

## **REPORT**

### **TECHNICAL CRITIQUE OF “A Preliminary Assessment of Potential Impacts of Uranium Mining in Virginia on Drinking Water Sources” by Michael Baker Corp.**

May 31, 2011

**Prepared for:** Virginia Uranium, Inc.  
231 Woodlawn Heights  
Chatham, Virginia 24531

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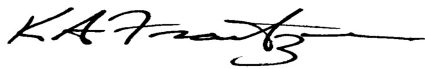
A Report Prepared for:

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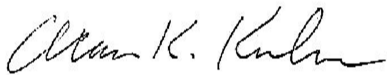
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## EXECUTIVE SUMMARY

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**TECHNICAL CRITIQUE OF**  
***“A Preliminary Assessment of Potential Impacts of***  
***Uranium Mining in Virginia on Drinking Water Sources”***  
**by Michael Baker Corp.**

***May 31, 2011***

**Kleinfelder West, Inc.**

Kleinfelder reviewed the subject report prepared by Michael Baker Corp. (Baker) for the City of Virginia Beach. The purpose of Baker’s study was to assess potential for contamination of the city’s water source at Kerr Reservoir resulting from a hypothetical release of uranium mill tailings from Virginia Uranium’s Coles Hill mill site. This document summarizes Kleinfelder’s critique of the Baker study, and the reader is referred to the full text of the critique for details.

Baker performed its study based primarily on the numerical fate and transport model CCHE1D and the hydrologic model HEC-RAS. For input values for the models, Baker made assumptions or used “best available data” about the existing hydrologic and sediment parameters, extreme storm events, tailing impoundment location and design, and flow paths of released tailings. The modeling predicted that concentrations of several radiological contaminants, resulting from the water-borne transport of tailings from the Coles Hill site, could exceed the US EPA’s Maximum Concentration Levels (MCLs) in Kerr Reservoir for short periods. This model ended at the reservoir, and it did not address movement or levels of contaminants between Kerr Reservoir and water consumers in the City of Virginia Beach.

Kleinfelder’s review and evaluation of the Baker study found that:

- The numerical fate and transport model CCHE1D and the hydrologic model HEC-RAS are generally accepted methods and appropriate for use by Baker.
- The assumptions made by Baker for input values for these models were unrealistic, making the prediction of contaminant levels in Kerr reservoir unreliable.

- Baker performed no probability analysis of the factors that might cause a tailings release from an impoundment. A simple probability analysis performed by Kleinfelder, based on regulatory standards, shows that the risk of such a release is effectively zero.
- Although the Baker report contains some caveats regarding unlikely events modeled in its study, these qualifiers are lost in the extensive report, leaving the reader with the wrong impression that the city's water supply could and would be endangered by the Coles Hill uranium tailings.
- The value of the Baker study was limited further because the fate and transport of potential contamination between Kerr Reservoir and the water consumer was omitted. Information available from the City of Virginia Beach municipal water system shows that the city monitors and treats its water for radiological contamination.

Kleinfelder's critique of the Baker study has four topics:

- The models;
- The assumptions made for selecting numerical values of input parameters for the models;
- The limitations of the study; and
- The probability of occurrence of the modeled scenarios.

Kleinfelder did not perform a fate and transport model for independent comparison to the Baker models. The modeling codes used by Baker are in common use. Our assessment focused on the input values Baker selected for the models.

Baker's tailing release scenario included assumptions about the conditions and events (factors) that could lead to release, and from these Baker assigned numerical values for the models. Such values are only as valid as the assumptions on which they are based, so the credibility of the results of their model is no better than the credibility of their assumptions. Lacking specific information about the Coles Hill site or potential tailing locations or design, Baker assumed tailing impoundment settings and designs that bear no relation to the Coles Hill site, nor do they account for mandatory regulatory siting requirements.

Baker also relied on historical records of dam failures and did not take into account the tailing disposal impoundment siting and design standards imposed by the US Nuclear Regulatory Commission (10 CFR 40 App A, 10 CFR 51) and US EPA (40 CFR 192, 40 CFR 61) among others. These standards are not easily bypassed as implied by Baker, and would govern the siting and design of tailing facilities at the Coles Hill site. Current regulatory standards require tailings to be placed away from stream channels and below ground level to the extent possible and to be protected from the Probable Maximum Flood (PMF) runoff, which is the peak runoff event resulting from the Probable Maximum Precipitation (PMP) event. Baker did not address the PMP or the resulting PMF for the Coles Hill location; they based their models on estimated hydrographs for the 10-percent (50 year flood), 1-percent (100 year flood), and 0.2-percent (200 year) annual-chance events. The PMF event, by contrast, has not more than a 0.1 percent-annual-chance. US NRC regulations require that tailings containments withstand a PMP storm event, larger than the storm events assumed in Baker's study.

Baker also assumed that floodwater stays within the boundaries of the model, not spreading across the flooded landscape and tributaries. In reality, should a large flood occur, the volume of tailings and hazardous chemicals that might be transported downstream from the Coles Hill site would be small in comparison to the sediment and contaminants that would be transported to Kerr Reservoir from other sources within the flooded areas such as septic systems, animal waste lagoons, gasoline storage tanks, and industrial facilities. The Baker model over-simplifies or ignores these considerations.

In addition to the limitations imposed by Baker's assumptions about its tailings release scenarios, the value of the study for informing policy-makers and the public is limited by the end-point of the model, Kerr Reservoir. The water supply of City of Virginia Beach comes from multiple sources, each with a number of contaminant sources; therefore, the City of Virginia Beach operates a modern water monitoring and treatment system capable of radiological detection and treatment. Baker did not address these facts.

The most important limitation of the study is the absence of probability. Although Baker acknowledged that its postulated release scenarios were unlikely, they did not perform a probability analysis of the factors in their scenarios to support a risk assessment of the release resulting in contamination of the reservoir or the drinking water of Virginia Beach. A simplified probability analysis performed by Kleinfelder yielded an extremely low probability,  $10^{-8}$  or one-in-10,000,000, of tailings ever being released. This represents a “risk effectively zero” on the Paling Perspective Scale (<http://www.riskcomm.com/visualaids/riskscale/example.php>). We routinely accept this level of risk as part of normal life.

Kleinfelder’s critique of the Baker study leads us to conclude that:

- The release scenarios postulated by Baker that would put tailing contamination into the river system upstream of Kerr Reservoir are unrealistic in that they are not based on representative site conditions and do not account for regulatory constraints.
- The probability of tailing release under the current regulations is extremely low, making risk to the public essentially zero and less than many risks of everyday life.
- Even if Baker’s modeled results of impacts to water in Kerr Reservoir are accepted as reasonable, the radiological contaminant levels in the drinking water in the City of Virginia Beach would be reduced substantially by the city’s other water sources and its treatment system; therefore, the concentrations in the water would remain well below MCLs.
- Because the Baker study does not address either probability of release or the monitoring and treatment of water in the municipal water system, it has caused unjustified alarm, however unintentional.

## 1.0 BACKGROUND

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In March 2010, the Michael Baker Corp. (Baker), on behalf of the Department of Public Utilities for the City of Virginia Beach, released a paper entitled, “*Uranium Mining in Virginia – Can Downstream Drinking Water Sources be Impacted*” (Baker 2010). That paper presented a conceptual case that the mining and milling of uranium ore reserves in Virginia, specifically in Pittsylvania County upstream of the John H. Kerr Reservoir (Kerr Reservoir) and Lake Gaston, will create an unacceptable hazard through either mine operation or failure of a mill tailings impoundment. Baker asserted that the anticipated precipitation and normal hydrology of Virginia is sufficient to move tailings downstream, if released. They further imply that mill tailings impoundment structures generally fail, raising concern about their placement in the state and in southern Virginia in particular.

Subsequently, in February 2011, Baker released its preliminary assessment report entitled, “*A Preliminary Assessment of Potential Impacts of Uranium Mining in Virginia on Drinking Water Sources*” in February (Baker 2011a). The purpose of this preliminary study was the assessment of potential impacts of a catastrophic failure of a uranium mill tailings impoundment structure and subsequent discharge of mill tailings (or tailings) to downstream water sources and resulting in radioactive contamination downstream, including the Kerr Reservoir. The core of this study was a one-dimensional (1-D) numerical modeling/simulation of the Banister and Roanoke Rivers and the Kerr Reservoir using a model developed by the University of Mississippi for the United States Department of Agriculture” (Baker 2011a, page ES-2). Their objectives included estimating the amount of uranium-contaminated sediment and water reaching Kerr Reservoir under normal and extreme precipitation events, and estimating the potential increase in radioactivity levels and other contaminants in Kerr Reservoir. The CCHE1D model used by Baker requires numerical values to make the model run, but Baker had few sources for values that would be relevant to the Coles Hill Uranium Project. Where relevant sources were lacking, Baker made assumptions about the necessary values.



One of Baker's assumptions is that the release of tailings would happen, despite their acknowledgement that regulatory standards are in place to minimize the likelihood of a tailings release:

*"Although presently uranium tailings are required to be stored in specially designed waste disposal facilities called containment cells or structures in compliance with Nuclear Regulatory Commission regulations, there is concern that a failure of the uranium tailings containment structures could result in the contamination of the downstream drinking water supply sources along the Banister River, Roanoke River, Kerr Reservoir and Lake Gaston"* (Baker, page ES-2).

The Baker report was silent about probability of a tailings release, and the study proceeded on the assumption that the above-cited "concern" of a failure was equivalent to a 100% certainty of failure under the conditions of their modeled storm and runoff events. This important distinction was not made by Baker; so the reader is left to figure out for himself/herself whether Baker's postulated release scenarios are realistic or not. Lacking any information in the report about the realism, or probability, of the postulated release scenarios, the reader naturally assumes that Baker's scenarios will occur. Predictably, the impact of the Baker report on the public perception of risk of water contamination from a tailings release has been immediate and has prompted some stakeholders to push for a ban on future uranium mining before they have had an opportunity to learn more about the Coles Hill Project and the actual risk from uranium tailings.

## 2.0 PURPOSE

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Virginia Uranium Inc. (VUI) tasked Kleinfelder West, Inc. (KLF) to provide a technical review of the final 2011 Baker document (Baker 2011a), and specifically to consider its methodology, assumptions, and conclusions. The KLF scope of work included:

- Review of the Baker model, specifically to examine what was and what was not included;
- Development of a conceptual site model that reflects actual conditions of the Coles Hill tailings site and realistic physical characteristics of an impoundment cell at that site;
- Evaluation of the possibility of a major flood event releasing tailings from the Coles Hill site into the local river system;
- Comparison of the realistic site model to the Baker site model used in their study; and
- Assessment of the probability of release of mill tailings affecting the City of Virginia Beach water supply.

Our critique excluded evaluation of the fate and transport model CCHE1D and the hydrologic model HEC-RAS used by Baker; Kleinfelder examined only the assumptions made by Baker for its input values to these models.

### 3.0 BAKER CONCEPTUAL MODEL

The models used in the Baker study are based upon two hydrologic flow networks: the Roanoke River alone and the combined basins of the Banister, Dan, and Roanoke Rivers. In these models, a hypothetical mill tailings facility was assumed to be located at the upstream end of either model:

- Approximately 10-miles upstream of the Long Island Road (County Road 761) bridge over the Roanoke River (see Figure 5-1 & 5-22 of Baker 2011); or
- Immediately upstream of the confluence of Whitethorn Creek with the Banister River.

The Baker models can be summarized as shown below:

Source	Release	Environmental Transport Mechanisms	Exposure Media & Exposure Point(s)	Exposure Route	Receptor <i>Human / Ecological</i>
Tailings Impoundment Reservoir	Failure/ Release	Initial Model Cross-Section		Surface Water	Kerr
		→ <i>Roanoke River Model*</i>	→		
		→ <i>Banister River Model†</i>	→		

\* see Figure 5-1 & 5-22 of Baker 2011

† see Figure 5-25 & 5-39 of Baker 2011

Baker's concept of how the impoundment fails relies upon their projections regarding enforcement of selected regulatory requirements and on the historical, retrospective study of Rico *et al.* (2008). Rico *et al.* developed an empirical method of predicting what happens when a tailings or impoundment dam fails. Baker assumed that a tailings impoundment would fail due to storm-induced damage; however, they did not discuss how this failure could (or would) actually happen, only that it happens and all at once. The modeled flood events were 0.2, 1, or 10-percent annual-chance storm hydrographs for the area, that is, the amount of water flow through a river network as the result of 200-year, 100-year, and 50-year storms.

In section 8 of their report, Baker presents the results of a “sunny-day” failure. A “sunny-day” failure is one that is due to factors, other than a storm event, that Baker does not describe. They appeared to operate the model in the same general way for the “sunny-day” failure as for the storm event failure, save for the initial cause. The purpose of modeling a “sunny-day” failure is to provide a comparison between a storm-induced failure and a failure that might occur for any other reason during a normal day.

Without accounting for the probability of a tailings impoundment release under storm or sunny day conditions, Baker assumed a breach of the impoundment dam, resulting in a tailings release trajectory that was in a single (uniform) direction (or unidirectional) as the initial event in their model. Based on the United States Code of Federal Regulations, that is 40 CFR 61 Subpart W (US EPA, 2001), Baker assumed the tailings impoundment to have a maximum area of 161,875 m<sup>2</sup> (1,742,408-square feet or 40-acres). They varied the impoundment volume, making it dependent upon the assumed height of a dam. The dam height was varied over an order-of-magnitude, that is, 5, 15, 30, or 50-meters (or about 16, 50, 98, or 164-feet), which resulted in an estimated volume of 0.8, 2.5, 5, or 8-million cubic meters (about 1, 3.2, 6.5, 10.5-million cubic yards).

Following Rico et al. (2008), Baker (2011a, §6 ):

- Estimated a maximum distance that the released tailings would travel or run-out over a lineal distance (in one direction) ranging from 0.5 to 43 kilometers (or about 0.3 to 27 miles) (see Baker 2011a, Table 6-1); and
- Assumed a triangular<sup>1</sup> volume outflow hydrograph<sup>2</sup> ranging from 25 minutes to 37 minutes, and they further assumed that the released tailings volume would all flow through the first cross-section<sup>3</sup> of each model (see Baker 2011a, Figure 6-2).

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<sup>1</sup> Triangular in this sense means that the flow changes from zero flow and then increases to a maximum outflow, subsequently decreasing to zero flow and a stable state.

<sup>2</sup> A hydrograph in this context is the amount of time to empty the impoundment.

<sup>3</sup> Cross-section means the cross-section of the river channel at a particular location. The first cross-section node of the model occurs at furthest upstream location, which is the first point of discharge into the model of the stream or river.

Upon entering the first cross-section of the model, the flow follows one of two networks modeled by Baker, that is:

- Approximately 90 miles of the Roanoke River basin, constituting an elevation drop of about 230 feet (see Baker 2011a, Figure 5-1); and
- Approximately 85 miles of the Banister River, Dan River, and Roanoke River basins, constituting an elevation drop of about 260 feet (see Baker 2011a, Figure 5-25).

Baker's assessment end-point (that is, the ultimate receptor for the purpose of the model) was Kerr Reservoir. The impairment of this drinking water source was assessed by modeling exceedances of the USEPA and VA-DEQ maximum contaminant levels (MCLs) for radium, thorium, and uranium.

## 4.0 CRITIQUE OF THE BAKER STUDY

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KLF's critique of the Baker study is separated into four topics:

- The models;
- The assumptions made for selecting numerical values of input parameters for the models;
- The limitations of the study; and
- The probability of occurrence of the modeled scenarios.

### 4.1 The Baker Models

KLF's review excluded an evaluation of the fate and transport model CCHE1D and the hydrologic model HEC-RAS used by Baker. These models are numerical methods using codes validated by others and that are generally accepted for similar applications.

The largest flood event modeled by Baker would result in substantial out-of-bank flooding throughout the Roanoke River system, during which the floodwaters would spread laterally and mix with other tributaries as well as sediment and contaminant sources not considered in the numerical one-dimensional model. The only scenario that Baker studied was the movement of tailing material through two river networks and the resulting suspension and dissolution of radionuclides such as radium, thorium, and uranium as water moves linearly downstream to the point of concern, the drinking water reservoir. The assumption that floodwater stays within the boundaries of the model, not spreading across a broader flooded landscape, leads to the expectation of ever-concentrating levels of radon, thorium, and uranium. In reality, should a large flood occur that breaches the tailing impoundment, the volume of tailings and hazardous chemicals that might be transported downstream from the Coles Hill site would be small in comparison to the sediment and contaminants that would be transported from other sources within the flooded areas such as septic systems, animal waste lagoons, gasoline storage tanks, and industrial facilities. The Baker model over-simplifies or ignores these other sources.

## 4.2 Assumptions Used in the Baker Study

To enable the CCHE1D and HEC-RAS models to function, numerical values are assigned to the input parameters of each model. Where values of parameters were known and available (“best available data” in some cases), Baker used them; however, some important values relating to the Coles Hill Uranium Project are not yet known (*e.g.*, location of the tailing impoundment and configuration of the impoundments). In such cases, Baker made assumptions; and while making assumptions is reasonable when specific parametric values are unknown, the reasonableness of certain choices made by Baker is questionable.

### Location of Tailing Impoundment

The Coles Hill uranium ore deposit is located east of U.S. Highway 29 between the towns of Gretna and Chatham in Pittsylvania County, Virginia. When they are built, tailings impoundments are typically located next to the mill, which is usually near the mine when the ore comes from that single source. In this case, the uranium ore will come from the two ore bodies located within one mile of each other on the property owned by VUI, and the mill will be located within the VUI property so that ore transportation costs and logistical requirements are minimized. The VUI property is located within the watershed of Whitethorn Creek, a tributary of the Banister River (see Figure 1). Therefore, Baker’s assumption of a tailing site in the upper Roanoke River basin is illogical, making the model of that basin irrelevant in assessing potential impacts from future operations by VUI.

Baker also assumed a hypothetical tailing impoundment location within both basins that would be immediately adjacent to the first (initial) cross-section node of each model; in other words, immediately adjacent to the river channel. This assumption is unrealistic because NRC regulations in 10 CFR 40 Appendix A, Criterion 1 (NRC, 1999) requires selection of tailing sites that includes:

*“Potential for minimizing erosion, disturbance, and dispersion by natural forces over the long term.....In the selection of disposal sites, primary emphasis must be given to isolation of tailings or wastes, a matter having long-term impacts, as opposed to consideration only of short-term convenience or benefits, such as minimization of transportation or land acquisition costs. While isolation of tailings will be a function of both site and engineering design, overriding consideration must be given to siting features given the long-term nature of the tailings hazards.”*

Criterion 4 of the same document requires that:

*“(a) Upstream rainfall catchment areas must be minimized to decrease erosion potential and the size of the floods which could erode or wash out sections of the tailings disposal area.”*

Both of these siting criteria contradict Baker’s assumption of a tailing impoundment location next to a river channel or alignment of the tailings dam that would allow direct trajectory of released tailings into the river. Criterion 1 means that the impoundment must be located away from rivers, not next to them. Criterion 4 means that the impoundment must be located as far upstream as possible in a watershed, minimizing the amount of flood water that could affect the impoundment.

### Design of Tailing Impoundment

In developing its study, Baker relied heavily on Rico *et al.*, 2008 as a reference for its dam failure scenarios. Rico *et al.* is a forensic study of historical dam failures. Such a study does not purport to represent the current state of practice in dam engineering, which is better described by a number of readily available references (e.g., USBR 1987 and USBR 1992-2007). While the historical record may be of some help in informing impoundment design in the future, even Rico *et al.* state that the, “...accuracy of these estimations should be approached with great caution....” Thus, the reader should be aware that the designs of dams that failed in the past do not reflect current practice, nor do they take into consideration the currently required design components necessary for licensing.



Baker does not specify whether the risk of failure (in either the catastrophic storm or “sunny-day” failure event) is linked to a weak foundation, a seismic event, excessive water level rise, overtopping, or excessive dam build-out rate, for example. The failure mode can be important to the timing of the release (fast, slow, etc.) and the behavior of the release over time (that is, the release hydrograph). For example, structural failure involving mass movement of the dam’s earthfill would be likely to release tailings more quickly than erosion of the earthfill due to overtopping of the dam. Both types of potential failure are anticipated and addressed by NRC (1999):

*“5A(4)—A surface impoundment must be designed, constructed, maintained, and operated to prevent overtopping resulting from normal or abnormal operations, overfilling, wind and wave actions, rainfall, or run-on; from malfunctions of level controllers, alarms, and other equipment; and from human error.*

*5A(5)—When dikes are used to form the surface impoundment, the dikes must be designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes. In ensuring structural integrity, it must not be presumed that the liner system will function without leakage during the active life of the impoundment.”*

The NRC (1999) makes its intention clear:

*“Criterion 3--The "prime option" for disposal of tailings is placement below grade, either in mines or specially excavated pits (that is, where the need for any specially constructed retention structure is eliminated). The evaluation of alternative sites and disposal methods performed by mill operators in support of their proposed tailings disposal program (provided in applicants' environmental reports) must reflect serious consideration of this disposal mode. In some instances, below grade disposal may not be the most environmentally sound approach, such as might be the case if a ground-water formation is relatively close to the surface or not very well isolated by overlying soils and rock. Also, geologic and topographic conditions might make full below grade burial impracticable: For example, bedrock may be sufficiently near the surface that blasting would be required to excavate a disposal pit at excessive cost, and more suitable alternative sites are not available. Where full below grade burial is not practicable, the size of retention structures, and size and steepness of slopes associated exposed embankments must be minimized by excavation to the maximum extent reasonably achievable or appropriate given the geologic and hydrologic conditions at a site. In these cases, it must be demonstrated that an above*

*grade disposal program will provide reasonably equivalent isolation of the tailings from natural erosional forces.”*

Criterion 3 allows consideration of options that accommodate specific site conditions but leaves no doubt that above-ground disposal must be justified. VUI has not selected the specific location for the tailing impoundment and, consequently, has not determined the disposal design. VUI is considering below-ground disposal in mine space, in fully excavated cells, and in cells that make optimal use of excavated space but also include earthfill embankments. Lacking a design to reference, Baker assumed that all tailings at the Coles Hill site would be placed in above-ground impoundments, retained behind embankments or dams, despite acknowledging the NRC criterion for below-grade disposal:

*“Although NRC’s...[regulations suggest that]...the containment of mill tailings [be] below grade, it is not a requirement...” (§6 ¶2 p86).*

The NRC does allow an applicant to propose alternatives to its criteria but places standards for its approval:

*“Licensees or applicants may propose alternatives to the specific requirements in this appendix. The alternative proposals may take into account local or regional conditions, including geology, topography, hydrology, and meteorology. The Commission may find that the proposed alternatives meet the Commission’s requirements if the alternatives will achieve a level of stabilization and containment of the sites concerned, and a level of protection for public health, safety, and the environment from radiological and non-radiological hazards associated with the sites, which is equivalent to, to the extent practicable, or more stringent than the level which would be achieved by the requirements of this Appendix and the standards promulgated by the Environmental Protection Agency in 40 CFR Part 192, Subparts D and E.” (NRC, 1999)*

The US EPA (2006) has similar requirements in 40 CFR 264.221, pertaining to design and operating requirements:

*“(g) A surface impoundment must be designed, constructed, maintained, and operated to prevent overtopping resulting from normal or abnormal operations; overfilling; wind and wave action; rainfall; run-on; malfunctions of level controllers, alarms, and other equipment; and human error.”*

*“(h) A surface impoundment must have dikes that are designed, constructed, and maintained with sufficient structural integrity to prevent massive failure of the dikes....”*

### Dismissal of Regulatory Constraints

Without more than its aforementioned statement for justification, Baker assumed that the NRC (1999) and EPA (1983, 2006) standards related to uranium tailing impoundments could be, and would be, treated merely as suggestions when the tailing disposal design is developed. No uranium mill license can be approved without extensive review of the application, which must include both the tailing impoundment design and the plans for operating and monitoring the impoundment, according to the requirements of 10 CFR 40.31 (NRC, 2008) and 10 CFR 51.60 (NRC, 2001). These requirements include opportunity for public comment during the application review process, allowing anyone to comment about the impoundment design. Therefore, Baker’s dismissal of the constraints on tailing impoundment design inherent in these regulations is unrealistic and misleading.

### 4.3 Limitations of the Baker Study

To provide a better understanding of potential risk from the VUI tailing to the Virginia Beach water supply, Baker should have examined the entire pathway of potential contamination, from the tailing impoundment (source) to the consumer’s water tap (receptor) (see Figure 2). Baker made assumptions to cover the source but failed to address the potential human receptor. Despite the title of its study, Baker did not address the entire pathway but focused on what would be below the source and an intermediate receptor, Kerr Reservoir, above the human receptor. Baker’s focus is illustrated simply below:

**|<-Baker’s Focus->|**  
Source → (Failure) Release → Transport → Exposure Route → Receptor

where the mechanism for release of tailings from the source (left side) and the pathway of exposure to the human receptor (right side) are omitted, with only the transport mechanism (middle) in the model.

Figures 1 and 2 illustrate a comparison of a more realistic source and release model to Baker's release and transport model. The conditions of tailing release (source) were framed by Baker using fundamentally unrealistic assumptions, as discussed in earlier sections of this critique, rather than on conditions more representative of the Coles Hill site and on requirements of the regulations. This approach limited Baker to a hypothetical exercise when, with more realistic assumptions of the potential tailing release conditions, a more relevant model with more meaningful results could have been generated.

The Baker study stopped at Kerr Reservoir, the intermediate receptor, rather than continuing on to examine the exposure route to the human receptor at the water tap, that includes transport of water through the municipal water treatment and distribution systems of the City of Virginia Beach.

At the time of Baker's study, VUI was conducting metallurgy and chemistry tests to evaluate options for optimizing extraction of uranium from the ore. The results of those tests will provide information about residual uranium and uranium solubility in the tailings. Lacking these site-specific data as input for their models, Baker assumed that values for these properties could be based on data from uranium tailings in other locations (e.g., Wyoming) and other types of ore bodies such as roll front deposits in sandstone. The Coles Hill uranium deposit is unlike these types of deposits.

Baker addressed only the assumed concentrations of tailing-related contaminants in the reservoir water that might exceed maximum contaminant levels (MCLs), not contaminants (radiological and non-radiological) from a variety of other sources such as septic systems, animal waste lagoons, gasoline storage tanks, and industrial facilities, all of which would risk being impacted by an extremely rare storm event. The water treatment system, designed to remove a variety of contaminants between Kerr Reservoir and consumers of the Virginia Beach

municipal water distribution system, was not considered in the Baker study; however, that treatment system is critical in delivering clean drinking water (below all MCLs) under any circumstances and should not be omitted from any risk assessment. Water in Kerr Reservoir and other sources requires treatment for a variety of contaminants, and the City of Virginia Beach describes this on its web site:

[http://www.vbgov.com/file\\_source/dept/putility/Document/Business\\_Division/Bill%20Inserts/2010\\_WaterQualityReport.pdf](http://www.vbgov.com/file_source/dept/putility/Document/Business_Division/Bill%20Inserts/2010_WaterQualityReport.pdf)), which provides the following information:

*“The mission of the Virginia Beach Department of Public Utilities is to provide a safe and sufficient water supply that will enhance and sustain our vibrant community. The Lake Gaston Water Supply Project helps fulfill that mission by providing water to Virginia Beach citizens through a 76-mile-long pipeline leading from Lake Gaston in Brunswick County to Lake Prince, a reservoir located in Suffolk but owned and operated by Norfolk. ....Water from Lake Gaston is blended with Norfolk’s water and treated at Norfolk’s Moores Bridges Water Treatment Plant. Lake Gaston and most of Norfolk’s water sources are surface water. Norfolk’s primary water supply comes from Lake Prince and Western Branch Reservoir in Suffolk, and Lake Burnt Mills in Isle of Wight. During extended dry periods, these lakes may be supplemented with water from four deep wells located around the lakes, or with water from the Blackwater and Nottoway rivers. Lakes within Norfolk and Virginia Beach also supplement Norfolk’s water supply. These include Lake Wright, Lake Whitehurst, Little Creek Reservoir, Lake Smith, Lake Lawson, and Stumpy Lake. From the reservoirs, water is pumped to the treatment plant. Here, the water undergoes a coagulation process causing small particles to clump together and sink to the bottom of a settling basin. Next, the water is filtered to further remove bacteria, algae, and other impurities. Finally, the water is disinfected to kill any remaining bacteria. The Moores Bridges Water Treatment Plant provides state of the art treatment technology and ensures water quality through continual monitoring and testing.”*

*“The sources of drinking water (both tap water and bottled water) include lakes, ponds, reservoirs, rivers, springs, streams, and wells. As water travels over the surface of the land or through the ground, it dissolves naturally-occurring organic and inorganic substances. Water also picks up contaminants from animals and human activity. Furthermore, fertilizers, herbicides, pesticides, metals, and salts wash off streets and lawns and enter the water supply. Neighboring communities, farms, and industries all contribute to these impurities. Left untreated, this water could make you sick. At the very least, untreated water would have an unpleasant taste, odor, or appearance. Treating and testing the water ensures that it is clean, safe, and pleasant to drink....”*

This information shows that the City of Virginia Beach draws water from several sources, not just Kerr Reservoir, that the water is routinely treated to remove particles and other impurities from a wide variety of sources, and that water quality is continuously monitored and tested so that the consumer can safely drink the water. The City's web site also states that its treatment system is designed to treat:

*"Radioactive Contaminants, which can be naturally occurring or be the result of oil and gas production and mining activities. The water treatment process removes these impurities and ensures the water is safe to drink."*

The following data are provided on this web site:

*Virginia Beach 2010 Water Quality Data*

*Average Concentration Level in Virginia Beach water versus Maximum Concentration Level (MCL) allowed in drinking water by the US EPA:*

- Gross Alpha Activity      0.4 pCi/L average    vs.    15 pCi/L MCL
- Gross Beta Activity      3.7 pCi/L average    vs.    50 pCi/L MCL
- Radium 226/228      0.4 pCi/L average    vs.    5 pCi/L MCL

Each of these contaminant concentrations would have to increase by 37.5, 13.5, and 12.5 times, respectively, to exceed the EPA drinking water standards. The municipal water treatment system is evidently capable of removing these contaminants, the same ones examined in the Baker study, which stopped short of this treatment system. With such low initial concentrations, several available sources of water, and the city's treatment capacity, radionuclide contaminants arriving in Kerr Reservoir would have a number of impediments to posing risk to the human receptors in the city. Baker did not address these readily available facts, thereby limiting the ability of the study to provide the reader with a more realistic picture of the level of risk posed by a potential release from the Coles Hill site.

## 4.4 Probability Assessment of Tailing Release

### The Importance of Probability

As important as the assumptions and limitations discussed above are in the critique of the Baker study, the most important issue affecting its relevance is the probability of tailings release occurring in the first place. Baker stated that it did not address this probability:

*“The model does not address the issue of whether there will be a catastrophe—it only simulates the outcome if one did occur” ...“The study is simulating a rare event that regulations are supposed to prevent” (Baker 2011b).*

The assumption of certainty of release and the absence of probability analysis in the structure of Baker’s study induces readers to accept Baker’s failure scenario regardless of its plausibility, causing unjustified alarm about very improbable events.

The assumed certainty of the triggering event is at odds with recommendations from the International Atomic Energy Agency (IAEA 2004) regarding this kind of evaluation:

*“In order to capture the random nature of such events, a probability of their occurrence would be estimated whenever possible. The acceptability of the additional effective doses would be assessed as a function of the probability of occurrence, taking into account the characteristics of the random events, the duration and types of radionuclide transfer through the biosphere, the characteristics of the exposure pathways, and the type critical group(s) considered.” (§8.6.2.5, p75)*

### Probability of Release of Tailings

Probabilistic risk assessments take many different forms and can be very complicated; however, to put the risk posed by the uranium tailings at the Coles Hill site in perspective, a simplified probability analysis is sufficient. While a more refined quantitative probability assessment requires additional information relating to the proposed location, design, and proximity of the facility to open waterways,



etc., it nevertheless is possible to estimate the likelihood of failure of the tailings impoundment dam using the method proposed by Murray, Chambers, *et al.* (1987). This method of evaluating likelihood involves the identification of events involved in the failure, assigning probabilities of occurrence, and multiplying them together to derive a composite probability of occurrence.

When assessing probability numerically, a factor with no probability (certain not to happen) is assigned a value of zero, and a factor that is certain to occur would be given a value of 1.0. In probability assessment, however, no factor is ever evaluated as impossible (zero) or certain (1.0). Any factor that is impossible is not considered in probability, and a factor that is certain has no influence of probability, but in its study Baker treated each of these factors in its release scenario as certain to occur.

In this simplified analysis of probability of release of tailings from the Coles Hill site, Kleinfelder considered several factors that would have to be present for Baker's postulated release to occur:

- 1) An extreme storm event occurs;
- 2) Tailings are placed in an above-ground impoundment;
- 3) Tailings are not protected against erosion;
- 4) The tailing impoundment is located next to a stream channel.

Each factor requires a numeric value between zero and 1.0. In this simplified assessment, each factor has equal weight, that is, each factor is considered to have the same importance on the compound probability, *i.e.*, the probability of tailing release.

#### Factor 1: An Extreme Storm Event Occurs

In the Baker study, the modeled storm events were 0.2, 1, or 10-percent annual-chance storm hydrographs for the area, representing the amount of flow through a river network as the result of a 200-year, 100-year, and 50-year storms. However,



the NRC requires that tailing impoundments and covers be designed and constructed to prevent impacts of an even larger storm event than those considered by Baker:

*“In disposing of waste byproduct material, licensees shall place an earthen cover (or approved alternative) over tailings or wastes at the end of milling operations and shall close the waste disposal area in accordance with a design which provides reasonable assurance of control of radiological hazards to (i) be effective for 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years...” (10 CFR 40 Appendix A Criterion 6 (1), NRC 1999)*

The existing hydrologic data do not extend back in time sufficiently to calculate the 1000-year annual-chance flood event, so the NRC requires that the design flood be the Probable Maximum Flood (or PMF) (NRC 2002):

*“...the NRC staff concludes that it is reasonable and prudent to use the PMF as the design flood, where reasonable assurance of non-exceedance for a time period of 1,000 years is desired.”*

The PMF is the flood that may be expected from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in a particular drainage area. The PMP and PMF for the Coles Hill location have not been estimated but will be based on local meteorological, terrain and hydrological data to characterize those most severe conditions. Although the annual probability of the PMF is unknown, assuming it will occur once in the 1,000-year protection period gives this extreme runoff event a probability of one in 1,000, or 0.001. Therefore, the PMF governing the protection of a tailings impoundment built in south central Virginia will be a more conservative event than Baker’s assumed worst case, the 0.2 percent annual chance or 0.002 annual probability event (Baker 2011a, Section 3.2.2).

### Factor 2: Tailings Are Placed In Above-Ground Impoundment

Although design has not started on the actual impoundment, VUI's design concept is to place tailings below grade, to the extent possible, in an excavated impoundment above the PMF floodplain or in the underground mine workings as backfill, or both.

The prime option for below-grade disposal in NRC's Criterion 3 (NRC 1999) is also VUI's prime option, and the design will attempt to achieve that objective. If a conservative approach is taken, estimating the odds of achieving this objective as only 50-50, then the probability of an above-ground impoundment is 0.5.

### Factor 3: Tailings Are Not Protected Against Erosion

The most likely mechanism for release of tailings is erosion of the impoundment structure (earthfill embankment) or the earthen cover. 10 CFR 40 Appendix A criteria 3, 5(A)4, and 5(A)5 (NRC 1999) as well as US EPA regulations (US EPA, 1983, 2001, 2006) provide clear standards for protection against erosion that could result in tailing release. During the license application technical review, the NRC, the EPA, their consultants, the public and outside experts are able to scrutinize the designs for tailing protection and to call attention to deficiencies. Consequently, it is very unlikely that the approved design would not provide adequate protection, so we have assigned a probability of 1 in 100, or 0.01 to this factor.

### Factor 4: The Tailing Impoundment is Located Next To a Stream Channel

Baker assumes that the impoundment will be located immediately adjacent to the model's first cross-section node, the entry point to the river channel, which would almost certainly place it in the PMF floodplain. Placement of a tailing impoundment close to a stream channel would also make below-ground disposal more difficult, if not impossible, because of shallow ground water. Such a location would be contrary to NRC's Criterion 1 and 4 (NRC 1999) and would also probably impact wetlands, which are protected under Section 404 of the Clean Water Act (US EPA

1972). Therefore, it is very unlikely that an impoundment would be located as postulated by Baker. This factor is assigned a probability of 1 in 100 or 0.01.

The probability of Baker's release scenario, treating each of the foregoing as independent and equally weighed factors, is accomplished as follows:

The calculated probability of failure release,  $5 \times 10^{-8}$ , is about a one-in-a-ten-million chance. The values for these factors are not absolute and may be varied up or down by other assessors, but even a net increase of an order of magnitude in the values of these factors would still result in a one-in-one-million chance of the tailing release presumed in the Baker report.

This represents a "risk effectively zero" on the Paling Perspective Scale (<http://www.riskcomm.com/visualaids/riskscale/example.php>). We routinely accept this level of risk as part of normal life.

## 5.0 CONCLUSIONS

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Kleinfelder's critique of the Baker study leads us to conclude that:

- The release scenarios postulated by Baker that would put tailing contamination into the river system upstream of Kerr Reservoir are unrealistic in that they are not based on representative site conditions and do not account for regulatory constraints.
- The probability of tailing release under the current regulations is extremely low, making risk to the public essentially zero and less than many risks of everyday life.
- Even if Baker's modeled results of impacts to water in Kerr Reservoir are accepted as reasonable, the radiological contaminant levels in the drinking water in the City of Virginia Beach would be reduced substantially by the city's other water sources and its treatment system; therefore, the concentrations in the water would remain well below MCLs.
- Because the Baker study does not address either probability of release or the monitoring and treatment of water in the municipal water system, it has caused unjustified alarm, however unintentional.

## **6.0 LIMITATIONS**

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Kleinfelder prepared this report in accordance with generally accepted standards of care that exist in Virginia at this time. This report may be used only by Virginia Uranium, Inc. (Client) and only for the purposes stated, within a reasonable time from its issuance, but in no event later than one (1) year from the date of the report. All information gathered by Kleinfelder is considered confidential and will be released only upon written authorization of Client or as required by law. Non-compliance with any of these requirements by Client or anyone else, unless specifically agreed to in advance by Kleinfelder in writing, will release Kleinfelder from any liability resulting from the use of this report by any unauthorized party and Client agrees to defend, indemnify, and hold harmless Kleinfelder from any claim or liability associated with such unauthorized use or non-compliance.

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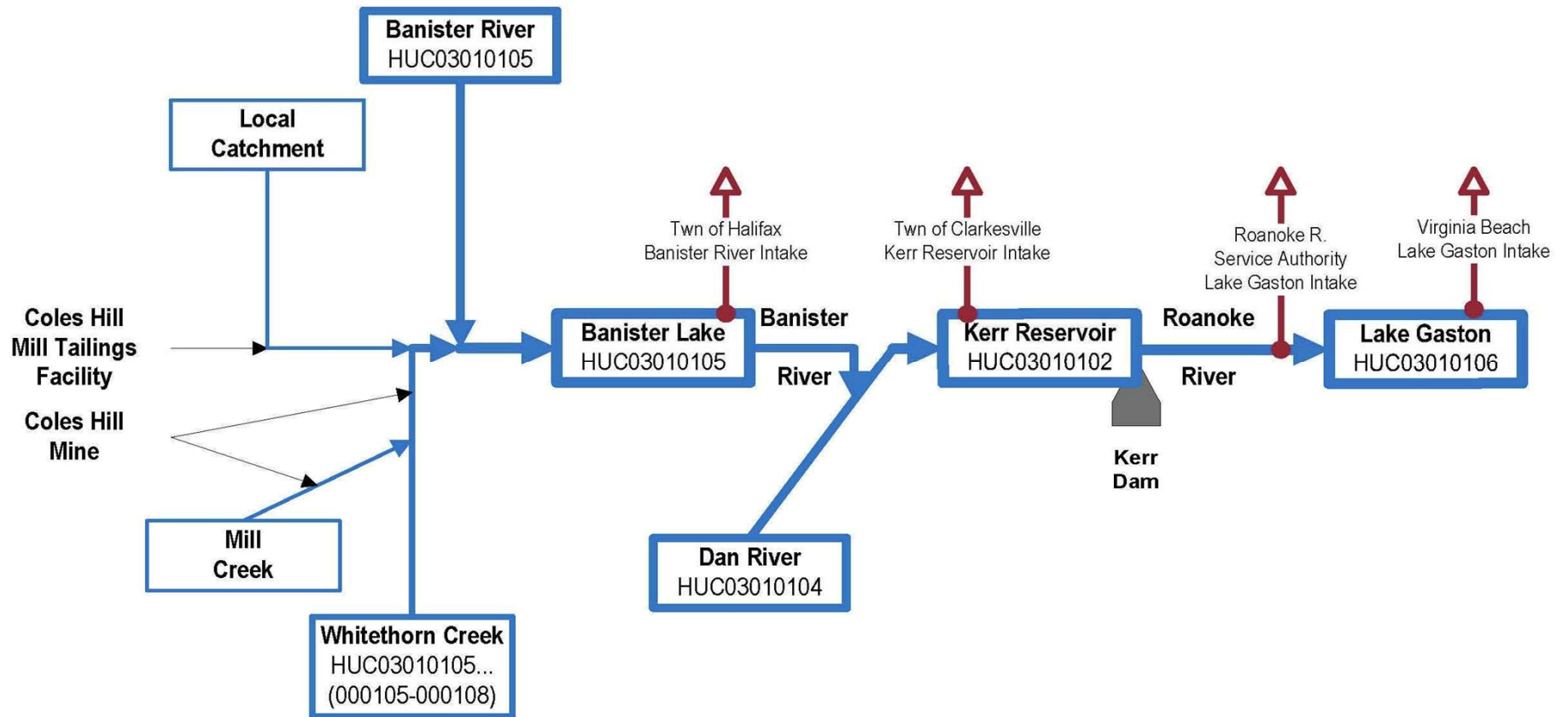
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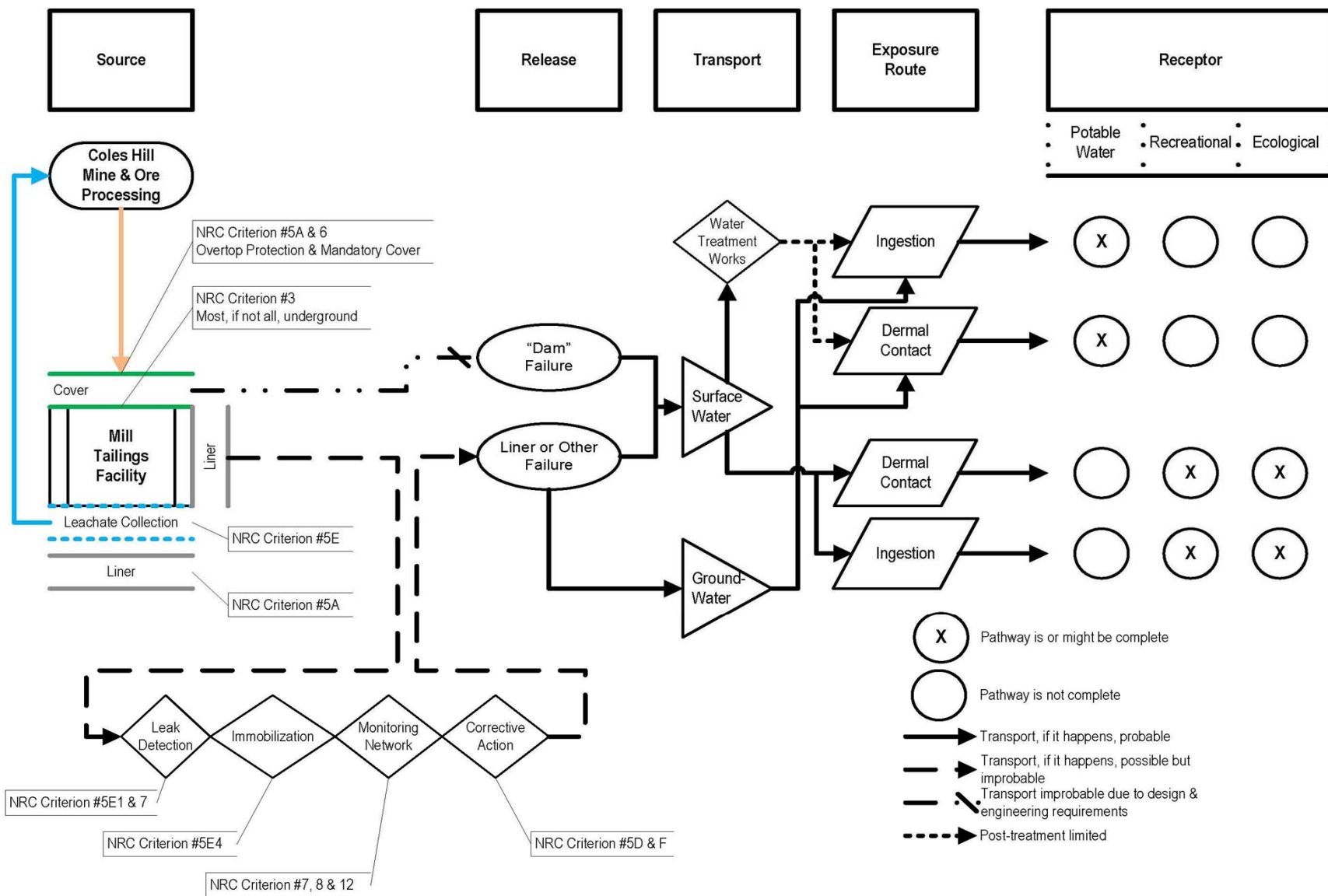
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## FIGURES



<div><div>www.kleinfelder.com</div><div><div><div>KLEINFELDER</div><div>Bright People. Right Solutions.</div></div></div></div>	PROJECT NO. : 117507.1	Hydrologic Flow Network Conceptual Site Model	Figure 1
	DRAWN: 3/29/2011		
	DRAWN BY: KAF	Coles Hill Uranium Mine Chatham, VA	
	CHECKED BY: SD & AK		
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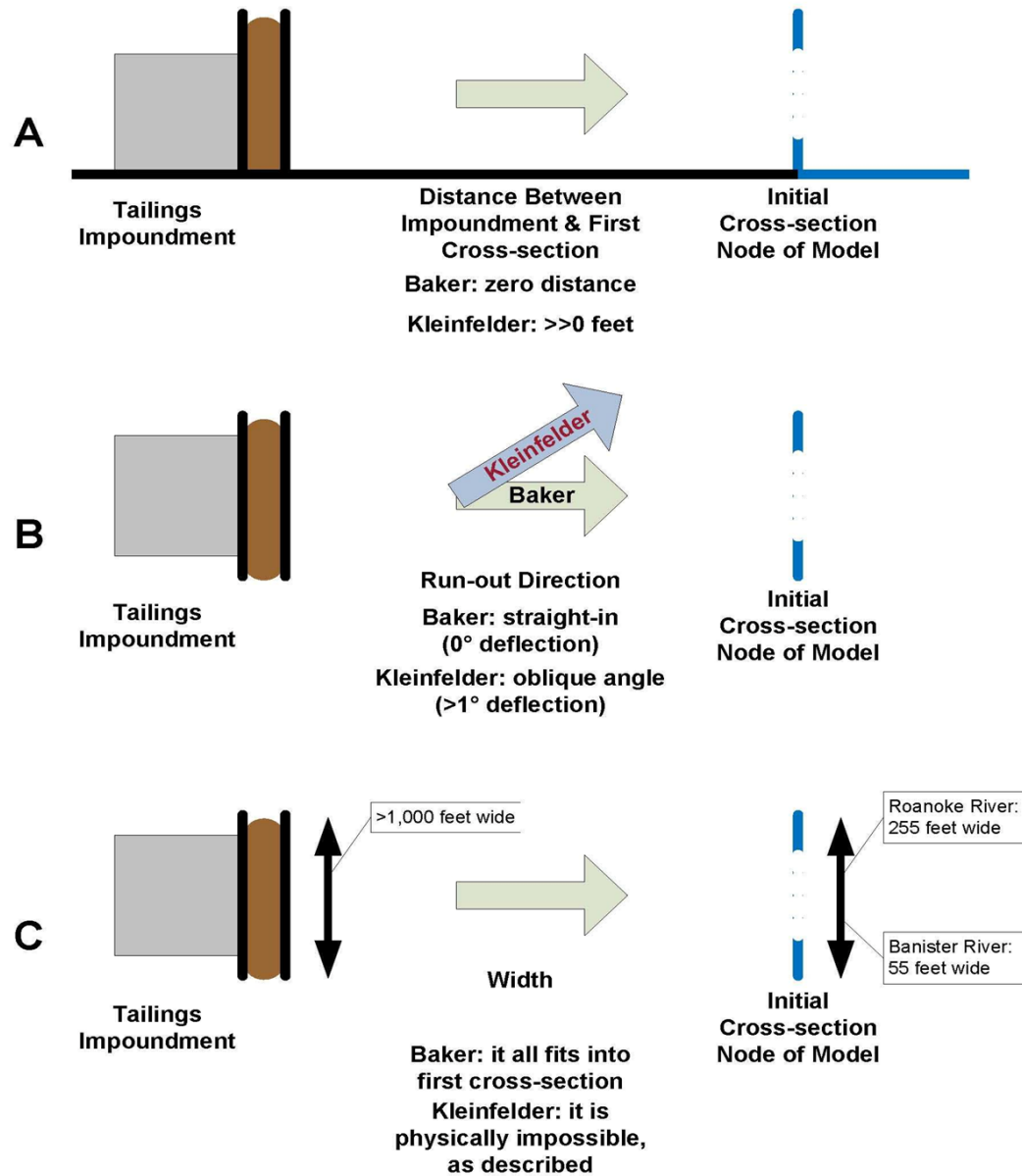
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**Conceptual Site Model**

**Coles Hill Uranium Mine  
Chatham, VA**

**Figure  
2**



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DRAWN: 4/11/2011

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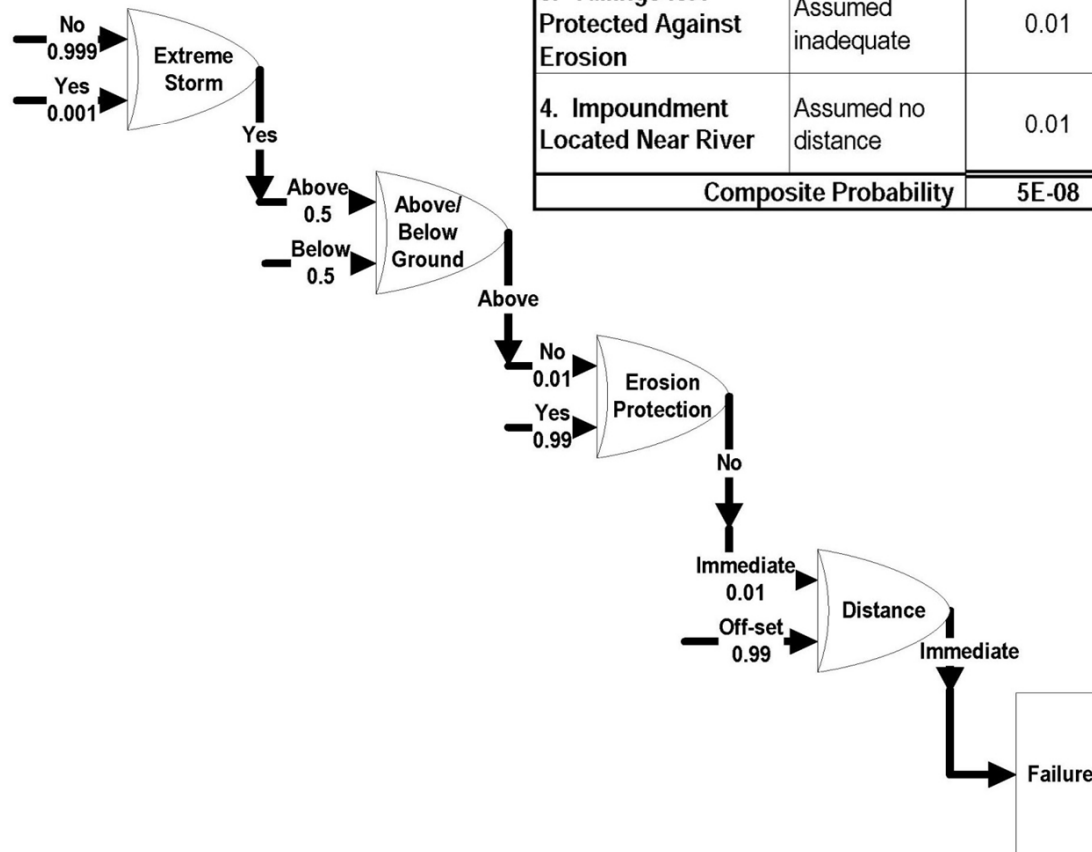
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Comparative Lay-out


Coles Hill Uranium Mine  
Chatham, VA

Figure  
3



Fault Mode	Decision	Forecast Probability	Comment	Reference
1. Extreme Storm Event	Assumed occurrence	0.001	1000-year flood event (Probable Maximum Flood or PMF)	10 CFR 40 App. A Criterion 6 (1)
2. Tailings Above Ground	Assumed aboveground	0.5	Baker assumption accepted, 50:50 chance of aboveground	NRC 1999
3. Tailings Not Protected Against Erosion	Assumed inadequate	0.01	Erosion protection inadequate, assumed 1% chance of design approval	10 CFR 40 App. A Criteria 3, 5(A)4, & 5(A)5
4. Impoundment Located Near River	Assumed no distance	0.01	Professional Judgment, assumed 1% chance that of no intervening distance to first node	NRC 1999
Composite Probability		5E-08		

Method Reference: Murray, et al. 1987

<div><div>www.kleinfelder.com</div><div><div><div>KLEINFELDER</div><div>Bright People. Right Solutions.</div></div></div></div>	PROJECT NO. : 117507.1	Mill Tailings Facility Failure Event Tree	Figure 4	
	DRAWN: 4/292011			
	DRAWN BY: KAF			
	CHECKED BY: SD & AK	Coles Hill Uranium Mine		
	FILE NAME: 117501.1-CSM.XLSX	Chatham, VA		