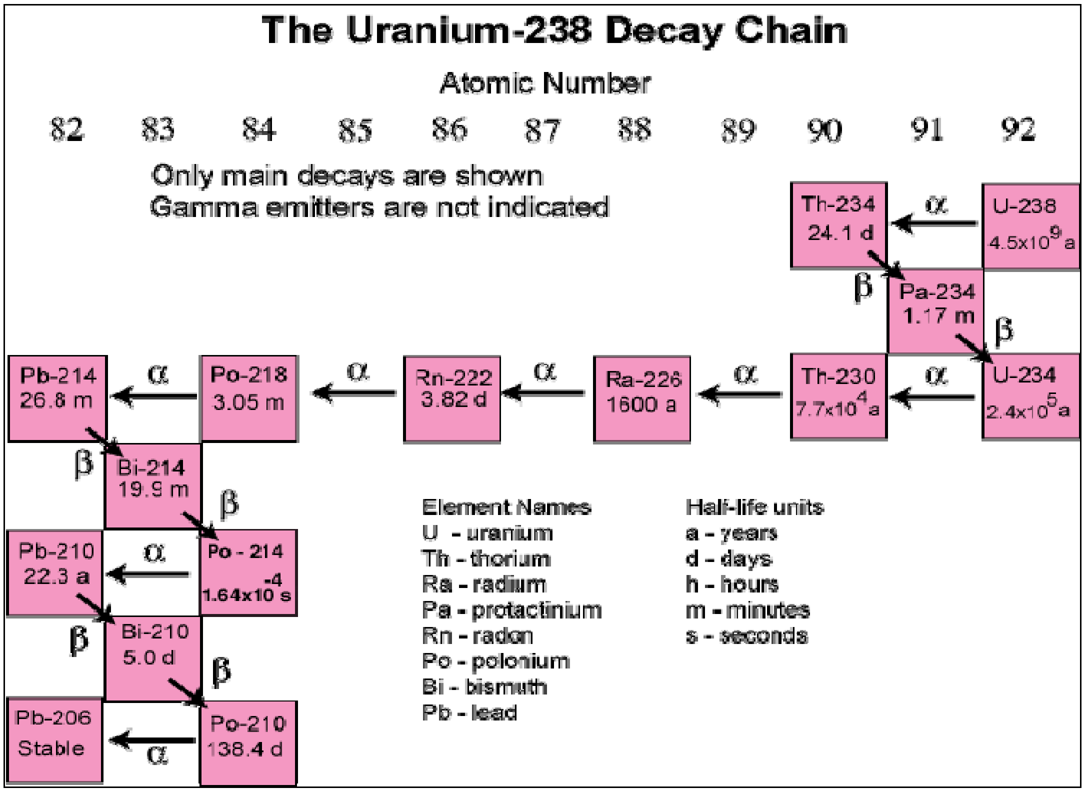
5.2.1 Uranium Occurrence in the Natural Environment

Uranium is typically present in the subsurface environment as a trace element with elevated natural concentrations in some geographical locations. Uranium isotopes are both unstable and radioactive. Uranium-238 comprises 99.284% of the uranium isotopes in the natural environment, followed by a smaller occurrence of uranium-235 (0.711%) and uranium-234 (0.0055%). Uranium is often present in the subsurface environment as uranium oxide or U_3O_8 (IEER, 2005).

5.2.2 Uranium Radioactive Decay

Elements with atomic numbers greater than 83 generally have radioactive isotopes. Uranium-238, the heaviest naturally occurring element, undergoes a natural decay cycle into a sequence of 13 radioactive daughter products prior to final decay into a stable, nonradioactive isotope of lead (lead-206). All daughter products are metals, with the exception of radon-222, which is a radioactive gas (IEER, 2005). The uranium-238 decay chain is illustrated in Figure 5-16.

Figure 5-16. Uranium-238 Decay Chain from Uranium-238 to Lead-206



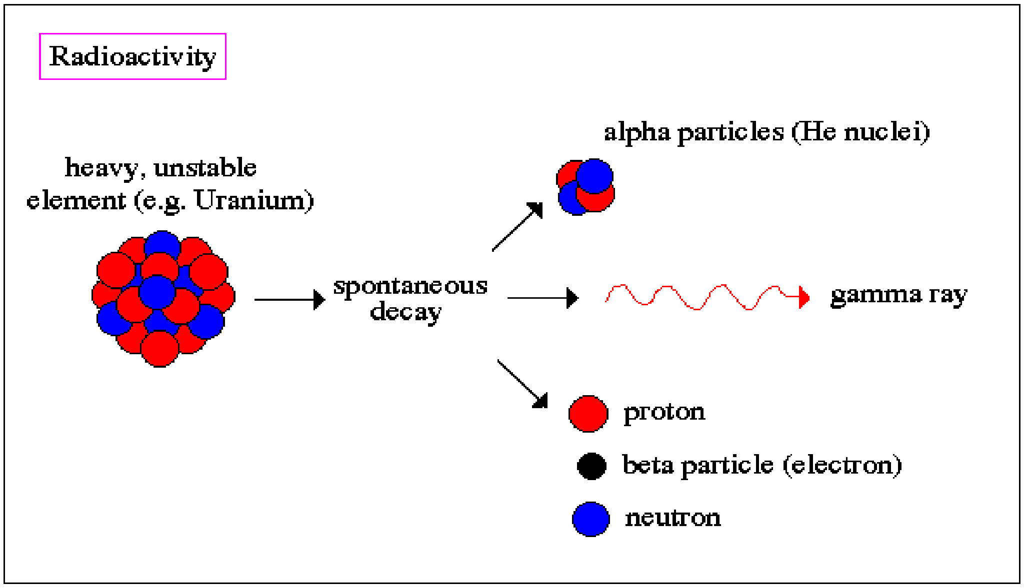
Source: USGS, 2004

The process of radioactive decay can be understood by considering the state of a radioactive isotope. The nucleus of each atomic element (i.e., uranium-238) has a strong nuclear force that contains elemental matter comprising protons and neutrons. Larger atomic elements have more protons and display more electrostatic repulsion because of their positive charge. In the largest elements, the nucleus is under constant pressure to maintain a strong nuclear force while concurrently exerting electrostatic repulsive force. If the repulsive force becomes dominant in the atomic nucleus, the nucleus undergoes decay to reduce the amount of electrostatic repulsion, making two smaller, more stable nuclei. This radioactive decay process can occur in as little as a second or as long as billions of years, based on the radioactive isotope's half-life. Uranium-238 has an extremely long half-life of approximately 4.46 billion years, while polonium-214 has a half-life of 163 microseconds. Continued radioactive decay in a series will change an atom into different, lower atomic weight elements, as shown in Figure 5-16 (IEER, 2001, 2005; Thinkquest Library, 2005).

5.2.3 Types of Radioactivity

When ionizing radiation hits other atoms, electrons can be removed, forming positively charged ions in the process called ionization. Ionization produces free radicals or atoms with unpaired electrons that can be particularly chemically reactive and may lead to biological damage. There are three major types of ionizing radiation: alpha particles, beta particles, and gamma rays. Uranium and its subsequent daughter products produce ionizing radiation during radioactive decay as illustrated in Figure 5-17.

Figure 5-17. A Radioactivity Illustration—Alpha Particles, Beta Particles, and Gamma Rays are the Three Types of Radioactivity Associated with Uranium Decay



Alpha particles are only emitted by heavy atomic elements, such as uranium. When alpha particles are emitted, the atomic mass of the atom decreases by four atomic mass units and becomes a new element. An alpha particle consists of a two-proton, two-neutron nucleus; it is essentially a helium nucleus. Because alpha particles do not have any electrons, the particle is positively charged and interacts with electrons of other atoms. Alpha particles are also the most damaging form of radiation if inhaled or ingested. However, because alpha particles are heavier than other types of radiation and positively charged, they do not travel far from their point of release. Human skin or even a sheet of paper can block alpha particles.

A beta particle is a displaced electron caused by beta decay, which removes electrons from atoms. These particles are much smaller than alpha particles and can be blocked by a sheet of aluminum foil. Similar to alpha particles, beta particles can significantly damage internal cells and tissue if inhaled or ingested.

Gamma rays are electromagnetic waves with a very short wavelength and a very high amount of energy, like x-rays. Gamma rays remove excess energy from newly formed nuclei. These rays travel further and can penetrate human skin. They can be blocked by more than 3 feet of water or a few inches of lead or concrete.

Gamma rays are the least damaging of the three types of ionizing radiation. Gamma rays damage more of a cell to a lesser amount, thereby increasing the likelihood of successful cellular repair, whereas alpha and beta particles damage less of the cell to a greater amount, which in turn increases the likelihood a cell will be permanently damaged or die (Klassen and Watkins, 2003; RERF, 2003;UIC, 2005).

5.2.4 Radiation Units of Measurement

Ionizing radiation can be measured in terms of its (1) strength, (2) energy, (3) level of radiation in the environment, and (4) the radiation dose or the amount absorbed by a human receptor. Different types of units are used for each of these types of measurement. Radioactivity or the strength of a radioactive source is measured in becquerels (Bq). Radiation energy is measured in electronvolts (eV), which can be converted to another common unit of energy, the joule (1 joule = 6.2e+18 eV). Radiation exposure is measured in units of roentgen (R), which refers to the amount of ionization present in the air (1 R is the amount of radiation required to liberate positive and negative charges of one electrostatic unit of charge in one cubic centimeter of dry air at standard temperature and pressure). Radiation dose expresses the amount of radioactive energy absorbed per unit weight of the organ or tissue exposed. A standard radiation dose unit is the gray (Gy), which is 1 joule of radiation energy absorbed per kilogram of organ or tissue weight. The rad is also a common radiation dose unit and is equal to 0.01 grays. Different types of ionizing radiation (e.g., alpha versus beta) are not equally harmful for equivalent doses. To account for this difference, radiation dose is typically expressed as equivalent dose in units of sievert (Sv). The equivalent dose is calculated by multiplying the absorbed dose (i.e., grays) by a radiation weighting factor that depends on the type and energy range of the radiation. For example, alpha particles have a weighting factor of 20, whereas the weighting factor for gamma rays and x rays is 1. Another common unit of equivalent dose is the Roentgen Equivalent Man (rem), which is equal to 0.01 Sv. Table 5-5 lists several common units describing radioactivity. Additional information about radiation units of measure can be found at http://www.ccohs.ca/oshanswers/phys_agents/ionizing.html, which was the primary basis for the above discussion.

Table 5-5. Common and SI Units of Measure for Radioactivity and Dose

Unit	Radioactivity	Absorbed Dose	Dose Equivalent
Common	curie (Ci)	Rad	rem
SI	becquerel (Bq)	gray (Gy)	sievert (Sv)

5.2.5 Relative Radiation Exposure

Natural background radiation is ubiquitous and derives from several sources. The majority of the natural radiation (around 74%) is from the inhalation of radon and associated decay products; cosmic and terrestrial radiation account for about 10% and 6%, respectively; other internally deposited radiation represents the remaining fraction (around 10%) with exposures to all natural sources averaging 3100 μSv per year in the United States (http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/bio-effects-radiation.html). Internally deposited radiation is primarily from food sources such as bananas and brazil nuts (e.g., through radioactive potassium isotopes). These types of sources lead to continuous and episodic low-level ambient exposures to natural radiation and account for around 50% of overall average radiation exposures in the United States. The remaining radiation exposures are artificial and predominantly derived from medical procedures such as CT scans. Artificial radiation from industrial and military sources (e.g., nuclear power production, fallout from weapons testing) account for less than 1% of overall average radiation exposures. Figures 5-18a and 5-18b illustrate the relative magnitude of natural and other radiation sources.

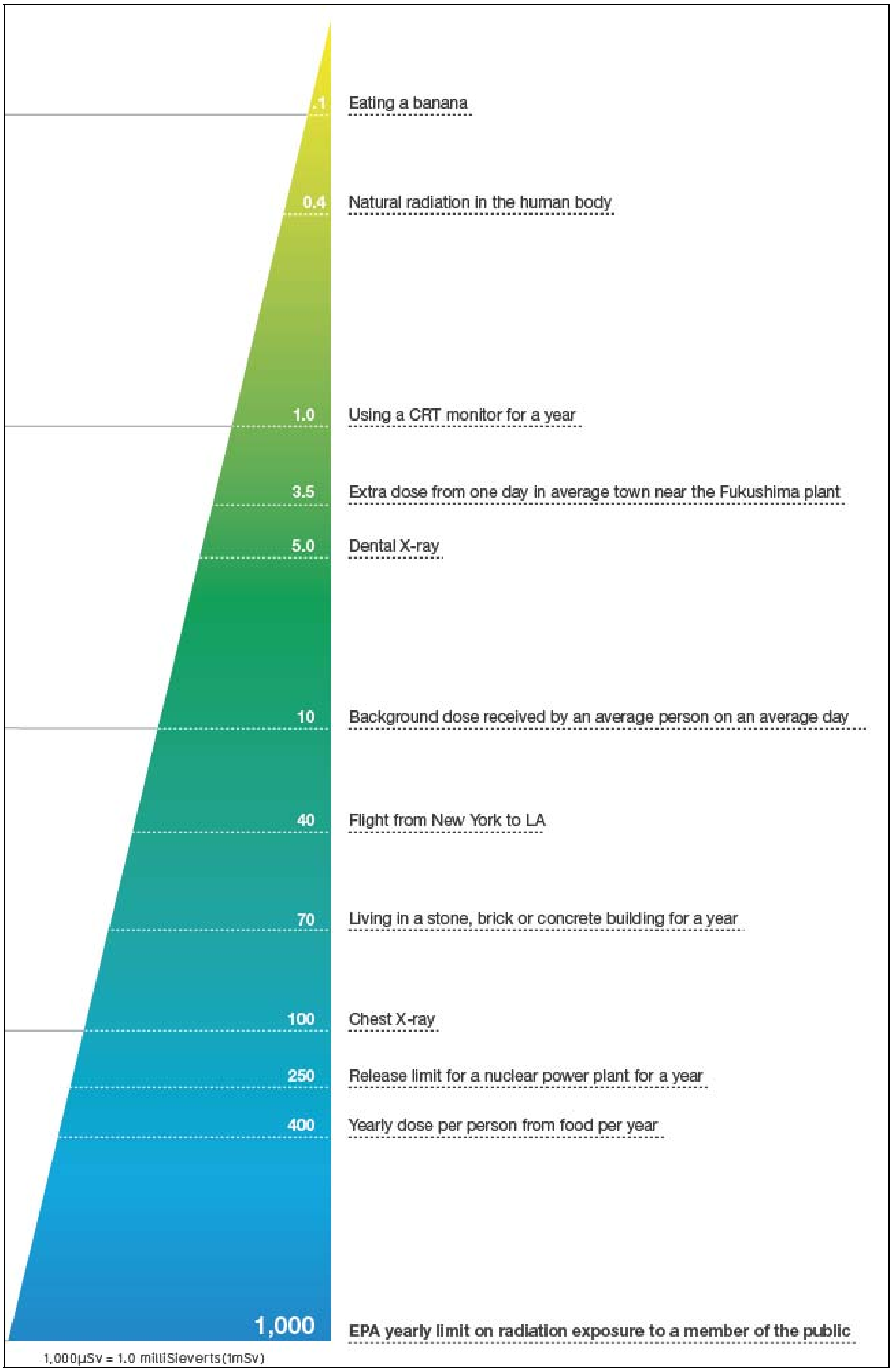
Regulatory levels are illustrated in Figure 5-18 to denote the maximum radiation dose allowable for U.S. citizens or workers per year. Higher levels of radiation exposure can cause both acute and chronic health effects, as shown in Figure 5-18b.

5.3 Potential Contaminant Transport from the Mine and Mill

This section evaluates the potential for contaminants released from the proposed facility to migrate and accumulate within environmental media in the surrounding area. Possible migration of contaminants from the mine and mill could result in exposure to receptors, including humans and ecological receptors (flora, fauna, ecological communities). Figure 5-19 presents a generalized diagram illustrating the possible exposure pathways for release and transport of contaminants from the mine and mill and subsequent potential exposures. The current section focuses on the transport media illustrated in this figure and considers the potential for transport and accumulation of contaminants in air, soil, surface water, and groundwater, respectively.

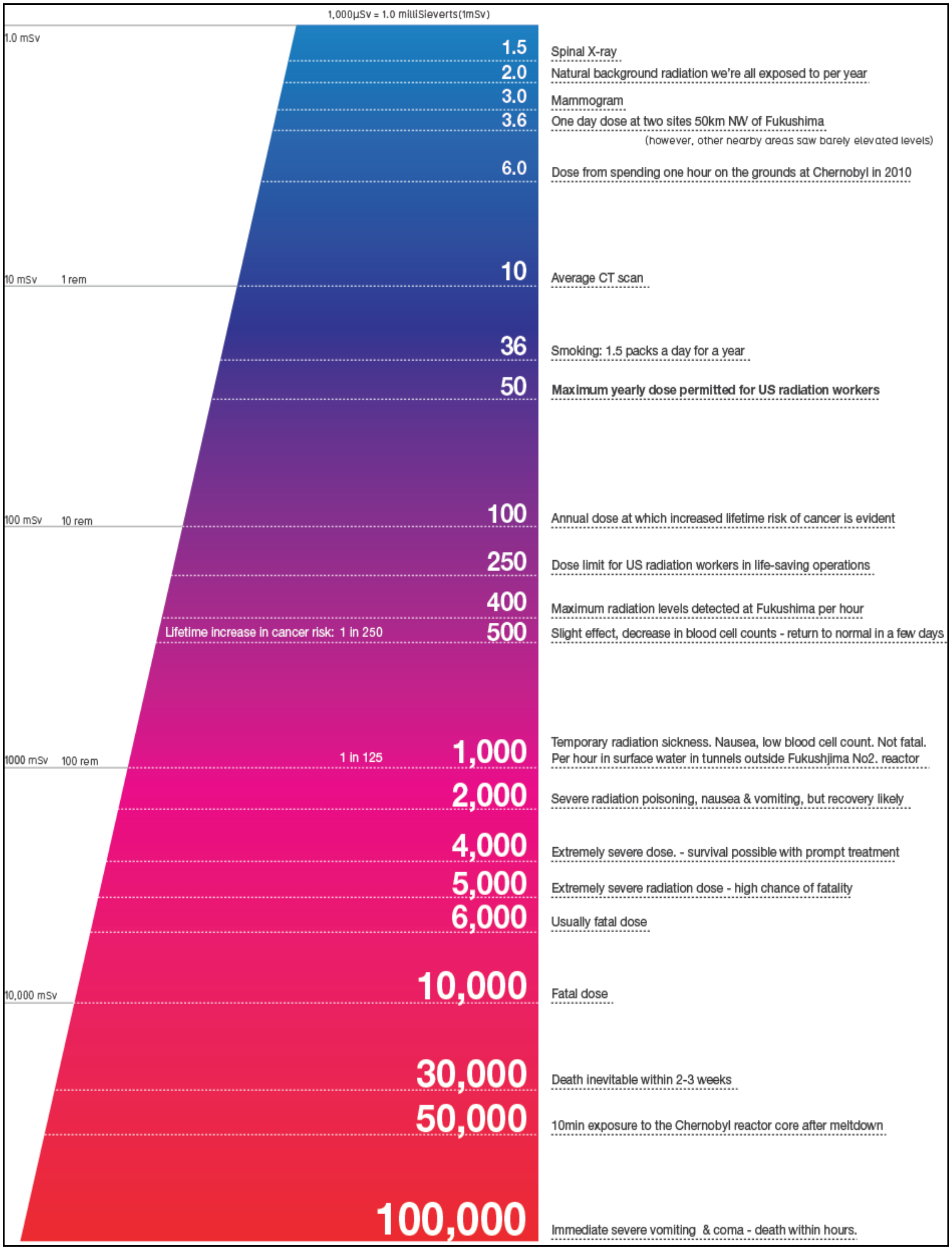
Evaluations in this section are necessarily general. Although site-specific information is considered when available, more detailed data and analyses are needed to evaluate the potential for environmental media impacts at the Coles Hill site more fully. As discussed in this section, some studies have been initiated by VUI, and further work will continue through the licensing and permitting actions if proposals for the facility go forward. Many of the potential environmental problems can be substantially mitigated through appropriate engineering controls and waste management practices. Indeed, many of the regulatory requirements are designed specifically to avoid negative environmental outcomes. Nevertheless, the routine operation of mines and mill facilities do typically result in some releases of contaminants to the environment as described in this section.

Figure 5-18a. Upper Pyramid of Relative Radiation Exposure Levels, from 0.1 to 1,000 μSv



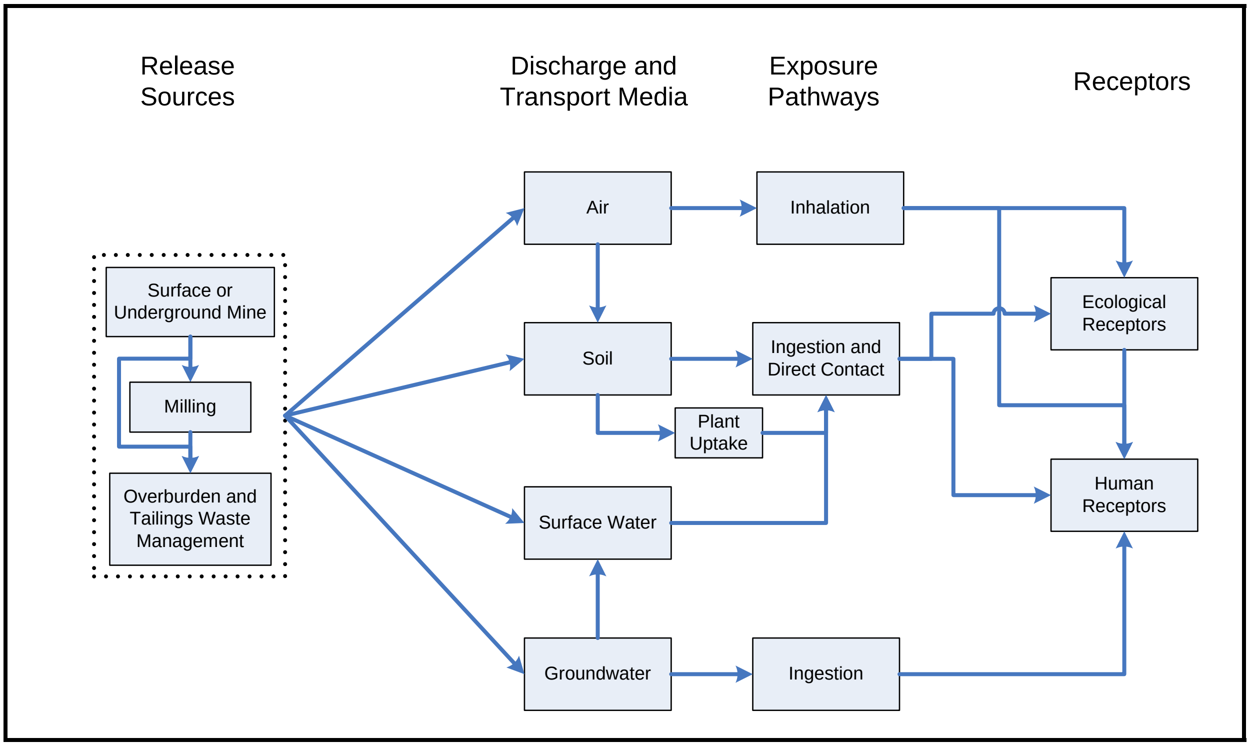
Source: McCandles, 2010

Figure 5-18b. Lower Pyramid of Relative Radiation Exposure Levels, from 1 to 10,000 mS



Source: McCandles, 2010

Figure 5-19. Generalized Exposure Diagram Illustrating Possible Routes of Transport and Exposure



5.3.1 Air Quality

Potential sources of air emissions from the mine and mill include

- rock blasting and excavation for an open pit or underground mine;
- underground mine vents;
- ore, subore, and overburden stockpiles;
- mill processes (crushing, grinding, leaching, precipitation, drying, and packaging, etc.);
- tailings management; and
- tailings impoundments.

These sources of air quality impacts and available environmental control and pollution prevention technologies are characterized more fully in Section 3. The sources can lead to increases in airborne concentrations of particulates, radon, and other gaseous emissions. These contaminants migrate in air based on local wind patterns and eventually will settle out and deposit back to the ground as either wet deposition (with precipitation) or dry deposition. While in air (or following deposition) chemical constituents may undergo transformations such as radiological decay or photolysis (chemical decomposition induced by light). For example, the radiological gas radon-222 undergoes radioactive decay (with about a 4-day half-life) to daughter products, including polonium and lead. Chemicals that transport through the air can lead to exposures through direct inhalation. In addition, deposition transfers chemicals to other media, typically surface soils, which in turn can migrate through erosion to surface water. Other potential deposition media include vegetation, which may then be consumed by animals.

5.3.1.1 Baseline Air Quality Conditions

Some data are available characterizing regional-scale particulate concentrations. Within EPA Region 3 (encompassing several Mid-Atlantic states), 2009 average PM10 concentrations were 41.5 $\mu g/m^3$ (PM10 includes all particulate matter less than 10 microns in size). Baseline air quality data were collected in 1983 by Marline, including particulates (and associated radioactivity) and radon. Mean total suspended particulate concentrations from the Marline assessment were 48.7 and 54.6 $\mu g/m^3$ in August and September 1983, respectively (the size fraction was not specified). Radiation associated with airborne particulates was measured based on concentrations of natural uranium, Th-230, Ra-226, and Pb-10; the total radiological concentration for these elements in airborne particulates was 1.3e-6 pCi/L, which is lower than EPA's reported average outdoor level of radon of 0.4 pCi/L (http://www.epa.gov/radon/healthrisks.html). The Marline assessment also measured airborne radon gas concentrations in the Coles Hill area and found a range from 0.32 to 8.5 pCi/L of Rn-222; EPA recommends mitigation for homes where radon levels exceed 4 pCi/L. These results suggest that radon in outdoor air in the site vicinity can be somewhat elevated over typical conditions, perhaps because of radon emissions from shallow ore and ore that is exposed at the surface.

VUI is planning to install at least one meteorological station at the site to monitor weather conditions, including wind, temperature, and rainfall. Site-specific weather data will allow evaluation of local air transport patterns that may differ from conditions at the nearest regional weather stations (e.g., Danville Regional Airport).

5.3.1.2 Estimated Transport in Air

Gaseous emissions other than radon may include nitrogen and sulphur oxides (generally from fossil fuel combustion sources), kerosene, and other operational volatile organic chemicals. Estimates of such emissions are typically well below standards. For example, the Nuclear Regulatory Commission's (NRC's) generic environmental impact statement for uranium milling estimates concentrations of SO_2 and NO_2 1,000 m (3,281 ft) from the source to be nearly two orders of magnitude below standards (NRC, 1980).

5.3.1.2.1 Particulate Transport

As documented in Section 3, estimates of particulate emissions were developed for ore-related and other potential sources and for open pit and subsurface mine scenarios. These estimated emission rates were used to simulate long-term average airborne particulate migration patterns from the mine and mill. Key inputs to the airborne particulate transport model (further documented in Appendix E) include the predominant wind strengths and directions and air stability/turbulence data. Such weather data are typically available from climate stations at nearby airports. This analysis relied on data from the nearby Danville, Virginia, and Greensboro, North Carolina, airports. The analysis considered migration of PM30 or particulates up to a size of 30 microns. Additional size classifications include PM10 and PM2.5, ranges that have regulatory thresholds designed to protect from inhalation health hazards (e.g., asthma, cardiovascular issues). The current analysis is based on PM30 to evaluate the overall potential for particulate migration, including mass transport of potential COCs bound to larger sized particulate matter.

Figures 5-20 through 5-23 show the estimated extent of migration of particulates down to an airborne concentration of 1 µg/m^3 for the various emissions scenarios. For nonore sources, the extent of airborne transport is greater for the open pit mine scenario because of the greater magnitude of nonore-related emissions (e.g., vehicular traffic). Underground mine emissions have somewhat greater concentrations near the mine/mill source, because the underground mine scenario sources are somewhat more concentrated (occurring over a smaller area). For ore-related sources, the extent of transport is similar for both scenarios, which is a result of the similar emission rates as described in Section 3. As with the nonore sources, the underground scenario has somewhat greater concentrations near the source because of the underground scenario sources occurring within a smaller area.

The results generally show limited migration of particulates, particularly when compared with regulatory limits for PM2.5 (15 µg/m^3, annual averaging period) and PM10 (150 µg/m^3, 24-hour averaging period). The simulations predict PM30 concentrations, which exceed PM2.5 and PM10 levels (PM30 is inclusive of the lower size fractions). Nevertheless, the comparison with PM2.5 and PM10 regulatory levels does indicate the relatively limited extent of transport at levels of concern for potential inhalation hazards such as asthma and cardiovascular issues.

Migration of particulates is also a pathway for mass transfer of any contaminants attached to the transported particles. For example, particulates deriving from the uranium ore can be expected to have percentages of U_3O_8 ranging approximately from 0.06% to 0.278%, which are the average percentages for the low- and high-grade ore categories described in a preliminary economic analysis of the mine (Lyntek, 2010). These concentrations were combined with particulate deposition rates from the airborne transport modeling (ore-related sources) to estimate rates of U_3O_8 deposition in the area surrounding the mine. To represent the significant uncertainty associated with these estimates, the high concentration value was assumed for the high-range particulate transport estimate (upper estimate), while the low concentration value was assumed for the low-range particulate transport (lower estimate). Results are provided in Figures 5-24 and 5-25 for open pit and underground mine scenarios, respectively. Given the similar source emission rates for the two scenarios (as described in Section 3), the pattern and extent of transport are similar for both scenarios. Estimation of the human health risks was outside the scope of this analysis. A comprehensive human health risk assessment would be needed to provide quantitative estimates of the potential risks associated with these emissions.

Figure 5-20. Estimated PM30 Annual Average Concentrations Associated with an Open Pit Mine and Nonore–Related Sources

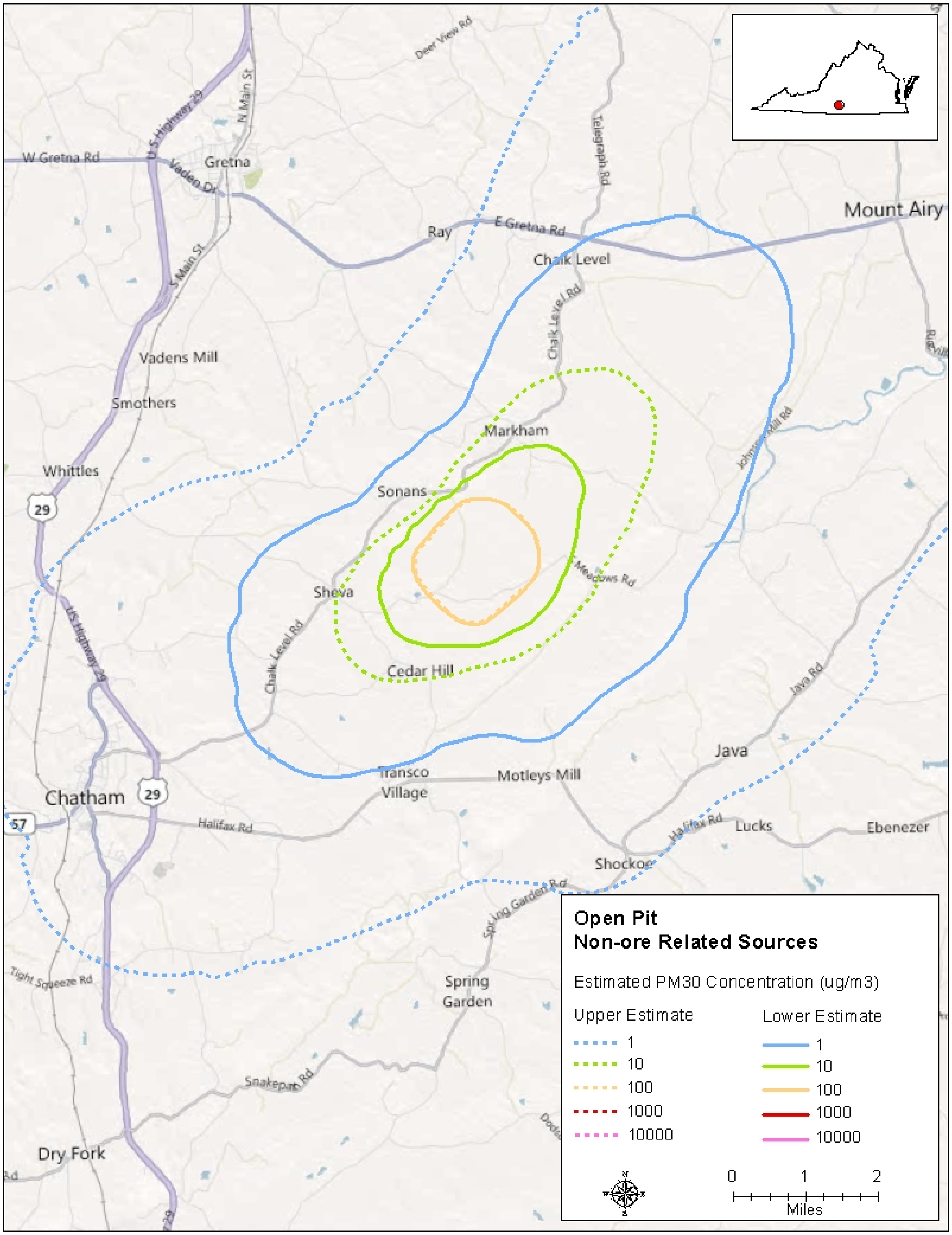


Figure 5-21. Estimated PM30 Annual Average Concentrations Associated with an Underground Mine and Nonore–Related Sources

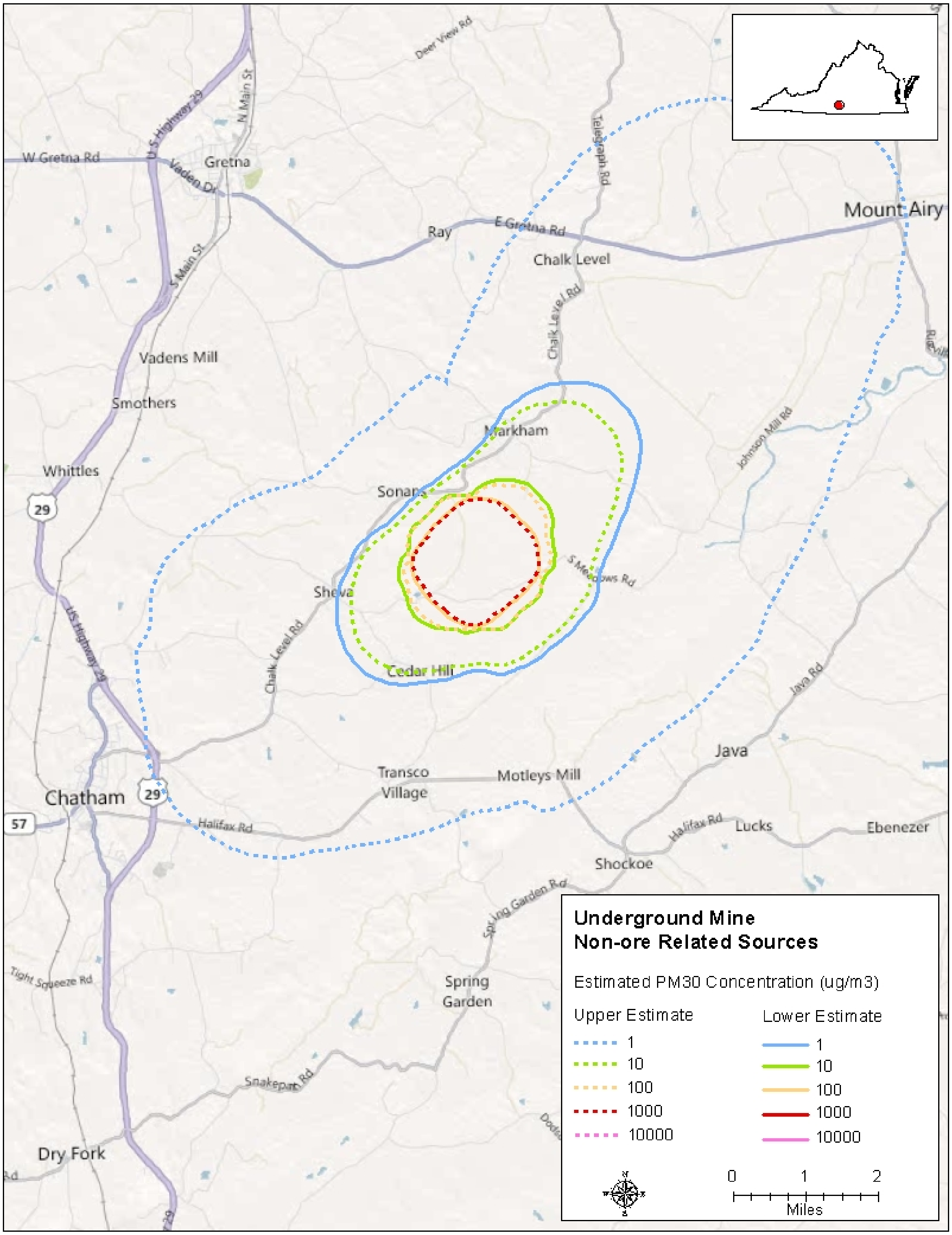


Figure 5-22. Estimated PM30 Annual Average Concentrations Associated with an Open Pit Mine and Ore-Related Sources

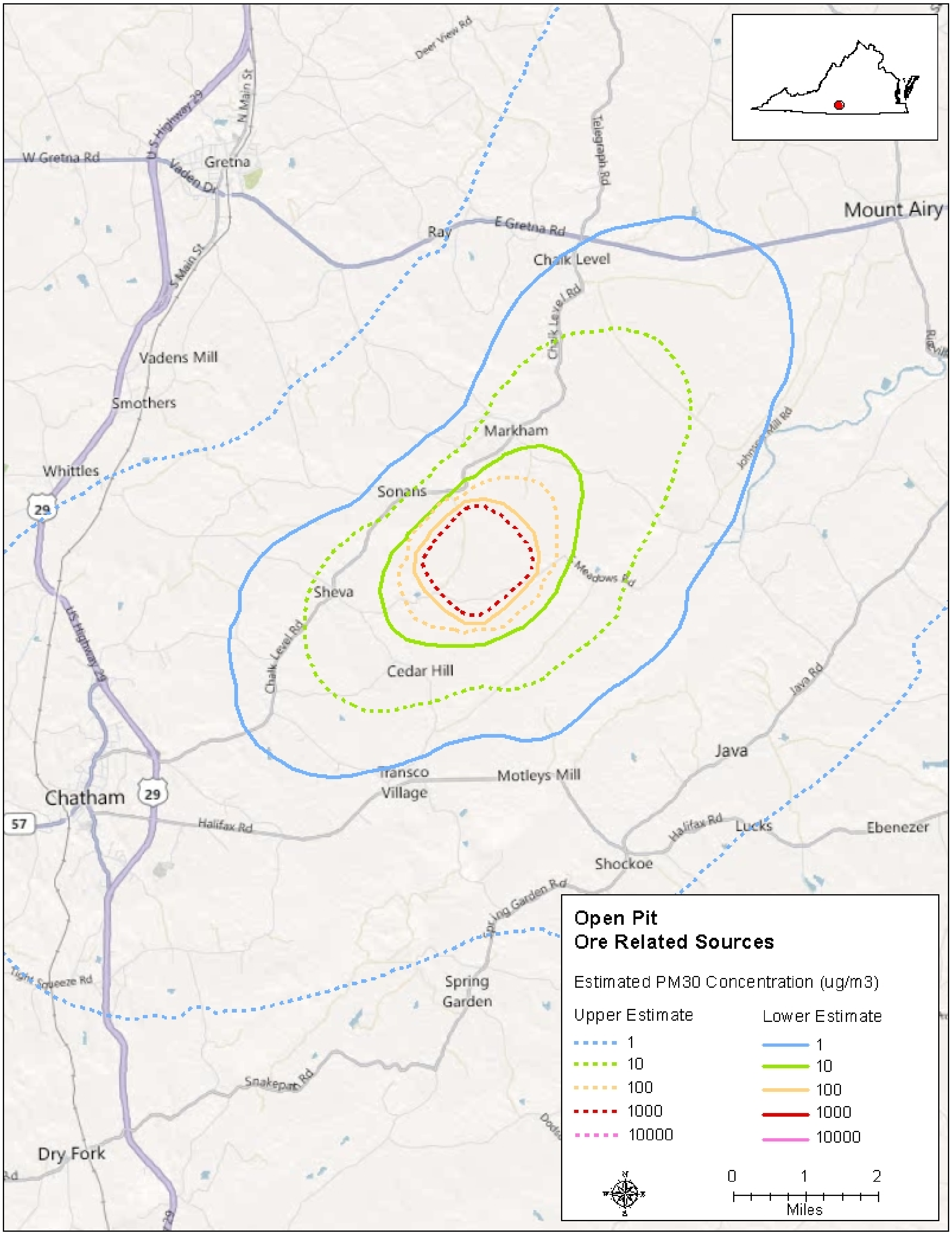


Figure 5-23. Estimated PM30 Annual Average Concentrations Associated with an Underground Mine and Ore-Related Sources

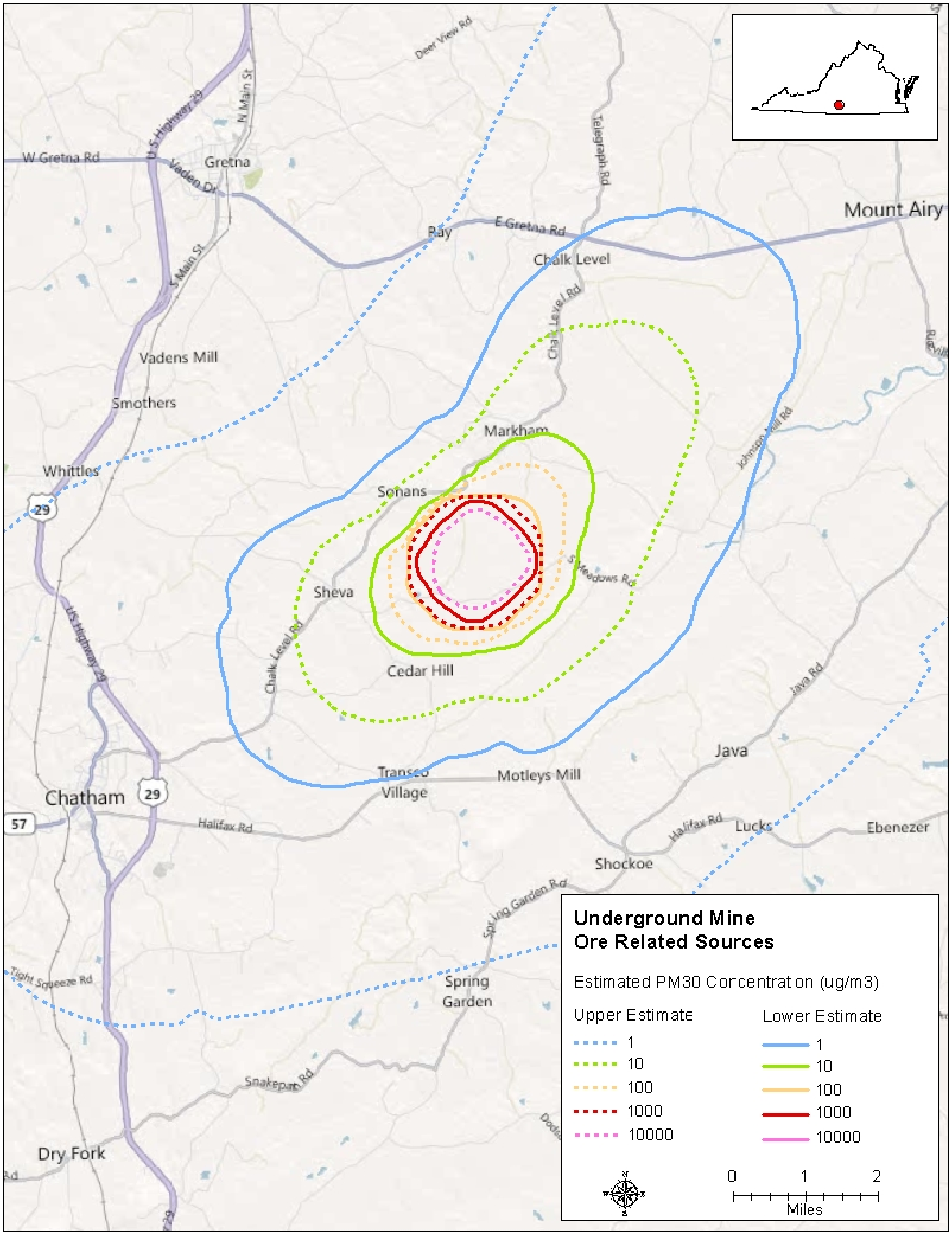


Figure 5-24. Estimated U_3O_8 Deposition Rate Associated with an Open Pit Mine and Ore-Related Sources

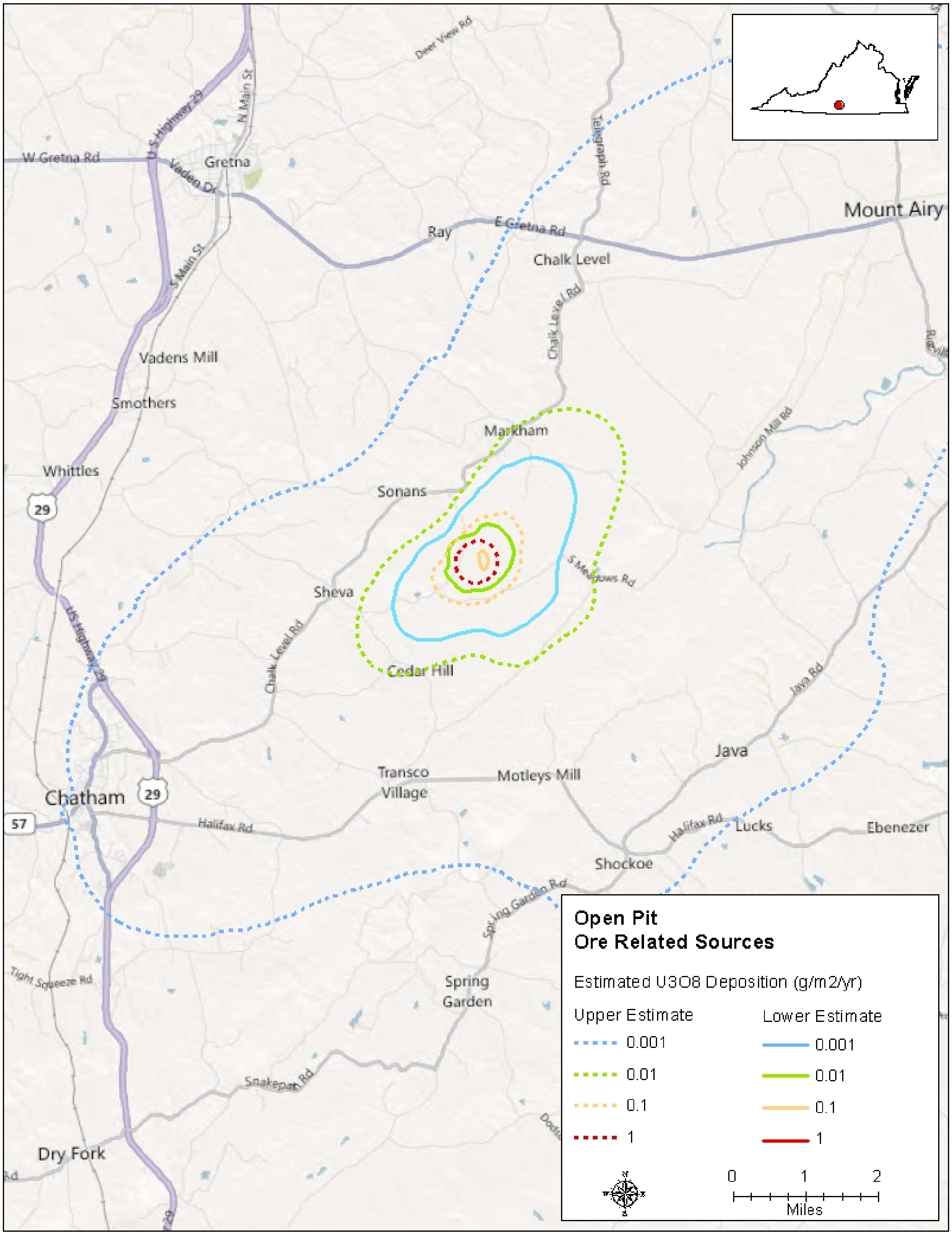
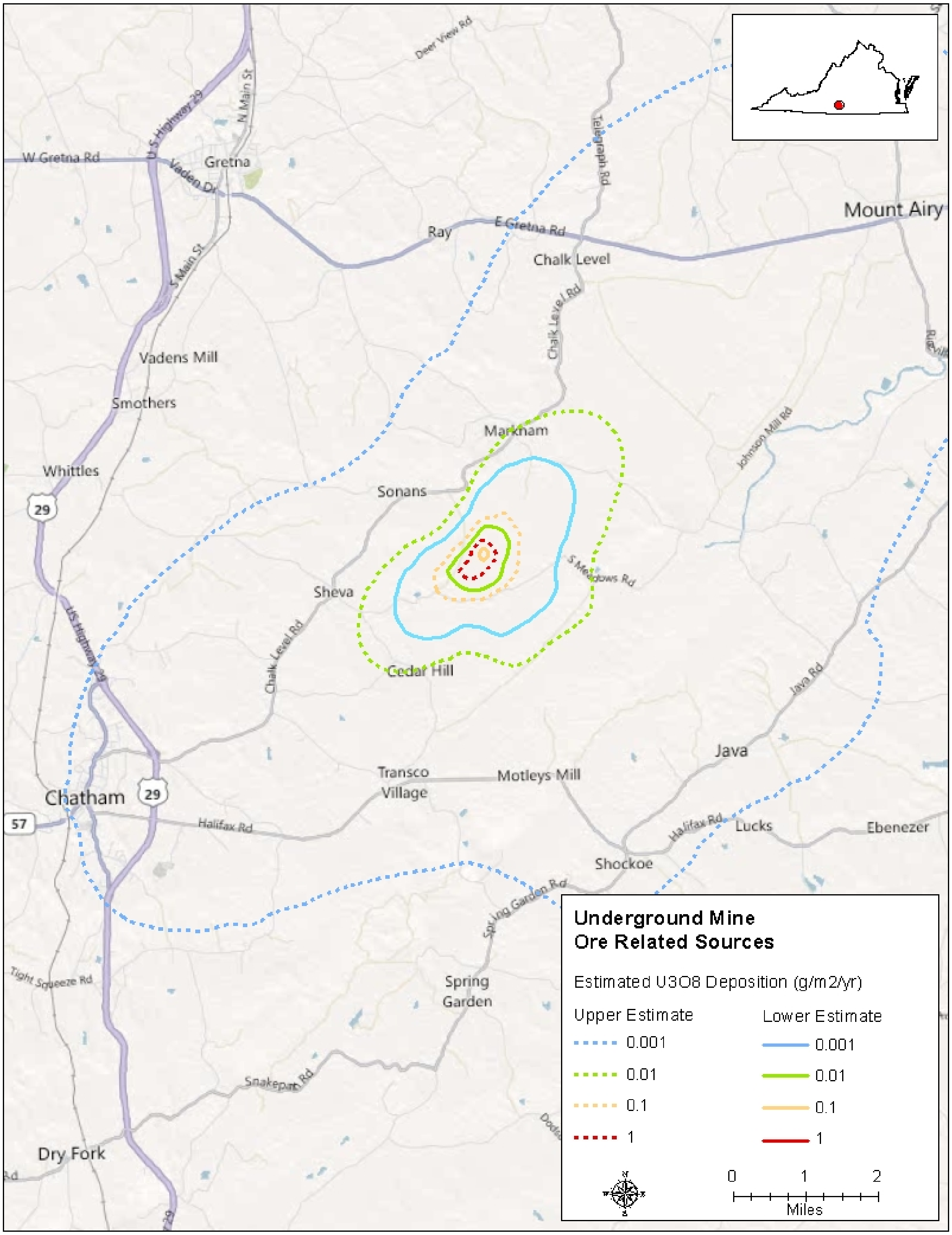


Figure 5-25. Estimated U_3O_8 Deposition Rate Associated with an Underground Mine and Ore-Related Sources



5.3.1.2.2 Radon Transport

Radon is a gaseous radiological decay product from constituents in uranium ore. Therefore, radon is emitted from operational activities involving ore or ore byproducts, and it will migrate in air from the mine and mill facility. Because it is a relatively heavy gas, radon is less mobile and will settle more readily than other gases. Rates of radon emission are strongly dependent on the ore geology and operational and waste management practices. Section 3 provides radon emission estimates. Given the significant uncertainties, estimates of radon transport have not been made for the current assessment.

5.3.2 Soil Quality

Soils at the site and in the surrounding area may be impacted from the transfer of contaminant mass via airborne particulates and radon. Over time, concentrations of contaminants in soils can increase because of such deposition from air. Erosion through wind and overland water runoff can remove some of the surface soils, decreasing soil concentrations but also transferring the mass to other areas (e.g., nearby streams receiving sediment loads with overland runoff). Soils also may migrate from the site via wind and water-driven erosion. These processes will lead to contaminant migration from the site if the eroding soils have elevated COC concentrations. Potential sources of soil contaminant migration through wind and water erosion from the mine/mill site include

- ore, subore, and overburden stockpiles;
- tailings management facilities; and
- tailings impoundments.

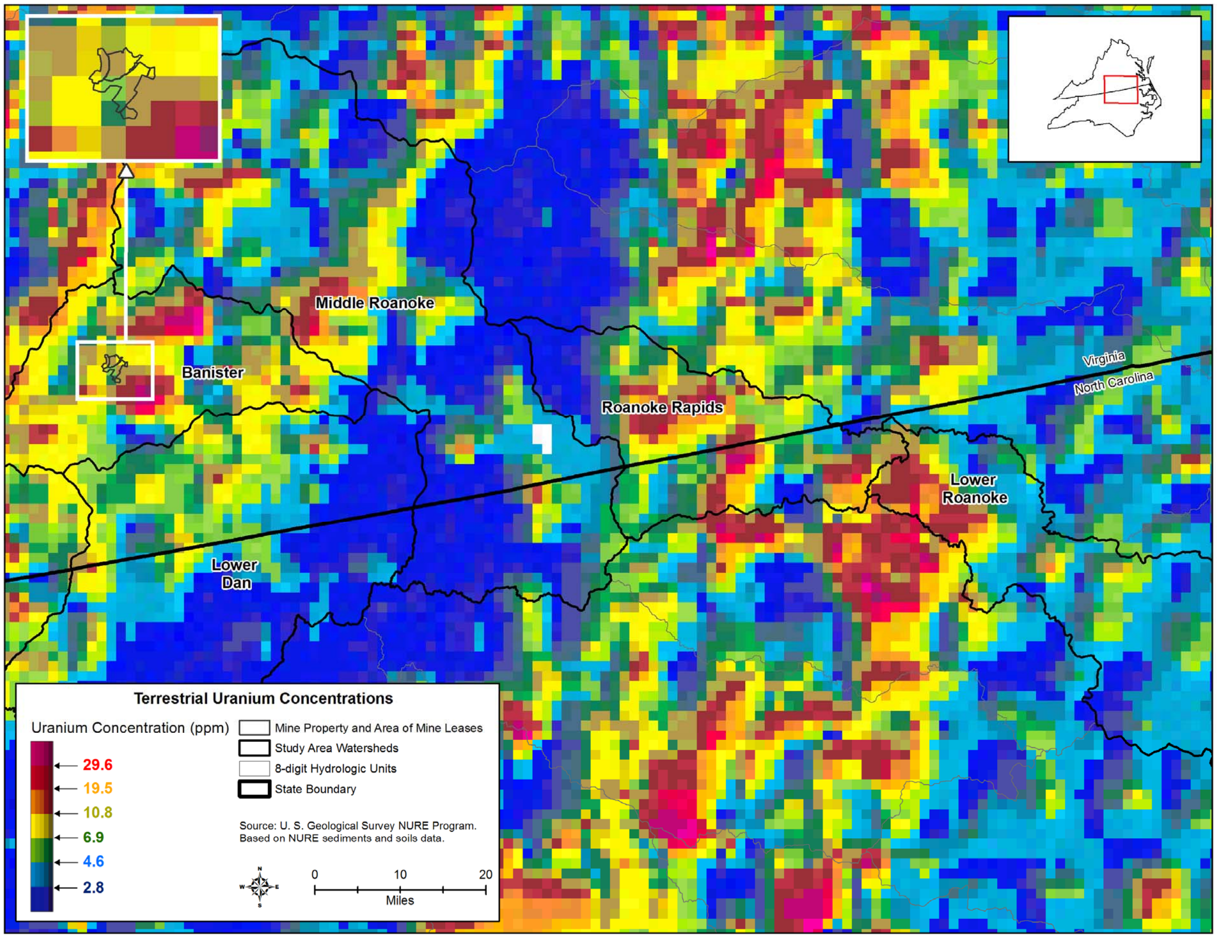
These sources and available environmental control and pollution prevention technologies are described more fully in Section 3.

5.3.2.1 Baseline Soil Quality Conditions

Given the nearly ubiquitous presence of many of the COCs, baseline characterization of soil conditions at the site and in the surrounding area is important. Regional-scale information is available from the USGS National Uranium Resource Evaluation (NURE) program, which assessed the potential for recoverable uranium resources across the country. Figure 5-26 shows estimated terrestrial uranium concentrations from the NURE program. As this figure indicates, baseline uranium concentrations range over approximately an order of magnitude from about 3 to 30 ppm with significant spatial variability. It is important to note that NURE results do not allow location-specific evaluation given that samples are not available at a high resolution. Interestingly, the NURE program did not identify the Coles Hill deposit. Nevertheless, this data source provides useful information about the range of conditions characteristic of regional scales.

Baseline studies by Marline (1983) provide additional information about soil conditions in the site area. Their assessments state that “radionuclide concentrations in the project area are at normal levels when compared to soils across the nation.” However, some elevated radiological concentrations were found in the direct vicinity of the ore outcrop. As discussed in Section 5.2, the Marline (1983) assessment concluded that heavy metals would not be an issue at the site. However, their report does cite

Figure 5-26. Terrestrial Uranium Concentrations (ppm) Based on NURE Geochemical Data



Source: U. S. Geological Survey NURE Program. Based on NURE sediments and soils data.

concentrations of several metals (e.g., chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, vanadium, and zinc) in at least selected samples that exceed average values typical for the United States. For example, chromium concentrations were as high as 230 ppm, while an average range for the United States is cited as 10 to 70 ppm.

Given the above results, additional characterization of site soils is needed both (1) to characterize baseline conditions fully and (2) to determine whether chemicals in addition to radiologicals may be of concern for facility operations. VUI is currently sponsoring an assessment of soils at the site through the Virginia Tech Agriculture and Soils Department. This effort involves the collection and analysis of 20 soil samples at two vertical horizons. Results are anticipated in 2012.

5.3.2.2 Estimated Transport of Soil

The potential for soils to leave the site with runoff and the potential for contaminants to be carried with those soils depend on multiple factors, including the detailed layout of facilities, storm water management controls installed with the facility, and waste management and environmental control technologies applied. Alternative approaches for managing stormwater are discussed in Section 3.

Given the absence of detailed information about the facility design, the current assessment does not attempt to estimate potential soil losses associated with the actual facility. Nevertheless, characteristic soil loss rates for the watersheds where the mine and mill are proposed can be estimated. To accomplish this, RTI developed a hydrological model coupled with a sediment load computation model. This model estimates the water balance for the area and computes the amount of sediment transport that might be generated by runoff under current conditions. The water balance describes the flow of water through the watershed and includes the following primary components: precipitation, runoff to surface water, infiltration to groundwater (ultimately flowing as groundwater base flow to surface water), and evapotranspiration. The simulations considered the period from 1976 through 2006 and relied on climate data such as precipitation and temperature and land use. Appendix E provides additional documentation of the approach, inputs, and results. Three scenarios were considered (minimum, maximum, and average) to represent the variability and uncertainty associated with the water balance and sediment load estimates. Based on these evaluations, annual sediment load estimates range from a minimum of 0.002 to a maximum of 0.129 tons/acre with an average of 0.021 tons/acre/year. The estimated average is below a literature-based estimate of sediment loads from crop land of 0.1 tons/acre/year (Ouyang et al., 2005). This analysis provides a general characterization of the erosion potential for the site of the proposed mine and mill. In addition, results of this analysis were used in Chapter 3 to inform the assumed facility water balance (e.g., runoff rates under alternative land use conditions).

5.3.3 Surface Water Quality

Potential releases to surface water from the mine and mill include

- discharge of treated wastewater from the mill,
- discharge of treated or untreated surface runoff from the property,
- discharge of sediments eroding with surface runoff from the property (and associated sources such as ore stockpiles and tailings management), and
- discharge of treated or untreated water from mine dewatering in excess of the water required to support the industrial processes.

These sources of water quality impacts are characterized more fully in Section 3 and available environmental control and pollution prevention technologies to mitigate such releases. These sources lead to increases in concentrations of COCs in surface water and sediments suspended in surface water and collected at the bottom of surface water bodies. Given their interrelationship, surface water and associated sediments are both considered in this section.

Contaminants migrate in surface water based on flow conditions that vary significantly depending on precipitation patterns. While in water, chemical constituents may undergo transformations such as radiological decay, hydrolysis, or adsorption to particulates suspended in surface water or deposited with sediments. As an example, uranium exhibits complex aqueous geochemistry and occurs in the environment primarily as U(IV) in reducing systems and U(VI) in oxic systems (typically systems with significant dissolved oxygen) (Davis and Curtis, 2003). In reducing waters, U(IV) often forms relatively less soluble solid precipitates. Under oxic conditions typical of most surface waters, U(VI) can form more soluble hydroxide and carbonate complexes. Increased solubility of U(VI) species leads to relatively increased mobility with flowing water. Nevertheless, even under oxic conditions uranium and other compounds typically bind to solid materials so that a significant fraction of their mass is associated with the solid rather than the aqueous phase. Adsorption, or the binding of the chemical to solids, is strongly dependent on pH and the presence of other dissolved chemicals (e.g., carbonates). Solid particles in the water (sediments) generally settle to the bottom of surface water bodies during relatively lower flow conditions but may become suspended and mobilize downstream during high flow events. Chemicals that migrate in surface water can lead to exposures through pathways such as direct contact (e.g., swimming) or ingestion if the water is used as a drinking water source.

The suspension of fine earth materials in rainwater runoff can be a significant issue associated with mining and mine processing sites. Mineral development disturbs soil and rock in the course of constructing and maintaining roads, open pits, and waste impoundments. In the absence of adequate prevention and control strategies, erosion of the exposed earth may carry substantial amounts of sediment into streams, rivers, and lakes. Excessive sediment can clog riverbeds and smother watershed vegetation, wildlife habitat, and aquatic organisms. Chapter 3 describes engineered systems (e.g., berms and collection ponds) that can be used to control runoff and sedimentation.

5.3.3.1 Baseline Surface Water Quality Conditions

Several sources of baseline surface water quality information are available, including

- studies of the site by Marline Uranium Corporation during the 1980s,
- current and recent studies of the site by VUI,
- U.S. Geological Survey (USGS) National Uranium Resource Evaluation (NURE) data, and
- EPA Clean Water Act (CWA) impaired waters information.

5.3.3.1.1 Marline Data

Baseline studies by Marline in the 1980s provide data for surface water streams and ponds in the vicinity of the proposed mine and mill. The Marline evaluation included 10 surface water and 5 pond sampling locations. Several parameters were measured, including general chemistry (e.g., pH, total suspended solids), metals (e.g., arsenic, manganese), and radiological compounds (e.g., uranium, thorium and radon). According to Marline (1983), the general surface water quality is good. However, Virginia public water supply standards were exceeded in several samples for soluble iron, soluble manganese, and phenols. Most other metals were at or below detection limits. The iron and manganese levels were thought likely to be associated with the geology of the area, which is characterized by schist, gneiss, and granite rocks. These materials are generally resistant to weathering and relatively low in metals and nutrients. The source of the phenols was unknown but hypothesized to be related to pesticide use and subsequent degradation in the area.

Marline (1983) also assessed baseline radionuclide concentrations in surface waters and sediments. The maximum observed gross alpha value for streams was 1 pCi/L (suspended and dissolved), and the greatest radium concentration (suspended and dissolved) was 1.43 pCi/L. These results were below drinking water standards (MCLs of 15 and 5 pCi/L for gross alpha and radium, respectively). For ponds, the highest gross alpha value was 4 pCi/L, and the greatest radium value was 2.6 pCi/L. Concentrations in ponds were slightly greater than stream concentrations but still below MCLs. Little quantitative information was found in the Marline report documenting radiological concentrations in stream or pond sediments, although it is stated that sediment concentrations are "low when compared to background levels of sediments from other uranium mining districts in the nation" Marline (1983). Radiological concentrations in pond sediments were slightly greater than sediment concentrations in streams with the maximum pond sediment levels found in the pond closest to the ore body.

5.3.3.1.2 VUI Data

VUI is currently sponsoring a study by Virginia Tech involving monthly, quarterly, and biannual sampling. It is also conducting an analysis of sediment transport in local streams through the Virginia Tech Department of Civil Engineering. Results from these studies are anticipated in 2012.

VUI provided surface water, pond water, and groundwater concentration data collected from 2007 through 2009 to RTI in the form of Microsoft Excel tables. Table 5-6 provides a summary of these results for ponds and surface water. The table includes all constituents in the dataset that exceeded the specified standard for any sample and within any of the sampled media (streams, ponds, groundwater). The results do show some levels above the specified standards. The significantly elevated levels for aluminum, iron, and manganese may warrant additional evaluation; however, the associated standard is an EPA secondary drinking water standard. Unlike MCLs, these secondary limits are not mandatory and are not developed based on health impacts; rather, secondary standards reflect aesthetic (e.g., taste, odor) and technical (e.g., corrosion) concerns. The elevated coliform levels likely reflect agricultural use in the area (e.g., cattle). It is also noteworthy that uranium levels in surface waters were not particularly elevated. We did note that a large percentage of the provided data were below detection limits; for example, out of 179 stream water uranium samples, 153 were below detection limits. It is possible that the detection limits for these analyses were relatively high, which could explain the large number of nondetects; however, we did not receive the detection limit values and could not review them. Given these limitations, these results are preliminary, and additional assessment of these data is needed along with the associated detection limits.

Table 5-6. Baseline Concentrations in Stream and Pond Water Collected from 2007 to 2009 by VUI

Parameter	Units	Standard		Pond Water		Surface Water	
				Min	Max	Min	Max
pH (SU)	SU	6.5–8.5	2	5.8	**10.0**	5.5	8.0
Benzene	ug/L	5.0	1	ND	ND	ND	ND
Al (Unfiltered)	ug/L	50–200	2	ND	**1,100.0**	**110.0**	**683.0**
Al (Filtered)	ug/L	50–200	2	**108.0**	**189.0**	ND	**921.0**
As (Unfiltered)	ug/L	10.0	1	ND	ND	ND	ND
As (Filtered)	ug/L	10.0	1	ND	ND	ND	7.2
Cu (Filtered)	ug/L	1,300.0	1	ND	ND	ND	ND
Fe (Unfiltered)	ug/L	300.0	2	138.0	**3,340.0**	120.0	**2,810.0**
Fe (Filtered)	ug/L	300.0	2	113.0	**876.0**	ND	**1,130.0**
Pb (Unfiltered)	ug/L	15.0	1	ND	7.1	ND	11.2
Pb (Filtered)	ug/L	15.0	1	ND	ND	ND	7.5
Mn (Unfiltered)	ug/L	50.0	2	6.8	**368.0**	4.2	**996.0**
U (Unfiltered)	ug/L	30.0	1	ND	3.5	ND	0.2
Zn (Unfiltered)	ug/L	50	3	ND	7.7	ND	13.7
Zn (Filtered)	ug/L	50	3	ND	5.3	ND	8.8
Gross Alpha (pCi/L)	pCi/L	15.0	1	ND	**30.0**	ND	4.0
Gross Beta (pCi/L)	pCi/L	50.0	3	ND	17.0	ND	19.9
Nitrate & Nitrite (as N)	mg/L	10.0	1	ND	2.5	ND	3.4
Ra 226 (pCi/L)	pCi/L	5.0	1	ND	2.8	ND	3.2
Ra 228 (pCi/L)	pCi/L	5.0	1	ND	3.1	ND	1.5
Sulfate	mg/L	250.0	2	2.2	10.6	ND	18.4
Total Coliform		presence/ absence	1	ND	**2,420.0**	**7.0**	**24,540.0**
TDS	mg/L	500.0	2	20.0	118.0	5.0	144.0
Turbidity (NTU)	NTU	5.0	1	3.5	**88.1**	1.8	**24.9**

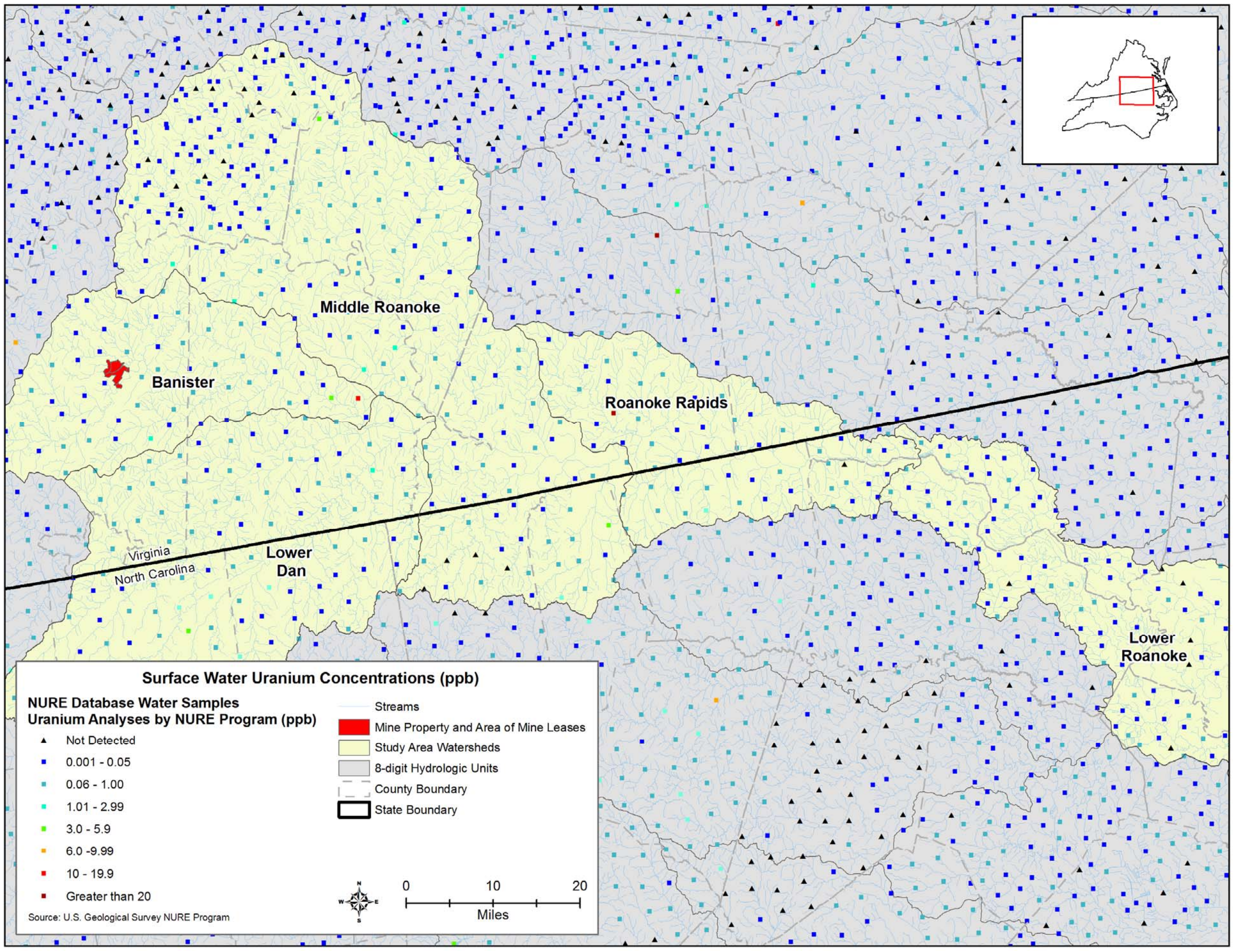
Standards:

1. EPA National Primary Drinking Water Standards (MCLs)
2. EPA National Secondary Drinking Water Standard
3. Virginia State Water Control Board Groundwater Standards 9 VAC 25-280-40 & Virginia Water Quality Standards 9 VAC 25-260-140

5.3.3.1.3 USGS NURE Data

Regional-scale information is available from the USGS NURE program, which assessed the potential for recoverable uranium resources across the country. Figure 5-27 shows measured uranium concentrations in surface water from the NURE program. Table 5-7 provides a statistical summary of these data for the area shaded watersheds in Figure 5-27. As these results indicate, baseline uranium concentrations in surface water range over several orders of magnitude and exhibit significant spatial variability. Figure 5-28 shows measured uranium concentrations in sediments from the NURE program. Table 5-8 provides a statistical summary of these data for the shaded watersheds in Figure 5-28. As these results indicate, baseline uranium concentrations in sediments range over about one order of magnitude and exhibit significant spatial variability. Data from the NURE program also include results for other constituents; a summary for several elements is provided in Table 5-9. It is important to note that NURE results do not allow location-specific evaluation given that samples are not available at a high spatial resolution. Nevertheless, this data source provides useful information about the range of conditions characteristic of regional scales.

Figure 5-27. Uranium Concentrations in Surface Water (ppb) from the USGS NURE Program



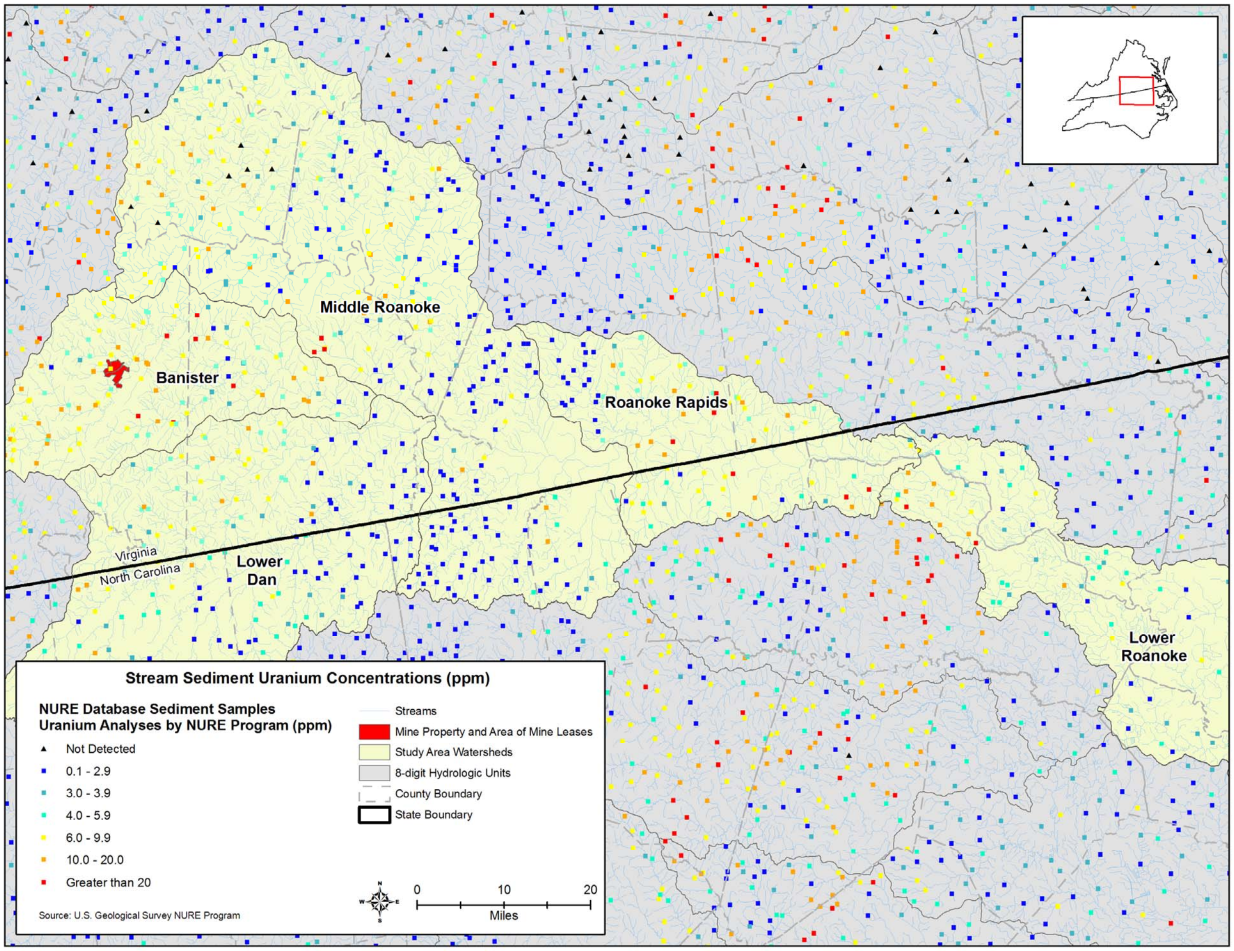
Source: U.S. Geological Survey NURE Program

Table 5-7. Summary of Regional Uranium Concentrations in Surface Water from NURE Data

Watershed ID (HUC)	Count		Uranium Concentration (ug/L)			
	Samples	ND Results	Max	Min	Average	Stand Dev
03010102	236	17	10.38	ND	0.201	0.833
03010104	117	3	4.192	ND	0.312	0.671
03010105	62	0	15.95	0.001	0.438	2.051
03010106	65	1	34.14	ND	0.643	4.223
03010107	173	23	0.659	ND	0.047	0.084

Note: Statistics were calculated using half the detection limit for nondetect results.

Figure 5-28. Uranium Concentrations in Stream Sediments (ppm) from the USGS NURE Program



Source: U.S. Geological Survey NURE Program

Table 5-8. Summary of Regional Uranium Concentrations in Sediments from NURE Data

	Count		Uranium Concentration (ppm)			
Watershed ID (HUC)	Samples	ND Results	Max	Min	Average	Stand Dev
03010102	448	0	25.4	0.9	4.3	4.2
03010104	351	0	17.9	0.7	4.0	2.9
03010105	207	0	60.2	1.5	9.4	8.2
03010106	160	0	47.6	1.1	7.9	8.3
03010107	97	0	24.7	1.3	5.0	4.3

Note: Statistics were calculated using half the detection limit for nondetect results.

Table 5-9. Summary of Regional Elemental Concentrations in Sediments from NURE Data

	Count		Concentration (ppm)			
Constituent	Samples	ND Results	Max	Min	Average	Stand Dev
Arsenic	326	0	14	1	2.2	1.8
Cerium	1,138	225	1,543	ND	83.3	99.0
Lead	699	516	547	ND	10.0	14.4
Uranium	1,263	0	60.2	0.7	5.6	5.0
Thorium	1,180	249	442	ND	16.2	22.4
Zinc	696	7	282	ND	19.1	19.3

Note: Statistics were calculated using half the detection limit for nondetect results.

5.3.3.1.4 U.S. EPA CWA Information

Section 303(d) of the CWA requires states to assess whether water bodies support beneficial uses such as aquatic life, fisheries, drinking water, recreation, industry, and agriculture. The resulting inventories characterize waters as (1) fully supportive of the beneficial uses, (2) impaired, or (3) threatened. A water body is considered impaired for a given use if it does not meet water quality standards. The law requires that jurisdictions establish priority rankings for impaired waterbodies and develop Total Maximum Daily Loads (TMDLs) for these waters to restore them. Typically, additional discharge permits are not allowed for streams exceeding the TMDL threshold. Table 5-10 documents impairments as of August 2010 for waters within the flow catchments in the region. Impairments in the area include mercury, polychlorinated biphenyls (PCBs), oxygen depletion, pathogens, and pesticides. One of the streams adjacent to the site, Whitethorn Creek, has an impairment for E. Coli that is likely a result of cattle farming in the area.

Table 5-10. Status for Beneficial Use Impairments of Streams in the Region (EPA, 2010)

WaterBody	Location	Cause of Impairment Group	Cause of Impairment	Designated Use(s) Affected	State TMDL Development Status
Banister Lake	From Its Impounding Structure To Its Backwaters On The Banister River	Oxygen Depletion	Dissolved Oxygen	Aquatic Life	TMDL needed
Banister River	Elkhorn Creek To Sandy Creek	Pathogens	E. Coli	Recreation	
	Sandy Creek To Banister Lake				
	Banister Lake To Burlington Industries Raw Water Intake 2000' Downstream Of Route 360 Bridge	Mercury	Fish Tissue	Fish Consumption	
		PCBs			
	Confluence Of Wolf Trap Creek To Its Mouth On The Dan River	Mercury			
		PCBs			
		Pathogens	E. Coli	Recreation	
		Mercury	Fish Tissue	Fish Consumption	
		PCBs			
Dan River	Peter Creek Confluence To Roanoke River Confluence (Kerr Reservoir)	Pathogens	E. Coli	Recreation	
		Mercury	Fish Tissue	Fish Consumption	
		PCBs			
	Dan River From The Banister River (Watershed Boundary) To The Peter Creek Confluence (Kerr Reservoir)	Pesticides	DDE		
			DDT		
		Pathogens	E. Coli	Recreation	
		Mercury	Fish Tissue	Fish Consumption	
		PCBs			
Kerr Reservoir	Kerr Reservoir From The John H. Kerr Dam To Its Backwaters, Excluding The Dan River Portion, Bluestone Creek And Buffalo Creek	Oxygen Depletion	Dissolved Oxygen	Aquatic Life	
		Mercury	Fish Tissue	Fish Consumption	
		PCBs			
Roanoke River	Kerr Dam To Route 1 Bridge	Oxygen Depletion	Dissolved Oxygen	Aquatic Life	TMDL alternative
		PCBs	Fish Tissue	Fish Consumption	TMDL needed
	Upper Portion Of Lake Gaston—Route 1 To The Confluence Of Smith Creek	Oxygen Depletion	Dissolved Oxygen	Aquatic Life	TMDL alternative
		PCBs	Fish Tissue	Fish Consumption	TMDL needed
		Mercury	Fish Advisories		
Lake Gaston	Lower Portion Of Lake Gaston On The Roanoke River- Smith Creek Confluence Downstream To The VA/NC State Line, Including Coves That Enter The Mainstream Within VA	Oxygen Depletion	Dissolved Oxygen	Aquatic Life	
		PCBs	Fish Tissue	Fish Consumption	
Roanoke Rapids Lake		Noxious Aquatic Plants	Aquatic Weeds		TMDL completed
Whitehorn Creek	Whitehorn Creek Mainstream From Its Mouth Upstream To The Confluence With Georges Creek	Pathogens	E. Coli	Recreation	TMDL needed

5.3.3.2 Estimated Surface Water Transport

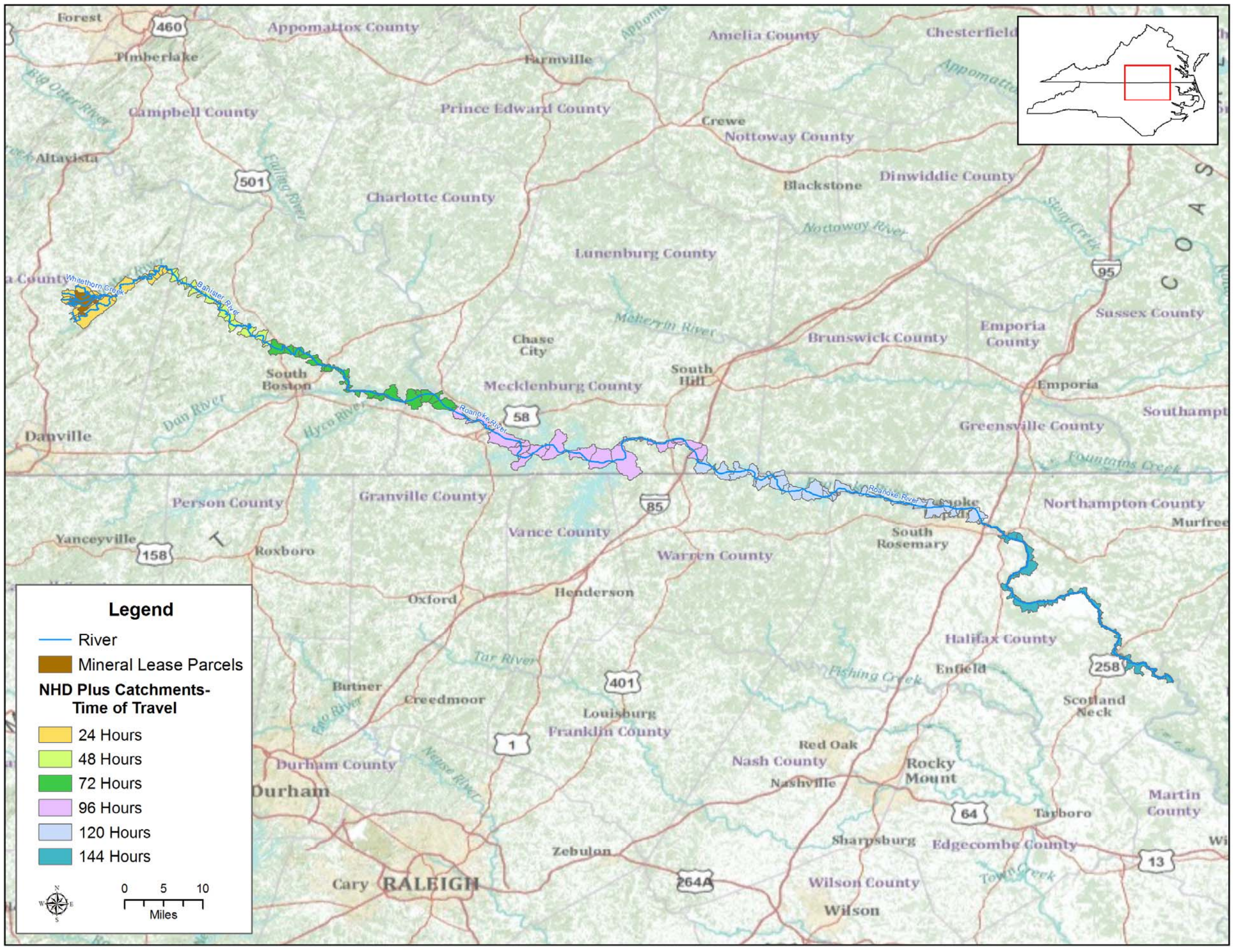
Analyses described in this section were developed to provide general characterization of the potential for contaminants to migrate from the site in surface waters. Given the limited available data and the undetermined facility configuration, the estimates are necessarily preliminary. Furthermore, the environmental transport of constituents of concern in surface waters is highly complex. As an example, the aqueous transport of uranium can involve the formation of various soluble and insoluble forms that are strongly dependent on conditions including pH, oxidation state, and the presence of other chemicals. The downstream transport of bottom sediments is also challenging to predict and strongly dependent on variable flow conditions and local characteristics (e.g., stream bed geometry, roughness). Given these uncertainties, this section presents relatively simplistic evaluations based only on flow and dilution in streams downgradient from the site. If the proposed mine and mill move forward, additional site-specific characterization will be required to support more rigorous evaluation of possible surface water and sediment transport.

The first evaluation in this section considers the time of travel in streams from the site location under annual average flow conditions. A time of travel of 6 days was considered, and the data source was NHDplus. The resulting 6-day travel distance was approximately 160 miles from the proposed mine site. The flow catchments that comprise the downstream time-of-travel in 24-hours segments are illustrated in Figure 5-29.

The second surface water transport evaluation in this section considers the discharge of process water from the facility and subsequent dilution as flow rates increase downstream because of groundwater inflow and intersection with other surface waters (e.g., confluence of Mill Creek and Whitethorn Creek). The QUAL2K model available from the U.S. EPA was used in this preliminary modeling simulation (http://www.epa.gov/athens/wwqtsc/html/qual2k.html). NHDPlus was used to define the stream geometries, interconnections, and flow rates. The model simulates the discharge of a hypothetical chemical at an arbitrary concentration of 1. Flows from tributaries and in Mill Creek above effluent discharge were assumed to have a concentration of 0. The facility discharge rates were based on the estimated facility water balance documented in Section 3. The results provide the relative downstream magnitude of concentration reductions because of dilution.

Importantly, this simplistic model evaluation does not consider any possible chemical transformations such as radiological decay and adsorption. Therefore, the predictions overestimate the potential transport of dissolved chemicals that might be discharged by the facility. For example, uranium and most metals typically adsorb strongly to solid particles, so that a significant fraction of mass in a water column will be attached to suspended solids, some of which will settle to the bottom of the surface water body. This process will decrease aqueous concentrations; note, however, that the settling of suspended particulates will also lead to increased concentrations of adsorbing chemicals in stream sediments.

Figure 5-29. Estimated Surface Water Travel Time Under Average Flow Conditions

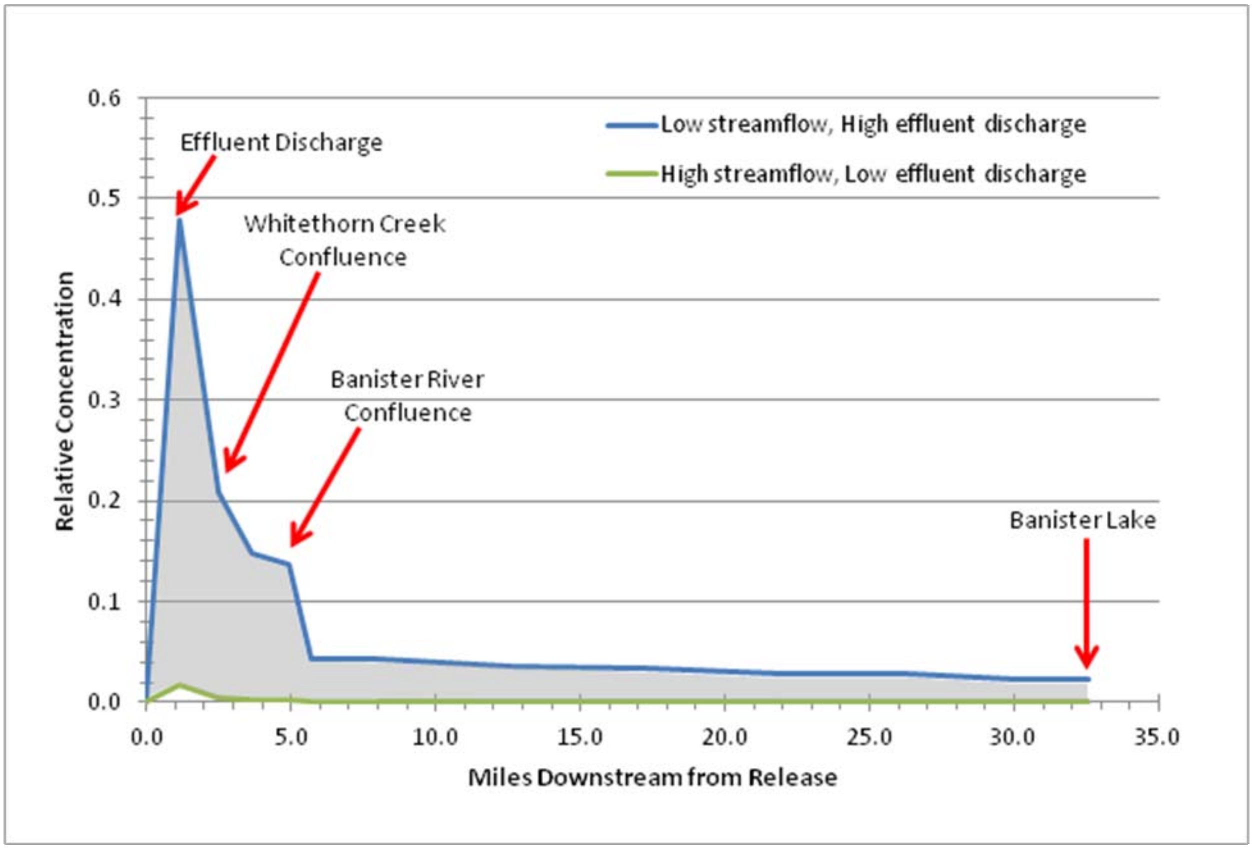


The model was set up by RTI to run from just upstream of the wastewater effluent discharge from the mine and mill (assumed to be Mill Creek south of the ore body) to the upstream end of Banister Lake for a total length of approximately 32.5 miles. Two different effluent scenarios were simulated to capture a range of potential water quality conditions:

1. High-Impact Scenario: An 830 gpm discharge with a concentration of 1 during a period of low flow (approximately 20% of average mean annual flow conditions)
2. Low-Impact Scenario: An 166 gpm discharge with a concentration of 1 during a period of high flow (approximately 200% of average mean annual flow conditions)

The two flow and effluent scenarios produced a range of potential downstream conditions as displayed in Figure 5-30. The high-impact scenario shows a peak concentration of nearly 0.5 just after discharge, with dilution downstream resulting in concentrations leveling out near 0.02 entering Banister Lake. Alternately, the low-impact scenario reveals a peak concentration of 0.018 and a leveling out of concentrations at 0.00045.

Figure 5-30. Estimated Relative Surface Water Concentrations Downstream from the Mine/Mill Discharge Location



5.3.4 Groundwater

Releases to groundwater from the mine and mill could result from

- leakage from tailings management and disposal facilities;
- leakage from impoundments supporting mine/mill operations if they contain elevated contaminant concentrations (e.g., treatment discharge impoundments, stormwater retention ponds); or
- infiltration of leachate from ore, subore, or overburden stockpiles if the leachate contains elevated contaminant concentrations.

Contaminated water entering the subsurface would migrate downward through the unsaturated zone (soil pore space occupied by air and water above the fully saturated water table). Upon reaching the water table, the contaminated infiltration would mix with the groundwater and then migrate with groundwater flow. Under typical conditions in the Piedmont, groundwater will flow from upland recharge areas toward lower-elevation groundwater discharge points, primarily springs and streams. The rates of flow can be very slow and depend on groundwater recharge rates, hydraulic properties of the subsurface (hydraulic conductivity, fracture inter-connection), and groundwater elevation gradients between the recharge and discharge locations. Marline (1983) estimated groundwater flow rates on the order of 0.5 ft/year. This may be a reasonable overall average rate, but additional characterization is needed to develop more reliable estimates. Furthermore, deep groundwater flows in fractures with highly variable interconnections and permeabilities. In some cases, fractures can transmit groundwater at much faster rates than the overall average rate (analogous to a pipe in the subsurface).

While the mine is operating, significant volumes of water would be recovered to dewater the mine (see Section 5.1.5). This groundwater recovery would lead to an area of depressed groundwater levels and groundwater flow toward the mine throughout the associated groundwater capture zone. If any releases to groundwater occur within this capture zone, the resulting groundwater impacts would migrate toward the mine, ultimately being collected by the dewatering system. After mine/mill operations are complete, subsurface groundwater levels will recover, and groundwater flow and potential contaminant transport will again occur generally from upland recharge areas to streams and springs.

In some cases, subsurface mining has permanently altered groundwater (and surface water) flow conditions and patterns due, for example, to the presence of large, open cavities remaining in the subsurface (see Section 4 for example case studies). Such open subsurface cavities also can be sources for post-mine impacts if groundwater becomes contaminated and migrates from the former mine with groundwater flow.

One tailings waste management option under consideration by VUI would involve mine backfill with low-permeability paste tailings (see Section 3). This option may offer advantages in terms of environmental impacts: a smaller volume of tailings would require management in surface impoundments; filling in open mine cavities would help mitigate possible undesirable changes in subsurface flow regimes; having the mine space filled with lower permeability material may help prevent significant groundwater flow through the former mine. However, subsurface paste tailings could be a source for groundwater contamination, particularly if placed below the water table. To prevent groundwater contamination, isolation of subsurface paste tailings from groundwater flow would be necessary.

5.3.4.1 Baseline Groundwater Quality Conditions

Two sources of baseline data were reviewed for this assessment, including recently collected data from VUI and data collected by Marline (1983).

Marline (1983) sampled groundwater from 60 residential wells in the site vicinity and springs and monitoring wells. They generally concluded that groundwater quality was excellent except for (1) some relatively saline waters encountered in the Triassic basin, (2) elevated iron and manganese levels (which can lead to stained bathroom fixtures), and (3) some elevated radiological concentrations in wells drilled in the ore body vicinity (e.g., radium-226 concentration of 315 pCi/L). Little evidence of lateral migration of radiologicals was identified; wells just outside of the immediate ore body vicinity showed much lower levels for radiologicals.

VUI has collected groundwater samples from 90 residential wells in the area of the proposed mine. VUI provided these data collected from 2007 through 2009 to RTI in the form of Excel tables.

Table 5-11 provides a summary of these results. The table includes constituents if any result in the dataset exceeded the specified standard. The results do show some levels above the specified standards. Several of the chemicals exceed EPA's secondary drinking water standard. Unlike MCLs, these secondary limits are not mandatory and are not developed based on health impacts; rather, secondary standards reflect aesthetic (e.g., taste, odor) and technical (e.g., corrosion) concerns. Several additional chemicals exceeded MCLs in some samples (e.g., arsenic, lead). These elevated baseline levels underscore the need for sufficient baseline characterization to be able to discriminate between potential impacts from the mine and mill and baseline conditions. The elevated concentrations also indicate that geologic materials in the area can lead to water quality conditions above health-based standards for some COCs. These chemicals should be evaluated for potential elevated concentrations associated with handling the ore and overburden materials. One of the samples exhibited much higher radiological levels than the others (e.g., gross alpha and uranium as high as 230 pCi/L and 193 ug/L, respectively). Analogous to the Marline (1983) results, this sample is likely within the ore body or in the immediate vicinity.

5.3.4.2 Contaminant Transport in Groundwater

The potential for migration of contaminants in groundwater depends on several factors, including groundwater flow rates, chemical transformations (e.g., radiological decay), and chemical interactions between the groundwater and the solid porous medium. The constituents of potential concern associated with the proposed mine/mill are primarily metals and radiologicals. These chemicals typically adsorb strongly to aquifer media, which can significantly decrease their mobility in the subsurface. Predicting their potential groundwater transport requires detailed understanding of geochemical conditions, including pH, oxidation-reduction potential, and the presence of other chemicals.

Empirical evidence characterizing the potential transport of radiologicals is available for the Coles Hill site. Results of the Marline and VUI groundwater baseline sampling provide little evidence of significant transport of radiological chemicals from the ore body vicinity. Jerden (2001) researched the geochemistry of the weathering process at Coles Hill and identified geochemical controls on the migration of uranium from the ore body. Specifically, relatively insoluble uranium phosphate minerals are formed along a relatively sharp redox front at the boundaries of the uranium deposits. The formation of these uranium minerals limits weathering and migration of uranium away from the ore deposit in the saprolite.

The most significant potential impacts to groundwater associated with uranium mining and milling are generally associated with the management of tailings. Historical tailings waste management practices have led to groundwater impacts at many sites (see Section 4). For example, investigation and remedial activities at 24 uranium mills (conducted through Title I of the UMTRCA) revealed at least local contamination at each of these sites (EPA, 1995). Groundwater quality parameters most frequently exceeded included uranium, molybdenum, manganese, nitrate, sulfate, and gross alpha activity, with the following additional parameters exceeded at some sites: arsenic, iron, selenium, radium, and total solids (EPA, 1987). The prevalence of such groundwater impacts was part of the justification for increasing waste disposal requirements under the UMTRCA. Current requirements include bottom liners and leakage detection systems (LDS) for synthetic liner systems (see Section 3). In addition, groundwater monitoring requirements around tailings management facilities have increased.

Table 5-11. Summary of Groundwater Quality Data Collected from 2007 to 2009 by VUI

Parameter	Units	Standard		Min	Max
pH (SU)	SU	6.5-8.5	2	4.0	**8.8**
Benzene	ug/L	5.0	1	ND	**7.3**
Al (Unfiltered)	ug/L	50-200	2	ND	**1770.0**
Al (Filtered)	ug/L	50-200	2	ND	**584.0**
As (Unfiltered)	ug/L	10.0	1	ND	**12.7**
As (Filtered)	ug/L	10.0	1	ND	**12.8**
Cu (Filtered)	ug/L	1300.0	1	ND	**9910.0**
Fe (Unfiltered)	ug/L	300.0	2	ND	**518000.0**
Fe (Filtered)	ug/L	300.0	2	ND	**10457.0**
Pb (Unfiltered)	ug/L	15.0	1	ND	**97.8**
Pb (Filtered)	ug/L	15.0	1	ND	**33.4**
Mn (Unfiltered)	ug/L	50.0	2	ND	**2220.0**
U (Unfiltered)	ug/L	30.0	1	ND	**193.0**
Zn (Unfiltered)	ug/L	50	3	ND	**710.0**
Zn (Filtered)	ug/L	50	3	ND	**1630.0**
Gross Alpha (pCi/L)	pCi/L	15.0	1	ND	**230.0**
Gross Beta (pCi/L)	pCi/L	50.0	3	ND	**215.0**
Nitrate & Nitrite (as N)	mg/L	10.0	1	ND	**23.1**
Ra 226 (pCi/L)	pCi/L	5.0	1	ND	**27.5**
Ra 228 (pCi/L)	pCi/L	5.0	1	ND	**5.8**
Sulfate	mg/L	250.0	2	ND	**381.0**
Total Coliform		presence/absence	1	ND	**2420.0**
TDS	mg/L	500.0	2	10.0	**1070.0**
Turbidity (NTU)	NTU	5.0	1	ND	**850.0**

Standards:

1. EPA National Primary Drinking Water Standards (MCLs)
2. EPA National Secondary Drinking Water Standard
3. Virginia State Water Control Board Groundwater Standards 9 VAC 25-280-40 & Virginia Water Quality Standards 9 VAC 25-260-140

Leakage through synthetic liners is possible as a result of factors such as deformation (stretching or shrinkage), improper seam construction, and stress loading. As of June 2008, only three conventional uranium milling facilities were active in the United States, and only one of those (White Mesa Uranium Mill, Utah) is known to have a double lined impoundment with a LDS. Leachate has been collected in the LDS at the White Mesa Mill, indicating compromises in the upper liner (Utah Division of Radiation Control, 2011). Liner repairs have been proposed. No clear evidence of groundwater contamination from this impoundment was identified.

Given the relatively small number of active facilities, site experience with uranium tailing management under current impoundment design requirements is limited. More extensive experience with double-lined systems with leakage detection is available for municipal landfills, many of which use this liner construction. Bonaparte et al. (2002) performed an extensive assessment of these liner systems. Leachate recovery rates from LDS systems were reviewed for 187 double-lined impoundments at 54 landfills. Most systems showed some leachate collected in the LDS with rates varying from insignificant to greater than 200 L/hectare-day. Some identified problems included defective construction, excessive deformation, and operational problems (e.g., clogged LDS). However, impacts to groundwater were only identified at one facility, and this impact was related to methane gas migration rather than leachate. Bonaparte et al. (2002) stated that double liner systems with leak detection are generally effective. However, they do emphasize the importance of proper engineering and construction and operational maintenance.

5.4 Potential Receptor Impacts

Human and ecological receptor impacts may result from contaminant releases and transport from the proposed mine and mill if concentration levels at receptors exceed thresholds above which impacts occur. Evaluations in this section are qualitative and consider the potential receptors, routes, and mechanisms of exposure (exposure pathways), and potential effects on humans and ecological receptors. Quantitative risk assessment was outside the scope of this analysis. Furthermore, additional site-specific data and operational details of the facility would be required to develop representative quantitative estimates of the risk for impacts.

5.4.1 Human Health

5.4.1.1 Human Receptors

Human receptors that could be exposed to COCs within the site and surrounding area include on-site or nearby workers, residents, farmers, and recreational users. The groups of people could be present at the mining and milling site, at home, on nearby agricultural or forested lands and at schools, churches or parks, or various commercial properties. The population of interest would include the area surrounding the site, and people located in downgradient directions for potential migration of contaminants, including in air, surface water, and groundwater.

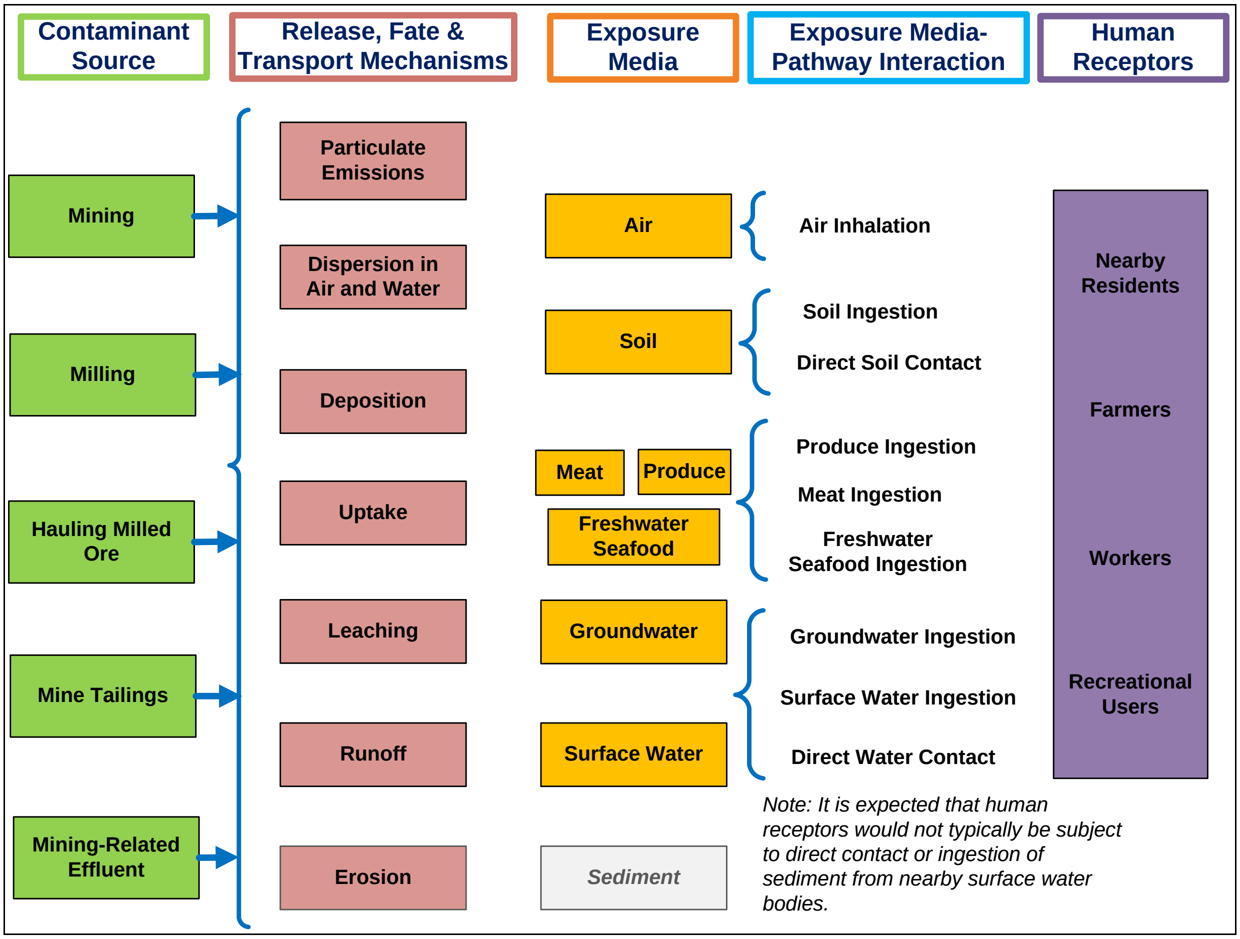
5.4.1.2 Potential Exposure Media-Pathway Interactions

To consider potential exposure scenarios, it is necessary to determine the media-pathway interactions that must be present for nearby human receptors to be exposed to potential COCs associated with the site. The potential environmental media include air, water, food, and soil, while the potential exposure pathways include inhalation, dermal absorption, and ingestion. The human health conceptual site model illustrated in Figure 5-31 identifies various characteristics that could lead to completed exposure pathways because of potential operations at the site.

Major factors included in the conceptual model include the contaminant source, release, fate and transport mechanisms, exposure media, and pathway. These factors comprise the various exposure media-pathway interactions possible for the applicable human receptors. As illustrated, the potential media-pathway interactions at or near the site include the following:

1. Air inhalation
2. Soil ingestion
3. Direct soil contact

Figure 5-31. Human Health Conceptual Site Model of Proposed Uranium Mine and Mill in Chatham, Virginia



Note: It is expected that human receptors would not typically be subject to direct contact or ingestion of sediment from nearby surface water bodies.

4. Produce ingestion
5. Meat ingestion
6. Freshwater seafood ingestion
7. Groundwater ingestion
8. Surface water ingestion
9. Direct water contact

The exposure scenarios that pose the major potential concern include air inhalation and water ingestion for drinking water sources. Exposure via air inhalation depends on a variety of factors, including the mining setup, pollution control technologies and effectiveness, pollution prevention strategies, the predominant wind direction, and the location of human receptors.

The potential for water ingestion is initially dependent on the use of groundwater, surface water, and springs surrounding the site. Drinking water wells and downgradient surface water intakes for drinking water could be impacted if COCs migrate off site above human health benchmarks. The possible migration of COCs off-site in groundwater and surface water similarly depends on the mining setup, use of treatment technologies, precipitation patterns, and the location of human receptors.

Exposure through direct water contact is possible if elevated COC concentrations are present in water sources (i.e., bathing) or in recreational water bodies (i.e., swimming). However, the overall risks posed by direct water contact is typically lower than risks from inhalation and ingestion pathways because of the relatively low chemical absorption rate for dermal contact of most of the potential COCs.

Because of the wide variability and long-distance transport of most produce, dairy products, meat, and freshwater seafood products, it is not anticipated that ingestion of these products (and soil ingestion from particulates on such products) would be a significant exposure route for potential human receptors. Freshwater seafood exposure could be higher for recreational fishermen in the area. Similarly, elevated produce and meat consumption from home gardeners or citizens who buy locally sourced farm goods could increase the potential risk for these exposure scenarios.

Direct soil contact could be an issue for workers if appropriate personal protection equipment (PPE) is not worn. However, it is typically not a major concern for off-site receptors because of the relatively small amount of soil that would be anticipated to migrate off-site coupled with the lower absorption rate associated with dermal contact.

It was presumed that human receptors would not have direct contact with or ingestion of sediment in surface water bodies, thus this exposure scenario was not illustrated.

5.4.1.3 Potential Health Effects

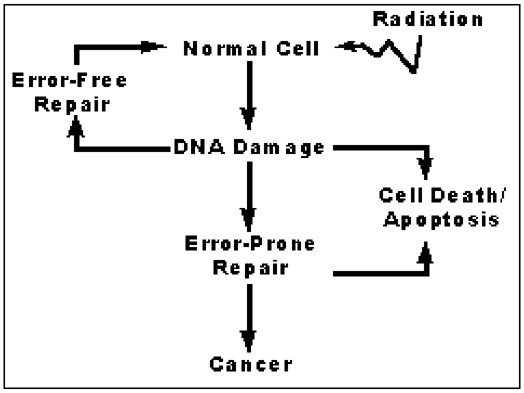
Noncancer health effects can be both acute and chronic in nature. Acute health effects are caused by short-term, elevated exposure to one or more chemicals. Chronic health effects are caused by long-term exposure to one or more chemicals. Acute exposure may result in short-term issues such as headaches, nausea and dizziness, while chronic exposure may result in health problems such as decreased fertility or lung functioning.

A reference dose (RfD) is considered to be a daily chemical exposure estimate that is not expected to increase the risk of adverse noncancer effects substantially throughout a lifetime. Individual RfDs are calculated for particular chemicals and endpoints. To calculate RfDs, the No Observable Adverse Effect Level (NOAEL) is divided by specific uncertainty factors. The NOAEL is the highest tested dose at which a test subject is exposed to a chemical and no statistically significant change in the studied response is seen, compared to a control group. The Lowest Observed Adverse Effect Level (LOAEL) is the lowest tested dose at which a test subject is exposed to a chemical and there is a statistically significant change in the studied response, compared to a control group. Slope factors may also be calculated as an upper bound estimate of increased cancer risk from lifetime exposure to a certain chemical. EPA also maintains a “weight-of-evidence” carcinogenicity classification scheme for chemicals. The major health effects of the primary COCs at the site are discussed below, along with a brief discussion of available toxicity information.

5.4.1.3.1 Ionizing Radiation

Uranium-238 and some of its daughter products emit ionizing radiation, including alpha particles, beta particles and gamma rays. Ionizing radiation can damage living cells or cause cell death by producing highly reactive oxygen species that destroy cellular integrity (Figure 5-32). When ingested or inhaled, alpha and beta particles can remove electrons from other atoms, including atoms making up the nasopharyngeal, tracheobronchial, and alveoli areas of the respiratory tract. Exposure to ionizing radiation can cause mutations, chromosomal aberrations, and cell death. Mutations mainly occur when ionizing radiation breaks either one strand or both strands of DNA, and the DNA is not properly repaired before the cell goes through mitosis. Even if the cell tries to fix the broken DNA strand(s), the DNA is often incorrectly repaired. Single strand breaks are easier to repair, because the undamaged DNA strand acts as a template. Double-strand breaks, which are much harder to repair, occur more frequently with exposure to ionizing radiation.

Figure 5-32. Potential Cellular Outcomes after Radiation Exposure in a Normal Cell (Mitchel and Boreham, 2000)



Exposure to ionizing radiation increases the risk of developing cancer from mutations and of having reproductive difficulties (including an increased chance of sterility, miscarriages, and children with chromosomal diseases). Many other health effects can emanate from cell damage and death, which causes a loss of cellular functioning in the areas exposed to ionizing radiation. Cancers that have been strongly associated with ionizing radiation include leukemia, multiple myeloma, thyroid, breast, bladder, colon, liver, lung, esophagus, ovarian, stomach, nasopharyngeal, pancreatic, bone and prostate. Areas of the body that undergo mitosis more quickly are more susceptible to cancer, because it is more likely that a cell will be replicated before the mutation is repaired (Klassen and Watkins, 2003).

The National Research Council published a 2005 report indicating that low-dose ionizing radiation causes DNA damage and cancer, and has the potential to cause additional health problems. Low-dose exposure was defined in this reference as nearly zero to 100 mSv. Furthermore, the report indicates that there is no effects threshold for ionizing radiation exposure, thus even a very low dose increases health risks (although by a small, incremental amount). Furthermore, animal study data indicate that reproductive cell mutations from radiation exposure can be passed on to future generations (NAS, 2005). After milling, up to approximately 86% of the original radiological activity of the uranium ore can retained in the milled tailings, which creates the need for long-term isolation of these waste materials (EPA, 2008a). Some researchers hypothesize that low-level radiation exposures actually can reduce risks through a mechanism called hormesis (Feinendegen, 2005). The NAS (2005) report discusses this issue and concludes that an assumption of hormetic effects is unwarranted at this time.

Under the Safe Drinking Water Act (SDWA), EPA assigned maximum contaminant levels (MCLs) in drinking water to alpha particles (15 pCi/L), beta particles (4 mrem/yr) and radium 226 and 228 (5 pCi/L) (EPA, 2011).

Limited research has evaluated exposures to humans via food pathways in the vicinity of uranium mines and mills. Au et al. (1994) evaluated potential genotoxic effects on people living in the vicinity of uranium mines active in Texas from the 1950s. The study results identified a higher frequency of abnormal DNA repair mechanisms in these populations. Lapham et al. (1989) showed that elevated levels of radionuclides were present in animals and vegetables exposed to uranium tailings in New Mexico. However, they concluded that the risks to humans were “minimal” unless large quantities are consumed. It is also noteworthy that these studies were associated with mining and milling operations active during the pre-regulatory period of the 1950s and 1960s.

5.4.1.3.2 Uranium

Aside from ionizing radiation, uranium can exhibit chemical toxicity to internal organs with potential adverse reproductive effects and increased cancer risk, especially lung cancer. Kidney damage (i.e., acute tubular necrosis) and respiratory diseases (i.e., lung irritation, fibrosis and emphysema) comprise the major possible noncancer health effects from uranium exposure (Klassen and Watkins, 2003).

EPA does not list toxicity data for natural uranium compounds that may be found during mining, because the data are currently under review. There is information available for soluble uranium salts, which could be associated with uranium processing. An oral reference dose of 0.003 mg/kg-day was established based on a 1949 study of soluble uranium salts, which measured body weight loss and moderate nephrotoxicity via oral exposure to rabbits over 30 days. EPA does not have a weight-of-evidence carcinogen classification for uranium or soluble uranium salts. According to EPA, a complete cancer evaluation and classification determination has not been conducted for uranium to date. Uranium daughter products also exhibit varying levels of chemical toxicity (IRIS, 1993; ATSDR, 2009).

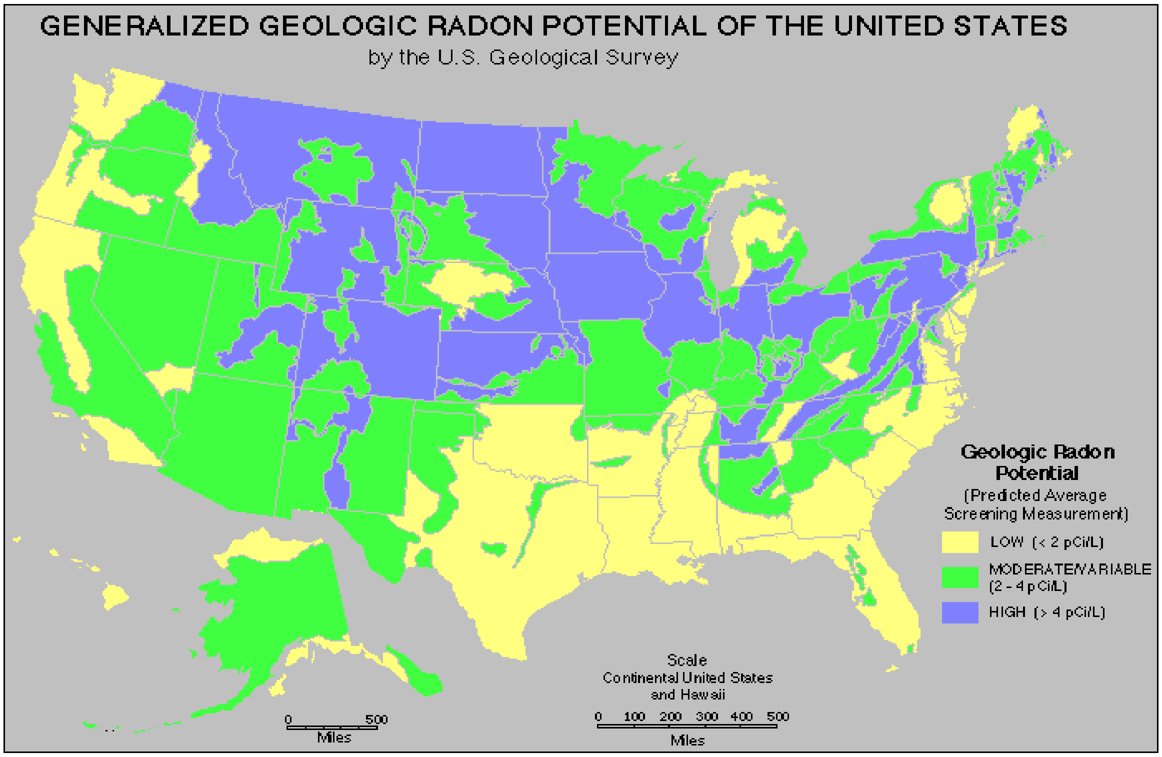
Under the SDWA, EPA assigned an MCL for uranium in drinking water of 30 ug/L (EPA, 2011b).

5.4.1.3.3 Radon Gas

Radon, a radioactive gas produced from natural decay of uranium, is widespread throughout many areas of the United States, as illustrated in Figure 5-33. In south central Virginia, naturally elevated levels of radon from uranium-bearing rocks and soils may infiltrate into homes through cracks in building foundations. Radon tends to concentrate in building basements and crawl spaces, but can be elevated in other areas of the home as well. Lung cancer is the only established health effect of radon exposure identified in humans to date. In fact, radon is the second leading cause of lung cancer after cigarette smoking. Smoking along with radon exposure causes a synergistic increase in the risk of lung cancer. Although substantial information links radon exposure to lung cancer, EPA does not have an RfD or weight-of-evidence carcinogen classification for radon. According to EPA, the carcinogen assessment summary was removed for further review.

An indoor residential radon action level of 4 pCi/L was set by EPA in an effort to reduce residential exposure to radon (areas shown in purple on map). EPA recommends remedial measures to reduce radon concentrations in indoor air if radon is above the action level. Remedial measures include the installation of a vapor mitigation system and sealing building foundations (ATSDR, 2010; IRIS, 1993).

Figure 5-33. Generalized Geologic Radon Potential of the U.S. (USGS, ND)



5.4.1.3.4 Heavy Metals

In addition to the concerns associated with radioactivity, uranium ore and tailings can contain a variety of heavy metals, including lead, arsenic, cadmium, chromium, iron, manganese, mercury, and zinc. Exposure to certain heavy metals can elicit both acute and chronic noncancer health effects and also increase the risk of certain types of cancer. Some metals are essential in moderate quantities to regulate bodily functions (i.e., iron). However, some heavy metals are considered xenobiotic, because the human body does not require such metals for normal functioning and exposure to small quantities can be toxic. In 2007, arsenic and lead were listed as the two highest priority hazardous substances by the Agency for Toxic Substances and Disease Registry (ATSDR, 2007).

For example, inhalation or ingestion of lead can cause rapid absorption into the human body, where lead binds to red blood cells, migrates to soft tissues, and is stored in bone. Lead is detrimental to the human body because (1) it imperfectly mimics and interferes with calcium's role in the regulation of gene expression and central nervous system functioning, and (2) lead exposure damages soft tissues in the body, including the gastrointestinal tract, blood, kidney, heart, and reproductive organs. Furthermore, acute exposure to elevated lead levels can cause adverse physiologic, reproductive, metabolic, neurologic, and behavioral changes. EPA does not provide a reference dose for lead because there is considered to be no threshold for health effects from lead exposure. EPA considers lead to be a Group B probable human carcinogen based on the incidence of renal cancer in animals exposed to lead (IRIS, 1988).

Acute exposure to elevated arsenic levels can cause gastrointestinal issues and central and peripheral nervous system disorders. Meanwhile, chronic arsenic exposure can cause a variety of noncancer health effects, including peripheral neuropathy, hyperpigmentation, liver damage, kidney damage, and reproductive problems. Furthermore, arsenic exposure increases the risk of multiple types of cancer (ATSDR, 1998). An oral reference dose of 0.0003 mg/kg-day was developed for inorganic arsenic based on 1968 and 1977 studies by Tseng el al., which measured hyperpigmentation, keratosis, and possible vascular complications associated with chronic oral exposure to arsenic in humans. EPA considers arsenic to be a Group A human carcinogen based on the incidence of lung, liver, kidney, bladder, and skin cancer in humans exposed to arsenic (IRIS, 1998). Under the SDWA, EPA assigned MCLs in drinking water to arsenic at 10 ug/L and lead at 15 ug/L. Additional heavy metals are listed under EPA's National Primary Drinking Water Regulations as well (EPA, 2011b).

5.4.2 Ecosystem Health

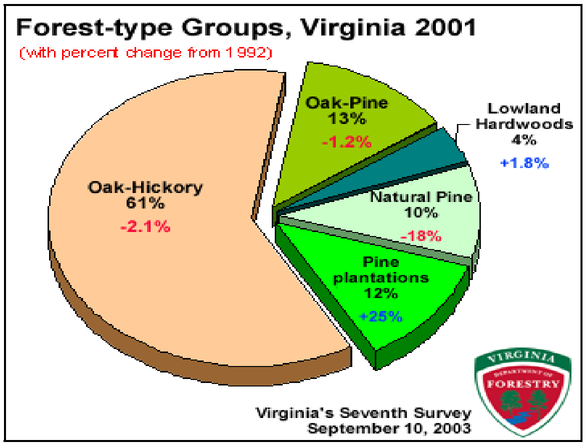
5.4.2.1 Ecological Receptors

Ecological receptors that could be exposed to COCs within the site and surrounding area include native plant and tree species, soil biota, terrestrial wildlife, pets, farm animals, and aquatic biota.

5.4.2.1.1 Regional Flora

The most common forest type in the state of Virginia is Oak-Hickory (61%), followed by Oak-Pine (13%), as illustrated in Figure 5-34. According to the Virginia Department of Environmental Quality (VDEQ), the most common trees in Virginia include various types of Oak, Pine, Maple and Hickory, and Tulip Poplar, Sweetgum, Black Gum and Beech (VDEQ, 2008).

Figure 5-34. Virginia Forest Type Groups Based on 2001 Survey (VDEQ, 2008)



Forested areas in the piedmont include the Southern Mixed Forest and Mesophytic Forest (in moist environments) (Figure 5-35). In the Southern Mixed forest, also known as the Southeastern Mixed Forest, there are various types of pine and hardwood trees. Oaks and hickories are the most prevalent hardwood canopy tree species. Loblolly pine is the most common planted pine tree, while Virginia, longleaf, and shortleaf pine are also prevalent naturally. Common understory deciduous trees include dogwood, red bud, cedar, and holly. There are two types of Mesophytic forests in the region—Mixed Mesophytic and Appalachian Oak. In Mixed Mesophytic forests, there are more than 30 common canopy tree species. The Appalachian oak forest is common in areas previously dominated by the American chestnut. Unforested, agricultural lands may include a variety of crops or may be used for animal grazing. Non-agricultural, unforested areas may include plant cover such as crab grass, blue grass, wildflowers, berry bushes, wire grass, broom sedge, sumac, and honeysuckle. Over time, old fields not used for grazing may begin succession into secondary growth forests (Gagnon, 2007; Hinkle et al., 1993; WWF, 2001). An example of the transition between fields, forests, and wetlands is shown for the Coles Hill site in Figure 5-36.

5.4.2.1.2 Regional Fauna

According to the World Wildlife Fund (WWF) Wildfinder database, there are at least 409 amphibian, reptile, mammal, and bird species in the Southeastern Mixed Forest ecoregion (classified as NA0413), which extends from the southeastern United States along the inner piedmont toward the eastern United States and is situated between the Appalachians to the west and the Coastal Plain to the east. Based on the Wildfinder database, the following classes of species are present within Southeastern Mixed Forests and could be present on or near the site:

Figure 5-35. Southeastern Mixed Forest Ecoregion [in lime green] Surrounding Site Region [blue dot] (WWF, 2008)

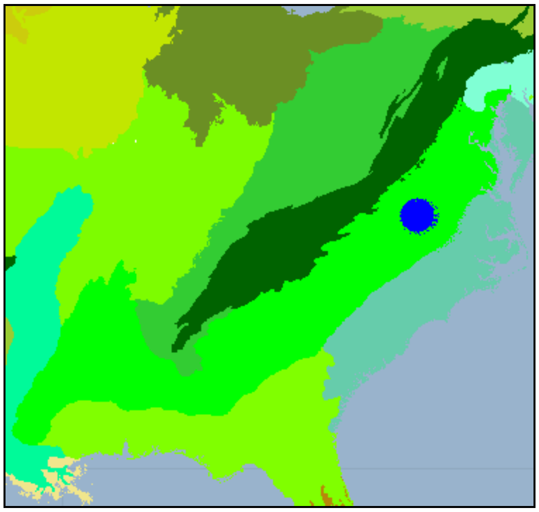


Figure 5-36. Representative Ecological Communities at the Coles Hill Site

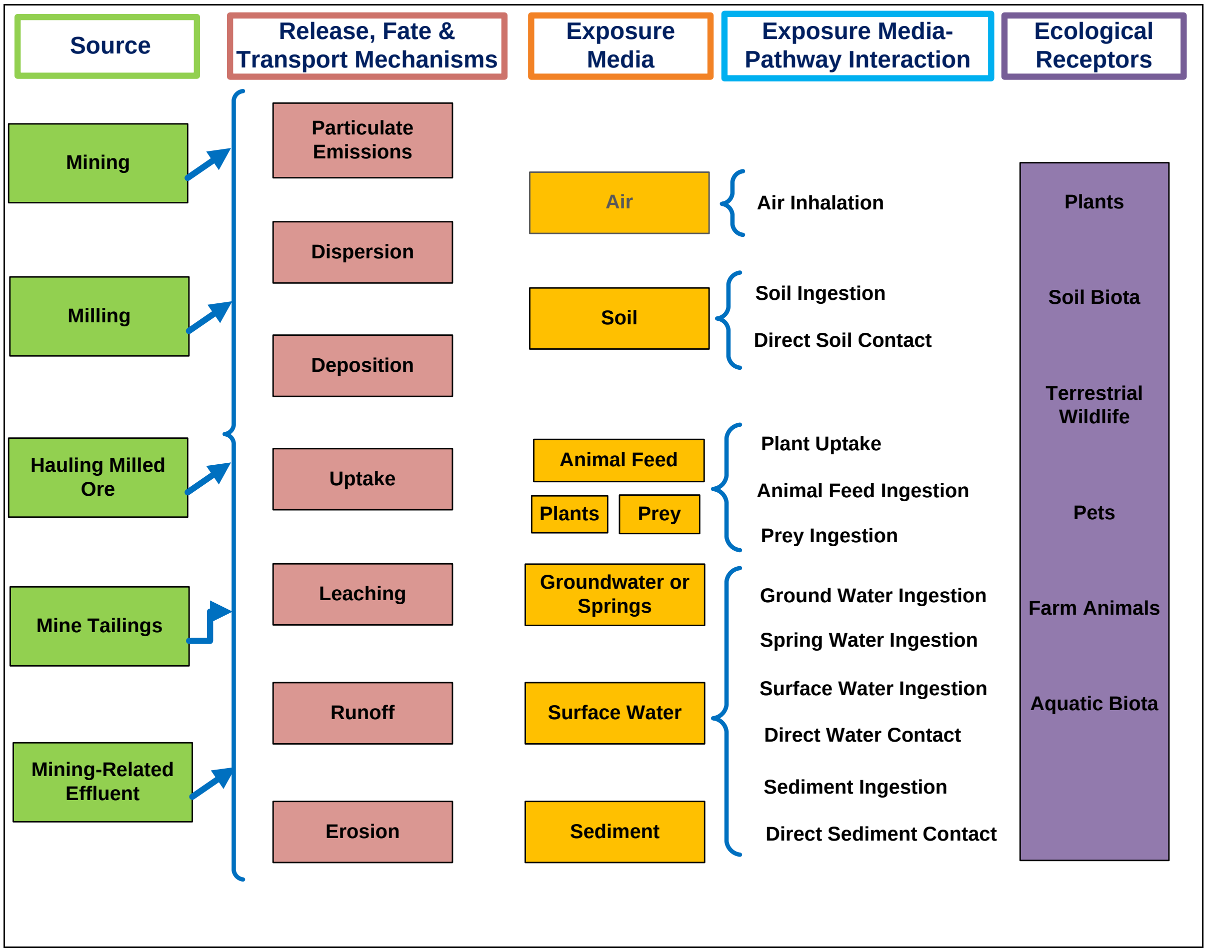
- Amphibians
  - 61 species, including salamanders, toads, and frogs
  - 6 species listed as Near Threatened or Endangered (e.g., spotted salamander)
  - 4 species listed as Near Threatened (e.g., red salamander)
- Reptiles
  - 72 species, including snakes, lizards, anoles, skinks, and turtles
  - 16 species listed as Vulnerable or Endangered (e.g., worm snake)
  - 5 species listed as Vulnerable (e.g., ringed map turtles)
- Mammals
  - 63 species, including deer, rabbits, chipmunks, squirrels, opossums, muskrats, woodchucks, foxes, bats, shrews/mice/voles/moles/rats, coyotes, skunks, weasels, and raccoons
  - 12 species listed as Near Threatened or Endangered
  - 1 species listed as Near Threatened
- Birds
  - 212 species, including predatory birds, song birds, and game birds
  - 10 species listed as Near Threatened, Vulnerable or Critically Endangered (e.g., pied-billed grebe)
  - 3 species listed as Vulnerable (e.g., painted bunting)
  - 6 species listed as Near Threatened (e.g., scarlet tanager)

Threatened species are classified to be critically endangered, endangered, or threatened (from highest risk to lowest risk). Lower risk species are classified as conservation dependent, near threatened, or least concern. Certain species may be localized to more confined areas within the ecoregion and are unlikely to be identified at the site. However, certain species, including many birds, could be present throughout this ecoregion. Further site-specific ecological evaluations would be necessary to determine the type and prevalence of species actually identified to inhabit, feed, or migrate across the site (Olson, 2001; WWF, 2011).

5.4.2.2 Potential Exposure Media-Pathway Interactions

The ecological conceptual site model illustrated in Figure 5-37 identifies the potential source, mechanism, media, and pathway interactions that could influence ecological exposure to mining and milling-related COCs.

Figure 5-37. Ecological Conceptual Site Model of Proposed Uranium Mine and Mill in Chatham, Virginia



The environmental media include air, water, food, and soil, while the potential exposure pathways include inhalation, dermal absorption, and ingestion. Major factors included in the conceptual model include the contaminant source, release, fate and transport mechanisms, exposure media, and pathway. These factors comprise the various exposure media-pathway interactions that could be possible for the applicable ecological receptors. As illustrated, the potential media-pathway interactions for ecological receptors include the following:

1. Soil ingestion
2. Direct soil contact
3. Plant uptake (and ingestion)
4. Animal feed ingestion
5. Prey ingestion

6. Groundwater ingestion
7. Spring water ingestion
8. Surface water ingestion
9. Direct water contact
10. Sediment ingestion
11. Direct sediment contact

The exposure scenarios that pose the largest potential concern for ecological receptors generally involve the ingestion pathway. Ecological receptors could be exposed to COCs by drinking from surface water, springs, or groundwater wells (for farm animals and pets); ingesting plants, animal food, or nearby prey; and inadvertently ingesting soil or sediment while eating. Soil biota, such as earthworms, can ingest large quantities of soil in relation to their bodyweight and are known to accumulate certain types of COCs. As such, ecological receptors that feed on earthworms (i.e., birds) can be particularly susceptible to COC exposure. If surface water impacts are present at and downgradient of the site, associated ecological receptors could be threatened.

The migration of COCs surrounding the site and off-site depend on the mining setup, treatment and pollution prevention technologies, precipitation patterns, and more. Additionally, the type and location of ecological receptors would influence the potential severity of ecological receptor impacts.

Direct water contact and direct sediment contact could be issues for aquatic organisms if elevated COCs are present. Furthermore, direct soil contact could be an issue for soil biota and burrowing terrestrial organisms. The air-inhalation exposure scenario could be an issue if air concentrations exceed levels of concern.

5.4.2.3 Potential Ecological Effects

The effects of uranium mining and milling on the surrounding ecosystem could include adverse effects to native flora and fauna, and farm animals, cultivated crops, and pets in the surrounding area. Mining and milling would disturb local ecosystems to some degree through land clearing, excavation of tailing ponds, maintaining material stockpiles, building infrastructure, roadways, and equipment. In addition to the mechanical influence of mining and milling, surrounding vegetation could be adversely affected by COCs. At higher concentrations, COCs can cause cellular damage to vegetation, making the surrounding flora either less productive, or in severe cases, increasing the risk of vegetation die offs. Native flora is an integral part of the surrounding ecosystem; however, this section predominantly focuses on the potential ecological effects of uranium mining and milling on fauna for which toxicity information is more widely available.

As discussed in Section 5.4.1.2, various mammal, bird, amphibian, and reptile species are native to south central Virginia and may be present at the site. Exposure to high concentrations of uranium compounds can cause respiratory, renal (kidney), ocular (vision), immunological, gastrointestinal, cardiovascular, body weight, neurologic, reproductive, developmental, genotoxic, and hematological noncancer health effects, and death. Acute ecological exposure issues can include kidney damage, decreased body weight, and death. Chronic ecological exposure issues could include adverse reproductive effects, genotoxic and hematological changes, and cancer (ATSDR, 2011a). The median lethal uranium dose (LD50) is referenced for ecological impacts as the dose level at which death occurs for 50% of the species being studied. Based on laboratory studies, the LD50 for terrestrial animals exposed to natural uranium ore intravenously has been shown to range from 0.1 mg/kg in rabbits to 20 mg/kg in mice (CalEPA, 2001).

An ecological benchmark is the media-specific concentration (i.e., water) not expected to cause an observed adverse effect (NOAEL) for a specific ecological receptor. Ecological benchmarks are available for a variety of chemical compounds, including uranium and several heavy metals, from ecological toxicity testing conducted by Oak Ridge National Laboratory (ORNL) in 1996 (Tables 5-12, 5-13, and 5-14). It should be noted that more soluble forms of uranium, arsenic, and lead were used for these studies; the chemicals were thus in forms that are more soluble and bioavailable than many of the COCs likely to be associated with the proposed mine and mill.

For uranium, mice orally exposed to uranium acetate were observed for reproductive health effects. The toxicity information obtained from the study was then estimated across other terrestrial species using available information on species sensitivity and disposition to obtain an estimated NOAEL for each species. Corresponding food and water concentration benchmarks were calculated for each species in parts per million (ppm), which is equivalent to mg/kg.

Table 5-12. Toxicity Information for Uranium as Uranyl Acetate (ORNL, 1996)

Species	Estimated NOAEL* (mg/kg-d)	Food Concentration Benchmark (ppm)	Water Concentration Benchmark (ppm)
Short-tailed Shrew	3.59	5.98	16.31
Little Brown Bat	4.27	12.8	26.67
White-footed Mouse	3.26	21.1	10.87
Cottontail Rabbit	1.2	6.08	12.41
Red Fox	0.86	8.62	10.21
Whitetail Deer	0.46	14.87	7

* Estimated NOAEL converted from NOAEL of 3.07 mg/kg-day derived during study of mice.

For arsenic, mice orally exposed to arsenite were observed for reproductive health effects. Toxicity information was derived using the same methods listed for uranium.

Table 5-13. Toxicity Information for Arsenic as Arsenite (ORNL, 1996)

Species	Estimated NOAEL* (mg/kg-d)	Food Concentration Benchmark (ppm)	Water Concentration Benchmark (ppm)
Short-tailed Shrew	0.15	0.25	0.68
Little Brown Bat	0.18	0.54	1.11
White-footed Mouse	0.14	0.88	0.45
Cottontail Rabbit	0.05	0.25	0.52
Red Fox	0.036	0.36	0.43
Whitetail Deer	0.019	0.62	0.29

* Estimated NOAEL converted from NOAEL of 0.126 mg/kg-day derived during study of mice.

For lead, rats orally exposed to lead acetate were observed for reproductive, body weight, and fetal kidney effects. Toxicity information was derived using the same methods listed for uranium.

Table 5-14. Toxicity Information for Lead as Lead Acetate (ORNL, 1996)

Species	Estimated NOAEL* (mg/kg-d)	Food Concentration Benchmark (ppm)	Water Concentration Benchmark (ppm)
Short-tailed Shrew	17.58	29.3	79.92
Little Brown Bat	20.91	62.73	130.68
White-footed Mouse	15.98	103.38	53.26
Cottontail Rabbit	5.88	29.77	60.82
Red Fox	4.22	42.25	50.03
Whitetail Deer	2.24	72.88	34.27

* Estimated NOAEL converted from NOAEL of 8 mg/kg-day derived during study of rats.

The ORNL studies did not measure cumulative or synergistic effects, which are possible when several chemicals are present simultaneously. Several additional factors should be considered in evaluating the relevance of these benchmarks, including the species conversions based on data from mice or rats, the number of species evaluated, and the age of the data.

Canadian water quality guidelines for uranium include an acute aquatic benchmark of 33 ug/L and a chronic aquatic benchmark of 15 ug/L (CCME, 2011). Acute health effects were observed in 50% and 95% of fathead minnows exposed to 10 ug/L and 50 ug/L of uranium, respectively. Acute health effects were also observed in 50% and 95% of rainbow trout exposed to 100 and 501 ug/L of arsenic, respectively. Chronic health effects were observed in 50% and 95% of brook trout exposed to 50 ug/L and 316 ug/L of lead, respectively. There is potential for cumulative or synergistic aquatic health effects from the full list of chemicals present in mined uranium ore and milled ore as well (ORNL, 1996). Freshwater screening benchmarks were developed by EPA for a variety of chemicals, including arsenic (5 ug/L), lead (2.5 ug/L), and uranium (2.6 ug/L). To develop the benchmarks, a literature review was conducted, with chronic nonlethal health effect endpoints included whenever possible (EPA Region 3, 2011). Regional screening levels are also available for some additional contaminants (EPA, 2007).

As described above, several laboratory studies and ecological benchmarks are available to evaluate potential ecological impacts. However, site-specific ecological studies prior to potential mining and milling activities at the site would provide much more accurate and relevant information. Ideally, the site-specific studies would evaluate baseline and potential future site conditions (e.g., sensitivity of local flora and fauna to increased COC concentrations). Such studies could include terrestrial, aquatic, and soil organisms and farm animals, agricultural crops, and native terrestrial and aquatic vegetation. Results from such studies would be useful to support a comprehensive risk assessment of potential ecological impacts from the mine and mill.

5.5 Summary

In this chapter, we evaluate potential implications of the proposed Coles Hill uranium mine and mill for human and ecological health. The general environmental setting was discussed along with its importance in controlling contaminant mobility from the mine and mill and possible resulting environmental impacts. Chemicals of potential concern were evaluated such as radiological elements and heavy metals that may be released as a result of mine/mill activities. In addition, this section considered the potential transport of these chemicals away from the facility in the various environmental media, including air, soil, surface water, and groundwater. Lastly, possible impacts to human health and ecosystems that might result from such contaminant releases and transport were discussed. Several of the key issues evaluated in this section are summarized below.

- The proposed mine and mill are in a climatic region with relatively greater rainfall than many uranium facilities, particularly in the southwestern United States. This characteristic raises concerns about the potential for flooding and accidental releases and possible challenges in containing wastes and other contaminants on the site. A maximum daily precipitation of 7.9 inches is predicted to occur once every 100 years. The flood plain associated with this predicted 100-year event has been delineated as shown in Figure 5-12. Any mine and mill facilities handling potential contaminants would clearly need to be located at elevations well above the area of potential flooding. Furthermore, stormwater management facilities would need to be designed to minimize runoff and erosion across the facility, particularly in areas where ore, ore byproducts, and wastes are handled.

- The ore body is located within watersheds for Mill Creek and Whitethorn Creek, streams located less than 1 mile to the south and north of the ore body, respectively. These waterbodies would be most subject to potential releases from the facility, including discharges from treatment and surface water management facilities and any uncontrolled surface runoff from the property.

- Mine dewatering would be necessary to lower groundwater levels from current depths of approximately 33 ft below the surface to the depth of the ore body (approximately 1500 ft). Recovered groundwater would be used to support the industrial processes. Any excess groundwater recovered beyond the facility demand would need to be managed (e.g., stored and treated if contaminant levels exceed regulatory thresholds). The groundwater system is complex and includes bedrock fractures with variable and unknown density and interconnectivity. Groundwater flow in fractured bedrock systems can be difficult to predict, so that estimates of potential groundwater pumping necessary to dewater the mine are highly uncertain. Preliminary estimates developed by RTI and reflecting this uncertainty suggest that the required groundwater pumping could range from 150 to 1,500 gallons per minute. These rates also could vary significantly over time. Additional hydrogeologic testing is needed to refine estimates of groundwater recovery necessary to dewater the mine and the potential extent of groundwater lowering.

- Groundwater levels in the area around the mine would lower as a result of the dewatering, which could impact nearby wells, springs, and surface water bodies. Wells and springs in the affected area could decrease in capacity or go dry. Groundwater flow to surface water could decrease, or surface water could flow back into the groundwater system in areas of lowered groundwater elevations, thus decreasing the surface water flows.

- Possible constituents of concern that may be encountered at the mine include (1) uranium and its radioactive daughter products (e.g., thorium, radium, radon gas); (2) heavy metals present in the ore or overburden; (3) acidic or alkaline leachate; (4) particulates, including the potential for chemicals to be bound to the particulates; and (5) other mine process chemicals (e.g., blasting chemicals, leaching chemicals).

- Preliminary information suggests that concentrations of heavy metals at the site may be limited, which would mitigate concerns about some potential contaminants from ore and overburden sources. However, this determination should be verified through more comprehensive sampling and analysis of rock and leachate samples from the site.

- Water in contact with uranium tailings (the primary waste material from the milling process) contains elevated radioactivity and concentrations of several metals well above regulatory thresholds (e.g., arsenic, cadmium, chromium). This information underscores the requirement for proper management and long-term isolation of tailings materials—because of the associated metals concentrations in addition to the elevated radiation levels.

- Based on communications with VUI, the ore appears to have significant buffering capacity, which partially accounts for the current plan to adopt an alkaline rather than an acid leach process. If the buffering capacity is sufficient, it may mitigate acid mine drainage concerns. Nevertheless, specific leachate testing of the ore and other potentially stockpiled materials (overburden, subore) would be necessary to confirm whether acid mine drainage would be an issue at this site.

- Many of the chemicals of potential concern are present naturally in the environment. It can be challenging to distinguish between natural and anthropogenic concentrations of these chemicals. Therefore, characterization of baseline conditions prior to facility construction would be important to understand future environmental concentrations and potential impacts because of operations. This report summarizes available baseline concentration data from various sources for air, surface water, groundwater, and soils. More comprehensive baseline characterization is needed. Several studies by VUI are ongoing with results anticipated in 2012.

- RTI estimates of airborne particulate emissions and subsequent transport generally show limited migration at levels of concern for potential inhalation hazards such as asthma and cardiovascular issues.

- RTI estimated the deposition rates of airborne particulates and the associated transfer of uranium mass. The deposition rates beyond one mile from the facility were less than 0.01 gm $U_3O_8/m^2/yr$. Estimation of associated human health risks was outside the scope of the current analysis. A comprehensive human health risk assessment would be needed to provide quantitative estimates of the potential risks associated with these emissions.

- RTI estimated the rates of sediment erosion from the proposed mine/mill watersheds under current conditions as ranging from 0.002 to 0.129 tons/acre/year. The local watersheds therefore have the potential to transfer significant sediment loads to local streams. If the mine/mill facility is built, the overland runoff and erosion conditions will be fundamentally altered. Estimates of erosion rates and associated mass transfer to local waterbodies under as-built conditions would be needed to quantify potential contaminant loads that may be transferred via sediment erosion.

- RTI estimated the downstream travel time of surface water from nearby Mill Creek under annual average conditions. The resulting 6-day travel distance was approximately 160 miles from the proposed mine site. RTI also estimated the downstream dilution in surface water because of confluence with other surface waters and the inflow of groundwater. A high-impact scenario showed reductions by a factor of 2 adjacent to the site and a factor of 50 entering Banister Lake. A low-impact scenario showed reductions by a factor of 55 adjacent to the site and more than 2,000 times entering Banister Lake. Importantly, these simplistic estimates do not consider any possible chemical transformations such as radiological decay and adsorption. Therefore, the predictions overestimate the potential transport of dissolved chemicals that might be discharged by the facility.

- One tailings waste management option under consideration by VUI would involve mine backfill with low-permeability paste tailings. This option may offer advantages in terms of environmental impacts: a smaller volume of tailings would require management in surface impoundments; filling in open mine cavities would help mitigate possible undesirable changes in subsurface flow regimes; having the mine space filled with lower permeability material may help prevent significant groundwater flow through the former mine. However, subsurface paste tailings could be a source for groundwater contamination, particularly if placed below the water table. To prevent groundwater contamination, isolation of subsurface paste tailings from groundwater flow would be necessary.

- The most significant potential impacts to groundwater associated with uranium mining and milling are generally associated with the management of tailings. Historical tailings waste management practices have led to groundwater impacts at many sites; however, most of these facilities were operational prior to the implementation of regulations requiring isolation of tailings wastes. In particular, current requirements include bottom liners and leakage detection systems for synthetic liner systems. In addition, groundwater monitoring requirements around tailings management facilities have increased. Site experience with uranium tailing management under current impoundment design requirements is limited. More extensive experience with double-lined systems with leakage detection is available for municipal landfills. Researchers have found that double-liner systems with leak detection are generally effective; however, they do emphasize the importance of proper engineering and construction and operational maintenance.

- Human receptors that could be exposed to COCs within the site and surrounding area include on-site or nearby workers, residents, farmers, and recreational users. Ecological receptors that could be exposed to COCs within the site and surrounding area include native plant and tree species, soil biota, terrestrial wildlife, pets, farm animals, and aquatic biota. Potential exposure pathways include inhalation, dermal absorption, and ingestion.

In closing this section, RTI would like to emphasize key factors that can mitigate potential impacts to human and ecological health if the Coles Hill mine and mill were constructed, including the following:

- comprehensive baseline characterization of environmental media and ecosystems before the mine is built;
- comprehensive and ongoing monitoring during operations of emissions and concentrations in media at the mine and in the mine vicinity, including, air, water, soil, agricultural products, flora, and fauna;
- use of effective technologies to reduce emissions;
- sustained focus on pollution prevention and reduction;
- collaboration and transparency between the mining company, regulators, and citizens throughout the planning, operation, and closure stages; and
- expedient and effective reclamation activities.

Many older uranium and non-uranium hard rock mines lacked effective treatment technologies and deployed irresponsible waste management practices, leading to long-term environmental degradation and risks to human and ecological receptors in surrounding areas. Wastes from many older mines were not isolated and were left without any reclamation. Many of these mines operated before the establishment of key U.S. laws and regulations, including the Clean Water Act and the Uranium Mill Tailings Radiation Control Act, laws which have placed restrictions on emissions, waste management practices, and reclamation.

Pollution control technologies are widely available today to minimize mining and milling effluent discharges in water, air, and soil. Such technologies would increase the likelihood for the proposed mining and milling operations in Virginia to comply with current regulations. Furthermore, the mine could develop practices to exceed regulatory standards in an effort to reduce the extent of potential liabilities and to further allay public concerns over the mine. A thorough and ongoing monitoring program coordinated with the public also could mitigate concerns if it demonstrated limited impacts to the surrounding environment (i.e., measuring concentrations in potentially impacted media).

Even if the mine and mill meet or even exceed regulatory standards, detectable concentrations of uranium and other COCs would be released from the facility into the surrounding area. Pollution control technologies and compliance with regulations do not eliminate uranium mining and milling discharges. Predicted risks to human health and the environment would be quite low if the facility meets regulatory requirements, and the associated human and ecological health impacts may not be easily detectable. Nevertheless, finite risks would exist and should be considered in evaluating the possible construction of the Coles Hill mine and mill.

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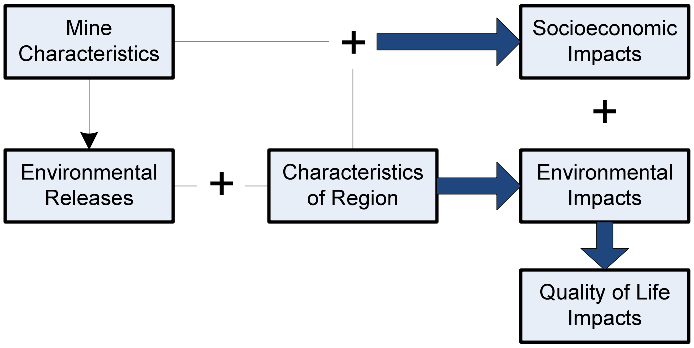
6

Estimated Economic and Community Impacts



Establishment of a uranium mine and mill in Pittsylvania County has the potential to provide much-needed jobs and opportunity to the region's residents. However, it also poses risks to the region's environment, reputation, and quality of life. Depending on the assumptions used, our quantitative illustration of potential impacts shows that employment could increase by nearly 900 on an ongoing basis during the first 20 years of operations, or it could actually fall by more than 100 if mining and milling employment is more than offset by declining demand and production in other sectors. State and local tax revenues could increase by approximately $11 million per year, but the Commonwealth and local governments would also face new responsibilities that could absorb a substantial share of those resources. The Commonwealth will need to develop regulatory systems and staffing, and will need to prepare a coordinated plan for responding to incidents such as mining or industrial accidents or traffic accidents involving trucks transporting yellowcake. Considering all the potential economic, environmental, and community impacts, we qualitatively consider the impacts on the overall quality of life in the region.

This section examines potential economic and community impacts resulting from creation of a uranium mine and mill at Coles Hill, Virginia. As shown above, the overall socioeconomic and community impacts resulting from the proposed Coles Hill uranium mine and mill include not only changes in employment, income, and spending, but also changes in environmental quality and other amenities associated with living in the region, which combine to affect quality of life for the region's residents.

The section begins with a summary of stakeholder perspectives on the possible economic and competitiveness impacts of the proposed project, based on interviews and focus groups conducted within the region, which helped inform our development of some of the scenarios used in the quantitative assessment. Then, the section describes the quantitative economic impact assessment, including a discussion of the analytical methods and the data and assumptions used. Examining construction and operation impacts separately, the quantitative assessment considers potential impacts under a variety of hypothetical scenarios, including a "reasonable" case assuming that a reasonable share[1] of the expenditures of the mine proponent, Virginia Uranium, Inc. (VUI), occur within a 50-mile radius of Coles Hill. We examine the potential impacts using both qualitative and quantitative methods, and also explore "best reasonable" and "worst reasonable" economic scenarios, under which economic impacts of the mine are either more or less positive than under the "reasonable" case. The alternative scenarios are described in greater detail below.

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[1] Approximately 70% of nonlabor construction spending and 76% of nonlabor operating spending are assumed to be spent within the region; labor spending is assumed to be entirely within the study region.

In addition to the quantitative simulation of economic impacts of the proposed mine and mill, we also consider qualitatively several factors that could affect the magnitude or even the direction of the economic impacts, such as fluctuations in the price of uranium and adverse economic development effects due to the presence of uranium mining and milling in the region. Finally, we attempt to assess the overall effect of the mine and mill on the region's well-being, considering not only potential economic impacts but also potential environmental and community impacts.

6.1 Stakeholder Perspectives on Economic Impacts

In interviews and focus groups, many stakeholders expressed interest and concern about the potential economic and community impacts of the proposed Coles Hill uranium mine and mill project. The recent decline of traditional industries, resulting unemployment, and lack of economic opportunity for the local labor force and the next generation are frequently cited concerns of regional residents. Regional residents expressed a hope that the mine and mill project would have a positive influence on employment and incomes. At the same time, residents expressed an appreciation for existing agriculture and outdoor recreation, as well as a concern that amenity-based or agriculture-related industries might be adversely affected by the project. This section summarizes the results of stakeholder interviews and focus groups conducted within the study region. In the following sections, we attempt to assess the potential for both positive and negative impacts on the region's economy and communities using a variety of data sources and methods.

6.1.1 Residents' Concerns about Jobs and the Economy

While interview and focus group participants seemed to have clear beliefs about impacts from the mine and mill to environment and health, they were more uncertain about potential impact to jobs and the local and regional economy. This was evident in both the focus groups and from responses made by individuals, as participants often argued back and forth about potential benefits and challenges to the economy.

Almost all of the participants recognized that the study region is facing economic challenges. With the collapse of the textile and furniture manufacturing industries in the region, as well as decreased tobacco farming, there are fewer well-paying jobs for residents. The region needs new industries and businesses to employ its citizens. Further, many people who are currently employed must regularly travel significant distances to other towns and cities within and outside the region to find work. The representatives from local governments that we interviewed expressed concern for decreasing populations in communities and the corresponding impact on local tax revenues. Participants in the focus groups voiced frustration that young people in the community were moving away or not coming home from college as a result of a lack of job opportunities in the region, leaving an aging population and fewer college-educated citizens.

6.1.1.1 Jobs

Given these challenges, the promise of new jobs, both those related directly to mine and milling operations and jobs created by other businesses supporting the mine, is appealing. Adding to these feelings are beliefs that jobs brought by the mine would pay better and potentially also attract new, skilled or educated workers to the region (e.g., engineers, mangers, headquarter staff for VUI). Countering this optimism, however, are concerns that the jobs for local people would be few and mostly of types that are low paying.

Other participants expressed concerns that any benefit from new jobs from the uranium mine and mill would be offset by potential losses of jobs in other economic sectors that would be negatively affected by the introduction of the mine and mill. In particular, participants in the research shared that the agriculture industry, which includes several large dairy and produce farms located in close proximity to the mine site, is an important aspect of the local and regional economy. Participants were concerned that any level of contamination of agricultural products as a result of the mine or mill, or even the perception of contamination, could damage these businesses in the region. In particular, the threat of uranium to crops was seen as a challenge to the smaller, organic-oriented farming taking place in the region. Similarly, individuals we interviewed, particularly from the town of Chatham, were concerned that the two private, secondary schools located in that town would face difficulty recruiting students, leading to decreased enrollments, in the competitive market for private residential education.

6.1.1.2 Economic Growth

Beyond jobs, there was some expectation that the mine, if opened, would increase tax revenues in local communities that could go to support needed infrastructure and educational improvements or be used to support activities that foster long-term economic growth in areas close to the mine.

At the same time, many of the participants saw the presence of the mine and mill as putting the region at a disadvantage in attracting new business, potentially limiting the overall growth of the region. Participants questioned if new businesses would want to locate employees in an area with a uranium mine. They felt the area had many good things to offer in terms of attracting business—a workforce, nice communities, good schools, and affordable housing—but the negative perceptions of having a mine in the community would be enough to stop new business from locating to the area. Similarly, a few interview participants cited a growing heritage tourism and recreation industries in the region, which they felt would be adversely affected by having a uranium mine in close proximity.

Other economic concerns included questions about how the mine would be affected by fluctuations in the market prices for uranium, and if the mine might have to close for periods if the price of uranium dropped too low. Others questioned what would happen to the local economy in 15 or 35 years (at least one participant in the interviews questioned VUI’s estimates that it would take 35 years to mine the uranium at Coles Hill, suggesting that the period of time could be as short as 15 years) when the mine closed, wondering if the region would experience another bust period as jobs ended. Also, residents wondered who would end up paying the costs of clean-up if an environmental accident were to occur at the mine site, and if these costs would ultimately fall back on local governments. A few participants also wondered if mining would be limited to Coles Hill or would they see uranium mines started in other locations in the region by other companies.

Among the individuals we interviewed living in Chatham and Gretna, the towns closest to the proposed site of the mine and mill, concern was also expressed that home values in areas near the mine and mill would decline as a result of their proximity to the mine. Some individuals felt that home values had already decreased in the area with fewer people willing to buy homes in the areas surrounding the mine.

6.1.2 Economic Developers' Concerns

Related to questions about the economy and jobs are issues related to the region's future economic development. To elaborate on these issues, RTI interviewed economic developers, directors of chambers of commerce, business owners, and representatives from industry and business associations to ask more specific questions about the economic development of the region as it relates to the proposed mine and mill. In these key informant interviews, RTI did not seek to poll attitudes about the proposed mine and mill; instead analysts sought to identify topics of greatest interest to those working in economic development as a guide to help sharpen the focus of RTI's research and better enable researchers to address issues important to economic developers.

While concerns in this section mirror the issues described in Section 4.2.3, this section reflects the perspectives from professionals and industry representatives who work to foster economic growth. This adds additional nuance to issues described above. It should be noted that on the whole, relevant officials near and west of Chatham either declined or did not respond to interview requests. Representatives from the east, north, and south of the site though were responsive and ready to share their perspectives.

6.1.2.1 Overarching Regional Economic Development Perspectives

Three more general economic development perspectives set the broader stage for more distinct insights gained about the proposed mine and mill.

- There was concern about the region's economic distress;
- There was a shared understanding that this study region could be described as two or even three different regional economies; and
- Areas east and south of the proposed site voice much more concern than those to the north.

All interviewees expressed concern about the economic downturn the region has experienced in the last 30 years. Similar concerns about prospects for renewed job growth in the future were also expressed. Declines in manufacturing, plant closings, job loss, population decline, and poor quality of education were noted as regional traits that continue to plague the region. Improving economic development through job creation, upgrades in workforce, small business support, and industry retention and attraction was a common priority among interviewees. There was also a shared respect and appreciation about the importance of the land to the area's economic history and culture, which is still evidenced by its use as farms, vineyards, and outdoor recreation such as hunting and fishing.

In terms of the region's economic development, the Virginia portion of the 50-mile-radius study area is in reality divided into two separate economies—one in the north with Roanoke and Lynchburg as anchors and one in the south with the Danville and Chatham as the anchor. One interviewee described Smith Mountain Lake, and associated tourism from the lake, as the only "big connector" between the two areas. Including the North Carolina counties, the study region could be thought of as three separate sub-region economies.

Finally, among the economic development interviews, those south and east of the proposed site, or "downstream," expressed much more concern about the impacts of the mine and mill than those north of the site or "upstream." Further, those generally north and northeast describe positive experiences working with the companies in the nuclear industry in and around Lynchburg. They cite dedicated commitment from leadership at these companies to the region as playing a role in this positive relationship. Others claim that these industries have had positive experiences with the region for two main reasons. First, they came in as companies with employment opportunities, not as a nuclear industry. Second, they did not have mining and milling components, which are viewed as more threatening to the land and its residents.

6.1.2.2 Perception of the Region's Environment

Issues around the negative perception of being located in a region with uranium mining and milling was by far the most pressing concern to those interviewed—even among those who viewed the mine and mill as a net positive to the region's economic potential. The underlying premise of this concern was that economic development officials worried that regardless of the safety assured by the mining company and regulators, the perceptions about what could happen can easily overpower reality and affect location and investment choices.

Industries or employers most prone to experiencing negative impacts from issues of perception were those industries linked to the land and water:

- agriculture,
- tourism,
- food and beverage manufacturing; and
- chemical manufacturing.

One economic developer commented that one of the region's greatest assets was availability of water, which is critical to manufacturers. (Manufacturers also tend to be large employers.) Several developers noted that if a food and beverage manufacturer left because their products were perceived to be contaminated with uranium or if a manufacturer did not locate in the region in the future, the benefits from the uranium mine and mill would not be worth it. Other specific employers that economic developers thought were at risk from negative perception were the private schools in Chatham—Hargrave Military Academy and Chatham Hall. These institutions are regarded as important anchors to Chatham's local economy because they employ educated workers and create spillover effects for the local service industry. Almost all of those interviewed stated that if the mine and mill do proceed, a substantial public relations and marketing strategy should be undertaken to mitigate the issues of perception.

6.1.2.3 Perceptions on Jobs, Workforce and Industry Attraction

The ability to create jobs and upgrade the workforce is a second focus for those working in economic development. Some see the mining and milling as a means to create jobs in the short-term whether through local jobs or relocation of workers to the Chatham/Danville area. Both were seen as generally positive to the region. Others speculated that a supply chain could be developed by attracting companies working in the uranium industry to co-locate in the region. Spillovers to local service businesses would also be captured and bring an injection of dollars to local businesses. Specialty businesses mentioned that could benefit include mechanics, mining equipment, and safety equipment. Some thought the uranium company would likely locate offices or facilities nearby.

Others thought the job prospects were minimal, especially for locals. They also claimed it was hard enough to attract a well-educated workforce to the region. It would be even more difficult to promote the region's quality of life with a uranium mine and mill. In terms of industry recruitment, about half of those interviewed said that regional developers already struggle to recruit companies; the last thing they need is another barrier to overcome to sell the region to business. One person speculated about the criteria list that companies consider for relocation. The developer questioned, "Can you imagine seeing a company's response when it sees uranium mining and milling on that list?"

To help clarify employment and other potential impacts, RTI has performed a quantitative economic impact assessment to illustrate the range of likely employment and spillover impacts that might result from the mine and mill (see Section 6.4, below). Descriptions of the uranium industry and its supply chain (see Appendix G) also help to inform the likelihood of building out a local supply chain for the industry. In addition, the socioeconomic case studies in Section 4 describe employment effects and other economic and community impacts that occurred in other locations in the United States, Canada, and Australia where there are operating uranium mines or mills. This information does not provide a direct answer to this economic development issue, but provides insights that may inform economic development stakeholders of potential impacts the study region may experience if the proposed mine and mill are built and operated.

6.2 Methods for Assessing Economic and Community Impacts

The creation of a uranium mine and mill would result in increased employment (an estimated 250 to 350 jobs during construction and an estimated 324 jobs during operation), with associated increases in income, output, and consumer spending. In addition, to the extent that VUI acquires capital equipment and other supplies from local firms, the company's spending would result in an increase in local economic activity. To illustrate the scale of potential economic impacts the study region might experience as a result of the proposed project, we conducted a quantitative assessment. *It is important to emphasize that this assessment provides insight into the possible scale of impacts, but due to the uncertainties surrounding the project, it should be regarded as an illustration, not a prediction, of the range of potential economic impacts.*

In addition to these strictly economic impacts, the proposed project would potentially impact many other aspects of life in the study region, including environmental quality and other amenities, housing, roads and other infrastructure, and state and local government revenues and expenses, all of which could affect the overall quality of life for the residents. First, we discuss a quantitative assessment of regional economic impacts; then we examine other potential impacts qualitatively.

6.2.1 Input-Output Analysis

To explore the possible regional economic impacts, we conducted a traditional input-output economic impact analysis using the commercially available IMPLAN modeling system. (MIG, 2011) The logic behind the model is that the new mine and mill would employ residents of the region (increasing incomes in the region) and would purchase some of their nonlabor inputs within the region. As a result, the overall economic impact of the project on the region would be larger than the immediate employment and spending associated with the mine and mill. The model uses historical data on the patterns of expenditures within the region to quantify the total changes in employment and spending that would result.

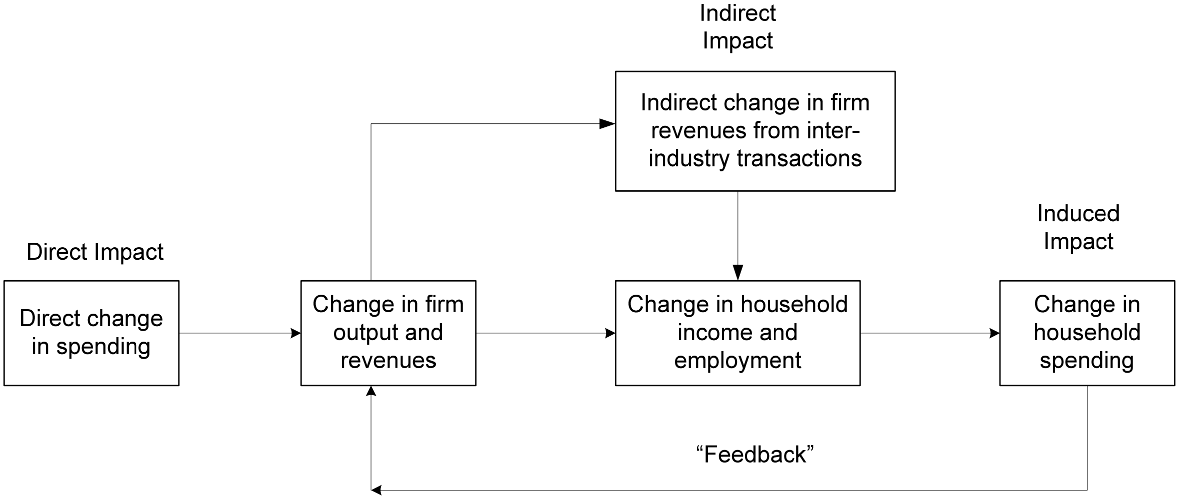
Input-output (I/O) models are based on I/O tables for a region, which quantify the share of each sector's inputs that is supplied by each other sector within the regional economy. For each dollar spent by the firm, these coefficients quantify the share that goes to each sector within the local economy, to households, to government, or outside the region. In addition, the models quantify the share of local residents' income that is spent in each sector within the local economy.

The *total* economic impact of the new firm, illustrated in Figure 6-1, is the sum of

- its *direct* spending or employment impact,
- the *indirect* spending and employment associated with firms in other sectors in the local economy that supply inputs to the new firm, and
- the *induced* spending and employment resulting from consumer purchases by the new firm's employees.

In the case of VUI's proposed uranium mine and mill, the *direct* impacts would be VUI's spending on inputs, including labor, within the study region. As they purchase nonlabor inputs from suppliers within 50 miles of Coles Hill, those suppliers in turn would purchase some of their inputs from other suppliers within the 50-mile-radius study region. Those employers, in turn, would also purchase a share of their inputs locally, and so forth. These successive rounds of business purchases of inputs and supplies from sources within the study region comprise the *indirect* impacts of the proposed mine and mill. Finally, if VUI's employees experience increased incomes and, in turn, choose to spend a share of their increased income within the study region, they would set off a round of household consumption spending, which is termed the *induced* impact of the proposed mine and mill.

Figure 6-1. Feedback Process That Generates a Program's Total Economic Impact Within the Region



6.2.2 Strengths and Limitations of Input-Output Analysis Approach

Input-output analysis, such as the IMPLAN modeling system used for this study, is a well-recognized and widely used approach for assessing the economic impacts of a change in policy or industry spending within a region. It has the advantage of being based on historical data that characterize the supply chain relationships within the region in great detail. The model is a detailed, historically accurate picture of all the spending patterns that link businesses with each other, and households with businesses. This level of detail has the potential to be both a strength and a weakness. In the short run, it is a strength; it estimates changes in economic activity based on the actual structure of the region's economy. In the long run, the fixed, detailed, historical specification of spending relationships within the region may be a liability. The proposed Coles Hill Uranium Project, if it goes forward, is expected to be in operation for more than 30 years. Because the structure of the region's economy would likely evolve over time, estimates derived based on its current structure may be less accurate in the long run than they are in the short run.

6.3 Data Sources and Assumptions for Quantitative Assessment

The "reasonable" case analysis is conducted using information about estimated expenditures based on two documents prepared for VUI by Lyntek and BRS Engineering:

- Coles Hill Uranium Project, Pittsylvania County, Virginia: Scoping Study and Cost Estimate, August 2010 (Lyntek/BRS, 2010a)
- NI 43-101 Preliminary Economic Assessment; Virginia Uranium Inc., Virginia Energy Resources Inc., Coles Hill Uranium Property, Pittsylvania County, Virginia, USA. December 2010 (Lyntek/BRS, 2010b).

For capital and construction spending, the reasonable case assumes 300 employees, and 70% of nonlabor spending within the region; for operations, the reasonable case assumes that 76% of nonlabor spending (86% overall) is spent within the region.

6.3.1 Impacts of Construction and Operation Analyzed Separately

In these two documents, Lyntek and BRS provide engineering assessments and estimated costs for constructing and operating the mine and mill. The cost estimates include:

- Lump sum or capital costs, including buildings and equipment, which would occur only once during the 35-year life of the mine and mill. Approximately half the capital spending would occur during the first 3 years; some additional replacement capital would be purchased as needed. Construction employment would be substantial, but short-lived. Our assessment of the impacts of proposed construction expenditures assumes that all the initial spending occurs in 1 year, which likely overstates the 1-year impacts somewhat.

- Operating costs, which are ongoing annual costs that are experienced for many years, or in some cases for the life of the mine. The operating costs used in the analysis correspond to expected spending during years 2 through 21 of the proposed project, while primary stoping would be ongoing. During years 22 through 35, the pillars would be mined, resulting in a lower rate of production at higher production costs per ton, but lower spending overall. Thus the “typical year” chosen reflects the upper range of operating costs and revenues.

6.3.2 Analysis Reflects Underground Mining and Alkaline Process Beneficiation

Lyntek and BRS evaluated the costs associated with both an open-pit mining method and an underground mining method. The costs are similar, and VUI has stated that they expect to use only underground mining (although they have not precluded use of open pit or a combination of open pit and underground methods). Thus, we estimate the economic impacts based on the costs of underground mining. Lyntek and BRS also evaluated both acid and alkaline processes for extracting and concentrating the uranium. Because of the chemistry of the deposit, they plan to use an alkaline process, and we base our assessment on those costs.

6.4 Baseline Economic Conditions within the Region

The first step in conducting the quantitative regional economic impact assessment is construction of a model of baseline conditions in the region. Using the IMPLAN software, we created a model including most of the counties that fall, at least in part, within the 50-mile radius surrounding the Coles Hill, Virginia, location of the proposed mine and mill. Counties that are partly in and partly out of the 50-mile-radius study region, and for which the majority of the population and economic activity are believed to fall outside the 50-mile radius, are omitted. Counties included in the model are shown in Table 6-1.

The additional employment and expenditures associated with first constructing and then operating the proposed Coles Hill project would change the study region’s baseline economic conditions. These baseline conditions, against which potential impacts should be compared, are summarized in Table 6-2. The IMPLAN model compiles data on employment, output, employee compensation, proprietor’s income, other property income, and indirect business taxes for 440 industries and other categories. In Table 6-2, these industries are grouped into 44 more aggregated sectors. As shown in the table, sectors with the greatest employment in the region at baseline include construction, retail trade, finance, insurance, and real estate services, business services, professional services, health services, accommodation and food services, and state and local government, especially state and local education.

Table 6-1. Jurisdictions in Virginia and North Carolina Included in Regional IMPLAN Model

Virginia Counties and Independent Cities		North Carolina Counties
Counties		
Amherst County	Appomattox County	Caswell County
Bedford County	Botetourt County	Granville County
Campbell County	Charlotte County	Person County
Floyd County	Franklin County	Rockingham County
Halifax County	Henry County	
Lunenburg County	Mecklenburg County	
Patrick County	Prince Edward County	
Pittsylvania County	Roanoke County	
Cities		
Bedford City	Danville City	
Lynchburg City	Martinsville City	
Roanoke City	Salem City	

6.5 Scenario Definitions

In the discussion that follows, we present first the potential impacts of VUI’s estimated spending on construction and capital equipment, then the potential impacts of VUI’s estimated annual spending during the first 21 years of operations. As in any situation where future behavior is projected, however, the assessment of potential impacts may not be as straightforward as implied by the foregoing presentation of input-output analysis.

Many decisions have yet to be made that would affect the outcome. At this point, it is uncertain whether VUI would choose to purchase inputs from suppliers within 50 miles of Coles Hill; this is a business decision, and they would likely base their choices on cost and quality comparisons. VUI projects production at a rate of 3,000 tons of ore per day for 20 years; this too may vary depending on uranium market conditions. Further, stakeholders express concerns that either actual risks associated with environmental degradation, or even the perception of such risks, might reduce the demand for some goods or services currently being produced within the study region, such as agricultural commodities, processed food or drink, or educational services. In such a situation, the positive economic impacts associated with the local spending by VUI could be at least partially offset by negative economic impacts resulting from reduced demand for the region’s other goods or services.

Table 6-2. Baseline Economic Conditions in the Study Region

Sector	Employment (jobs)	Output (million $2011)	Employee Compensation (million $2011)	Proprietor Income (million $2011)	Other Property Type Income (million $2011)	Indirect Business Tax (million $2011)
Agriculture, forestry, fisheries, and associated support activities	13,722	844.4	101.2	69.0	97.6	17.5
Mining, extraction of oil and gas, and support activities	416	106.9	11.1	9.3	28.6	2.2
Electric power, natural gas distribution water and sewer	1,795	1,136.3	173.7	22.8	371.9	118.6
Construction, maintenance, and repair	31,548	3,432.7	1,007.4	229.5	195.5	19.9
Food and beverage manufacturing	3,437	2,133.6	178.1	5.1	151.9	5.5
Alcoholic beverage manufacturing	807	824.8	80.5	2.6	70.3	169.3
Tobacco products manufacturing	420	988.7	50.0	0.0	346.0	205.7
Fiber, textile, apparel, and footwear manufacturing	6,644	1,397.2	255.9	0.8	92.4	15.2
Wood products manufacturing	5,357	978.3	224.1	6.7	132.1	8.6
Pulp and paper, paperboard, paper products manufacturing	4,703	1,601.6	268.3	15.3	140.1	17.5
Petroleum and coal products	486	872.8	44.3	7.9	125.0	3.0
Chemical products mfg	4,463	3,535.5	305.1	19.0	414.4	10.1
Plastics	2,675	831.6	139.6	0.5	125.7	5.7
Tires and other rubber products	3,631	1,136.9	253.5	1.5	126.1	45.9
Pottery, ceramics, and glass mfg	1,303	289.0	63.0	4.1	40.5	2.0
Cement and concrete mfg	1,410	366.0	71.4	2.2	46.7	3.9
Lime and stone products	37	7.1	1.5	0.5	1.2	0.0
Nonmetallic mineral mfg	58	16.6	2.4	0.1	1.8	0.1
Primary metals mfg	1,267	861.6	83.3	2.3	84.3	7.7
Fabricated metals mfg	6,553	1,931.1	470.8	6.0	345.5	12.7
Machinery mfg	4,798	1,517.6	287.7	8.4	142.5	9.0

(continued)

Table 6-2. Baseline Economic Conditions in the Study Region (continued)

Sector	Employment (jobs)	Output	Employee Compensation	Proprietor Income	Other Property Type Income	Indirect Business Tax
		(million $2011)	(million $2011)	(million $2011)	(million $2011)	(million $2011)
Electrical equipment and component mfg	4,030	1,560.3	305.0	6.6	174.0	13.5
Transportation equipment and parts mfg	2,715	1,030.0	161.6	0.3	74.1	7.9
Cabinets and furnishing mfg	4,839	703.0	190.7	2.3	96.3	3.5
Instruments, jewelry, sporting goods mfg	1,675	301.6	78.4	4.6	50.1	1.7
Wholesale trade	18,117	2,688.4	963.1	40.2	351.8	371.1
Retail trade	62,909	3,339.9	1,525.8	160.1	536.8	592.7
Transportation and warehousing	19,971	2,543.3	743.9	120.8	306.7	41.2
Information services	5,381	1,328.1	270.0	13.2	321.4	66.4
Finance, insurance, real estate services	29,412	8,783.7	900.2	295.8	3,726.3	680.1
Rental services	2,280	370.7	67.4	19.5	120.3	23.4
Professional services	22,365	2,257.8	1,017.8	156.5	205.6	38.8
Business services	35,496	2,453.5	1,138.8	66.0	237.5	29.7
Educational services	10,391	598.3	300.4	10.9	18.1	4.9
Health services	53,907	5,430.3	2,554.1	224.1	186.3	45.7
Child care and other family care services	11,277	418.5	226.7	31.9	6.1	2.3
Arts and entertainment	6,373	236.9	83.8	11.7	19.7	12.6
Accommodations and food service	33,577	1,817.0	588.9	25.7	175.8	98.2
Other personal services	15,453	1,063.2	276.4	283.3	29.3	78.5
Religious and civic organizations	11,999	807.5	293.0	9.1	-11.7	13.5
Household operations	6,172	53.1	53.1	0.0	0.0	0.0
Federal government	10,901	1,013.8	821.5	0.0	114.5	0.0
State and local government, excluding education	26,272	2,235.3	1,251.6	0.0	237.6	−89.7
State and local government, education only	40,198	2,224.0	1,957.7	0.0	266.3	0.0
Total	**531,241**	**68,069.4**	**19,843.0**	**1,896.1**	**10,322.7**	**2,716.1**

The uncertainty about the magnitude and even the direction of the net economic impact led us to assess the economic impacts under several different sets of assumptions, which we refer to as the "reasonable" case, the "best reasonable" case, and the "worst reasonable" case economic scenarios.

6.5.1 Scenario Definitions for Analysis of Impacts of Construction and Capital Spending

For the assessment of the impact of **potential construction and capital equipment** spending during the first 3 years after project initiation, the scenarios reflect assumptions about what share of VUI's spending occurs within the 50-mile-radius study region.

- Under the "**reasonable**" case, construction employment is assumed to be 300, and 70% of the nonlabor inputs are assumed to be purchased, from regional suppliers.
- Under the "**best reasonable**" case, construction employment is assumed to be 350, and 98% of nonlabor inputs are assumed to be purchased from regional sources.
- Under the "**worst reasonable**" case, construction employment is assumed to be 250, and 44% of nonlabor inputs are assumed to be purchased from regional sources.

6.5.2 Scenario Definitions for Analysis of Impacts of Annual Operations

To analyze the impacts of **potential annual operations**, we used varying "regional share" assumptions, but also varied some other aspects of the proposed project:

- Under the **"reasonable" case**, we assume that 76% of nonlabor inputs (84% of all input spending) occurs within the study region. We assume that the future market price of yellow cake would be $60 per pound, and we assume that the quantity of uranium mined is, as assumed in VUI's Scoping Study and Cost Estimate, (Lyntek, 2010a) 3,000 tons per day.
- Under the **best reasonable** case, all but the most specialized inputs are assumed to be purchased locally (99% of all input spending), and the market price of uranium is assumed to be $75 per pound.
- Finally, the **worst reasonable** case assumes the price of uranium falls to $45 per pound, resulting in a 25% reduction in output and employment, and assumes a smaller share of share of VUI's inputs are purchased within the region (overall nonlabor input spending falls to 35% of reasonable case, due to the combination of lower production and lower regional share).

The employment and cost estimate data in VUI's studies is based on an assumed production rate of 3,000 tons per day of ore, and associated production of yellow cake. The "reasonable," "best reasonable" cases assume this level of production, while the "worst reasonable" case assumes production falls by 25% , reflecting historical volatility in the market for uranium. Current expectations are that the price of uranium will likely increase, as supply derived from decommissioned weapons is exhausted and societies seek alternatives to carbon-based energy sources. Evidence for this is that new contracts have a price that exceeds the spot price for uranium. Table 7 of the U.S. Energy Information Agency's Uranium Marketing Report (EIA, 2011b) shows that in 2010, spot prices were approximately $45 per pound, while long term contracts (for delivery at least a year out) averaged approximately $50 per pound. Economic theory would indicate that if the price of uranium were higher than anticipated, more of the ore would be considered economical to mine and mill, and production would increase. However, increasing the production *rate* (tons of ore per day) would be difficult under the plans VUI currently has, so the increased production is assumed to result in extending the life of the mine rather than increasing production; thus, the "best reasonable" case does not adjust employment and output upward for the "typical year" represented in the model. However, the price of uranium has historically been volatile, and interviews with stakeholders near an existing uranium mine and mill in the western U.S. mentioned fluctuating employment and economic and community impacts as a result of price fluctuations. Thus, it is possible that some future event could result in a decline in the demand for and the price of uranium. If that happened, it could be that uranium production at the proposed mine and mill might decline, or be suspended entirely, until the price increases sufficiently to make mining and milling profitable. This potential is reflected in our "worst reasonable case."

In addition to this worst reasonable case analysis, we perform sensitivity analysis reflecting alternative assumptions. First, we examine the possibility that price and output of uranium remain at $60 per pound and 3,000 tons per day (as in the reasonable case), but that the local share of VUI's spending may be lower than assumed in the "reasonable" case analysis. (Nonlabor spending in the region is assumed to be about 50% lower than the reasonable case; overall spending in the region is about 10% lower than reasonable case.) Then, in response to concerns expressed about impacts on other regional industries, we also examine a situation where there is a reduction in demand for some of the other goods and services currently produced in the region due to perceived risks associated with uranium. Reflecting our expectation that any "stigma" impacts such as this would be relatively local to the mine and mill, we compute the reduction in output of affected sectors based on the sectors' baseline output within Pittsylvania County. In this scenario, the spending associated with the lower regional share assumption is offset by an assumed reduction in sales of agricultural products, livestock and dairy, food and drink manufacturing, and private educational services totaling $31.6 million.

6.6 Regional Economic Impacts Based on Input-Output Model

6.6.1 Economic Impacts of Construction and Capital Expenditures

In this section, we present quantitative simulations of possible economic impacts resulting from VUI's construction spending and purchases of capital equipment, based on three scenarios. We present the "reasonable" case first, then the best reasonable case, then the worst reasonable case. We examine impacts of initial construction and capital expenditures as if they occur in a single year, which likely overstates their impacts, because developing and constructing the mine and mill is projected to take up to 3 years. Table 6-3 presents the spending and employment inputs under each scenario. As shown, these inputs include the construction employment and associated spending value (ranging from 250 to 350 employees and $28.4 million to $39.8 million in that sector). Including specific capital equipment assumed to be purchased within the region under each scenario (approximately 30% of capital equipment purchased within the region under the worst reasonable scenario, 65% under the reasonable scenario, and 95% under the best reasonable scenario), construction and capital employment input ranges from 318 to 545 jobs, and the construction and capital spending input ranges from $56.8 million to $130.1 million. The dollar values include the value of capital equipment assumed to be purchased within the region under each scenario, plus the value of construction output that corresponds to 250, 300, and 350 employees. These inputs result in the direct impacts of construction and capital spending under each scenario.

Table 6-3. Capital and Construction Cost Inputs by Scenario

IMPLAN Sector	Sector	Spending (million $2011)	Employment (jobs)	Spending (million $2011)	Employment (jobs)	Spending (million $2011)	Employment (jobs)
36	Construction of other new nonresidential structures	$34.1	300	$39.8	350	$28.4	250
161	Ready-mix concrete manufacturing	$5.2	17	$5.2	17	$5.2	17
170	Iron and steel mills and ferroalloy manufacturing	$5.5	5	$5.5	5	$0.0	0
186	Plate work and fabricated structural product manufacturing	$3.1	9	$6.2	18	$0.0	0
239	Other communications equipment manufacturing	$0.3	1	$0.3	1	$0.3	1
256	Watch, clock, and other measuring and controlling device manufacturing	$2.1	7	$2.1	7	$1.0	4
266	Power, distribution, and specialty transformer manufacturing	$1.5	4	$3.0	7	$0.0	0
319	Wholesale trade businesses	$40.3	53	$58.9	77	$18.9	25
335	Transport by truck	$1.0	7	$1.7	12	$0.0	0
359	Funds, trusts, and other financial vehicles	$0.0	0	$0.9	2	$0.0	0
369	Architectural, engineering, and related services	$6.1	43	$2.1	15	$2.9	21
374	Management, scientific, and technical consulting services	$0.0	0	$4.6	34	$0.0	0
	Total Construction and Capital Inputs	$99.1	446	$130.1	545	$56.8	318
		$65.0		$90.3		$28.3	
	Total nonlabor	$95.0	$95.0	$95.0	$95.0	$95.0	$95.0
		68%		95%		30%	

6.6.1.1 Construction Economic Impact Simulations

As described previously, input-output analysis traces economic impacts resulting from a new expenditure or new employment within a region by looking at impacts resulting from increased demand for inputs produced within the region (indirect impacts) and impacts resulting from consumer spending by workers within the region. Table 6-4, below, summarizes possible impacts of estimated construction and capital spending for the proposed project, under different capital expenditure and employment assumptions. For more detailed sector-specific impacts results, please see Appendix F.2.

Table 6-4. Scenario Impacts: Capital Expenditures, by Type of Effect

Impact Summary Impact Type	Employment (jobs)	Output (million $2011)	Labor Income (million $2011)
Baseline values			
Total at baseline	531,241	68,069.4	19,843.0[a]
"Reasonable" Case Capital and Construction Impacts			
Direct effect	446	66.4	22.2
Indirect effect	165	22.1	7.9
Induced effect	211	23.2	7.5
Total effect	822	111.7	37.6
Best Reasonable Case Capital and Construction Impacts			
Direct effect	545	82.4	27.4
Indirect effect	202	26.8	9.5
Induced effect	261	28.5	9.3
Total effect	1,008	137.7	46.2
Worst Reasonable Case Capital and Construction Impacts			
Direct effect	318	41.5	14.6
Indirect effect	104	13.9	5.1
Induced effect	137	15.1	4.9
Total effect	559	70.5	24.6

[a] Baseline value is employee compensation, which includes labor income, benefits, and employer-paid taxes. Impact estimates show labor income only.

The impacts shown in Table 6-4 are based on an assumption that all the initial construction and capital spending occurs in a single year. As shown above, the impacts of VUI's planned capital expenditures (purchase of plant and equipment and associated construction labor) depend crucially on what share of the spending occurs within the region. As shown in Table 6-3, much of the capital equipment is assumed to be purchased through a wholesale supplier. The commodities purchased through a wholesaler may or may not be produced within the study region, but if the purchases are made through a regional supplier, the local economy benefits. Another significant influence is the size of the construction workforce, assumed to be between 250 and 350 workers. Overall, employment is projected to increase by 559 to 1,008 additional employees within the region, and output within the region is projected to increase by between $70 million and $112 million--increases ranging from 0.1% to 0.2% of baseline regional values for employment and output. Because construction of the mine and mill would likely spread over 3 years, these impacts may overstate the changes in the region's economy. In any case, construction activities are short-lived, so their impacts, while considerable, are also short-term. In the following section, we illustrate a range of potential impacts that might occur annually during years 2 through 21 of the proposed project's operation.

6.6.1.2 Economic Impact Simulations of Mine, Mill, and Tailings Management Operations

During years 2 through 21of the proposed project, VUI would be mining approximately 3,000 tons per day of ore from the primary stopes. During years 22 through 35 of operations, they would be mining the pillars, producing 1,000 tons per day of ore. Although the cost per ton would be higher while mining the pillars, the overall costs are estimated to be higher for mining the primary stopes; thus, we use projected annual employment and spending for this period to illustrate the economic impacts of operations of the proposed project. Uranium mining and milling falls under IMPLAN Sector 24, Mining Gold, Silver, and Other Metal Ore. Currently, this sector does not exist in the region, so historical data on it are unavailable. To prepare the model, we created a new Sector 24, using national input purchase patterns for that sector. Next, we perturb the regional IMPLAN model based on assumed employment and spending under reasonable, best reasonable, and worst reasonable scenarios, resulting in a range of estimated regional economic impacts. In addition, we conduct further sensitivity analysis around the worst reasonable scenario, to reflect conditions that would be either more or less adverse to the region's economy, relative to the worst reasonable scenario assumptions. For Sector 24, we assume employment ranging from 240 to 324 new employees, and we compute sector revenues based on uranium prices and quantities as shown in Table 6-5, below. As described above in Section 6.5, VUI's proposed production level (3000 tons per day of ore, or 1.76 million pound per year of U_3O_8, is approximately their productive capacity; thus, while annual production levels fall proportional to a lower market price, a higher market price is expected to result in a longer period of production but no change in annual production.

Table 6-5. Market Price and Uranium Output Assumptions

Scenario	Assumed Price of Uranium ($/pound)	Assumed Production of Uranium (pounds/year)
Reasonable Scenario	$60	1.76 million
Best Reasonable Scenario	$80	1.76 million
Worst Reasonable	$45	1.32 million

Table 6-6, below, presents the spending and employment inputs used to shock the IMPLAN model. Relative to the Reasonable case, the Best Reasonable Scenario assumes higher uranium prices and a larger share of spending within the region, while the worst reasonable share assumes a lower market price for uranium, lower production, employment, and a lower share of spending within the region. We chose to designate this scenario as the "Worst Reasonable Scenario" because it is based on historical patterns displayed by uranium markets. In addition to this scenario, we examined two sensitivity analyses around this set of assumptions, as shown:

- (1) uranium price and production levels are unchanged from the Reasonable case scenario, but the share of spending that occurs within the region is lower, and

Table 6-6. Employment and Spending Inputs for Operations Impact Scenarios

Sector	Description	Sensitivity Analyses									
		Reasonable Scenario		Best Reasonable Scenario		Worst Reasonable Scenario		Lower Regional Share		Reduced demand	
		Industry Sales (million $2011)	Employ-ment (jobs)	Industry Sales (million $2011)	Employ-ment (jobs)	Industry Sales (million $2011)	Employ-ment (jobs)	Industry Sales (million $2011)	Employ-ment (jobs)	Industry Sales (million $2011)	Employ-ment (jobs)
24	Mining gold, silver, and other metal ore	$105.58	324	$140.77	324	$59.39	240	$105.58	324	$105.58	324
31	Electric power generation, transmission, and distribution	$1.70	3	$1.70	3	$1.27	2	$1.70	3	$1.70	3
33	Water, sewage and other treatment and delivery systems	$0.21	1	$0.21	1	$0.16	1	$0.21	1	$0.21	1
319	Wholesale trade businesses	$11.25	82	$16.00	116	$3.32	4	$4.43	6	$4.43	6
335	Transport by truck	$1.61	12	$1.72	13	$0.67	5	$0.89	6	$0.89	6
359	Funds, trusts, and other financial vehicles	$0.85	2	$0.85	2	$0.13	1	$0.17	0	$0.17	0
369	Architectural, engineering, and related services	$0.00	0	$2.10	15	$0.00	0	$0.00	0	$0.00	0
Sector	**Sectors with reduced demand**										
3	Vegetable and melon farming									−$0.1	−1
4	Fruit farming									−$0.3	−3
7	Tobacco farming									−$4.8	−151
11	Cattle ranching and farming									−$1.7	−24
12	Dairy cattle and milk production									−$2.9	−41
69	All other food manufacturing									−$5.7	−17
70	Soft drink and ice manufacturing									−$3.8	−6
391	Private elementary and secondary schools									−$12.4	−282
	Total	$121.20	424	$163.36	474	$64.93	253	$64.93	340	$81.36	−185

- (2) conditions in (1) plus reduction in demand for the output of several sectors in the region's economy, because of safety concerns or stigma.

As noted above, our analysis recognizes the uncertainties inherent in any prospective analysis; as a result we are illustrating a range of possible impacts that the region could incur if the mine and mill were operating and various other conditions obtained.

The estimated impacts under each of the main Operations scenarios are shown in Table 6-7. Under the Reasonable Case Scenario, employment is projected to increase by 724 (0.1% of the region's baseline employment), while output and labor income are both projected to increase by 0.2% (an increase of $162 million in output and $33 million in labor income respectively). The best reasonable case, assuming higher income for VUI and a larger regional share of spending, results in an increase in employment of nearly 900 (0.2% of the region's baseline level), while output is projected to increase by $220 million per year (0.3% of baseline output) and labor income is projected to increase by $45 million per year, or 0.2% of baseline. In the worst reasonable scenario, under the assumption that production falls because of lower uranium prices, employment increases by only 385, and output increases by only $81 million per year, and labor income increases by only $15 million per year (0.1% of baseline values for all three). The sensitivity analyses illustrate a less adverse and a more adverse version of "worst case," with the more adverse version (reduced demand for several types of agricultural products, processed food and drink, and educational services within the region), overall employment is projected to fall slightly (by 152 workers), while output and labor income rise slightly.

Examination of the impact summaries in Table 6-7 reveals that the proposed mine and mill would generally have a positive impact on the region's economic activity, as measured by the value of the region's output. The magnitude of potential impacts depends on several elements:

- The share of the operating expenditures that occur within the study region;
- The ongoing demand for uranium, and resulting steady or rising price of uranium. This would enable the firm to mine at a steady rate and maintain employment at the projected level over time;
- No reduction in demand for products and services provided by local suppliers in environmental- and amenity-related sectors such as agriculture, food and beverage preparation, and education, due to perceptions by potential customers that the presence of the mine or mill has somehow reduced quality.

Output in the region could increase by more than $200 million annually, and employment could increase by almost 900 workers, if all goes well. Reduced demand for, and price of, uranium (assumed in this case to result in a decrease in mine and mill employment to 240), coupled with a lower regional share of input purchases, could reduce the positive impacts on output and employment by approximately 50%. If demand for other sectors' output falls, employment in those sectors could fall. Indeed, if all the above-listed adverse impacts occurred, overall employment could actually fall slightly in the region.

The demand for uranium is projected by the U.S. Energy Information Agency to increase by 0.3% per year (U.S. EIA, 2011a) in their reference case projections, and the price of electricity is projected to remain relatively constant in real terms over the period 2009 to 2035. Based on this projection, demand for uranium should grow slowly and the price should remain relatively stable.

Table 6-7. Summary of Estimated Economic Impacts of Mine and Mill Operations, Under Alternative Scenarios

Impact Type	Employment (jobs)	Output million $2011)	Labor Income (million $2011)
Baseline values			
Total at baseline	531,241	68,069.4	19,843.0[a]
“Reasonable” Case Impacts			
Direct Effect	424	121.2	20.0
Indirect Effect	118	21.1	6.2
Induced Effect	182	20.1	6.5
Total Effect	724	162.4	32.7
Best Reasonable Case			
Direct Effect	475	163.4	27.9
Indirect Effect	161	28.6	8.4
Induced Effect	253	27.9	9.1
Total Effect	889	219.9	45.3
Worst Reasonable Case: Reduced uranium price and production			
Direct Effect	253	62.2	8.9
Indirect Effect	51	10.1	2.8
Induced Effect	82	9.0	2.9
Total Effect	385	81.3	14.6
Sensitivity Analyses Around Worst Reasonable Case			
Lower Regional Share			
Direct Effect	341	109.4	15.4
Indirect Effect	87	17.6	4.9
Induced Effect	142	15.6	5.1
Total Effect	569	142.6	25.4
Lower regional share and reduced demand for other sectors in the region			
Direct Effect	−185	77.8	4.8
Indirect Effect	−16	7.5	2.1
Induced Effect	48	5.3	1.7
Total Effect	−152	90.5	8.6

Interviews with stakeholders and review of reports concerning the economies of regions located near mines and mills in the Western U.S. and elsewhere have not indicated any adverse impacts on agriculture or tourism, both environment-sensitive sectors. Although the two regions are very different topographically, climatically, and in population density, this is an encouraging indicator that a well-managed uranium facility need not have an adverse impact on the demand for other sectors of the regional economy. Nearby (within the study region, in fact), educational institutions and others in Lynchburg express that they have experienced no adverse impacts due to the presence of two nuclear fuel manufacturing facilities in Lynchburg; the input and output of those facilities is considerably more radioactive than the yellowcake that would be produced by the mine and mill. Nevertheless, concerns about the perception of risk and reduced quality should be taken seriously, because such perceptions could blunt or counteract the positive impacts of the mine and mill on the region's economy.

6.6.2 Limitations and Caveats

The analysis above estimates the total change in employment and output that would result within the study region from VUI's projected spending and hiring under a variety of more- or less-optimistic assumptions. To properly interpret the results of the analysis, one must bear in mind the underlying assumptions and limitations of the method used to estimate the impacts. Input-output analysis is useful in enabling the analyst to trace the impacts of direct spending or hiring due to a particular project, through all the affected sectors of the economy. To do this requires a detailed characterization of all the production and consumption relationships in the economy. Once the "snapshot" of production and consumption relationships is identified at baseline, it is assumed to remain unchanged throughout the analysis. While quantities can change due to the project being analyzed, production "recipes" and other spending patterns do not change. Over the time frame of the proposed mine and mill, technological change would undoubtedly occur. The farther out in the future one goes, the less accurate the 2009 structure of production relationships is likely to be.

6.7 Potential to Grow Other Parts of the Uranium Value Chain

As illustrated by the analysis above, introduction of a uranium mine and mill in Pittsylvania County, Virginia would likely result in output and employment increases greater than the actual spending and employment projected by the mine and mill. This is true because the suppliers within the study region from which VUI would purchase inputs would in turn purchase some of their inputs from other suppliers within the region. Further, the employees of VUI and other firms and organization in the study region, having increased incomes, would purchase consumer goods and services, some of which are produced within the region. The mine and mill, if established, might attract suppliers of its inputs to the area, or cause existing ones to grow.

In other industries, the establishment of a production facility in a region might attract other facilities to the area that would use the products of the first facility as input to their production process. In the case of uranium, however, there are substantial barriers to establishing new facilities that enrich uranium, produce fuel from it, or use it for power generation. All such facilities are highly regulated, and take a long time to come on line. Given the presence of two uranium fuel manufacturing facilities in Lynchburg, a firm wishing to site a uranium enrichment facility might find Virginia an attractive location. Existence of a uranium mine and mill within the state would be an additional plus. However, the process of obtaining the necessary approvals to site a nuclear value chain facility is costly and time consuming, and the outcome is not guaranteed. Thus, it is uncertain whether the mine and mill would contribute to attracting additional uranium manufacturing facilities to the area.

6.8 Possible Impacts on State and Local Governments

The creation of a mine and mill in Pittsylvania County would result in both increased revenues and increased responsibilities for state and local governments.

6.8.1 Estimated Tax and Fee Revenues Associated with the Proposed Mine and Mill

Both the assets of the mine and mill and the income (both corporate and personal) earned at the mine and mill are taxable under Virginia law and would yield increased revenues for the State and County governments. County revenue sources include real property tax, machine tool tax, and business, professional, and occupational license tax (although Pittsylvania County does not currently have a BPOL tax. State taxes include individual and corporate income taxes. Table 6-8 presents current State and County Tax rates.

Table 6-8. Applicable State and Local Tax Rates

Virginia State Tax Rates	North Carolina Tax Rates	Pittsylvania County Tax Rates
Personal Income Tax: 5%	Personal Income Tax: 6% to 8%	Real Property Tax: 0.52 % of assessed value
Corporate Income Tax: 6%	Corporate Income Tax: 6.9%	Personal Property Tax: 8.5% of assessed value
Sales and Use Tax: 5% with 1% local	Sales and Use Tax: 4.75% plus 2 % local	Machine Tool Tax: 4.5% of assessed value, assessed at 10% of original cost

Source: Virginia Department of Taxation; NC Department of Revenue, http://www.dornc.com/index.html Pittsylvania County website: http://www.pittgov.org

The IMPLAN model estimated the increased state and local taxes that would be associated with each of the scenarios. Table 6-9 presents the estimated state and local taxes that would result from the "Reasonable" construction and capital scenario and the "Reasonable" operations scenario. As shown above, the states of Virginia and, to a lesser degree, North Carolina, would receive most of these additional revenues, including social insurance taxes, most of the sales taxes, motor vehicle taxes, and personal and corporate income taxes. Affected counties, especially Pittsylvania (where the proposed mine and mill would be located) would receive real property and personal property taxes, a proportion of sales tax revenues, and other such as taxes and fees such as the Virginia Machine Tool tax. The construction and capital equipment expenditures would result in an estimated $4.3 million in revenues, mostly sales and use taxes and social insurance taxes for the construction work force. Operations would result in annual revenues from taxes on dividends, sales taxes, property taxes, and personal and corporate income taxes, totaling an estimated $11.2 million per year.

Table 6-9. Estimated State and Local Tax Revenues associated with Construction and Operation of the Proposed Mine and Mill

Tax or Fee Type	Estimated Revenues, Construction and Capital Spending ($million)	Estimated Annual Revenues, Operation ($million)
Dividends	$0.02	$1.26
Social Ins Tax- Employee Contribution	$0.06	$0.02
Social Ins Tax- Employer Contribution	$1.24	$0.05
Indirect Bus Tax: Sales Tax	$1.51	$3.36
Indirect Bus Tax: Property Tax	$0.03	$4.12
Indirect Bus Tax: Motor Vehicle Lic	$0.00	$0.09
Indirect Bus Tax: Severance Tax	$0.27	$0.00
Indirect Bus Tax: Other Taxes	$0.19	$0.73
Indirect Bus Tax: S/L NonTaxes	$0.08	$0.52
Corporate Profits Tax	$0.65	$0.37
Personal Tax: Income Tax	$0.10	$0.56
Personal Tax: NonTaxes (Fines- Fees)	$0.03	$0.09
Personal Tax: Motor Vehicle License	$0.02	$0.03
Personal Tax: Property Taxes	$0.01	$0.01
Personal Tax: Other Tax (Fish/Hunt)	$0.08	$0.01
Total State and Local Tax	$4.28	$11.21

Source: IMPLAN, (MIG 2011)

6.8.2 State and Local Government Responsibilities

In addition to potentially generating state and county tax revenues, the proposed Coles Hill mine and mill would impose some additional responsibilities and costs on both Virginia and county and local government agencies. These potential additional burdens are discussed below.

6.8.2.1 Virginia Regulatory Responsibilities

The department directly responsible for regulation of mining in the Commonwealth of Virginia is the Department of Mines, Minerals, and Energy (DMME). Virginia is currently an “agreement state” with respect to regulation of uranium mining. Because Virginia’s DMME has a long history of regulating coal mining and other mineral extraction, they likely already have the expertise to adequately oversee the proposed uranium mine, with respect to miner safety and public health. However, if Virginia chooses to become an agreement state with respect to regulation of mill tailings, some additional expertise and manpower would likely be required.

Other Virginia Departments that would likely incur new responsibilities as a result of the proposed project include The Virginia Department of Environmental Quality (VDEQ), the Virginia Department of Health (VDH), and the Virginia Department of Agriculture and Consumer Services (VDACS).

- VDEQ would be responsible for water, soil, and air releases and ambient conditions. To do this, they would likely need to hire some additional staff.
- VDH would be responsible for monitoring worker safety and the proposed mine and mill, as well as monitoring public health in the region surrounding the mine and mill. Again, this would likely require hiring some additional staff with specialized expertise.
- VDACS would be responsible for monitoring agricultural products in the region for the presence of radionuclides and heavy metals that may have been deposited on the soil or plants, and either directly contaminate vegetables, fruit and forage, or indirectly contaminate livestock and dairy products through ingestion. Even if no such contamination occurs (or if levels in agricultural products are demonstrated to be extremely low, this monitoring will provide information that will enable agricultural producers in the area to demonstrate to potential that their products are safe.

Overall, it seems likely that the Commonwealth of Virginia would need to hire between 10 and 20 additional employees with specialized expertise. This would entail an expenditure of between $2 million and $5 million, depending on the number of employees hired and the additional equipment and administrative support required to perform these monitoring and regulatory activities. While these numbers are relatively small relative to the existing Department employment and budgets, Commonwealth budgets have been tight in recent years, and hiring has been slow to nonexistent. Thus, a re-orientation of Virginia’s hiring priorities could be needed to ensure comprehensive, coordinated regulation of the proposed mine and mill.

6.8.2.2 Other State Responsibilities

Other responsibilities, that involve development of plans for responding to accidents and other emergencies, will also need to be addressed by Commonwealth Agencies. Examples include:

- ***State Road Upgrades***. Among the nonregulatory responsibilities facing the Commonwealth of Virginia is upgrading of some state roads near the site of the proposed mine and mill so that they are adequate to carry the additional traffic, including both commuting workers and shipments of materials into the site and yellowcake out of the site. The Virginia Department of Transportation (VDOT) generally requires developers to pay the cost of any upgrades that are required as a result of their projects, so this cost would likely fall on VUI rather than the taxpayer.
- ***Preparing to Respond to Incidents***. If the proposed mine and mill project goes forward, the Commonwealth would need to prepare to respond to incidents such as mining and industrial accidents and traffic accidents involving shipments of yellowcake. DMME could build off existing response plans for other mining and industrial accidents, incorporating information from Federal Mine Safety and Health Administration and from localities with existing mines and mills to develop a comprehensive plan for responding in the case of an accident at the site. Yellowcake is considered a hazardous material, and a plan should be developed by VDOT, VDH, and Virginia State Highway Patrol so that first responders and transporters know how best to respond in case of an accident.

These planning and training responsibilities are not expected to impose significant additional costs, as they can likely be addressed as part of ongoing processes at the affected agencies.

6.9 Possible Impacts on Housing Markets in the Region

Construction of the mine and mill may have a short-term impact on the demand for housing, health care, and other public services, depending on whether the construction workers are brought in from outside the region, or are already residents.

6.9.1 Increased Demand for Housing due to Workers Moving into Region and Potential Higher Incomes

The mine and mill would be constructed over a period of only a few years, and it is possible that as many as several hundred temporary residents may relocate to the region during that time. Data in Section 2 indicate that Pittsylvania County has sufficient vacant housing units available to accommodate such a number. Because of the short-term nature of the job, some construction workers coming into the region from elsewhere to work on the project would likely not bring their families with them; nevertheless, if construction workers relocate to the area, it could result in a short-term increase in demand for school classroom space and for health care.

During operations, VUI plans to hire as many workers from within the region as possible; this choice, if implemented, would minimize the impacts of the mine and mill on the demand for housing, education, health care, and public safety within the region. If we assume that 90% of the workforce would be hired locally (as VUI hopes), only 33 additional workers would move into the region in response to the mine and mill. This would imply that only 33 housing units would be needed, and data in Section 2 on vacant housing units indicate that there is plenty of capacity in Pittsylvania County's housing stock to accommodate 33 new households.

Potentially, increased employment due to the direct, indirect, and induced effects of the mine would result in increased income, at least in the short run. Section 6.6 describes these effects and provides estimates under different scenarios. Assuming that the median proportion of income spent on housing is 26%[2] (US Census Bureau, 2009), this may imply that roughly $8 million of the $33 million (for the Reasonable Case Scenario) in increased labor income may be spent on housing throughout the study region. Table 6-10 provides estimates of increased spending on housing under the different scenarios.

It should be noted that this section is intended as an illustration of the scale of impacts on the housing market that might result from higher incomes in the region. This is because the actual proportion of spending may differ from the average depending on the size and type (whether married couples and children are present in the household, etc) of the households and their income. For example, if more people with larger families are employed rather than those with smaller families, this may lead to a larger proportion of income being spent on housing. Also, households may choose to do home improvements rather than buy new homes.

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[2] This is the average median value for homeowners and renters. The Census document (2009) provides data from two surveys the American Community Survey (2007) and American Housing Survey (2007) and the average values from these two proportions is 26%. It should be noted that the average median value for the Danville Primary Metropolitan Statistical Area which includes Pittsylvania county and Danville city from 2000 Census data is also 26%. (Source: 5% PUMS data, Census 2000).

Table 6-10. Summary of Estimated Housing Expenditure Impacts of Mine and Mill Operations, Under Alternative Scenarios

Impact Type	Labor Income	Increases in Housing Expenditures
Baseline values		
Total at baseline	19,843.00	5,159.2
"Reasonable" Case Impacts		
Direct Effect	20	5.2
Indirect Effect	6.2	1.6
Induced Effect	6.5	1.7
Total Effect	32.7	8.5
Best Reasonable Case		
Direct Effect	27.9	7.3
Indirect Effect	8.4	2.2
Induced Effect	9.1	2.4
Total Effect	45.3	11.8
Worst Reasonable Case: Reduced Uranium Price and Production		
Direct Effect	8.9	2.3
Indirect Effect	2.8	0.7
Induced Effect	2.9	0.8
Total Effect	14.6	3.8
Sensitivity Analyses Around Worst Reasonable Case		
Lower Regional Share		
Direct Effect	15.4	4.0
Indirect Effect	4.9	1.3
Induced Effect	5.1	1.3
Total Effect	25.4	6.6
Lower Regional Share and Reduced Demand for Other Sectors in the Region		
Direct Effect	4.8	1.2
Indirect Effect	2.1	0.5
Induced Effect	1.7	0.4
Total Effect	8.6	2.2

The type of housing occupied by people may also change. Table 6-11[3] indicates that households in the study region occupy a greater proportion of mobile homes than the national average. Also, more

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[3] Data Source: U.S. Census Bureau, 2005-2009 American Community Survey

households live in less expensive housing compared to the national average (Table 6-12[4]). Households may move to bigger and more expensive houses than they are currently occupying.

Table 6-11. Type of Housing in Study Region Compared to the US

Type of Housing	United States	Study Area
Single Family	67%	72%
Duplex	4%	2%
Multi-unit	22%	12%
Mobile Home	7%	14%

Table 6-12. Summary of Owner-Occupied Housing Values and Rents in Study Region Compared to the US

	United States	Study Area
Owner-Occupied Housing Values		
Less than $90,000	20%	32%
$90,000–$174,999	27%	39%
$175,000–$399,999	33%	23%
$400,000–$999,999	17%	5%
Greater than $1,000,000	2%	1%
Rents		
Less than $250	8%	14%
$250–$449	16%	38%
$450–$649	24%	32%
$650–$899	24%	11%
Greater than $900	29%	5%

6.9.2 Reduced Demand for Housing in the Region due to Perceptions and Safety Concerns

In general, locations near sites with possible adverse environmental and health consequences are considered undesirable for residences. Examples of such sites include industrial facilities, mines, leaking underground storage tanks, etc. This undesirability is called “stigma”[5] in environmental economics literature. Risks to health and safety concerns are reflected in lower property values of properties close to such sites (as compared to similar properties farther away). This trend is statistically examined by

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[4] Data Source: U.S. Census Bureau, 2005-2009 American Community Survey

[5] Gregory, Flynn, and Slovic (1995) associate the word "stigma" with places, products, and technologies that have one or more of the following characteristics: dread consequences, involuntary exposure, inequitable distribution of impacts (e.g., children and pregnant women suffer disproportionately), unbounded effects, violations of right or natural standards, and the existence of serious questions about management.

economists using empirical data (popularly known as “hedonic” studies) and is typically used to infer the value that people attach to living further from the site. This can be viewed as a measure of the disamenity (welfare loss) associated with an “undesirable” site located near their homes. Studies surveying residents (popularly known as “contingent valuation” studies) about the “premium” they are willing to pay to live away from such locations are also used to infer the value that people attach to such disamenities.

One important point to consider is that households who locate close to the site may be doing so because either they do not view it as a disamenity or because they cannot afford to live further away due to lower incomes. Thus, it is important to account for income in the statistical analysis so that the “premium” associated with living further away from the site can be separated from affordability of housing issues. Other factors also need to be accounted for in the analysis. These factors could be house specific (such as size of the house and surrounding land, age of the house, etc), neighborhood specific (such as measures of ethnic composition, poverty levels, distance to airports, safety etc), community specific (such as presence of good public schools, social and religious organizations, etc) and environment specific variables (such as general air quality in the area, etc). Statistical methods are used to isolate the effect of each factor on value of the properties.

Several interesting questions arise in this context:

(a) What is the magnitude of the disamenity or stigma associated with the site?

(b) What are the factors that increase the stigma effect?

(c) Beyond what distance from the site, does the disamenity fade?

(d) Do the perceptions and safety concerns remain after the site is closed and/or cleaned up? How long does the stigma associated with the site remain? This raises the issue of perceived versus real risks associated with an “undesirable” site. Even if the site is closed and cleaned up, the immediate location around it may still be considered undesirable due to perceived risks and the stigma associated with it may persist in the long run.

To gain insights into the possibility of reduced demand for housing due to stigma effects in the immediate vicinity of the proposed mine and mill, we examined the relevant literature on property values associated with industrial facilities such as power plants, mines, leaking underground storage tanks and landfills. We also include Superfund sites. Although they may not be representative of contaminated sites in general, they do provide some insights into the extent and length of stigma effects for more severely contaminated sites as compared to less contaminated sites.

The relevant details of each study and the main results are summarized in Table 6.13. The magnitude of the reduction in housing prices in the immediate vicinity of a contaminated site varies widely (see Table 6-13), ranging from 3% to 20%. A study of a localized outbreak of pediatric leukemia on housing prices showed that housing prices declined by 15.6% during maximum risk period (Davis, 2004). Different studies show that that the stigma effect persists for a radius ranging from 1km to 6 km around the site.

More contaminated sites can impact home values more and interestingly, publicized sites impact home values more (Guignet, 2010). Publicity may impact home values in two ways. First, awareness of the contamination leads to more people being reluctant to move close to the site, as opposed to a situation where there is a lack of information. Also, publicity may potentially affect the perception of risk and increase the public's concern.

Property values recover most of their initial losses toward the end of the cleanup process (Hurd, 2002). While cleanup of sites causes housing values to rise, effects are mostly very localized (Gamper-Rabindran & Timmins, 2011). Cheaper houses closest to the site experience the most appreciation because they are the ones more likely to be exposed to hazardous waste sites. Thus, cleanup causes a bigger rebound in prices in properties in the immediate vicinity than those farther away.

Results from a study on property-specific contamination such as private wells suggest that the stigma associated with sites that are less contaminated may not have long-lasting effects that are typical of Superfund sites (Boyle et al, 2010). This study does note that it is difficult to know whether to attribute the rebound in prices to the cleanup effects or to a decline in stigma. Thus, it may be difficult to distinguish changes in actual versus perceived risks. Another study indicates that when cleanup is delayed by 10, 15, or 20 years, the discounted benefits of the cleanup are lost, thus suggesting that expedited cleanup may reduce the effects of stigma (Messer et al, 2006).

Although these experiences in other contexts are not predictive of what might happen if the mine and mill are established at Coles Hill, they do demonstrates a range of experiences from which stakeholders in the Danville region may learn. The environmental economics literature commonly uses the term stigma to characterize the undesirability and risks associated with contaminated sites. There is a possibility that reductions in housing demand, and reduced house prices, may occur in the near term due to both actual and perceived risks or stigma effects associated with the potential mine. Such stigma impacts are likely to be localized within a few kilometers of the mine and mill. In the absence of actual contamination, stigma effects may fade with time. If contamination occurs, quick and efficient cleanup may help reduce the stigma effect.

6.10 Possible Impacts on Education, Health Care, and Public Safety in the Study Region

VUI estimates that during operations, 324 employees would work at the proposed mine and mill. They have stated that they hope to hire up to 90% from within the study region. If this is the case, and fewer than 50 employees move in from outside the region, the impact on schools, health care, public safety, and other services within the region should be minor. An addition of at most 100 additional students in the Pittsylvania County public schools would be able to be accommodated without serious crowding, provided they don't all end up in one or two schools.

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Dale et al (1999)	Hedonic	Lead Smelter	Dallas County, Texas	Each mile a house is located away from smelter adds approximately 2% to the home price	Property values around the smelter were lowered before cleanup activities, but prices continued to rise after the cleanup across all neighborhood types (although poorest neighborhoods rebounded the slowest).	1979–1995	Urban	203,353
McCluskey & Rausser (2003)	Hedonic	Hazardous Waste Site	Dallas County, Texas	Temporary stigma and long-term stigma are possible after knowledge and cleanup of a waste site. Environmental impacts can create temporary stigma effects, but if these cause the demographic component of the neighborhood to change then they can impact housing prices long-term.	Home prices depend critically on distance from hazardous waste site. Long-term stigma only exists in 1.2 mile radius.	1979–1995	Urban	205,397 home sales

(continued)

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values (continued)

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Longo & Alberini (2006)	Hedonic	General Contaminated Site	Baltimore City, Maryland	Stigma effects are not cleared for commercial properties within proximity to a contaminated site once cleaned up or pronounced harmless. Increasing distance from a contaminated site from 500m to 1km increases the price by 4.36%–6.98%	Industrial properties are unaffected by proximity to contaminated sites, while commercial properties do have lower prices related to proximity to contaminated sites	1990–2000	Urban	2,430
Messer et al (2006)	Hedonic	Superfund	Sites in California, New Jersey, and Massachusetts	When cleanup is delayed by 10, 15, or 20 years, the discounted benefits of the cleanup are lost	If clean up was expedited this would minimize stigma and reduce losses to home prices. Another 5 to 10 years may be needed after cleanup is complete to recover from effects of STIGMA. Cleanup should be less publicized to maximize benefits.	1970–1999	Urban	34,000 home sales
Hurd (2002)	Hedonic	Superfund, Landfill	Monterey Park, California	Property values recovered 80% their initial losses from initial Superfund listing 10 years later (usually toward the end of the cleanup process)		two time samples: 1983–1985; 1994–1996	Urban	

(continued)

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values (continued)

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Boyle et al (2010)	Hedonic	Well water arsenic contamination	Buxton & Hollis, Maine	Home prices were only depressed for 2 years. Results may suggest that property-specific contamination (private well) may not have long-lasting effects like Superfunds that can depress prices for a decade.	Debatable whether reduction in prices is due to in-home water treatment systems or due to a decline in stigma	1992–2003	Rural, "bedroom" communities of Portland, ME	1,669 Buxton home sales and 542 Hollis home sales
Williamson, Thurston, Heberling (2007)	Hedonic	Acid Mine Drainage	Cheat River Watershed, West Virginia	Location near an acid min drainage impaired stream has an implicit marginal cost of $4,783 on housing (within 1/4 mile of stream)	Houses located beyond 1/4 of mile from the stream, housing prices were not affected.	1984–2005	Rural low-income West Virginia (70% lower than national median household income)	1,608 property sales
Kim & Goldsmith (2009)	Hedonic	Concentrated Animal Feeding Operations (CAFOs)	Craven County, North Carolina	1 mile from a CAFO with 10K swine median house value fell $6,800–$5,200		2003	Rural	25,684
Herriges, Seechi, & Babcock (2005)	Hedonic	Concentrated Animal Feeding Operations (CAFOs)	Five rural Iowa counties	a 9% drop in property value if a moderate sized CAFO locates itself upwind near residential housing	Homes that are downwind from CAFO in summer: distance from hog farm is statistically significant	1992–2002	Rural	1,145
Kim & Harris (1995)	Hedonic & Contingent Valuation Method (CVM)	Copper (open-pit mine & mill)	Green Valley, Arizona	Consumer surplus loss between 116 to 169 million from the decreased air quality and visibility	CS loss from dust air pollution is more than twice than the CS lost from degraded view (tailings banks are visible)	1993	Retirement community with population of 21,000	20

(continued)

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values (continued)

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Reichert, Small, & Mohanty (1992)	Contingent Valuation Method (CVM)	Landfills	Cuyahoga County, Ohio	5.5%–7.3% decline in market value (expensive housing). Less expensive/older area experienced a 3–4% decline in market value	expensive homes are most affected	1985–1989		2,243
Payne (1987)	Hedonic	Low level radioactive waste	Chicago, Illinois		publicity about the contamination began in July 1976. After this period, houses that were built pre 1950 were more sensitive to distance of the site while newer home prices were not sensitive to the site	Pre publicity years 1973–1976 and Post publicity years 1977–1982		
Smolen, Moor, & Conway (1992)	Hedonic	Low level radioactive waste	Toledo, Ohio	Negative impact on housing prices dissipated soon after public resistance cause the proposal to be cancelled. Distance variable was significant out to the 5.75 mark	The real estate markets reacts quickly to bad news, but readjusted once the public believed the radioactive landfill would not occur	1989–1990		
Guignet (2010)	Hedonic	Leaking Underground Storage Tanks (LUSTs)	Baltimore and Frederick Counties, Maryland		Little evidence that simply being near a LUST site affects property values. Groundwater well tests for contamination negatively impacted prices by 7–10%	1996–2007		111,107

(continued)

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values (continued)

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Zabel & Guignet (2011)	Hedonic	Leaking Underground Storage Tanks (LUSTs)	Baltimore, Baltimore City, and Frederick Counties, Maryland	More publicized and more contaminated sites can impact home values negatively by over 10%	An average LUST site unlikely to have a significant impact on home prices.	1996–2007	Urban and rural	136,816 home sales located near 219 LUST sites
Simons & Saginor (2006)	Meta-analysis	Several Types Contaminated Sites	Across the United States		The coefficient for log distance from contamination was positive. Nuclear large negative effect. Superfund/Landfill not statistically significant. Air/CAFO significant and negative	various		228 observations from previous studies
Boxall, Chan & McMillan (2005)	Hedonic	Oil and Natural Gas facilities	Calgary, Alberta, Canada		Property values are negatively correlated with oil and ng facilities when located within 4km	1994–2001	Urban and rural	532
Davis (2011)	Hedonic	Power Plants	Across the United States	within 2 miles, housing values and rents decreased by 3%–7%		1993–2000	Various	86,000 home values near 92 plants, about 90,000 home values from the rest of the US
Gawande & Jenkins-Smith (2001)	Hedonic	Transportation of spent nuclear fuel shipments from Savannah River site to New Mexico	Charleston, Berkeley, and Aiken Counties, South Carolina	In Charleston County, being 5 miles away from the nuclear shipment route gave the housing property 3% more value than a house located on the route	Property values lowered in populous urban areas but areas with lower risk perception and more experience with nuclear materials, shipments did not affect property values	1991–1996	Charleston county is urban, Berkeley and Aiken are rural	9,432

(continued)

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values (continued)

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Alberini (2007)	Hedonic	Superfund	Colorado	Properties with confirmed contamination sell at a 43%–56% discount. Participation in voluntary cleanup programs do tend to raise the property price.	Participation in a voluntary clean-up is most likely when the site has a high redevelopment potential	1974–2002		115 sales transactions
Kiel & Zabel (2001)	Hedonic	Superfund	Woburn, Massachusetts	Benefits from cleanup of 2 Superfund sites were in the range of &72–$122 million (1992$)	Likely that benefits are greater than estimated costs of site clean up	1975–1992	Boston suburb	2,191
Gamper-Rabindran & Timmins (2011)	Hedonic	Superfund	Sites in California, New Jersey, Connecticut, and Massachusetts	Benefits from cleanup of Superfund sites does appreciate housing values, but mostly very localized. Values appreciate by 19% for census blocks within 1 km and only 5.8% for block within 3km.	The cheaper houses within the 1-kilometer radius experience the most appreciation because they are the ones more likely to be exposed to hazardous waste sites	Housing transaction from 1988–2008	Urban	158 census tracts
Williams & Vossler (2011)	Hedonic	Surface coal mining	Across the United States	Addition of a surface mine decrease in median property value by 7.5–14.8 million (1999$)	For a county of 1,000 sq miles with median home price of $76,658, the addition of one surface mine decrease housing value by $200.84.	2000 (census data)	Various	around 30K housing units

(continued)

Table 6.13. Summary of Studies Examining the Impact of Environmental Contamination on Property Values (continued)

Study	Type of Study	Type of Contamination/ Unwanted Location	Region of Study	Main Findings (Hedonic Premium)	Other Findings	Time Period of Study	Demographics of Area	Sample Size
Smolen, Moor, & Conway (1992)	Hedonic	Toxic Chemical (Hazardous) Waste Landfill	Toledo, Ohio	From 0–2.6 miles away, $14, 200 premium found for each mile the house was located away from Landfill		1986–1990		49 home sales
Farber (1998)	Meta-analysis	Several Types Contaminated Sites	Across the United States		Housing markets are sensitive to the real or perceived risks. Adverse property effects are very localized close to the undesirable facility.	various	Various	25 previous studies
Davis (2004)	Hedonic	Cancer Cluster of Pediatric Leukemia	Churchill County, Nevada	Housing prices declined by 15.6% during maximum risk period	Statistical value of pediatric leukemia is $5.6 million	1990–2002	Rural	11,834

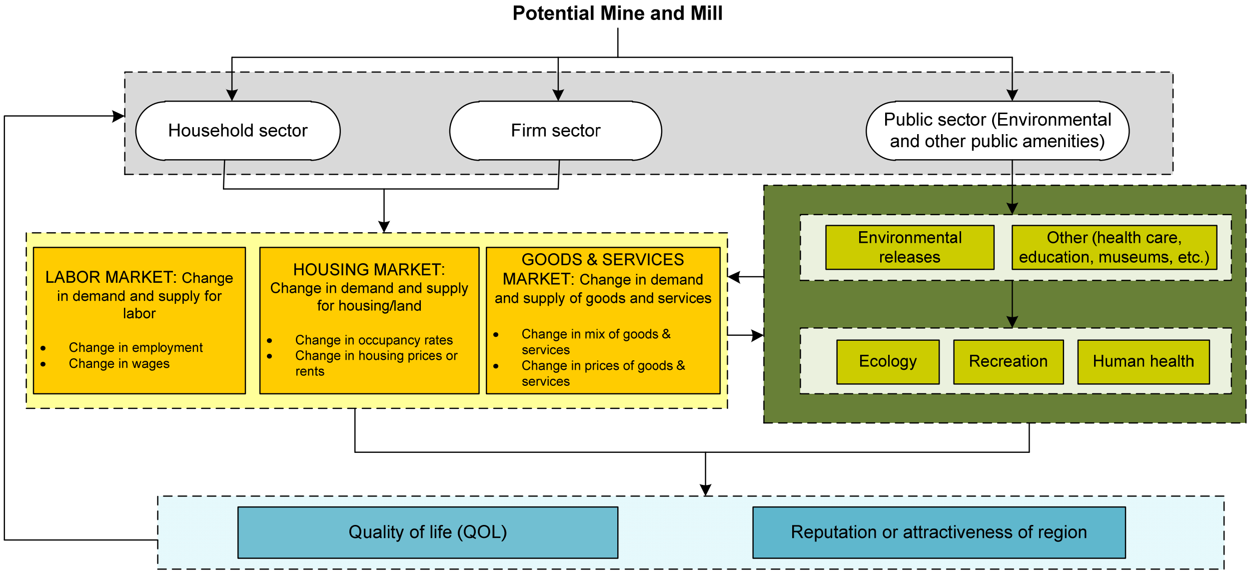
Health care facilities near the site of the proposed project include small clinics staffed only during business hours. Thus, there would be no “coverage” by local health care providers during more than half of the round-the-clock operating schedule. The nearest trauma center is in Danville, approximately 30 miles away. Local emergency responders would need to transport any seriously injured individuals to Danville.

Some specialized training would be required for emergency service and health care workers, but mining and industrial activities (even having to do with radioactive materials) would generally be likely to give rise to injuries similar to those incurred by farmers and workers in existing manufacturing industries in the region. In addition, coordination between emergency service and health care organizations in the region and at the state level would guarantee appropriate responses to incidents and accidents. The Health Department of Pittsylvania County could choose to increase its monitoring and public education about radiation exposure, but because radon is already present in some areas this may not represent an incremental effort. Overall, although some additional effort and resources would be needed, it does not appear that the creation of the mine and mill would impose serious additional burdens on the region’s public services.

6.11 Overall Impact of the Proposed Mine and Mill on Quality of Life in the Study Region

Economists use analytical frameworks provided by economic theory as well as simulation models to study potential impacts of changes in an economy. Broadly speaking, conditions in economy can be represented by the characteristics of the set of households and firms in that region. The other major components characterizing an economy consist of environmental amenities and other public amenities such as education, healthcare, safety, transportation, etc. In the event that a mine or mill is established at Coles Hill, these are the different sectors or entities in the local or regional economy that may be impacted. Changes in the condition of the region result from numerous interactions and feedback mechanisms among these different entities. This is illustrated in Figure 6-2. Entries inside boxes with dotted lines typically interact with each other. Thus, for example, if the mine and mill opens, there may be changes in the demand and supply of labor and interactions among the household and firm sector may result in changes in wages and employment levels. Similarly effects may be seen in the housing and other goods and services market. This is reflected in the yellow dotted box. This may result in changes in the tax base and thus this might alter public spending on amenities such as hospitals, schools, etc. Thus, there may be interactions among the “market” sector (i.e., firms and households) and the “non-market” or public sector. Similarly, if a mine opens, there may be changes in environmental releases and, consequently, changes in the ecology, human health, and recreation in the region. This is depicted in the green dotted box. All of these different effects contribute to both the quality of life as well as the attractiveness of the region (to both households and firms considering migrating to the area as well as tourists visiting the area). This is represented by the blue dotted box at the bottom. In the long run, there may be feedback effects on the households, firms, and the public sector. Thus, potential tradeoffs may arise between the changes in the different sectors. There could also be tradeoffs between short term and long term changes due to feedback effects. It would be important to consider and evaluate these different tradeoffs when assessing the overall impacts of the proposed mine and mill.

Figure 6-2. Study Framework Showing Linkages Between Environment, Economy, and Quality of Life



6.11.1 Factors Affecting Quality of Life

Studies that focus on estimating quality of life indices for different cities are primarily based on the notion that cities with more desirable amenities attract more households. In general, this results in lower wages and higher costs of living in desirable locations. Thus “premiums” associated with more desirable cities reflect the value households attach to each of the amenities in that city[6]. These studies assemble city – specific amenity data such as environmental characteristics, neighborhood, and community characteristics for multiple cities across the nation. Other factors that affect wages (such as education and experience of the worker, occupation, etc) and housing prices (such as housing size, type and age of house, etc) are also accounted for. Statistical methods are used to isolate the effect of each factor on value of the properties and wages, respectively. The contribution of each of these factors can be viewed as the value that households attach to each amenity or the “implicit price” they are willing to pay for the amenity. These implicit prices for each are weighted (by some measure of the quantity of amenity) to obtain quality of life indices. It is important to note that these are relative “indices” and are primarily used to rank cities. Examples of such studies include Blomquist et al. (1988); Gyourko and Tracy (1991), Cragg and Kahn (1999) and Bayer, Keohane and Timmins (2006) and Albouy (2010)[7].

Empirical evidence from this literature provides insights into amenities that households place value on. Studies have tended to show that in general, households place positive (and statistically significant) values on ten categories of public amenities (listed below) and are attracted to cities that have

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[6] This result is true under certain assumptions such as firm’s costs of production are unaffected by amenities (Roback, 1982) and if households and firms are “perfectly mobile” (Graves and Mueser (1993) and Greenwood et al. (1991)). Perfect mobility implies that they have no migration costs and housing and labor markets do not take any time to adjust to altered levels of demand and supply conditions.

[7] The primary focus, assumptions and statistical techniques that are used for these studies are different but the basic underlying logic is broadly similar.

some or all of these amenities. These public amenities (represented in the green box in Figure 6-2) are listed below:

1. Mild climates
2. Distance from undesirable sites
3. Good air and water quality and availability and associated effects on human health
4. Abundance of ecological assets and natural beauty
5. Good schools and/or educational system
6. Lack of crime and safety
7. Roads and transportation access *(connectivity to highways, airports, rail etc)*
8. Access and quality of healthcare
9. Outdoor recreation opportunities *(parks, hunting, fishing, hiking, golf courses etc)*
10. Indoor recreational opportunities *(movies, street fairs, community events, museums, etc)*

Economic considerations (represented in the yellow box in Figure 6-2) also add to desirability of cities. These include:

1. good employment opportunities
2. higher incomes
3. availability of housing and lower cost of living
4. availability of other goods and services

A weighted combination of all these values is indicative of the quality of life associated with a city. Any change in some or all of these factors lead to changes in the quality of life. We draw from the empirical literature on quality of life for a comprehensive list of factors that have been found to be important contributors to the quality of life and the attractiveness of regions. Qualitative research conducted through interviews of community members and stakeholders allowed us to refine this list and focus on factors that are most relevant and/or of concern to the study region. The expected changes to the different components or factors contributing to quality of life are described in various sections of the report and are summarized below. Overall, it appears that the proposed project would potentially have both positive and negative impacts on quality of life in the study region; the impacts would potentially vary by sector and location within the region. Consequently, tradeoffs may be involved among the different potential impacts in the short run. Both actual and perceived risks may potentially result in various impacts on the quality of life and attractiveness of the region and these may vary over time. Feedback effects on the different sectors may lead to impacts in the long run, and these may differ from short run impacts. Thus, there are also potential tradeoffs between short run impacts and long run impacts.

6.11.2 Potential Impacts of the Mine and Mill on Quality of Life

Affects on Public Amenities

Some public attributes of the region, such as its mild climate, and access to and quality of health care, are not likely to be affected by the proposed mine and mill. Impacts on air, soil and water quality, availability of water, and associated effects on human and ecological health depend on levels of contaminants released by the mine and mill. Preliminary analyses suggest limited exposures to human population and consequent changes in health, and limited changes in ecological health, provided best practices are implemented and regulatory requirements are met. A full scale risk assessment (based on site-specific information) would be necessary to quantify the magnitude and extent of impacts.[8] There may be some loss in aesthetic value in the immediate vicinity of the proposed mine and mill. Both actual and perceived environmental and health risks may discourage outdoor recreation and tourism. Interviews with local communities have revealed concerns for tourism in areas around Smith Mountain Lake. Since the lake is located northeast of the proposed site, actual environmental risks associated with the area are unlikely. Also, areas near uranium sites in the southwestern U.S. have experienced increasing tourism, despite nearby uranium sites. However, perceived risks may potentially impact the tourism in this area, at least until monitoring demonstrates that environmental quality is acceptable. Indoor recreational opportunities (movies, street fairs, community events, museums, etc), on the other hand, may improve as a result of some increased demand from increased incomes (both within and outside the region) in the short run, although this may change in the long run, after the mine and mill close.

It does not appear that the current school systems would be overburdened; thus, it is unlikely that new public schools would be needed or that the quality of public schools would change significantly. There is concern that some private schools may be adversely impacted. This may or may not occur, but the loss of any of these institutions and their associated employment and contributions would be detrimental to the region.

Safety and transportation access may be affected, but not negatively. It does not appear that the current public response system would be adversely affected, although additional training and coordination between agencies would be needed. Some roads may be improved in the immediate vicinity of proposed mine and mill. Major adverse effects on transportation (congestion, etc.) are unlikely.

Economic Factors

Economic factors affecting quality of life in the region are likely positive, at least in the short run. Employment opportunities are likely to improve and incomes are likely to increase due to mine and mill operation. Increased incomes and economic activity could lead to an increase in the variety and quality of goods and services available in the region. However, there is concern that negative perceptions about uranium mining and milling could cause reduced employment in other sectors**,** or discourage new businesses from moving to the region, which could offset the influence of the mine and mill.

There could be increased demand for housing, due to higher incomes and increased population if labor is hired from outside the region. Given vacancy rates, availability of housing should not be a constraint, and overall housing costs are unlikely to go up. There is also some possibility that negative

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[8] If quantitative estimates of health effects or ecological effects become available (based on site-specific risk assessment), values attached to these health or ecological impacts could be estimated. For example, estimates of changes in risks to certain health outcomes (such as cancer) can potentially be combined with estimates of population exposures and the average value households attach to avoided cancer to obtain total value of impacts. Examples of studies which estimate the value households place on (1) avoiding certain health outcomes such as cancer (2) improved groundwater quality (reflecting health impacts associated with contamination and/or quantity of drinking water) and (3) improved surface water quality (reflecting recreational and ecological impacts with contamination of freshwater or surface water) are provided in Appendix H.

perceptions about the mine and mill may lead to reduced demand for housing close to the site. In the long run, perceived risks may diminish with proper management and cleanup/closure procedures, and transparent communication about environmental conditions.

6.12 Summary

RTI used both quantitative and qualitative approaches to assess potential economic and community impacts that might be associated with the proposed Coles Hill uranium mine and mill. As indicated by data characterizing existing conditions in the region, and interviews and focus groups conducted with residents within the 50-mile radius surrounding the proposed site, there is a need for economic development and additional employment opportunities within the region, which has been hurt by the decline of traditional manufacturing industries such as furniture and textiles. While residents and others expressed hope that the employment and spending that would be associated with construction and, especially, operation of the mine and mill might result in increased prosperity and opportunity, they also expressed anxiety that the stigmas associated with mining and uranium, not to mention potential genuine health and ecological risks, would outweigh any benefits resulting from the proposed project. We explored these possible outcomes using a quantitative input-output simulation model that estimated the total changes in employment, output, and other economic variables under a variety of scenarios. The total impact under each scenario includes both VUI’s direct spending and employment but also spending and employment by other suppliers within the region and by households within the region experiencing higher incomes.

Using the IMPLAN input-output modeling system (MIG, 2011), we simulated the overall impacts on the region’s employment and output under three scenarios termed the reasonable case (assuming approximately 60% of VUI’s annual spending occurs within the region), best reasonable case (assuming higher uranium prices and a higher share of spending within the region), and worst reasonable case (assuming lower uranium prices result in reduced production and employment). To further explore possible downside economic risks, we also illustrated a situation where the stigma of uranium mining and milling caused reduced demand for some of the resource-based industries in the region, including agriculture, food processing, and education. Construction and capital purchases are estimated to add between 559 and 1,008 jobs (over a short 2- or 3-year period) and between \$70.5 and \$137.7 million in output to the region’s economy. Operation of the mine and mill is estimated to add between 385 and 889 jobs and between \$81.3 million and \$219.9 million in output each year for 20 years, under the worst reasonable and best reasonable operating scenarios. Sensitivity analysis around the worst reasonable scenario shows that, if the demand for other regional sectors falls due to stigma or reputational effects, the resulting reduction in output and employment in those sectors could counteract the benefits of the proposed project, and employment could actually decline. The quantitative simulation also shows that state and local tax revenues could increase by \$11 million annually during the operating period, but our investigation also reveals that both state and local governments would incur the costs of meeting new responsibilities as a result of the proposed project.

Combining the information developed to illustrate possible economic impacts with information about potential pollutant releases and environmental impacts, we attempt to qualitatively assess impacts on the region's overall quality of life.[9] Aspects of the region that are expected to be positively affected include incomes, employment opportunities, and indoor recreation opportunities. Aspects of the region that may be adversely affected include air and water quality (minimal adverse impacts under normal conditions), natural resources and outdoor recreation opportunities (may be adversely affected by stigma of mine and mill), and housing values close to the mine and mill. Other regional characteristics, such as climate, infrastructure, schools, and health care, should not be affected significantly if the project goes forward.

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[9] We chose not to quantify such impacts due to uncertainties about both the environmental and economic impacts of the proposed mine and mill. Strong assumptions would be necessary for quantifying such impacts and it is unlikely that these assumptions would hold in reality.

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Summary

7.1 Questions about the Mine and Mill

During the spring and summer of 2011, RTI conducted a number of key stakeholder interviews and focus groups to help identify regional stakeholders' questions about the proposed mine and mill that the study could help address. Throughout the discussion of concerns and benefits of the mine and mill, participants voiced a variety of explicit and implicit questions or uncertainties as well. Below is a list of these questions in order of frequency discussed. While this report does not answer all of the questions asked, several of the questions are addressed; where this is the case, the section that discusses the topic is referenced below. Further, it is important to remember that since these discussions, several reports have been published and public symposia have been held in various locations in Virginia, so similar discussions held today might reveal different priorities.

- *How do we get enough information to make an informed decision?* Far and away, the most common questions revolve around the concern over lack of adequate information and participants not feeling educated enough to make a smart decision about supporting or opposing the proposed project.

- *How would the mining or milling actually work*? Why they need to mine the uranium; how mining is done; how the uranium is stored as well as transported safely; what will happen to the displaced dirt, the waste, and the tailings; how technology will be updated to keep the operation safe; how deep they will mine; and what the visual impact on the landscape will be.

- *How would the operation be regulated?* There is quite a bit of uncertainty around how the mine, milling operation, will be regulated, by whom, and who will be responsible for "cleaning it up" safely and appropriately and monitoring it going forward. Who, if anyone, would help the community recover if it has negative repercussions on the land, the economy, or the environment is also unclear.

- *What are the health and safety risks of contamination?* General safety and health questions are a high priority for participants. Many questions center around the fear that the mining or milling might lead to contamination of the area (potentially due to radioactivity) and participants wonder if this could cause health concerns such as cancer or birth defects, health problems for local livestock/agriculture, and contamination fears from ingesting local produce.

- *What kinds of jobs and staffing opportunities would it bring?* In addition to how many jobs the operation would create, participants wonder if the company would hire local workers for all those positions or if they would bring their own people. Worker qualifications, pay scales, and if positions would be full-time or part-time are also uncertainties.

- *What would be the environmental impact?* Participants question what the effect on water quality will be if the operation takes place and what effect it will have on the landscape.

Many wonder if the uranium or by-products remain in the displaced dirt and how far potential contaminants could travel in the water, the soil, or dust in the air. A related concern is the potential impact of a hurricane, earthquake or other natural disaster.

- *What will be the economic impact?* Questions about both the positive and negative economic effects were voiced. Fearing negative repercussions, some participants question if the property will be worth anything when the operation moves in, what will happen to farmers if their land is destroyed, and if industries will move to an area with uranium mining. Conversely, some wonder what the net economic gain would be and how long the economic benefits would be projected to last. Also questioned was whether the proposed project would remain viable throughout its estimated lifetime, or if it would stop producing because the demand for uranium falls.
- *What would be the impact on our community?* Only a few participants posed questions specifically about the effect this could have on the community. Some are unsure if people will stay in the area or if they will move away due to the negative stigma. Others wonder if this will be an issue for the area sooner or later, regardless of the outcome for this proposed operation. Other community-related questions include: do citizens have a right to vote on it and how will it affect Main Street.

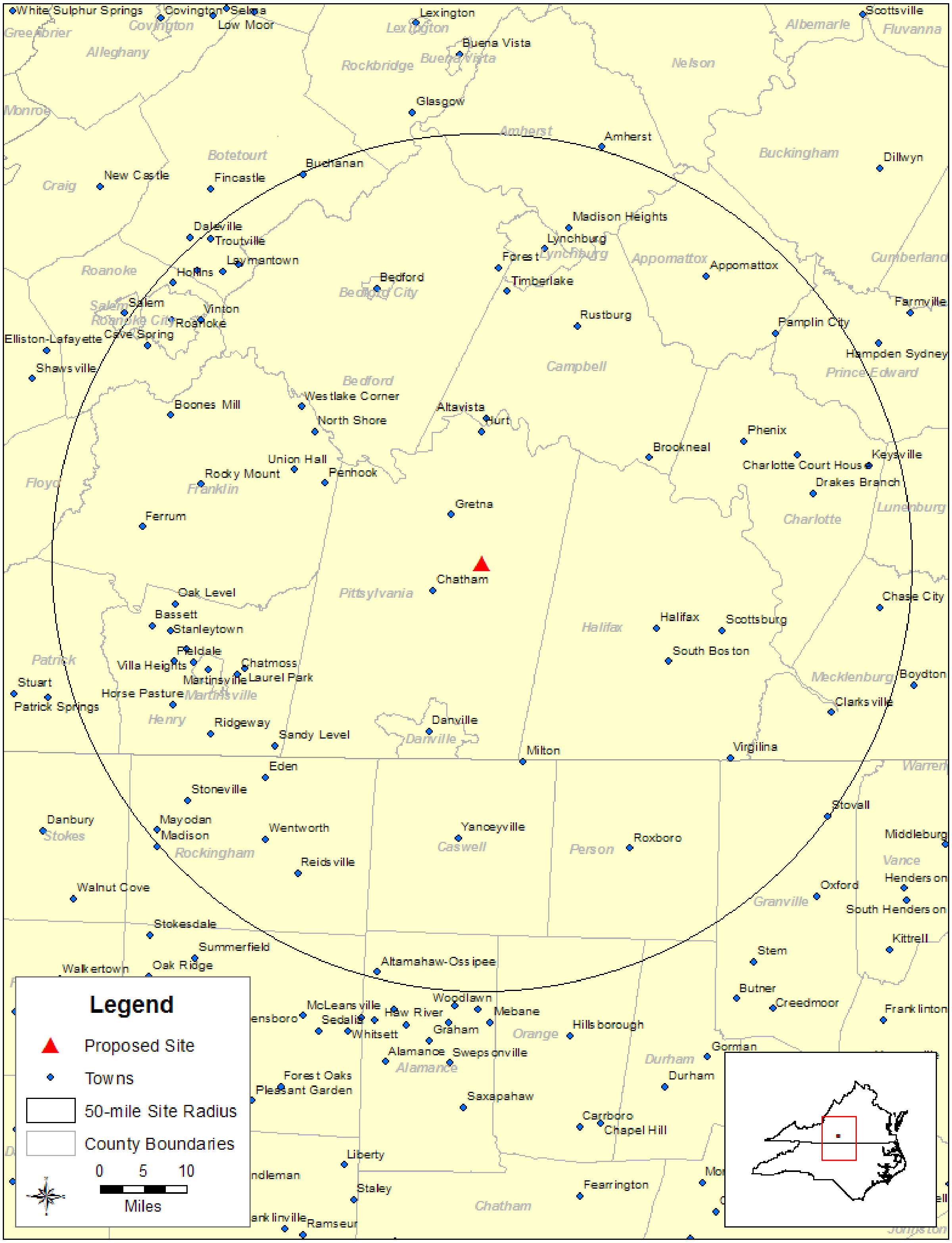
Below, we summarize our study findings.

7.1.1 Study Scope and Purpose

The purpose of this year-long socioeconomic study was to evaluate the potential impacts of developing and operating a uranium mine and mill on a region within 50 miles of Coles Hill. Figure 7-1 shows areas included within the study region. This report is intended to serve as a resource for all interested parties as they consider the variety of ways that this potential development may affect their communities and environment. As such, the primary goal of the study is to enable stakeholders to formulate informed opinions, to make the best collective decision possible, and in the case of an eventual mine and mill project, to be aware of questions and concerns they may want to investigate further or monitor going forward. The focus is on anticipating what might be entailed in the proposed mining and milling project, and on identifying possible ramifications of the project in social, economic, and environmental terms. To do this, our efforts are targeted toward providing realistic information about the types of possible impacts and which important factors of the project will drive these impacts, as opposed to providing extensive mathematical projections of specific metrics. Some modeling and projections will be used to describe the upper and lower bounds of potential impacts across a number of parameters. However, it should be noted that these numerical forecasts are intended to place the qualitative assessments in context and allow this report to serve as a useful reference document as the stakeholders of the region prepare themselves with the best available information to understand this important decision.

The study does not reach any conclusions or make any recommendations as to the advisability of lifting the moratorium and allowing mining and milling of uranium in Virginia. Instead, the study is designed to provide a repository of information about the various types of impacts that may be experienced if the mine and mill are developed.

Figure 7-1. The Study Region, a 50-Mile Radius around Coles Hill, Virginia



7.1.2 Study Methods

To ensure that our study meets the goal of serving as a reference document for the residents of the region, our approach must (1) identify and address the interests and concerns of regional residents and (2) provide as much well-documented, defensible information as feasible (subject to assumptions and data availability). Thus, our study combines an assessment of possible impacts predicted by environmental and social sciences, with an investigation of stakeholder interests and concerns within the study region. Our qualitative research into residents' interests and concerns helps us to specify the environmental and economic impact assessments. In addition, we provide illustrative information based on case studies of other mines and mills (U.S. and international) along with their surrounding regions.

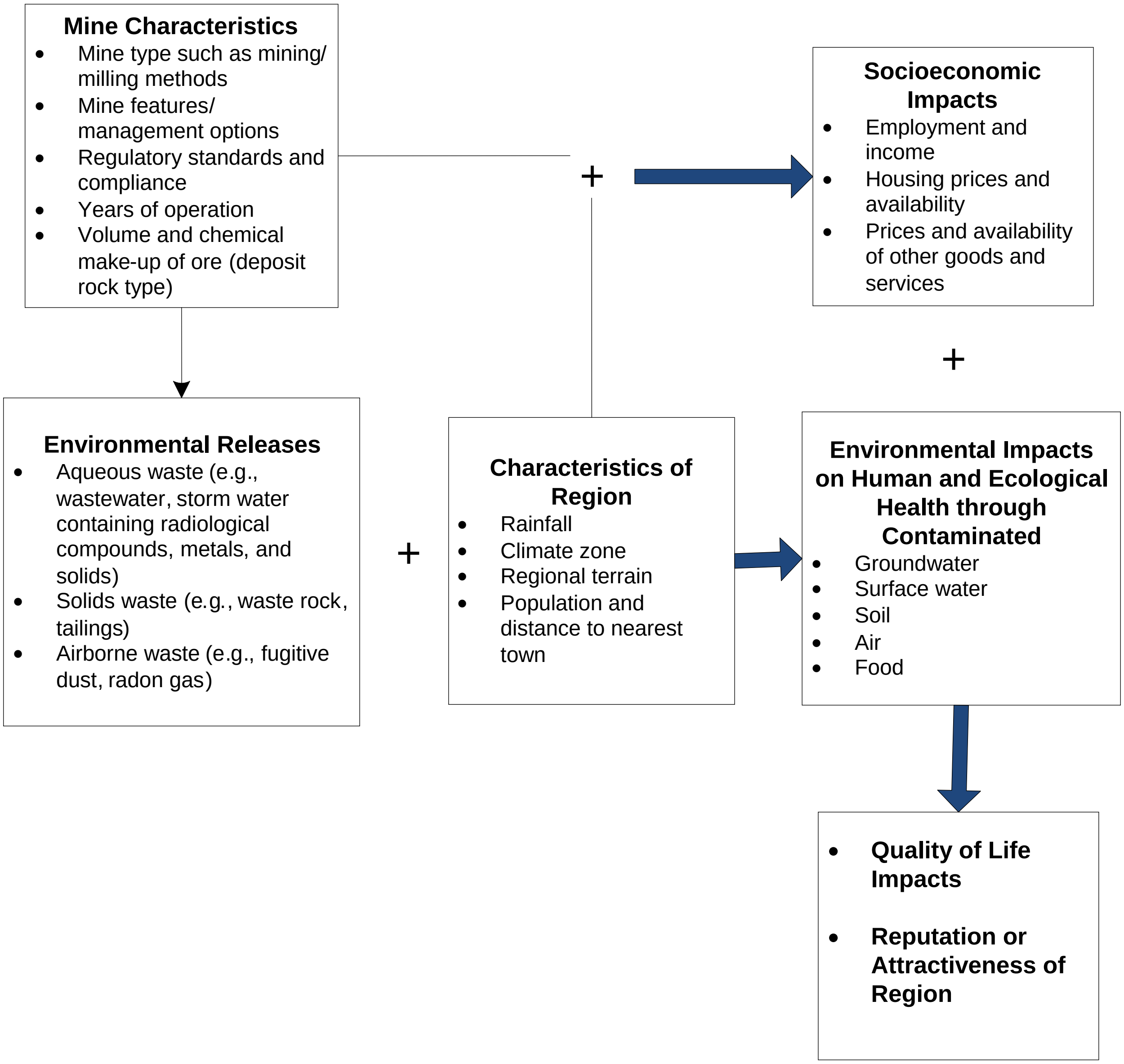
7.1.2.1 Overall Analytical Framework

Our analysis is structured on a model of the interactions between households, firms, and the environment. Where the objective is to make the region the best place to live that it can be, the outcome depends not only on production, consumption, employment, and income, but also on other nonmarket conditions such as environmental quality and the availability of high-quality public services, recreation, etc. In this sense the assessment of environmental impacts of the proposed mine and mill is a part of the overall assessment of socioeconomic impacts. Broadly speaking, conditions in the region's economy can be represented by the characteristics of the set of households and firms in that region. The other major components characterizing an economy consist of environmental amenities and other public amenities such as education, health care, safety, and transportation. In the event that a mine or mill is established at Coles Hill, these are the different parts of the regional economy that may be impacted. Changes in the condition of the region result from numerous interactions and feedback mechanisms among these different entities. This is illustrated in Figure 7-2. Within each box are a set of variables that could be affected by the establishment of the mine and mill. Characteristics of the mine include not only the mining, milling, and tailings management methods, but also production rate, hiring decisions, regulations that apply and extent of compliance with the regulations. These all combine to determine likely pollutant releases to the environment, which combined with baseline environmental conditions in the region surrounding the mine, determine likely environmental impacts. Narrowly defined socioeconomic impacts (employment, income, output levels within the region) are determined by operations at the mine and mill and socioeconomic characteristics of the region, which include not only characteristics of households and firms, but also tax rates, provision of public services, and other market and nonmarket characteristics. Finally, the overall impact of the proposed Coles Hill uranium mine and mill on the region's quality of life and reputation depend on both the socioeconomic impacts and the environmental impacts of the project.

7.1.2.2 Understanding Interests and Concerns of the Region's Residents

Borrowing a framework from the field of decision analysis, our study draws on the interests of the community to help define the fundamental structure of the analysis, ensuring that the questions pursued and impacts assessed will address the questions and reflect the values of the affected communities. A decision analysis approach has been used to guide information collection, facilitate the involvement of multiple stakeholders, and understand the characteristics of the linkages identified in Figure 7-2, below.

Figure 7-2. Analytical Framework for Assessing Socioeconomic Impacts



Unlike a decision-making approach that begins by identifying alternatives (e.g., to develop the mine vs. to take steps to ban the development of the mine), the decision analysis approach steps back to first identify the values underlying the decision and translate those values into objectives that the ultimate decision should support. Alternative decisions can then be evaluated with respect to how well they will meet these stakeholder-defined objectives. By then considering alternatives with respect to their effects on the objectives at hand, tradeoffs between the alternatives can be more clearly understood. Often, more alternatives are identified than were originally under consideration, because the focus on objectives allows for creative thinking.

In pursuit of this values-based approach, we sought the opinions and viewpoints of multiple stakeholders as we structured the analysis. The concerns and interests of those to be affected by this decision have been gathered and organized into a hierarchy of objectives articulated by the community. A hierarchy of regional objectives was assembled based on an amalgamation of opinions from across a wide range of stakeholders, including community leaders, business owners, and a broad spectrum of citizens in multiple counties and communities. In addition to serving as a facilitative tool for incorporating the views and communication desires of multiple stakeholders, this hierarchy of community objectives (the decision analytic framework) highlights the interconnectivity of many of the decisions facing the community, and can be used to explore and possibly uncover alternative steps the affected communities could take to achieve their objectives.

7.1.3 Qualitative Research on Community Characteristics and Concerns

To better understand potential social and economic impacts from introducing uranium mining and milling in the Southside region of Virginia, RTI conducted qualitative research into people's shared or collective notions of the region and its communities, and research into how residents of the region potentially see aspects of the community as changing or being affected as a result of the introduction of uranium mining in their community. RTI used three primary data collection activities in conducting the qualitative research: (1) Community Advisory Panel (CAP), (2) Key Stakeholder Interviews (KSIs), and (3) Focus Groups:

- *Community Advisory Panel*: The CAP engaged five community leaders[1] from the study area to review the design of the project's research activities and provide guidance on working in the communities around the proposed mine. The CAP members provided critical guidance and information about the region's strengths, challenges, and concerns.

- *Key Stakeholder Interviews*: Individuals participating in the KSIs were chosen because their knowledge, previous experience, or position in a community was thought to offer a unique or specialized perspective on the issue of the mine in the community and included community leaders and representatives in areas of business, community development, community advocacy, economic development, education, environment, health, religion, and government. In addition to interviews, the KSI participants were asked to complete a Structured Ethnographic Questionnaire that asked participants to rate the impact of the mine and mill on specific qualities or features in the areas of economic, environmental, and community issues

- *Focus Groups*: Focus groups were use to develop a more nuanced understanding of the values and concerns of individuals in different communities within the region. The focus groups were conducted with convenience samples of citizens from five communities in the Southside region. Participants in the focus groups were recruited through a local recruitment firm that phoned households in the targeted areas. An RTI interviewer and notetaker facilitated the discussions. Focus group participants were also asked to complete the same Structured Ethnographic Questionnaire as provided in the KSIs.

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[1] CAP members included Larry Campbell, Danville City Council; Jeff Liverman, Danville Science Center; Laurie Moran, Danville-Pittsylvania Chamber of Commerce; Dan Sleeper, Pittsylvania County Administrator; and Martha Walker, Community Viability Specialist with the Cooperative Extension Service. Mr. Sleeper was asked to step down from the CAP by the Board of Supervisors, so for the last several months of the project, there were four CAP members.

The KSI and focus group information was analyzed using qualitative data reduction techniques, where detailed interview and focus group notes were reduced to main themes. The analysis was aided by software for qualitative analysis (Nvivo 9). The structured ethnographic survey responses were analyzed using descriptive statistics.

7.2 Baseline Conditions in the Region Surrounding Coles Hill

To characterize baseline conditions in the study region, we combined data from publicly available sources (U.S. Census Bureau, Bureau of Labor Statistics, and others) with qualitative information gathered from stakeholders within the region. This characterization sets the context against which to compare the possible impacts that we estimate could result from the proposed mine and mill.

The approximately 7,850-square mile study region lies partly in Virginia and partly in North Carolina, including all or part of 28 counties and six independent cities. The proposed mine and mill site is located between the towns of Chatham and Gretna, in Pittsylvania County, Virginia. This is a rural area, within a relatively rural county. The nearest cities are Danville, approximately 25 miles to the south, and Lynchburg, approximately 45 miles to the north. The nearest towns, Chatham and Gretna, each have fewer than 1,500 residents. Population for the region as a whole is projected to grow by approximately 5.3% between 2010 and 2030, although some counties within the region are projected to grow more or less slowly, and a few jurisdictions (Charlotte County and Henry County, and the cities of Bedford, Roanoke, and Salem) are projected to experience falling population. The population of Pittsylvania County is projected to grow by less than 1% over the 20-year period. Based on information from the National Land Cover Dataset (NLCD), the majority of the land in the study region is used for agriculture or is forested. Specifically, the predominant land uses in the study region are deciduous forest, grassland, and pasture/hay. However, several cities and many small towns in the study region are home to a population long tied to the land and associated commerce in agricultural-based products. The region has a long tradition of agriculture, and includes counties that are leading producers of tobacco, pigs, beef cattle, and dairy products.

Interviews and focus groups conducted in communities within the study region helped us better understand the region and what people living there value about it. Insights from this qualitative research included the following:

- People valued a strong sense of community they felt in their towns and cities, and a less stressful rural lifestyle that still permeates the region. The communities were credited with having good schools and being safe places for families to raise children.

- Many participants also valued the natural resources of the region for its aesthetics and recreation opportunities, such as its parks and lakes.

- Although many participants in the research recognized that the region’s economy has been struggling with the loss of several major industries, they felt the region has the right ingredients in terms of an available workforce, quality of living, necessary infrastructure, and proximity to major cities to attract new business and develop a vibrant economy. Some looked to tourism as a potential growth area for communities and jobs.

- Some challenges for the region, particularly for the region’s economic prospects, mentioned by participants included loss of younger people because of a lack of jobs, attitudes in the community that resist change, a traditionally lower value on higher education, and an undertrained workforce.

- For the future, people are hoping the area will attract more businesses, ideally in clean industries, with more high-paying jobs. In addition, they would like to see the region gain some of the social and cultural resources that will help attract or retain the younger population.

Data from the Census Bureau’s American Community Survey for 2005–2009 confirm that the region is overall somewhat poorer and has somewhat lower educational attainment relative to both the Commonwealth of Virginia and the United States. During the 2005–2009 period, per capita income in the region was $6,000 lower on average than for the nation, and $10,000 lower than for Virginia. Sectors in which the region’s employment increased faster than national employment included health care, retail trade, and management. Manufacturing and construction employment, however, did not fare well within the region. Manufacturing has historically been more important to the region’s economy than it is to the national economy; over the period 2001 to 2009, manufacturing employment fell faster within the region than it did nationally. Overall, manufacturing employment fell by 43% within the region over that period, and some counties (including Caswell and Person Counties in North Carolina, and Charlotte, Henry, and Pittsylvania Counties in Virginia) experienced even steeper declines. These data emphasize the need to grow or attract new businesses in the region; at the same time, the comparatively low educational attainment of the workforce may hamper efforts to recruit high-paying jobs.

The region has 24 employers with more than 1,000 employees, including nine school systems, four hospitals, and two nuclear fuel manufacturing facilities in the Lynchburg area. However, job growth in the region has been fueled largely by firms with fewer than 10 employees. Overall, our examination of current conditions in the study region shows an area with many natural and cultural assets, and one seen by its residents as having much value and potential. However, the decline of traditional textile and furniture manufacturing and tobacco farming poses economic challenges for the region, which badly needs additional employment opportunities.

7.3 Insights from Case Studies

Potential impacts of developing and operating a uranium mine and mill include a combination of environmental and socioeconomic impacts and both of these affect residents’ quality of life. These impacts result from the complex interplay of various factors. Case studies can provide valuable insights into the experiences of other communities with uranium and other hard rock mines. They can also be useful in providing context for assumptions used by RTI in economic and environmental modeling.

It should be noted that lack of data on baseline characteristics (before the mine and mills went into operation) and detailed information on other regional changes that might have occurred at the same time as the opening of mines and mills prevent us from separating out effects of the mines and mills from other influences in these locations. Thus, no attempt is made to attribute the socioeconomic characteristics of the surrounding region directly to the mine and mill. More detailed information and rigorous statistical analysis would be necessary for this.

7.3.1 Insights into Environmental Impacts and their Drivers

Key factors contributing to environmental impacts include characteristics of the mine such as mining and milling methods, management options, volume and chemical makeup of ore, regulatory standards determining pollutant releases, and geographical characteristics of the region such as rainfall, climate zone and regional terrain. Distance to population centers and population density consequently determine human and ecological exposures to constituents of concern (contaminants are chemically reactive and can potentially cause cell damage).

Examining publicly available data on these key factors and the documented environmental impacts of other mines yields several broad insights:

- Common environmental impacts include presence of particulate matter and radon gas concentrations in the air; groundwater and surface water contaminated with radionuclides and heavy metals and associated radiation; subsidence issues; and contaminated soils and sediments.

- There is no mine and mill that mirrors the characteristics of the proposed VUI mine and mill and its surrounding area. Thus, it is not possible to make direct predictions of impacts of the proposed Coles Hill mine and mill based on mines and mills elsewhere. For example, some mines and mills are similar in geographical characteristics such as precipitation or terrain but may differ in the mine type. Others may be close to dense population centers but may differ in the nature of the mineral and mining method. There is also no other operating uranium mine or mill that is close to a city with a population that compares with the area surrounding Coles Hill. Most mines and mills are located in sparsely populated areas. Thus, the selection of mines and mills RTI gathered information about are aimed at providing a wide range of experiences to draw from rather than provide a prediction of what is to be expected for the proposed mine and mill.

- Closed mines and mills provide some insights into postclosure releases and management procedures for cleanup. However, it should be noted that some of them may be both operational and older and reflective of different technology and regulation stringencies.

- Superfund sites provide useful lessons in terms of reclamation activities and postclosure releases and management procedures for cleanup. However, they also have high levels of contamination associated with them and are not reflective of average mines and mills.

- Other “heavy” metals provide interesting insights on similar contamination issues, such as acid rock drainage. One of these (although closed) is also the only mine that is surrounded by a more densely populated area that is more similar to Coles Hill as compared to the other mines and mills included in the case studies.

7.3.2 Insights into Socioeconomic Impacts, Quality of Life, and their Drivers

Insights into socioeconomic impacts and quality of life changes experienced by other communities were also explored. Some of the more important factors for gaining potential comparable insights for Coles Hill are operational mines' and mills' proximity to an existing population center and location that has an existing industry base other than mining and milling. The mines and mills most relevant for comparison in this section are the Arizona 1 Mine (United States), the White Mesa Mill (United States), Rabbit Lake Mine (Canada), and the Ranger Mine (Australia). These mines and mills were selected because they are currently in operation (and thus reflect newer mining technologies), use underground and surface mining methods, and are subject to regulations comparable in stringency to those that would be developed for the proposed mine and mill. In addition, Ranger Mine and Mill are located in an area affected by monsoons; their experience provides insights into possible impacts of hurricanes or other heavy rainfall situations at the Coles Hill location. It is important to note that analysts did not identify an active uranium mine that is similar in all aspects to the proposed mine and mill.

Much of the information in this section is gleaned from publically available research and interviews from these nearby communities. Social and economic impacts are mixed in these cases on the whole and many of the impacts experienced cannot be directly attributed to the presence of the mining and milling. There are eight themes pertaining to social and economic impacts which may provide useful insights for the communities within the study area to understand. They are (1) experiences related to job creation, (2) environmental and community health, (3) revenues to local governments, (4) industry spillovers and local business growth, (5) community reaction, (6) lessons learned, (7) socioeconomic trends and (8) community development and quality of life. Each theme is discussed briefly below.

Job Creation

- Employment impacts from these mines range from 60 to over 500 depending on the size of the mine and mill and fluctuations resulting from changes in the value of uranium and related production rates. There is typically a split between locals hired and workers coming in from outside the area to work at the mine and mill. Most cited positive employment impacts but some claimed that these gains came at a cost to the broader community.

Environmental and Community Health

- Of the operating mines and mills selected for deeper social and economic examination, only one has reported adverse health effects: Ranger Mine in Australia, where workers were made ill by drinking water accidentally contaminated with uranium in 2004. In another incident at Ranger, heavy equipment was allowed to leave the site while still contaminated with uranium, resulting in contamination which then had to be cleaned up. In the other locations there was no documentation of environmental or health-related incidents, although some regulatory violations (reporting discrepancies, etc.) had occurred. Interviewees from these communities confirmed that environmental and human health impacts had not occurred.

Revenues to Local Governments

- From the U.S. mines local governments reported positive impacts from mining and milling in the form of property taxes and income taxes. At White Mesa, the county experiences most of the benefits from property taxes of the mill itself. The towns tend to see benefits through increases in payroll and sales taxes. In nearby towns it is the employees, not the mine or mill, that generate the most positive impact on local finances.

Industry Spillovers and Local Business Growth

- Most communities reported experiencing additional business and industry impacts in two ways: through an increase to their service industry and through additional mines located nearby. Interviewees commented that the mines and mills did not attract other associated industries or businesses to the area.

Community Reaction

- Communities we examined had a mixed response in terms of embracing or rejecting uranium mining operations. In some communities it seems to have created a culture and tradition around mining that brings them together, while in others it has reportedly left parts of the community feeling disenfranchised, or disrupted traditional lifestyles.

Lessons Learned

- Interviewees were asked about insights they would offer to other communities considering uranium mining and milling. Two interviewees stated the importance of the owners and managers of the mine being local to the community. Another interviewee said that it was very helpful in his community when residents and stakeholders take the emotion out of the issue and focus on the facts and risks instead. A strong advocate and supporter for mining and milling in another community recommended that those in the Coles Hill region never discount the environment. The participant said the community should set up the mechanisms and monitor air and water quality itself so that the community can satisfy itself with the facts about any changes to the local environment.

Socioeconomic Data Trends

- Analysts at RTI also reviewed trend data for socioeconomic conditions in some of the mining and milling communities to track what these areas have experienced in terms of data points such as housing costs, population change, and employments rates. The data reported in this section cannot be attributed in any way as a result of mining and milling in these communities. Instead they describe socioeconomic trends in these communities over a time period in which mining and milling has occurred. Each region had a different experience. On the whole, housing prices jumped significantly and average weekly wages increased, although it was not possible to distinguish the effect of the mine and mill from broader trends. Data such as number of business establishments and overall employment tended to stay stagnant.

Community Development and Quality of Life

- Community and quality of life factors were often not discussed in reports. Additionally, it is not possible to attribute these reported impacts to mining or milling without a detailed statistical analysis, which was beyond our scope. Thus, these insights should be interpreted as stakeholder opinion on impacts from mining and milling. First, in several of the mine and mill locations there are indigenous populations that are most affected by the mining and milling. It was reported that even if these groups benefited with job opportunities, they often came at costs such as reduced quality of life and negative impacts on traditional hunting and fishing practices. According to interviewees in Saskatchewan, the mining lifestyles in the region was said to be disruptive to the community’s way of life.

- Another negative perceived impact is that irregular work patterns (either because of uranium market fluctuations or because of 2 week on-2 week off work schedules) have negative social consequences, including increased heavy or binge drinking. Although there is no documented causal connection to the mill, Blanding Utah also noted an increase in nonviolent crime over the past 5 years.

- Some community members in Utah and Arizona, however, report positive experiences to their communities and civic life as a result of mining and milling. Increased participation in civic activities by the influx of workers from outside the community and greater job opportunities to their region were factors to this positive experience. These towns also have long histories of mining so a local culture supportive of the industry is present. Fluctuation in demand for housing and housing prices, as a result of fluctuating production rates at the mine or mill, was the main issue described as somewhat difficult for local officials to manage.

7.4 Characterization of the Mine and Mill and Possible Environmental Releases

Potential environmental releases from the proposed Coles Hill uranium mine are related to the chemical composition of the host ore and surrounding earth, the mining and million methods used, waste management practices employed, and regulatory standards and limitations.

The Coles Hill Uranium ore deposit was discovered in 1978 and has been extensively studied. There is an estimated 60,000 tons of total uranium (as U_3O_8), of which 32,000 tons are minable from two deposits. The uranium concentration and economic factors dictate the amount of minable ore. The estimated 32,000 minable tons are based on a cutoff grade of 0.06%. The two deposits are each about 1,150 feet long and 800 feet wide and have a depth of 1,500 feet below the surface. The mine is expected to be in operation for 35 years and produce 1 million tons of ore per year.

The primary uranium-containing ore mineral at the Coles Hill site are coffinite ($USiO_4$) and uraninite (UO_2, UO_3). Additional metallic species are also present in the host ore, although not at an economically recoverable concentration. Some of these elements can potentially have a negative environmental impact. Therefore, proper management and treatment of waste associated with these constituents is critical to ensure safe mining operations. Listed below are selected metallic constituents of interest that have been identified within the ore of the Coles Hill site.

Uranium (U)
Zinc (Zn)
Lead (Pb)
Strontium (Sr)
Molybdenum (Mo)
Yttrium (Y)
Arsenic (As)
Silver (Ag)
Thorium (Th)
Chromium (Cr)
Copper (Cu)
Tin (Sn)
Barium (Ba)
Zirconium (Zr)
Manganese (Mn)
Nickel (Ni)
Cobalt (Co)
Vanadium (V)
Beryllium (Be)
Cadmium (Cd)

The proposed Coles Hill project would consist of both mining and milling operations. The end product known as yellowcake (uranium oxide) would be transported off-site to a processing facility.[2] There are multiple mining and milling methods available to the operator and they are selected based in part on the following criteria to make the operation viable: (1) concentration of uranium in the ore; (2) geology; (3) location; (4) cost of mining; (5) cost of processing; (6) waste management practices; (7) social/community acceptance; and (8) uranium market price. Uranium mining methods typically include underground mining, surface mining, in situ leaching (ISL), or a combination of each approach. Milling operations include the crushing and grinding of the ore and leaching the uranium by either an acid or alkaline solutions. Based on a preliminary analysis, VUI is proposing an underground mine and an alkaline leaching process. This approach produces much less overburden material that requires management compared to surface mining. VUI has not ruled out surface mining, or a combination of surface and underground mining; thus, we consider both methods in estimating environmental releases. The geology at the site is not favorable for ISL, and VUI is not considering ISL.

Waste emissions from uranium mining and milling operations can be classified into three primary classes: (1) aqueous waste (e.g., wastewater, storm water); (2) solids waste (e.g., waste rock, tailings); and (3) airborne waste (e.g., fugitive dust, radon gas). In general, solid waste generated at the proposed site will be treated and disposed on site. The largest solid waste stream from the mining operation is typically overburden. An estimated 30 million tons of overburden can be generated per year by surface mining while 1.5 to 16 million tons per year can be generated by underground mining. Although controlled, potential exists to emit air contaminants in the form of fugitive dust and radon gas and water containing radiological compounds, metals, and solids. An estimated 2,833 tons per day of waste tailings will be generated from the milling operation. As required by the NRC, the tailings will be mixed with cement and stored in at least six impoundments. The resulting paste tailings process results in the stabilization and solidification of the tailings and will result in dramatically reducing the potential of contaminants transported from the site.

The facility will generate, treat, and discharge wastewater to the environment. The sources of water from the site include (1) mine water, (2) process water, (3) tailings water, and (4) storm water runoff. Based on the most recent information, an estimated 182 to 300 gallons per minute will be discharged from the wastewater treatment facility and 232 to 2,173 gallons per minute will be discharged from the storm water and mine water treatment system. Using the lower and upper discharge flow rates above, and assuming that the facility complies with effluent discharge limits based on EPA’s Effluent Limitations for Mine Drainage of New Uranium Mines,[3] we estimated a range of constituent discharge rates to surface water, shown in the table below.

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[2] VUI estimates that at full production during years 1 through 21, it would mine 3,000 tons of ore per day (1,050,000 tons per year); data in the Lyntek/BRS Scoping Study (Lyntek/BRS, 2010a) indicates that at full production, it would produce approximately 1,760,000 pounds of yellowcake per year.

[3] Actual pollutant discharge limitations are facility-specific, based on the National Pollutant Discharge Elimination System permit (NPDES) issued the facility. EPA regulation may be found at 44Code of Federal Regulations Subpart C.

Constituent	Low-Impact Scenario	High-Impact Scenario
Chemical Oxygen Demand (COD)	90 kg/day	452 kg/day
Zinc	0.9 kg/day	4.5 kg/day
Radium 226 (dissolved)	31 pCi/s	57 pCi/s
Radium 226 (total)	105 pCi/s	189 pCi/s
Uranium	1.8 kg/day	9 kg/day
Total Suspended Solids (TSS)	18 kg/day	90 kg/day

There are a variety of control technologies to remove uranium or radium from wastewater. The technologies range in complexity from simple precipitation and sedimentation to advanced membrane processes and range in effectiveness from 50% to 99% removal of pollutants.

Groundwater at the site will be regulated by EPA or the agreement state as defined in Code of Federal Regulations 40 Part 92. Contaminant concentrations that exceed the limits established in the regulation trigger remediation (i.e., cleanup).

The primary air emissions from the proposed mine and associated mill are dust (PM_{30}) and radon gas. Estimates were made based on the best available information about the proposed site and established EPA methods. Estimated dust emissions from the mine and mill conducting open-pit mining range between 379.8 and 2,138 kg/yr, while an underground operation would range between 302.1 and 1,544 kg/yr. Estimated radon emissions rates based on the open-pit mining scenario for the overburden storage area ranged between 5.46×10^6 and 1.64×10^8 pCi/s and 1.59×10^6 and 1.59×10^7 pCi/s from the tailings management area.

Dust control measures include management strategies that limit dust emissions, wetting agents to prevent dust formation, and control technologies that remove dust from the air. The effectiveness of these measures range from low (10% to 30% dust removal efficiency), moderate (30% to 50%) and high (50% to 75%).

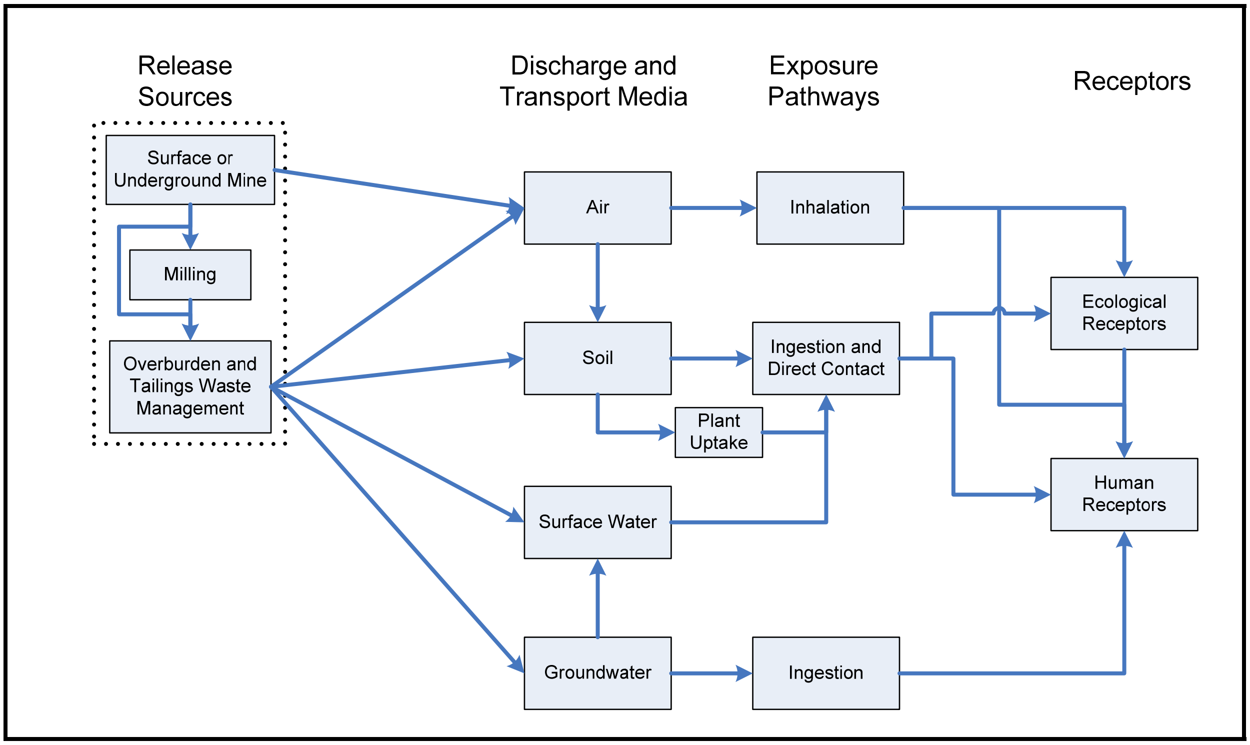
Uranium mines and mills are regulated by both federal and state agencies. EPA, NRC, and DOE each have specific mining and milling activities they are responsible for regulating. Due to a moratorium on uranium mining, the state of Virginia does not have any regulations associated with these activities. The Atomic Energy Act (AEA), Uranium Mill Tailings Radiation Control Act (UMTRCA), Clean Air Act (CAA), Clean Water Act (CWA), and Safe Drinking Water Act (SDWA) are the statutes in place to regulate emissions, wastes, and water from uranium mining and milling.

Postmining activities include dismantling of the infrastructure associated with the mine and mill and long-term monitoring to ensure that environmental standards are not compromised.

7.5 Human and Ecological Health

Using information about the possible environmental releases from the proposed mine and mill, together with a characterization of the region’s environment, we evaluated potential implications of the proposed Coles Hill uranium mine and mill for human and ecological health. The general environmental setting was discussed along with its importance in controlling contaminant mobility from the mine and mill and possible resulting environmental impacts. Chemicals of potential concern were evaluated such as radiological elements and heavy metals that may be released as a result of mine/mill activities. In addition, this section considered the potential transport of these chemicals away from the facility in the various environmental media, including air, soil, surface water, and groundwater. Lastly, possible impacts to human health and ecosystems that might result from such contaminant releases and transport were discussed. Figure 7-3, below, presents a conceptual illustration of the impacts analyzed.

Figure 7-3. Generalized Exposure Diagram Illustrating Possible Routes of Transport and Exposure



Several of the key issues evaluated in this section are summarized below.

Surface Water

- The proposed mine and mill are in a climatic region with relatively greater rainfall than many uranium facilities, particularly in the southwestern United States. This characteristic raises concerns about the potential for flooding and accidental releases and possible challenges in containing wastes and other contaminants on the site. A maximum daily precipitation of 7.9 inches is predicted to occur once every 100 years. The flood plain associated with this predicted 100 year event has been delineated as shown in Figure 5-12 of the project report. Any mine and mill facilities handling potential contaminants would clearly need to be located at elevations well above the area of potential flooding. Furthermore, stormwater management facilities would need to be designed to minimize runoff and erosion across the facility, particularly in areas where ore, ore byproducts, and wastes are handled.

- The ore body is located within watersheds for Mill Creek and Whitethorn Creek, streams located less than 1 mile to the south and north of the ore body, respectively. These waterbodies would be most subject to potential releases from the facility, including discharges from treatment and surface water management facilities and any uncontrolled surface runoff from the property.

Groundwater

- Mine dewatering would be necessary to lower groundwater levels from current depths of approximately 33 ft below the surface to the depth of the ore body (approximately 980 ft). Recovered groundwater would be used to support the industrial processes. Any excess groundwater recovered beyond the facility demand would need to be managed (e.g., stored and treated if contaminant levels exceed regulatory thresholds). The groundwater system is complex and includes bedrock fractures with variable and unknown density and interconnectivity. Groundwater flow in fractured bedrock systems can be difficult to predict, so estimates of potential groundwater pumping necessary to dewater the mine are highly uncertain. Preliminary estimates developed by RTI and reflecting this uncertainty suggest that the required groundwater pumping could range from 150 to 1,500 gallons per minute. These rates also could vary significantly over time. Additional hydrogeologic testing is needed to refine estimates of groundwater recovery necessary to dewater the mine and the potential extent of groundwater lowering.

- Groundwater levels in the area around the mine would lower as a result of the dewatering, which could impact nearby wells, springs, and surface water bodies. Wells and springs in the affected area could decrease in capacity or go dry. Groundwater flow to surface water could decrease, or surface water could flow back into the groundwater system in areas of lowered groundwater elevations, thus decreasing the surface water flows.

Constituents of Concern

- Possible constituents of concern that may be encountered at the mine include (1) uranium and its radioactive daughter products (e.g., thorium, radium, radon gas); (2) heavy metals present in the ore or overburden; (3) acidic or alkaline leachate; (4) particulates, including the potential for chemicals to be bound to the particulates; and (5) other mine process chemicals (e.g., blasting chemicals, leaching chemicals).

- Preliminary information suggests that concentrations of heavy metals at the site may be limited, which would mitigate concerns about some potential contaminants from ore and overburden sources. However, this determination should be verified through more comprehensive sampling and analysis of rock and leachate samples from the site.

Tailings Management

- Water in contact with uranium tailings (the primary waste material from the milling process) contains elevated radioactivity and concentrations of several metals well above regulatory thresholds (e.g., arsenic, cadmium, chromium). This information underscores the requirement for proper management and long-term isolation of tailings materials because of the associated metals concentrations in addition to the elevated radiation levels.

Testing for Acid Mine Drainage

- Based on communications with VUI, the ore appears to have significant buffering capacity, which partially accounts for the current plan to adopt an alkaline rather than an acid leach process. If the buffering capacity is sufficient, it may mitigate acid (or alkaline) mine drainage concerns. Nevertheless, specific leachate testing of the ore and other potentially stockpiled materials (overburden, subore) would be necessary to confirm whether acid (or alkaline) mine drainage would be an issue at this site.

Need for Baseline Characterization

- Many of the chemicals of potential concern are present naturally in the environment. It can be challenging to distinguish between natural and anthropogenic concentrations of these chemicals. Therefore, characterization of baseline conditions prior to facility construction would be important to understand future environmental concentrations and potential impacts due to operations. The report summarizes available baseline concentration data from various sources for air, surface water, groundwater, and soils. Additional, more comprehensive baseline characterization is needed. Several studies by VUI are ongoing with results anticipated in 2012.

Airborne Particulate Emissions and Deposition

- RTI estimates of airborne particulate emissions and subsequent transport generally show limited migration at levels of concern for potential inhalation hazards such as asthma and cardiovascular issues.

- RTI estimated the deposition rates of airborne particulates and the associated transfer of uranium mass. The deposition rates beyond one mile from the facility were less than 0.01 gm $U_3O_8/m^2/yr$. Estimation of associated human health risks was outside the scope of the current analysis. A comprehensive human health risk assessment would be needed to provide quantitative estimates of the potential risks associated with these emissions.

Potential for Sediment Erosion to Contaminate Streams

- RTI estimated the rates of sediment erosion from the proposed mine/mill watersheds under current conditions as ranging from 0.002 to 0.129 tons/acre/year. The local watersheds therefore, have the potential to transfer significant sediment loads to local streams. If the mine/mill facility is built, the overland runoff and erosion conditions will be fundamentally altered. Estimates of erosion rates and associated mass transfer to local waterbodies under as-built conditions would be needed to quantify potential contaminant loads that may be transferred via sediment erosion.

Substantial Dilution of Surface Water Contaminants

- RTI estimated the downstream travel time of surface water from nearby Mill Creek under annual average conditions. The resulting 6-day travel distance was approximately 160 miles from the proposed mine site. RTI also estimated the downstream dilution in surface water due to confluence with other surface waters and the inflow of groundwater. A high-impact scenario showed dilution to 50% of source pollutant concentrations adjacent to the site and dilution to 2% of source concentration entering Banister Lake. A low-impact scenario showed dilution to 1.8 % of source pollutant concentration adjacent to the site and to less than 0.05% of source concentrations entering Banister Lake. Importantly, these simplistic estimates do not consider any possible chemical transformations such as radiological decay and adsorption. Therefore, the predictions overestimate the potential transport of dissolved chemicals that might be discharged by the facility.

Paste Tailings Backfill Has Both Advantages and Risks

- One tailings waste management option under consideration by VUI would involve mine backfill with low-permeability paste tailings. This option may offer advantages in terms of environmental impacts: a smaller volume of tailings would require management in surface impoundments; filling in open mine cavities would help mitigate possible undesirable changes in subsurface flow regimes; having the mine space filled with lower permeability material may help prevent significant groundwater flow through the former mine. However, subsurface paste tailings could be a source for groundwater contamination, particularly if placed below the water table. To prevent groundwater contamination, isolation of subsurface paste tailings from groundwater flow would be necessary.

Proper Tailings Management Is Critical

- The most significant potential impacts to groundwater associated with uranium mining and milling are generally associated with the management of tailings. Historical tailings waste management practices have led to groundwater impacts at many sites; however, most of these facilities were operational prior to the implementation of regulations requiring isolation of tailings wastes. In particular, current requirements include bottom liners and leakage detection systems for synthetic liner systems. In addition, groundwater monitoring requirements around tailings management facilities have increased. Site experience with uranium tailing management under current impoundment design requirements is limited. More extensive experience with double-lined systems with leakage detection is available for municipal landfills. Researchers have found that double liner systems with leak detection are generally effective; however, they do emphasize the importance of proper engineering and construction and operational maintenance.

Exposure Pathways

- Human receptors that could be exposed to constituents of concern (COCs) within the site and surrounding area include on-site or nearby workers, residents, farmers, and recreational users. Ecological receptors that could be exposed to COCs within the site and surrounding area include native plant and tree species, soil biota, terrestrial wildlife, pets, farm animals and aquatic biota. Potential exposure pathways include inhalation, dermal absorption and ingestion.

Key Mitigating Factors

In closing this section, RTI would like to emphasize key factors that can mitigate potential impacts to human and ecological health if the Coles Hill mine and mill were constructed, including the following:

- comprehensive baseline characterization of environmental media and ecosystems before the mine is built;

- comprehensive and ongoing monitoring during operations of emissions and concentrations in media at the mine and in the mine vicinity, including, air, water, soil, agricultural products, flora, and fauna;

- use of effective technologies to reduce emissions;

- sustained focus on pollution prevention and reduction;

- collaboration and transparency between the mining company, regulators and citizens throughout the planning, operation and closure stages; and
- expedient and effective reclamation activities.

Many older uranium and non-uranium hard rock mines lacked effective treatment technologies and deployed irresponsible waste management practices, leading to long-term environmental degradation and risks to human and ecological receptors in surrounding areas. Wastes from many older mines were not isolated and were left without any reclamation. Many of these mines operated before the establishment of key U.S. laws and regulations, including the Clean Water Act (CWA) and the Uranium Mill Tailings Radiation Control Act (UMTRCA), laws which have placed restrictions on emissions, waste management practices, and reclamation.

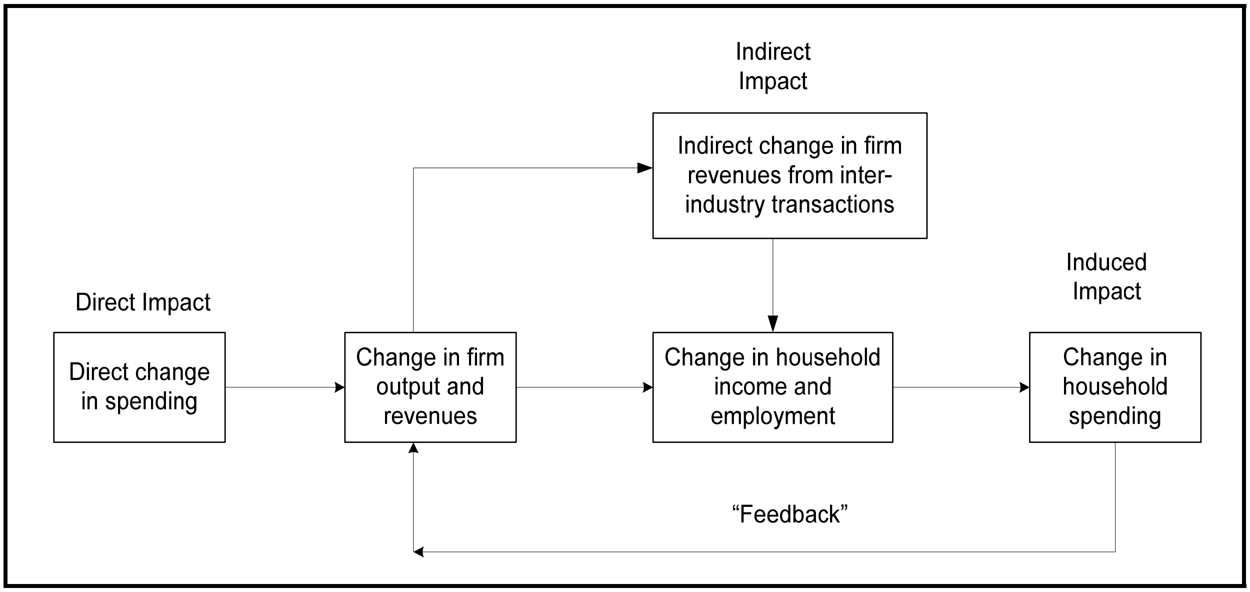
Pollution control technologies are widely available today to minimize mining and milling effluent discharges in water, air, and soil. Such technologies would increase the likelihood that the proposed mining and milling operations in Virginia would comply with current regulations. Furthermore, the mine could develop practices to exceed regulatory standards in an effort to reduce the extent of potential liabilities and to further allay public concerns over the mine. A thorough and ongoing monitoring program coordinated with the public also could mitigate concerns if it demonstrated limited impacts to the surrounding environment (i.e., measuring concentrations in potentially impacted media).

Even if the mine and mill meet or even exceed regulatory standards, detectable concentrations of uranium and other COCs would be released from the facility into the surrounding area. Pollution control technologies and compliance with regulations do not eliminate uranium mining and milling discharges. Predicted risks to human health and the environment would be quite low if the facility meets regulatory requirements, and the associated impacts may not be easily detectable. Nevertheless, finite risks would exist and should be considered in evaluating the possible construction of the Coles Hill mine and mill.

7.6 Potential Economic and Community Impacts

RTI used both quantitative and qualitative approaches to assess potential economic and community impacts that might be associated with the proposed Coles Hill uranium mine and mill. To identify potential economic and community impacts that should be examined, we combined insights derived from economic theory with insights gained through interviews and focus groups with regional residents and insights from case studies of other mining regions. As indicated by data characterizing existing conditions in the region, and interviews and focus groups conducted with residents within the 50-mile radius surrounding the proposed site, there is a need for economic development and additional employment opportunities within the region, which has been hurt by the decline of traditional manufacturing industries such as furniture and textiles. Although residents and others expressed hope that the employment and spending that would be associated with construction, and especially operation of the mine and mill might result in increased prosperity and opportunity, they also expressed anxiety that the stigmas associated with mining and uranium, not to mention potential genuine health and ecological risks, would outweigh any benefits resulting from the proposed project. We explored these possible outcomes using a quantitative input-output simulation model that estimated the total changes in employment, output, and other economic variables under a variety of scenarios. The input-output framework is illustrated in Figure 7-4, below. The total impact under each scenario includes both VUI's direct spending and employment but also spending and employment by other suppliers within the region and by households within the region experiencing higher incomes.

Figure 7-4. Feedback Process That Generates a Program's Total Economic Impact Within the Region



Using the IMPLAN input-output modeling system (MIG, 2011), we simulated the overall impacts of the proposed project on the region's employment and output under three scenarios reflecting more- or less-optimistic assumptions about the project. Construction and capital expenditures were evaluated based on assigning the initial capital and construction spending to a single year (in fact, construction is likely to take 2 to 3 years). Then, we illustrate possible annual impacts from ongoing operations based on estimated costs and employment associated for years 2 through 21 of the proposed mine and mill's operation. Reflecting uncertainty (about VUI's purchasing and hiring decisions, future uranium market conditions, and whether stigma associated with uranium mining and milling would affect demand for other commodities and services produced in the region, for example), we examine three scenarios as described below. It is important to note that, although these simulations result in quantitative impact estimates, they are not meant to be precise predictions of spending on employment that might result under the proposed project. Instead, they should be regarded as illustrations of the range of potential impacts.

For the assessment of the impact of **potential construction and capital equipment** spending during the first 3 years after project initiation, the scenarios reflect assumptions about what share of spending occurs within the study region.

- Under the "**reasonable**" case, construction employment is assumed to be 300, and 70% of the nonlabor inputs are assumed to be purchased from regional suppliers.

- Under the "**best reasonable**" case, construction employment is assumed to be 350, and 98% of nonlabor inputs are assumed to be purchased from regional sources.
- Under the "**worst reasonable**" case, construction employment is assumed to be 250, and 44% of nonlabor inputs are assumed to be purchased from regional sources.

To analyze the impacts of **potential annual operations**, we used varying "regional share" assumptions, but also varied some other aspects of the proposed project:

- Under the **"reasonable"** case, we assume that 76% of nonlabor inputs (84% of all input spending) occurs within the study region. We assume that the future market price of yellow cake would be $60 per pound, and we assume that the quantity of uranium mined is, as assumed in VUI's Scoping Study and Cost Estimate (Lyntek, 2010a), 3,000 tons per day.
- Under the **best reasonable** case, all but the most specialized inputs are assumed to be purchased locally (99% of all input spending), and the market price of uranium is assumed to be $75 per pound.
- Finally, the **worst reasonable** case assumes the price of uranium falls to $45 per pound, resulting in a 25% reduction in output and employment, and assumes a smaller share of share of VUI's inputs are purchased within the region (overall nonlabor input spending falls to 35% of reasonable case, due to the combination of lower production and lower regional share).

The employment and cost estimate data in VUI's studies is based on an assumed production rate of 3,000 tons per day of ore, and associated production of yellow cake. The basic "reasonable," "best reasonable," and "worst reasonable" cases are all based on this level of production.

The market for uranium has historically been quite volatile. Current expectations are that the price of uranium will likely increase, as supply derived from decommissioned weapons is exhausted and societies seek alternatives to carbon-based energy sources. Evidence for this is that new contracts have a price that exceeds the spot price for uranium. Table 7 of the U.S. Energy Information Agency's Uranium Marketing Report (EIA, 2011b) shows that in 2010, spot prices were approximately $45 per pound, while long-term contracts (for delivery at least a year out) averaged approximately $50 per pound. Economic theory would indicate that if the price of uranium were higher than anticipated, more of the ore would be considered economical to mine and mill, and production would increase. However, increasing the production *rate* (tons of ore per day) would be difficult under the plans VUI currently has, so the increased production is assumed to result in extending the life of the mine rather than increasing production; thus, the "best reasonable" case does not adjust employment and output upward for the "typical year" represented in the model.

However, the price of uranium has historically been volatile, and interviews with stakeholders near an existing uranium mine and mill in the western United States mentioned fluctuating employment and economic and community impacts as a result of price fluctuations. Thus, it is possible that some future event could result in a decline in the demand for and the price of uranium. If that happened, it could be that uranium production at the proposed mine and mill might decline, or be suspended entirely, until the price increases sufficiently to make mining and milling profitable. This potential is reflected in our worst reasonable case.

In addition to this worst reasonable case analysis, we perform sensitivity analysis reflecting alternative assumptions. First, we examine the possibility that price and output of uranium remain at $60 per pound and 3,000 tons per day (as in the reasonable case), but that the local share of VUI's spending may be lower than assumed in the "reasonable" case analysis. Then, in response to concerns expressed about impacts on other regional industries, we also examine a situation where there is a reduction in demand for some of the other goods and services currently produced in the region due to perceived risks associated with uranium. Reflecting our expectation that any "stigma" impacts such as this would be relatively local to the mine and mill, we compute the reduction in output of affected sectors based on the sectors' baseline output within Pittsylvania County.

Model results under each scenario are shown in Table 7-1, below. Construction and capital purchases are estimated to add between 559 and 1,008 jobs (over a short 2- or 3-year period) and between $70 and $138 million in output to the region's economy. Operations is estimated to add between 385 and 889 jobs and between $81 million and $220 million in output each year for over 20 years, under the worst reasonable and best reasonable operating scenarios. Sensitivity analysis around the worst reasonable scenario shows that, if the demand for other regional sectors falls due to stigma or reputational effects, the resulting reduction in output and employment in those sectors could counteract the benefits of the proposed project, and employment could actually decline. The quantitative simulation also shows that state and local tax revenues could increase by $11 million annually during the operating period, but our investigation also reveals that both state and local governments would incur the costs of meeting new responsibilities as a result of the proposed project.

Table 7-1. Estimated Regional Economic Impacts: Estimated Impacts of Construction and Operation of Proposed Mine and Mill by Scenario

Impact Summary Impact Type	Employment (jobs)	Output (million $2011)	Labor Income (million $2011)[a]
Baseline values			
Total at baseline	531,241	68,069.4	19,843.0[a]
Estimated one-time Impacts due to Construction and Capital Equipment Purchases			
Reasonable Case Capital	822	111.7	37.6
Best Reasonable Case Capital	1,008	137.7	46.2
Worst Reasonable Case Capital	559	70.5	24.6
Estimated Annual Impacts due to Operations of Proposed Mine and Mill			
Reasonable Case Operating	724	162.4	32.7
Best Reasonable Case Operating	889	219.9	45.3
Worst Reasonable Case Operating	385	81.3	14.6
Sensitivity Analyses Around Worst Reasonable Case			
Lower Regional Share Operating	569	142.6	25.4
Lower Regional Share and Lower Demand for other Sectors, Operating	−152	90.5	8.6

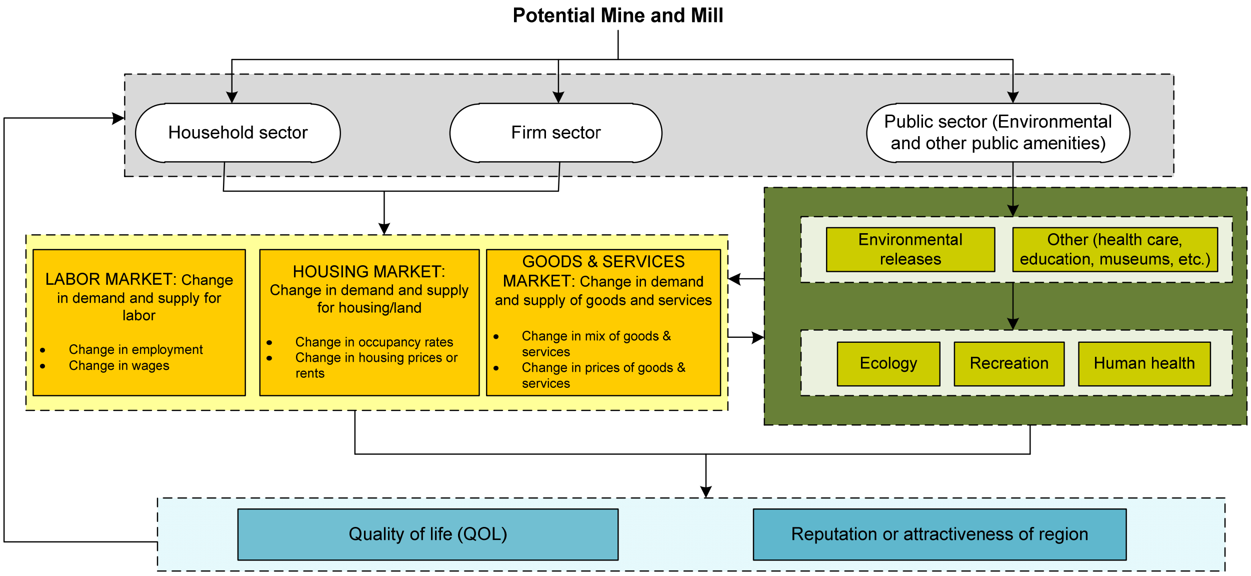
[a] Baseline value is employee compensation, which includes labor income, benefits, and employer-paid taxes. Impact estimates show labor income only.

Possible impacts on the market for housing in the region are mixed. Increased incomes within the region may increase demand for housing. Because of vacancy rates in the region, we do not anticipate that availability of housing will generally be an issue or that prices will be bid up very much because of this increased demand; instead, we expect that residents may use their increased incomes to purchase larger or better quality existing homes, or improve their own homes. On the other hand, properties located close to the proposed mine and mill may experience reduced demand and prices. A survey of economics literature dealing with the impact on property values of proximity to an undesirable site shows that the stigma associated with such sites may reduce demand for them. Properties within a few kilometers of the undesirable location generally do experience reduced property values due to the stigma associated with the site. The reduction in value varies significantly among the studies examined. More contaminated sites or more publicized sites generally reduce housing values more. The impact may fade over time, and if actual contamination occurs, rapid and comprehensive cleanup can restore most of the lost property value.

Combining the information developed to illustrate possible economic impacts with information about potential pollutant releases and environmental impacts, we attempt to assess the overall impact the proposed mine and mill might have on the region's quality of life. Economists use analytical frameworks provided by simulation models to study potential impacts of changes in an economy. Broadly speaking, conditions in an economy can be represented by the characteristics of the set of households and firms in that region. The other major components characterizing an economy consist of environmental amenities and other public amenities such as education, healthcare, safety, and transportation. In the event that a mine or mill is established at Coles Hill, these are the different sectors or entities in the local or regional economy that may be impacted. Changes in the condition of the region result from numerous interactions and feedback mechanisms among these different entities. This is illustrated in Figure 7-5. Entries inside boxes with dotted lines typically interact with each other. Thus, for example, if the mine and mill opens, there may be changes in the demand and supply of labor and interactions among the household and firm sector may result in changes in wages and employment levels. Similarly effects may be seen in the housing and other goods and services market. This is reflected in the yellow dotted box. This may result in changes in the tax base and thus this might alter public spending on amenities such as hospitals and schools. Thus, there may be interactions among the "market" sector (i.e., firms and households) and the "non-market" or public sector. Similarly, if a mine opens, there may be changes in environmental releases and, consequently, changes in the ecology, human health, and recreation in the region. This is depicted in the green dotted box. All of these different effects contribute to both the quality of life and the attractiveness of the region (to both households and firms considering migrating to the area and tourists visiting the area). This is represented by the blue dotted box at the bottom. Thus, in the long run, there may be feedback effects on the households, firms, and the public sector.

Economists create quality of life (QOL) indices for various locations based on the idea that cities with more desirable amenities are more attractive to households; this generally results in lower wages and higher cost of living. To determine the most relevant contributors to QOL in the study region, we considered amenities identified by stakeholders as important, and also amenities shown in the literature to be important. Studies comparing the QOL among cities use data on the cities' environmental, community, economic, and population characteristics, and use statistical methods to attach a value to each of the amenities; these can then be used to create an index of quality of life for each location. Because of the

Figure 7-5. Framework for Assessing Overall Socioeconomic Impacts



uncertainties associated with the possible impacts of the proposed project (both environmental and economic), we did not attempt to quantify QOL impacts. Instead, we characterize the overall impact on QOL in the region qualitatively, based on the result of our analyses. Minimal adverse impacts on environmental quality and ecological assets are anticipated under normal conditions; public safety, school quality, health care, and infrastructure are unlikely to be affected. Overall, demand for housing may increase, but in the immediate vicinity of the mine and mill, property values might decline. There is a possibility that this stigma effect could diminish after over time, and especially after closure, if efficient and thorough closure and cleanup procedures are used. Opportunities for outdoor recreation would generally be unaffected, although some resources may be perceived as less valuable due to stigma. Indoor recreation, employment opportunities, incomes could be improved, at least during the operating period.

7.7 References

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