EXHIBIT J

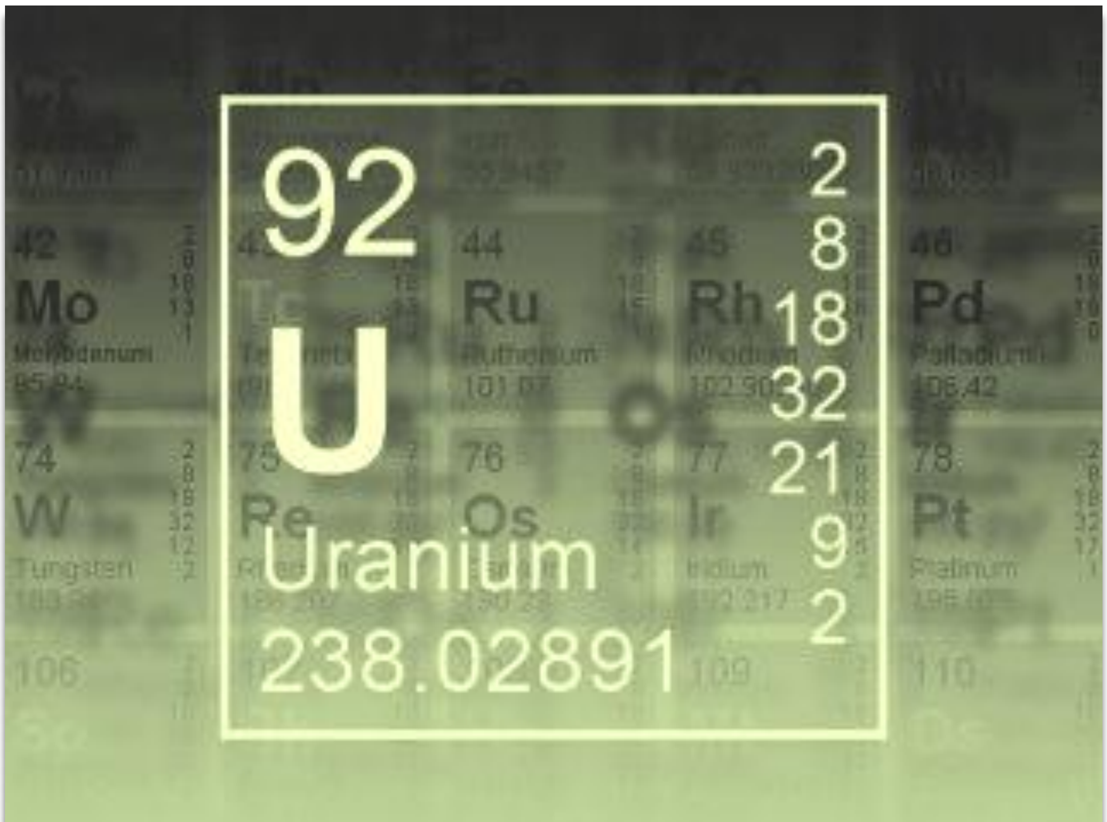
VDH URANIUM STUDY:

INITIAL REPORT

Uranium Study:
Initial Report

Commonwealth of Virginia
Department of Health

Date: October, 2012



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APPENDICES

ABBREVIATIONS

AD	Administrative
AEA	Atomic Energy Act
AEA	American Economic Association
ALARA	As Low As Reasonably Achievable
ALL	Acute Lymphocytic Leukemia
AQD	Air Quality Division
ARARs	Applicable or Relevant and Appropriate Requirements
ATSDR	Agency for Toxic Substances and Disease Registry
BEIR	Biological Effects of Ionizing Radiation
BK	Background
BMP	Best Management Practices
CAA	Clean Air Act
CDPHE	Colorado Department of Public Health and Environment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLL	Chronic Lymphocytic Leukemia
CNSC	Canadian Nuclear Safety Commission
COC	Contaminant of Concern
Corps	Corps of Engineers
COV	Commonwealth of Virginia
CRCPD	Conference of Radiation Control Program Directors
CWA	Clean Water Act
DCR	Department of Conservation and Recreation
DEQ	Department of Environmental Quality
DG	Draft Guide
DMME	Department of Mines, Minerals and Energy
DOD	Department of Defense
DOE	Department of Energy
DRF	Danville Regional Foundation
EFR	Energy Fuels Resources
EIA	Environmental Impact Assessment

EIA	Energy Information Administration
EIA	Environmental Impact Analysis
EPA	Environmental Protection Agency
ERR	Excess Relative Risk
FDA	Food and Drug Administration
FSME	Federal and State Materials and Environmental
IA	Impact Assessment
IAEA	International Atomic Energy Agency
IARC	International Agency for Research on Cancer
ICRP	International Commission on Radiological Protection
IRPA	International Radiation Protection Association
ISL	In Situ Leach
ISO	International Organization for Standardization
ISR	In Situ Recovery
KPI	Key Performance Indicators
MCL	Maximum Contaminant Levels
MD	Management Directives
MeV	Million Electron Volts
MOU	Memorandum of Understanding
MSHA	Mine Safety and Health Administration
NAGPRA	Native American Graves Protection and Repatriation Act
NAP	National Academies Press
NAS	National Academy of Sciences
NCI	National Cancer Institute
NCRP	National Council on Radiation Protection
NEPA	National Environmental Protection Act
NGO	Non-Governmental Organization
NHPA	National Historic Preservation Act
NIOSH	National Institute of Occupational Safety and Health
NMSS	Nuclear Material Safety and Safeguards
NRC	Nuclear Regulatory Commission
NRC DG	Nuclear Regulatory Commission Draft Guide
NUREG	Nuclear Regulatory Commission Regulation

OMB	Office of Management and Budget
OSHA	Occupational Safety and Health Administration
OSL	Optically Stimulated Luminescent
PDCA	Plan, Do, Check, and Act
PHMSA	Pipeline and Hazardous Materials Safety Administration
PMP	Probably Maximum Precipitation
PPE	Personal Protective Equipment
RCRA	Resource Conservation and Recovery Act
RFP	Request for Proposal
RRs	Relative Risks
RTI	Research Triangle Institute
SA	State Agreements
SDWA	Safe Drinking Water Act
SEER	Surveillance, Epidemiology and End Results
SI	International System
SIR	Standardized Incidence Ratios
SL	State Liaison
SMR	Standardized Mortality Ratios
SPCC	Spill, Prevention, Control, and Countermeasures Plan
TI	Temporary Instruction
TLD	Thermo Luminescent Dosimeters
UMTRCA	Uranium Mill Tailings Radiation Control Act
UNSCEAR	United Nations Scientific Committee on the Effects of Atomic Radiation
UPSAT	Uranium Production Site Appraisal Team
USEPA	United States Environmental Protection Agency
USNRC	United States Nuclear Regulatory Commission
UWG	Uranium Working Group
VAC	Virginia Administrative Code
VB	Virginia Beach
VCCER	Virginia Center for Coal and Energy Research
VCEC	Virginia Children's Engineering Council
VDACS	Virginia Department of Agriculture and Consumer Services
VDEQ	Virginia Department of Environmental Quality

VDGIF	Virginia Department of Game and Inland Fisheries
VDH	Virginia Department of Health
VDMME	Virginia Department of Mines, Minerals and Energy
VUI	Virginia Uranium, Inc.
WHO	World Health Organization
WL	Working Level
WLM	Working Level Months
WNA	World Nuclear Association

1.0 INTRODUCTION

Renewed interest in uranium development and the desire to do such development safely has prompted the Commonwealth of Virginia (Virginia) to undertake studies assessing the range of possible regulatory frameworks that might be adopted should the existing moratorium on uranium mining be lifted. On January 19, 2012, the Governor directed members of his cabinet to form a Uranium Working Group (UWG) with staff from the Virginia Department of Mines, Minerals and Energy (VDMME), the Virginia Department of Environmental Quality (VDEQ), and the Virginia Department of Health (VDH). This Uranium Working Group was established to:

"…provide a scientific policy analysis to help the General Assembly assess whether the moratorium on uranium mining in the Commonwealth should be lifted, and if so, how best to do so."

A study by the National Academy of Sciences titled "Uranium Mining in Virginia: Scientific, Technical, Environmental, Human Health and Safety, and Regulatory Aspects of Uranium Mining and Processing in Virginia" (NAS, 2011) as well as other recent studies related to uranium mining and milling in Virginia have identified important issues related to protection of public and occupational health, safety and the environment and potential socioeconomic impacts. Consequently, the UWG has been directed to conduct fact-finding and propose a conceptual regulatory framework that would address these issues as well as others issues identified by the various stakeholders, the UWG and the public.

In order to respond to this directive, the UWG issued two requests for proposal (RFP) to solicit expert advice. Due to the different areas of focus and responsibility of the staff within the UWG, two procurements were developed; one to address issues related to the VDEQ and VDMME areas of responsibility and one to address the areas of responsibility related to VDH. This Initial Report has been developed in response to the VDH procurement. The VDH procurement is briefly described below.

1.1 Procurement Summary

On March 2, 2012, the VDH issued RFP # 1200001-999 (Uranium Study). The purpose of the procurement was to acquire contractor services to provide information and expert analysis of uranium mining and milling issues in Virginia relevant to the statutory jurisdictions of the VDH. A proposal was submitted on April 3, 2012, and contract #1200001-999 was awarded on June 6, 2012.

The Contract identifies four work tasks (A through D). Work Task A involves the development of an initial report based on a review of studies related to uranium mining and milling in

Virginia, a comparison of existing regulatory programs and international emerging standards. This initial report is developed in response to work task A.

Work tasks B-D involve ongoing technical advice and assistance to the VDH. The future tasks will result in a series of interim reports analyzing a range of issues identified in the RFP, as well as other issued identified with the VDH and the UWG. The efforts of tasks B-D will provide additional detail to the issues and recommendations addressed in this initial report.

1.2 Purpose and Objectives

The purpose of this Initial Report is to respond to the Work Task A requirement in Contract # 1200001-999. The objective of this report is to increase the UWG's understanding of a range of state and federal regulatory programs and emerging international standards through a concise, high-level program comparison with specific recommendations applicable to the existing or a potential future regulatory framework in Virginia. In general terms, this initial report sets the stage for the remainder of the project by identifying issues, potential gaps in the regulatory structure and listing aspects or recommendations from existing studies and best practices.

2.0 INITIAL LITERATURE ANALYSIS

A number of studies have been conducted to assess issues associated with potential uranium mining in Virginia. The studies considered a wide range of topics including uranium resources, mining and milling technologies, potential risks to workers and the public, potential releases of radionuclides and of materials to the environment and potential socioeconomic impacts from uranium extraction. This section focuses on findings or comments on the various reports related to health impacts or characteristics of potential concern to the VDH. A brief analysis of each report finding or concern is listed below.

2.1 National Academy of Sciences/National Academies Press (NAS/NAP)

The National Academy of Sciences Committee on Uranium Mining in Virginia report (NAS, 2012) addresses a wide variety of topics including uranium resources and markets, mining and milling processes, potential human health and environmental effects, regulation and long-term stewardship.

Section 5.0 of the report summarizes potential human health effects of uranium mining, processing and reclamation. The key findings and concepts are quoted below with comments regarding the concepts.

NAS Report Finding: **"***Uranium mining and processing carries with it a wide range of potential adverse human health risks. Some of these risks arise out of aspects of uranium mining and processing specific to that enterprise, whereas other risks apply to the mining sector generally, and still others are linked more broadly to large-scale industrial or construction activities.*"

> **Analysis:** It is generally true that health risks from uranium recovery are most often associated with workers in the industry. As with any industrial activity, safety issues are significant and may result in acute, rather than chronic health detriment. This includes, but is not limited to injuries from various activities, as well as potential exposures to uranium and its decay chain products and processing chemicals.
>
> Potential risk to the surrounding population from certain exposures and their associated risks can extend via environmental pathways to the general population. Pathways most often associated with uranium mining include releases of particulates and radon from stored or processed ore, and potential releases from tailing impoundments. As mentioned in Section 3.0 below, there are essentially no recent studies that show a positive correlation between uranium mining or milling and cancer in the surrounding population.

NAS Report Finding: **"***Protracted exposure to radon decay products generally represents the greatest radiation related health risk from uranium-related mining and processing operations.*

Radon's alpha emitting radioactive decay products are strongly and causally linked to lung cancer in humans."

Analysis: Various studies conclude that radon progeny exposure resulted in an increased risk of lung cancer in miners. As described in the epidemiology section below, studies of eleven different cohorts from seven countries found a statistically significant excess relative risk (ERR) for all cohorts. The ERR ranged from 0.2 to 5.1 per 100 working level month (WLM) exposure. The estimated ERR when combining all cohorts was 0.59 per 100 WLM exposure. Both Mine Safety and Health Administration (MSHA, 30 CFR § 57.5038) and the Nuclear Regulatory Commission (NRC, 10 CFR Part 20 Appendix B) limit exposure of workers to radon daughters to 4 (WLM) per calendar year. At that level, the ERR would be 0.0236 or 2.36 per 10,000 per year of exposure.

As mentioned in the NAS report, other carcinogenic materials, most notably tobacco smoking, in combination with radon exposure can have a synergistic effect as studies of miners described in Section 2.2 have demonstrated.

NAS Report Finding: "*In 1987, the National Institute for Occupational Safety and Health (NIOSH) in the Centers for Disease Control and Prevention recognized that current occupational standards for radon exposure in the United States do not provide adequate protection for workers at risk of lung cancer from protracted radon decay exposure, recommending that the occupational exposure limit for radon decay products should be reduced substantially. To date, the recommendation by NIOSH has not been incorporated into an enforceable standard by the U.S. Department of Labor's Mine Safety and Health Administration or Occupational Safety and Health Administration*."

Analysis: As noted in the NAS report, NIOSH recommended lower occupational standards for radon. The NRC's occupational dose standard for radon progeny is consistent with the standards for radiation dose in general as it requires summation of doses from all pathways. However, the MSHA radiation protection standard treats radon separately from direct gamma radiation resulting in the potential for much higher doses to miners than would be allowed under NRC regulations.

NAS Report Finding: "*Radon and its alpha-emitting radioactive decay products are generally the most important, but are not the only radionuclides of health concern associated with uranium mining and processing.*"

Analysis: It is true that uranium recovery workers may be exposed to other radionuclides, including naturally occurring isotopes of uranium, which undergo radioactive decay by alpha, beta, and gamma emission. Decay products of uranium that emit the highest energy photons include Pb-214 (26.8 minute half-life) and Bi-214 (19.9 minute half-life), both of which are short-lived Rn-222 progeny. Exposure of workers to external radiation from uranium decay chain radionuclides is typically measured using thermo luminescent (TLD) dosimeters or optically stimulated luminescent (OSL) dosimeters.

NAS Report Finding: **"***Radiation exposures to the general population resulting from off-site releases of radionuclides (e.g., airborne radon decay products, airborne ^{230}Th or ^{226}Ra particles, ^{226}Ra in water supplies) present some risk. The potential for adverse health effects increases if there are uncontrolled releases as a result of extreme events (e.g., floods, fire, earthquakes) or human error. The potential for adverse health effects related to releases of radionuclides is directly related to the population density near the mine or processing facility.*"

Analysis: It is true that any event that would disperse materials from the point of origin to the population might be considered to increase the risk to the population. Estimating the potential risk from extreme events is highly dependent on the exposure scenario that might occur. If more people are in the vicinity of the release area, more people would be affected, but an individual would not necessarily receive a higher dose.

This statement should not be confused with the concept of collective dose, in which a small dose is calculated for a large population and then summed over the population to create a population dose in terms of person-rem. If more people are exposed the collective dose would increase, but there is no regulatory standard for collective dose except that doses should be kept as low as reasonably achievable (ALARA). It should be noted that the International Commission on Radiological Protection (ICRP) cautions against calculating risks based on very small doses to large populations (ICRP, 2007).

NAS Report Finding: *"Internal exposure to radioactive materials during uranium mining and processing can take place through inhalation, ingestion, or through a cut in the skin. External radiation exposure (e.g., exposure to beta, gamma, and to a lesser extent alpha radiation) can also present a health risk."*

Analysis: It is not true that external exposure to alpha particles constitutes a health risk since alpha radiation cannot penetrate the layer of dead skin cells that covers the body. However, alpha emitters on skin that are ingested, inhaled or absorbed will contribute to the internal dose.

NAS Report Finding: **"***Because thorium–230 and radium-226 are present in mine tailings, these radionuclides and their decay products can—if not controlled adequately—contaminate the local environment under certain conditions, in particular by seeping into water sources and thereby increasing radionuclide concentrations. This, in turn, can lead to a risk of cancer from drinking water (e.g., cancer of the bone) that is higher than the risk of cancer that would have existed had there been no radionuclide release from tailings."*

Analysis: The term "mine tailings" is a misnomer with respect to the uranium recovery industry. Generally speaking ore associated with a mine that is not processed because the mineral content is too low to be profitable is known as protore or waste rock. Mill tailings are the residues from processing uranium ore in a conventional mill. In practice, most of the uranium (96%) is removed by the processing, but the uranium decay chain radionuclides remain in the tailings. Thorium -230 and Ra-226, its initial decay products are major constituents of mill tailings. Thorium-230 is very long-lived (77,000 years) and emits both alpha particles and weak gamma rays. Radium-226 has a long decay chain that includes Rn-222 and emits mostly alpha particles and gamma rays.

It is possible that tailings could be released from the storage facility. New technologies such as paste tailings greatly reduce the amount of moisture associated with tailings disposal and could reduce the likelihood a water-borne releases due to dam failure.

NAS Report Finding: **"***A large proportion of the epidemiologic studies performed in the United States, exploring adverse health effects from potential off-site radionuclide releases from uranium mining and processing facilities, have lacked the ability to evaluate causal relationships (e.g., to test study hypotheses) because of their ecologic study design."*

Analysis: Ecological studies differ from cohort studies in terms of known information about individuals. In the case of ecological studies there is no information available about the individual members of the populations being compared, and often little quantitative information about the exposures to characteristics of the populations. In a cohort study the both exposure and health outcome is presumably known for each individual.

Ecological studies are useful because they are relatively inexpensive and take advantage of data that is already available. If interesting and potential associations are observed, the results of ecological studies can provide the opportunity for later, more carefully designed studies (though more expensive and time-consuming) to build on the initial observations.

In Section 3.0 Summary of Epidemiologic Studies, a number of cohort studies for uranium miners are reviewed.

NAS Report Finding: "*The decay products of uranium (e.g., ^{230}Th, ^{226}Ra) provide a constant source of radiation in uranium tailings for thousands of years, substantially outlasting the current U.S. regulations for oversight of processing facility tailings*."

Analysis: It is true that Th-230 and Ra-226 are long-lived radionuclides. As components of uranium ore, they have been in the environment in an unprocessed state for literally billions of years.

The Uranium Mill Tailings Radiation Control Act (UMTRCA) requires uranium mill tailings to be disposed of in engineered repositories. General stewardship requirements for an active site upon reclamation are described in 10 CFR 40.28. Cover design requirements include a maximum average radon flux < 20 pCi/m^2-s, saturated hydraulic conductivity Ksat < 1x10^{-7} cm/s *or d*rainage flux from cover < 3.0 mm/yr and a longevity of 200 – 1000 years. A long-term surveillance plan for a reclaimed site would include a description of as-built conditions of the repository, definition of stewardship responsibilities, specifics of surface inspection and ground water monitoring requirements, and an outline of contingencies and emergency responses.

NAS Report Finding: "*Radionuclides are not the only uranium mining- and processing-associated occupational exposures with potential adverse human health effects—two other notable inhalation risks are posed by silica dust and diesel exhaust. ….Thus, workers in the uranium mining and processing industry can be coexposed to several separate lung carcinogens, including radon decay products, silica, and diesel. To the extent that cigarette smoking poses further risk in absolute terms, there is potential for increased disease, including combined effects that are more than just additive."*

Analysis: As the report points out, the non-radioactive materials, specifically silica dust and diesel exhaust, are not unique to uranium recovery operations. The International Agency for Research on Cancer (IARC), of the World Health Organization (WHO), recently reclassified diesel exhausts from its group 2A of probable carcinogens to its group 1 category of substances that have definite links to cancer. Increased monitoring for diesel fume concentrations in the work place could help lower exposures.

Tobacco use among uranium recovery workers, which has a possible synergistic effect with radon progeny for lung cancer, should be prohibited while at the work place. It is common practice to prohibit tobacco use as well as eating and drinking to specific selected areas inside the facility's restricted area, such as lunch room. This is most often is accomplished as a license condition for the facility.

NAS Report Finding: "*Although uranium mining-specific injury data for the United States were not available for review, work-related physical trauma risk (including electrical injury) is particularly high in the mining sector overall and this could be anticipated to also apply to uranium mining. In addition, hearing loss has been a major problem in the mining sector generally, and based on limited data from overseas studies, may also be a problem for uranium mining.*"

Analysis: The report is correct that physical trauma risk is higher in mining than in some other industries. As the report points out, these risks are not specific to the uranium sector. MSHA and OSHA regulations that apply to any mining would also apply to uranium mining with added regulation for radiation exposure.

NAS Report Finding: **"***A number of other exposures associated with uranium mining or processing, including waste management, also could carry the potential for adverse human health effects, although in many cases the detailed studies that might better elucidate such risks are not available.*"

Analysis: As with other findings of the report, there may be multiple potential exposures to various chemicals that could occur during uranium extraction that are shared with other mining sectors and non-mining industries. Existing MSHA and OSHA regulations should be evaluated to determine whether they are adequate to protect workers in a setting that includes potential radiation exposure.

NAS Report Finding: **"***Assessing the potential risks of multiple combined exposures from uranium mining and processing activities is not possible in practical terms, even though the example of multiple potential lung carcinogen exposures in uranium mining and processing underscores that this is more than a theoretical concern*".

Analysis: Section 2.2 describes studies that have assessed multiple combined exposures. Such studies are difficult to carry out given the multiple exposures and uncertainty regarding life-style exposures (i.e., indoor radon). However, carefully designed worker monitoring programs can limit the impacts of multiple exposures.

NAS Report Finding: **"***Significant potential environmental risks are associated with extreme natural events and failures in management practices*."

Analysis: We agree that there are potential risks associated with extreme events such as uncommon rainfall events. It is important that any new facility have the capacity to contain or treat potentially contaminated water that would result from an extreme rainfall event. As mentioned above, modern tailings management practices include impoundments that are below grade to prevent the likelihood of a dam failure. Impoundment design could incorporate enough freeboard to plan for an extreme rainfall event. The same is true of the ultimate repository design.

There are a series of NOAA and USGS documents that describe the potential for extreme rainfall events in various portions of the country (USGS, 2003; Schreiner and Riedel, 1980; DOC, 1961). These documents should be taken into account in the design and licensing process for mining or milling facility. Data specific to Virginia's meteorology will be added to the final report.

NAS Report Finding: **"***Models and comprehensive site characterization are important for estimating the environmental effects of a specific uranium mine and processing facility*."

Analysis: State-of-the-art modeling depends on adequate data to support the model. Meteorological data can be collected prior to granting a site license and would continue during site operations. The groundwater regime of the mining or milling site will be important to understand where to place monitoring wells for both pre-operational and operational purposes. NRC Regulatory Guide 4.14 has specific requirements for sampling and monitoring prior to and during operations. Virginia should review the requirements of Regulatory Guide 4.14 to determine whether they should be supplemented or revised. Regulatory Guide 4.14 is a 30-year old document and is in the process of revision. Much progress has been made in monitoring methods since the guide was published.

2.2 Virginia Beach Studies

Council of the City of Virginia Beach Resolution

On November 18, 2008, the Council of the City of Virginia Beach (VB) adopted "A RESOLUTION OPPOSING THE MINING OF URANIUM IN THE COMMONWEALTH OF VIRGINIA IN THE ABSENCE OF AN UNBIASED, CONCLUSIVE STUDY ON THE POTENTIAL EFFECTS THEREOF". This resolution supported the continuation of the uranium mining moratorium until certain studies were conducted and demonstrated that certain assurances could be ensured.

Recommendations from the Resolution

This resolution contains the following recommendations regarding public and worker health and safety and environment issues that could potentially affect the VDH and its programs for the protection of public and worker health and the environment, its present legislative authority, and its present regulations:

"*That unless and until it can be demonstrated a reasonable degree of scientific certainty that there will be no significant release of radioactive sediments downstream under any circumstances, including, but not limited to, a direct hit on the mining facilities by a Probable Maximum Precipitation (PMP) storm event, the City of Virginia Beach is opposed to: (1) uranium mining in Virginia, including the proposed Virginia Uranium operation; (2) the elimination of the existing legislative moratorium on uranium mining, and (3) any attempt to develop a regulatory framework for uranium mining*." (Lines 108-114)

"*That any study commissioned by or used by the Commonwealth of Virginia to determine the feasibility of uranium mining in Virginia must include the following criteria:*

1) *The study must thoroughly evaluate the risks, including those resulting from a worst-case scenario as previously described, to the citizens of Virginia and assess whether uranium mining and milling in Virginia can be undertaken in a manner that will*

completely safeguard the Commonwealth's environment, natural and historic resources, agricultural lands, and the health and well-being of its citizens;

2) *The entire study process must be open to the public and the press;*

3) *The City of Virginia Beach and other potentially impacted jurisdictions must be included as active participants in the study process;*

4) *The study must be conducted, and the conclusions of such study shall be determined, by a group of qualified and impartial experts, such as the National Academy of Sciences, who are completely independent of the uranium mining industry, the nuclear power industry, and any state commission that has assumed or been charged with the responsibility for providing such a study;*

5) *A peer review group that is independent of the VCEC and the VCCER and includes adequate representation from environmental, public health, water supply and water resource agencies, including the Army Corps of Engineers, is established to monitor and critique the study; and*

6) *That the study must be adequately funded and under no deadline for the completion of the study." (Lines 119-150).*

Issues, Impacts, and Concerns Raised in Virginia Beach (VB) Study That Are Potentially Related to VDH

This resolution raises the following issues, impacts, and concerns regarding public and worker health and safety and the environment that would potentially affect the VDH and its programs for the protection of public and worker health and safety and the environment, its present legislative authority, and its present regulations:

VB Issue: *"… historically, tailings pile confinement structures have failed in the United States and elsewhere, resulting in the release of radioactive particles and sediments to downstream surface waters*"

> **Analysis**: Although the failure of tailings pile confinement structures at uranium milling facilities in the United States has been relatively rare this is a legitimate concern that must be addressed adequately in regulations and in the design, construction, and operation of tailings pile confinement structures. It should be noted that, to the best of our knowledge, no uranium tailings pile containment structures designed to current regulatory standards and operational requirements has failed. The design and construction of tailings pile confinement structures and the operation of these must be reviewed by technically qualified experts and approved in the licensing process for a uranium mill before construction of these structures in started.

Many early tailings impoundment dams were built as the impoundments were being filled using tailings themselves as the embankment materials. Embankments were often at or near the angle of repose for the materials. Modern tailings impoundment dams are designed and built with selected construction soils with less steep slopes on the embankments. Tailings are not used for the construction of the embankments themselves. Impoundment structures are required to be constructed prior to the placement of any tailings into the impoundment

VB Issue: *"… it is well-documented and generally agreed within the scientific community that long-term exposure to the level of radiation that could result from a failure of a tailings pile confinement structure, or even a less catastrophic release, are highly deleterious to human health."*

Analysis: The radiation exposure to persons affected by failures of uranium mill tailings confinement systems, including measures needed to implement and sustain hazard mitigation should be considered. Currently federal regulations for the annual dose limits for a uranium mill under normal operating conditions are:

(a) The annual dose equivalent does not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials, radon and its daughters excepted, to the general environment from uranium fuel cycle operations and to radiation from these operations. {40 CFR 190.10a, 10 CFR 20.1301(e), and 10 CFR 40, Appendix A, Criterion 8}

These limits can be exceeded under the following conditions and limitations: § 190.11 Variances for unusual operations. The standards specified in §190.10 may be exceeded if:

(a) The regulatory agency has granted a variance based upon its determination that a temporary and unusual operating condition exists and continued operation is in the public interest, and

(b) Information is promptly made a matter of public record delineating the nature of unusual operating conditions, the degree to which this operation is expected to result in levels in excess of the standards, the basis of the variance, and the schedule for achieving conformance with the standards. {40 CFR 190.11}

Regulations regarding uranium tailings pile containment systems should include the requirements for analysis of the potential for failures and include secondary systems to contain or limit the impacts to off-site environments including water ways. In addition the entire design, construction, and operation of the uranium tailings pile containment system should be evaluated with the ALARA principle, i.e., limiting the radiation dose to as low as reasonably achievable below the regulatory limits.

VB Issue: *"… historically, many uranium mines have not been properly operated or closed, or in many instances have been abandoned, resulting in radioactive contamination of ground and surface waters, and in some cases leaving a legacy of environmental and human tragedy"*

Analysis: While the situations described in this statement are undeniably true, it reinforces the need for a strong, vigilant regulatory program(s) to be in place prior to the beginning of any uranium mining if the moratorium on uranium mining is rescinded. This regulatory program must include appropriate legislative authority to regulate uranium mining, to adopt regulations including financial security requirements for uranium mining operations, and to establish and implement permitting and inspection programs with adequately trained and equipped professional staff. Under existing federal law and regulations the owner/operator of a licensed uranium mill must provide a funding mechanism to ensure that an adequate source of funding will exist to properly close and decommission and perpetually monitor the uranium mill and associated uranium tailing piles in the event the owner/operator is unable or unwilling to properly close the site. Ultimately the site must be transferred to the DOE and maintained under NRC licensure. VDH could potentially be involved as the primary or secondary regulatory agency for such a regulatory program.

VB Issue: *"… all uranium mines in the United States have, to date, been located in states with low rainfall and high evaporation rates, both of which are important factors in managing water and minimizing flooding, whereas Virginia's climate includes frequent tropical storms, hurricanes, and nor'easters, many of which have produced more rainfall in a few hours than the total annual precipitation of the arid states where the nation's uranium mines are located*." (Lines 43-48)

Analysis: While this statement is not totally true (for example, uranium mines in South Texas are subject to frequent tropical storms and hurricanes and tornadoes) it serves to emphasize the importance of consideration of these natural phenomena in any decision regarding rescinding the ban on uranium mining in Virginia. While presently all uranium production in Texas is done using *in situ* mining technology, Texas has historically had four conventional uranium mills and over 70 open-pit uranium mines. One of these conventional mill sites was closed as a Title I site under UMTRCA. The other three conventional uranium mills are currently under state licensure and in the final stages of decommissioning by the private companies (or their successors) that owned/operated the conventional mills. Similarly the open pit mines have either been reclaimed or are in the process of being reclaimed.

The regulatory framework and the successes and failures of these efforts should be reviewed to determine effective measures for control in situations that more closely resemble the hydrological conditions in Virginia. The more humid climate found in Virginia than in the western United States may provide for enhanced containment structures management including the vegetation of these structures to reduce erosion from rainfall events.

If the moratorium on uranium mining were to be rescinded, a regulatory program(s) that takes these natural precipitation events into account in all decisions involving whether or not to permit a uranium mine should be in place prior to the beginning of any uranium mining. VDH could potentially be involved as the primary or secondary regulatory agency for such a regulatory program.

VB Issue: *"…by contrast, Virginia's surface water hydrology has the capacity to cause significant erosion and structural damage to tailings piles, dams, and caps while simultaneously providing long-distance, transport and dispersal downstream of radioactive sediments released as a consequence of such erosion and damage, and many of the uranium mining catastrophes in arid states were caused by the inability to properly manage water, even though water management in such states is much less problematic than in Virginia*." (Lines 50-56)

Analysis: This statement mixes uranium mining and milling, but the need to have adequate water management structures and procedures are essential for both activities. Even in the Western U.S., and certainly in the South Texas uranium area, water management programs are essential because frequent flash floods and less frequent other floods can cause severe erosion and structural damage. This environmental hazard is not unique to Virginia, but is certainly a serious consideration that must be included in a regulatory program if a relaxation of the uranium mining ban is to be considered. These considerations should include location of containment structures, design, construction, maintenance, and operation of the containment structures, routing of runoff diversion structures, and placement of secondary containment structures to prevent releases of tailings to areas offsite during extreme weather events.

VB Issue: *"…these past environmental disasters were also attributable to serious deficiencies in the practices of the uranium mining industry and inadequate federal regulation, such that in the United States, the federal government was forced to intervene to remediate the harm and damage, and after two and one-half decades of remediation and billions of dollars of expenditures, those efforts are still underway*." (Lines 58-62)

Analysis: This statement emphasizes the importance of having adequate regulations and governmental programs in place to enforce them for both uranium mining and milling prior to a relaxation of the current ban on uranium mining.

VB Issue: *"…if a flood of the magnitude of that caused by Hurricane Camille in 1969 were to fragment one or more tailings piles and transport radioactive mill tailings downstream into Kerr Reservoir and Lake Gaston, the Lake Gaston Project might be rendered inoperable for an indefinite period of time* " (Lines 69-72)

> **Analysis:** The impact of such an event should be addressed, evaluating the mechanism for transport of radioactive and other hazardous constituents and taking into account the portion of releases that would be insoluble particulate material and the portion that could be transported as dissolved components of the release. An evaluation should be made of the portion of the releases that could be expected to settle as sediment in stream beds and in the lakes.
>
> For that portion of the release that is liquid or water soluble, the water treatment programs currently used to treat water from Lake Gaston and other public water supplies prior to its being place into a public water supply system should be evaluated by the Office of Drinking Water with regard to their effectiveness in removing or reducing these constituents.
>
> Based upon the analysis of the effectiveness of current water treatment processes and the necessity for implementing alternate water treatment technologies, the potential additional costs for added treatment could be estimated.

The Baker Report: Uranium Mining in Virginia – Can Downstream Drinking Water Sources Be Impacted?

Following the adoption of the Resolution discussed above the City of Virginia Beach contracted for a study with Michael Baker Jr., Engineer, Inc. to provide background on uranium mining and milling and the environmental conditions presence in Virginia. This contract resulted in a report entitled *Uranium Mining in Virginia - Can Downstream Drinking Water Sources be Impacted*, published in March 2010 (Baker, 2010).

This purpose of this study as stated in the report was:

"*This white paper provides a brief background on uranium mining and milling, as well as the hazards these activities can pose to downstream water resources; describes Virginia's climate, including the extent of near-PMP rainfall events in the vicinity of Pittsylvania County; and outlines the purpose of the City's preliminary study*."

This study makes no recommendations nor does it speak to or answer the question in its title.

Analysis of the Baker Report

The Baker report presents a straightforward presentation on uranium: its occurrence in nature and how it is mined; how the ore is processed to recover the uranium; and the wastes (overburden, waste rock, and tailings) that result from these activities. Adverse historical events and potential adverse health and environmental issues are identified.

The environment of Virginia and in particular the drainage areas in and around Coles Hill (this drainage area also includes several other sites where uranium deposits have been identified) and the downstream areas from there including the John H. Kerr Reservoir and Lake Gaston are described. Lake Gaston serves as a source of public drinking water for Virginia Beach and other cities in the area. This information is of importance to VDH since it regulates public water supplies.

Much of the information presented concerns precipitation and flooding events and includes data and information related to PMP events and their possibility in the area. Comparisons of these events and their magnitude and frequency are alluded to in comparison to the Western United States (U.S.) where “most’ of the uranium mines and mills have located.

The uranium mines and mills in Texas are given only passing mention in the Baker Report. This is unfortunate because the South Texas uranium area has conditions which are the closest to the environmental conditions found in Virginia. The South Texas uranium area has had four conventional uranium mills (Susquehanna-Western near Falls City, ExxonMobil Ray Point, Conoco Conquista, and Chevron Panna Maria) and more than 70 open pit uranium mines with limited side-wall shaft mining. These facilities are located in the drainage areas of the San Antonio River and the Nueces River that serve as the sources of water for public water supplies for Corpus Christi and other cities in the area similar to the situation in Virginia.

The sizes of the tailings ponds, uranium extraction process used, and ore processing capacity for each of these four mill sites are provided in Table 2-1.

Although the average annual rainfall in the South Texas uranium area is less than in Virginia, the area is more frequently subjected to tropical storms, hurricanes, torrential rains, and tornadoes than is Virginia. The PMP maps show that the South Texas uranium area is at a higher level of risk than is the Virginia area in this study.

Any future studies regarding impacts on water should compare the South Texas uranium area and the practices and incidents that have occurred there for a more realistic comparison of what one might expect in the Virginia environment.

The Baker report does not specifically address private water wells that may provide drinking water for individuals, irrigation, and stock watering. This is an area that should be addressed and included in the background data and information that an applicant for a radioactive materials license for milling of uranium would be required to provide in environmental reports supporting the application. The completeness and adequacy of the applicant’s data and information should be evaluated and compared to data and information from other sources including VDH.

2.3 Chmura Studies

The report entitled "Socioeconomic Impacts of Uranium Mining and Milling in the Chatham Labor Shed, Virginia" was prepared by Chmura Economics and Analytics under contract to the Virginia Coal and Energy Commission (Chmura, 2011). The report was released November 29, 2011.

The Chmura study specifically addressed potential impacts of the Coles Hill potential mining and milling operations as presented by Virginia Uranium Incorporated (VUI) and does not include other areas of Virginia nor does it address the impacts if other mines there opened to feed ore to the Coles Hill mill. This could occur particularly in the latter years of the mill operation when the Coles Hill mine is not projected to keep the mill operating at full capacity.

As indicated by the report title it focuses primarily on the "socioeconomic" impacts of the projects, but as a part of those impacts public health and safety, environmental effects, and monetary impacts on Commonwealth agencies, including the VDH, are assessed within separate sections of the report.

Chmura Report Executive Summary

According to the Executive Summary, the stated purpose of the study was *"...producing a socioeconomic study to broadly consider the net benefits from a mining and milling operation in the Commonwealth." The report purportedly "...provides the facts and context to understand the magnitude of economic benefits and the socioeconomic costs stemming from a uranium mine and mill in Virginia" and "...provides a framework for Virginia legislators to assess and balance the health and environmental risks against the economic rewards inherent to this industry."*

Again according to the Executive Summary, "*the Coles Hill site is expected to support more than 1,000 jobs annually (direct, indirect, and induced) and have an annual net positive economic impact of approximately $135 million. This net benefit comes after subtracting for a broad array of potential socioeconomic costs (such as public health and the environment) and negative "stigma" effects on some sectors (such as tourism and agriculture), which under specific circumstances, Chmura judges most likely to be minimal."*

This bottom-line assessment was "*predicated on the assumption that the Coles Hill site will be continuously operated and ultimately decommissioned within established federal guidelines, which, by law, reduce environmental and public health risks to the surrounding communities to near negligible levels.*"

A key finding *"is that the most significant driver of the socioeconomic costs is not the reclamation and remediation price-tag to clean up the environment, but rather the potential* *negative stigma effects impacting agriculture, tourism, and possibly other industries. It may also be possible to mitigate some of these stigma effects to reduce the negative impact."*

The study identifies four potential impact scenarios:

> Scenario 1: Negligible environmental impact. The qualities of air, water, noise, and soil are not materially altered from today's existing conditions.
>
> Scenario 2: (BASELINE) Moderate environmental impact in terms of the qualities of air, water, noise, and soil—all contamination remains within limits set by current federal standards.
>
> Scenario 3: Significant environmental impact in terms of the qualities of air, noise, or soil (but not water). At least in one of these three areas, (air, soil, or noise, but not water) contamination exceeds the limits set by current federal standards.
>
> Scenario 4: Severe environmental impact in terms of the qualities of air, water, noise, and soil. Contamination of both water and at least one other area (air, soil, or noise) exceeds the limits set by current federal standards.

The report states that "*Chmura makes no determination as to the likelihood for each of these scenarios, save noting that the baseline scenario is more probable than the others to occur. The basis for this determination is detailed throughout this report but stems primarily from the strict regulatory environment that VUI will have to operate within and advances in tailings management technologies and industry practices that work to minimize the impact on the environment from the uranium mining and milling operations. This judgment assumes that the current regulatory environment—if fully enforced—is sufficient to result in a "moderate" environmental impact. There is some debate as to whether the current standards for regulating the uranium industry in the United States adequately protect the environment and public health. Such a debate is outside the scope of this report*".

Key findings of Chmura's Analysis of the Baseline Scenario (from the Executive Summary)

Among the Key Findings listed are these potentially affecting the VDH:

- This impressive positive economic impact is net of anticipated socioeconomic costs realized due to possible negative stigma effects, added costs of regulation, added use of public services, emergency planning, and risks to public health and the environment.
- "Agreement States" are those that have signed a formal agreement with the NRC pursuant to Section 274 of the Atomic Energy Act. Assuming Virginia becomes an Agreement State (discussed further in Section 4.1 and 6.1) for the purposes of

regulating the mill tailings portion of the Coles Hill operation, Virginia will need to spend an additional $2.5 million per year to monitor the industry.

- Under the assumptions of the baseline scenario, the Coles Hill operation will not result in any increase in cancer rates or other fatal illnesses. A portion of the approximately 2,700 people living within five miles of the Coles Hill site who are already sensitive to air quality issues could experience increased asthma-related symptoms or other respiratory problems.
- Given the assumptions of the baseline scenario, the Coles Hill operation poses minimal risk to degrade the surrounding environment—air, soil, and water.
- Addressing the issue of environmental justice, African Americans, the area's predominant minority community, are unlikely to be disproportionally impacted—either positively or negatively—by the Coles Hill site relative to their peers. The Virginia chapter of the National Association for the Advancement of Colored People currently opposes uranium mining in Virginia.

The sections of the report that address regulatory issues including cost to regulatory agencies and public and worker health and safety and the environment include the following:

Chmura 3.3: Government Service and Regulation

Analysis: This section only describes the outreach methods used by Chmura to prepare the analysis and body of the report related to this topic.

Chmura 3.4: Public Health and Environment

Analysis: This section only describes the methods used by Chmura to prepare the analysis and body of the report and the background under which these were developed.

Chmura 5.6.2: Stigma and Environmental Contamination Risks on Real Estate Values

Chmura states the following with regard to the stigma and environmental contamination effects:

"*The public generally associates this industry with environmental degradation, water contamination, and increased health risks. This sentiment is particularly prevalent among environmental groups. In short, the uranium industry could be a source of negative stigma, and people when asked if they would like to live near mild radioactive industrial waste generally say no. But ample research has also shown the economic impact of this type of stigma on property values is limited to properties in close proximity to the site and is by and large temporary.*"

"*Nonetheless, the transitory nature of negative stigma effects suggests that should the qualities of water, air, and soil near any mining and milling operation remain unaffected during the early years of operation, the majority of the stigma effects on most of the properties within five miles* *would disappear. In short, Chmura judges that if no accidents occur, and the mine and milling sites are properly maintained and reclaimed afterwards, any negative effect on residential property value in Pittsylvania County is likely to short-lived, localized, and in most cases negligible."*

Analysis: These statements emphasize the importance of controlling environmental releases and preventing accidents as a result of any uranium mining and milling that could occur in the Coles Hill area. The VDH would potentially be a major player in this regulatory effort.

If the VDH were to be the radioactive materials licensing and regulatory agency for the uranium milling portion of a project it would be necessary for VDH to have legal and regulatory authorities for these programs as well as adequately trained personnel and equipment in appropriate quantities to conduct this regulatory function. The Office of Drinking Water will likely play a major role in the collection and analysis of water samples from public and private sources of drinking, springs, ponds, and streams within a five mile radius around the site. An estimate of the additional work load for this activity cannot be made until a complete inventory of these water sources has been conducted.

The Division of Radiological Health can anticipate the necessity for increased environmental monitoring activities including monitoring for radon, airborne particulates, and direct external radiation measurements, plus sampling of vegetation and animals for laboratory analysis. Accordingly, additional resources (funding, staffing and equipment) would be necessary should a mining and milling operation be permitted.

If the NRC were to be the licensing agency for a mill, the VDH would still be impacted because of its responsibility to monitor and protect the health of the people of Virginia. These efforts would include independent environmental monitoring for radioactive and other hazardous materials present at the site, conducting epidemiologic studies for adverse health effects, and protecting public and private drinking water sources.

The VDH may want to evaluate its potential roles in the regulation of uranium mining. In addition to miner health and safety, the VDH may want to consider evaluating and controlling radioactive emissions from a mine and associated waste rock and over-burden piles and setting standards for the radiological clean-up of mine sites. These considerations and activities should be coordinated with DMME.

This is just one example of interagency cooperation and coordination that will required between Commonwealth agencies in order for Virginia to have a comprehensive regulatory program should the ban on uranium mining be lifted. Other specific examples are mentioned later in this report and its recommendations.

Chmura 5.7: Fiscal Impact on State and Local Governments

This section and the following subsections are primarily devoted to analyses of potential increases (and decreases) in the tax bases of the Commonwealth and local governmental entities and not the costs that may result to VDH.

Chmura 5.8.4: Stigma and Environmental Contamination Risks to the Agricultural Sector

This report contains the following statements:

"Studies have shown that uranium mill tailings can spread radionuclides to forage grasses and other vegetation—such as vegetables or grains—that can then be consumed directly by people or by cattle or other livestock, which will then produce milk or meat for human consumption. However, the limited research that exists regarding the exposure to humans of uranium via the food chain concludes that animals and vegetables exposed to uranium tailings pose only "minimal" risk to human health, although at least one study recommends against eating liver and kidneys (the organs where radionuclides tend to accumulate) from cattle that forage on land near uranium tailings."

"Since current research suggests vegetables, meat, and milk produced in the local area would be safe for human consumption, these products should not be subject to any stigma. However, Chmura recognizes that there is substantial risk to the future of Chatham Labor Shed's agriculture if uncertainty over the safety of the locally produced foodstuffs exists."

> **Analysis:** These findings suggest that VDH and VDACS may be called upon to monitor locally produced foodstuffs to ensure that they are safe. VDH and VDACS should establish close working relationships and determine their respective roles in sample collection and analysis and standard setting responsibilities. A baseline study should be conducted prior to any mining in the area. The baseline study, as required by the NRC in the application and permitting process, should be commenced at least one year prior to any mining in the area in order to measure and account for seasonal and crop variations. These efforts would be needed for mining, whether or not VDH licenses and regulates the milling operations.
>
> In states where agriculture is an important industry, environmental monitoring programs for nuclear power reactors, fuel fabrication facilities, uranium mills, and other fuel cycle facilities have been put into place to measure the effects of those facilities on agriculture. The value of such a study is to ensure that foodstuffs do not include unacceptable levels of radioactive materials and to measure the impact of a uranium mine and mill on these levels.
>
> Since virtually all foodstuffs contain some radioactive materials it is important to be able to know if there are increases following mine and mill operations and if those increases,

if observed, are acceptable. Certainly VDACS will play a very important role in such a program. Once a specific site is chosen VDACS will most likely be able to identify what crops are being grown for human and animal consumption near a planned facility. Plants, including pasture land grasses, would need to be monitored for uptake from the soil and from deposition of radioactive airborne contaminates. Milk from cows, goats, and sheep used for drink and the making of cheese would need to be included in the sampling and analysis plan. Each of these products would need to be analyzed for uranium and its progeny including radium

The report makes the following recommendation:

"In the case of Pittsylvania County, monitoring the water quality of private wells for radionuclides—a source of drinking water for humans and animals—and other toxic substances should be included in any regulatory regime."

Analysis: This recommendation is appropriate for VDH to implement. In order to implement this recommendation an inventory of all private water wells within five miles of the potential Coles Hill site should be conducted. These wells should be sampled for at least one year prior to any uranium mining at the Coles Hill site. In addition to the standard suite of analyses performed on ground waters there should be analyses for uranium and progeny and other hazardous materials that might be used in the mining and milling processes. Data should also include depth to water, total well depth, and in situ water temperature. After a complete inventory of private water wells VDH should conduct a fiscal review of the anticipated additional costs of this enhanced environmental surveillance program.

A similar inventory and analysis should be conducted for all wells used as sources for public water supplies.

Similarly a sampling and analysis program should be conducted at the intake points for all surface waters within the watershed downstream from the site that are used for public water sources.

Chmura 5.9.1: Temporary Idling of Mining and Milling Operations

The report makes the following statement with regard to a need in the event there was a temporary idling of mining and/or operations:

"*Regulations would need to be developed to establish protective measures necessary to ensure public health and safety while the plant was idled and VUI was unready or unwilling to implement full remediation and reclamation efforts*."

Analysis: The responsibility for developing (and enforcing) these regulations would be a responsibility of VDH (and possibly other Commonwealth regulatory agencies) if the Commonwealth became an Agreement State for uranium milling. Current NRC regulations address radiation protection and other issued associated with an idle or closed mill prior to final reclamation and decommissioning. NRC would require that VDH have similar regulations if Virginia were to become an Agreement States for uranium mills.

Chmura 6: Government Service and Regulation and Section 6.1. Government Cost for Regulation

The analyses conducted by Chmura are based upon the following:

"*This section is predicated on the assumption that the Commonwealth of Virginia chooses (a) to become an "agreement state" for the purposes of regulating mill tailings (i.e., the waste-rock residue leftover after the crushing and initial processing of raw uranium ore), and (b) to remain an "agreement state" for the purposes of regulating uranium mining. Should Virginia choose to allow the federal Nuclear Regulatory Commission (NRC) to manage and regulate the milling portion of the Coles Hills site, then the additional costs to the Commonwealth of Virginia are likely to be relatively minimal. Correspondingly, Chmura judges that the Virginia Department of Mines, Minerals, and Energy (DMME) currently has adequate resources and the technical expertise to manage solely the mining portion of the uranium operation.*"

"*Conversely, a decision for the DMME to supplant the NRC for licensing, permitting, and inspecting the milling portion of the operation would involve hiring new personnel as well as utilizing existing resources and personnel. Other Virginia agencies may incur some additional hiring if Virginia becomes a full-agreement state. These costs are conservatively estimated to be $2.5 million per year and they are examined briefly in the sections that follow.*"

Analysis: The author of this portion of the report is apparently under the mistaken impression that the NRC regulates uranium mining. Except for the mining of uranium using the in situ leach (ISL) process, the NRC does not regulate the mining of uranium. Therefore the analysis of the cost to government may need to be revisited.

However, the VDH should take notice of the estimated costs if Virginia decides to become "a full-agreement" state. These "*are conservatively estimated to be $2.5 million per year…"* The VDH should to develop a budget (if it has not already done so) for the cost to the VDH for administering a program for the regulation of uranium milling.

Chmura 6.1.1: Virginia Department of Environmental Quality

The report makes the following estimate of costs to DEQ:

"*DEQ would likely have to hire 2 to 3 additional employees to monitor water, soil, and air standards as a result of the introduction of uranium mining and milling in Virginia. The direct cost to DEQ of such hires is likely to be roughly $200,000*."

> **Analysis:** The responsibility for monitoring could likely fall to VDH instead of DEQ depending upon the legislative authorities of each agency; however, VDH should take notice of this estimated cost.

Chmura 6.1.2: Virginia Department of Health

The Chmura report provides the following regarding the costs to VDH:

"*VDH anticipates the need to hire up to 4 additional employees with expertise in biology and engineering to conduct appropriate monitoring and field testing to ensure the health of the workers at the Coles Hill site and surrounding communities. The direct cost to VDH of such hires is estimated to be $500,000 in salaries and benefits and they would likely need an amount roughly equal to this in budgetary expenses, equipment, and supplies based on the analysis conducted in 1985 for the Virginia Coal and Energy Commission. Because VDH is a fee-based operation, most if not all of these costs will be recouped via various fees charged to the industry or company requiring VDH services, and thus these additional expenses would be budget-neutral.*"

> **Analysis:** The analyst appears to base these costs on the assumption that VDH would not be the licensing agency under an Amended Agreement for uranium milling. It is unclear whether the 1985 estimates cited above assumed that VDH would be the Agreement State regulatory agency for uranium milling or not. If this was an estimate by VDH for conducting the entire Agreement State portion of the uranium milling program, this may be an appropriate amount, but the estimate should be re-examined. The licensing phase of the regulatory program for a uranium mill is very labor intensive requiring the expertise of many scientific and engineering disciplines, including health physics, geology, hydrology, structural engineering, chemical engineering, and financial analysis
>
> The statement that "*Because VDH is a fee-based operation, most if not all of these costs will be recouped via various fees charged to the industry or company requiring VDH services, and thus these additional expenses would be budget-neutral.*" is highly suspect. Currently the Annual Fee charged by the NRC for a conventional uranium mill is $32,300. Either VDH would have to charge a much larger annual fee than does the NRC or set up a fee system based on the hours works on the licensing project for this to be a "budget-neutral" program for Virginia.

Chmura 6.1.5: Other Virginia Departments Impacted

The report presumes an active role for VDACS in agricultural monitoring and in a communications campaign:

"*In 1985, the VCEC estimated that the cost of agricultural sampling would be $1,500 (roughly $3,120 adjusted for inflation) per year and they anticipated no other costs to the Virginia Department of Agriculture and Consumer Services (VDACS). Chmura judges the costs to VDACS will be much greater than this. In addition to a new program for testing both radionuclides and heavy metals in grasses, grains, fruits, vegetables, and livestock, a marketing and communication campaign will need to be implemented to counteract any potential stigma effects. Chmura judges these costs could easily reach the same level as the combined costs of the added personnel and operating expenses for DEQ and DMME, or approximately $1 million per year*."

> **Analysis:** The degree to which the monitoring program outlined could/would be incorporated into the environmental monitoring programs of VDH and the site operator should be evaluated. Could VDH conduct the sampling and/or analyses envisioned?
>
> If the monitoring program as envisioned were to be undertaken, it would be same whether or not Virginia was an Agreement State for uranium milling.

Chmura 6.1.6: Interagency Coordination and Program Development

The report develops an estimate of the additional costs to Virginia for developing a monitoring and regulatory program for the uranium industry:

"*In addition to the direct costs of personnel, supplies, equipment, and testing, the Commonwealth of Virginia will incur some costs in developing a program and interagency process to coordinate the comprehensive monitoring and regulation of the uranium mining and milling industry. … Chmura estimates an additional $500,000 will be needed to develop a program that will comprehensively monitor the uranium industry in Virginia. It will be important for these state agencies to work together*."

> **Analysis:** The analysis of the costs that follows this estimate uses Arizona as an example of the anticipated costs; however, in the analysis the Arizona Radiation Regulatory Agency is not mentioned nor its costs included. The analysis admits some difficulties in using Arizona for a comparison due to land ownership situations and other considerations.
>
> Nonetheless the conclusion that "it will be important for these state agencies to work together" is valid for a Commonwealth regulatory system for the uranium industry considering the number of Commonwealth agencies that would potentially be involved.

Chmura 6.4: Cost of Contingency Planning and Disaster Preparedness

As a part of the analysis of these costs two transportation events were used as examples of potential accidents that should be considered. These involved two trucking accidents that involved, in the first example, the spillage of yellow cake (processed uranium) and the second the spillage of unprocessed uranium ore on public roadways. The section concludes with:

"*In the case of the Coles Hill site and Virginia Uranium Inc., an integrated hazmat response team could be formed and trained to include teams from the company itself, local fire and rescue departments, highway patrol, health department, and regional PHMSA staff. As with any disaster or emergency, communication and coordination is critical, as local emergency service providers are the likely first responders. The costs of such an emergency response program are largely confined to training, coordinating procedures, and conducting event simulations for testing and validating procedures.* ***For the sake of this study, Chmura assumes these costs can be absorbed by the existing training budgets for state and local emergency response organizations and agencies***." (Emphasis added.)

> **Analysis:** Although there should be no hauling of ore on public roadways at the proposed Coles Hill project there is the potential for such activity if other uranium mines were to be developed. The transport of yellowcake from the Coles Hill site to a uranium conversion facility would most certainly involve the use of public roads. VDH and other Commonwealth agencies need to include this consideration in planning, staffing, and equipping emergency response programs.
>
> Although the study concludes that these costs could be absorbed within existing budgets, this aspect should be carefully evaluated by the VDH.

Chmura 6.7.1*:* Fines

In discussing sources of funding to offset cost to governmental agencies, the report suggests fines as one such source:

"…Virginia agencies such as DEQ, DMME, and DCR all have the ability to directly or indirectly (via a judge's decision in a civil case regarding a levied fine) to fine a company if permitting conditions are breached or specific laws or regulations are broken. However, current Virginia law does not allow for civil penalties to be brought against Virginia's mining industry, which is currently dominated by coal mining and hard-rock quarries."

> **Analysis:** VDH is not mentioned as one of the Commonwealth agencies having authority to fine a company. This is an oversight as VDH does currently have statutory authority to level fines.

Chmura 7: Public Health and Environment

The report bases its assessment of impacts on public health and the environment on the following:

"*Uranium mining and milling operations unambiguously increase the exposure of the public and the environment to mildly radioactive substances, toxic chemicals, heavy metals and other carcinogenic material. Even under the best of circumstances, Chmura judges some adverse health effects and environmental contamination is likely. Under the baseline scenario these health and environmental risks are estimated and analyzed in the sections that follow and are ultimately characterized as minimal. Implicit in this assumption is the notion that so long as any contamination at the Coles Hill site of air, water, or soil remains within current federal regulations, then the impact on the environment is moderate and the health risks to the general public are reduced to negligible levels*."

Chmura 7.1: Impact on Public Health

The report makes the following statement with regard to potential impacts on public health:

"Research shows that lung cancers are the cancers most associated with uranium mining and milling, but renal cancer and kidney disease are also cited in the literature as being linked to the uranium industry."

> **Analysis:** The statement identifies the most commonly identified diseases having potential negative impacts associated with uranium mining and milling. This points to need for the VDH to aggressively and continuously monitor these diseases among workers, their families, and other people living in areas where uranium mining and milling occurs. Baseline retrospective epidemiological studies should be done prior to the commencement of uranium mining and continue at least throughout the life on any uranium operations.

Chmura 7.1.1: Sources of Risk to Public Health and the Environment

The report identifies heavy metals and radiation from a uranium mining and mill as potential sources of risks to public health and the environment:

"Understanding the health risks associated with exposure to many heavy metals could be seen as incomplete and evolving, but it is known that these toxic substances are particularly harmful to infants and young children."

"There are 22 different cancers associated with radiation exposure, and the most common cancer associated with uranium mining and milling workers is lung cancer. This is most likely because radon and its decay products are primarily airborne and pose the greatest cancer risk of all the radionuclides emitted per the findings of an EPA study. Other studies have indicated

that long-term worker exposure to uranium mill tailings is weakly associated with elevated risks for birth defects, stillbirths, and other adverse outcomes of pregnancy; however, the authors stated "a lack of clear evidence for an increase in cancer risk to miners should be reassuring." A different study conducted in 2008 reviewing multiple papers on the health risks relating to the uranium industry found that the association of worker uranium exposure and cancer "is limited." There are also several studies that have indicated no detectible increases in cancer to populations surrounding uranium mines or mills."

> **Analysis:** In addition to the diseases previous mentioned, the VDH should ensure any retrospective and on-going epidemiological studies include diseases related to heavy metal exposure to infants and young children.
>
> These studies should also include birth defects, stillbirths, and other adverse outcomes of pregnancy among workers, their families, and the general public.

Chmura 7.1.2: Pathways of Exposure to Harmful Material

The report identifies several pathways for exposure to harmful material:

"The EPA and scientific authorities have defined three primary pathways by which mine and mill workers, as well as the public, can be exposed to the harmful effects of uranium mining and milling by-products. These are (1) breathing air containing windblown dust and radon decay products, (2) drinking water containing uranium and its decay products, or (3) eating food contaminated by either air or water."

"While previous health and environmental studies have focused on exposure to airborne radon and radon-decay products (called daughters, such as polonium-210) or the potential for uranium or its decay products (daughters such as radium-226) to seep into the groundwater, the relatively wet environment of southern Virginia suggests that rain runoff may be one of the most important pathways to control in order to limit the spread of radionuclides, other acidic compounds, and heavy metals into nearby surface waters and soil. "

> ***Analysis:*** It is prudent to consider all the pathways identified above in any preoperational and operational environmental monitoring plans that the VDH develops, and if VDH becomes the Agreement State licensing agency, the VDH should require that these pathways be monitored by the operator as well.
>
> Among the pathways to be included are direct exposure, airborne transport of both radioactive particulates and radon, water transport via both ground waters and surface waters, and ingestion of food and liquids including both water and milk. Dose modeling should be done using environmental data to determine potential off-site doses and doses to workers. The MILDOS computer code or other appropriate computer codes should be used to calculate the potential radiation doses from each pathway. Results of modeling

for conventional mills most often results in doses to off-site populations in the few mrem/hr with the vast majority of the dose resulting from potential inhalation of particulates and radon decay products.

Chmura 7.1.3: Cost Estimates of Treating Additional Cancer Cases

The report presents data from the United States Environmental Protection Agency (EPA) on the potential risks from uranium mining and milling operations to persons living near the facilities. The models used by the EPA to make their estimates of health risk for inactive mines and mills were based upon the assumptions that no actions were taken to mitigate exposure to radionuclides and other carcinogens and that the uranium mine and the mill tailings were simply abandoned with no remediation or decommission processes taking place. The EPA also calculated the health risks from an operating mine and mill. Calculated health effects to populations within 50 miles of the mine and mill and on a hypothetically 'most exposed' individual living one mile from a surface or underground mine and mill were presented in Table 7.1 of the report. For persons living within one mile of the site those estimates of cancer risks to the most exposed individual range from 2.0 cancers per 100,000 to 4.4 in 1,000 (presumably a worker in the mine). For the average exposed person living within 50 miles of the site, the risks ranged from 6.3 in 100,000,000 to 5.5 in 10,000.

Analysis**:** The estimated population within one mile of the Coles Hill is less than 100 persons. The estimated population within 50 miles of the site (which includes the cities of Roanoke and Lynchburg) is approximately 742,000. These data amplify the necessity for any epidemiological study undertaken to be extremely robust in order to detect any change in the cancer death rate within these populations.

Chmura 7.1.4: Health Assessment of the Citizens in the Coles Hill Region

For this report and analysis Chmura relied heavily on reports and other data from VDH. The basic outcome of these reviews led to the following assessments related to the population in the Coles Hill area:

"Overall, the area suffers from inequities in birth outcomes, life expectancy, and mortality when comparing it to more socially advantaged populations elsewhere in the Commonwealth. Simply put, this region already has a compromised health profile. Consistent with its education and poverty profile, this region has a consistently poorer health status across almost all health indicators. The region's primary minority group, African-Americans, experience an even more distressed health situation, as they typically face shorter life expectancies and higher mortality rates for most of the major causes of death compared to other racial and ethnic groups."

Chmura notes the following observations from the health review:

- *"Pittsylvania County has a significantly higher rate for malignant neoplasm (cancerous malignant tumors) than the state-wide norm;*
- *Pittsylvania County and Danville City both have significantly higher rates for heart disease, cerebrovascular diseases (strokes), chronic lower respiratory diseases, and diabetes mellitus than state-wide norms;*
- *Pittsylvania County and Danville City both have elevated rates for chronic liver disease, septicemia (blood poisoning), nephritis and nephrosis (kidney diseases), and influenza and pneumonia than state-wide norm;*
- *The Pittsylvania County area has a significant smoking population which is increasing and exceeds national and state levels;* and
- *Lung cancer rates in Danville are increasing and exceed national and state levels."*

"Several studies suggest that the health risks posed by uranium mining and milling will exacerbate the health risks that stem from lifestyle choices, such as smoking, already associated with the population of Pittsylvania County and the remaining labor shed, and further elevate the already high lung cancer rates in the region. At least one study suggests that African-Americans may be more sensitive to the health effects of long-term exposure to uranium byproducts—primarily inhalation of radon gas—than other peer groups, and African-American women may be more at risk than other peer groups for breast cancer should uranium or its byproducts contaminate surface or groundwater."

> ***Analysis:*** The Chmura report findings regarding health assessment for the area agree with Weldon Cooper Center findings, and those of the recently released Virginia Health Equity Report 2012 published by VDH (VDH, 2012). The findings that the area has lower than state-wide levels for health of the population will likely place greater burdens on the VDH Office of Minority Health and Health Equity and local health districts and local health care providers if a uranium mining and milling facility were to be built at the Coles Hill site. Measuring the effects of these operations in epidemiologic studies by VDH could be confounded by the already existing poor quality of health in the area. Future studies of the quality of health in the area could indicate that the area has a poorer quality of health than the Virginia average, and that lower quality of health could be attributed to the existence of the uranium mine and mill rather than to pre-existing conditions.

Chmura 7.3.4: Issues Relating to the Watershed

The report makes the following observations regarding water issues within the watershed around the Coles Hill site and downstream from its location:

"Water management and isolation is a major challenge to any firm in the uranium mining and milling industry. Any plan to mine and mill uranium at Coles Hill must consider negative water implications arising from run-off of moisture (from rain, snow, fog, dew, etc.) from mine waste, mill tailings, and stockpiled ore that will be located on site. Additional consideration must be made for the dewatering of underground works through constant pumping of water to the surface for processing. Lastly, contaminated water must be isolated from leaching into the groundwater that is utilized by the surrounding communities which ultimately forms part of the greater Roanoke River basin. There is also the long-term challenge of keeping waterfowl, mammals, and unsupervised persons out of contaminated water which will be held above ground. The risks to both public health and the environment stem in large part from the potential exposure of nearby surface and groundwater sources to water from the Coles Hill site that may contain unsafe levels of radionuclides, heavy metals, and other toxins."

"The only hydrogeological study of the Coles Hill site that Chmura is aware of was limited in scope and recommended a more thorough and comprehensive study be conducted. In general, this study found the groundwater system "complex" and extensive. It noted that the "groundwater at Coles Hill is recharged not only locally but also at more distant locations." The complexity of how groundwater moves through fractured rock only adds to the level of caution that is warranted when considering the issues of water management and the health risks it poses to the broader community and environment."

> ***Analysis:*** While the Chmura report's findings on the potential issues related to surface and ground water are very important and emphasize the need for extensive engineering and operational controls to minimize, or eliminate these effects, they do not address all potential impacts of the mining operations.
>
> The report has little to say about the potential impacts and issues related to private wells in the area. This issue would be a major concern for people in the area. Not only must one consider the potential for contamination of the private wells, one must also consider the potential excessive draw-down in the levels of water in private wells within the aquifer due to mining operations and the "constant pumping of water to the surface for processing". This issue, whether actual or perceived, will be a challenge for VDH to address and warrants inclusion of depth to water data in any environmental monitoring program for private wells.

Chmura 7.4: Environmental Justice

The Chmura report provides the following statements and conclusion with regard to the issue of environmental justice with regard to the proposed Coles Hill uranium mining and milling operation:

"In general, all stakeholders—schools, the business community, Non-Governmental Organizations (NGOs), and public advocacy groups, among others—have indicated they would like more information about what the uranium mine and milling operation will involve, including what types of mining techniques and technologies will be employed to minimize the risks to both public health and the environment. These disparate groups raised very similar concerns relating to both health and safety. Opinions within and across groups were split as to whether the potential economic gains—as they understood them at the time—outweighed the health and environmental risks to the community."

"Directly addressing the issue of environmental justice, the entire labor shed (as was noted in Section 4) has both below-average incomes and higher rates of poverty. Thus Chmura's treatment of the public as well as a comprehensive group of stakeholders throughout the labor shed was an appropriate focus for soliciting views and ensuring ample opportunity for input. The socioeconomic profile for the labor shed is quite similar to that of the broader watershed, and in both areas the most relevant minority group is the African-American community."

"Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies."

"Meaningful involvement means that (1) community residents in the potential impact area—primarily Pittsylvania County—have an appropriate opportunity to participate in decisions about a proposed activity that will affect their environment and/or health; (2) the public's contribution can influence the regulatory agency's decision, as in the Virginia state legislature; (3) the concerns of all participants involved will be considered in the decision-making process; and (4) the decision-makers seek out and facilitate the involvement of those in the potential impact area. Environmental justice can be achieved when everyone—regardless of race, culture, or income—enjoys the same degree of protection from environmental and health hazards and has equal access to the decision-making process."

"The African-American community in the region has lower average incomes and poverty rates of more than double their white neighbors. The health profile of the African-American community is also less robust than their white peers, with higher rates of several chronic diseases and slightly shorter life spans."

"Chmura concludes that based on the assumptions of the baseline scenario, demographic statistics and residential records, the African-American community is unlikely to experience any greater environmental risks than any other community in the Coles Hill labor shed. Two reasons for this are that the African-Americans neither disproportionately live in proximity to the Coles Hills site, nor live disproportionately along the main transit corridors to and from the site. Similarly, in the broader watershed, the African-American community is not at any

disproportionate risk than any other community. Also at this point, Chmura has no reason to believe the African-American community will face any additional risks associated with working in the mines. This comes from the assumption that they would not be hired in greater numbers than would their non-African-American peers or other peer group."

Analysis: The Chmura report lays out the rationale for its decision regarding the satisfaction of the environmental justice issue; however, environmental justice is an issue that must be actively addressed in all licensing and permitting decisions. Commonwealth agencies involved in permitting the mines should ensure that this issue is addressed in their processes for making decisions regarding whether or not to permit the uranium mining.

Likewise if the VDH ultimately becomes an Agreement State for uranium, VDH must provide an open and meaningful engagement and discussion of environmental justice in its public hearings, license application review, and decision regarding whether or not a radioactive materials license will be issued for uranium milling at the Coles Hill site.

If the NRC retains licensing authority for uranium milling in Virginia, the NRC regulations, policies, procedures, and practices mandate that environmental justice be considered in any licensing decision it makes.

Regardless of whether the NRC or VDH is the licensing authority for a radioactive materials license to mill uranium, the process must assure that meaningful input into the process by African Americans, low income residents, and other disadvantaged communities is sought, encouraged, and considered in all decisions.

Chmura 9: Summary and Conclusion

The Chmura report provides the following regarding the Coles Hill uranium mining and milling proposal:

"This study has laid out a comprehensive socioeconomic impact of a potential uranium mining and milling operation in Pittsylvania County, Virginia. Chmura has utilized four distinct scenarios to provide a context for assessing the magnitude of the costs associated with different levels of environmental contamination vis-à-vis public health, property values, remediation efforts, regulatory costs, and the impact on other industries and neighboring communities. Under the baseline scenario—a set of circumstances Chmura judges to be the most likely to occur— the industry brings substantial economic benefits to the region and the costs and risks to region's image, public health, and environment are modest."

Analysis: It is beyond the scope of this study to evaluate this conclusion. It is ultimately a decision of the Commonwealth as to whether or not the benefits of uranium mining and milling within Virginia outweigh the risks.

In addition to the analyses which Chmura provides in the main body of the report, appendices look at other scenarios and provide case studies of existing uranium mining and milling operations both in the United States and in other countries.

2.4 RTI Study

This report entitled "Proposed Uranium Mine and Mill, Coles Hill Virginia: An Assessment of Possible Socioeconomic Impacts" was prepared by RTI International (RTI) under contract to the Danville Regional Foundation (DRF) (RTI, 2011). The Final Report was released in December 2011, and consisted of two volumes. Volume 1 contains the main body of the report. Volume 2 contains eight appendices to the report. Another document prepared by RTI International titled "A Short, Nontechnical Summary of RTI's Report" was issued January 23, 2012 (RTI, 2012).

"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."

The study specifically addressed potential impacts of the potential Coles Hill mining and milling operations and does not include other areas of Virginia nor does it address the impacts if other mines there opened to feed ore to the Coles Hill mill. This could occur particularly in the latter years of the mill operation when the Coles Hill mine is not projected to keep the mill operating at full capacity.

As indicated by the title, the report focuses primarily on the "socioeconomic" impacts of the projects, but as a part of those impacts public health and safety, environmental effects, and monetary impacts on Commonwealth agencies, including the VDA, are assessed within separate sections of the report.

The RTI International utilized a Community Advisory Panel, stakeholder interviews, and stakeholder focus groups in the course of its research and development of the report.

"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."

This report contains the following sections that make statements and findings regarding public and worker health and safety and environment issues that could potentially affect the VDH and its programs for the protection of public and worker health and the environment and its present legislative authority and regulations:

RTI 1.4.2.1: Environmental Concerns

From the individual interviews and focus group meetings RTI learned the following regarding 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 n the air to surrounding areas."

Analysis: Interviews and focus group meetings found that individuals were most concerned about potential adverse impacts on water. This finding is consistent with the findings of other studies and points to the need to ensure that these water impacts are carefully evaluated and addressed.

Adverse impacts on air quality and the failure of containment systems due to natural disasters and human actions were also identified as concerns.

RTI 1.4.2.2: Concerns About Health

From the individual interviews and focus group meetings RTI learned the following regarding health concerns:

"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). 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.

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."

> **Analysis:** The health concerns expressed during the interviews and focus group meeting are not unexpected. In general people associate exposure to radiation with cancer and birth defects. This concern amplifies the need for preoperational and on-going epidemiologic studies to measure the effects of the mine and mill operations on the incidence of these and other diseases.

RTI 1.4.2.4: Government-Related Concerns

From the individual interviews and focus group meetings RTI learned the following regarding 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."

> **Analysis:** These findings point out common concerns and attitudes of people have regarding the government and its ability to adequately regulate activities involving radioactive and other hazardous materials and the industries using those materials. The findings also point out the necessity for VDH to have strong regulatory programs in place if it is to be involved in the regulation of uranium mining and milling.

RTI 2: The Coles Hill Region

The RTI report provides socioeconomic data for the study area that is the area within a 50 mile radius of the Coles Hill site. This section provides descriptions and data for presently existing conditions. This area includes six independent cities and all or parts of 28 counties in Virginia and North Carolina. Although there is considerable variation from area to area within the study area the general characteristics are that the people in the area are poorer and have lower levels of educational attainment than does Virginia as a state.

> **Analysis:** These conclusions are consistent with the findings of other socioeconomic studies of the area.

RTI 3: Potential Environmental Releases

Using information and data primarily from VUI regarding the ore body, mining methods, extraction chemistry, effluent controls, and projected life of the project RTI analyzed these to estimate anticipated quantities of radioactive and other hazardous materials (including other metals). The detailed assumptions and methodologies used to determine estimates of releases are presented in the subsections of this section.

The RTI report summarizes the potential releases from the operation of the proposed mine and mill as:

"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 (PM30)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 x 106 – 1.64 x 108 pCi/s and 1.59 x 106 – 1.59 x 107 pCi/s from the tailings management area."

> **Analysis:** These estimates for environmental releases would need to be validated by the regulatory agencies of Virginia during the permitting and licensing reviews for the mines and mill. An applicant for milling license should provide independent estimates of these releases in documents supporting the application. If VDH is the licensing authority for a mill, VDH will need to understand the methods and analyses used to make the estimates and assess their validity in its evaluation of the application
>
> Environmental programs conducted by VDH would need to include each of the mentioned pathways (air and water) and the radionuclides of interest, including uranium, radium, and radon as well as other radionuclides in the uranium decay series.

Commonwealth regulatory agencies would need appropriate regulations, inspection programs and enforcement powers to ensure that operations at the site were conducted so that environmental releases were maintained within regulatory limits.

RTI 3.1.1: Uranium-Related Site Features

Mention is made of creeks, ponds, and free flowing springs in the vicinity of the proposed Coles Hill mine and mill.

Analysis: These creeks, ponds, and springs should be included in any environmental monitoring program conducted by VDH and other Commonwealth regulatory agencies. A complete inventory of springs and surface water features such as creeks and ponds should be conducted prior to any mining activities. For springs it is particularly important that flow volumes be included since these could be potentially adversely affected by mining activities.

RTI 3.1.2: Chemical Makeup of Ore and Host Rock

Among the information presented in this subsection are data on the presence and abundance of other metallic constituents in the ore to be mined.

Analysis: Baseline environmental monitoring of waters including drinking water sources (public and private) in the area should include analyses for these other metallic constituents.

RTI 3.2: Uranium Mining

For this study the term "mining" is assumed to include all operations prior to milling and involve mining and handling the ore.

The report goes on to say:

"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."

Subsequent subsections describe the types of uranium mining which are commonly used to recover uranium/uranium ore.

Analysis: The differential of the components of mining and milling follows conventional usage of these terms.

The description of what will occur at the Coles Hill site is consistent with other studies and reports however it should be noted that these are based upon information provided by VUI.

RTI 3.3: Milling

This section of the report briefly describes the uranium milling process and the steps that occur in the process.

Analysis: This subsection provides an accurate description of the uranium milling process for conventional uranium mills.

RTI 3.4: Potential Waste Streams

This section and subsequent subsections identify solid wastes, aqueous wastes, and airborne wastes (air emissions). Solid wastes are identified as overburden, waste rock, and tailings. Aqueous wastes (water) are identified as mine water, process water, tailing water, and site runoff water (storm drainage). Airborne wastes, or air emissions, are not specifically addressed in this section or its subsections.

Analysis: The waste streams identified in the report are those commonly associated with uranium mining and conventional uranium milling.

The waste streams associated with the operation of the uranium mine are not regulated by the NRC. Regulation of these wastes is typically done by the state agency for mining and environmental quality; however, the wastes may be regulated, at least in part, by the state radiation regulatory agency.

The waste streams associated with the milling operation are regulated by the NRC if the operations occur in a Non-Agreement State. If Virginia chooses to sign an Amended Agreement with the NRC for uranium recovery operations then the VDH would regulate these waste streams.

RTI 3.5: Emissions Estimates

Estimates are presented quantities of mine water, process water, nonpoint source water discharges, and air emissions (including radon) from the proposed uranium mines and mill.

Also included are discussions of the applicable permitting and water quality standards that must be met for water releases.

Analysis: It cannot be determined if the estimated releases to water and air are accurate for the actual uranium mining and milling operations proposed at Coles Hill until final plans are submitted for review and permitting. The estimates appear to be appropriate based upon the preliminary plans that have been seen for the project. These estimates would have to be closely reviewed if a formal application is submitted for approval. Any application should have new or revised estimates for emissions included in the submission.

Current federal regulations (40 CFR 190.10a, 10 CFR 20.1301(e), and 10 CFR Part 40, Appendix A, Criterion 8) limit the radiation annual dose equivalent during normal operations to persons offsite to a whole body dose of 25 millirems per year not including the dose due to radon and its progeny. This limit has been achievable for most conventional uranium mills built after the early 1980's. This dose is based on all pathways of exposure. Since this is a very small dose (equivalent to less than 0.003 millirem per hour) and includes both external and internal doses it cannot be measured directly and compliance with this limit must be determined by the use of the MILDOS computer code or other appropriate computer code based upon environmental monitoring data. For uranium mills located at the mouth of the uranium mine as is proposed at Cole Hill, the issue of doses from mill releases is complicated by the fact that under such circumstances releases from the mine cannot be distinguished from those coming from the mill itself**.**

RTI 3.6: Mitigation and Control Options

This section and its subsections describe mitigation and control methods and equipment to limit the release of radioactive and other hazardous materials via the water and airborne pathways. There are discussions of the limitations placed on these releases based on EPA regulations and programs or by state agencies with EPA delegated authorities.

Analysis: The roles of the NRC or an Agreement state in this area are not discussed. The NRC or an Agreement State would play a major role in determining the acceptability of mitigation and control practices and equipment during the review and evaluation of a uranium mill license application. Application of the ALARA requirements would necessitate that processes, practices, and equipment be state of the science and the best available. It would be incumbent upon the VDH to ensure that this occurred if Virginia were to become an Agreement State for uranium recovery operations.

RTI 3.7: Regulations

This section and its subsections describe the laws and regulations that apply to uranium mining and milling.

"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."

> **Analysis:** This summary and the follow-on discussions of the laws and regulations appear to be accurate except for the inclusion of DOE in the listing of federal agencies having a role in the regulation of uranium mining and milling.

RTI 3.8: Post-closure Releases

This section and its subsections provide a description of the process and conditions for the final release of a uranium milling site from regulatory control. It concludes with the statement:

"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."

> **Analysis:** This section and subsections provide an accurate description of the requirements and process for the ultimate closure and decommissioning of a uranium mill.
>
> Although not highlighted in the discussion, when the tailings facility is finally closed the ownership and title to the land and the tailings must be transferred to the state or federal government. If transfer is to the Commonwealth it creates an on-going obligation for the Commonwealth to provide perpetual monitoring and maintenance of the disposal site.
>
> Typically the analysis of the perpetual care and monitoring costs are estimated at the time the license application is reviewed and evaluated, and the financial surety instrument/arrangement is put in place prior to issuance or concurrently with the issuance of the license for a mill. Periodic reviews and adjustments to these amounts are made throughout the life of the mill. These monies to fund these activities are required to be paid by the uranium mill owner/operator.

RTI 4: Insights from Case Studies

RTI selected 18 mines to profile. These included eleven uranium mines and seven non-uranium metal mines located in the United States, Canada, Australia, and Tanzania. Fifteen of these mines had mills adjacent to them. Five of the mines and mills were still operating. At four of the operating mines and mills stakeholders were also interviewed.

From its profiling studies and interviews RTI identified the following insights:

- *"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."*
- *"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."*
- *"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."*
- "*Economic impacts were reported as generally positive, but social and community impacts were reported as both positive and negative*."

Analysis: This section and its subsections look at both positive and negative impacts and opinions regarding mining including uranium mining and milling. The case study approach is an appropriate methodology to analyze potential impacts of the Coles Hill project.

In the studies both active and inactive sites were reviewed and older sites and more recently facilities built under present day standards and regulations were included. These studies look not only at the failures but also the successes. One can learn from the failures, but equally important is the review of successes to see what has worked and could be incorporated into a regulatory program for Virginia if the ban on uranium mining were to be lifted.

Also included in the review was a site with annual rainfall amounts more characteristic of Virginia's rainfall than those included in other studies. The Ranger Mine site in Australia has approximately one and a third the annual rainfall of the Coles Hill site. Future studies should include other mines and mills with rainfall similar to that of the Virginia area (for example, the South Texas uranium area).

An extensive list of references for each site reviewed is included; these references are invaluable for future evaluations of potential uranium mining and milling operations in Virginia.

RTI 5: Environmental, Human, and Ecological Health Impacts

This section and its subsections provide data, information, and analyses of:

Environmental Setting including:

- Location;
- Topography;
- Physiography, Geology, and the Uranium Ore Deposit;
- Climate;
- Hydrology;
- Hydrogeology; and
- Land Use.

Potential Constituents of Concern including:

- Uranium Occurrence in the Natural Environment;
- Uranium Radioactive Decay;
- Types of Radioactivity;
- Radiation Units of Measurement; and
- Relative Radiation Exposure.

Potential Contaminant Transport from the Mine and Mill including:

- Air Quality;
- Soil Quality;
- Water Quality; and
- Groundwater.

Potential Receptor Impacts including:

- Human Health; and
- Ecosystem Health.

Much of the data and information in this section of the report is derived from the Marline report published in 1983 (Marline, 1983) and information and data furnished to RTI.

In summarizing the data and information in this section RTI states:

"… 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:

"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."

> **Analysis:** This section and its subsection provide a great deal of data and information on the existing environmental background conditions in the Coles Hill area and presents reasonable expectations for their impacts based upon anticipated mining and milling design, construction, operation and regulatory controls.
>
> The data and information presented would have to be updated prior to mining and milling and the environmental parameters closely monitored during operation and closure to ensure that anticipated impacts are controlled and minimized.

RTI 6: Estimated Economic and Community Impacts

RTI summarizes its analysis of the estimated economic and community impacts as:

"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."

The only mention of impacts on Commonwealth regulatory agencies and in particular VDH is presented in subsection 6.8.2.1, below.

RTI 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."

Analysis: There is a misunderstanding within the report regarding the NRC and Virginia's legal authority under its Agreement State status regarding uranium mining. The AEA does not give the NRC and therefore Agreement States the authority to regulate uranium mining.

The assumed roles of the agencies of Virginia (i.e., DEQ, VDH, and VDACS) does not mention the DMME and its role. The actual eventual roles may differ from those mentioned.

However, the mining and milling of uranium at Coles Hill would have potentially significant programmatic and fiscal impacts on the VDH Division of Radiological Health, Office of Drinking Water, Office of Environmental Health, and Office of Minority Health and Health Equity, and its Epidemiology programs. Therefore a detailed analysis of the impacts on these activities should be performed to determine the likely fiscal and programmatic impacts.

RTI 7: Summary

In the Summary section of the report RTI identifies several questions were raised during its study:

- How do we get enough information to make an informed decision?
- How would the mining or milling actually work?
- How would the operation be regulated?
- What are the health and safety risks of contamination?
- What kinds of jobs and staffing opportunities would it bring?
- What would be the environmental impact?
- What will be the economic impact?

- What would be the impact on our community?

Analysis: These are valid questions for the citizens of Virginia and for the Commonwealth. Decision makers will want to consider these questions in their deliberations regarding whether or not to lift the moratorium on uranium mining in Virginia.

If the moratorium were to be lifted these are undoubtedly questions that would have to be addressed in the permitting and licensing process for uranium mines and mills. VDH and other Commonwealth regulatory agencies must be prepared to answer these questions openly and honestly throughout their licensing and permitting evaluations and approval/denial processes.

3.0 SUMMARY OF EPIDEMIOLOGIC STUDIES

The health effects attributable to the uranium recovery process, including mining and milling, have been recognized and extensively studied since the 16th century. The major epidemiologic studies, summarized in this Section, include only papers published in the peer-reviewed literature and analyses published by the National Academy of Sciences (NAS), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), and the International Commission on Radiological Protection (ICRP). Some anecdotal reports of adverse health effects, particularly in regard to impacts on members of the public and communities, have been publicized; however, in order to maintain consistency and a high level of credibility, they are not included in this summary report.

3.1 Review of Epidemiologic Studies Related to Uranium Mining

The epidemiologic studies of uranium miners have, historically, focused on exposure to radon decay products in mine air. There are many studies demonstrating an increased risk of lung cancer with increased exposure to radon, principally its short-lived progeny. A few of the more recent studies have documented and quantified the risk of other adverse health outcomes.

The uranium miner epidemiologic studies do not distinguish between radon-222 (^{222}Rn) from the uranium-238 (^{238}U) decay series and radon-220 (^{220}Rn) from the thorium-232 (^{232}Th) decay series. In almost all cases, the exposure parameter measured is ^{222}Rn. Radon-220 can be a concern in mines where ^{232}Th is a prominent part of the ore or host rock; however, there is very little in the miner epidemiologic literature that addresses ^{220}Rn.

3.1.1 History of Uranium Miner Studies

Underground miners have been known for centuries to suffer from lung disease associated with their work. In 1556 Agricola described the condition as “this terrible consumption” (Agricola, 1556). This disease was identified as lung cancer as early as 1879 (Harting, 1879) and associated with airborne radioactivity in the 1920s and 30s (Pirchan, 1932). By 1951, the lung cancers were found to be associated with exposure to radon progeny, i.e., the short-lived decay products of radon, a mixture of alpha and beta emitters, rather than the radon itself (Holaday, 1969). The first substantial epidemiologic study of uranium miners was initiated by the US Public Health Service in 1949 (Holaday, 1967). The classic study of the health of Colorado Plateau uranium miners was followed by numerous epidemiologic studies in the US, Europe and Canada. The BEIR IV Report, Health Risks of Radon and Other Internally Deposited Alpha-Emitters (NAS, 1988) and the later BEIR VI Report, Health Effects of Exposure to Radon (NAS, 1999) describe in detail the epidemiologic studies involving miners. The conclusion from the studies was that inhalation of radon progeny in uranium and other hard rock mines caused an increased risk in cancer, particularly among workers who smoked.

The concentration of radon progeny in air is a complex function of time since the radon is generated by the decay of radium. A special unit was derived to express the exposure to radon progeny was defined, recognizing that the particular exposure of concern in regard to radon progeny is alpha radiation from the decay of ^{218}Po and ^{214}Po. The "working level" is a measure of the potential alpha energy in a liter of air. Potential alpha energy means the total alpha radiation energy that would be released when the radon progeny decay to stable lead-206 (^{20}6Pb) or lead-208 (^{208}Pb). The beta emitting radon progeny, bismuth-214 (^{214}Bi) and lead-214 (^{214}Pb) contribute to the alpha energy since they decay to ^{214}Po.

3.1.2 Radon Progeny Concentration and Exposure (Working Level and Working Level Month)

Inhalation of radon progeny has been shown to be the most significant cause of adverse health effects in uranium mining. The risk of adverse health effects from exposure to radon in air is a function of the amount of energy absorbed by tissue. The predominant adverse health effect due to radon is lung cancer. The terminology related to radon progeny exposure can be confusing thus is reviewed in this section.

As introduced in Section 2.1, the concentration of radon progeny in air is expressed in working level (WL). The exposure to radon progeny is a function of exposure time and concentration in air. Exposure is expressed in units of "working level months" (WLM). One WL is the concentration of short-lived radon progeny in air that will result in the emission of 1.3 x 10^5 million electron volts (MeV) of energy per liter of air. One WLM is equivalent to exposure to 1.0 WL for 170 hours, originally, the average number of hours worked by a miner in one month. An exposure of 1.0 WLM would result in a Total Effective Dose Equivalent of 10 mSv (1.0 rem) (NCRP, 2009). The estimated lifetime risk from an exposure of 1.0 WLM is 5 x 10^{-4} (ICRP, 2011).

The WL was defined at a conference in Salt Lake City in 1955 as a radon concentration of 10^{-10} curies of radon in equilibrium with its short-lived decay products per liter of air (100 pCi/l) (Holaday, 1969). This was originally intended as an occupational standard. That standard was later reduced by a factor of three to its current level or 4 WLM/year or 30 pCi/L ^{222}Rn in equilibrium with its short-lived progeny. Routine, systematic radon progeny measurement in uranium mines was not instituted until about 1956. Therefore, the exposure data for early miners used in epidemiologic investigations was uncertain. This is a limitation of much of the early miner epidemiology since most of the exposure occurred during years when there is insufficient quantitative information of radon progeny concentrations.

3.1.3 Uranium Miner Epidemiology Studies – Lung Cancer

While adverse health effects have been observed in underground miners for centuries, the first systematic epidemiologic study of uranium miners in the United States occurred in the early 1950s (PHS, 1951, as mentioned in Section 3.1.1). Nearly all of the epidemiologic studies since that time have focused on the short-lived radon progeny as the causative agent. The results of these studies are summarized in the BEIR IV Report (NAS, 1988), BEIR VI Report (NAS, 1999), ICRP 115 (ICRP, 2011), UNSCEAR 2006 (USNCEAR, 2006), and the Uranium Mining in Virginia Report prepared by the National Academy of Sciences (NAS, 2011). The BEIR IV and BEIR VI Reports derived risk models based on the miner studies. These risk models have been applied to risk from radon progeny in residential settings as well. The studies conclude that radon progeny exposure resulted in an increased risk of lung cancer in miners. The risk coefficients vary based on attained age, time since last exposure, exposure rate and duration of exposure. BEIR VI also reviewed studies that included information on exposure to arsenic and silica. Two miner cohorts had data on exposure to arsenic. The excess relative risk (ERR) for radon did not vary across arsenic exposure categories. In a study of New Mexico miners, there was no evidence of association between silica exposure and lung cancer risk (Samet, 1994).

The major limitations in the early miner studies include uncertainty in radon exposure due to the lack of routine radon monitoring. Inadequate data on smoking in the miner cohorts is a major limitation for many of the early miner studies. Later investigations included smoking data.

BEIR VI Report (NAS, 1999)

Data from eleven cohorts were used in the BEIR VI analyses (follow up dates are included in parentheses):

- Chinese tin miners (1976-1987);
- Czech Republic miners (1952-1990);
- Colorado Plateau uranium miners (1950-1990);
- Ontario miners (1955-1986);
- Newfoundland fluorspar miners (1950-1984);
- Swedish iron miners (1951-1991);
- New Mexico uranium miners (1943-1985)
- Beaverlodge (Canada) uranium miners (1950-1980);
- Port Radium (Canada) uranium miners (1950-1980);
- Radium Hill (Australia) uranium miners (1948-1987); and
- French uranium miners (1948-1986).

The studies are summarized in the BEIR VI Report. A statistically significant excess relative risk was found for all cohorts, ranging from 0.2 to 5.1 per 100 WLM exposure. The "excess relative risk" (ERR) is the incremental relative risk (RR) greater than 1.0, i.e., ERR is equivalent to the value of the RR minus 1. The estimated combined ERR was 0.59 per 100 WLM exposure.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

UNSCEAR produced a report on the risk of inhalation of radon decay products in 2006 as an Annex to its 2009 Report to the General Assembly (UNSCEAR, 2006; UNSCEAR, 2009). The 2006 UNSCEAR Annex includes a summary of the radon miner epidemiology and Excess Relative Risks (ERR) based on analyses of ten cohorts:

- Colorado Plateau miners;
- Ontario uranium miners;
- Czechoslovak miners;
- Swedish iron miners;
- Beaverlodge, Saskatchewan miners;
- Wismut, Germany miners;
- Port Radium miners;
- French uranium miners;
- Newfoundland fluorspar miners; and
- Chinese tin miners.

The results of the UNSCEAR (2006) analyses are summarized by cohort in Table 3-1.

The ERR as noted in Table 2 is the incremental relative risk. For example, the risk of lung cancer for the Colorado Plateau miners was found to be a factor of 0.42 greater than the risk with no exposure per 100 WLM. The ERR appears to be inversely related to the average exposure in WLM. The five studies with cumulative exposures less 100 WLM show higher risk levels (ERRs). The average ERR per 100 WLM for cumulative exposures less than 100 WLM based on these studies is 1.0, ranging from 0.8 to 1.6. The average ERR for cumulative exposures greater than 100 WLM is 0.33, ranging from 0.16 to 0.47. The National Research Council report on "Health Effects of Exposure to Radon: Time for Reassessment?" addresses this inverse relationship in detail (NAS, 1994).

ICRP Publication 115 – Lung Cancer Risk from Radon and Progeny

The international Commission on Radiological Protection (ICRP) published an analysis of risk from radon in 1993 (ICRP Publication 65) in which the risk was calculated based on epidemiological data (ICRP, 1993)). After studies subsequent to 1993 showed that the risk of inhalation of radon progeny was approximately twice what had been previously assumed, the ICRP published a re-evaluation of the radon risk in 2010 (ICRP, 2010). The results of several reviews are summarized in ICRP Publication 115, as shown in Table 3-2.

Radon exposures in uranium mines have decreased significantly as protective measures have taken effect. Therefore, epidemiologic studies that focused on lower levels of exposure are more relevant to current conditions than the earlier research that included the much higher levels of exposure prevalent in the early years of uranium mining. The ICRP Publication No. 115 includes an analysis of low exposure and exposure rate studies. The results are summarized in Table 3-3.

NAS Report: Uranium Mining in Virginia (NAS, 2011)

The NAS Report also summarizes the history, exposures, and epidemiologic studies involving uranium mining. As with the BEIR IV, BEIR VI, ICRP No. 115, and UNSCEAR summaries, the conclusion is that high concentrations of the short-lived radon progeny in air represent the greatest health risk to uranium miners. The Virginia Report includes a discussion of other hazards in uranium mining including uranium dust, silica, other carcinogens (arsenic), and physical hazards. However, there is very little epidemiological evidence to quantify the impact of such hazards specific to uranium mining. All mining includes physical and chemical hazards that should be considered part of the risk of uranium mining.

3.1.4 Adverse Health Effects Other Than Lung Cancer

The results of much of the uranium miner data regarding lung cancer risk and radon progeny exposure are summarized in the NAS and UNSCEAR Reports and the ICRP Publication 115 evaluation of radon risk. These studies are not addressed individually in this report since they have been thoroughly reviewed and reported on. However, studies that add significantly to the body of information on uranium mining hazards, particularly in regard to non-lung cancer health outcomes, impacts to millers and communities in the vicinity of uranium recovery facilities, and smoking are discussed in the following sections.

The majority of the uranium miner studies focused on the risk of lung cancer from inhalation of the short-lived radon progeny. However some studies also looked at the potential for other adverse health effects such as heart disease. One of the largest and most recent study involved miners employed by Wismut in East Germany between 1946 and 1990. The follow-up of nearly 59,000 men employed at the Wismut facilities extends to 2003 and includes two million person-years. The total number of deaths to the end of 2003 was 20,920; 6,373 cancers of which 3016 were lung cancers and 3,053 were extra-pulmonary solid cancers (Kreuzer, 2008; Walsh, 2010). The ERR per 100 WLM exposure are given in Table 3-4 for cancers with ERR significantly greater than zero and summarized for other cancers. (Kidney cancer is listed separately because of the accumulation of uranium in the organ and toxicity.)

The risk of death from cardiovascular diseases was also studied in the German Wismut cohort (Kreuzer, 2010). The study showed no increase in either coronary heart disease (ERR/WLM = 0.0003%) or cerebrovascular diseases (ERR/WLM = 0.001%). The authors state that there is no evidence for mortality from cardiovascular diseases. Based on data available for the cohort, most of the miners were heavy smokers (Kreuzer, 2002).

A cohort study of Eldorado Nuclear Ltd workers at Port Hope, Port Radium, and Beaverlodge was published in 2006 (Howe, 2006). The study compared the causes of death for Eldorado workers, including but not limited to miners, to the Canadian population. The Standardized Mortality Ratios (SMRs), i.e., the ratio of the number of deaths in the cohort to the expected number of deaths, were tabulated for specific causes as well as all causes and all cancer. A total of 35 different causes of death were tabulated for the 16,236 males in the cohort with 5148 deaths. The only causes with SMRs greater than 1 were lung cancer at 1.3 (95% CI 1.2, 1.4), hypertensive disease at 1.7 (1.2, 2.3), alcoholism at 1.6 (1.2, 2), motor vehicle accidents at 1.3 (1.1, 1.5), suicide at 1.7 (1.5, 1.9), homicide at (1.9 (1.3, 2.7) and other direct causes at 1.7 (1.5, 1.9). Of the 17 cancer types investigated only lung cancer had a SMR greater than 1. The SMRs for all cancers and all causes were 1 (0.9, 1). The number of women in the cohort was significantly smaller at 5148 with only 184 deaths. The only cause of death for women with a SMR greater than 1 was lung cancer at 1.5 (95% CI 0.9, 2.2). It is not clear whether the excess lung cancers were due to smoking or work-related causes.

A case-cohort study of Czech uranium miners looked at the incidence of leukemia, lymphoma, and multiple myeloma (Rericha, 2006). The relative risks comparing higher radon exposure (110 WLM) to lower exposure (3 WLM) were 1.75 (95% CL, 1.10, 2.78) for all leukemia combined and 1.98 (95% CL, 1.10, 3.59) for chronic lymphocytic leukemia (CLL). Neither non-hodgkin lymphoma nor multiple myeloma were significantly associated with radon exposure. In the past, CLL has not been considered a radiogenic cancer in contrast to acute lymphocytic leukemia (ALL).

A case control study of non-lung solid cancers in Czech uranium miners found a relative risk of 0.88 for all non-lung solid cancers combined and 0.87 for all digestive cancers when comparing 180 WLM of cumulative radon exposure to 3 WLM. The relative risk for kidney cancer was 1.13; 2.39 for gallbladder cancer; and 2.92 for malignant melanoma. No relative risks were statistically significant.

Vacquier (Vacquir, 2008) noted an increased risk of silicosis and kidney cancer deaths in the French cohort of uranium miners. The Standardized Mortality Ratio (SMR) for kidney cancer was 2.0 (95% CL: 1.22, 3.09). The study also showed an excess risk of silicosis in the French cohort of uranium miners. The Standardized Mortality Ratio (SMR) was 712 (95% CL 4.51, 10.69). A recent study of the French uranium miners that included gamma radiation doses as well as radon progeny exposure found an increase in brain and central nervous system cancer (SMR = 2.00 (95% CL: 1.09, 3.35) (Vacquier, 2011.)

A cohort study of uranium miners in west Bohemia showed an increased mortality rate for accidents, homicide, mental disorders, cirrhosis, and non-rheumatic circulatory disease (Tomasek, 1994). Elevated risks of tuberculosis and non-malignant, non-infectious respiratory conditions were noted 25 or more years after the start of mining. The authors related these risks to the general mining conditions and lifestyle.

Samet (Samet, 1984) found an increase in respiratory abnormalities in New Mexico uranium miners. Only the prevalence of dyspnea was related to the duration of uranium mining. Two other spirometric parameters were slightly affected. Twelve of the study participants showed evidence of silicosis.

3.1.5 Effects of Exposures to Toxins Other Than Radon Progeny

Uranium miners are exposed to potential carcinogens other than radon progeny including: uranium, arsenic, silica, and diesel exhaust. Several of the uranium miner studies, discussed below, have considered these other agents.

Smoking and Radon

Smoking has long been known as a confounding factor in studies of lung cancer risk related to radon progeny exposure in uranium miners. The early perception was then, only miners who smoked got lung cancer from radon progeny exposure. However later studies showed an increased risk among non-smokers as well. A cohort of non-smoking uranium miners, employed between 1956 and the early 1900s, who participated in a screening program for lung cancer, showed a relative risk of 29.2 for miners whose cumulative exposure was greater than 1,450 WLM compared to those exposed to less than 80 WLM (Gilliland, 2000).

Effects of Exposures to Uranium

The primary concern with intake of uranium is chemical toxicity as described in the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profile for Uranium (ATSDR, 2011). While natural uranium is an alpha emitter, there are no data to demonstrate conclusively that uranium deposition in the body causes cancer. The NAS document on Uranium Mining in Virginia summarizes the data on uranium toxicity. The International Agency for Research on Cancer (IARC) lists internally deposited alpha emitting radionuclides as Group 1 carcinogens but lists specific radionuclides only if there is "sufficient evidence" in humans. Uranium is not specifically listed as a Group 1 carcinogen by IARC.

While uranium ore dust is present in mines, miner studies show no increased risk of renal disease associated with inhalation of uranium. In contrast, a study of uranium mill workers (discussed further in Section 3.2) showed evidence of renal toxicity (Thun, 1985). Uranium, a heavy metal, is excreted from the body through the kidneys and its chemical toxicity is generally considered to be greater than its radiotoxicity (CNSC). Intake of uranium may result in kidney dysfunction which is indicated by the presence of proteins, enzymes, or glucose in the urine. Kidney dysfunction may be temporary. Kidney toxicity has not been seen at low doses. Insoluble uranium is retained in the lung and produces a radiation dose to the lung tissue. However, due to the much higher radon decay product doses, it is not possible for epidemiologic studies to separate out the fraction of the lung cancers in miners that may be attributable to inhalation of uranium in ore dust. The International Agency for Research on Cancer (IARC) lists internally deposited alpha emitting radionuclides as Group 1 carcinogens but lists specific radionuclides only if there is "sufficient evidence" for human carcinogenicity. Uranium is not specifically listed implying that the evidence for human carcinogenicity for uranium specifically is insufficient to categorize it as carcinogenic to humans.

The Agency for Toxic Substances and Disease Registry (ATSDR) has published a draft revision to the Uranium Toxicity Profile (ATSDR, 2011). The report states that no cardiovascular or gastrointestinal effects have been reported in humans from inhalation of uranium. The report notes that inhalation exposure to uranium has had no effect on hematological parameters but cites a study that showed mortality from lymphatic and hematopoietic tissue effects other than leukemia that may have been due to Th-230. While uranium is nehrotoxic, no increase in mortality due to renal disease was reported for uranium workers. Thun found that uranium mill workers showed a higher excretion of beta-2-microglobulin than a reference group of cement plant workers noting that the "renal effects of chronic occupational exposure to soluble uranium should not be ignored." (Thun, 1985).

The ATSDR review notes that none of the epidemiologic studies of uranium workers showed increased incidence of death due to diseases of the immune system. The review states that it is unlikely that inhalation of uranium "produces a significant effect on reproductive health and that no studies reported effects of uranium on development in humans or animals.

Effects of Exposures to Other Hazardous Agents

Exposure to other hazardous agents in the mine environment is not unique to uranium mining. Epidemiologic data are available for other types of mining; however, epidemiologic studies specifically singling out uranium facilities were not found. These hazards are discussed in the NAS report on Uranium Mining in Virginia (NAS, 2011).

Direct Gamma Radiation

Direct gamma radiation levels in uranium mines are elevated due to the presence of the gamma emitting decay products of U-238, primarily the short lived radon progeny. Dose rates are dependent on ore grade and can range from levels several times background in low grade mines to very high levels that require remote mining such as those found in some Canadian mines. The only demonstrated adverse health impact of exposure to ionizing radiation at occupational levels is increased risk of cancer. It is not possible to separate out the impact of direct gamma radiation from inhalation of radon progeny with regard to lung cancer. However, a Canadian study of Eldorado uranium workers (Lane, 2010) found an EER of chronic lymphocytic leukemia (7.28 per sievert) and bladder cancer (2.83 per Sievert) with direct gamma radiation exposure, but neither of the ERRs were statistically significant. Colon cancer was the only other type of cancer to show a positive ERR (0.31)._All other cancers showed negative ERRs. The paper did not give the range of doses for the miners in the study.

Diesel Exhaust

Uranium miners are often exposed to diesel exhaust, which has been recently reclassified as Group 1, carcinogenic to humans, by the IARC (IARC, 2012). A study of lung cancer deaths among non-metal miners demonstrated an increasing trend of lung cancer mortality in increasing cumulative exposure (Silverman, 2012).

A cohort mortality study consisting of 12 315 underground non-metal miners looked at all causes of death and found standardized mortality ratios (SMRs) for several outcomes to be elevated in the underground compared to state-based mortality rates: lung cancer (1.26, 95% CI 1.09, 1.44), esophageal cancer (1.83, 95% CI 1.16, 2.75), and pneumoconiosis (12.20, 95% CI 6.82, 20.12). Mortality rates for all-causes, bladder cancer, heart disease, and chronic obstructive pulmonary disease were not elevated (Attfield, 2011). This study was confined to non-metal miners because it was considered that radon progeny exposure would confound the effect of diesel exhaust.

Diesel exhaust contains individual substances that have been determined to be carcinogenic (arsenic, benzene, formaldehyde and nickel). In addition, exposure to diesel exhaust can cause irritation of the eyes, nose, throat and lungs. According to the California Office of Environmental Health hazard Assessment, exposure to diesel fumes may exacerbate allergies and "aggravate chronic respiratory symptoms and increase the frequency or intensity of asthma attacks." **(**http://oehha.ca.gov/public_info/facts/dieselfacts.html, accessed 7/18/12).

No data on diesel exhaust specific to uranium mines has been found in the published literature to date. As noted for the Attfield study, it would be difficult to separate the fraction of lung cancers in uranium miners attributable to diesel exhaust from those attributable to radon progeny exposure. Underground uranium mines are very well ventilated to control the concentration of radon progeny.

Silica

The health effects of occupational exposure to respirable crystalline silica have been known for centuries. Silica is a naturally-occurring crystal found in most rock beds. It forms dust during mining, quarrying, tunneling, and other such activities. It is the main constituent of sand. Inhalation of silica dust can cause a variety of adverse health effects including lung cancer, immunologic disorders, renal disease, bronchitis, chronic obstructive pulmonary disease and emphysema. No studies were found to show impacts of silica on reproductive outcome.

Silicosis varies in severity in accordance with the intensity of exposure and the duration. Simple chronic silicosis, the most common form, involves swelling in the lungs and chest lymph nodes leading to trouble in breathing. It results from long-term exposure to low concentrations of silica.

Accelerated silicosis occurs after shorter term exposure to higher amounts of silica and is evidenced by swelling in the lungs with symptoms occurring faster than seen with simple chronic silicosis. Acute silicosis that causes inflammation of the lungs and edema causes severe shortness of breath and low blood oxygen levels results from short term exposure to high levels of silica. Progressive massive fibrosis that causes lung scarring can occur with silica exposure. Silicosis can occur within a year but generally symptoms appear after 10 to 15 years of exposure (NIOSH, 2002: PubMedHealth, accessed July 18, 2012).

Silica is believed to be a carcinogen causing increased risk of bronchogenic carcinoma but the data are confounded by smoking. Gastric and stomach cancer as well as other non-lung cancers have been reported in some studies but most did not adjust for confounding factors. Non-malignant respiratory diseases studies have been published reporting autoimmune disease, chronic renal disease, and subclinical renal changes.

Silica is generally present in hard rock mines such as uranium facilities. Several studies of uranium mines have demonstrated adverse effects of silica exposure. As noted in above, Vacquier (2008) found an excess risk of silicosis in the French cohort of uranium miners with an SMR of 7.12 (95% CL 4.51, 10.69).

Samet (1984) found a significant increase in the prevalence of dyspnea related to the duration of uranium mining. Twelve of the 143 miners studies showed category 1/0 pneumoconiosis compatible with silicosis. In a later study of New Mexico miners, there was no evidence of association between silica exposure and lung cancer risk (Samet, 1994).

Arsenic

Arsenic is commonly present in uranium ore and would be a contaminant in air particulates in underground and surface mines as well as potential particulate releases to the environment. In addition, arsenic may be present in groundwater effluents from uranium recovery facilities.

The ATSDR Toxicological Profile for Arsenic (ATSDR, 2007) provides details on the toxicological properties of arsenic by route of exposure based on human epidemiologic studies and animal studies. The health effects of inorganic arsenic exposure are summarized in Table 6.

There are few uranium miner studies that focus on arsenic. Radon progeny exposure is a confounding factor with regard to lung cancer induced by arsenic. Kusiak reported excess lung cancer mortality in Ontario uranium miners and suggested that the excess mortality may be related to the proportion of miners who are or have been smokers (Kusiak, 1993). The study also noted that part of the excess mortality in the Ontario miners may be due to exposure to arsenic in earlier employment in gold mines. The study showed that the lung cancer mortality from exposure to arsenic increased as the exposure to radon progeny increases and is ”consistent with the hypothesis that the risk of lung cancer from exposure to arsenic is enhanced by exposure to other carcinogens.”.

A case-control study of tin miners in China assessed the lung cancer risk from exposure to arsenic. The results indicated that the miners with the highest cumulative arsenic exposure had a relative risk (odds ratio) of 22.6 (95% CI 4.8, 106.4) compared to miners without arsenic exposure "after adjustment for radon and tobacco exposure" (Taylor, 1989). The Chinese tin miners were known to have high radon progeny exposures.

Accidents and Injuries

Mine safety is a function of the Mine Safety and Health Administration (MSHA). According to data reported by mining companies to the U. S. Department of Labor, the total number of fatalities in metal mines in 2010 was 4. The total number of reported non-fatal injuries was 936 (DOL, 2012). Accident and injury statistics are not available specifically uranium mining.

Other Exposures

No specific data on exposures in the uranium recovery industry other than arsenic were identified.

3.2 Review of Epidemiologic Studies Related to Uranium Millers

There are few epidemiologic studies of uranium mill workers in the literature. The epidemiology is confounded by the fact that many mill workers also worked in the mines at some point in their careers. Uranium miners and millers work under two separate regulatory systems. This results in a disconnect in the manner in which the work environment is monitored. However there are two studies specifically relating to uranium milling; one involving Colorado Plateau millers and one in regard to millers in the Grants, New Mexico mineral belt.

The Colorado Plateau mill worker study evaluated the mortality experience of 1484 men employed for at least one year after January 1, 1940 in the seven mills (Pinkerton, 2004). The results showed mortality from all causes and all cancers was less than the US mortality rate. Non-malignant respiratory disease mortality, e.g., emphysema and pneumonoconioses, was significantly higher than the U.S. population. Non-significant increases in lung cancer, chronic renal disease, and lymphatic and hematopoietic cancer were observed; however, positive trends with employment duration were not seen in the cohort. Workers hired prior to 1955 showed higher mortality from lung cancer and emphysema. The study was limited by the small size of the cohort and lack of smoking data. The authors noted that these limitations rendered conclusion about the increased mortality and mill exposures from this study impossible.

No statistically significant elevation for any cause of death was observed in a cohort of 904 non-miners, employed in uranium mills in the Grants, New Mexico area between 1979 and 2005 (Boice, 2008). Even the 708 millers with the highest potential for exposure to uranium ore showed no statistically significant increase in deaths due to lung cancer or any other cancer of concern with regard to uranium processing. The SMRs for all causes of death and malignant neoplasms for the millers with the highest potential for exposure were 1.00 and 0.94 respectively. The SMR for heart disease was 0.84; for kidney disease (nephritis and nephrosis) was 1.30 but was not statistically significant.

A study of mortality in populations near uranium and vanadium mining and milling operations separated out the mill workers for analysis (Boice, 2007b). As with the Grants study, the SMRs for all causes of death and for malignant neoplasms were less than 1.00.

Boice summarized the SMRs for the three studies, as presented in Table 3-6 (Boice, 2008).

Boice concludes that the data from millers supports the body of evidence that uranium ore and uranium compounds are not human carcinogens. The International Agency for Research on Cancer (IARC) lists internally deposited alpha emitting radionuclides as Group 1 carcinogens but lists specific radionuclides only if there is "sufficient evidence" for human carcinogenicity. Uranium is not specifically listed.

An earlier study of mortality patterns among mill workers found mortality rates were lower than the rates for the US white male population (Waxweiller, 1983). Significant excess risks were found for non-malignant respirator disease and accidents.

3.3 Epidemiologic Studies Regarding Populations in the Vicinity of Uranium Recovery Facilities (Mines and Mills)

The epidemiological information regarding the impact of uranium mining on local communities is sparse. The socioeconomic and health impacts to Navajo communities surrounding and within uranium mining districts have been studied but the confounding factors in those communities such as tobacco use, general economic status, as well as their general health status make it difficult to separate the effects of radiation and other potential health impacts attributable to mining from other factors. Several other studies in uranium mining districts have been published. Other studies of health impacts in areas where uranium has been processed are included in this discussion, recognizing that they are not directly applicable to mining, but may provide some insight into the potential health effects of environmental levels of uranium. In addition, studies have been published regarding uranium in public water supplies not associated with uranium mining or milling.

The Canadian Nuclear Safety Commission conducted a study of health risks of residents of the town of Port Hope, Ontario (CNSC, 2009). While this was not a mining community, it had within its borders two uranium processing facilities: the Port Hope Conversion Facility and the Cameco Fuel Manufacturing Inc. The CNSC reviewed thirteen epidemiological studies comparing the health status of the residents and workers of Port Hope to assess the relationship between occupational and residential exposures and adverse health effects. The studies were a mixture of case-control and cohort studies. The CNSC found no evidence of health effects from past and current uranium and radium industries. Cancer incidence rates were found to be comparable with the general population of Ontario and Canada. Port Hope residents had an excess of lung cancer, particularly among women; however, the rates were consistent with the rest of Northumberland County. The rates of all childhood cancers and leukemia were consistent with the rest of the Ontario population. A large cohort study of approximately 3,000 Port Hope radium and uranium workers found the mortality rates from lung cancer and leukemia, and in fact, all cancers was comparable to the rates for the general male Canadian population. No evidence was seen of excess mortality from kidney disease.

The Colorado Department of Health conducted a study of cancer in central Colorado for the years 1997 through 1999 (CDPHE, 2001). Cancer rates were tabulated by county for the eight counties. The Cotter Corporation uranium mill had been operating in Fremont County since the 1950s. The incidence rate for all diagnosed cancer in Fremont County was slightly below the average rate for the region and for the state of Colorado. The mortality rate was slightly above the rate for central Colorado but nearly identical to the rate for the state. The rates for specific cancers except lung cancer were consistent with the rest of the state and region. The lung cancer rate in Fremont County was the lowest for the eight counties and approximately 60% of the average for the region and the state. The annual average age-adjusted incidence rate for all diagnosed cancers was slightly below the average for the region but slightly above the average for the state. The report is simply a tabulation of data and does not reach any conclusions with regard to the cancer incidence statistics except to note that the cancer mortality rates in Colorado are among the lowest in the United States.

Four studies have assessed adverse health effects in communities with prior uranium mining and milling activities. Three of the studies address mortality only while the fourth looks at mortality and incidence.

A mortality survey was conducted in Karnes County, site of three uranium mills and over 40 operating mines (Boice, 2003c). The numbers of deaths and rates were compared to four control counties in the same region with similar age, race, urbanization, and socioeconomic distribution. SMRs and relative risks were calculated for Karnes County. There was no difference in mortality rates, total cancer mortality rates, or any cancer when compared with the U. S. Population the State of Texas or the control counties.

A similar cancer mortality study was conducted for Montrose County, Colorado spanning the years 1950 to 2000 (Boice, 2007a). Vanadium and uranium had been mined and processed in the county since the early 1900s. Mortality rates between 1950 and 2000 were compared to rates for five similar counties, the state of Colorado and the US as a whole. There were no differences in total cancer rates between Montrose County and the comparison counties or statistically significant increases in death rates for any causes of death likely to be of concern for uranium processing. The lung cancer deaths among males were statistically greater in Montrose County;

however, lung cancer deaths among females were lower than for the comparison counties. The increased lung cancer rate in males is probably associated with underground uranium mining and cigarette smoking.

Uravan, Colorado was a company town built around a uranium mill in the mid 1930s when vanadium was processed. The town was occupied until the mid-1980s when the uranium mill was closed and the site along with the town, remediated. A cohort mortality study of the town residents showed no significant increase in lung cancer among female residents or mill workers (Boice, 2007b). The males who lived in the town and worked in the uranium mines showed a significant increase in lung cancer mortality (SMR = 2.0). No increases in kidney cancer, liver, breast, lymphoma or leukemia or non-malignant respiratory disease, renal disease or liver disease were observed among Uravan residents.

The Grants Mineral Belt, including Cibola County, New Mexico, has been the site of extensive uranium mining and milling. A study of the population found lung cancer mortality significantly increased among uranium miners (Boice, 2010). Cancer mortality was evaluated for the 1950 – 2004 period. Cancer incidence was evaluated for the 1982-2004 time period. Standardized incidence ratios (SIRs) and SMR were calculated for lung cancer, total cancers as well as other cancers. The SMR and SIR for lung cancer in males were elevated as would be expected for miners. The SMR was not significantly elevated among women. The mortality for stomach cancer among women was elevated; however the stomach cancer increase was highest before the uranium mill began operation. The stomach cancer rate subsequently decreased to “normal” levels.

There is no evidence to support an increased risk of adverse health effects among residents of communities where uranium has been mined or milled except for the lung cancer risk due to underground mining.

Boice (2003a, 2003b) conducted several cancer mortality studies in communities surrounding nuclear processing facilities in Pennsylvania where uranium and plutonium fuels were processed. He compared 40,000 cancer deaths in the two counties surrounding the facilities to 77,000 cancer deaths in six control counties (Boice, 2003a). The relative risks (RRs) for specific cancers and all cancers were calculated for three time periods. The RRs were for all cancers were less than 1.0. The RRs for all specific cancers studies were either less than 1.00 (13 of 21) or between 1.00 and 1.10 (8 of 21). There were no statistically significant RRs above 1.00. The RRs for lung cancer and leukemia were 0.95 and 0.91 respectively and were significantly less than 1.00 (probability less than 0.05).

Boice also compared cancer incidence in the eight municipalities nearest the nuclear processing facilities (Boice, 2003b) to Pennsylvania cancer incidence. The standardized incidence rates for cervical, rectal, and bladder cancer were statistically 1.00 or greater. The lung cancer and leukemia incidence rates were not significantly elevated. The SIR for total cancers was 1.02.

These two studies show no evidence of increased cancer risk with proximity to facilities processing uranium and plutonium.

Negative impacts of uranium mining and milling on Navajo lands were reported by Dawson (Dawson, 2011). However, no quantitative data were provided and the report included health effects on miners. No specific health effects on the communities, other than the miners and their families, were quantitatively assessed in this study. Psychosocial effects such as depression and anxiety as well as lung cancer and nonmalignant respiratory disease were reported. Birth outcomes among the Navajo residents of Shiprock, New Mexico were investigated by Shields et al (1992). They found a statistically significant excess of certain group of adverse birth outcomes, including cerebral palsy, hip dysplasia, and stillbirth among women who lived in the vicinity of uranium mines or mill. However, the same statistically significant excess for that same group of outcomes was found among women who worked at a local electrical plant. The authors of the study note the limitations, including small numbers, and conclude that "lack of clear evidence for increased risk to miners should be reassuring."

The studies of the impact of uranium mining on communities reviewed do not address accidents such as the 1979 Church Rock dam failure or the use of uranium waste materials in construction, as was common during the early years of uranium mining and milling. The 1979 Church Rock dam failure resulted in release of 93 million gallons of mine water and 1100 tons of mill tailings to the Rio Puerco River outside of Gallup, New Mexico. No published epidemiologic studies could be found at this point with regard to this event.

3.4 Summary of Existing Studies

Epidemiologic studies conclusively demonstrate that uranium miners have an increased risk of lung cancer due to inhalation of the short-lived radon progeny. The risk is greater with increased exposure. Smoking is a major confounding factor. Individual epidemiologic studies have reported increased risk of other adverse health effects such as leukemia and non-malignant respiratory disease but lung cancer is the only effect consistently demonstrated in all studies. Epidemiologic studies do not demonstrate increased risk of cancer in mill workers with no mining experience. However, a potential increased risk of non-malignant respiratory disease and renal toxicity was observed in one study. No significant human health impacts due to uranium recovery operations were demonstrated in the most recent epidemiologic studies of surrounding communities. Limitations of some of the epidemiologic studies include small populations and lack of adequate exposure data. The miner studies were generally cohort studies with specific radon progeny exposure data for individual miners. Most of the miner studies include exposures incurred during periods when radon concentrations were neither adequately controlled nor measured and may not represent current mining conditions. However, even studies at radon progeny exposures less than 100 WLM show increased risk of lung cancer with risk inversely related to the cumulative exposure indicating that lower exposures may carry a greater risk per unit exposure than higher levels.

The epidemiologic studies involving populations surrounding uranium recovery are, by necessity, ecologic studies, that is, there are no specific individual exposure data. Inferences with regard to exposure are based on location. Since in general, members of the public are not individually monitored, exposure must be presumed based on other factors. The National Academy of Sciences, National Research Council recently published Phase 1 of its Analysis of Cancer Risks in Populations near Nuclear Facilities (NAS, 2012). The NAS document includes several recommendations for this study that might be considered by VDH including an ecologic study of multiple cancer types in populations living near the facilities and a case-control study of cancers in children born near such facilities.

3.5 Local Statistics

The primary human health concern with regard to radiation exposure is an increased risk of cancer. The public is sensitive to this issue. The latent period for solid tumors is ten to thirty years and the latent period for leukemia averages about five years so cancers attributable to new industrial activities such as uranium recovery would not be apparent for a period of years after the start of operations. However, baseline data should be obtained for the cancers of concern with radiation, uranium, and arsenic exposure. Lung, breast, and leukemia cancers are associated with radiation. Kidney, bladder, and liver cancer may be associated with ingestion of arsenic. The National Cancer Institute (NCI) data, reported on the Surveillance, Epidemiology and End Results (SEER) web site, for the US, Virginia, and Pittsylvania County as well as the Virginia Cancer Registry data for these cancers for the Commonwealth and the Pittsylvania/Danville Health District are summarized in Tables 3-8 and 3-8.

The Virginia Cancer Registry data for 2000-2004 show slightly lower incidence rates than the 2005-2009 NCI data.

3.6 Other Potential Adverse Health Effects

While the probability is negligible that radiation from a uranium recovery facility would result in an increase in adverse reproductive effects among members of the public, existing registries for birth defects should be maintained or could be established if Virginia does not have such capability. This would enhance public confidence in the surveillance provided by the Department of Health.

Medical surveillance programs focused on uranium recovery workers and their families will have the highest probability of detecting the effects, if any, of uranium recovery operations on workers and members of the public since they will be the most highly exposed. The details of such a program will be included in subsequent reports.

Environmental monitoring data will be an important factor in demonstrating whether effluent from any potential uranium recovery facility meets health-based state requirements. Therefore, there will not be a need for tracking non-cancer health outcomes.

3.7 Other Potential Toxins Associated With Uranium Extraction

Other toxins and health hazards that could possibly be associated with uranium recovery are listed in Table 3-9. A preliminary assessment of the potential for health and environmental impacts considered whether such impacts are likely. More specific information about the potential exposures will be developed.

4.0 EXISTING REGULATORY PROGRAMS

4.1 Uranium Milling

This section will briefly describe the various processes of uranium milling and how regulations pertinent to them vary.

4.1.1 Types of Uranium Milling

There are three methods used to extract uranium from ore: conventional milling, *in situ* recovery (ISR) and heap leach. Only one conventional mill, the White Mesa mill operated by Denison Mines near Blanding, UT is currently operational. The Cañon City, CO, mill, owned by Cotter Corp., is awaiting decommissioning. A conventional mill proposed by Energy Fuels Resources to be located near Paradox, Colorado, has been licensed, but not yet constructed. That license is presently undergoing litigation.

Six operating ISR facilities in Wyoming and one in Nebraska are regulated by NRC. Others are proposed or undergoing license application. Approximately six ISR facilities operate in Texas. The third method, known as heap leaching has also been used to extract uranium from ore at conventional mills, but no such facilities exist at the present.

Table 4-1, adapted from the NRC website, compares various traits of the three extraction methods.

4.1.2 Regulatory Authority

The NRC has authority over milling of mined materials, in situ processes used to recover uranium, and mill tailings waste. The NRC regulates conventional uranium mills, including heap leach processes, and in situ recovery (ISR) facilities under the auspices of 10 CFR Part 40: Domestic Licensing of Source Material.

The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) amended the Atomic Energy Act to require the NRC to re-evaluate the Agreement State programs for regulation of uranium recovery facilities in effect at the time UMTRCA was passed. Upon application from a state to amend its existing agreement between the NRC and the determination by NRC that the Agreement State's revised program was adequate to protect human health and safety and the environment, the NRC was authorized to enter into an Amended Agreement with a state which allowed a state to continue to regulate uranium recovery facilities. Provisions were included for additional states to enter into such agreements with the NRC.

Following the passage of UMTRCA, four of the five states which had previously licensed and regulated uranium recovery facilities signed Amended Agreements. Colorado, New Mexico, Texas, and Washington signed Amended Agreements; at that time the fifth state, Arizona, relinquished it regulatory authority back to the NRC. New Mexico later relinquished its authority back to the NRC. Subsequently, Utah has signed an Amended Agreement with the NRC.

As discussed in Section 2.3, "Agreement States" are those that have signed a formal agreement with the NRC pursuant to Section 274 of the Atomic Energy Act. Under this agreement the NRC has relinquished regulatory control over certain by-product, source and special nuclear material uses in the state. NRC periodically assesses the compatibility and adequacy of the state's program for consistency with the national materials program for Atomic Energy Act radioactive material. There are currently 37 Agreement States, of which Virginia is one, however, Virginia's Agreement State status does not include the authority to regulate uranium processing.

Virginia has licensing regulations (12 VAC5-481, Part III), recordkeeping and reporting regulations (12 VAC5-481, Part IV, Article 12 and 13), inspection and enforcement regulations (in 12 VAC5-481-110 and statute 32.1-234.1), financial assurance regulations (12 VAC5-481-630), occupational dose limits 12 VAC5-481, Part IV, Article 3), dose limits for members of the public (12VAC5-481, Part IV, Article 4), survey and monitoring regulations (12 VAC5-481, Part IV, Article 6), and liquid waste disposal regulations (12 VAC5-481-920). As a condition of being an Agreement State, Virginia's regulations must be compatible with NRC regulations.

Colorado, Texas, Utah, and Washington have currently effective Amended Agreements with the NRC to regulate uranium recovery facilities in their states. This means that regulations in those states are equivalent to and compatible with 10 CFR Part 40. Periodic reviews of an Agreement State's regulations are conducted to ensure that statutory or regulatory changes have not made the state rules incompatible with 10 CFR 40 and changes that have been made to 10 CFR Part 40 since the state's regulations were initially accepted by the NRC.

4.1.3 The Agreement State Process

In general, the process of becoming an Agreement State includes the following:

- Governor files Letter of Intent with Chairman;
- NRC Office of Federal and State Materials and Environmental Management; Programs (FSME) assigns a Project Manager;
- State develops Draft Request;
- NRC staff reviews Draft Request for completeness;
- State develops Formal Request;
- A Complete Request includes supporting State legislation, regulations, and program description;
- Governor submits Formal Request and certifies State has adequate program;

- NRC staff evaluates request against 1981 and 1983 Criteria for Agreements, using FSME Procedure, SA-700;
- Commission approves publication in the Federal Register for public review and comment;
- NRC staff analyzes public comments;
- Commission approves Agreement;
- Chairman and Governor hold signing ceremony;
- State assumes regulation authority; and
- NRC staff and the State continue post-Agreement exchange-of-information and assessment of program performance.

FSME is responsible for establishing and maintaining working relationships between the NRC and States, local government, other Federal agencies and Native American Tribal Governments. FSME serves as the primary contact for policy matters between NRC and these external groups and it keeps such external groups other NRC offices informed of each other's activities.

FSME publishes a list of program procedures designed to define processes and guidelines associated with Agreement State status.

FSME procedures include the following general headings:

Background (BK);

State Agreements (SA);

State Liaison (SL);

Administrative (AD);

Temporary Instruction (TI); and

Management Directives (MD).

The procedures may be found on the following website: **http://nrc-stp.ornl.gov/procedures.html**.

The NRC process of approving an Agreement State is rigorous and takes several months to complete. FSME has published a "Handbook for Processing An Agreement" to provide guidance for the preparation and review of a State request for an Agreement (FMSE, 2009).

Agreement States are free to present their regulations for uranium mills in any format they desire as long as they are compatible with NRC regulations. The NRC has established a compatibility hierarchy that it uses to define the level of compatibility for each section of NRC regulations.

Table 4-2 shows these compatibility levels and the NRC interpretation of what each means.

The compatibility level that the NRC has determined applies to each section within 10 CFR Part 40 is provided in Table 4-3. For a state to obtain an Amended Agreement for authority to regulate uranium recovery facilities within the state, the state must have regulations in place prior to the signing of the Amended Agreement that meet the compatibility levels shown in the table. The compatibility table can be found at: **http://nrc-stp.ornl.gov/regulationtoolbox/10cfr40.pdf**.

4.1.4 Role of Suggested State Regulations for Control of Radiation in Regulation Development

The Conference of Radiation Control Program Directors (CRCPD) develops and maintains the Suggested State Regulations for Control of Radiation (SSRCR). The SSRCRs provide model state regulations for the regulation of the various types and uses of radioactive materials, other sources of ionizing radiation, and sources of non-ionizing radiation. The purposes of the SSRCRs are to promote uniformity of regulations between states and to provide model state regulations that are more state centric than are some mandatory federal regulations that a state must adopt.

Committees of CRCPD members with resource people from NRC, EPA, Food and Drug Administration (FDA) and other federal agencies develop these model regulations. Once the draft regulations are developed they are sent to NRC, FDA, and EPA for concurrence to ensure that they are acceptable to those federal agencies and do not conflict with federal regulations. Once concurrence is received from the federal agencies, the Board of Directors of the CRCPD approves their publication as an official Part of the SSRCRs.

Part U of the SSRCRs covers uranium recovery operations. Unfortunately, although work on Part U was begun shortly after UMTRCA was adopted, the four states that initially signed Amended Agreements had signed their Amended Agreements before Part U was completed. Because there was no pressing need for the model regulations, work on Part U was not completed.

Recently work on Part U was reactivated and a draft Part U has now been developed and forwarded to the federal agencies for concurrence and subsequent adoption by the CRCPD. This process should be completed in the near future. When Part U is finalized by the NRC and CRCPD it should be used by Virginia, it should be available to assist in the development of regulations if Virginia decides to become an Agreement State for the regulation of uranium facilities.

4.1.5 The Licensing Process

ISR Facilities

There are several NRC documents that help guide the process of licensing a uranium extraction facility. For ISR facilities, NRC FSME, in conjunction with the Wyoming Department of Environmental Quality, Land Quality Division published a Final Generic Environmental Impact Statement, NUREG-1910 (NRC, 2009). NRC Office of Nuclear Material Safety and Safeguards (NMSS) published a Standard Review Plan for In Situ Leach Uranium Extraction License Applications, NUREG-1569 (NRC, 2003a).

Conventional Mills

The most current NRC document associated with conventional uranium mills is the Final Generic Environmental Impact Statement on Uranium Milling, NUREG-0706 (NRC, 1980). This report does not include the changes regarding groundwater protection that were added to 10 CFR Part 40 in the 1980's. There is currently no standard review plan for licensing of a conventional uranium mill, although one is apparently under development. Regulatory Guide 3.5 Standard Format and Content of License Applications for Uranium Mills, Revision 1, was published for comment, but never finalized (NRC, 1977).

CDPHE does not have a formal standard review process for conventional mills, but used an informal internal checklist. Energy Fuels Resources (EFR) whose license with CDPHE is currently rescinded pending a public hearing, created a cross reference checklist to DG-3024. That document is available on the CDPHE website (www.colorado.gov/cdphe).

NRC NMSS published a final report on Environmental Review Guidance for Licensing Actions Associated With NMSS Programs as NUREG-1748 (NRC, 2003b). EFR also created a cross reference checklist to NUREG-1748 that may also be found on the CDPHE website.

4.1.6 Elements of an Environmental Impact Analysis

This section covers the elements of a comprehensive environmental impact analysis (EIA). Public perception of uranium mining and milling in the US has been historically contentious due to several national and international nuclear incidences. Therefore, if uranium mining and milling were to become a proposed action for a site in Virginia, the Commonwealth could require an impact analysis that is comparable to the National Environmental Protection Act (NEPA) analysis. An Environmental Impact Statement (EIS) is required for a uranium mill license by the NRC (Regulatory Guide 3.8, 1982). The first task in an Environmental Impact Analysis (EIA) or EIS would be to set forth a clear and concise purpose and need statement, including areas of interest for each element (such as a watershed, or a five mile diameter). This area would be derived from the applicant or proponent's Environmental Report (10 CFR 51.45) also required by the NRC. A Notice of Intent would then be issued to the stakeholders (public and private entities) based on a proposed action from the proponent. Initially, the lead agency, Virginia, would assemble a team of interdisciplinary experts from their departments, in each resource area. Agencies often use a Third Party Contractor, under an Memorandum of Understanding (MOU), that would assist them in the EIA process. Virginia's physical, biological, socioeconomic and resources would be researched and existing conditions and baselines documented. Concurrently, potential impacts to resources could be compiled from past and future uranium milling and mining issues generated by public meetings and studies such as the National Academy of Sciences National Research Council Study (NAS, 2011). This study addresses a series of detailed questions about uranium mining, processing, and reclamation, and could be the basis of an EIA (see Sect. 2.0, Initial Literature Analysis for more information). After sufficient public and agency input, the project team would develop alternatives to the proposed action (uranium mining and/or milling). Alternatives to the proposed action would need to meet the specific purpose and need set forth. The information herein is intended to provide the VDH examples of the issues and concerns surrounding the potential effects (or consequences) from uranium mining and milling in general, as applied to both human health and the environment. The interdisciplinary team (or project team) would then research and suggest best management practices and/or mitigation methods to minimize the effects of the proposed action.

Table 4-4 presents a condensed, comprehensive overview of suggested elements typical of large-scale NEPA environmental impact statements. The table lists the resources (or elements) that might be affected by the proposed action (Column 1).The second column presents summarized potential issues and concerns that were derived from past public meetings and studies (see Sect. 2.0 of this report). The third column shows potential toxins associated with the impact. The fourth column references applicable national regulations, guidance and standards. The fifth denotes the Virginia department that may oversee, license or permit activities associated with the respective resource. The last column in Table 4-4 lists several best management practices, or design features that could be considered to reduce impacts. As the Virginia uranium studies progresses, the comprehensive elements of an EIA will be clarified and supplemented.

Baseline/Background studies of resources are essential in the EIA process. Studies such as ambient air quality, background radiation in air and soil, ambient water quality in surface and groundwater provide a basis for the long term monitoring of resources, which is a best management practice for many resources. Baseline information already exists for some resources, as documented by the NAS (NAS, 2011). However, a full scale EIA/EIS would require more data.

Impacts to the resources could be analyzed from the issues and concerns expressed in Table 4-4. Initially, the EIA would need to have a predetermined geographical unit, based on the proponent's statement of work and environmental report (10 CFR 51.45). An area of interest might be a watershed (for groundwater resources), a county for socioeconomics or a radius surrounding a specific site. The area of interest is usually determined from the licensing or permit application from the proponent.

The comprehensive EIA is usually divided into Physical, Biological, Socioeconomic and Other elements. Resources associated with these elements are listed below and detailed in Table 4-4.

Physical Elements

The environmental and climatic characteristics of Virginia were well documented in the NAS 2011 Final Report. This study could be used as the basis of the existing environmental descriptions in an EIA. The area of interest is generally within the Piedmont region of Virginia. The Piedmont stretches from the falls of the Potomac, Rappahannock and James Rivers to the Blue Ridge Mountains. The region is 50 miles wide, more or less, and 100 miles in length. At its northern corners are the major cities of Washington, DC and Harpers Ferry, West Virginia; on the southern corners, Charlottesville and Richmond, Virginia. It encompasses the counties of Loudoun, Fauquier, Prince William, Culpeper, Madison, Greene, Orange, Louisa, Albemarle, Fluvanna and Pittsylvania in Virginia.

The following resources would be described in their existing condition, and analyzed for impacts to human health and the environment:

- Geography and Climate;
- Air Quality;
- Geology (including Paleontology, Geologic Hazards, Mineral Resources);
- Soils; and
- Water Resources (including Surface Water, Groundwater, Hydrology, Water Useage, Watershed Health, and Drinking Water).

Biological Elements

The Virginia Department of Game and Inland Fisheries (VDGIF) manages over 203,000 acres for the benefit of citizens. The VDGIF wildlife action plan would need to be reviewed, and consultation on biological resources obtained. If wetlands that are considered Waters of the United States are present on the proposed action area of interest, the DOD corps of Engineers would need to be consulted.

According to the NAS Uranium Study (NAS 2011),

"There are 3,388 native species of plants and animals documented in Virginia (Stein et al., 2000). Of these, 47 animal species and 17 plant species are on the federal endangered or threatened species lists, and 115 animal and 27 plant species are listed by the state as endangered or threatened (Townsend, 2009; Roble, 2010). Based on state criteria, 52 percent of

the natural community types in Virginia are either critically imperiled or imperiled, and another 21 percent are vulnerable; 40 percent are critically imperiled or imperiled and 20 percent are vulnerable according to federal criteria (Fleming, 2010). Mineral extraction related to coal and gravel mining is cited as one of the major threats to conservation (VA DGIF, 2005)."

The following resources would be described in their existing condition, and analyzed for impacts to human health and the environment:

- Wildlife;
- Threatened and Endangered Species;
- Aquatic Wildlife;
- Vegetation;
- Wetlands.

Socioeconomic Elements

Socioeconomic elements were described by Chmura in 2011, and confined to the Chatham Labor Shed, in Pittsylvania County, which is within the Piedmont. An expanded analysis might be necessary for an EIA that include the findings of made Chmura study but apply to a larger area of interest. Virginia's Piedmont is a mix of cities, small towns and rural areas. Livestock and agriculture are plentiful; the area has abundant rivers and lakes and streams; fishing, hunting and water sports are popular pastimes.

The following resources would be described in their existing condition, and analyzed for impacts to human health and the environment:

- Socioeconomic;
- Human Health and Mine Workers;
- Land Use and Public Lands (Wilderness, Parks, etc);
- Scenic or Visual Resources; and
- Environmental Justice.

Other Elements

Other elements of a comprehensive EIA could include resources specific to Virginia. The issues listed below should be considered in a comprehensive EIA:

- short-term uses and long-term productivity;

- irreversible and irretrievable commitments of resources and a cumulative impacts analysis;
- cultural resources;
- transportation;
- noise; and
- wastes, solid and hazardous.

Best Management Practices and Design Features

The proponent, or the entity that proposes uranium mining and milling, includes design features and best management practices in their statement of proposed action. Some of these design features are typical of any construction or mining project, including uranium milling and mining. They help to avoid or minimize environmental effects to the specific resources described below. They could include such items as: safety programs for the worker, dosimetry, radiological monitoring, air quality and storm water permitting, preparation of an erosion and sediment control plans, a noxious weed management plan, a traffic control plan, a health and safety plan, and reclamation plans with specific practices related to the area of interest in Virginia. Also, the use of emerging efficient technologies to reduce emissions could prevent and reduce pollution.

Characterization of baseline conditions prior to permit issuance would set the stage for on-going monitoring. In this case, a statistically designed background or baseline study of radionuclides in air, water and soil could be conducted to use in long term monitoring. These studies help distinguish measured contaminant levels in the future from existing natural background levels; and are essential. Comprehensive and ongoing monitoring during operations could be effective in ensuring that operations are not exceeding standards set forth by regulating agencies.

The measures mentioned above are expected to avoid or reduce impacts associated with various resource aspects of the project. There may be some effects, such those to wetlands, that when impacted, must be mitigated in kind. A comprehensive EIA could include appropriate site modeling and demonstration of the application of best practices for mining and milling projects. This would validate that proposed operations, waste management and reclamation activities would be protective of public health, safety and the environment.

Consultation with other Virginia departments and US Federal agencies is instrumental in defining the existing condition of resources, as well as documenting any regulations and statutes that are already in place to protect the resources. Examples are the Nuclear Regulatory Commission (NRC), the Environmental Protection Agency (EPA), and the Mine Safety and Health Administration (MSHA), and Department of Defense (DOE), Corps of Engineers (Corps), and the existing Commonwealth regulations set forth by the Departments of Environmental Quality and the Department of Mining, Minerals and Energy.

4.2 Uranium Mining

As discussed in Section 4.1, uranium mining may take several forms, either underground in hard rock, in open pits, or using solutions to dissolve soluble ore, called ISR. Regulation of the three forms of mining varies depending on the state or regulatory agency with jurisdiction. For mining activities, the regulatory responsibility depends on the extraction method that the given facility uses. Conventional mining in which uranium ore is removed from deep underground shafts or shallow open pits) is regulated by the Office of Surface Mining, the U.S. Department of the Interior, and the individual States where the mines are located.

4.2.1 NRC Authority

The Atomic Energy Act does not give the NRC the authority to regulate mining. However, NRC defines beneficiation as occurring when ore is sized or ground, which most often happens at a milling facility, not at a mine. With *in situ* recovery (ISR), beneficiation is considered to begin when the ore is separated from the underground strata via injection wells. Hence, NRC regulates ISR, in which uranium ore is chemically altered underground before being pumped to the surface for further processing.

Virginia, as well as other states, has a wide variety of regulations that deal with permitting, operations, reclamation and closure and financial assurance of mines of various types in the state. These regulations are under the purview of the Department of Mines, Minerals and Energy and the Department of Environmental Quality, not the VDH.

A review of radiation control programs for states having a uranium agreement indicates that only Texas has any language regarding uranium mining. The Texas regulatory language is shown below.

> *Texas Exemptions and General Licenses for Uranium*
>
> *§289.251(d)(2)*
>
> *251-2 (September 2004)*
>
> *(2) Any person is exempt from this section and §289.252 [Licensing of Radioactive Material] of this title if that person receives, possesses, uses, or transfers unrefined and unprocessed ore containing source material; provided that, except as authorized in a specific license, such person shall not refine or process such ore. This exemption does not apply to the mining of ore containing source material.*
>
> *289.251(f)(3)(C)*
>
> *(C) A general license is issued to mine, transport, and transfer ores containing source material without regard to quantity. In addition to the provisions of subsection (f) of*

this section, persons who mine, transport, and transfer ores containing source material in accordance with this section shall comply with the provisions of §289.202(n) [Dose Limits for Individual Members of the Public] and (ff) [General Requirements for Waste Management] of this title.

The Texas exception was enacted prior to passage of the UMTRCA to allow the then Texas Department of Health to regulate releases from open pit mines and set standards to regulate contamination in air from mines and potential spilled ore. The regulations could today also be used to regulate radon content leaving a mine site.

4.2.2 EPA Regulations Applicable to Uranium Mining

The EPA public dose standards for the uranium fuel cycle, 40 CFR 190, are applicable to uranium mills but not to mines (40 CFR 190.02(b)). The regulations limit doses to members of the public to 25 mrem per year total effective dose equivalent and 25 mrem per year to any organ except the thyroid, excluding the dose from radon and its progeny (40 CFR 190.10(a)). The cleanup requirements under 40 CFR 192.32 are not applicable to sites in which meet the 5 pCi/g Ra-226 at the surface and 15 pCi/g Ra-226 concentration limits (40 CFR 192.32(b)(2)), i.e., the NRC's 10 CFR 40 release limits. These NRC's cleanup standards for uranium recovery facilities are considered likely Applicable or Relevant and Appropriate Requirements (ARARs) for cleanup conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (Luftig, 1997, Luftig, 1998). In contrast to the NRC decommissioning dose limit of 25 mrem per year, the EPA deems a cancer risk in the range of 10^{-4} to 10^{-6} to be protective for carcinogens under CERCLA. The EPA has concluded that an annual effective dose rate of 15 mrem per year, which equates to a cancer risk approximately equal to 3×10^{-4}, as protective and achievable (Luftig, 1997). The remediation goals were updated to include the benchmark dose cleanup criteria for all radionuclides in the uranium decay series in addition to the Ra-226 concentration criteria as a "potentially relevant and appropriate requirement (Luftig, 2000). While the NRC and the states have the primary responsibility for uranium recovery operations, CERCLA has been implemented at some active and inactive sites such as the Cotter uranium mill in Colorado and the Midnite Mine in Washington State.

5.0 INTERNATIONAL CONSIDERATIONS

The international community has continued evaluating the health risks associated with uranium extraction for many decades. This report reviews lessons learned from several sources that reflect much of the recent thought in this area.

- The International Atomic Energy Agency (IAEA);
- The International Commission on Radiological Protection(ICRP); and
- The World Nuclear Association (WNA).

5.1 International Atomic Energy Agency (IAEA)

Baseline data collection is undertaken to document the conditions at a site prior to activities that alter the environment. Comprehensive baseline data will enable reliable demonstration of future environmental and social impacts. It is only with good baseline data that early detection of deviations from expected or predicted performance can be identified.

In the context of uranium resource extraction, the focus of the IAEA, an internationally-funded organization based in Vienna and involving some 150 nations, is ideally suited to the development of overarching concepts. The IAEA provides both documentation and on-the-ground assistance to member states, with a great deal of its work dedicated to the collection of historical information identifying, defining and illustrating past errors, and the polling of experts to define current best practice. It emphasizes providing bases for sustainable development, for example, and techniques to implement actions using optimal concepts and technologies. Much of the work done by the Agency is focused on developing countries, where resources are limited both at the Agency and in the countries themselves. This focus is also helpful for all member States, encouraging efficient use of funds.

5.1.1 2010 Report on Best Practices: Key Concepts

Recognition and adoption of best practice principles are fundamental cornerstones of sustainable development. Best practice includes consideration of social and environmental aspects, and includes the active search, documentation and implementation of those practices and principles that are most effective in improving performance. Best practice is the development of systems that integrate global and local knowledge. Best practice principles should be applied to every aspect of uranium extraction, from exploration to waste management. The successful application requires long term commitment. Best practices, by nature, are not static but continuously evolve in response to new technology, increased understanding and awareness of environmental and social impacts, and increasing regulatory requirements and public expectations."

Uranium extraction can have both positive and negative environmental, economic and social impacts on communities. Uranium extraction can provide employment and business opportunities to local communities, and may provide the support to remediate legacy sites. However, improperly managed activities can adversely impact the environment, affect the local population, and, in the worst cases, result in severe or catastrophic social and/or environmental impacts as evidenced by many legacy sites still awaiting remediation. Key benefits that result from the application of best practice principles are:

- improved environmental management;
- improved socioeconomic outcomes;
- demonstrated good governance and accountability;
- improved liability management; and
- improved quality control.

As a global society, we have the ability to make development sustainable — to ensure that it meets the needs of the present without compromising future generations. This concept can be broken down into four conditions:

- material and other needs for improved quality of life must be available to this generation;
- considerations should be global, and as equitable as possible;
- ecosystem limits must be understood and respected; and
- the basis on which future generations can meet their own needs must be considered.

This generation should not deplete resources that will be vital to future generations. The environment must not be adversely impacted so as to leave the earth with severe constraints on future human use. This condition imposes constraints on the manner in which uranium resources are developed. Applying best practice guiding principles to uranium extraction requires that each of the four cornerstones of sustainable development are put into practice with the following as key objectives:

1) Environmental aspects:

- promote responsible stewardship of natural resources and the environment, including remediation of past damage;
- minimize waste and environmental damage throughout the whole supply chain;
- exercise prudence where impacts are unknown or uncertain; and
- operate within ecological limits and protect critical natural capital.

2) Social aspects:

- ensure a fair distribution of the costs and benefits of development for all those alive today;
- respect and reinforce the fundamental rights of human beings, including civil and political liberties, cultural autonomy, social and economic freedoms, and personal security;
- seek to sustain improvements over time by ensuring that depletion of natural resources will not deprive future generations. This is accomplished through replacement with other forms of capital; and
- optimize utilization of human resources.

3) Economic aspects:

- maximize human well-being;
- ensure efficient use of all resources, natural and otherwise, by maximizing returns;
- seek to identify and internalize environmental and social costs; and
- maintain and enhance the conditions for viable enterprise.

4) Governance aspects:

- ensure transparency by providing all stakeholders with access to relevant and accurate information;
- ensure accountability for decisions and actions;
- encourage cooperation in order to build trust and shared goals and values; and
- ensure that decisions are made at the appropriate level as close as possible to and with the people and communities most directly affected.

The scope of a baseline data collection program must clearly define the parameters to be understood. The data sets required will be site-specific and timeframe-specific, and the effects of seasonal variation must be evaluated. Baseline analysis includes:

Socioeconomic characterization:

- current and historic land uses;
- archeological and heritage surveys;
- identification of all stakeholders;

- identification of beneficial uses of land and water; and
- documentation of the regulatory regime under which the project would operate.

Environmental characterization:

- hydrological and hydrogeological conditions;
- geological and geochemical characterization;
- flora and fauna surveys;
- climate data;
- soil surveys;
- radiological surveys; and
- contaminated site assessments.

5.1.2 2010 "Best Practices" Report: Key Findings

The IAEA 2010 report on Best Practices provides detailed discussions of the following topics.

- Public/stakeholder involvement
- Impact Assessment
- Risk Assessment
- Design
- Operations/Management
- Waste
- Closure

Stakeholder Involvement

Identifying and successfully engaging stakeholders is a fundamental building block in the development of a successful project. Without stakeholder involvement there is a risk of rejection, potentially leading to an adversarial relationship.

An effective program will actively involve stakeholders in the planning process at all stages. The process goes beyond informing or consulting stakeholders, and facilitates openness and trust among the various parties. The key stakeholders are those who may be affected by the project at any stage such as:

- project operators;

- shareholders;
- owners of the land impacted by the operation;
- surrounding landowners;
- local communities economically dependent on the operation or the land impacted;
- local government;
- regulators;
- employees;
- unions;
- Non-Governmental Organiziations (NGOs);
- contractors; and
- suppliers.

The stakeholder group includes individuals and organizations with vastly different skill sets, technical abilities and expectations. Bringing them together to achieve an outcome that meets most of their expectations is a task requiring specialized skills and significant resources, starting as early as possible is highly desirable. Key points to consider include:

- Selection - participants must represent the identified groups, speaking with their authority. Disruptive, external influencers should be avoided as feasible.
- Timing - engagement begins as early as possible. Quickly establishing objectives will help to ensure a focus on results.
- Commitment - decision makers must actively listen, and must demonstrate action on stakeholder input.
- External constraints (e.g.: time, funds, regulations) should be clearly communicated.
- Participation - expect differing levels of skills/resources. It may be necessary to allocate additional resources (including information and training) to some individuals to allow them to participate on an equal footing.
- Flexibility is required as the project proceeds.

Effective participation needs to be a dynamic, two-way process. Dictating to or informing the public of decisions is not useful stakeholder participation.

It is imperative for project developers to consider the core values, needs and concerns of local communities. There are numerous cases where an authority did not work to secure stakeholder support, and consequently failed. Where there is inadequate engagement with stakeholders, or failure to identify legitimate stakeholders, the following can result:

- delays or cancellation;
- lack of public support;
- loss of public trust;
- media criticism;
- legal action; and
- social conflict and violence.

Sustainable community development planning is another aspect that must be considered and addressed early. However its importance continues throughout the life of the operation and beyond. It may include:

- *Adopting a strategic approach:* Development of activities is linked to long term strategic objectives, and aligned with existing and future community, regional and national plans.
- *Ensuring consultation and participation:* Local communities must be actively involved in all stages.
- *Working in partnership:* Private, governmental, NGO and community organizations bringing different skills and shared interests can achieve more through working together than individually. Partnerships can reduce costs, avoid duplication and reduce community dependency.
- *Strengthening capacity:* Programs that emphasize strengthening of local community, NGO and government capacity are more sustainable in the long term than the simple supply of cash, materials or infrastructure. While infrastructure is often essential, it will be sustained only if a well-designed, long-term participatory process is included.

Stakeholder involvement and consultation requires a communication strategy that addresses the following as a minimum:

- objectives of communication strategy;
- historical issues influencing planning;
- current communication systems, considering the communication environment (e.g., availability of high-speed data connections);
- risks;

- opportunities;
- key issues and concerns;
- key messages; and
- key audiences.

Impact Assessment

The impact assessment (IA) process identifies potential adverse impacts, including populations likely to be disproportionately burdened by the project. This process has evolved into an effective tool for project planning and decision making that supports sustainable development. It is, in general, an organized study of the potential impacts that a proposed project, development or activity may have on the environment. The term "environment" is broad, encompassing living and abiotic components including natural resources, human health and socioeconomic security.

Impact assessment is a process of identification, communication, prediction and interpretation of information to focus on and manage potential impacts (both adverse and beneficial). Impacts are predicted using baseline information and anticipated future conditions. Alternative options are considered, and choices may be identified that reduce overall environmental impact.

Tools for impact assessments range from the relatively simple (e.g.: water load balances) to complex deterministic modeling assessments (e.g.: atmospheric transport modeling). The objective, regardless of the tool, is to identify and quantify impacts and issues. Once issues are identified and addressed, analytical methods applied and impacts forecast, significance is determined. This may involve weighing human values against environmental consequences.

Risk Assessment

Risk is the probability of an adverse effect occurring as the result of an activity or an event. There are a number of formal risk assessment tools used to evaluate the risks and benefits for a range of options being considered. A risk assessment considers a combination of:

- the likelihood of an event occurring;
- the consequences of that event; and
- measures required to reduce the risk (likelihood, severity and/or consequence) to an acceptable level.

The objective of risk management is to provide information to assist decision makers in accomplishing the following.

- Achieving acceptable levels of risk: The benefits from a particular action outweigh potential loss.

- Avoiding unacceptable levels of risk, where the potential loss outweighs the expected benefits, or where the loss magnitude, regardless of likelihood, is such that it cannot be reversed or mitigated.

Three possible outcomes of the screening level risk assessment:

- all potential risks are ruled out;
- some risks are identified, but decisions are made on the basis of the initial risk assessment and no further assessment is required; or
- risks are identified during initial review, and further assessment is required.

Formal risk assessment processes usually require the following actions:

- identify and involve stakeholders;
- establish the context;
- identify and analyze the hazards;
- evaluate the risks and determine acceptability;
- decide to accept or mitigate the risks;
- monitor controls and outcomes; and
- have contingency plans ready.

Sensitivity analysis examines how robust an alternative is to changes in information or assumptions. Such analysis can help to show how the variation of certain parameters can affect the outcome of a decision making process. Excellent tools including the computer code Crystal Ball© are available to help make a sensitivity analysis transparent.

Summary: Risk assessment and sensitivity analysis are fundamental components of the application of best practice principles.

Design

Within an IA, careful consideration should be given to social, environmental and economic impacts of a project. An acceptable design minimizes potential long-term impacts. This is often called Designing for Closure.

Recognizing the impacts of evolving health risk standards, for example, is compatible with the IAEA's Sustainable Development Principles. Those ten principles are:

(1) Implement and maintain ethical business practices and sound systems of governance.

(2) Integrate sustainable development considerations within the decision-making process.

(3) Uphold fundamental human rights and respect cultures, customs and values in dealings with those who are affected by an activity.

(4) Implement risk management strategies based on valid data and sound science.

(5) Seek continual improvement of health and safety performance.

(6) Seek continual improvement of environmental performance.

(7) Contribute to conservation of biodiversity and integrated approaches to land use planning.

(8) Facilitate and encourage responsible product design, use, reuse, recycling and disposal.

(9) Contribute to the social, economic and institutional development of our communities.

(10) Implement effective and transparent engagement, communication and independently verified reporting arrangements with our stakeholders.

Operations and Management

Best practice principles suggest incorporation of an Environmental Management System (EMS).

Two series of International Organization for Standardization (ISO) standards, the ISO 9000 and 14000 series, are particularly relevant in the area of management systems for environmental performance improvement. The ISO 9000 series focuses on quality; the ISO 14000 system implements a commitment to continuous improvement. Compliance requires commitment of personnel at all levels, and may involve the adoption of new technologies and additional employee training. These standards require continuing quality assurance systems, continuing efforts at performance improvement, and regular reporting and re-certification.

Key performance indicators (KPI) are targets that may be either quantitative or qualitative, used to measure performance against objectives or values. Monitoring allows comparison against targets from EMS KPIs, and against other markers. The purpose of monitoring is twofold: 1) to check whether an operation is impacting the environment; and, 2) to determine whether rehabilitation efforts are performing properly. The first is impact or compliance monitoring, the second, performance monitoring.

For impact or compliance monitoring to be meaningful, sufficient baseline data are required. This requirement reinforces the need to collect baseline information early in any proposed development. A correctly designed impact/compliance monitoring program should be able to provide early warning of adverse environmental impacts, and should be teamed with a planned response process.

Performance monitoring checks the effectiveness of remediation work against predicted outcomes. Performance monitoring also provides field-scale data to refine and calibrate models.

Waste

Management systems required for waste products are project-specific. In certain uranium producing regions, a growing number of waste management facilities may suggest interaction in terms of human/environmental health risk. For example, some jurisdictions now plan to access under-utilized waste disposal opportunities at adjacent production sites. This may involve:

- development of regional facilities to focus health and environmental protection resources more effectively; and
- transport of contaminants to a centralized disposal location.

However, regional optimization of waste management is generally not feasible, and each site must manage waste streams which generally include:

- water;
- waste rock;
- process residues; and
- contaminated equipment.

Current best practice for cover system design, optimizing environmental and human health protection, must consider the following questions.

- Why are we going to cover the waste facility?
- What are the issues we are trying to manage/control?
- What do we want the cover to do?
- How will the cover achieve what we want it to do?
- What variables will affect the cover's performance?
- How will we measure whether the cover is performing as required?
- For how long will the cover remain effective?
- Will the cover's performance improve or decrease over time?"

Covers can be broken up into two basic types: wet or dry. Wet covers involve disposal areas covered by a layer of water (e.g. placed in an open pit then flooded, or contained behind a dam designed to hold a water cover into perpetuity). Dry covers vary greatly, from single uncompacted soil covers to multilayered designs incorporating low permeability layers, capillary layers, oxygen consumption layers, plant root protection, rock armor, etc. The choice of design depends on factors which include:

- cimatic conditions;
- hydrogeological conditions;
- acceptable levels of impacts to the receiving environment;
- type of cover system selected;
- availability of proximate resources (capable rock, e.g.);
- physical, geochemical and radiological properties of the material to be covered; and
- physical and geochemical properties of available cover materials.

Closure

Continued stewardship is required to meet the best practice of sustainable development. This includes:

- ongoing monitoring;
- collection and treatment of contaminated water;
- management and storage of water treatment sludge; and
- maintenance of facilities such as water diversion structures, covers, etc.

5.1.3 Occupational Radiation Protection

We present below some key environmental and human health-related concepts developed in an additional IAEA report focused on uranium extraction.

"**Occupational Radiation Protection in the Mining and Processing of Raw Materials**." (IAEA, 2004).

Topics to be considered when evaluating the risks associated with a specific uranium extraction proposal:

- proposed work activities;
- mining leases;
- site, including geology, mineralogy and extraction techniques;
- measures for radiation protection;
- procedures for dealing with accidental releases of contaminants;
- water treatment;
- stockpiles of ore and waste rock;

- overburden;
- estimates of workplace exposures and individual doses for workers;
- impacts on public health and safety; and
- proposed decommissioning plans.

In this context, information is required concerning the following:

- siting or construction (general plan);
- conceptual design of the mining or processing facility;
- siting of tailings and storage facilities for ore and waste rock;
- radiation protection measures;
- methods for monitoring air quality;
- estimates of workplace exposures and individual doses for workers;
- procedures for accident prevention;
- management of effluents; and
- environmental impacts.

Operational environmental and human health risk information requirements include:

- mine or processing facility itself (a detailed description as required by the regulatory body);
- mining methods and engineering controls for radiation protection, including methods of shielding, ventilation and control of air quality;
- description of programs for operational radiation protection, including equipment and facilities;
- estimates of workplace exposures and individual doses for workers
- emergency action plans;
- details of the effluent management system and waste management system;
- transport of processed ore; and
- security measures.

When workplace monitoring, combined with a knowledge of occupancy times, is used for individual dose assessments.

- Locations at which workplace monitors are deployed for measuring contaminant concentrations in air should be selected to be representative of the air breathed by workers, particularly where workers move through areas with differing exposure rates.
- Instrumentation used to measure dose rates and contaminant concentrations should be calibrated and maintained regularly, under a quality assurance program.
- Ambient conditions of humidity and temperature should be monitored, so as to be able to estimate their influence on the results of the dose assessment.
- Where grab sampling is used, it should be demonstrated that the samples are representative of average ambient conditions — as a method, grab sampling is only appropriate in environments for which conditions are known to be generally stable.
- Records of the period of time individuals spend at each work location should be maintained, with the degree of detail specified in operating instructions.
- Even under routine conditions, it may be appropriate to undertake occasional individual monitoring to verify that the results obtained are representative.

Order of application of measures: Control measures including design, quality control, installation, maintenance, operation, administrative arrangements and instruction of personnel should be employed before personal protective equipment is used. In circumstances in which control measures are not sufficient to provide safe working conditions, or in circumstances in which emergency work has to be carried out, protective equipment should be provided, under a detailed storage and use plan, to restrict the exposures of the workers.

A key point: "Adequately designed and properly controlled ventilation systems are the most effective means of minimizing the exposure to airborne radioactive substances in underground mines and in processing plants. In underground mines, surface coatings and/or barriers may also be effective in restricting exposure to radon and its progeny."

5.2 International Council on Radiation Protection (ICRP)

Documents published recently by the ICRP may influence any development of regulations by the state of Virginia to address uranium recovery operations. The ICRP is an international consensus body of radiation protection experts tasked with developing and maintaining an international system of radiological protection. The recommendations of the ICRP are generally adopted by most nations. ICRP recommendations are summarized in the sections below.

5.2.1 ICRP Recommendations - Publication 103

The ICRP's Publication 103 (ICRP, 2007) maintains the basic principles of radiation protection initially recommended in its 1990 Recommendations (ICRP, 1990).

- *Justification:* The benefit of a planned activity involving radiation or a proposed remedial action in an emergency or existing exposure situation must be greater than the detriment.
- *Optimization:* Radiation exposures should be kept as low as reasonably achievable, economic and societal factors being taken into account.
- *Limitation:* Dose limits from planned exposures must be implemented to avoid undue risk to individuals.

Table 5-1 compares the 2007 ICRP recommended dose limits to current radiation protection regulations in the Code of Federal Regulations (10 CFR 20).

The ICRP distributed draft radon protection recommendations in December, 2011 (ICRP, 2011a). The report re-affirms the reference level of 300 Bq/m^3 (8.1 pci/l) for dwellings, and recommends a reference level of 300 Bq/m^3 for the workplace. The draft report cites a detriment-adjusted risk coefficient of 8 x 10^{-10} per Bq-h/m^3 (3 x 10^{-11} per pCi-hr/m^3; 5 x 10^{-4} per working level month) and states that there is no consistent evidence of any excess cancer risk for tumors other than lung cancer due to inhalation of radon decay products. The draft recommendations specific to the uranium mining industry note that exposures should be controlled by the optimization process. The ICRP recommends a dose constraint or optimized dose below a dose limit. The recommendations also include use of real-time monitors and personal dosimeters in situations with high and variable radon concentrations. Periodic monitoring would be sufficient where radon concentrations are low and stable.

NRC Response to ICRP 103 Recommendations

The NRC issued a staff memo to the Commission including recommendations for policy and technical direction (NRC, 2012), in April, 2012. In general, the NRC staff recommends that the Commission approve development of policy and technical information to:

1) update guidance to recognize and use current scientific information models, numerical values, and terminology for radiation exposure;

2) reduce the occupational dose limit for effective dose, lens of the eye, and the embryo/fetus of a declared pregnant worker; and

3) consider the benefits and impacts of increased use of the International System (SI) of units, and the reporting of occupational exposure information by additional categories of users and licensees.

5.3 The World Nuclear Association (WNA): Summary of Guidance and Best Practices

The WNA is an international organization that supports the global nuclear industry. The WNA sees its roles as, 1) raising public awareness of the environmental necessity of nuclear power, 2) fostering cooperation within the world nuclear industry, 3) acting as a global forum and commercial meeting place for leaders and specialists representing all aspects of the industry and, 4) representing the nuclear industry in world forums that shape the policy environment.

Note that the WNA indicates that it interacts with international standard-setting bodies to challenge unbalanced and unwarranted regulation that hinders the beneficial use of nuclear power. The WNA coordinates industry action to surmount impediments that block or hinder efficiency in the responsible mining of uranium and the safe transport of nuclear fuel.

The WNA has produced some documents that are of interest in Virginia's environmental and human health risk evaluation of uranium extraction systems. One of those is policy document "Sustaining Global Best Practices in Uranium Mining and Processing: Principles for Managing Radiation, Health and Safety, Waste and the Environment" (WNA, 2008). Key points are noted in the section below.

5.3.1 Principles for Managing Radiation, Health and Safety, Waste and the Environment

WNA sets out principles for the management of radiation, health and safety, waste and the environment applicable to sites throughout the world (WNA, 2008). In national and regional settings where activities of the nuclear fuel cycle have reached advanced stages of development, these principles already serve as the underpinning for "Codes of Practice" that govern uranium extraction. The principles are equally relevant for operators, contractors, and regulators newly engaged in uranium extraction. Moreover, experience shows that close cooperation among these three parties is a key to successful management of radiation, health and safety, waste and the environment.

The following principles are extracted from a list of the 11 principles presented in the document, with some details provided for those principles that are of interest and relevant to Virginia's evaluation of uranium extraction health and safety.

Principle 1: Adherence To Sustainable Development

This is a principle focused on sound practices for operators.

Principle 2: Health, Safety And Environmental Protection

In all management practices, ensure adequate protection of employees, contractors, communities, the general public, and the environment.

Mining Safety: Ensure safe, well maintained site conditions for the protection of employees and the public from all conventional mining hazards, including those related to airborne contaminants, ground stability and structure, geological and hydro-geological conditions, storage and handling of explosives, mine flooding, mobile and stationary equipment, ingress and egress, and fire.

Radiation Safety: Ensure compliance with the occupational and public standards laid down by the appropriate national and international bodies. In so doing, classify areas according to risk, site personnel and radiation exposure. Plan and carefully monitor employee/contractor doses and radioactive emissions, as well as resulting environmental concentrations and exposure rates. Estimate potential radiological impacts on the public and the environment.

Personal Protective Equipment: Ensure that employees and visitors are provided personal protective equipment (PPE) appropriate for the hazard being controlled and compliant with relevant specifications to control exposure to safe levels. Ensure that relevant personnel remain properly trained on the use and maintenance of this equipment.

Ventilation: Ensure that workplaces are adequately ventilated and that airborne contaminants are minimized in workplaces. Pay particular attention to controlling radon and related radiation exposures in uranium extraction facilities.

Water Quality: Develop and implement site-specific water management practices that meet defined objectives for surface and ground waters (focusing particular attention on potable water supplies). Subject water-quality objectives to periodic review to ensure that people and the environment remain protected.

Environmental Protection: Avoid the pollution of water, soil and air; optimize the use of natural resources and energy; minimize any impact from the site and its activities on people and the environment. In so doing, include considerations of sustainability, bio-diversity and ecological systems in guarding against environmental impact.

Principle 3: Compliance

Ensure that all activities are authorized by relevant authorities and conducted in full compliance with applicable requirements, including in particular the Safety Standard Principles of the International Atomic Energy Agency (IAEA).

Principle 4: Social Responsibility

At all stages of uranium mining and processing, properly inform – and seek, gain and maintain support from – all potentially affected stakeholders, including employees, contractors, host communities, and the general public. Establish an open dialogue with affected stakeholders, carefully consider their views, and provide feedback as to how their concerns are addressed.

Principle 5: Management Of Hazardous Materials

Act systematically to establish and implement controls to minimize risks from such wastes and contaminated materials.

Control and minimize any releases into the environment, using carefully planned strategies that involve pollution control technologies, robust environmental monitoring, and predictive modeling to ensure that people and the environment remain well protected.

Focus particular attention on managing ore stockpiles and potentially significant sources of contamination including waste rock, tailings and contaminated water or soils. For tailings, concentrate special effort on the design and construction of impoundments and dams, and on the application of a recognized tailings management system for operations, monitoring, maintenance and closure planning.

As an integral aspect of mining and processing, characterize ore and waste rock. Consider geochemistry and assess the risk of acid rock drainage.

To the extent practicable, recover, recycle and re-use such wastes and materials, regarding waste disposal as a last-resort option.

Principle 6: Quality Management System

Employ a recognized quality management system – including the quality-assurance steps of Plan, Do, Check and Act (PDCA) – in administering the management of all activities pertinent to radiation, health and safety, waste and the environment.

At all development and operational stages, plan for the management of radiation, health and safety, waste and the environment.

In developing a uranium mining or processing project, prepare a formal Environmental Impact Assessment (EIA) that deals with all questions and concerns related to radiation, occupational and public health and safety, waste and the environment, as well as socio-economic impact.

Apply risk assessment and management procedures to radiation, occupational and public health and safety, waste and the environment.

Principle 7: Accidents And Emergencies

Identify, characterize and assess the potential for incidents and accidents, and apply controls to minimize the likelihood of occurrence. Develop, implement and periodically test emergency preparedness and response plans. Ensure the availability of mechanisms for reporting and investigating all incidents and accidents so as to identify "root causes" and facilitate corrective actions.

Principle 8: Transport Of Hazardous Materials

Package and transport all hazardous materials (radioactive and non-radioactive) - including products, residues, wastes, and contaminated materials - safely, securely, and in compliance with laws and regulations. With radioactive materials, adhere to IAEA Regulations for the Safe Transport of Radioactive Material, relevant IAEA Safety Guides, applicable international conventions, and local legislation.

Principle 9: Systematic Approach To Training

In each area of risk, provide systematic and recurring training to all site personnel (employees and contractors) to ensure competence and qualification; include in such training the handling of non-routine responsibilities. Extend such training, where appropriate, to visitors and relevant persons in communities potentially affected by these risks, particularly focusing on emergency responders. Regularly review and update this training.

Principle 10: Security Of Sealed Radioactive Sources And Nuclear Substances

Ensure the security of sealed radioactive sources and nuclear substances, using the chain-of-custody approach where practicable and effective. Comply with applicable laws, international conventions and treaties, and agreements entered into with stakeholders on the safety and security of such sources and substances.

Principle 11: Decommissioning And Site Closure

In designing any installation, plan for future site decommissioning, remediation, closure and land re-use as an integral and necessary part of original project development. In such design and in facility operations, seek to maximize the use of remedial actions concurrent with production. Ensure that the long-term plan includes socio-economic considerations, including the welfare of workers and host communities, and clear provisions for the accumulation of resources adequate to implement the plan. Periodically review and update the plan in light of new circumstances and in consultation with affected stakeholders.

In connection with the cessation of operations, establish a decommissioning organization to implement the plan and safely restore the site for re-use to the fullest extent practicable. Engage in no activities or acts of omission that could result in the abandonment of a site without plans and resources for full and effective decommissioning, or that would pose a burden or threat to future generations.

5.3.2 Considerations: Worker Health

In Australia all uranium mining and milling operations are undertaken under the Code of Practice and Safety Guide: *Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing* (ARPANSA, 2005) which sets strict health standards for radiation and radon gas exposure, for both workers and members of the public. In Canada the Canadian Nuclear Safety Commission is responsible for regulating uranium mining as well as other aspects of the nuclear fuel cycle. In Saskatchewan, provincial controls also apply concurrently, and set strict health standards for both miners and local people. Similar standards are set in other countries.

At the concentrations associated with uranium mining and milling, radon is a potential health hazard, as is dust. Precautions taken during the mining and milling of uranium ores to protect the health of the workers include:

- Good forced ventilation systems in underground mines to ensure that exposure to radon gas and its radioactive daughter products is as low as possible and does not exceed established safety levels.
- Efficient dust control; the dust may contain radioactive constituents and may emit radon gas.
- Limiting the radiation exposure of workers in mine, mill and tailings areas to levels as low as feasible, that in any event do not exceed the allowable dose limits set by the authorities. In Canada this means that mining in very high-grade ore is undertaken solely by remote control techniques and by fully containing the high-grade ore where practicable.
- The use of continuously-monitoring radiation detection equipment in all mines and plants.
- Imposition of strict personal hygiene standards for workers handling uranium oxide concentrate.
- Employees likely to be exposed to radiation or radioactive materials should be monitored for alpha radiation contamination; personal dosimeters are worn to measure exposure to gamma radiation. Routine monitoring of air, dust and surface contamination is undertaken.

5.3.3 WNA-Related Recommendations/Observations

1) The WNA provides some valuable materials in this context. Of particular note is its position statement on Best Practices in Uranium Mining and Processing (WNA, 2008) waste, and the environment applicable to sites throughout the world. Although the principles hold special relevance for emerging uranium producing countries that do not

yet have fully developed regulations for the control of radiation, health and safety, waste, and protection of the environment, they can provide a good focus for any authorities.

2) The WNA's 11 principles provide a good summation of important considerations in operation of a uranium mining and milling facility.

3) Note: Primarily an industry-oriented organization, the WNA is not a primary source for identification of emerging standards.

4) Therefore, Virginia should instead look upon WNA information as a secondary source for summarizing health risk considerations.

5.4 Summary: Human Health and Environmental Items Recommended to be Considered by VDH, in the Context of the International Community

- Assess the range of air quality, meteorological data collection, and radiological baseline characterization requirements currently employed, recognizing that U.S. "best practice" in this area has not been updated in many years. Consider the development of a more detailed set of specifications that encompass current technology and the need to establish a very detailed baseline understanding of air quality, including radon gas and radioactive particulate air concentrations.
- Consider the periodic application of site-specific data for permitting model verification/validation, to ensure that up-to-date information is available for regulatory evaluations.
- Consider how modeling results should be evaluated and used with respect to permit modifications, providing regulatory staff with the most detailed and accurate information and estimates feasible.
- Consider development of a stakeholder process with goals that include the following:
    - ensure that participants are representative of all groups, and speak with authority;
    - engage participants as early as possible;
    - listen actively, demonstrate actions based on input;
    - communicate external financial constraints; and
    - remain flexible as conditions change.
- Consider the development of regulations that encourage the following operational practices:
    - ue of ISO 9000 standards for quality assurance; and
    - use of ISO14000 standards for continuous improvement, including the measurement of performance against specific objectives or set values/outcomes.
- Consider the fact that adequately designed and properly controlled ventilation systems are the most effective means of minimizing the exposure to airborne

radioactive substances in underground mines and in processing plants. In underground mines surface coatings and/or barriers may also be effective in restricting exposure to radon and its progeny.

- Consider requesting an IAEA Uranium Production Site Appraisal Team (UPSAT) to provide an international perspective during evaluation of the health risks associated with uranium extraction. An UPSAT mission is a peer review by a team of international experts having direct experience in the technical areas specific to the topic. The review is a technical exchange of experience and work practices, and may be targeted on strengthening the development of a firm basis for health risk assessment and radiation protection.

- Consider the need for environmental remediation and decommissioning early in the development process, allowing for organization of activities in such a way that use of natural resources is optimized, waste generation minimized and contamination of environmental media avoided.

- Consider the following principles established by the International Commission on Radiological Protection:
    - Justification: The benefit of a planned activity must be greater than the detriment.
    - Optimization: Radiation exposures should be kept as low as reasonable achievable.
    - Limitation: Dose limits must avoid undue risk to individuals.

- Consider the following principles recommended by the World Nuclear Association:
    - adherence to sustainable development;
    - health, safety and environmental protection;
    - compliance;
    - social responsibility;
    - management of hazardous materials;
    - quality management system;
    - accidents and emergencies;
    - transport of hazardous materials;
    - systematic approach to training;
    - security of sealed radioactive sources and nuclear substances; and
    - decommissioning and site closure.

5.5 International Radiation Protection Association

The recent 13th International Congress of the International Radiation Protection Association held in Glasgow, Scotland, May 13-18, 2012 offered a number of papers that may be relevant to the situation in Virginia. Titles and authors are listed in Appendix A; key papers will be reviewed during the course of the project.

6.0 RECOMMENDATIONS TO VIRGINIA DEPARTMENT OF HEALTH

Some of the recommendations below are based upon the fact that if the moratorium is lifted VDH might amend the current NRC agreement to include uranium milling. If the NRC maintains the authority some of these recommendations will not occur since the NRC will be performing those functions.

If not explicitly stated in a recommendation, VDH should coordinate with the responsible regulatory state agency to assure that recommendations are accomplished.

6.1 Licensing and Agreement State Issues

R**ecommendation L1:** To provide a general license for uranium mining, VDH should consider adding language in the general licenses portion of its regulations for this activity: "A general license is issued to mine, transport, and transfer ores containing source material without regard to quantity. In addition to the provisions of subsection (?) of this section, persons who mine, transport, and transfer ores containing source material in accordance with this section shall comply with the provisions of (the basic radiation protection sections, specify which sections)." This would apply the basic radiation protection standards for mine worker radiation exposures, limit radioactive materials concentrations to air and water, and set radioactive cleanup standards/requirements.

Recommendation L2 The VDH may want to make these some of the Criteria listed in Table 4-3 more stringent by removing certain permitted practices and providing more prescriptive requirements in other cases.

Recommendation L3: VDH may want to evaluate its potential role in the regulation of uranium mining. This role could include evaluating and controlling radioactive emissions from a mine and associated waste rock and over-burden piles and setting standards for the radiological clean up of mine sites.

Recommendation L4: For VDH to effectively regulate uranium milling would require staff with knowledge of and experience in uranium processing and potential impacts. It is recommended that that VDH develop or contract for specialized training in uranium radiation safety operations for some of their staff.

Recommendation L5: VDH should work with other state agencies to clearly delineate lines of regulatory authority. This would be especially important should an uranium mine and uranium mill become co-located.

Recommendation L6: VDH may want to evaluate its potential role in the regulation of uranium mining. This role could include evaluating and controlling radioactive emissions from a mine and associated waste rock and over-burden piles and setting standards for the radiological clean-up of mine sites.

Recommendation L7: It is recommended that VDH explore the NRC Uranium Agreement State process in detail. This would entail meeting with NRC staff and reading guidance documents from NRC that describe the initial process as well as the periodic assessment process.

Recommendation L8: It is recommended that VDH develop and conduct a survey to interview radiation protection program staff of the four uranium Agreement States to assess the manpower that each has devoted to licensing and monitoring specific to uranium production facilities in that state. The state of Texas contains only operating ISR facilities and several conventional mills that are in various states of decommissioning. Colorado and Wyoming have no operating mills. The Cotter Corp. mill in Canon City, CO, is in the process of decommissioning as is the Dawn Mining mill in Washington. Utah has the only operating conventional mill in the country.

Recommendation L9: VDH should contact existing Agreement States to discuss their licensing process for specific types of uranium extraction processes. Any future studies regarding impacts on water should compare the South Texas uranium area and the practices and incidents that have occurred there for a more realistic comparison of what one might expect in the Virginia environment.

Recommendation L10: VDH should conduct a cost-benefit analysis of potential costs associated with the process of becoming an Agreement State and the practice of serving as an Agreement State. It would be beneficial to survey costs in existing Agreement states, adjusting for the size of the uranium extraction industry and the type of recovery utilized in each state.

Recommendation L11: Several acts have been passed by the Colorado General Assembly in the past few years that have been geared toward regulating a specific facility. These have placed the state as potentially being incompatible with NRC regulations. VDH should consult with staff of Colorado Public Health and Environment Radiation Management Unit for their perspective on the legislation.

6.2 Human Health

6.2.1 Workers

Recommendation H1: In order to give VDH the authority to regulate radiation doses to mine workers, releases of radioactive materials from the proposed mine and other mines that may be developed, and to set standards for radioactive cleanup at the surface of mines, VDH may want to consider changing its equivalent of 10 CFR Part 40.13(b) to state that uranium mining itself is not exempt. This could be accomplished by adding the sentence, “This exemption does not apply to the mining of ore containing source material.” Removal of the exemption has been approved by the NRC in another state with an Amended Agreement.

Recommendation H2: Dust inhalation may impact human health, most likely to a greater degree than radionuclides. Explore including a license condition requiring PM-10 sampling at the plant boundary co-located with radon and air particulate monitors. This is not required by NRC regulation or, to the best of our knowledge, any state radiation regulations.

Recommendation H3: Consider implementing a program of medical monitoring for mine and mill workers and their families. (Specific recommendations will be developed and will be forthcoming in a later report.) The rationale for this recommendation is that if there are any non-radiological short-term impacts to be seen in workers and members of the public (e.g., kidney damage), a medical monitoring program for the individuals potentially most highly exposed could be effective. Long term effects such as increased risk of lung cancer would not be seen for at least fifteen years. An evaluation of the potential of cancer studies in uranium miners detecting any effect concluded that "the ability of any study to detect an excess risk of lung cancer from working in today's uranium mines would be so low the results would be meaningless" (SENES, 2003).

Recommendation H4: Because Virginia's regulations must be compatible with NRC requirements, the occupational dose limit in state regulations cannot be lower than the 50 mSv (5 rem) per year 10 CFR 20 dose limit. Given the fact that radiation doses for uranium recovery operations rarely exceed 10 mSv (1 rem) per year, an ALARA constraint could be included as a license condition to reflect the ICRP occupational dose limit of 20 mSv (2 rem) per year and the ICRP recommendations with regard to constraint limits.

Recommendation H5: Because diesel fumes have recently been reclassified as a Class 1 carcinogen by IARC, it is recommended that VDH tabulate existing data from the literature or conduct diesel fume sampling at existing mines in Virginia.

6.2.2 General Public

Recommendation H6: VDH should consider baseline health studies of the population in the vicinity of any proposed uranium recovery facility. Depending on environmental monitoring data, such studies should continue should such a facility become operational. The potential for adverse health effects attributable to a uranium recovery facility is very low based on the studies that are reviewed in Section 3.2. However, public perception is an important issue that should be addressed. Mine and mill worker health effects would be tracked though occupational health and safety requirements.

6.3 Environmental

6.3.1 Drinking Water – Including Private Water Wells

Recommendation E1: It is recommended that VDH consider creating a system for sampling of private water wells. Each well owner could be assigned a password or code to identify their results which would be posted on the web, independent of well location.

Recommendation E2: An inventory of all private water wells within 5 miles of the Coles Hill site should be conducted. These wells should be sampled for at least one year prior to any uranium mining at the Coles Hill site. The standard suite of analyses, as specified in 10CFR40 Appendix A should be performed on ground waters. Collected data should also include depth to water, total well depth, well yield and *in situ* water temperature. VDH should work with other agencies to conduct a similar inventory and analysis for all wells in the potentially affected area that used as sources for public water supplies.

Recommendation E3: To create transparency in the process of licensing and regulating a potential uranium mill, should the moratorium be lifted, VDH should consider creating and maintaining a web-based system to tabulate results of waterworks sampling results by milling licensees, VDH and other entities. The results should be continuously available to the public.

Recommendation E4: VDH should consider requirements for characterization of baseline water conditions prior to issuing any mine. These baseline studies should include but not necessarily be limited to natural occurring constituents and radionuclides identified in State drinking water standards and NRC regulations identified in 10 CFR Part 40, Appendix A, Criterion 5. This requirement is important to enable an understanding of potential future environmental concentrations and potential impacts, and will also help to distinguish measured contaminant levels in the future from natural levels.

Recommendation E5: Consideration should be given to performing sampling in keeping with recommendations for preoperational sampling found in the current version of NRC Regulatory Guide 4.14. Although Reg Guide 4.14 is reportedly under revision into three sections, one each for conventional milling, *in situ* leaching and heap leach recovery, the current guide recommends preoperational water sampling by a potential licensee of any type of site as follows:

- Groundwater samples that may be used for drinking water by humans or livestock or for crop irrigation should also be analyzed for suspended natural uranium (U-nat), Th-230, Ra-226, Po-210 and Pb-210.
- Surface water samples from ponds or other impoundments should be analyzed quarterly for U-nat, Th-230 and Ra-226 and semiannually for Pb-210 and Po-210. Samples should be analyzed separately for dissolved and suspended radionuclides.
- Surface water samples from streams should be analyzed monthly for U-nat, Th-230 and Ra-226 and semiannually for Pb-210 and Po-210. Samples should be analyzed separately for dissolved and suspended radionuclides.

While this sampling is generally performed by the license applicant and operator, independent sampling by VDH or VDEQ would provide a clear baseline for public understanding of natural radionuclides in the environment should the mining moratorium be lifted. An alternative to

VDH performing the sampling would be for VDH to direct a potential licensee to sample and split samples with VDH for independent analysis.

6.3.2 Recreational Water

Recommendation E6: VDH should consider sampling of any recreational water bodies that might be impacted by uranium mining or milling. Those results should be publicly available and compared to any applicable standards.

6.3.3 Gamma Exposure Rate

Recommendation E7: NRC Regulatory Guide 4.14 requires that a licensee make gamma exposure measurements to establish a baseline gamma field prior to mill construction and if possible, prior to mining. Measurements are required at 150-meter intervals in each of the either compass directions out to a distance of 1,500 meters from the center of the milling area, as well as at sites chosen for air particulate samples.

As mentioned above, Regulatory Guide 4.14 is in the process of being revised for conventional milling, in situ leaching and heap leach extraction facilities. Recent advances in technology that allows more or less continuous gamma measurements coupled with GPS location processing have made it feasible to conduct more thorough exposure mapping to establish the background of the mining or milling area prior to construction or operational activity.

VDH should consider making a series of gamma exposure measurements of the vicinity of Coles Hill prior to any action being taken that might increase background levels.

6.3.4 Animal Health and Food Production

Recommendation E8: VDH, or another agency, perhaps VDACS, may be called upon to monitor food stuffs to ensure that they are safe. A baseline study should be conducted prior to any uranium mining in the area. Once a specific site is chosen VDACS will most likely be able to identify what crops are being grown for human and animal consumption near a planned facility. Plants, including pasture land grasses, would need to be monitored for uptake from the soil and from deposition of radioactive airborne contaminates. Milk from cows, goats, and sheep used for drink and the making of cheese should be included in the sampling and analysis plan. Constituents of the sampling should include uranium and uranium decay products, namely Th-230 and Ra-226.

6.3.5 Environmental Impact Analysis

Recommendation E9: An EIA would be initiated by the NRC unless Virginia becomes an Agreement State (see Section 6.1). If Virginia becomes an Agreement State, VDH, in conjunction with other Commonwealth departments, should initiate an EIA, by using the NRC's NEPA process as a guideline. The NRC has a Generic EIS (GEIS) for in situ uranium recovery facilities that encompasses the NEPA process. The NRC Regulatory Guide 3.8 provides instructions for the preparation of environmental reports for uranium mills in order to comply with 10 CFR Part 51 (NRC, 1982). NRC Guide 3.8 advises the applicant (or proponent) to consider the cumulative or synergistic effects of uranium mining activities where the mine site is in the vicinity of the mill site. The first step of the process would be to form an interdisciplinary team made up of specialists that represent the various departments of Virginia (made up of representatives from VDH, VDEQ, VDMME, and others) in order to set forth a clear statement of purpose and need for the scope of the proposed action. This process would culminate in a reasonable scope for the EIA. Public involvement should be robust, and stakeholders should be identified and notified throughout the process. Background and baseline studies of air, soils, surface and groundwater and other resources would be initiated by the team. Concurrently, information based on public input and previous studies would be used to formulate issues of concern. The issues would then be analyzed by resource experts, and best management practices (BMPs), design or mitigation would be recommended. The EIA should be disclosed as a public document, where issues and concerns are addressed. Virginia (or NRC) could then decide on whether to approve and carry forth the proposed action. Table 10 provides further details the elements of a comprehensive EIA.

7.0 SUMMARY OF FINDINGS

Consideration of a potential lifting of the moratorium on uranium mining in Virginia does not affect regulations of the Department of Health directly since VDH does not have a role in regulating mining itself. However, should uranium resources in the state be developed, VDH will be central to development of regulations to govern uranium milling or extraction by other means. Uranium milling and *in situ* recovery are regulated by the U.S. NRC under 10 CFR Part 40 or by states that have agreed to use regulations compatible with 10 CFR 40.

Whether NRC or Virginia were to regulate milling activities, there would be organizational and fiscal impacts to the state. The Agreement State process is relatively rigorous and would require that staff be devoted to both the development and maintenance of the agreement between Virginia and NRC and the actual regulation of the milling activity.

The decision to become an Agreement State requires an understanding of the process as well as the potential impacts to the state in terms of regulations required and potential costs. It is recommended that VDH contact other Agreement States to gauge their experience in both transitioning to Agreement State status and to operating as an Agreement State. These findings would need to be normalized by the size of the state's uranium production industry.

Because of the very public and political nature that results from consideration of lifting of the uranium mining moratorium, it is recommended that VDH take steps to make data available to characterize the existing environment of the state, particularly with regard to water. A publicly available website that houses existing data would allow a baseline representation of water conditions relative to current standards.

Besides issues associated with environmental releases, concerns about potential public health impacts also need to be addressed. Potential toxic releases from mines and mills should be evaluated to assess the possible public health impacts. Any data that is currently available to describe "background" levels of such potential toxins should be compiled.

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TABLES

Table 2-1 Characteristics of Four Conventional Uranium Mills in Texas

Conventional Mill	Size of Tailings Ponds	Process	Ore Capacity
Susquehanna-Western Falls City – UMTRA Site	7 tailings ponds totaling 146 acres*	Acid Leach	1,000 tons per day
ExxonMobil Ray Point	50 acres	Alkaline Leach	1,000 tons per day
Conoco Conquista	250 acres	Acid Leach	1,750 tons per day
Rio Grande Resources Corporation (formerly Chevron Panna Maria)	290 acres	Acid Leach	2,500 tons per day

*The Falls City mill processed 2.72 million tons of ore, second only to Ambrosia Lake, New Mexico among the Title I sites. This produced the largest disposal cell volume among the Title I sites of 5.8 million cubic yards.

Table 3-1 Excess Risk of Lung Cancer in Miners

Cohort	Average ERR Per 100 WLM (95% CL)	Mean Cumulative Exposure (WLM)	Main Potential Confounders
Colorado Plateau	0.42 (0.3, 0.7)	807.2	Exposure uncertainty; other hard rock mining; smoking
Ontario uranium miners	0.89 (0.5, 1.5)	30.8	Other hard rock mining; smoking
Czech uranium miners	1.6 (1.2, 2.2)	70	Exposure uncertainty in early years; smoking
Swedish iron miners	0.95 (0.1, 4.1)	80.6	Exposure uncertainty; smoking
Beaverlodge uranium miners	0.96 (0.56, 1.58)	23.2	Exposure uncertainty; smoking
Wismut uranium miners	0.21 (0.18, 0.24)	242	Exposure uncertainty (especially prior to 1966); smoking; arsenic; asbestos
Port Radium uranium miners	0.37 (0.23, 0.59)	174.2	Exposure uncertainty; smoking
French miners	0.8 (0.3, 1.4)	36.5	Exposure uncertainty prior to 1956; smoking
Newfoundland fluorspar miners	0.47 (0.28, 0.65)	378	Exposure uncertainty; smoking; high dust levels
Chinese tin miners	0.16 (0.1, 0.2)	277.4	Exposure uncertainty; smoking; arsenic; age at exposure

Table 3-2 Summary of Excess Relative Risk per 100 WLM from Combined Analyses (adapted from ICRP No. 115)

Reference	No. of cohorts	ERR/100 WLM
BEIR VI (NAS, 1999)	11	0.59
UNSCEAR (2009)	9*	0.59
Tomasek et al (2008)	2	1.60

*Discrepancy between UNSCEAR and ICRP 115 cohort number is not explained.

Table 3-3 ERR per WLM for Low Exposure Level Studies (adapted from ICRP No. 115)

Reference	Cumulative Exposure	ERR per 100 WLM (95% CI)
NAS (1999)	<100 WLM	0.81 (0.30, 1.42)
BEIR VI (NAS, 1999)	<50 WLM	1.18 (0.20, 2.53)
Howe (2006)	Mean 85 WLM	0.96 (0.56, 1.56)
Kusiak (1993)	Mean 31 WLM	0.89 (0.5, 1.5)
Vacquier (2008)	Mean 17 WLM	2.0 (0.91, 3.65)
Tomasek (2008)	Mean 47 WLM	2.7 (1.7, 4.3)

Table 3-4 Excess Relative Risk for Lung Cancer and Extra-pulmonary Solid Cancers

Cancer Site	ERR per 100 WLM (95% CL)
Lung	0.197 (0.170,0.224)
Stomach	0.022 (0.001, 0.042)
All extra-pulmonary	0.014 (0.006, 0.023)
Pharynx, Tongue/mouth, liver, non-hodgkin, rectum, larynx, gallbladder, bladder, kidney, colon, multiple myeloma, leukemia, prostate	ERR greater than zero but non-significant.
Pancreas, brain, esophagus	ERR less than zero
Kidney (potential due to uranium toxicity	0.017(-0.023,0.058
Pharynx	0.16 (-0.042,0.367)
Tongue/mouth	0.045 (-0.085, 0.175)
Liver	0.044 (-0.008, 0.095)

Table 3-5 Summary of Observed Health Effects of Arsenic

Organ System	Inhalation	Ingestion	Dermal
Respiratory	Irritation to the mucous membranes; laryngitis, bronchitis or rhinitis; increased mortality due to respiratory disease reported in arsenic-exposed workers	Effects with acute oral poisoning but not widely associated with oral ingestion of low arsenic doses	No studies in humans
Cardiovascular effects	Peripheral vascular disease (Raynaud's phenomenon); increased blood pressure; increased risk of mortality from cardiovascular disease	Heart disease; damage to the vascular system (Blackfoot Disease	No studies in humans
Gastrointestinal effects	Nausea, vomiting and diarrhea with acute arsenic poisoning not typically associated with inhalation	Nausea, vomiting, diarrhea observed in short-term, high-dose exposures	
Hematological Effects	No effects	Anemia and leukopenia	No studies in humans
Hepatic effects	No evidence of effect	Liver damage	No studies in humans
Renal effects	No kidney effects	No clinical signs of significant renal injury	No studies in humans
Dermal effects	Dermatitis; hyperpigmentation	Generalized hyperkeratosis and formation of warts or corns on palms and soles; hyperpigmentation	Contact dermatitis
Ocular Effects	Chemical conjunctivitis	Periorbital swelling; facial edema.	No studies
Immunological effects	No abnormalities in serum immunoglobin but serum levels of other proteins elevated	No studies	
Neurological effects	Peripheral neuropathy	Encephalopathy at acute high dose exposures; chronic low level exposures peripheral neuropathy	
Reproductive effects	No human studies	Increase in spontaneous abortion	
Developmental effects	Increased incidence of spontaneous abortion and increased incidence of congenital malformations	Not extensively investigated; chronic exposure associated with low birth weight; potential increase in lung cancer risk from exposure in utero	
Cancer	Lung cancer	Skin cancer; bladder, kidney, liver, lung and prostate	No studies in humans

Table 3-6 Summary of Selected SMRs for Uranium Miller Studies

Cause of Death	Grants, NM SMRs (Boice, 2008) (95% confidence limits)	Uravan, CO SMRs (Boice, 2007b)	Colorado Plateau (Pinkerton, 2004)
All causes	1.00 (0.87-1.14)	0.80 (0.69-0.92)	0.92 (0.86-0.99)
All malignant neoplasms	0.94 (0.71-1.22)	0.83 (0.62-1.11)	0.90 (0.78-1.04)
Bronchus, Trachea, and Lung	0.88 (0.52-1.38)	1.26 (0.81-1.87)	1.13 (0.89-1.41)
Bone	0.00 (0.00-34.7)	0.00 (0.00-39.3)	Not given
Lymphatic	0.69 (0.19-1.77)	0.55 (0.11-1.60)	1.12 (0.69-1.71)
All heart disease	0.84 (0.65-1.08)	0.76 (0.58-0.97)	0.84 (0.75-0.94)
Non-malignant respiratory disease	1.22 (0.78-1.81)	0.99 (0.63-1.47)	1.43 (0.65-1.05)*
Nephritis and nephrosis	1.30 (0.27-3.79)	1.09 (0.23-3.19)	

*as reported in Boice; obvious error in upper confidence limit

Table 3-7 Comparison of Cancer Rates for Pittsylvania County with US and Virginia Rates (2005-2009)

Cancer Site	Death Rate*			Incidence Rate **		
	US	Virginia	Pittsylvania County	US	Virginia	Pittsylvania County
All cancers	178.7	183.2	212.8	465.0	451.5	497.9
Lung and Bronchus	50.6	53.1	60.3	67.2	67.5	77.9
Female Breast	23.0	24.8	26.9	122.0	124.2	115.7
Leukemia	7.1	6.9	8.1	12.4	10.3	11.9
Kidney and Renal Pelvis	4.0	4.0	8.0	15.6	14.6	17.8
Bladder	4.4	4.1	No data (3 or fewer cases)	21.1	18.9	24.4
Liver and Bile Duct	5.5	5.0	No data (3 or fewer cases)	6.6	5.7	4.6

*Annual death rate – deaths per 100,000

** Annual incidence rate – cases per 100,000 population per year

Table 3-8 Cancer Incidence Rates for Pittsylvania/Danville Health District (2000-2004) Virginia Cancer Registry

Cancer Site	Incidence Rate *		
	US (NCI data)	Virginia (VCR data)	Pittsylvania/Danville Health District (VCR data)
All cancers	465.0	432.2	457.2
Lung and Bronchus	67.2	65.1	72.5
Female Breast	122.0	121.9	123.1
Leukemia	12.4	8.9	8.3
Kidney and Renal Pelvis	15.6	11.7	11.6
Bladder	21.1	18.5	18.7
Liver and Bile Duct	6.6	3.8	3.2

* Annual incidence rate – cases per 100,000 population per year age adjusted to 2000 US population.

Table 3-9 Potential Health Risks Associated With Uranium Mining and Milling (+ possible impact, - unlikely impact, u unknown impact)

Toxic material	Worker	Population	Water	Air	Plants	Animals
Uranium (radiological or chemical effects)	+	+	+	+	u	u
Radium (radiological effects)	+	+	+	+	u	u
Silica	+	-	-	+	-	-
Diesel Emissions , /Diesel Particulate Matter	+	-	+	+	-	-
Physical Injury	+	-	-	-	-	-
Electrical Hazards	+	-	-	-	-	
Noise and Vibration	+	u	-	-	-	-
Nitrogen Oxides, Explosive Gases	+	-	-	-	-	-
Carbon Monoxide	+	-	-	-	-	-
Welding, Metalworking fluids	+	-	-	-	-	-
Arsenic	u	u	u	u	u	u
Vanadium	u	u	u	u	u	u
Selenium	u	u	u	u	u	u
Iron	u	u	u	u	u	u
Mold-related Illness (blastomycosis/histoplasmosis)	+	-	-	-	-	-
Sulfuric Acid	+	-	u	-	-	-
Sulfur Dioxide	u	u	u	u	u	u
Acrylamide or Polymeric Flocculants	+	u	u	u	u	u
Tertiary Amines	u	u	u	u	u	u
Decanol	u	u	u	u	u	u
Kerosene	u	u	u	u	u	u
Sodium Hydroxide/Hydrogen Peroxide/Ammonia	u	u	u	u	u	u
Lead	u	u	u	u	u	u
Dust/Particulate NOS	+	u				

Table 4-1 Comparison of Conventional Mill, Heap Leach Facility and In Situ Recovery Facility

Feature	Conventional Uranium Mill	Heap Leach Facility	In Situ Recovery Facility
Recovery Method	Physical and chemical process to extract uranium from mined ore.	Physical and chemical process to extract uranium from mined ore that has been piled in a heap.	Chemical process to extract uranium from underground deposits.
Siting/Location	Generally located in the vicinity of the ore body. Mined ore can be trucked from the mine to the mill. The mine can be either a deep underground shaft or a shallow open pit. The NRC does not regulate the mining of ore.	Generally located in the vicinity of the ore body. Mined ore can be trucked from the mine to the mill. The mine can be either a deep underground shaft or a shallow open pit. The NRC does not regulate the mining of ore.	The well field area is located within the ore body. The processing plant is typically in the vicinity of the ore body.
Surface Features	Mill building(s), process tanks, tailings impoundment, and evaporation ponds	Process buildings, heap pile consisting of ore crushed to a size of approximately 1-inch in diameter, with an engineered liner system beneath the heap pile and liquid application on top of the pile	Well field(s) consisting of groundwater injection and extraction wells, header house(s), pipes, processing facility, storage or evaporation pond(s), and deep injection wells for liquid waste
Approximate Size	Impoundments are limited to 40 acres in size; however, a facility can have multiple impoundments and typically total on the order of hundreds of acres	Heap piles are limited to 40 acres in size; however, a facility can have multiple piles and typically total on the order of hundreds of acres	Thousands of acres
Wastes Generated	Mill tailings, a sandy material left over from the crushing process, disposed of within an impoundment; pipes, pumps, and other process equipment that cannot be decontaminated	Heap pile remains in place after processing; pipes, pumps, and other process equipment that cannot be decontaminated	Liquid waste, which is disposed of in a deep disposal well or through an evaporation system; pipes, pumps, and other process equipment that cannot be decontaminated are sent to an NRC-licensed facility for permanent disposal
Decommissioning	Buildings, final cover system installed over tailings pile, groundwater monitoring	Demolition of site buildings, final cover system installed over heap pile, groundwater monitoring	Restoration of groundwater, decommissioning of injection wells, removal of pipes and processing building
Status at End Use	Site permanently transferred to U.S. Department of Energy (DOE) for long-term care; annual inspections performed	Site permanently transferred to DOE for long-term care; annual inspections performed	Site released for unrestricted use when cleanup criteria are met

Table 4-2 NRC Categories of Compatibility and Explanation of Their Meanings (adapted from FSME, 2009)

COMPATIBILITY CATERGORY	EXPLANATION OF CATERGORY	COMMENTS
A	Basic radiation protection standard or related definitions, signs, labels or terms necessary for a common understanding of radiation protection principles. The State program element should be essentially identical to that of NRC.	
B	Program element with significant direct transboundary implications. The State program element should be essentially identical to that of NRC.	
C	Program element, the essential objectives of which should be adopted by the State to avoid conflicts, duplications or gaps. The manner in which the essential objectives are addressed need not be the same as NRC, provided the essential objectives are met.	
D	Not required for purposes of compatibility.	
NRC	These are NRC program elements that address areas of regulation that cannot be relinquished to Agreement States pursuant to the Atomic Energy Act or provisions of 10 CFR regulations. The State should not adopt these program elements.	
H&S	Program elements identified by H&S are not required for purposes of compatibility; however, they do have particular health and safety significance. The State should adopt the essential objectives of such program elements in order to maintain an adequate program.	The NRC reviews of proposed State regulations appear in many cases to consider the H&S category as one in which the regulations must be identical to those of the NRC with little latitude for deviation in the wording.

Table 4-3 NRC Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10CFR Part 40 Compatibility Table, November 11, 2011)

NRC REGULATION SECTION	TITLE	LEVEL OF COMPATIBILITY	ANALYSIS	COMMENTS
General Provisions				
Sec.				
40.1	Purpose	D		
40.2	Scope	D		
40.2a	Coverage of Inactive Tailings Sites	A – States with authority to regulate U mill activities D – States without authority		
40.3	License Requirements	C		
40.4	Definitions	A through D, H&S, NRC		Level of Compatibility Depends on Word or Phrase Being Defined
40.5	Communications	D		
40.6	Interpretations	D		
40.7	Employee Protection	D		
40.8	Information collection requirements: OMB approval	D		
40.9	Completeness and accuracy of information	D		
40.10	Deliberate misconduct	C		
Exemptions				
40.11	Persons using source material under certain Department of Energy and Nuclear Regulatory Commission contracts.	B		
40.12	Carriers	B/NRC		
40.13	Unimportant quantities of source material	B/NRC		
40.14	Specific Exemptions	D		See Note 1
General Licenses				
40.20	Types of licenses	C/D		
40.21	General license to receive title to source or byproduct material	C		See Note 2

Table 4-3 NRC Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10CFR Part 40 Compatibility Table, November 11, 2011)

NRC REGULATION SECTION	TITLE	LEVEL OF COMPATIBILITY	ANALYSIS	COMMENTS
40.22	Small quantities of source material	B		
40.23	General license for carriers of transient shipments of natural uranium other than in the form of ore or ore residue	NRC		
40.24	[Reserved]	Not Applicable		
40.25	General license for use of certain industrial products or devices	C		
40.26	General license for possession and storage of byproduct material as defined in this part	C – States with authority to regulate U mill activities D – States without authority		
40.27	General license for custody and long-term care of residual radioactive material disposal sites	NRC		
40.28	General license for custody and long-term care of uranium or thorium byproduct materials disposal sites	NRC		
License Applications				
40.31	Application for specific licenses	D, NRC, H&S		
40.32 40.32	General requirements for issuance of specific licenses	D, H&S, NRC		
40.33	Issuance of a license for a uranium enrichment facility	NRC		
40.34	Special requirements for issuance of specific licenses	B, D		
40.35	40.35 Conditions of specific licenses issued pursuant to § 40.34	B, C, D,		

Table 4-3 NRC Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10CFR Part 40 Compatibility Table, November 11, 2011)

NRC REGULATION SECTION	TITLE	LEVEL OF COMPATIBILITY	ANALYSIS	COMMENTS
40.36	Financial assurance and recordkeeping for decommissioning	H&S, NRC		
40.38	40.38 Ineligibility of certain applicants	NRC		
Licenses				
40.41	Terms and conditions of licenses	C, D, NRC, H&S		
40.42	Expiration and termination of licenses and decommissioning of sites and separate buildings or outdoor areas	D, H&S		
40.43	Renewal of licenses	D		
40.44	Amendment of licenses at request of licensee	D		
40.45	Commission action on applications to renew or amend	D		
40.46	Inalienability of licenses	C		
Transfer of Source Material				
40.51	Transfer of source or byproduct material	C, NRC		
40.52	Restrictions on the use of Australian-obligated source material	NRC		
40.53	[Reserved]			
40.54	[Reserved]			
40.55	[Reserved]			
40.56	[Reserved]			
Records, Reports, and Inspections				
40.60	Reporting requirements	C, D		
40.61	Records	C, D, H&S		
40.62	Inspections	D		
40.63	Tests	D		
40.64	Reports	NRC		

Table 4-3 NRC Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10CFR Part 40 Compatibility Table, November 11, 2011)

NRC REGULATION SECTION	TITLE	LEVEL OF COMPATIBILITY	ANALYSIS	COMMENTS
40.65	Effluent monitoring reporting requirements	C – States with authority to regulate U mill activities D –States without authority		
40.66	Requirements for advance notice of export shipments of natural uranium	NRC		
40.67	Requirement for advance notice for importation of natural uranium from countries that are not party to the Convention on the Physical Protection of Nuclear Material	NRC		
Modification and Revocation of Licenses				
40.71	Modification and revocation of licenses.	D		
Enforcement				
40.81	Violations.	D		
40.82	Criminal penalties.	D		
Appendix A	Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Produced	Definitions – A for States with authority to regulate U mill activities. Criterion 1		
I. Technical Criteria		C		
Criterion 1		C		
Criterion 2		C		See Note 3
Criterion 3		C		See Note 3
Criterion 4		C		See Note 3
Criterion 5		C		See Note 3
Criterion 6		C		
Criterion 6A		C		
Criterion 7		C		
Criterion 8		C		
Criterion 8A		C		

Table 4-3 NRC Uranium Regulations 10 CFR Part 40 with Compatibility Levels (adapted from 10CFR Part 40 Compatibility Table, November 11, 2011)

NRC REGULATION SECTION	TITLE	LEVEL OF COMPATIBILITY	ANALYSIS	COMMENTS
II. Financial Criteria				
Criterion 9		C		
Criterion 10		C		
III. Site and Ownership Byproduct Material				
Criterion 11		NRC for 11A through F		
IV. Long-Term Site Surveillance				
Criterion 12		NRC		
V. Hazardous constituents				
Criterion 13		C		

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
Geology and Soils (including Palentology, Geologic Hazards and other Mineral Resources)	• Change in topography • Potential mine and mill tailings release • Exposure to sure to nearby populations. • Cumulative effects from other Commonwealth mining operations • Exposure of uranium deposits could result in long-term exposure to heavy metals and radiological elements. • Destruction of archeological, paleontologic and historic sites	Radionuclides, Silica, Heavy Metals Diesel Emissions/Particulate Matter	**NRC** **MSHA** **OSHA**	VDMME VDEQ **VDH**	• Stabilization of soils, contouring • Appropriate disposal of waste • See BMPs for Water Resources • Reclamation bonding • Paleo surveys before, during and after proposed action • Metallurgic testing of ore to determine heavy metals content (Moran 2012)
Water Resources (including Surface Water, Groundwater, Water Useage, Watershed Health, Drinking Water)	• In-situ leaching process for extracting uranium may not be safe. • Uranium, heavy metals and others may be transported in solution to groundwater. • The Uranium mining and milling activities potential of a catastrophic failure (from floods, extreme rainfall) of a uranium tailings containment structure and subsequent discharge of uranium tailings into nearby water features (Baker 2012). • Radiological contaminants Ra-	Radionuclides, Heavy Metals	**Clean Water Act** **NRC**	**VDH** VDEQ	• Storm Management Plan, --Baseline Studies • Predictive Modeling • Independent State Surface and Groundwater Sampling • Monitoring the water quality of private wells • Detailed hydrologic characterization (Moran) • Conduct epidemiological and other scientific data and studies • Conduct Baseline/Background Studies

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
	226 an Th-230 in the water column and sediments in the project area • Maximum contaminant levels (MCL) for combined radium (Ra-226 and Ra-228) in drinking water may be exceeded for an extended period of time. • Mine dewatering could reduce groundwater levels and affect nearby wells, springs and surface water bodies (RTI 2012) • Properties within 2 miles of the mining/milling operation could be affected for the long ter (Chmura 2012). • Uranium mining and milling may require the use of water that is currently used for residential and agricultural purposes.				
Public Lands (Wilderness, Parks, etc.)	• Noise and dust created by traffic and construction could be detectable on the adjacent private and public properties above current standards.	Particulate matter (same as air and water)	**Clean Water and Air Acts** **NRC**	VDEQ	• See Air and Water • Consultation with public entities that manage the land

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
Wild and Scenic Rivers	• Recreational and scenic rivers could be affected by milling and mining activity.	Same as water resources	**Clean Water Act**	VDEQ	• See Air and Water • Consultation with public entities that manage the rivers, especially if they are recreational rivers.
Scenic or Visual Resources	• Is the project area is visible from from residential or public lands? • There could be a long-term color and topography changes. -These may cause - effects to tourism and residental activities.	n/a	**Federal Land Management Policy Act** **Wilderness Act**	VDEQ	• Locate new roads so they are visually screened (by topography or forest vegetation) from travel ways, when practicable.
Transportation	• Local, state and federal roads and highways may not have the capacity for additional traffic volume. • Pollution will increase from additional traffic.	Emissions, Carbon Dioxide, Dust, Fumes	**Clean Air Act**	**VDH** VDEQ	• Comprehensive and ongoing monitoring of emissions, coupled with use of effective technologies to reduce pollution (RTI 2012)
Air Quality	• Soil and rock would be removed during mining and could result in the generation of radioactive particulate matter to the air. • Radon gas may be released from the proposed mining.	Particulate Matter, Fugitive Dust Radon Gas NOx, SOx, VOCs	**Clean Air Act** **National Ambient Air Quality Standards (NAAQS)** **40 CFR 61, subpart B**	VDEQ	• State Air Quality Permits requiring dust abatement measures, radon monitoring • Assuring compliance with Federal standards • Refer to Human Health and Worker Resource

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
Noise	• The overall effects from noise could be above allowable levels.	Exceedence of noise standards in Decibels (70 dB for NIOSH) OSHA MSHA	**Federal Highway Administration (FHWA) noise regulations (23 CFR 772) requiring permit applicants to develop a project cost-benefit analysis that defines the break-even price for mining and/or milling.**	VDEQ VDOT	• Construction of Berms, Tree rows, and other sound-proofing techniques.
Vegetation	• Removal of surface layer would result in loss of vegetation. • The operations could spread noxious and invasive weed species. • Uranium mill tailing can spread radionuclides to forage grasses and other vegetation	Same as Air and Water	**NAAQS Secondary standards**	VDEQ **VDH**	• Weed Management Plan • Reclamation • Insurance bonding would ensure remediation efforts were funded
Wetlands	• Proposed action may affect wetlands in the Commonwealth. • If public wetlands are disturbed, the Corps could seek in-kind mitigation in order to comply with Section 404b.	Same as Air and Water	**Executive Order 11990** **Section 404 of the Clean Water Act**	VDEQ	• Corps of Engineers Involvement (if needed for 404b process)

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
Wildlife, Fish, and Plants	• There may be direct, indirect or cumulative effects to sensitive species, species of viability concern, or federally listed species.	Same as Air and Water	**U.S. Fish and Wildlife Service Standards** **Clean Water Act** **Clean Air Act** **Wildlife Regulations**	VDGIF VDEQ	• Consult with Virginia Department of Game and Inland Fisheries. • Conduct biological surveys before, during and after the proposed action.
Agriculture	• Agriculatural products may be contamined by mining and milling through human injestion pathways.	Same as Air and Water	**Clean Water Act** **Clean Air Act** **NRC**	VDACS **VDH**	• See water resources, soil, and socioeconomics
Cultural Resources	• Cultural Resources could be effected if known archeological sites are present or new sites were uncovered in the surface of the uranium deposit area.	n/a	**Native American Graves Protection and Repatriation Act (NAGPRA)** **Antiquities Act of 1906** **16 USC 431-433**	VDEQ SHPO	• Cease all activities must after locating a discovery area. • Surveys before, during and after • Further actions may also require compliance under provisions of the National Historic Preservation Act of 1966 (NHPA) and the Archaeological Resources Protection Act. • Consult State Historic Preservation Office (SHPO)
Recreation	• Recreation in the area could be effected.	n/a	**Public Land Use Requirements**	VDEQ	• Consult with agencies responsible for public lands
Socioeconomics (may include Travel Management)	• Substantial benefits to the state could result from an increase in jobs. • There could be an increase in tax revenue and industry. • Local infrastructure such as emergency response systems	Radionuclides, heavy metals	**NRC 10 CFR Part 20** **48 CFR Chapter 15 EPA Federal Acquisition Regulations System**	VDEQ VDOT	• If this is applied to Federal Lands, the Clean Air and Clean Water Acts would be applied. • Appropriate design, pollution control. • Pre-assess property values in proposed mining areas.

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
	would have to be upgraded (RTI report). • In some sectors, the proposed action could bring a negative stigma (egs: tourism and agriculture). • Private property values near mining could decrease.				• Involvement and communication among all stakeholders in the form of committees, public meetings and notices. • Requiring permit applicants to develop a project cost-benefit analysis that defines the break-even price for mining and/or milling.
Environmental Justice	• The health and environment of communities may be affected. These effects may be disproportionately distributed across various socioeconomic, racial and ethnic groups resulting in inequities. • This subject must be analyzed in most NEPA documents, and usually carries over to State and County assessments as well.		**Policy from EPA Office of Environmental Justice**	VDEQ **VDH**	• Public Meetings • Literature available to the public
Wastes, Hazardous and Solids	• Potential of exposure to mill and mine tailings. • Potential of exposure to heavy metals. • Mining operations could result in spills and contamination of the surrounding environment.	Full suite of chemicals and radionuclides associated with every aspect of mining and milling of uranium (including exploratory drilling)	**RCRA/ CERCLA**	VDEQ **VDH** VDMME	• Locating impoundments away from water features. • Appropriate engineering of impoundments and ponds. • Emergency and accident response plans • Frequent Monitoring • Spill Prevention, Control and Countermeasures Plan (SPCC) • See Air and Water Quality Resources

Table 4-4 Summary of EIA Elements and Related Potential Effects from Uranium Mining and Milling in the Commonwealth of Virginia

Element/ Resource	Issues and Concerns Related to Human Health and the Environment[1]	Potential Toxins	Applicable Federal Regulations and Entities	COV Oversight, Permitting or Licensing Entity	Potential or Suggested BMPs for Mitigation
Human Health and Worker Health and Safety	• The mine/mill worker may be exposed to toxins. • Exposure to Ra-226 and radon gas from uranium milling and mining may cause health effects such as cancer, heart disease and stroke. • Human health and environmental risks are magnified (Halifax County 2008) because Virginia has a more people per square mile than Western States. • Tailings exposed to the surface may cause long term risks to future generations (Halifax County 2008).	Ra-226, radon gas, heavy metals	**NRC 10 CFR Part 20** **MSHA** **OSHA** **NIOSH**	VDEQ **VDH** VDMME	• Dosimetry, Radiological Monitoring, • Predictive Modeling • BMPs from MSHA, OSHA and DOD radiation worker safety practices. • Involvement and communication among all stakeholders • Use and dissemination of existing and new scientific studies concerning long-term exposure to heavy metals and mildly radioactive substances. • Adopt applicable BMPs from IAEA 2010 Report. • Requirement to have Fire/Emergency Response/Health and Safety Plans

[1] Effects/Consequences were derived from the following references: Baker 2011, NAS 2011, RTI Study 2012a, 2012b, Senes 1984, Moran 2012.

Table 5-1 Comparison of ICRP 103 Dose Limits to 10CFR20 Dose Limits

	ICRP 103 Dose Limit	Current 10CFR20 Dose Limit (units as written in 10CFR20)
Occupational Exposure		
Effective Dose	20 mSv/y (2rem/y) averaged over 5 years with no more than 50 mSv (5rem) in any one year	5 rem/y (0.05Sv/y)
Lens of the eye	150 mSv/y (15 rem/y) [recommendation changed in 2011 to 20 mSv/y (2 rem/y)]	
Skin	500 mSv/y (50 rem/y)	50 rem/y (0.5 Sv/y)
Hands and Feet	500 mSv/y (50 rem/y)	50 rem/y (0.5 Sv/y)
Other organs	No Equivalent	50 rem/y (0.5 Sv/y)
Pregnant woman	1 mSv (0.1 rem) for the remainder of the pregnancy (after declaration)	0.5 rem (0.0005 Sv) for the period of gestation (requires determination of dose prior to declaration)
Members of the Public (during operation)		
Effective Dose	1 mSv/y (0.1 rem/y)	0.1 rem/y (1 mSv/y) with provision for doses up to 0.5 rem/y under specified conditions and with prior approval.
Lens of the eye	15 mSv/y (1.5 rem/y)	No Equivalent
Skin	50 mSv/y (5 rem/y)	No Equivalent

APPENDIX A

LIST OF PERTINENT PAPERS AND AUTHORS

FROM IRPA 13

Presentations
13th International Congress of the International Radiation Protection Association
Glasgow, Scotland

May 13-18, 2012

TSA6a.1	Updating the UNSCEAR Methodology For Estimating Human Exposures due To Radioactive Discharges.	C. Robinson
TSA8a.4	Comparison of Provisions for Exclusion and Exemption of NORM Radionuclides Associated with the Oil and Gas Industry in the North Sea.	A. Stackhouse
TS10a.1	Management of Operational and Existing Exposure Situations due to NORM and Natural Radiation: Radiation Protection and Scientific Challenges.	R. O'Brien
TS10a.3	Exposure Caused by Natural Radionuclides in Building Materials: Current Practice and Regulation and Future Radiation Protection Requirements.	F. Maringer
TS8b.1	The Importance and Uncertainties of Parameters Related to the Radiological Analysis of NORM for use in Public Dose Assessments.	D. De Villiers
TS8b.4	Disposal Activities Within the IAEA Division of Radiation, Transport and Waste Safety.	G. Bruno
TS10b.7	Guidance on the Assessment of Exposure from Land Contaminated with Hetero-generously Distributed Radioactive Material.	W. Oatway
TS10b.6	Challenges in the Nuclear Legacy Regulation.	M. Kiselev
TS1b.1	Risk of Lung Cancer Death Associated To Radon Exposure Corrected for Measurement Error Among Uranium Miners.	D. Laurier
TS1c.1	Radon Risk in Uranium Mining and ICRP.	D.B. Chambers
TS6c.1	Radiation Protection Challenges for Exposures to Naturally Occurring Radioactive Material (NORM).	P. Haridasan
TS6c.2	Estimates of Effective Doses Among Czech Uranium Miners.	L. Tomasek
TS6c.3	Problems Experienced when Dealing with the Decommissioning of NORM Contaminated Oil Production Installations and Vessels.	B. Heaton
TS6c.4	Dose Assessments Uncertainties for NORM Management in Conventional Hazardous Waste Disposals.	J. Mora
TS6c.5	A Prospective Radiological Risk Assessment for a Phosphate Industry Project.	D. Da Costa Lauria
TS6c.6	Radioactivity in Raw Materials and Waste from NORM industries in China.	J. Luo
TS2d.7	Radon Exhalation from Mine Tailings Dams in South Africa.	J. Ongori

TS3c.5	Considerations of Transfrontier Shipment of NORM Waste from the North Sea Oil and Gas Industries.	M. Nilsen
TS3c.6	Regulatory Standards to Control Radio-logical and Nuclear Fuel Cycle Facilities.	L. Castro
TS2e.6	What can you say when there is almost nothing? Decision Thresholds Associated with Multiple Measurements and their Use for Environmental Monitoring.	G. Magnificat
TS10c.1	Recent Developments in the Regulatory Garcia-Talavara Control of Radon Exposure in Spain.	Garcia-Talavara
TS10c.3	Radon prevention and remediation in EU Countries, RADPAR questionnaire study.	H. Arvela
TS3d.4	The Influence of ICRP 103 on Current of the U.S. Environmental Protection Agency.	M. Boyd
TS3d.5	What Resources Were Needed to ICRP 60, and What Resources May Be Needed To Implement ICRP 103?	J. Valentin
S10.1.2	ICRP Radon recommendations.	J. Lecomte
S10.1.4	The National Radon Program - a Success Story Continuing in Canada.	J. Chen
S11.1.1	Principles and Concepts in Radiation Protection of the Environment.	J. Pentreath
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PL4.7	NORM Sector Perspective.	G. Liebenberg
P01.08	A New Look at the Environmental Health Impact of Radon and its Daughters in Light of Combustion Products.	Lykken, GI; Momcilovic, B; Ward, T; Jagam, P
P01.50	Mortality from Cardiovascular Diseases and Occupational Uranium Exposure: Cohort and Nested Case-Control Studies of French Uranium Workers.	Guseva Canu, I; Garsi, JP; Chablais, L; Samson, E; Jovanovich, I; Caër-Lorho, S; Acker, A; Niogret, C; Laurier, D
P01.59	Possible Source of Uncertainty in Radon Epidemiological Studies at Low Radon Concentrations.	Magnoni, M
P01.63	Lifetime Radiation Mortality Risk from Lung Cancer. Direct and Indirect Estimates of Non-linear Dose Trend.	Obesnyuk, VF; Sokolinikov, ME
P01.67	TRACY: The French Cohort of Uranium Cycle Workers.	Samson, E; Guseva Canu, I; Acker, A; Laurier, D
P01.71	Epidemiological Study of Health Status of Population Around a Jadugoda Uranium Mines in India.	Thakur, HP; Sapra, BK
P01.72	Risk from Occupational and Environmental Radon and Role of Smoking.	Tomasek, L
P01.78	Radiological Health Risk from Soil, Well Water and Borehole to the Inhabitants of Some Cities across Ondo and Ekiti States in Nigeria.	Arogunjo, AM; Ogunware, AE

P01.82	The Social-Psychological Status of the Population Residing in the Contaminated Territories of the Urals Region.	Burtovaya, EY; Belova, MV; Akleyev, AV
P01.93	Radioactive Decay Series in Drinking Water Sources of Iran.	Mohommadi, S
P01.94	RBE of Radon: An In Vitro Study Using Chromosomal Aberrations as a Biomarker.	Mohankumar, MN; Meenakshi, C
P02.10	An Evaluation of the Equivalent Dose due to Natural Radioactivity in the Soil Around the Consolidated Tin Mine in Bukuru-Jos, Nigeria.	Ajayi, IR
P02.12	A Passive Radiation Dosemeter for Environmental Photon and Beta Monitoring	Langridge, D
P02.38	Personal Dosimetry Management a Nuclear Industry Good Practice Guide.	Collison, R; Barnes, M; Corns, A; Ridgley, A; Wilson, Christine; West, D; Wilkins, G; Bradshaw, J; Hales, L; Stock, P; Sanders, S; Morris, S
P02.46	Study of Random Exhalation Rate from Soil and Rock Samples and Gamma Exposure Rate in Chamaraja Nagar District, India.	Chandrashekara, MS; Rajesh, BM; Nagaruju, KM; Paramesh, L
P02.61	Establishing of National Dose Reference Levels (DRLs) for Dental Radiology Practices at the UAE.	Alsuwaidi, JS; Saleh, NM; AlMoosawi, IS; Janaczek, J; Al Kaabi, F; Al Amei, AS; Booz, SM; AlShamsi, WM
P02.69	A Bayesian Analysis of Uncertainties on Lung Doses Resulting from Occupational Exposures to Uranium	Puncher, M; Birchall, A; Bull, RK
P02.73	Measurements of Uranium Radionuclides in Urine Samples and Internal Dose Assessments for the Personnel of Uranium-Mining Industry in Ukraine.	Bonchuk, Y; Likhtarov, I; Tsygankov, N
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P02.77	Dosimetry of Natural Uranium Exposure by Integrating Alimentary Uranium Contribution to Biossay Measurements.	Davesne, E; Blanchin, N; Chojnacki, E; Touri, L; Ruffin, M; Blanchardon, E; Franck, D
P02.83	Uranium & Dosimetry in Aquatic Organisms: Which Isotopes & Descendants to Consider?	Frelon, S; Simon, O; Cagnat, X; Gurriaran, R; Beaugelin, K; Gilbin, R
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P02.102	Content of Uranium in Urine of Uranium Miners In Relation to Personal Dosimetry of Long Lived Alpha Radionuclides.	Malátová, I; Beèková, V; Tomášek, L; Hùlka, J; Marušiaková, M
P02.104	Controlling Radiological and Chemical Intakes of Uranium in the Workplace: Applications of Bio-kinetic Modeling and Occupational Monitoring Data.	Meck, RA; Legget, RW; Eckerman, KF; McGinn, CW

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P02.150	ESR Dosimetry Study of Workers from Stepnogorsk Uranium Processing Plant, Kazakhstan.	Zhumadilov, K; Kazymbet, P; Ivannikov, A; Bakhtin, M; Zharlyganova, D; Zhumadilov,Z; Hoshi,M
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P10.84	The Measurement of Radon in the Environment: Publication Of a New ISO Standard.	Calmet, D; Améon, R; Beck, T; De Jong, P; Herranz, M; Kiett, A; Michel, R; Richards, T; Schuler, C; Tokonami, S; Woods, M; Jiranek, M; Rovenska, K; Duda, JM; Haug, T
P10,87	Exposure to Radon from Concrete with Fly Ash: A Proposed Model, In-Situ and Laboratory Measurements.	Haquin, G; Kolver, K; Becker, R
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