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UniStar
NUCLEAR ENERGY

10 CFR 50.4
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June 30, 2010

UN#10-178

ATTN: Document Control Desk
U.S. Nuclear Regulatory Commission
Washington, DC 20555-0001

Subject: UniStar Nuclear Energy, NRC Docket No. 52-016
Response to Request for Additional Information for the
Calvert Cliffs Nuclear Power Plant, Unit 3,
RAI No. 104, Question 02.04.13-4, Liquid Radioactive Release

References:
1) John Rycyna (NRC) to Robert Poche (UniStar Nuclear Energy), "RAI No. 104 RHEB 2093.doc (PUBLIC)" email dated April 20, 2009

2) UniStar Nuclear Energy Letter UN#10-153, from Greg Gibson to Document Control Desk, U.S. NRC, Response to RAI No. 104, Question 02.04.13-4, Liquid Radioactive Release, dated June 17, 2010

The purpose of this letter is to respond to the request for additional information (RAI) identified in the NRC e-mail correspondence to UniStar Nuclear Energy, dated April 20, 2009 (Reference 1). This RAI addresses Liquid Radioactive Release, as discussed in Section 2.4 of the Final Safety Analysis Report (FSAR), as submitted in Part 2 of the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 Combined License Application (COLA), Revision 6.

Reference 2 provided a June 30, 2010 schedule for the response to RAI 104, Question 02.04.13-4. The enclosure provides our response to RAI 104, Question 02.04.13-4, and includes revised COLA content. A Licensing Basis Document Change Request has been initiated to incorporate these changes into a future revision of the COLA.

This letter does not contain any sensitive or proprietary information.

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NRO

If there are any questions regarding this transmittal, please contact me at (410) 470-4205, or Mr. Wayne A. Massie at (410) 470-5503.

I declare under penalty of perjury that the foregoing is true and correct.

Executed on June 30, 2010

Christian Clement

for Greg Gibson

Enclosure: Response to NRC Request for Additional Information RAI No. 104, Question 02.04.13-4, Liquid Radioactive Release, Calvert Cliffs Nuclear Power Plant, Unit 3

cc: Surinder Arora, NRC Project Manager, U.S. EPR Projects Branch
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Getachew Tesfaye, NRC Project Manager, U.S. EPR DC Application (w/o enclosure)
Loren Plisco, Deputy Regional Administrator, NRC Region II (w/o enclosure)
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GTG/RDS/mdf

Enclosure

Response to NRC Request for Additional Information RAI No. 104, Question 02.04.13-4, Liquid Radioactive Release, Calvert Cliffs Nuclear Power Plant, Unit 3

RAI No. 104

Question 02.04.13-4

Provide a discussion of the technical basis for concluding that the postulated groundwater pathway is conservative, including discussion of the following:

- The assumption that a transport analysis that does not consider hydrodynamic dispersion is conservative for a constituent subject to decay;
- A conservative analysis of the limiting value for a radionuclide mixture considers the possible combination of radionuclides at the boundary of the unrestricted area due to variation in K_d values and does not simply assume minimum K_d values for all radionuclides in the mixture;
- Possible alternative pathways, e.g., to the underlying aquifer or to St. John's Creek and Branch 3;
- The impact of site construction (excavation and fill) on possible alternative transport pathways;
- Consistency with FSAR Sections 2.4.12 and 2.5.4.

Response

First Bullet

A higher concentration estimate at a compliance point, relative to a lower concentration estimate, is conservative for transport analyses that attempt to estimate potential exposure to radioactivity. Solute transport via mechanical dispersion can be represented macroscopically as proportional to the spatial concentration gradient. Dispersive transport moves solute from areas of relatively high concentration to relatively low concentration. As a result, hydrodynamic dispersion increases the dilution of the solute because the solute volume is spread across a larger volume of porous media. Radioactive decay reduces the concentration of the solute as time elapses. Because decay reduces solute concentration with time, transport incorporating decay reduces solute concentration at a compliance point relative to purely advective transport, assuming that time elapses during travel to the compliance point. Both hydrodynamic dispersion and decay operate to reduce solute concentrations relative to purely advective transport. Thus both hydrodynamic dispersion and decay are transport processes that produce a less conservative analysis relative to an analysis that considers only advective transport.

Dispersion and decay may interact to affect concentration. Hydrodynamic dispersion spreads the concentration of the solute spatially. This spreading will reduce the time required for a constituent to appear at a compliance point after release (i.e. will reduce the constituent breakthrough time) because of spreading in the direction parallel to the direction of groundwater flow. However, reduction in breakthrough time reduces the total time available for the constituent to decay. Because of the potential reduction in breakthrough time, it is possible that a combination of hydrodynamic dispersion and radioactive decay could produce higher concentrations at a compliance point than an analysis that only considered advection and

decay. To examine this possibility, the effects of hydrodynamic dispersion were also evaluated. The conclusion of this analysis was that for specific conditions of the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 site; not considering hydrodynamic dispersion produces higher concentrations for all the constituents of interest.

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might impact existing and future water users in the vicinity of CCNPP Unit 3 based on an instantaneous release of the radioactive material contents of a Reactor Coolant Storage Tank. This analysis includes a four-step sequential screening process which includes both hydrodynamic dispersion and decay. The screening component assumes that it is conservative to eliminate radionuclides having calculated concentrations smaller than one percent of their effluent concentration limits (*ECL*s) from further steps in the analysis. This is because the concentrations of individual radionuclides not exceeding one percent of their *ECL*s are used in the sum of ratios (unity rule) evaluation specified in 10 CFR Part 20, Appendix B. The analysis shows that the concentration (C) from step one will always equal or exceed the concentration in the following steps (i.e., step 1 C ≥ step 2 C ≥ step 3 C ≥ step 4 C).

The four steps in the screening process are:

1. Consideration of advection and radioactive decay.
2. Consideration of advection, radioactive decay, and linear adsorption (i.e. retardation).
3. Consideration of advection, radioactive decay, adsorption, and dilution in the receiving surface water body (flowing stream) where applicable.
4. Consideration of advection, radioactive decay, adsorption, hydrodynamic dispersion, and dilution in the flowing stream. Dilution is not considered in Chesapeake Bay.

For three critical pathways, the predicted radionuclide concentrations from the transport analysis were also evaluated for the potential for biological uptake of radiological contamination and the human consumption of fish, and crustaceans and mollusks in Chesapeake Bay.

Additional information on this approach and on the treatment of dispersion and decay in the analysis is contained in the attached proposed FSAR Section 2.4.13 revisions.

<u>Second Bullet</u>

A conservative analysis of accidental releases provides the highest bounding concentrations at compliance points. A bounding and conservative analysis for accidental releases at a particular site also considers site specific conditions.

The distribution coefficient, K_d, provides the equilibrium partitioning of a solute between liquid and solid phases. This partitioning reduces the concentration of the radionuclide in liquid phase over time as a portion of the solute adsorbs to the solid phase. The retardation factor, R, is employed to relate sorption to the change in dissolved concentration of a radionuclide over time.

$$R = 1 + \frac{\rho_b}{n} K_d \qquad \text{Equation (1)}$$

A larger K_d value in Equation (1) will generate a larger reduction in concentration due to sorption with the solid phase. The minimum K_d value when applied to Equation (1) will generate the

smallest reduction of concentration and the highest estimate of concentration, or the most conservative estimate, at the compliance point. Assumption of minimum K_d values will provide a more conservative analysis relative to a distribution of K_d values, all but one of which would necessarily exceed the minimum value.

When site-specific radionuclide K_d values were unavailable, a conservative K_d value of zero was used. As part of the sequential screening analysis mentioned above, site specific minimum K_d values were employed in the analysis of radionuclide concentrations at compliance points. Use of site-specific minimum K_d values for those radionuclides expected at a site provides a conservative analysis of the limiting value for the radionuclide mixture. Additional information on conservatism of this approach is contained in the attached proposed FSAR Section 2.4.13 revisions.

Third Bullet

Each pathway provides the route from the postulated accidental release point in the Nuclear Auxiliary Building to a compliance point that represents the intersection of the pathway and the perimeter of the restricted area. In this case, the compliance point represents the intersection of the pathway and the property boundary. A conservative bounding estimate of radionuclide concentration at the property boundary is the highest concentration, calculated considering site specific conditions, at compliance points representing feasible groundwater pathways. If the physical characteristics (e.g., dispersivity, groundwater velocity, distribution coefficients) of the groundwater system are the same among pathways, then the shortest pathway with the shortest travel time will provide the highest concentrations and the more conservative estimate.

Different pathways may provide different physical characteristics like different groundwater velocities due to variation in hydraulic gradient with direction and different dispersivities and distribution coefficients due to variations in porous media properties. If different surface water bodies are considered as part of the pathways, then varying degrees of surface water dilution may need to be accounted for considering the characteristics of the receiving waters.

A bounding conservative analysis includes analysis of concentrations at compliance points along feasible groundwater pathways using site specific information. The pathways to Branch 2 and to the Chesapeake Bay through the Upper Chesapeake unit are the most feasible. Possible alternative pathways include a pathway to Branch 1, a pathway to Johns Creek, a pathway to Branch 3, and a pathway to Branch 2 that traverses engineered fill material rather than the Upper Chesapeake unit. Branch 3 provides the closest discharge point from the Auxiliary Building in the Johns Creek system.

Analysis of groundwater level data collected from observation wells on site and from the output of the computer model for proposed post-construction conditions suggests two likely pathways. One pathway is from the Nuclear Auxiliary Building to Branch 2; the second pathway is from the Nuclear Auxiliary Building directly to Chesapeake Bay. For these two postulated pathways, accidentally released effluent would travel through the Upper Chesapeake unit from beneath the Nuclear Auxiliary Building until discharging in a surface water body. An alternate pathway to Branch 2 is directly through the fill material, without the effluent ever getting into the Upper Chesapeake Unit. Branch 2 provides the nearest surface water discharge point from the Nuclear Auxiliary Building and the postulated pathway with the shortest travel time. Assuming homogeneous physical characteristics, the pathway to Branch 2 through the fill will provide a

conservative estimate of concentration because this is the shortest pathway in terms of distance and travel time.

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might impact existing and future water users in the vicinity of CCNPP Unit 3 based on an instantaneous release of the radioactive material contents of a Reactor Coolant Storage Tank and on travel along six different potential pathways. These pathways are:

1) to Branch 2 through the Upper Chesapeake unit (Primary),
2) to Chesapeake Bay (Primary),
3) to Branch 1 (Alternate),
4) to Johns Creek (Alternate),
5) to Branch 3 (Alternate), and
6) to Branch 2 through engineered fill material (Alternate).

Additional information concerning these pathways and the results of transport analysis for each pathway is provided in the attached proposed FSAR Section 2.4.13 revisions.

Fourth Bullet

The site of CCNPP Unit 3 will be graded to create a flat pad for the planned footprint of the unit. The finished grade level around the nuclear island will be approximately 82 to 83 ft MSL. Part of the Unit 3 site will be excavated for building foundations. The Reactor Building, Fuel Building, Control Building, Radwaste Building, and Turbine Building will have deep foundations.

The pre-construction site has a water table in the Surficial aquifer which is underlain by a potentiometric surface that is about 40 ft below the water table in the Upper Chesapeake unit. The Surficial aquifer and a portion of the Upper Chesapeake aquitard in the power block area at the Unit 3 site will be removed as part of foundation excavation. Engineered fill and building foundations will replace the removed material. The proposed engineered fill will have a high hydraulic conductivity relative to the Surficial aquifer and the Upper Chesapeake aquitard. Consequently, groundwater models of post-construction conditions show a drop in water table across the areas subject to excavation and emplacement of fill to approximately fifteen feet above the elevation of the current potentiometric surface in the Upper Chesapeake unit due to the relatively high conductivity of the fill material and removal of the aquitard material. Although the water table elevation will be lower, the piezometric levels in the Upper Chesapeake unit will be higher. As a result, the hydraulic gradient in the Upper Chesapeake unit is expected to increase for post-construction conditions.

A topographic divide currently exists to the west of the CCNPP Unit 3 site. A groundwater divide exists in the same area, providing a subdued representation of the topographic divide in both the surficial aquifer and the Upper Chesapeake unit. Groundwater modeling of post-construction conditions suggests that the existing groundwater divide will remain and that the Nuclear Auxiliary Building will remain east of this groundwater divide. After site construction, groundwater flow from the area near the Nuclear Auxiliary Building is expected to be toward the east or northeast (i.e. away from the divide). The most likely groundwater pathways from the

Nuclear Auxiliary Building, which is the potential accidental release point, are toward Branch 2 and towards Chesapeake Bay.

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might impact existing and future water users in the vicinity of CCNPP Unit 3 based on an instantaneous release of the radioactive material contents of a Reactor Coolant Storage Tank and on travel along six different potential pathways. These pathways are enumerated above in Subpart (c). Post-construction conditions as obtained from groundwater modeling of the site and from the properties of materials that will be used in construction are included in the radionuclide transport analysis. Post-construction conditions are conservatively represented by using the highest calculated piezometric level beneath the Nuclear Auxiliary Building from groundwater modeling of post-construction conditions to set the hydraulic gradient for five pathways. The sixth pathway (to Branch 2 through engineered fill) employs the minimum travel time obtained from a particle-tracking analysis of post-construction conditions and uses the largest hydraulic conductivity value estimated for engineered fill material. Engineered fill material is expected to have a higher hydraulic conductivity than the water-bearing units identified at the site. From this analysis, the bounding (i.e. highest) radionuclide concentrations are calculated for the pathways to Branch 2 and to the Chesapeake Bay.

Additional information concerning these six pathways, the conservatism of the representation, and the results of transport analysis for each pathway are provided in the attached proposed FSAR Section 2.4.13 revisions.

Fifth Bullet

A bounding and conservative analysis for accidental releases at a particular site provides the highest radionuclide concentration(s), calculated considering site-specific conditions, at feasible compliance points. FSAR Sections 2.4.12 and 2.5.4 provide details of site-specific conditions related to groundwater flow and transport. Consistency with these two sections ensures that site-specific conditions are addressed in a conservative analysis.

A radionuclide transport analysis has been conducted that provides a sequential screening analysis which incorporates site specific conditions. The analysis includes post-construction conditions estimated from groundwater modeling of post-construction conditions and from the properties of materials that will be used to construct Unit 3. Site-specific conditions are also obtained from hydrogeologic data collected for and presented in FSAR Section 2.4.12. Soil properties, as presented in Section 2.5.4, are included in the analysis.

Additional information on site-specific information employed in the analysis and on the degree of conservatism incorporated into the analysis is provided in the attached proposed FSAR Section 2.4.13 revisions.

COLA Impact

FSAR Sections 2.4.13.1 through 2.4.13.3 are being replaced with the following:

2.4.13.1 Groundwater

This subsection provides a conservative analysis of a postulated, accidental liquid release of effluents to the ground water at the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 site. The accident scenario is described, and the conceptual model used to evaluate radionuclide transport is presented, along with potential pathways of contamination to water users. The radionuclide concentrations that a water user might be exposed to are compared against the regulatory limits.

2.4.13.1.1 Source Term

This subsection describes the ability of groundwater and surface water systems to delay, disperse, or dilute a liquid effluent if accidentally released from the site. The US EPR Design Certification Project General Arrangement Drawings were reviewed to determine which component in each of the main areas of the Nuclear Island outside containment could contain the maximum radionuclide concentration/volume. This review also indicated that the proposed design includes no buildings, facilities, or tanks containing radionuclides outside of the Nuclear Island. Components were evaluated based on their respective volumes and whether they could contain reactor coolant activity. Except for the Reactor Building, there is no secondary containment in the Nuclear Island compartments/buildings. The tanks and components that are designed to contain or process radioactive liquids are within the Nuclear Island. These components include (AREVA, 2007 and AREVA, 2008):

- Reactor Coolant Storage Tanks (RCSTs) (total of six, each with a gross volume of 4414 ft^3 [125 m^3]) in the Nuclear Auxiliary Building
- Liquid Waste Storage Tanks (total of five, 2473 ft^3 [70.0 m^3] net) in the Waste Building
- Volume Control Tank (350 ft^3 [9.9 m^3]) in the Fuel Building
- LHSI Heat Exchanger (total of four, 33 ft^3 [0.93 m^3] each) in the Safeguards Building

The RCST located in the Nuclear Auxiliary Building is the largest tank outside containment with radioactive contents. The liquid source terms considered included waste system Group I liquid waste hold-up tanks. The highest liquid source term is in the RCSTs with the assumptions of 0.25 percent failed fuel, unpurified, undiluted, and un-decayed reactor coolant. As a result, the total activity released from one RCST with the assumptions made bounds all the other radioactive liquid sources (AREVA, 2007).

The inventory of radionuclides in reactor coolant water, and its radionuclide activities are shown in Table 2.4-44. The reactor coolant activity levels represent the maximum activity levels without radioactive decay based on a 0.25 percent defective fuel rate (AREVA, 2007). The 0.25 percent defective fuel rate was selected to be consistent with the fuel failure rate prescribed by the U.S. EPR FSAR. This fuel failure rate is two times the 0.12 percent failure rate prescribed by Branch Technical Position (BTP) 11-6 (NRC, 2007) and provides a conservative bounding estimate of the radionuclide inventory and associated activity levels in the postulated release.

2.4.13.1.2 Groundwater Pathway

This subsection provides a conservative analysis of a postulated accidental liquid release of effluents to the groundwater at the CCNPP Unit 3 site. The accident scenario is described in this subsection along with the conceptual model used to evaluate the radionuclide transport with potential pathways of contamination to water users. The radionuclide concentrations to which a water user might be exposed are compared against the regulatory limits.

The analysis as outlined in NUREG 0800 Standard Review Plan (SRP) 2.4.13 and BTP 11-6 (NRC, 2007) considers the impact of a release on the nearest potable water supply and the use of water for direct human consumption or indirectly through animals (livestock watering), crops (agricultural irrigation), and food processing (water as an ingredient). For direct consumption, results are considered acceptable if an accidental release will not result in radionuclide concentrations in excess of the effluent concentration limits (*ECL*s) included in Appendix B (Table 2, Column 2, under the unity rule) to 10 CFR Part 20 (NRC, 2009) in the nearest source of potable water, located in an unrestricted area. For indirect exposure, bioaccumulation in the consumed animal or plant organisms is the pathway for exposure. For the CCNPP Unit 3 site, the potential for biological uptake, concentration, and human consumption of fish, crustaceans, and mollusks was considered for the groundwater pathway. For indirect exposure, results are considered acceptable if the dose associated with an accidental release does not exceed the annual dose limit given in 10 CFR 20.1301.

The groundwater pathway evaluation includes the components of advection, decay, retardation, and hydrodynamic dispersion. Where applicable, dilution of the postulated groundwater contaminant plume by the receiving surface water bodies is also considered.

A radionuclide assumed to be undergoing purely advective transport travels at the same velocity as groundwater. This approach is conservative because advective flow does not account for hydrodynamic dispersion, which would normally dilute radionuclide concentrations in groundwater through the processes of molecular diffusion and mechanical dispersion. However, this assumption is evaluated as the effects of hydrodynamic dispersion are also considered. Radionuclides in groundwater flow systems are subject to radioactive decay, the rate of which depends on the half-life of the radionuclide. Table 2.4-44 includes the half-lives of the radionuclides of concern. Retardation considers chemical interactions between dissolved groundwater constituents and the aquifer matrix. Contaminants that react with the aquifer matrix are retarded relative to the groundwater velocity. Reactions with the aquifer matrix include cation/anion exchange, complexation, oxidation-reduction reactions, and surface sorption. Site-specific partitioning coefficients (K_d) are presented in Table 2.4-45.

2.4.13.1.3 Conceptual Model

Figure 2.4-102 illustrates the conceptual model used to evaluate an accidental release of liquid effluent to groundwater, or to surface water via the groundwater pathway through the Upper Chesapeake unit. The most plausible groundwater pathways are north-northeast from CCNPP Unit 3 to a discharge location in Branch 2, and northeast along the shortest line to Chesapeake Bay (Figure 2.4-103). Besides these pathways, several other less likely alternative groundwater pathways were analyzed in order to conservatively bound the evaluation. The alternative pathways considered are the following (Figure 2.4-103):

- A pathway to the east-southeast discharging in Branch 1

- A pathway to the south-southwest discharging in Branch 3
- A pathway to the southwest discharging in Johns Creek
- A north-northeast pathway leading through the Engineered fill material to Branch 2. The possibility of this pathway is indicated by a groundwater model simulation in which the hydraulic conductivity of the fill is assigned the high end (28.34 ft/day) [0.01 cm/s] of its potential range (Section 2.4.12)

The first three of the four alternative pathways (to Branch 1, Branch 3 and Johns Creek) are not supported by the results of the post-construction groundwater flow model (Section 2.4.12). The key elements and assumptions embodied in the conceptual model of the most plausible pathways to Branch 2 and Chesapeake Bay, as well as in the alternative plausible conceptual models, are described and discussed below. The conceptual model of the site groundwater system is based on information presented in Section 2.4.12.

As previously indicated, a Reactor Coolant Storage Tank with a capacity of 4414 ft^3 (125 m^3) is assumed to be the source of the release. The tank is located within the Nuclear Auxiliary Building, which will have a building slab top depth of approximately 41 ft below grade (12.5 m), at an elevation of approximately 45 ft MSL (13.7 m MSL). The Reactor Coolant Storage Tank is postulated to rupture, and 80 percent of its liquid volume (3531.2 ft^3 [100 m^3]) is assumed to be released in accordance with BTP 11-6 (NRC, 2007). Flow from the tank rupture is postulated to flood the building and migrate past the building containment structure and sump collection system and enter the subsurface at the top of the building slab at an elevation of approximately 45 ft (13.7 m) MSL. The groundwater model of post-construction conditions at the site suggests that the maximum potentiometric surface elevation at the Nuclear Auxiliary Building is approximately 55 ft (16.8 m) MSL (Section 2.4.12) (Figure 2.4-105). The effluent will flow vertically down through the saturated portion of the foundation fill material into the Upper Chesapeake unit.

For the pathways through the Upper Chesapeake unit, any travel time through the engineered fill between the Nuclear Auxiliary Building and the aquifer is conservatively neglected. Figure 2.4-106 depicts a cross-section from the post-construction groundwater model along this pathway. For the pathway through the engineered fill, the entire quantity of the accidental liquid effluent release remains in the fill material during subsurface transport and discharges to Branch 2, i.e. there is no downward vertical migration of the accidental liquid effluent release from the fill material to the Upper Chesapeake unit. Figure 2.4-108 depicts a cross-section from the post-construction groundwater model along this pathway. This assumption is consistent with results from the groundwater model used in sensitivity analysis of fill properties. Figure 2.4-108 displays results from this model which show horizontal flow through the fill material. The assumption that the entire pathway is through fill material is conservative relative to Figure 2.4-106 because the fill material has a higher hydraulic conductivity and lower effective porosity relative to the Upper Chesapeake unit. A higher hydraulic conductivity value and a lower effective porosity result in higher groundwater velocities, shorter travel times, and consequently greater radionuclide concentrations in the fill.

The entire 3531.2 ft^3 (100 m^3) volume of effluent is assumed to be instantaneously released into the groundwater system beneath the Nuclear Auxiliary Building. The effluent will continue flowing through the Upper Chesapeake unit (or engineered fill) with groundwater to the point of aquifer discharge.

The pre-construction site groundwater system consists of two water bearing units beneath the site; the Surficial aquifer and the Upper Chesapeake unit. The unconsolidated sediments comprising the Surficial aquifer consist primarily of fine- to medium-grained sands and silty or clayey sands. The Surficial aquifer extends above an elevation of approximately 65 ft MSL (19.8 m MSL). It is absent in some areas of the site where the elevation of the existing ground surface is below the base of the Surficial aquifer. Because the Surficial aquifer lies at an elevation well above the elevation of the postulated release point, it is not impacted by the postulated release from the Nuclear Auxiliary Building. Additionally, the water table elevation in the Surficial aquifer (approximately 81 ft (24.7 m) MSL) is approximately 46 ft (14.0 m) higher than the pieziometric elevation of the Upper Chesapeake unit (approximately 35 ft (10.7 m) MSL) as observed in observation well cluster 319 (Section 2.4.12). The post-construction groundwater model suggests that the potentiometric surface beneath the Nuclear Auxiliary Building in the Upper Chesapeake unit will be somewhat higher (approximately 55 ft (16.8 m) MSL) after construction (Figure 2.4-105). The elevation of the water table in the remaining portions of the Surficial aquifer will be similar to pre-construction levels. Consequently, the difference in elevation between the water table in the Surficial aquifer and the potentiometric surface in the Upper Chesapeake unit will still exceed 15 ft (4.6 m). Therefore, upward vertical transport from the Upper Chesapeake unit to the Surficial aquifer cannot occur, and the Surficial aquifer is not retained in the conceptual model.

The Surficial aquifer and a portion of the Upper Chesapeake aquitard in the power block area at the Unit 3 site will be removed as part of foundation excavation. Engineered fill and building foundations will replace the removed material. The proposed engineered fill will have a high hydraulic conductivity relative to the Surficial aquifer and the Upper Chesapeake aquitard. Groundwater models of post-construction conditions show a drop in water table to about 15 ft (4.6 m) above the elevation of the existing potentiometric surface in the Upper Chesapeake unit due to the relatively high conductivity of the fill material and removal of the aquitard material. Although the water table elevation will be lower, the piezometric levels in the Upper Chesapeake unit will be higher due to the removal of portions of the Upper Chesapeake aquitard and replacement with fill material. Consequently, the hydraulic gradient in the Upper Chesapeake unit is expected to increase for post-construction conditions.

For the first primary pathway, the effluent release immediately enters the Upper Chesapeake unit and remains within this unit as it flows to the projected discharge point in Branch 2 approximately 580 ft (177 m) down-gradient. Groundwater seepage would enter Branch 2 and eventually discharge with Branch 2 surface water into the Chesapeake Bay. For conservatism, it is assumed that the entire mass of nuclides from the postulated accidental effluent release will be discharged into Branch 2 (Figure 2.4-102).

Based on the results of the post-construction groundwater model, only a small fraction of groundwater flow in the Upper Chesapeake unit discharges into Branch 2. The majority of this flow passes under Branch 2 and discharges to Chesapeake Bay. This is the second primary pathway option (Figure 2.4-102, Figure 2.4-106, and Figure 2.4-109). Site specific subsurface investigation data indicates the basal portion of the Upper Chesapeake unit extends eastward beneath Chesapeake Bay (Schnabel, 2007). Therefore, a portion of the contaminated groundwater may discharge directly to the Bay rather than to the surface water in Branch 2. Because of this, the second primary pathway extending approximately 1315 ft (401 m) down-gradient from the Nuclear Auxiliary Building northeast along the shortest line to Chesapeake Bay is considered (Figure 2.4-103). For conservatism, this second plausible pathway assumes

that none of the contaminant slug is intercepted by site streams and the entirety of the slug discharges to Chesapeake Bay.

Although the post-construction groundwater modeling analysis indicates a flowpath from the Nuclear Auxiliary Building north-northeast toward Branch 2 or northeast directly to Chesapeake Bay, it is conceivable that the groundwater elevation contours could change in such a way that the groundwater pathway could lead east toward Branch 1, could lead south-southwest towards Branch 3, or southwest towards Johns Creek. The pathways toward the south-southwest and southwest are considered very unlikely, as their occurrence would necessitate a more substantial change in the piezometric elevations beneath the site. Nonetheless, to demonstrate the conservatism of the analysis, this evaluation also considers the alternative potential groundwater pathways.

The presence of perennial flow in site streams indicates that the groundwater system is discharging steadily to surface water, and thus the water table must intersect the ground surface along these valleys. The piezometric level at Branch 2 to the north-northeast of Unit 3 (Figure 2.4-102) is assumed to be equal to the surface water elevation in the creek, which is approximately at elevation 22 ft (6.7 m) MSL at the predicted accidental release discharge point in Branch 2. The piezometric level at the bay, for the pathway to Chesapeake Bay, is assumed to be 0 ft MSL. For the alternative groundwater pathways to Branch 1, Johns Creek, and Branch 3, the downstream piezometric levels at the points of discharge to surface water are assumed to be equal to the ground surface elevations at the streams.

There are no existing water-supply wells between the postulated release points and the area where groundwater discharges.

2.4.13.1.4 Radionuclide Transport Analysis

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might impact existing and future water users in the vicinity of CCNPP Unit 3 based on an instantaneous release of the radioactive material contents of a RCST. A sequential screening analysis is employed to analyze contamination as described in Section 2.4.13.1.4.2. Radionuclide concentrations resulting from the analysis in each step are compared against the *ECL*s identified in 10 CFR Part 20, Appendix B, Table 2, Column 2 (NRC, 2009) to determine compliance. If the results for a step in the process exceed 1% of the *ECL*, that radionuclide is further analyzed in the following step. Results for each pathway evaluated are presented in Table 2.4-206 through Table 2.4-211.

This analysis accounts for the parent radionuclides expected to be present in the RCST plus progeny radionuclides that would be generated subsequently during transport; source radionuclide concentrations are listed in Table 2.4-44. The analysis considered progeny in the decay chain sequences that are important for dosimetric purposes. International Commission on Radiological Protection (ICRP) Publication 38 (ICRP, 1983) was used to identify the member for which the decay chain sequence can be truncated. For some of the radionuclides expected to be present in RCST, consideration of up to three members of the decay chain sequence was required. The derivation of the equations governing the transport of the parent and progeny radionuclides is presented in the following section.

2.4.13.1.4.1 Transport Equations for Parent and Progeny Radionuclides Accounting for Advection, Radioactive Decay, and Adsorption

The following equations are presented in terms of radionuclide activity concentrations, C. Activity concentration is the mean number of decays or disintegrations per unit time within a unit volume, measured in units of Curies (Ci), where 1 Ci = 3.70×10^{10} disintegrations per second. It is proportional to N, the number of radionuclide atoms present within the unit volume at that time, according to the relation $C = \lambda N$, in which λ is the radioactive decay constant.

Two-dimensional radionuclide transport along a groundwater flowline is governed by the advection-dispersion-reaction equation (Javandel, 1984), which can be stated for the parent radionuclide as:

$$R_1 \frac{\partial N_1}{\partial t} = D_x \frac{\partial^2 N_1}{\partial x^2} + D_y \frac{\partial^2 N_1}{\partial y^2} - v \frac{\partial N_1}{\partial x} - \lambda_1 R_1 N_1 \qquad \text{(Equation 2.4.13-1)}$$

where:

- N = radionuclide concentration in terms of the number of atoms per unit volume;
- R = retardation factor;
- D_x = coefficient of longitudinal hydrodynamic dispersion;
- D_y = coefficient of lateral (transverse) hydrodynamic dispersion;
- v = average linear groundwater velocity;
- λ = radioactive decay constant;
- t = groundwater travel time from source to receptor or point of discharge to surface water;
- x = distance along the groundwater flowline; and
- y = distance normal to the groundwater flowline.

Subscripts on N, R and λ indicate the order in the decay chain, if daughter nuclides are produced.

The retardation factor is provided by Equation (6) in Javandel, 1984:

$$R = 1 + \frac{\rho_b K_d}{n_e} \qquad \text{(Equation 2.4.13-2)}$$

where:

- ρ_b = bulk density (g/cm^3);
- K_d = distribution coefficient (cm^3/g); and
- n_e = effective porosity (dimensionless).

The average linear groundwater velocity (v) is determined using Darcy's law:

$$v = \frac{q}{n_e} = -\frac{K}{n_e}\frac{dh}{dx} \qquad \text{(Equation 2.4.13-3)}$$

where:

- q = average linear Darcy velocity;

K = hydraulic conductivity; and
dh/dx = hydraulic gradient (h representing the hydraulic head and x the distance along the direction of ground water flow).

The radioactive decay constant (λ) can be written as:

$$\lambda = \frac{\ln(2)}{t_{1/2}} \qquad \text{(Equation 2.4.13-4)}$$

where:
$t_{1/2}$ = radionuclide half-life.

The dispersion coefficients, neglecting molecular diffusion, are estimated by:

$$D_x = \alpha_x v \; ; \; D_y = \alpha_y v \qquad \text{(Equation 2.4.13-5)}$$

where α_x and α_y are the longitudinal and lateral dispersivity, respectively. Based on the estimated dispersivities for the pathway to Branch 2, the products α_x v and α_y v are at least three to four orders of magnitude larger than the molecular diffusion coefficient. Therefore, the contribution of molecular diffusion to the dispersion coefficient is negligible.

As described in Konikow, 1978, the method of characteristics (MOC) approach can be used on Equation (2.4.13-1) to determine the material derivative of concentration:

$$\frac{dN}{dt} = \frac{\partial N}{\partial t} + \frac{dx}{dt}\frac{\partial N}{\partial x} \qquad \text{(Equation 2.4.13-6)}$$

The MOC approach provides the solution for a single particle of fluid moving along a pathline dictated by the groundwater velocity field. As C is constant across the particle, a spatial C gradient does not exist for the particle and hydrodynamic dispersion is dropped from the analysis. The characteristic equations for Equation (2.4.13-1) can then be expressed as follows:

$$\frac{dN}{dt} = -\lambda N \qquad \text{(Equation 2.4.13-7)}$$

$$\frac{dx}{dt} = \frac{v}{R} \qquad \text{(Equation 2.4.13-8)}$$

Equation (2.4.13-7) is the radioactive decay reaction for the radionuclide of interest and Equation (2.4.13-8) describes the particle pathline. The solutions of the system of equations comprising Equations (2.4.13-7) and (2.4.13-8) can be obtained by integration to yield the characteristic curves of Equation (2.4.13-1). For transport of a parent radionuclide, expressed in terms of activity, the equations representing the characteristic curves are:

$$C_1(t) = C_1^0 \exp(-\lambda_1 t) \qquad \text{(Equation 2.4.13-9)}$$

$$t = R_1 \frac{x}{v}$$ (Equation 2.4.13-10)

where:

$C_1(t)$ = parent radionuclide activity concentration at time t;
C_1^0 = initial bounding parent activity concentration (Table 2.4-44);
λ_1 = radioactive decay constant for parent from Equation (2.4.13-4);
R_1 = retardation factor for the parent radionuclide from Equation (2.4.13-2);

Similar relationships exist for progeny radionuclides. For the first progeny in the decay chain, the advection-dispersion-reaction equation is:

$$R_2 \frac{\partial N_2}{\partial t} = D_x \frac{\partial^2 N_2}{\partial x^2} + D_y \frac{\partial^2 N_2}{\partial x^2} - v \frac{\partial N_2}{\partial x} + d_{12}\lambda_1 R_1 N_1 - \lambda_2 R_2 N_2$$ (Equation 2.4.13-11)

where:

subscript 2 denotes properties/concentration of the first progeny; and
d_{12} = fraction of parent radionuclide transitions that result in production of progeny (also called the branching coefficient).

The characteristic equations for Equation (2.4.13-11), assuming $R_1 \approx R_2$ can be derived as:

$$\frac{dN_2}{dt} = d_{12}\lambda_1 N_1 - \lambda_2 N_2$$ (Equation 2.4.13-12)

$$\frac{dx}{dt} = \frac{v}{R_2}$$ (Equation 2.4.13-13)

Recognizing that Equation (2.4.13-12) is formally similar to Equation B.43 in Kennedy and Strenge (1992), these equations can be integrated to yield an expression for the activity concentration of the first progeny radionuclide:

$$C_2 = K_1 \exp(-\lambda_1 t) + K_2 \exp(-\lambda_2 t)$$ (Equation 2.4.13-14)

$$t = R_2 \frac{L}{v}$$ (Equation 2.4.13-15)

for which:

$$K_1 = \frac{d_{12}\lambda_2 C_1^0}{\lambda_2 - \lambda_1}$$ (Equation 2.4.13-16)

$$K_2 = C_2^0 - \frac{d_{12}\lambda_2 C_1^0}{\lambda_2 - \lambda_1}$$ (Equation 2.4.13-17)

The advection-dispersion-reaction equation for the second progeny in the decay chain is:

$$R_3 \frac{\partial N_3}{\partial t} = D_x \frac{\partial^2 N_3}{\partial x^2} + D_y \frac{\partial^2 N_3}{\partial y^2} - v \frac{\partial N_3}{\partial x} + d_{13}\lambda_1 R_1 N_1 + d_{23}\lambda_2 R_2 N_2 - \lambda_3 R_3 N_3 \qquad \text{(Equation 2.4.13-18)}$$

where:

subscript 3 denotes properties/concentration of the second progeny radionuclide;

d_{13} = fraction of parent radionuclide transitions resulting in production of the second progeny (also called the branching coefficient);

d_{23} = fraction of first progeny transitions that result in production of the second progeny (also called the branching coefficient).

The characteristic equations for Equation (2.4.13-18), assuming $R_1 \approx R_2 \approx R_3$ can be derived as:

$$\frac{dN_3}{dt} = d_{13}\lambda_1 N_1 + d_{23}\lambda_2 N_2 - \lambda_3 N_3 \qquad \text{(Equation 2.4.13-19)}$$

$$\frac{dx}{dt} = \frac{v}{R_3} \qquad \text{(Equation 2.4.13-20)}$$

Considering the formal similarity of Equation (2.4.13-19) to Equation B.54 in Kennedy and Strenge (1992), Equations (2.4.13-19) and (2.4.13-20) can be integrated to yield:

$$C_3 = K_1 \exp(-\lambda_1 t) + K_2 \exp(-\lambda_2 t) + K_3 \exp(-\lambda_3 t) \qquad \text{(Equation 2.4.13-21)}$$

$$t = R_3 \frac{L}{v} \qquad \text{(Equation 2.4.13-22)}$$

for which:

$$K_1 = \frac{d_{13}\lambda_3 C_1^0}{\lambda_3 - \lambda_1} + \frac{d_{23}\lambda_2 d_{12}\lambda_3 C_1^0}{(\lambda_3 - \lambda_1)(\lambda_2 - \lambda_1)} \qquad \text{(Equation 2.4.13-23)}$$

$$K_2 = \frac{d_{23}\lambda_3 C_2^0}{\lambda_3 - \lambda_2} - \frac{d_{23}\lambda_2 d_{12}\lambda_3 C_1^0}{(\lambda_3 - \lambda_2)(\lambda_2 - \lambda_1)} \qquad \text{(Equation 2.4.13-24)}$$

$$K_3 = C_3^0 - \frac{d_{13}\lambda_3 C_1^0}{\lambda_3 - \lambda_1} - \frac{d_{23}\lambda_3 C_2^0}{\lambda_3 - \lambda_2} + \frac{d_{23}\lambda_2 d_{12}\lambda_3 C_1^0}{(\lambda_3 - \lambda_1)(\lambda_3 - \lambda_2)} \qquad \text{(Equation 2.4.13-25)}$$

2.4.13.1.4.2 Sequential Screening Analysis Steps

To estimate radionuclide concentrations at groundwater discharge points, Equations (2.4.13-9), (2.4.13-14), and (2.4.13-21) were applied as appropriate along the groundwater pathway that would originate at the liquid effluent release point beneath the Nuclear Auxiliary Building at Unit 3 and terminate at the point of groundwater discharge, e.g., in Branch 2, or Branch 1, etc. The analysis was performed sequentially as described below.

1. First a screening analysis was completed considering advection and radioactive decay only.

2. Those radionuclides that exceeded one percent of their *ECL* in step 1 were then analyzed in step 2. The step 2 analysis accounts for advection and radioactive decay as well as retardation due to linear adsorption. One percent was chosen because, based on the number of radionuclides analyzed, if each exceeded one percent of its *ECL*, then the total dose could exceed the unity rule requirements established in 10 CFR Part 20, Appendix B (NRC, 2009). This was based on engineering judgment.

3. Those radionuclides that still exceeded one percent of their *ECL* after step 2 were analyzed further by accounting for advection, radioactive decay, adsorption, and dilution in the receiving surface water stream where applicable. For primary pathway 2, which goes from the Nuclear Auxiliary Building directly to Chesapeake Bay, dilution was not included in the analysis because the discharge point represents the boundary of the Upper Chesapeake unit and the bay.

4. Those radionuclides that still exceeded one percent of their *ECL* were analyzed further by accounting for advection, radioactive decay, adsorption, hydrodynamic dispersion, and dilution in surface water. Dilution was not employed in the analysis of the pathway directly to Chesapeake Bay as mentioned above.

In calculating the sum of the concentration to *ECL* ratios, all nuclides are included. For those nuclides whose analysis is not carried through a particular step, the contribution to the sum is taken from the last calculated activity concentration. For steps 1 to 3, if the activity concentration of any member of a radioactive decay chain exceeded one percent of its *ECL*, the entire decay chain was carried to the next step.

Implicit in this sequential screening approach is an assumption that it is conservative to eliminate radionuclides having concentrations smaller than one percent of their *ECL*s from further steps in the analysis. This is because the concentrations of individual radionuclides not exceeding one percent of their *ECL*s are used in the sum of ratios (unity rule) evaluation specified in 10 CFR Part 20, Appendix B. In other words, it is assumed that the concentration from step one will always exceed the concentration in step two, and so on (i.e., step 1 C > step 2 C > step 3 C > step 4 C), which results in conservative (high) concentration estimates for those radionuclides that are dropped in the earlier steps of the screening analysis.

The predicted radionuclide concentrations for the pathway directly to Chesapeake Bay and for the pathways through the Upper Chesapeake unit and through structural fill material to Branch 2 were also evaluated for the potential of biological uptake of radiological contamination and the human consumption of fish, crustaceans and mollusks harvested in the immediate vicinity of discharge in Chesapeake Bay.

2.4.13.1.4.3 Advection and Radioactive Decay

The initial screening analysis was performed considering advection and radioactive decay only. This analysis assumed that radionuclides migrate at the same rate as the groundwater and considered neither adsorption nor retardation, which would otherwise have resulted in a longer travel time and more radioactive decay. The concentrations of the radionuclides appearing in

Table 2.4-44 were decayed for a period equal to the groundwater travel time from their point of release to their point of discharge. Retardation was not considered in this analysis so the analysis is equivalent to using Equations (2.4.13-9), (2.4.13-14), and (2.4.13-21) with a retardation factor of R=1. The resulting estimated activity concentrations are presented in Section 2.4.13.1.4.8.

2.4.13.1.4.4 Advection, Radioactive Decay, Retardation and Adsorption

The radionuclides retained from the initial screening analysis for the pathways are further evaluated considering adsorption and retardation in addition to advection and radioactive decay. The distribution coefficients used for these radionuclides were obtained from laboratory testing of samples from the site to determine site-specific K_d values for Mn, Co, Zn, Sr, Cs, Ce, Fe, and Ru (SRNL, 2007). The site-specific distribution coefficients (K_d) were obtained from analysis of 20 soil samples obtained from the CCNPP Unit 3 site – 11 samples from the Upper Chesapeake unit material, and 9 from the Surficial aquifer material (SRNL, 2007). The results of the laboratory K_d analysis are summarized in Table 2.4-45. For this analysis, the lowest K_d values measured for each radionuclide within the Upper Chesapeake unit or Surficial aquifer (for the engineered fill) were used . K_d values of zero were assigned to radionuclides for which site-specific tests were not available. Retardation factors were then calculated using Equation (2.4.13-2). Concentrations were determined at the points of groundwater discharge using Equation (2.4.13-9), (2.4.13-14), or (2.4.13-21) with the appropriate retardation factors, the results are presented in Section 2.4.13.1.4.9.

2.4.13.1.4.5 Advection, Radioactive Decay, Retardation, Adsorption, and Dilution in Surface Water

The radionuclides with concentrations greater than one percent of their respective *ECL*s after a screening analysis that accounted for advection, radioactive decay, and adsorption were further analyzed to additionally account for dilution in the receiving surface water streams. As the direct pathway to Chesapeake Bay assumes the entirety of the contaminant slug discharges directly to Chesapeake Bay, surface water dilution was not evaluated for this pathway.

Surface water concentration after dilution was estimated from the equation:

$$C_{sw} = C_{gw} d_f \qquad \text{(Equation 2.4.13-26)}$$

where:

C_{sw} = radionuclide concentration in surface water downstream;
C_{gw} = radionuclide concentration in the groundwater; and
d_f = dilution factor.

The dilution factor is defined as:

$$d_f = \frac{Q_{gw}}{Q_{gw} + Q_{sw}} \qquad \text{(Equation 2.4.13-27)}$$

where:

Q_{gw} = flow rate of the liquid effluent released from the groundwater and discharging into the surface water;
Q_{sw} = surface water flow available for dilution; and
d_f = dilution factor.

The flow rate of the liquid effluent in the groundwater is defined as:

$$Q_{gw} = A \cdot q \qquad \text{(Equation 2.4.13-28)}$$

where:
A = cross sectional area of the contaminant slug; and
q = Darcy velocity, which may be obtained from Equation (2.4.13-3).

2.4.13.1.4.6 Advection, Radioactive Decay, Retardation, Adsorption, and Hydrodynamic Dispersion

The radionuclides with concentrations greater than one percent of their respective *ECL*s after the screening analysis that accounted for advection, radioactive decay, adsorption, and dilution were further analyzed to also account for hydrodynamic dispersion in groundwater. Advection, decay, retardation, and hydrodynamic dispersion were accounted for in the transport of the radionuclide to the discharge point. Surface water dilution, where applicable, was then calculated as dilution of the groundwater concentration by assuming complete mixing at the discharge point to the surface water body.

For parent radionuclides, the effects of dispersion were analyzed using the analytic solution of the two-dimensional advection-dispersion equation presented by Codell and Duguid (Equation 4.33 in AREVA, 2007) for transport in a vertically averaged layer of thickness b, and an instantaneous release of activity M uniformly distributed over width w. Using this method, the activity concentration, C, at the point of groundwater discharge (i.e., at horizontal position (x, y) relative to the source, where the groundwater pathline flows in the x direction) at time t is calculated as a function of the total initial radionuclide activity concentration, M as:

$$C(x,y,t) = \frac{M}{n_e R} X_1 Y_2 Z_2, \qquad \text{(Equation 2.4.13-29)}$$

where X_1, Y_2, and Z_2 are given by the expressions:

$$X_1 = \frac{1}{\sqrt{4\pi D_x t/R}} \exp\left[-\frac{(x - vt/R)^2}{4D_x t/R} - \lambda t\right], \qquad \text{(Equation 2.4.13-30)}$$

$$Y_2 = \frac{1}{2w}\left\{\operatorname{erf}\left[\frac{(w/2+y)}{\sqrt{4D_y t/R}}\right] + \operatorname{erf}\left[\frac{(w/2-y)}{\sqrt{4D_y t/R}}\right]\right\}, \text{ and} \qquad \text{(Equation 2.4.13-31)}$$

$$Z_2 = \frac{1}{b}, \qquad \text{(Equation 2.4.13-32)}$$

where w is the conceptualized width of the contaminant slug in the aquifer, y is the lateral position with respect to the center of the pathline (i.e., distance to the left or right), b is the saturated thickness of the aquifer, and M is the released activity, which is equal to the activity concentration of each nuclide in the effluent times the postulated volume of the effluent release 3531.2 ft^3 (100 m^3).

The longitudinal dispersivity is estimated using the following two methods from the literature. An estimate of the longitudinal dispersivity, α_x, was obtained using Equation (32) in Neuman, 1990:

$$\alpha_x = 0.32x^{0.83} \qquad \text{(Equation 2.4.13-33)}$$

An alternative estimate of the dispersivity was computed using Equation (14b) from Xu, 1995:

$$\alpha_x = 0.83\mathrm{Log}_{10}(x)^{2.414} \qquad \text{(Equation 2.4.13-34)}$$

In Equations (2.4.13-33) and (2.4.13-34), x and α_x are in units of meters. In both cases, the lateral dispersivity was estimated to be one tenth of the longitudinal dispersivity, i.e., $\alpha_y = 0.1 \times \alpha_x$, based on Bear, 1979.

The resulting radionuclide concentrations in groundwater predicted by Equations (2.4.13-29) and (2.4.13-35) were reduced to account for surface water dilution in the receiving streams using Equation (2.4.13-26).

Equation (2.4.13-29) is only applicable to parent radionuclides. In this calculation, seven progeny nuclides were found to have a concentration greater than one percent of their *ECL*s after accounting for advection, decay, adsorption, and dilution. These seven progeny nuclides and their parent nuclides are listed in Table 2.4-46, along with their half-lives. For decay chains containing three members, the parent that produces the larger fraction of the daughter nuclide is listed, as determined by the branching coefficients, which are included in Table 2.4-46.

It may be seen from Table 2.4-46 that the half-lives of Y-90 (Yttrium), Te-127 (Tellurium), and Te-129 are much shorter than the half-lives of their parent nuclides. Consequently, these progeny nuclides would decay very quickly relative to their parents, and for groundwater pathways having long travel times (e.g., months and years, rather than hours), the concentration of these progeny nuclides at down-gradient locations would be governed by the concentration of their parents. Therefore, in this analysis, the concentrations of Y-90, Te-127, and Te-129 at groundwater discharge points were calculated directly from the predicted concentrations of Sr-90, Te-127m, and Te-129m, respectively, using the appropriate branching coefficients:

$$C_2(x,t) = d_{12}C_1(x,t) \qquad \text{(Equation 2.4.13-35)}$$

where:

$C_1(x,t)$ = concentration of parent nuclide at distance x and time t from Equation (2.4.13-29); and

$C_2(x,t)$ = concentration of progeny nuclide at distance x and time t.

Equation (2.4.13-35) predicts that the activity concentrations of Y-90, Te-127, and Te-129 will be limited to the rates at which they are produced from the decay of Sr-90, Te-127m, and

Te-129m (i.e., it neglects any progeny nuclide concentrations from upgradient locations). Because Y-90, Te-127, and Te-129 decay quickly, this is a reasonable approximation.

The relationship of the parent – daughter half-lives for Np-239 – Pu-239 decay chain is the reverse of the relationship of the three decay chains mentioned above. The half life of Np-239 (2.355 days) is very short relative to Pu-239 (8.79E+06 days). Therefore, the concentration of Pu-239 was estimated by assuming that all Np-239 instantly decays to Pu-239 at t=0 and then applying Equation (2.4.13-29) to the Pu-239. Using the relationship $A = \lambda N$, the initial activity concentration, C_2^0, of Pu-239 was estimated from the initial Np-239 concentration, C_1^0, as:

$$C_2^0 = \lambda_2 \frac{C_1^0}{\lambda_1} \qquad \text{(Equation 2.4.13-36)}$$

The simplifying approximations used above do not hold true for the decay chains that generate Nb-95 (Niobium), I-131 (Iodine), and La-140 (Lanthanum), due to the relatively smaller differences in their parent-progeny half-lives. Therefore, neither Equation (2.4.13-29) nor (2.4.13-35) could be reasonably applied to predict the effect of dispersion for these progeny nuclides. Accounting for dispersion in the transport of radioactive decay chains requires the simultaneous solution of the transport equations for the parent and the progeny (e.g., Equations 2.4.13-1 and 2.4.13-11). Instead of developing this solution, a simpler approach is applied in which dispersion is neglected, i.e., using Equations 2.4.13-9, 2.4.13-14, 2.4.13-21, and 2.4.13-26 as appropriate. Because of this, only advection, decay, retardation, and dilution (when applicable) have been applied for the Nb-95, I-131, and La-140 screening evaluations. The effect of dispersion is not accounted for, leading to conservative, i.e., higher, estimates of concentration.

2.4.13.1.4.7 Advection, Radioactive Decay, Retardation, Adsorption, Hydrodynamic Dispersion, and Biological Uptake and Potential Consumption of Fish, Crustaceans, and Mollusks

From the boundaries of the CCNPP Unit 3 site, all discharge, both surface water and groundwater, eventually reaches the Chesapeake Bay. Neither surface water nor groundwater discharge from the CCNPP Unit 3 site is used as a drinking water source. In the case that compliance with the *ECL*s is not demonstrated at the boundary of the restricted area, biological uptake and the corresponding potential for human exposure by ingestion is examined to ensure that *ECL* exceedance at the boundary will not lead to adverse human exposure. In this case, radionuclide concentrations predicted to be discharging into Chesapeake Bay were also evaluated for biological uptake and human ingestion of fish, crustaceans, and mollusks harvested from this area. The concentrations predicted to be discharging in surface streams, or discharging from groundwater for the Chesapeake Bay pathway, were considered as the exposure concentration for Chesapeake Bay biota, without accounting for any additional dilution in the Bay. These undiluted concentrations were used to estimate the biological uptake using the fish-water and mollusk-crustacean uptake ratios given in Table D-5 of ANL, 2001 and in Eckerman, 1988.

The dose via each consumption pathway (mollusk/crustacean and fish) was determined using assumptions for fraction of food contaminated for mollusks/crustaceans (50 percent) and fish (25 percent), and standard default assumptions for annual consumption (5.4 kg/year fish and

0.9 kg/year crustacean/mollusk) and converted to a dose in millirem based on dose conversion factors from Table D.1 of ANL, 2001 and in Eckerman, 1988. The rationale for using non-default values for the percent of contaminated fish, crustaceans, and mollusks is based on the likelihood that fishermen would fish outside of the area of contamination for at least 25% of the time and that fish, themselves are wide-ranging and would spend time both in and outside of the area of potential discharge, while for crustaceans and mollusks the assumption is that harvesting would be 50% outside the contaminated area due to the narrow width of the contamination plume entering the Bay (Section 2.4.13.1.4.10). The resultant dose for each compound by each intake exposure pathway was summed and a total exposure was determined. The total annual activity uptake from marine biota ingestion is:

$$A_i = CB_wIF_c \qquad \text{(Equation 2.4.13-36)}$$

where:

C = radionuclide groundwater concentration (pCi/L)
B_w = biota/water ratio (L/Kg)
I = biota intake (Kg/yr); and
F_c = fraction of biota that is contaminated (unitless)

The annual dose from ingestion of contaminated biota is:

$$D_a = A_iDcf \qquad \text{(Equation 2.4.13-37)}$$

where:

Dcf = dose conversion factor (mrem/pCi)

2.4.13.1.4.8 Screening Analysis: Transport Considering Only Advection and Radioactive Decay

An initial screening analysis was performed considering only advection and radioactive decay. This analysis assumed that radionuclides migrate at the same rate as groundwater and considered no adsorption / retardation, which would otherwise result in a longer travel time and more radioactive decay. The concentrations of the radionuclides assumed to be released from the Reactor Coolant Storage Tank were decayed for a period equal to the groundwater travel time from the point of release to the point of discharge (e.g., Branch 2, Chesapeake Bay, etc.), using Equations (2.4.13-9), (2.4.13-14), or (2.4.13-21) as appropriate with $R_1=R_2=R_3=1$. Radionuclides having concentrations less than 1 percent of their respective *ECL*s were eliminated from consideration because their concentrations would be well below their regulatory limits. Any radionuclides having a concentration greater than or equal to 1 percent of their *ECL* were retained for further evaluation.

The travel times along the groundwater pathways were conservatively determined based on site-specific data and the post-construction groundwater model described in Section 2.4.12. A hydraulic conductivity of K = 13.7 ft/day (4.2 m/day) and an effective porosity of n_e = 0.145 were applied to all pathways through the Upper Chesapeake unit. For the alternative pathway through the fill material to Branch 2, a hydraulic conductivity of K = 28.3 ft/day (8.64 m/day or 0.01 cm/s) and an effective porosity of n_e = 0.082 were applied.

The average horizontal hydraulic gradient, dh/dx, was calculated for each groundwater pathway from its length, x, and from the hydraulic head at the point of release (the Nuclear Auxiliary

Building at Unit 3), h_0, and the head at the point of discharge, h_1, as predicted by the post-construction groundwater model using the expression $\frac{dh}{dx} = \frac{h_1 - h_0}{x}$. The hydraulic head at the point of release was based on the maximum potentiometric surface level at the proposed Nuclear Auxiliary building location estimated to be 55 ft (16.8 m) MSL. The hydraulic gradient calculations for the pathways considered in this calculation are shown below. For the alternative pathway through the fill material to Branch 2, h_0, h_1, and dh/dx are not used. Rather, the groundwater travel time for this pathway is obtained from particle tracking in the groundwater model (Section 2.4.12). Its velocity was calculated from its length and travel time. The length of this pathway was shortened from 580 (176.8 m) to 540 (164.6 m) ft to account for the higher elevation of the fill material, which would discharge on a seepage face above Branch 2.

Use of the maximum groundwater level observed at the point of release is conservative because it results in the steepest gradients, the largest groundwater velocities, and shortest travel times. This assumption is very conservative because the surface water dilution is calculated using the 100-year low annual mean flow (Section 2.4.13.1.4.1.7), the occurrence of which would not likely coincide with a period of maximum hydraulic gradients.

The hydraulic gradients were entered into Equation (2.4.13-3) to determine the average linear groundwater velocity for each pathway. Straight-line distances were used in these calculations in order to obtain conservative estimates of the hydraulic gradients and groundwater velocities. Initial groundwater travel times were calculated from these lengths and velocities using Equation (2.4.13-10) with R_1 =1. The resulting hydraulic gradients, groundwater velocities, and travel times are shown in Table 2.4-47.

It may be seen that the pathway to Branch 2 has the steepest hydraulic gradients and the shortest travel time.

Using Equations (2.4.13-9), (2.4.13-14), or (2.4.13-21) as appropriate with R = 1, the initial concentrations were decayed for a period equal to the travel time along each groundwater pathway. Radioactive decay data and decay chain specifications were taken from ICRP Publication 38 (ICRP, 1983) and Kennedy and Strenge, 1992. Tables 2.4.13-206 through 2.4.13-211 summarize the results and identify those radionuclides that would exceed their *ECL*s by more than 1 percent for each pathway evaluated. These radionuclides are listed for each groundwater pathway considered.

It may be seen that, when only advection and radioactive decay are considered, the pathways with the shortest travel times have the greatest number of radionuclide concentrations in excess of their effluent concentration limits. The nuclides listed in Table 2.4-48 are retained for step 2 in the transport analysis in which adsorption is also considered.

2.4.13.1.4.9 Transport Considering Advection, Radioactive Decay, and Adsorption

The radionuclides retained from the radioactive decay screening analysis were further evaluated considering retardation in addition to advection and radioactive decay.

Site-specific distribution coefficients were used for Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce. These values were based on the laboratory K_d analysis of eleven soil samples obtained from the Upper

Chesapeake unit at the CCNPP Unit 3 site (SRNL, 2007) [Table 2.4-45]. For each of these radionuclides, the lowest K_d value measured in the Upper Chesapeake unit was used in the transport analysis to ensure conservatism. Distribution coefficients for tritium and iodine were taken to be zero because these elements are not expected to interact with the aquifer matrix based on their chemical characteristics. Distribution coefficients for other elements were also set equal to zero.

For the alternative pathway through the fill material to Branch 2, the minimum site-specific distribution coefficients for Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce that were measured in the Surficial aquifer material were adopted (based on nine soil samples, SRNL, 2007). Distribution coefficients for all other elements were set equal to zero for this pathway.

Retardation factors, R, were calculated using Equation (2.4.13-2) with the site specific distribution coefficients and with the effective porosity of n_e=0.145 and the bulk density of ρ_b=1.53 g/cm^3 for pathways through the Upper Chesapeake unit; n_e=0.082 and ρ_b=2.24 g/cm^3 were used for the alternative pathway through the fill material. Retardation factors for radionuclides with site-specific measurements (Mn, Fe, Co, Zn, Sr, Ru, Cs, and Ce) are shown in Table 2.4-49. Retardation factors for all other radionuclides were set to one (i.e. K_d = 0). Nuclides exceeding one percent of their *ECL*s are listed in Table 2.4-50. The nuclides are retained for step 3 of the transport analysis in which surface water dilution is also considered.

2.4.13.1.4.10 Transport Considering Advection, Radioactive Decay, Adsorption, and Dilution

For the purpose of evaluating the effects of the spill material on the surface water systems downstream of the discharge point, the average concentration and discharge of the highly diluted liquid effluent discharged from the aquifer were determined. The analysis presented below is based on the conservative assumption that there is no longitudinal or transverse dispersion of the liquid effluent in the groundwater.

Dimensions of the Contaminant Slug

The volume of the liquid release has been assumed to be 3,531.2 ft^3 (100 m^3), which represents 80 percent of the 4,414 ft^3 (125 m^3) capacity of one Reactor Coolant Storage Tank [NUREG-0800, BTP 11-6 (NRC, 2007) recommends that 80 percent of the liquid volume be considered in this analysis]. The volume of the Upper Chesapeake unit that would be occupied by the release is estimated by dividing the release volume (3,531.2 ft^3 [100 m^3]) by the effective porosity of 0.145. This results in an estimated volume of 9,543.8 ft^3 (270.3 m^3). For the alternative pathway through the fill material, the contaminant slug would occupy a volume of 23,541 ft^3 (667 m^3) due to the lower effective porosity of 0.082.

For the purpose of this evaluation, it is assumed that the entire content of the tank leaks into the subsurface displacing all of the groundwater. This would result in a contaminant slug that is in the shape of a rectangular box. This is a simplifying assumption made for the purpose of this calculation. This slug then moves at the same rate as the surrounding groundwater and exhibits no dilution or dispersion, until it is discharged into the creek. This assumption results in a conservative estimate of the discharge concentration.

The shape of the resulting contaminant slug is assumed to be square in plan view and to extend vertically throughout the entire saturated thickness, b, of the Upper Chesapeake unit (the thickness of which varies along each flowpath). For the flowpath leading to Branch 2, the average thickness is estimated to be b = 33.7 (10.3 m) ft based on a cross-section taken from the groundwater model and shown in Figure 2.4-106 and Figure 2.4-108. The area of the contaminant slug in plan view is then estimated by dividing the volume by the saturated thickness, b. Consistent with the assumption that the contaminant slug is square in plan view, cross-sectional width, w, is equal to the square root of the planar area. The cross-sectional area of the contaminant slug normal to the groundwater flow direction would therefore be equal to the product of the saturated thickness, b, and the width, w.

The computation of the contaminant slug dimensions is shown in Table 2.4-200 for each of the groundwater pathways considered in this calculation. The aquifer thickness along each flow path was estimated from the Upper Chesapeake unit layers as defined in the groundwater model of post-construction conditions as discussed in Section 2.4.12.

The cross-sectional areas, A, shown in Table 2.4-201 are used in the calculation of the rates of discharge from the Upper Chesapeake unit for the various groundwater pathways.

Computation of Effluent Discharge Rates and Dilution Factors

The radionuclides discharging with the groundwater into the surface waters of Branches 1, 2, 3, or Johns Creek would mix with surface flows and with uncontaminated groundwater discharging in these streams, leading to the reduction of concentrations through dilution. No surface water dilution is assumed for the pathway discharging directly to Chesapeake Bay. The list of isotopes evaluated for dilution, provided in Table 2.4-50, includes those retained after the advection, radioactive decay, and adsorption screening evaluations described above and summarized in Table 2.4-206 to Table 2.4-211.

In order to estimate the dilution factors for each pathway, the rates of groundwater discharge passing underneath the Nuclear Auxiliary Building of Unit 3 to the discharge points must be estimated. It is assumed that in the event of an accidental release of the contents of a Reactor Coolant Storage Tank, the release will move directly into the Upper Chesapeake unit, neglecting any travel time through the unsaturated zone and/or through the fill material. The rate at which a release from a Reactor Coolant Storage Tank discharges to surface water is determined by the hydraulic properties of the Upper Chesapeake unit. A release would undergo saturated flow through the Upper Chesapeake unit to the aquifer discharge point (e.g., Branch 2).

The discharge rate itself is a function of the Darcy velocity (q), and of the assumed volume and dimensions of the resulting contaminant slug. The Darcy velocity for each groundwater pathway is calculated from the hydraulic conductivity and the horizontal hydraulic gradient using Equation (2.4.13-3). The discharge rate, Q_{gw}, from each groundwater pathway is determined using Equation (2.4.13-28). This is the rate at which groundwater contaminated with radionuclides would flow to the point of discharge from each pathway.

Compliance with 10 CFR Part 20 is assessed for the nearest potable water supply in an unrestricted area (BTP 11-6). The area between the site and the mouths of Branches 1 and 2 at Chesapeake Bay, and the location where the Chesapeake Bay pathway reaches Chesapeake Bay are considered restricted areas, because they are within land owned by CCNPP Unit 3 site. Therefore, for the pathways discharging to Branches 1 and 2, and

Chesapeake Bay, compliance with *ECL*s is evaluated at the shoreline. Branch 3 flows into Johns Creek within CCNPP Unit 3 site property; Johns Creek flows west-southwest, exiting the CCNPP Unit 3 site property a short distance upstream of crossing Solomons Island Road. Therefore, for the pathways discharging to Branch 3 and Johns Creek, compliance is evaluated at the point where Johns Creek crosses the CCNPP Unit 3 site property line.

The 100-year low annual mean flows for these locations are used to derive surface water dilution factors. The 100-year low annual mean flow is defined as the average discharge over the course of one year having a non-exceedance return period of 100 years. It is anticipated that during the year in which the 100-year low annual mean flow occurs, surface flows in the watersheds may be intermittent or ephemeral, rather than perennial. However, over the course of the year, they would still yield some runoff in response to precipitation events. Baseflows may occur during the cooler and relatively less dry parts of the year. It is assumed that 100-year low annual mean flows in small watersheds in the southern region of the Coastal Plain physiographic province of Maryland may be estimated based on the observed flows in other watersheds in this region using an inverse-distance relationship (Carpenter, 1996). It is assumed that this relationship, which was derived for use in predicting the 7-day, 14-day, and 30-day low-flows for return periods of 2, 10, and 20 years, may be used to estimate annual (365-day) low-flows with 100-year return periods.

The dilution factors are calculated using Equation (2.4.13-27) with the assumption that the accidental liquid effluent release occurs during the 100-year low annual mean flow in the receiving stream. Calculation of the dilution factors is presented in Table 2.4-201.

The dilution factors shown in Table 2.4-201 are applied to the radionuclides whose concentrations exceed one percent of their *ECL*s after screening step 2, to account for dilution in addition to advection, radioactive decay, and adsorption. The predicted activities of the radionuclides considering the combined effects of advection, radioactive decay, retardation, and dilution in surface water are summarized in Table 2.4-206 through Table 2.4-211. Nuclides exceeding one percent of their *ECL*s are listed in Table 2.4-202. These nuclides are further analyzed in step 4.

2.4.13.1.4.11 Transport Considering Advection, Radioactive Decay, Adsorption, Dispersion, and Dilution

This section presents the transport analysis considering the effects of advection, radioactive decay, adsorption, and hydrodynamic dispersion in groundwater. Surface water dilution is also accounted for as presented in Section 2.4.13.1.4.5.

Results presented in the preceding section, and summarized in Table 2.4-206 through Table 2.4-211, show that ratios of concentrations to *ECL*s would exceed one percent for fifteen radionuclides for the pathway to Branch 2 if the effect of dispersion in groundwater is not considered (Table 2.4-202). Similarly, concentrations exceed one percent of the *ECL* ratios for twelve radionuclides for the Chesapeake Bay pathway. Therefore, transport for the nuclides and groundwater pathways listed above was analyzed using a method that includes the effects of hydrodynamic dispersion.

An analytical solution (Codell and Duguid, 1983) was used to model transport of the radionuclides listed above through the Upper Chesapeake unit from underneath the Nuclear

Auxiliary Building to the points of discharge to surface water. The two-dimensional mass transport equation given by Equation (2.4.13-29) was selected. Equation (2.4.13-29) accounts for advection, radioactive decay, adsorption, and longitudinal and lateral dispersion in groundwater. This modeling approach is still conservative, because it neglects the effect of dispersion in the vertical direction, which would further reduce the radionuclide concentrations.

The longitudinal dispersion coefficient was estimated as the product of the dispersivity and the transport velocity. The dispersivity is a property of the porous media and is a function of the scale of transport (Neuman, 1990). The longitudinal dispersivity, α_x, was estimated for each pathway using the following two methods from the literature:

- Equation (32) in Neuman, 1990, provided as Equation (2.4.13-33) above.
- Equation (14b) in Xu, 1995, provided as Equation (2.4.13-34) above.

These two methods provided a range of dispersivity estimates to consider in the calculation. It was decided to consider the range of estimated dispersivities given by these equations to identify conditions leading to the most adverse contamination. The resulting longitudinal dispersivity range for each pathway is shown in Table 2.4-203.

For two-dimensional solute transport, the transverse dispersivity must also be estimated. Bear (1979) indicates that the ratio of longitudinal to transverse dispersivity ranges from 5 to 24. In the lateral direction, the dispersivity was therefore reduced by a factor of 10.

With the exceptions of Ba-140 discharging to Branch 2 and of Co-60 and Te-129 discharging to the Chesapeake Bay pathway, the calculated peak concentrations of nuclides for these pathways result from the smaller of the dispersivity values. It is noted that using a higher dispersivity value (approximately 77 ft (23.5 m) and 152 ft (46.3 m) for discharge to Branch 2 and Chesapeake Bay respectively) typically produces earlier, but lower, peak concentrations than the dispersivity of 19 ft (5.8 m) because the higher longitudinal dispersivity causes greater spreading of the contaminant plume in the direction parallel to the average pore velocity. Except for Co-60 discharging to Chesapeake Bay, this trend is observed for all radionuclides evaluated for the effects of dispersion. This trend does not hold for the three noted exceptions due to a relatively high K_d value, in the case of Co-60, and to relatively short half-lives. Nuclides exceeding their *ECL*s after applying the dispersivity screening step are listed in Table 2.4-204.

The timing of the peak radionuclide concentrations varies due to differences in the retardation factors. Yttrium (Y-90) and Tellurium (Te-127 and Te-129) are exceptions to this finding. The timing of the Y-90, Te-127, and Te-129 peaks match the timing of the Sr-90, Te-127m, and Te129m peaks because the daughters are predicted directly from the parents.

As seen in Table 2.4-204, tritium (H-3) exceeds its *ECL* for the Chesapeake Bay pathway and the pathways through the Upper Chesapeake unit and the fill to Branch 2. In addition, Iodine (I-131) exceeds its *ECL* for the two pathways to Branch 2.

2.4.13.1.4.12 Transport Considering Advection, Radioactive Decay, Adsorption, Dispersion, and Biological Uptake and Potential Consumption of Fish, Crustaceans, and Mollusks

The activity concentrations resulting from the transport analysis were used to evaluate potential biological uptake and human ingestion of fish, crustaceans, and mollusks harvested in the immediate vicinity of groundwater discharge in Chesapeake Bay or in the vicinity of the point where Branch 2 flows into Chesapeake Bay using the method discussed in Section 2.4.13.1.4.7. The concentrations predicted to be discharging in surface streams, or discharging from groundwater for the Chesapeake Bay pathway, were considered as the exposure concentration for Chesapeake Bay biota, without accounting for any additional dilution in the Bay. This analysis was performed for the pathways having tritium (H-3) and Iodine (I-131) concentrations in excess of their *ECL*s at the points of discharge into Chesapeake Bay: the pathways to Branch 2 and the direct pathway through the Upper Chesapeake unit to the Bay. The predicted radionuclide concentrations (Tables 2.4.13-206, 2.4.13-207 and 2.4.13-211) were considered directly available for biological uptake, and a fish-water and mollusk-crustacean uptake ratio was applied from Table D-5 of Eckerman (1988). The results of these calculations and the evaluations are presented in Tables 2.4.13-206, 2.4.13-207 and 2.4.13-211. The total ingestion exposure for the direct Chesapeake Bay pathway is 9.50 millirem per year. For the pathways to Branch 2, the total ingestion exposure is 21.17 millirem per year for transport through the Upper Chesapeake unit and is 23.02 millirem per year for transport through the fill material. These exposures are well below the allowable exposure level to individual members of the public of 100 millirem per year required in 10 CFR 20.1301. In addition, these estimates are very conservative because do not account for dilution due to the mixing of ground or surface water discharges into Chesapeake Bay, which may be expected to reduce the total ingestion exposure levels by at least one to two orders of magnitude.

2.4.13.1.5 Compliance with 10 CFR Part 20

As previously stated, the Upper Chesapeake unit is considered the most likely groundwater pathway to be impacted by an accidental release (tank rupture). Branch 2 and direct discharge to Chesapeake Bay are the most likely projected surface water discharge points of the hypothetically contaminated Upper Chesapeake unit groundwater. The radionuclide transport analysis presented above indicates that, with few exceptions, radionuclides accidentally released to the groundwater are individually below their *ECL*s prior to discharge offsite. The exceptions are tritium (H-3) concentrations for the pathways through the Upper Chesapeake unit and the fill to Branch 2 and in groundwater discharging directly to Chesapeake Bay. In addition, Iodine (I-131) exceeds its *ECL* for the two pathways to Branch 2. These exceptions result from very conservatively estimated hydraulic conductivities (i.e., 28.3 ft/day (8.6 m/day) for the fill, and 13.7 ft/day (4.2 m/day) for the Upper Chesapeake unit, the maximum observed value for this material) and effective porosities (0.145 for the Upper Chesapeake unit and 0.082 for the fill material).

10 CFR Part 20, Appendix B imposes additional requirements when the identity and activities of each radionuclide in a mixture are known. In this case, the ratio (groundwater activity concentration/*ECL*) present in the mixture and the concentration otherwise established in 10 CFR Part 20, Appendix B for the specific radionuclide not in a mixture must be determined. The sum of such ratios for all of the radionuclides in the mixture may not exceed "1" (i.e., "unity"). This sum of fractions approach has been applied to the radionuclide concentrations

conservatively estimated above for each of the groundwater pathways considered. Results are summarized in Table 2.4-205.

An accidental liquid release of effluents to groundwater would not exceed 10 CFR Part 20 limits at the boundary for the pathways to Branch 1, John Creek, and Branch 3. The radionuclide mixture ratio used in this analysis represents the minimum calculated value observed for each radionuclide as it is carried through the advection / decay retardation / dispersion / dilution screening process. Individual radionuclides are carried through subsequent screening steps if their calculated values exceed one percent of the *ECL*. If individual radionuclide concentrations do not exceed one percent of their respective *ECL*s, the screening process stops and that calculated value is used in the sum of the fractions evaluation. This approach adds an additional level of conservatism since most radionuclides are not carried through the entire screening process.

For the pathways to Branch 2 and to Chesapeake Bay, the tritium (H-3) concentrations exceed the *ECL* when the most conservative hydraulic conductivity estimates are applied, as discussed above. Similarly, the iodine (I-131) concentration exceeds its *ECL* for the pathways to Branch 2, which discharges into Chesapeake Bay at the boundary of the restricted area. Although the water from Chesapeake Bay is not potable, indirect human exposure could theoretically result from the consumption of Chesapeake Bay fish and shellfish that have bioaccumulated radionuclides from the postulated accidental release. However, radionuclide concentrations would be greatly diluted by surface water in the Chesapeake Bay. Additionally, H-3, the only nuclide exceeding its *ECL* for the direct pathway to Chesapeake Bay, does not bioaccumulate in the environment. I-131 bioaccumulates at a moderate rate relative to the other nuclides in the source term.

Nonetheless, an evaluation of the annual human radiological dose received from the ingestion of Chesapeake Bay biota potentially contaminated from direct discharge to the Bay was performed for the pathway through the Upper Chesapeake unit to Chesapeake Bay and for the pathways to Branch 2. The results of this evaluation indicate the total ingestion exposure is 21.17 millirem per year for the pathway through the Upper Chesapeake unit to Branch 2, is 9.50 millirem per year for transport through the Upper Chesapeake unit to Chesapeake Bay, and is 23.02 millirem per year for alternative transport through the fill material to Branch 2. In all cases, the exposure is well below the allowable total exposure level to individual members of the public of 100 millirem per year required in 10 CFR 20.1301. As discussed above, the estimated exposures are conservative because they do not account for dilution due to the mixing of ground or surface water discharges into Chesapeake Bay.

NUREG-0800 Section 15.7.3 requires NRC staff to assess if an evaluation considers the impacts of the postulated tank failure on the nearest potable water supply in an unrestricted area. "Supply" is defined as a well or surface water intake that is used as a water source for direct human consumption or indirectly through animals, crops, or food processing. Branch 2 is located in a restricted area and is not used for potable water supply, and the Chesapeake Bay is not used as a potable water supply. The alternative pathways to Branch 1, Johns Creek, and Branch 3 show compliance at the property boundary.

2.4.13.2 Surface Water Pathway

Calvert Cliffs Nuclear Power Plant Unit 3 facilities containing radionuclide inventories are located in the Nuclear Island (AREVA, 2007). For the Nuclear Auxiliary and Waste Buildings, the depth of the top of the basemat is approximately 41 ft (12.2 m) below grade (i.e., 86 ft - 45 ft). Assuming liquid releases from postulated Reactor Coolant Storage Tank and/or Liquid Waste Storage Tank ruptures would flood the lowest levels of the Nuclear Auxiliary and Waste Buildings, respectively, it is unlikely that a release could reach the ground surface and be capable of impacting surface water.

The concrete floor supporting the Volume Control Tank in the Fuel Building is at grade level. However, the room containing this tank is centrally located in the interior of the Fuel Building, and the tank is entirely surrounded by concrete walls. There are no doors providing entry to this room and access is only possible via a ladder through the top of the room. Therefore, a postulated release from the Volume Control Tank will not leave the Fuel Building, reach the ground surface, and impact surface water.

Two heat exchangers in each of the three Safeguards Buildings are located at grade level. One Safeguards Building (Building 2/3) houses its grade level heat exchangers within double wall concrete containment, and has no exterior doors leading into the building at grade level. The remaining Safeguard Buildings (Buildings 1 and 4) do not have double wall containment, and grade level exterior entry doors are present. However, these doorways are designed with six inch concrete thresholds, and the doors are watertight to a flood depth of one meter. Therefore, it is unlikely that a release from the grade level Heat Exchangers in the Safeguard Buildings will reach the ground surface and impact surface water.

Because there are no outdoor tanks that could release radioactive effluent, no accident scenario could result in the release of effluent directly to the surface water from outdoor tanks.

2.4.13.3 References

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FSAR Section 2.0 is being updated as follows:

2.0 SITE CHARACTERISTICS

{This Chapter of the U.S. EPR FSAR is incorporated by reference with the following departures and/or supplements.

Chapter 2 describes the geological, seismological, hydrological, and meteorological characteristics of the Calvert Cliffs Nuclear Power Plant (CCNPP) site and vicinity. The site characteristics are described in conjunction with present and projected population distribution, land use, and site activities and controls. The CCNPP site characteristics were developed in accordance with the relevant requirements of Title 10 CFR Part 20, Subpart D (CFR, 2007a); Title 10 CFR Part 50 (CFR, 2007b); Title 10 CFR Part 100 (CFR, 2007c); and Regulatory Guide 1.206 (NRC, 2007).}

The U.S. EPR FSAR includes the following COL Item in Section 2.0:

> A COL applicant that references the U.S. EPR design certification will compare site-specific data to design parameter data in Table 2.1-1. If the specific data for the site falls within the assumed design parameter data and characteristics in Table 2.1-1, then the U.S. EPR standard design is bounding for the site. For site-specific design parameter data or characteristic that are outside the bounds of the assumptions presented in Table 2.1-1, the COL applicant will confirm that the U.S. EPR design acceptably meets any additional requirements that may be imposed by the more limiting site-specific design parameter data or characteristic, and that the design maintains conformance to the design commitments and acceptance criteria described in this FSAR.

This COL Item is addressed as follows:

{The CCNPP Unit 3 site-specific parameters and characteristics have been reviewed and compared to determine if they are within the bounds of the assumed parameters and characteristics for a U.S. EPR. This comparison is provided in Table~~s~~ 2.0-1~~ and 2.0-2~~. For the CCNPP Unit 3 site-specific parameters or characteristics that are outside the bounds of the conservative limiting assumptions presented in Table~~s~~ 2.0-1~~ and 2.0-2~~, justification of the acceptability of these conditions is provided in the associated section ~~of Chapter 3, Design of Structures, Components, Equipment and Systems or~~ as specified in the table.}

FSAR Table 2.0-1 is being updated as follows:

Table 2.0-1—{U.S. EPR Site Design Envelope Comparison}

	U.S. EPR FSAR Design Parameter Value/Characteristic	CCNPP Unit 3 Design Parameter Value/Characteristic
Inventory of Radionuclides Which Could Potentially Seep Into the Groundwater		
Bounding Values for Component Radionuclide Inventory	See Table ~~2.0-2~~ 2.1-2	U.S. EPR FSAR Table 2.1-2 used. See Table ~~2.0-2~~ 2.4-44

FSAR Table 2.0-2 is being updated as follows:

Table 2.0-2 ~~{Comparison of Inventory of Radionuclides Which Could Potentially Seep Into the Groundwater~~ Not Used~~}~~

	~~U.S. EPR FSAR Design Parameter Value/Characteristic~~	~~CCNPP Unit 3 Design Parameter Value/Characteristic (See Section 2.4.13)~~
~~Nuclide~~	~~Activity (Ci/g)~~	~~Activity (Ci/g)~~
~~Br-83~~	~~3.2E-02~~	~~3.2E-02~~
~~Br-84~~	~~1.7E-02~~	~~1.7E-02~~
~~Br-85~~	~~2.0E-03~~	~~2.0E-03~~
~~I-129~~	~~4.6E-08~~	~~4.6E-08~~
~~I-130~~	~~5.0E-02~~	~~5.0E-02~~
~~I-131~~	~~7.4E-01~~	~~7.4E-01~~
~~I-132~~	~~3.7E-01~~	~~3.7E-01~~
~~I-133~~	~~1.3E+00~~	~~1.3E+00~~
~~I-134~~	~~2.4E-01~~	~~2.4E-01~~
~~I-135~~	~~7.9E-01~~	~~7.9E-01~~
~~Cs-134~~	~~1.7E-01~~	~~4.4E-01~~
~~Cs-136~~	~~5.3E-02~~	~~1.1E-01~~
~~Cs-137~~	~~1.1E-01~~	~~1.7E-01~~
~~Cs-138~~	~~2.2E-01~~	~~2.3E-01~~
~~Cr-51~~	~~2.0E-03~~	~~2.1E-03~~
~~Mn-54~~	~~1.0E-03~~	~~1.1E-03~~
~~Fe-55~~	~~7.6E-04~~	~~8.1E-04~~
~~Fe-59~~	~~1.9E-04~~	~~2.0E-04~~
~~Co-58~~	~~2.9E-03~~	~~3.1E-03~~
~~Co-60~~	~~3.4E-04~~	~~3.6E-04~~
~~Na-24~~	~~3.7E-02~~	~~3.8E-02~~
~~Zn-65~~	~~3.2E-04~~	~~3.4E-04~~
~~W-187~~	~~1.8E-03~~	~~1.9E-03~~
~~Rb-88~~	~~1.0E+00~~	~~1.0E+00~~
~~Rb-89~~	~~4.7E-02~~	~~4.7E-02~~
~~Sr-89~~	~~6.3E-04~~	~~6.7E-04~~
~~Sr-90~~	~~3.3E-05~~	~~4.6E-05~~
~~Sr-91~~	~~1.0E-03~~	~~1.1E-03~~
~~Sr-92~~	~~1.7E-04~~	~~1.7E-04~~
~~Y-90~~	~~7.7E-06~~	~~1.1E-05~~
~~Y-91m~~	~~5.2E-04~~	~~5.4E-04~~
~~Y-91~~	~~8.1E-05~~	~~8.6E-05~~
~~Y-92~~	~~1.4E-04~~	~~1.4E-04~~
~~Y-93~~	~~6.5E-05~~	~~6.7E-05~~
~~Zr-95~~	~~9.3E-05~~	~~9.9E-05~~

Table 2.0-2—~~{Comparison of Inventory of Radionuclides Which Could Potentially Seep Into the Groundwater~~ Not Used~~}~~

	~~U.S. EPR FSAR Design Parameter Value/Characteristic~~	~~CCNPP Unit 3 Design Parameter Value/Characteristic (See Section 2.4.13)~~
~~Nb-95~~	~~9.3E-05~~	~~9.9E-05~~
~~Mo-99~~	~~1.1E-01~~	~~1.3E-01~~
~~Tc-99m~~	~~4.6E-02~~	~~5.7E-02~~
~~Ru-103~~	~~7.7E-05~~	~~1.1E-04~~
~~Ru-106~~	~~2.7E-05~~	~~6.2E-05~~
~~Rh-103m~~	~~6.8E-05~~	~~9.4E-05~~
~~Rh-106~~	~~2.7E-05~~	~~6.2E-05~~
~~Ag-110m~~	~~2.0E-07~~	~~1.0E-06~~
~~Te-127m~~	~~4.4E-04~~	~~6.6E-04~~
~~Te-129m~~	~~1.5E-03~~	~~1.9E-03~~
~~Te-129~~	~~2.4E-03~~	~~3.1E-03~~
~~Te-131m~~	~~3.7E-03~~	~~4.6E-03~~
~~Te-131~~	~~2.6E-03~~	~~3.0E-03~~
~~Te-132~~	~~4.1E-02~~	~~5.0E-02~~
~~Te-134~~	~~6.7E-03~~	~~6.7E-03~~
~~Ba-137m~~	~~1.0E-01~~	~~1.6E-01~~
~~Ba-140~~	~~6.2E-04~~	~~7.1E-04~~
~~La-140~~	~~1.6E-04~~	~~1.9E-04~~
~~Ce-141~~	~~8.9E-05~~	~~9.7E-05~~
~~Ce-143~~	~~7.6E-05~~	~~8.3E-05~~
~~Ce-144~~	~~6.9E-05~~	~~7.3E-05~~
~~Pr-143~~	~~8.8E-05~~	~~9.7E-05~~
~~Pr-144~~	~~6.9E-05~~	~~7.3E-05~~
~~Np-239~~	~~8.7E-04~~	~~1.5E-03~~

FSAR Tables 2.4-44 through 2.4-50 are being replaced with the following tables:

Table 2.4-44 – {Reactor Coolant Storage Tank Radionuclide Inventory}

Radionuclide	Half-life[1] $t_{1/2}$ (days)	Concentration[2] (µCi/g)	Radionuclide	Half-life[1] $t_{1/2}$ (days)	Concentration[2] (µCi/g)
H-3	4.51E+03	1.0E+00	Te-127m	1.09E+02	4.4E-04
Na-24	6.25E-01	3.7E-02	Te-127*	3.90E-01	0.0E+00
Cr-51	2.77E+01	2.0E-03	I-129	5.73E+09	4.6E-08
Mn-54	3.13E+02	1.0E-03	I-130	5.15E-01	5.0E-02
Fe-55	9.86E+02	7.6E-04	Te-129m	3.36E+01	1.5E-03
Fe-59	4.45E+01	1.9E-04	Te-129*	4.83E-02	2.4E-03
Co-58	7.08E+01	2.9E-03	Te-131m	1.25E+00	3.7E-03
Co-60	1.93E+03	3.4E-04	Te-131*	1.74E-02	2.6E-03
Zn-65	2.44E+02	3.2E-04	I-131*	8.04E+00	7.4E-01
Br-83	9.96E-02	3.2E-02	Te-132	3.26E+00	4.1E-02
Kr-83m*	7.63E-02	0.0E+00	I-132*	9.58E-02	3.7E-01
Br-84	2.21E-02	1.7E-02	I-133	8.67E-01	1.3E+00
Br-85	2.01E-03	2.0E-03	Xe-133m*	2.19E+00	0.0E+00
Kr-85*	1.87E-01	0.0E+00	Xe-133*	5.25E+00	0.0E+00
Rb-88	1.24E-02	1.0E+00	Te-134	2.90E-02	6.7E-03
Rb-89	1.06E-02	4.7E-02	I-134*	3.65E-02	2.4E-01
Sr-89*	5.05E+01	6.3E-04	I-135	2.75E-01	7.9E-01
Sr-90	1.06E+04	3.3E-05	Xe-135m*	1.06E-02	0.0E+00
Y-90*	2.67E+00	7.7E-06	Xe-135*	3.79E-01	0.0E+00
Sr-91	3.96E-01	1.0E-03	Cs-134	7.53E+02	1.7E-01
Y-91m*	3.45E-02	5.2E-04	Cs-136	1.31E+01	5.3E-02
Y-91*	5.85E+01	8.1E-05	Cs-137	1.10E+04	1.1E-01
Sr-92	1.13E-01	1.7E-04	Ba-137m*	1.77E-03	1.0E-01
Y-92*	1.48E-01	1.4E-04	Cs-138	2.24E-02	2.2E-01
Y-93	4.21E-01	6.5E-05	Ba-140	1.27E+01	6.2E-04
Zr-95	6.40E+01	9.3E-05	La-140*	1.68E+00	1.6E-04
Nb-95m*	3.61E+00	0.0E+00	Ce-141	3.25E+01	8.9E-05
Nb-95*	3.52E+01	9.3E-05	Ce-143	1.38E+00	7.6E-05
Mo-99	2.75E+00	1.1E-01	Pr-143*	1.36E+01	8.8E-05
Tc-99m*	2.51E-01	4.6E-02	Ce-144	2.84E+02	6.9E-05
Ru-103	3.93E+01	7.7E-05	Pr-144m*	5.00E-03	0.0E+00
Rh-103m	3.90E-02*	6.8E-05	Pr-144*	1.20E-02	6.9E-05
Ru-106	3.68E+02	2.7E-05	W-187	9.96E-01	1.8E-03
Rh-106*	3.43E-04	2.7E-05	Np-239	2.36E+00	8.7E-04
Ag-110m	2.50E+02	2.0E-07	Pu-239*	8.79E+06	0.0E+00
Ag-110*	2.85E-04	0.0E+00			

Notes:
1 Values from ICRP (1983) and Kennedy and Strenge (1992)
2 Values from Reference AREVA, 2007.
* Decay chain progeny.

Table 2.4-45 – {Summary of the Radionuclide K_d Values for 20 Soils (mean of two replicates) and Averages (units: ml/g)}

Soil	Ground-water[a]	pH[b]	Mn		Co		Zn		Sr		Cs		Ce		Fe		Ru[c]	
			Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev	Avg	Stdev
C-1C	SA	6	5.6	0.6	6.9	1.2	11	1.6	6	2.5	>579.0	9.4	>121.3	19.8	338.4	264.2	3315	1321
C-2C	CU	7.6	586.3	2.5	>1104.9	0	>444.8	8.1	18.1	10.9	>895.5	8	>115.8	0.8	>2066.9	9.3	**1979**	368
C-3C	SA	2.6	6.2	0.5	7.1	0.6	8.5	2	11.8	5.2	>558.0	7.4	>111.6	29.8	**0**	0.1	**158**	20
C-4C	SA	5.9	**1.5**	0.5	**1.7**	0.9	**1.6**	1.3	**1.7**	2.5	>707.2	234.4	**35.1**	3.5	>1053.4	1458.9	>5694	5965
C-5C	CU	7	172	106.2	424.6	378.5	>373.1	1.9	35.3	37.1	>1169.5	369.8	>102.9	1.3	>2093.9	5.2	>8014	722
C-6C	CU	7.4	63.7	1.4	88.7	20.7	>504.2	238.9	17.6	15.8	>856.5	13.5	>94.7	1.4	>2079.0	26.9	3615	661
C-7C	SA	3	5.4	0.6	5.3	0.5	1069.4	1502	30.8	12	>588.6	2.8	51.9	1.3	0	0.1	388	5.01
C-8C	SA	4.9	8.8	5.4	9.3	4.2	9.8	3.6	>25.9	20.7	>693.9	153.2	>109.6	28.4	1319.1	205.1	>8051	5957
C-9C	SA	5.8	11.7	5.6	11.4	5.8	12.6	5.5	13.3	7.3	>727.9	157.2	>98.5	1.4	>2070.6	8.7	6029	870
C-10C	SA	7.8	10.4	2.3	8.9	1.3	10.3	2	12.6	1	>588.8	1.2	>87.0	0.7	1060.9	406.6	>7933	151
C-11C	SA	3.9	5	0.1	6.1	0.6	9	0.3	9.7	7.8	**>553.2**	12.1	75.3	18.7	0	0.6	615	158
C-12C	CU	7.3	614.6	26.4	>1046.5	33	>469.9	24.1	>58.3	1.4	>971.0	59.1	>122.7	2.7	>2092.0	3.7	>7134	820
C-13C	CU	7.4	24.5	11.8	46.8	20.7	>384.0	28.4	10	6.8	>1141.1	154.9	>104.0	0.8	>2089.9	11.5	>4719	4000
C-14C	CU	7.8	611.5	29.8	>1061.0	83.3	>469.3	1.7	44.4	14	>1401.1	655.9	>118.5	2.6	>2073.3	17.3	3522	224
C-15C	CU	7.8	262.9	38.1	>557.8	144.5	>185.4	14.2	>22.4	0.1	>454.9	70.9	>50.2	1.9	>2074.9	3.9	>4817	597
C-16C	CU	7.7	25.5	14.4	39.7	12.5	>163.3	27.5	**3.3**	3.1	**>325.9**	31.6	**>41.9**	0.8	>2079.6	4.1	>3959	1422
C-17C	CU	3.4	**4.9**	1	**5.9**	1.5	**6.6**	1.4	9.2	3.3	>421.7	218.9	>68.9	52.6	**203.3**	56.2	>10148	698
C-18C	SA	6.4	617.1	2.5	>1143.6	37.1	>462.1	18.7	>59.7	2.1	>884.9	50.9	>119.0	11	>2100.3	3	>5650	39.2
C-19C	CU	7.2	25.2	19.4	76	76.5	>332.3	125.5	10.8	4.1	>756.0	57.3	>87.9	25.8	>2080.7	6	>5812	62.8
C-20C	CU	4.9	584.5	20.9	>1121.0	36.3	>429.2	9.7	>93.4	46.8	>993.5	27	>76.6	2.4	>2161.8	131.4	>7122	2955
Average	All		182.4	257.3	>338.7	471.4	>267.8	277.1	>24.7	23.4	>763.4	275.8	>89.7	28	>1452	868	>4934	2775
Average	SA	only	74.6	203.5	>133.4	378.9	>177.1	366.6	>19.0	17.8	>653.5	109.9	>89.9	30.5	>883	850	>4204	3181
Average	CU	only	270.5	271.4	>506.6	488.2	>342.0	157.7	>29.3	27.1	>853.4	339.2	>89.5	27.3	>1918	569	>5531	2380

Values in **bold** text represent the minimum observed (most conservative) K_d values and represent the K_d values used in the retardation analysis.

[a] CU = Upper Chesapeake Aquifer; SA = Surficial Aquifer

[b] pH 1:1 soil: water (Reported in Schnabel, 2007)

[c] Ru K_d values are semi-quantitative due to large analytical uncertainties (Relative Standard Deviation (RSD) = 20%; typically RSD = 10%) associated with the Inductively Couple Plasma – Mass Spectrometry (ICP-MS) analyses.

Table 2.4-46 – {Progeny Nuclides with Activity Concentrations > 1% of *ECL*s After Accounting for Advection, Decay, Adsorption, and Dilution}

Parent Nuclide	Progeny Nuclide	Parent Branching Coefficient	Parent Half-life (days)	Progeny Half-life (days)
Sr-90	Y-90	1.000	1.06E+04	2.67E+00
Zr-95	Nb-90	0.993	6.40E+01	3.52E+01
Te-127m	Te-127	0.976	1.09E+02	3.90E-01
Te-129m	Te-129	0.650	3.36E+01	4.83E-02
Te-131m	I-131	0.778	1.25E+00	8.04E+00
Ba-140	La-140	1.000	1.27E+01	1.68E+00
Np-239	Pu-239	1.000	2.36E+00	8.79E+06

Table 2.4-47 – {Calculated Hydraulic Gradients, Groundwater Velocities, and Travel Times}

Aquifer / flow medium	Upper Chesapeake Unit					Fill
Discharges to	Branch 2	Chesapeake Bay	Branch 1	Johns Creek	Branch 3	Branch 2
X (feet)	580	1,315	1,515	2,900	2,510	540
H_0 (feet)	55	55	55	55	55	*
H_1 (feet)	22	0	28	30	34	*
dh/dx	-0.0569	-0.0418	-0.0178	-0.00862	-0.00837	*
K (ft/day)	13.7	13.7	13.7	13.7	13.7	28.3
Darcy velocity, **q** (ft/day)	0.779	0.573	0.244	0.118	0.115	0.385
Effective porosity, n_e	0.145	0.145	0.145	0.145	0.145	0.082
Velocity, v (ft/day)	5.38	3.95	1.68	0.815	0.790	4.70
Velocity, v (ft/year)	1963	1443	615	297	289	1715
Travel time, **t** (yrs)	0.295	0.911	2.46	9.75	8.69	0.315

* Gradient data are not used for the fill pathway because its travel time was extracted directly from the groundwater model. Its velocity was calculated from its length and travel time. The length of this pathway was shortened from 580 to 540 ft to account for the higher elevation of the fill material, which would discharge on a seepage face above Branch 2.

Table 2.4-48 – {Summary of Results for the Transport Analysis Considering Only Advection and Radioactive Decay}

Aquifer / Flow medium	Discharges to	Radionuclides with Activity Concentration > 1% of *ECL*
Upper Chesapeake Unit	Branch 2	H-3, Cr-51, Mn-54, Fe-55, Fe-59 Co-58, Co-60, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Cs-134, Cs-136, Cs-137, Ba-140, La-140, Ce-141, Ce-144, Pr-144, and Pu-239
	Chesapeake Bay	H-3, Mn-54, Fe-55, Co-58, Co-60, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-106, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Cs-134, Cs-137, Ce-144, Pr-144, and Pu-239
	Branch 1	H-3, Mn-54, Fe-55, Co-58, Co-60, Zn-65, Sr-90, Y-90, Ru-106, Te-127m, Te-127, I-129, Cs-134, Cs-137, Ce-144, Pr-144 and Pu-239
	Johns Creek	H-3, Mn-54, Fe-55, Co-60, Sr-90, Y-90, Ru-106, I-129, Cs-134, Cs-137, and Pu-239,
	Branch 3	H-3, Mn-54, Fe-55, Co-60, Sr-90, Y-90, Ru-106, I-129, Cs-134, Cs-137, and Pu-239
Fill	Branch 2	H-3, Cr-51, Mn-54, Fe-55, Fe-59 Co-58, Co-60, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Cs-134, Cs-136, Cs-137, Ba-140, La-140, Ce-141, Pr-143, Ce-144, Pr-144, and Pu-239

Table 2.4-49 – {Retardation Factors Calculated Using Site-Specific Distribution Coefficients}

Aquifer / Flow medium	Value	Mn	Co	Zn	Sr	Cs	Ce	Fe	Ru
Upper Chesapeake Unit	K_d	4.9	5.9	6.6	3.3	325.9	41.9	203.3	1979
	R	52.7	63.3	70.6	35.8	3440	443	2146	20883
Fill	K_d	1.5	1.7	1.6	1.7	553.2	35.1	0	158
	R	42	47.5	44.8	47.5	15130	961	1	4322

Table 2.4-50 – {Summary of Results for the Transport Analysis Considering Advection, Radioactive Decay, and Adsorption}

Aquifer / Flow medium	Discharges to	Radionuclides with Activity Concentration > 1% of *ECL*
Upper Chesapeake Unit	Branch 2	H-3, Cr-51, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Ba-140, La-140, and Pu-239
	Chesapeake Bay	H-3, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-129m, and Pu-239
	Branch 1	H-3, Sr-90, Y-90, Te-127m, Te-127, I-129, and Pu-239
	Johns Creek	H-3, Sr-90, I-129, and Pu-239
	Branch 3	H-3, Sr-90, I-129, and Pu-239
Fill	Branch 2	H-3, Cr-51, Fe-55, Fe-59, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Ba-140, La-140, and Pu-239

The following tables are being added as FSAR Tables 2.4-200 through 2.4-211:

Table 2.4-200 – {Dimensions of the Contaminant Slug}

Aquifer / flow medium	Upper Chesapeake Unit					Fill
Discharges to	Branch 2	Chesapeake Bay	Branch 1	Johns Creek	Branch 3	Branch 2
Volume of release, ft^3	3,531.2	3,531.2	3,531.2	3,531.2	3,531.2	3,531.2
Effective porosity, n_e	0.145	0.145	0.145	0.145	0.145	0.082
Volume in aquifer, **V**, ft^3	24353	24353	24353	24353	24353	43063
Vertical thickness: **b**, ft	33.7	30.8	38.5	43.8	44.1	10.0
Planar area: **V/b**, ft^2	722	792	633	556	552	4306
Cross-sectional width: $w = (V/b)^{0.5}$, ft	26.9	28.1	25.2	23.6	23.5	65.6
Cross-sectional area: **Axc = b×w**, ft	907	865	968	1033	1036	656

Table 2.4-201 – {Calculation of Effluent Discharge Rates and Dilution Factors}

Aquifer / flow medium		Upper Chesapeake Unit					Fill
Discharges to		Branch 2	Chesapeake Bay	Branch 1	Johns Creek	Branch 3	Branch 2
Dh/dx	ft/ft	-0.0569	-0.0418	-0.0178	-0.00862	-0.00837	---**
K	ft/day	13.7	13.7	13.7	13.7	13.7	28.3
Darcy velocity, **q**	ft/day	0.779	0.573	0.244	0.118	0.115	0.385
Cross-sectional area **Axc**	ft^2	907	865	968	1033	1036	656
Effluent discharge Q_{gw}*	ft^3/day	706.6	495.9	236.3	122.0	118.8	252.7
	ac-ft/yr	5.925	4.158	1.982	1.023	0.996	2.119
100-yr low annual mean flow, Q_{sw}	ac-ft/yr	57.5	N/A	19.8	288	288	57.5
Dilution factor, d_f		0.0934	1	0.0910	0.00354	0.00345	0.0355
Inverse: $1 / d_f$		10.7	1	11.0	282	290	28.1

*Q_{gw} is the flow rate of the liquid effluent released to the ground water and discharging into the surface water.
**Gradient data are not used for this flow path because its travel time was obtained directly from the groundwater model. The travel time was obtained from particle tracking in the model.

Table 2.4-202 – {Summary of Results for the Transport Analysis Considering Advection, Radioactive Decay, Adsorption, and Dilution in Surface Water}

Aquifer / Flow medium	Discharges to	Radionuclides with Activity Concentration/*ECL* > 1%
Upper Chesapeake Unit	Branch 2	H-3, Cr-51, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Te-127m, Te-127, I-129, Te-129m, Te-129, I-131, Ba-140, and La-140
	Chesapeake Bay	H-3, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Ag-110m, Te-127m, Te-127, I-129, Te-127m and Pu-239
	Branch 1	H-3, Sr-90, Y-90, Te-127m, and I-129
	Johns Creek	H-3
	Branch 3	H-3
Fill	Branch 2	H-3, Fe-55, Fe-59, Co-60, Sr-90, Y-90, Zr-95, Nb-95, Te-127m, Te-127, Te-129m, and I-131

Table 2.4-203 – {Estimated Longitudinal Dispersivities}

Aquifer / flow medium		Upper Chesapeake Unit					Fill
	Discharges to	Branch 2	Chesapeake Bay	Branch 1	Johns Creek	Branch 3	Branch 2
	x (feet)	580	1,315	1,515	2,900	2,510	540
α_x (feet)	Neuman, 1990	77.0	152	171	293	260	72.6
	Xu, 1995	19.2	27.4	29.0	37.0	35.1	18.6

Table 2.4-204 – {Summary of Results for the Transport Analysis Considering Advection, Radioactive Decay, Adsorption, Dispersion, and Dilution}

Aquifer / Flow medium	Discharges to	Radionuclides with Activity Concentration >*ECL*
Upper Chesapeake Unit	Branch 2	H-3, I-131
	Chesapeake Bay	H-3
	Branch 1	None
	Johns Creek	None
	Branch 3	None
Fill	Branch 2	H-3, I-131

Table 2.4-205 – {Sum of Radionuclide Activity Concentration / *ECL* Ratios for each Pathway}

Aquifer / flow medium	Upper Chesapeake Unit					Fill
Discharges to	Branch 2	Chesapeake Bay	Branch 1	Johns Creek	Branch 3	Branch 2
Sum of Activity Concentration/*ECL* ratios	8.12	5.60	0.299	0.0102	0.0222	5.20

Table 2.4-206 – {Transport Analysis for Pathway to Chesapeake Bay [(1)]}

(Page 1 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation Total Dose -- Aquatic Ingestion (mrem/year)
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL			
H-3		1.00E-03	12.348	1.0E+00	9.50E-01	9.50E+02	9.50E-01	9.50E+02	9.50E-01	9.50E+02	5.35E-03	5.35E+00	5.35E-03	5.35E+00	6.16E-01
Na-24		5.00E-05	0.002	3.7E-02	2.0E-162	3.93E-158							1.96E-162	3.93E-158	3.26E-157
Cr-51		5.00E-04	0.076	2.0E-03	4.8E-07	9.68E-04							4.84E-07	9.68E-04	8.34E-02
Mn-54		3.00E-05	0.857	1.0E-03	4.8E-04	1.60E+01	1.36E-20	4.53E-16					1.36E-20	4.53E-16	1.54E-12
Fe-55		1.00E-04	2.700	7.6E-04	6.0E-04	6.01E+00	6.96E-222	6.96E-218					6.96E-222	6.96E-218	7.22E-216
Fe-59		1.00E-05	0.122	1.9E-04	1.1E-06	1.07E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Co-58		2.00E-05	0.194	2.9E-03	1.1E-04	5.58E+00	9.23E-93	4.62E-88					9.23E-93	4.62E-88	1.64E-86
Co-60		3.00E-06	5.284	3.4E-04	3.0E-04	1.01E+02	1.77E-07	5.91E-02	1.77E-07	5.91E-02	9.41E-11	3.14E-05	9.41E-11	3.14E-05	1.25E-03
Zn-65		5.00E-06	0.668	3.2E-04	1.2E-04	2.49E+01	3.11E-33	6.21E-28					3.11E-33	6.21E-28	2.62E-25
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00		
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00		
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	6.6E-06	8.31E-01	5.65E-75	7.06E-70					5.65E-75	7.06E-70	6.59E-69
Sr-90		5.00E-07	29.120	3.3E-05	3.2E-05	6.46E+01	1.52E-05	3.04E+01	1.52E-05	3.04E+01	2.48E-09	4.97E-03	2.48E-09	4.97E-03	4.46E-02
	Y-90	7.00E-06	0.007	7.7E-06	3.2E-05	4.61E+00	1.52E-05	2.17E+00	1.52E-05	2.17E+00	2.48E-09	3.55E-04	2.48E-09	3.55E-04	1.31E-02
Sr-91		2.00E-05	0.001	1.0E-03	1.1E-256	5.49E-252	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	7.0E-257	3.48E-254	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	1.7E-06	2.14E-01	4.05E-66	5.07E-61					4.05E-66	5.07E-61	1.89E-59
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	7.5E-243	3.75E-238							7.50E-243	3.75E-238	1.67E-236
Zr-95		2.00E-05	0.175	9.3E-05	2.5E-06	1.26E-01	2.53E-06	1.26E-01	2.53E-06	1.26E-01	2.04E-08	1.02E-03	2.04E-08	1.02E-03	3.15E-02
	Nb-95m	3.00E-05	0.010	0.0E+00	1.9E-08	6.23E-04	1.87E-08	6.23E-04	1.87E-08	6.23E-04			1.87E-08	6.23E-04	1.94E-02
	Nb-95	3.00E-05	0.096	9.3E-05	5.5E-06	1.82E-01	5.45E-06	1.82E-01	5.45E-06	1.82E-01			5.45E-06	1.82E-01	6.31E+00
Mo-99		2.00E-05	0.008	1.1E-01	4.1E-38	2.06E-33							4.12E-38	2.06E-33	3.73E-33
	Tc-99m	1.00E-03	0.001	4.6E-02	4.0E-38	3.97E-35							3.97E-38	3.97E-35	7.23E-35
Ru-103		3.00E-05	0.108	7.7E-05	2.2E-07	7.23E-03							2.17E-07	7.23E-03	9.82E-02
	Rh-103m	6.00E-03	0.000	6.8E-05	2.2E-07	3.61E-05							2.16E-07	3.61E-05	3.73E-04
Ru-106		3.00E-06	1.008	2.7E-05	1.4E-05	4.81E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	1.4E-05		0.00E+00						0.00E+00		0.00E+00
Ag-110m		6.00E-06	0.684	2.0E-07	7.9E-08	1.32E-02	7.95E-08	1.32E-02	7.95E-08	1.32E-02	4.71E-10	7.85E-05	4.71E-10	7.85E-05	1.80E-03
	Ag-110	NaN	0.000	0.0E+00	1.1E-09		1.06E-09		1.06E-09				1.06E-09		0.00E+00

Table 2.4-206 – {Transport Analysis for Pathway to Chesapeake Bay (1)}

(Page 2 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation Total Dose – Aquatic Ingestion (mrem/year)
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL			
Te-127m		9.00E-06	0.298	4.4E-04	5.3E-05	5.89E+00	5.30E-05	5.89E+00	5.30E-05	5.89E+00	3.51E-07	3.90E-02	3.51E-07	3.90E-02	1.66E+00
	Te-127	1.00E-04	0.001	0.0E+00	5.2E-05	5.19E-01	5.19E-05	5.19E-01	5.19E-05	5.19E-01	3.43E-07	3.43E-03	3.43E-07	3.43E-03	1.36E-01
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	4.60E-08	2.30E-01	2.58E-10	1.29E-03	2.58E-10	1.29E-03	4.01E-03
I-130		2.00E-05	0.001	5.0E-02	1.6E-196	7.75E-192							1.55E-196	7.75E-192	4.13E-191
Te-129m		7.00E-06	0.092	1.5E-03	1.6E-06	2.24E-01	1.57E-06	2.24E-01	1.57E-06	2.24E-01	3.54E-08	5.06E-03	3.54E-08	5.06E-03	2.17E-01
	Te-129	4.00E-04	0.000	2.4E-03	1.0E-06	2.55E-03	1.02E-06	2.55E-03	1.02E-06	2.55E-03			1.02E-06	2.55E-03	1.18E-01
Te-131m		8.00E-06	0.003	3.7E-03	2.7E-83	3.37E-78							2.70E-83	3.37E-78	1.41E-76
	Te-131	8.00E-05	0.000	2.6E-03	6.1E-84	7.59E-80							6.07E-84	7.59E-80	3.14E-78
	I-131	1.00E-06	0.022	7.4E-01	2.6E-13	2.57E-07							2.57E-13	2.57E-07	7.71E-07
Te-132		9.00E-06	0.009	4.1E-02	7.4E-33	8.23E-28							7.40E-33	8.23E-28	3.99E-26
	I-132	1.00E-04	0.000	3.7E-01	7.6E-33	7.63E-29							7.63E-33	7.63E-29	2.89E-28
I-133		7.00E-06	0.002	1.3E+00	3.4E-116	4.85E-111							3.40E-116	4.85E-111	1.98E-110
	Xe-133m	NaN	0.006	0.0E+00	4.1E-48								4.08E-48		
	Xe-133	NaN	0.014	0.0E+00	2.1E-20								2.09E-20		
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
	Xe-135	NaN	0.001	0.0E+00	7.0E-265								7.00E-265		
Cs-134		9.00E-07	2.062	1.7E-01	1.3E-01	1.39E+05	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	1.2E-09	1.99E-04							1.20E-09	1.99E-04	3.69E-02
Cs-137		1.00E-06	30	1.1E-01	1.1E-01	1.08E+05	3.94E-33	3.94E-27					3.94E-33	3.94E-27	5.40E-25
	Ba-137m	NaN	0.000	1.0E-01	1.0E-01		3.72E-33						3.72E-33		0.00E+00
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	8.5E-12	1.06E-06							8.50E-12	1.06E-06	7.68E-06
	La-140	9.00E-06	0.005	1.6E-04	9.8E-12	1.09E-06							9.79E-12	1.09E-06	4.05E-05
Ce-141		3.00E-05	0.089	8.9E-05	7.4E-08	2.46E-03							7.37E-08	2.46E-03	1.05E-01
Ce-143		2.00E-05	0.004	7.6E-05	1.1E-77	5.34E-73							1.07E-77	5.34E-73	2.38E-71
	Pr-143	2.00E-05	0.037	8.8E-05	4.0E-12	1.98E-07							3.96E-12	1.98E-07	1.09E-05
Ce-144		3.00E-06	0.778	6.9E-05	3.1E-05	1.02E+01	5.11E-161	1.70E-155					5.11E-161	1.70E-155	5.29E-154
	Pr-144m	NaN	0.000	0.0E+00	5.5E-07		9.09E-163						9.09E-163		0.00E+00
	Pr-144	6.00E-04	0.000	6.9E-05	3.1E-05	5.11E-02	5.11E-161	8.52E-158					5.11E-161	8.52E-158	0.00E+00
W-187		3.00E-05	0.003	1.8E-03	4.6E-104	1.54E-99							4.62E-104	1.54E-99	2.07E-97
Np-239		2.00E-05	0.006	8.7E-04	2.533E-46	1.27E-41	2.53E-46	1.27E-41	2.53E-46	1.27E-41			2.53E-46	1.27E-41	1.82E-40
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	2.33E-10	1.17E-02	1.31E-12	6.55E-05	1.31E-12	6.55E-05	3.96E-04
Highlighted values exceed one percent of the ECL.													**Sum =**	**5.60**	**9.50**

(1): There is no dilution for this pathway because it discharges directly into Chesapeake Bay. Dilution in Chesapeake Bay is neglected.
Footnotes for Table 2.4-206 are shown after Table 2.4-211

Table 2.4-207 – {Transport Analysis for Pathway to Branch 2}

(Page 1 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation Total Dose – Aquatic Ingestion (mrem/year)
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL			
H-3		1.00E-03	12.348	1.0E+00	9.84E-01	9.84E+02	9.84E-01	9.84E+02	9.19E-02	9.19E+01	1.53E-03	1.53E+00	1.53E-03	1.53E+00	1.76E-01
Na-24		5.00E-05	0.002	3.7E-02	4.0E-54	8.00E-50							4.00E-54	8.00E-50	6.65E-49
Cr-51		5.00E-04	0.076	2.0E-03	1.3E-04	2.69E-01	1.34E-04	2.69E-01	1.26E-05	2.51E-02	2.96E-07	5.92E-04	2.96E-07	5.92E-04	5.10E-02
Mn-54		3.00E-05	0.857	1.0E-03	7.9E-04	2.62E+01	3.40E-09	1.13E-04					3.40E-09	1.13E-04	3.86E-01
Fe-55		1.00E-04	2.700	7.6E-04	7.0E-04	7.04E+00	1.54E-74	1.54E-70					1.54E-74	1.54E-70	1.59E-68
Fe-59		1.00E-05	0.122	1.9E-04	3.5E-05	3.54E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Co-58		2.00E-05	0.194	2.9E-03	1.0E-03	5.04E+01	2.78E-32	1.39E-27					2.78E-32	1.39E-27	4.94E-26
Co-60		3.00E-06	5.284	3.4E-04	3.3E-04	1.09E+02	2.93E-05	9.77E+00	2.74E-06	9.12E-01	9.76E-10	3.25E-04	9.76E-10	3.25E-04	1.30E-02
Zn-65		5.00E-06	0.668	3.2E-04	2.4E-04	4.71E+01	1.25E-13	2.51E-08					1.25E-13	2.51E-08	1.06E-05
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00		
	Kr-85	NaN	0.001	0.0E+00	4.5E-179								4.52E-179		
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	1.5E-04	1.82E+01	5.86E-27	7.33E-22					5.86E-27	7.33E-22	6.84E-21
Sr-90		5.00E-07	29.120	3.3E-05	3.3E-05	6.55E+01	2.57E-05	5.13E+01	2.40E-06	4.79E+00	1.13E-09	2.26E-03	1.13E-09	2.26E-03	2.03E-02
	Y-90	7.00E-06	0.007	7.7E-06	3.3E-05	4.68E+00	2.57E-05	3.67E+00	2.40E-06	3.42E-01	1.13E-09	1.61E-04	1.13E-09	1.61E-04	5.96E-03
Sr-91		2.00E-05	0.001	1.0E-03	9.6E-86	4.81E-81	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	6.1E-86	3.04E-83	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	2.5E-05	3.07E+00	1.14E-24	1.43E-19					1.14E-24	1.43E-19	5.33E-18
Sr-92		4.00E-05	0.000	1.7E-04	3.9E-292	9.86E-288							3.94E-292	9.86E-288	9.98E-287
	Y-92	4.00E-05	0.000	1.4E-04	2.4E-223	6.08E-219							2.43E-223	6.08E-219	2.27E-217
Y-93		2.00E-05	0.001	6.5E-05	4.6E-82	2.32E-77							4.64E-82	2.32E-77	1.04E-75
Zr-95		2.00E-05	0.175	9.3E-05	2.9E-05	1.44E+00	2.89E-05	1.44E+00	2.70E-06	1.35E-01	5.00E-08	2.50E-03	5.00E-08	2.50E-03	7.70E-02
	Nb-95m	3.00E-05	0.010	0.0E+00	2.1E-07	7.13E-03	2.14E-07	7.13E-03	2.00E-08	6.65E-04			2.00E-08	6.65E-04	2.07E-02
	Nb-95	3.00E-05	0.096	9.3E-05	5.1E-05	1.69E+00	5.06E-05	1.69E+00	4.73E-06	1.58E-01			4.73E-06	1.58E-01	5.47E+00
Mo-99		2.00E-05	0.008	1.1E-01	1.7E-13	8.51E-09							1.70E-13	8.51E-09	1.54E-08
	Tc-99m	1.00E-03	0.001	4.6E-02	1.6E-13	1.64E-10							1.64E-13	1.64E-10	2.98E-10
Ru-103		3.00E-05	0.108	7.7E-05	1.1E-05	3.82E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-103m	6.00E-03	0.000	6.8E-05	1.1E-05	1.91E-03	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ru-106		3.00E-06	1.008	2.7E-05	2.2E-05	7.35E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	2.2E-05		0.00E+00						0.00E+00		0.00E+00
Ag-110m		6.00E-06	0.684	2.0E-07	1.5E-07	2.47E-02	1.48E-07	2.47E-02	1.38E-08	2.31E-03			1.38E-08	2.31E-03	5.28E-02
	Ag-110	NaN	0.000	0.0E+00	2.0E-09		1.97E-09		1.84E-10				1.84E-10		0.00E+00

Table 2.4-207 – {Transport Analysis for Pathway to Branch 2}

(Page 2 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation Total Dose -- Aquatic Ingestion (mrem/year)
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL			
Te-127m		9.00E-06	0.298	4.4E-04	2.2E-04	2.46E+01	2.22E-04	2.46E+01	2.07E-05	2.30E+00	3.63E-07	4.04E-02	3.63E-07	4.04E-02	1.72E+00
	Te-127	1.00E-04	0.001	0.0E+00	2.2E-04	2.17E+00	2.17E-04	2.17E+00	2.03E-05	2.03E-01	3.55E-07	3.55E-03	3.55E-07	3.55E-03	1.41E-01
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	4.30E-09	2.15E-02	7.13E-11	3.56E-04	7.13E-11	3.56E-04	1.11E-03
I-130		2.00E-05	0.001	5.0E-02	4.3E-65	2.15E-60							4.30E-65	2.15E-60	1.15E-59
Te-129m		7.00E-06	0.092	1.5E-03	1.6E-04	2.31E+01	1.62E-04	2.31E+01	1.51E-05	2.16E+00	3.28E-07	4.68E-02	3.28E-07	4.68E-02	2.01E+00
	Te-129	4.00E-04	0.000	2.4E-03	1.1E-04	2.64E-01	1.05E-04	2.64E-01	9.85E-06	2.46E-02	2.13E-07	5.33E-04	2.13E-07	5.33E-04	2.47E-02
Te-131m		8.00E-06	0.003	3.7E-03	3.8E-29	4.81E-24	3.85E-29	4.81E-24	3.59E-30	4.49E-25			3.59E-30	4.49E-25	1.88E-23
	Te-131	8.00E-05	0.000	2.6E-03	8.7E-30	1.08E-25	8.66E-30	1.08E-25	8.09E-31	1.01E-26			8.09E-31	1.01E-26	4.19E-25
	I-131	1.00E-06	0.022	7.4E-01	6.8E-05	6.76E+01	6.76E-05	6.76E+01	6.31E-06	6.31E+00			6.31E-06	6.31E+00	1.02E+01
Te-132		9.00E-06	0.009	4.1E-02	4.4E-12	4.91E-07							4.41E-12	4.91E-07	2.38E-05
	I-132	1.00E-04	0.000	3.7E-01	4.5E-12	4.55E-08							4.55E-12	4.55E-08	1.72E-07
I-133		7.00E-06	0.002	1.3E+00	4.3E-38	6.21E-33							4.35E-38	6.21E-33	2.53E-32
	Xe-133m	NaN	0.006	0.0E+00	3.5E-17								3.54E-17		
	Xe-133	NaN	0.014	0.0E+00	1.7E-07								1.69E-07		
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	9.4E-119	3.12E-114							9.37E-119	3.12E-114	1.19E-113
	Xe-135m	NaN	0.000	0.0E+00	1.5E-119								1.50E-119		
	Xe-135	NaN	0.001	0.0E+00	3.7E-86								3.74E-86		
Cs-134		9.00E-07	2.062	1.7E-01	1.5E-01	1.71E+05	7.30E-150	8.11E-144					7.30E-150	8.11E-144	1.47E-141
Cs-136		6.00E-06	0.036	5.3E-02	1.8E-04	2.93E+01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-137		1.00E-06	30	1.1E-01	1.1E-01	1.09E+05	7.01E-12	7.01E-06					7.01E-12	7.01E-06	9.62E-04
	Ba-137m	NaN	0.000	1.0E-01	1.0E-01		6.63E-12						6.63E-12		0.00E+00
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	1.8E-06	2.19E-01	1.75E-06	2.19E-01	1.63E-07	2.04E-02	1.05E-08	1.31E-03	1.05E-08	1.31E-03	9.48E-03
	La-140	9.00E-06	0.005	1.6E-04	2.0E-06	2.24E-01	2.02E-06	2.24E-01	1.88E-07	2.09E-02			1.88E-07	2.09E-02	7.79E-01
Ce-141		3.00E-05	0.089	8.9E-05	8.9E-06	2.97E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-143		2.00E-05	0.004	7.6E-05	1.8E-28	9.10E-24	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	3.9E-07	1.94E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-144		3.00E-06	0.778	6.9E-05	5.3E-05	1.77E+01	1.65E-55	5.49E-50					1.65E-55	5.49E-50	1.70E-48
	Pr-144m	NaN	0.000	0.0E+00	9.4E-07		2.93E-57						2.93E-57		0.00E+00
	Pr-144	6.00E-04	0.000	6.9E-05	5.3E-05	8.84E-02	1.65E-55	2.74E-52					1.65E-55	2.74E-52	0.00E+00
W-187		3.00E-05	0.003	1.8E-03	4.4E-36	1.46E-31							4.37E-36	1.46E-31	1.96E-29
Np-239		2.00E-05	0.006	8.7E-04	1.406E-17	7.03E-13	1.41E-17	7.03E-13	1.31E-18	6.57E-14			1.31E-18	6.57E-14	9.45E-13
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	2.18E-11	1.09E-03			2.18E-11	1.09E-03	6.58E-03
Highlighted values exceed one percent of the ECL.													**Sum =**	**8.12**	**21.17**

Footnotes for Table 2.4-207 are shown after Table 2.4-211

Table 2.4-208 – {Transport Analysis for Pathway to Branch 1}

(Page 1 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL		
H-3		1.00E-03	12.348	1.0E+00	8.71E-01	8.71E+02	8.71E-01	8.71E+02	7.92E-02	7.92E+01	2.94E-04	2.94E-01	2.94E-04	2.94E-01
Na-24		5.00E-05	0.002	3.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Cr-51		5.00E-04	0.076	2.0E-03	3.3E-13	6.67E-10							3.34E-13	6.67E-10
Mn-54		3.00E-05	0.857	1.0E-03	1.4E-04	4.55E+00	2.48E-49	8.28E-45					2.48E-49	8.28E-45
Fe-55		1.00E-04	2.700	7.6E-04	4.0E-04	4.04E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Fe-59		1.00E-05	0.122	1.9E-04	1.6E-10	1.56E-05							1.56E-10	1.56E-05
Co-58		2.00E-05	0.194	2.9E-03	4.3E-07	2.17E-02	3.03E-245	1.51E-240					3.03E-245	1.51E-240
Co-60		3.00E-06	5.284	3.4E-04	2.5E-04	8.20E+01	4.52E-13	1.51E-07					4.52E-13	1.51E-07
Zn-65		5.00E-06	0.668	3.2E-04	2.5E-05	4.96E+00	1.15E-82	2.30E-77					1.15E-82	2.30E-77
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00	
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	2.8E-09	3.47E-04							2.77E-09	3.47E-04
Sr-90		5.00E-07	29.120	3.3E-05	3.1E-05	6.22E+01	4.04E-06	8.08E+00	3.68E-07	7.35E-01	4.40E-11	8.79E-05	4.40E-11	8.79E-05
	Y-90	7.00E-06	0.007	7.7E-06	3.1E-05	4.45E+00	4.04E-06	5.77E-01	3.68E-07	5.25E-02	4.40E-11	6.28E-06	4.40E-11	6.28E-06
Sr-91		2.00E-05	0.001	1.0E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	2.1E-09	2.58E-04							2.07E-09	2.58E-04
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Zr-95		2.00E-05	0.175	9.3E-05	5.4E-09	2.72E-04							5.44E-09	2.72E-04
	Nb-95m	3.00E-05	0.010	0.0E+00	4.0E-11	1.34E-06							4.02E-11	1.34E-06
	Nb-95	3.00E-05	0.096	9.3E-05	1.2E-08	4.02E-04							1.21E-08	4.02E-04
Mo-99		2.00E-05	0.008	1.1E-01	3.6E-100	1.79E-95							3.57E-100	1.79E-95
	Tc-99m	1.00E-03	0.001	4.6E-02	3.4E-100	3.44E-97							3.44E-100	3.44E-97
Ru-103		3.00E-05	0.108	7.7E-05	9.8E-12	3.27E-07							9.80E-12	3.27E-07
	Rh-103m	6.00E-03	0.000	6.8E-05	9.8E-12	1.63E-09							9.78E-12	1.63E-09
Ru-106		3.00E-06	1.008	2.7E-05	5.0E-06	1.65E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	5.0E-06		0.00E+00						0.00E+00	
Ag-110m		6.00E-06	0.684	2.0E-07	1.6E-08	2.75E-03							1.65E-08	2.75E-03
	Ag-110	NaN	0.000	0.0E+00	2.2E-10								2.19E-10	

Table 2.4-208 – {Transport Analysis for Pathway to Branch 1}

(Page 2 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL		
Te-127m		9.00E-06	0.298	4.4E-04	1.4E-06	1.60E-01	1.44E-06	1.60E-01	1.31E-07	1.46E-02	9.69E-10	1.08E-04	9.69E-10	1.08E-04
	Te-127	1.00E-04	0.001	0.0E+00	1.4E-06	1.41E-02	1.41E-06	1.41E-02	1.28E-07	1.28E-03	9.23E-10	9.23E-06	9.23E-10	9.23E-06
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	4.19E-09	2.09E-02	1.19E-11	5.95E-05	1.19E-11	5.95E-05
I-130		2.00E-05	0.001	5.0E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Te-129m		7.00E-06	0.092	1.5E-03	1.3E-11	1.86E-06							1.30E-11	1.86E-06
	Te-129	4.00E-04	0.000	2.4E-03	8.5E-12	2.12E-08							8.49E-12	2.12E-08
Te-131m		8.00E-06	0.003	3.7E-03	7.8E-220	9.78E-215							7.82E-220	9.78E-215
	Te-131	8.00E-05	0.000	2.6E-03	1.8E-220	2.20E-216							1.76E-220	2.20E-216
	I-131	1.00E-06	0.022	7.4E-01	1.5E-34	1.52E-28							1.52E-34	1.52E-28
Te-132		9.00E-06	0.009	4.1E-02	3.1E-85	3.43E-80							3.09E-85	3.43E-80
	I-132	1.00E-04	0.000	3.7E-01	3.2E-85	3.18E-81							3.18E-85	3.18E-81
I-133		7.00E-06	0.002	1.3E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-133m	NaN	0.006	0.0E+00	4.0E-126								4.05E-126	
	Xe-133	NaN	0.014	0.0E+00	6.0E-53								6.04E-53	
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
	Xe-135	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Cs-134		9.00E-07	2.062	1.7E-01	7.4E-02	8.25E+04	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	1.1E-22	1.87E-17							1.12E-22	1.87E-17
Cs-137		1.00E-06	30	1.1E-01	1.0E-01	1.04E+05	1.04E-86	1.04E-80					1.04E-86	1.04E-80
	Ba-137m	NaN	0.000	1.0E-01	9.8E-02		9.85E-87						9.85E-87	
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	3.4E-25	4.27E-20							3.41E-25	4.27E-20
	La-140	9.00E-06	0.005	1.6E-04	3.9E-25	4.37E-20							3.93E-25	4.37E-20
Ce-141		3.00E-05	0.089	8.9E-05	4.1E-13	1.38E-08							4.13E-13	1.38E-08
Ce-143		2.00E-05	0.004	7.6E-05	8.0E-202	4.00E-197							8.01E-202	4.00E-197
	Pr-143	2.00E-05	0.037	8.8E-05	1.0E-24	5.13E-20							1.03E-24	5.13E-20
Ce-144		3.00E-06	0.778	6.9E-05	7.7E-06	2.56E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Pr-144m	NaN	0.000	0.0E+00	1.4E-07		0.00E+00						0.00E+00	
	Pr-144	6.00E-04	0.000	6.9E-05	7.7E-06	1.28E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00
W-187		3.00E-05	0.003	1.8E-03	1.9E-275	6.33E-271							1.90E-275	6.33E-271
Np-239		2.00E-05	0.006	8.7E-04	8.543E-119	4.27E-114	8.54E-119	4.27E-114	7.77E-120	3.89E-115			7.77E-120	3.89E-115
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	2.12E-11	1.06E-03			2.12E-11	1.06E-03
Highlighted values exceed one percent of the ECL.													Sum =	0.299

Footnotes for Table 2.4-208 are shown after Table 2.4-211

Table 2.4-209 – {Transport Analysis for Pathway to Branch 3}

(Page 1 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL		
H-3		1.00E-03	12.348	1.0E+00	6.14E-01	6.14E+02	6.14E-01	6.14E+02	2.12E-03	2.12E+00	3.44E-06	3.44E-03	3.44E-06	3.44E-03
Na-24		5.00E-05	0.002	3.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Cr-51		5.00E-04	0.076	2.0E-03	6.2E-38	1.25E-34							6.23E-38	1.25E-34
Mn-54		3.00E-05	0.857	1.0E-03	8.8E-07	2.94E-02	1.13E-164	3.78E-160					1.13E-164	3.78E-160
Fe-55		1.00E-04	2.700	7.6E-04	8.2E-05	8.15E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Fe-59		1.00E-05	0.122	1.9E-04	6.3E-26	6.30E-21							6.30E-26	6.30E-21
Co-58		2.00E-05	0.194	2.9E-03	9.2E-17	4.58E-12							9.16E-17	4.58E-12
Co-60		3.00E-06	5.284	3.4E-04	1.1E-04	3.62E+01	1.60E-35	5.33E-30					1.60E-35	5.33E-30
Zn-65		5.00E-06	0.668	3.2E-04	3.9E-08	7.71E-03							3.86E-08	7.71E-03
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00	
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	7.6E-23	9.45E-18							7.56E-23	9.45E-18
Sr-90		5.00E-07	29.120	3.3E-05	2.7E-05	5.37E+01	1.99E-08	3.98E-02	6.87E-11	1.37E-04			6.87E-11	1.37E-04
	Y-90	7.00E-06	0.007	7.7E-06	2.7E-05	3.83E+00	1.99E-08	2.85E-03	6.88E-11	9.82E-06			6.88E-11	9.82E-06
Sr-91		2.00E-05	0.001	1.0E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	4.0E-21	5.04E-16							4.04E-21	5.04E-16
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Zr-95		2.00E-05	0.175	9.3E-05	1.1E-19	5.34E-15							1.07E-19	5.34E-15
	Nb-95m	3.00E-05	0.010	0.0E+00	7.9E-22	2.63E-17							7.90E-22	2.63E-17
	Nb-95	3.00E-05	0.096	9.3E-05	2.4E-19	7.91E-15							2.37E-19	7.91E-15
Mo-99		2.00E-05	0.008	1.1E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Tc-99m	1.00E-03	0.001	4.6E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ru-103		3.00E-05	0.108	7.7E-05	3.6E-29	1.19E-24							3.57E-29	1.19E-24
	Rh-103m	6.00E-03	0.000	6.8E-05	3.6E-29	5.94E-27							3.56E-29	5.94E-27
Ru-106		3.00E-06	1.008	2.7E-05	6.8E-08	2.28E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	6.8E-08		0.00E+00						0.00E+00	
Ag-110m		6.00E-06	0.684	2.0E-07	3.0E-11	4.99E-06							2.99E-11	4.99E-06
	Ag-110	NaN	0.000	0.0E+00	4.0E-13								3.98E-13	

Table 2.4-209 – {Transport Analysis for Pathway to Branch 3}

(Page 2 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL		
Te-127m		9.00E-06	0.298	4.4E-04	7.5E-13	8.32E-08							7.49E-13	8.32E-08
	Te-127	1.00E-04	0.001	0.0E+00	7.3E-13	7.33E-09							7.33E-13	7.33E-09
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	1.59E-10	7.93E-04			1.59E-10	7.93E-04
I-130		2.00E-05	0.001	5.0E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Te-129m		7.00E-06	0.092	1.5E-03	5.4E-32	7.64E-27							5.35E-32	7.64E-27
	Te-129	4.00E-04	0.000	2.4E-03	3.5E-32	8.71E-29							3.48E-32	8.71E-29
Te-131m		8.00E-06	0.003	3.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Te-131	8.00E-05	0.000	2.6E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-131	1.00E-06	0.022	7.4E-01	9.6E-120	9.64E-114							9.64E-120	9.64E-114
Te-132		9.00E-06	0.009	4.1E-02	1.8E-295	2.02E-290							1.82E-295	2.02E-290
	I-132	1.00E-04	0.000	3.7E-01	1.9E-295	1.88E-291							1.88E-295	1.88E-291
I-133		7.00E-06	0.002	1.3E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-133m	NaN	0.006	0.0E+00	0.0E+00								0.00E+00	
	Xe-133	NaN	0.014	0.0E+00	1.5E-183								1.52E-183	
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
	Xe-135	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Cs-134		9.00E-07	2.062	1.7E-01	9.1E-03	1.02E+04	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	5.7E-75	9.58E-70							5.75E-75	9.58E-70
Cs-137		1.00E-06	30	1.1E-01	9.0E-02	9.00E+04	9.58E-302	9.58E-296					9.58E-302	9.58E-296
	Ba-137m	NaN	0.000	1.0E-01	8.5E-02		9.07E-302						9.07E-302	
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	5.8E-79	7.29E-74							5.83E-79	7.29E-74
	La-140	9.00E-06	0.005	1.6E-04	6.7E-79	7.46E-74							6.71E-79	7.46E-74
Ce-141		3.00E-05	0.089	8.9E-05	3.5E-34	1.15E-29							3.46E-34	1.15E-29
Ce-143		2.00E-05	0.004	7.6E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	3.1E-75	1.56E-70							3.13E-75	1.56E-70
Ce-144		3.00E-06	0.778	6.9E-05	3.0E-08	9.99E-03							3.00E-08	9.99E-03
	Pr-144m	NaN	0.000	0.0E+00	5.3E-10								5.34E-10	
	Pr-144	6.00E-04	0.000	6.9E-05	3.0E-08	5.00E-05							3.00E-08	5.00E-05
W-187		3.00E-05	0.003	1.8E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Np-239		2.00E-05	0.006	8.7E-04	0.000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00
	Pu-239	2.00E-08	24,065	0.0E+00	2.330E-10	1.17E-02	2.33E-10	1.17E-02	8.04E-13	4.02E-05			8.04E-13	4.02E-05
Highlighted values exceed one percent of the ECL.													Sum =	0.0222

Footnotes for Table 2.4-209 are shown after Table 2.4-211

Table 2.4-210 – {Transport Analysis for Pathway to Johns Creek}

(Page 1 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL		
H-3		1.00E-03	12.348	1.0E+00	5.79E-01	5.79E+02	5.79E-01	5.79E+02	2.05E-03	2.05E+00	2.75E-06	2.75E-03	2.75E-06	2.75E-03
Na-24		5.00E-05	0.002	3.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Cr-51		5.00E-04	0.076	2.0E-03	4.1E-42	8.11E-39							4.05E-42	8.11E-39
Mn-54		3.00E-05	0.857	1.0E-03	3.8E-07	1.25E-02	3.38E-184	1.13E-179					3.38E-184	1.13E-179
Fe-55		1.00E-04	2.700	7.6E-04	6.2E-05	6.22E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Fe-59		1.00E-05	0.122	1.9E-04	1.6E-28	1.56E-23							1.56E-28	1.56E-23
Co-58		2.00E-05	0.194	2.9E-03	2.1E-18	1.05E-13							2.11E-18	1.05E-13
Co-60		3.00E-06	5.284	3.4E-04	9.5E-05	3.16E+01	2.53E-39	8.44E-34					2.53E-39	8.44E-34
Zn-65		5.00E-06	0.668	3.2E-04	1.3E-08	2.58E-03							1.29E-08	2.58E-03
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00	
	Kr-85	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	3.8E-25	4.78E-20							3.82E-25	4.78E-20
Sr-90		5.00E-07	29.120	3.3E-05	2.6E-05	5.23E+01	8.11E-09	1.62E-02	2.87E-11	5.74E-05			2.87E-11	5.74E-05
	Y-90	7.00E-06	0.007	7.7E-06	2.6E-05	3.74E+00	8.11E-09	1.16E-03	2.87E-11	4.10E-06			2.87E-11	4.10E-06
Sr-91		2.00E-05	0.001	1.0E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	4.2E-23	5.26E-18							4.20E-23	5.26E-18
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Y-93		2.00E-05	0.001	6.5E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Zr-95		2.00E-05	0.175	9.3E-05	1.6E-21	8.23E-17							1.65E-21	8.23E-17
	Nb-95m	3.00E-05	0.010	0.0E+00	1.2E-23	4.06E-19							1.22E-23	4.06E-19
	Nb-95	3.00E-05	0.096	9.3E-05	3.7E-21	1.22E-16							3.65E-21	1.22E-16
Mo-99		2.00E-05	0.008	1.1E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Tc-99m	1.00E-03	0.001	4.6E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ru-103		3.00E-05	0.108	7.7E-05	4.0E-32	1.33E-27							3.98E-32	1.33E-27
	Rh-103m	6.00E-03	0.000	6.8E-05	4.0E-32	6.63E-30							3.98E-32	6.63E-30
Ru-106		3.00E-06	1.008	2.7E-05	3.3E-08	1.10E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	3.3E-08		0.00E+00						0.00E+00	
Ag-110m		6.00E-06	0.684	2.0E-07	1.0E-11	1.71E-06							1.03E-11	1.71E-06
	Ag-110	NaN	0.000	0.0E+00	1.4E-13								1.37E-13	

Table 2.4-210 – {Transport Analysis for Pathway to Johns Creek}

(Page 2 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL		
Te-127m		9.00E-06	0.298	4.4E-04	6.5E-14	7.18E-09							6.46E-14	7.18E-09
	Te-127	1.00E-04	0.001	0.0E+00	6.3E-14	6.33E-10							6.33E-14	6.33E-10
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	1.63E-10	8.14E-04			1.63E-10	8.14E-04
I-130		2.00E-05	0.001	5.0E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Te-129m		7.00E-06	0.092	1.5E-03	1.9E-35	2.71E-30							1.89E-35	2.71E-30
	Te-129	4.00E-04	0.000	2.4E-03	1.2E-35	3.08E-32							1.23E-35	3.08E-32
Te-131m		8.00E-06	0.003	3.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Te-131	8.00E-05	0.000	2.6E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-131	1.00E-06	0.022	7.4E-01	3.6E-134	3.64E-128							3.64E-134	3.64E-128
Te-132		9.00E-06	0.009	4.1E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-132	1.00E-04	0.000	3.7E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
I-133		7.00E-06	0.002	1.3E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-133m	NaN	0.006	0.0E+00	0.0E+00								0.00E+00	
	Xe-133	NaN	0.014	0.0E+00	1.2E-205								1.18E-205	
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Xe-135m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00	
	Xe-135	NaN	0.001	0.0E+00	0.0E+00								0.00E+00	
Cs-134		9.00E-07	2.062	1.7E-01	6.4E-03	7.13E+03	0.00E+00	0.00E+00					0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	8.1E-84	1.35E-78							8.08E-84	1.35E-78
Cs-137		1.00E-06	30	1.1E-01	8.8E-02	8.78E+04	0.00E+00	0.00E+00					0.00E+00	0.00E+00
	Ba-137m	NaN	0.000	1.0E-01	8.3E-02		0.00E+00						0.00E+00	
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	4.6E-88	5.76E-83							4.61E-88	5.76E-83
	La-140	9.00E-06	0.005	1.6E-04	5.3E-88	5.90E-83							5.31E-88	5.90E-83
Ce-141		3.00E-05	0.089	8.9E-05	9.4E-38	3.12E-33							9.35E-38	3.12E-33
Ce-143		2.00E-05	0.004	7.6E-05	0.0E+00	0.00E+00							0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	8.8E-84	4.39E-79							8.78E-84	4.39E-79
Ce-144		3.00E-06	0.778	6.9E-05	1.2E-08	3.91E-03							1.17E-08	3.91E-03
	Pr-144m	NaN	0.000	0.0E+00	2.1E-10								2.09E-10	
	Pr-144	6.00E-04	0.000	6.9E-05	1.2E-08	1.95E-05							1.17E-08	1.95E-05
W-187		3.00E-05	0.003	1.8E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00
Np-239		2.00E-05	0.006	8.7E-04	0.000E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00			0.00E+00	0.00E+00
	Pu-239	2.00E-08	24,065	0.0E+00	2.330E-10	1.17E-02	2.33E-10	1.17E-02	8.25E-13	4.12E-05			8.25E-13	4.12E-05
Highlighted values exceed one percent of the ECL.													**Sum =**	**0.0102**

Footnotes for Table 2.4-210 are shown after Table 2.4-211

Table 2.4-211 – {Transport Analysis for Pathway to Branch 2 through Fill}

(Page 1 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL			Total Dose – Aquatic Ingestion (mrem/year)
H-3		1.00E-03	12.348	1.0E+00	9.82E-01	9.82E+02	9.82E-01	9.82E+02	3.49E-02	3.49E+01	3.56E-03	3.56E+00	3.56E-03	3.56E+00	4.10E-01
Na-24		5.00E-05	0.002	3.7E-02	1.5E-57	3.02E-53							1.51E-57	3.02E-53	2.51E-52
Cr-51		5.00E-04	0.076	2.0E-03	1.1E-04	2.25E-01	1.13E-04	2.25E-01	3.99E-06	7.99E-03			3.99E-06	7.99E-03	6.88E-01
Mn-54		3.00E-05	0.857	1.0E-03	7.8E-04	2.58E+01	2.25E-08	7.50E-04					2.25E-08	7.50E-04	2.56E+00
Fe-55		1.00E-04	2.700	7.6E-04	7.0E-04	7.01E+00	7.01E-04	7.01E+00	2.49E-05	2.49E-01	2.55E-06	2.55E-02	2.55E-06	2.55E-02	2.64E+00
Fe-59		1.00E-05	0.122	1.9E-04	3.2E-05	3.17E+00	3.17E-05	3.17E+00	1.12E-06	1.12E-01	1.39E-07	1.39E-02	1.39E-07	1.39E-02	1.60E+00
Co-58		2.00E-05	0.194	2.9E-03	9.4E-04	4.70E+01	1.74E-26	8.70E-22					1.74E-26	8.70E-22	3.08E-20
Co-60		3.00E-06	5.284	3.4E-04	3.3E-04	1.09E+02	4.78E-05	1.59E+01	1.70E-06	5.66E-01	4.55E-09	1.52E-03	4.55E-09	1.52E-03	6.07E-02
Zn-65		5.00E-06	0.668	3.2E-04	2.3E-04	4.62E+01	1.42E-10	2.84E-05					1.42E-10	2.84E-05	1.20E-02
Br-83		9.00E-04	0.000	3.2E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Kr-83m	NaN	0.000	0.0E+00	0.0E+00								0.00E+00		
Br-84		4.00E-04	0.000	1.7E-02	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Br-85		NaN	0.000	2.0E-03	0.0E+00								0.00E+00		
	Kr-85	NaN	0.001	0.0E+00	1.6E-190								1.63E-190		
Rb-88		4.00E-04	0.000	1.0E+00	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Rb-89		9.00E-04	0.000	4.7E-02	0.0E+00	0.00E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Sr-89	8.00E-06	0.138	6.3E-04	1.3E-04	1.65E+01	1.78E-36	2.22E-31					1.78E-36	2.22E-31	2.07E-30
Sr-90		5.00E-07	29.120	3.3E-05	3.3E-05	6.55E+01	2.31E-05	4.62E+01	8.21E-07	1.64E+00	1.81E-09	3.61E-03	1.81E-09	3.61E-03	3.24E-02
	Y-90	7.00E-06	0.007	7.7E-06	3.3E-05	4.68E+00	2.31E-05	3.30E+00	8.21E-07	1.17E-01	1.81E-09	2.58E-04	1.81E-09	2.58E-04	9.54E-03
Sr-91		2.00E-05	0.001	1.0E-03	3.8E-91	1.90E-86	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91m	2.00E-03	0.000	5.2E-04	2.4E-91	1.20E-88	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Y-91	8.00E-06	0.160	8.1E-05	2.3E-05	2.82E+00	6.93E-33	8.66E-28					6.93E-33	8.66E-28	3.23E-26
Sr-92		4.00E-05	0.000	1.7E-04	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	Y-92	4.00E-05	0.000	1.4E-04	8.5E-238	2.12E-233							8.48E-238	2.12E-233	7.93E-232
Y-93		2.00E-05	0.001	6.5E-05	3.8E-87	1.92E-82							3.84E-87	1.92E-82	8.56E-81
Zr-95		2.00E-05	0.175	9.3E-05	2.7E-05	1.34E+00	2.68E-05	1.34E+00	9.50E-07	4.75E-02	1.09E-07	5.45E-03	1.09E-07	5.45E-03	1.68E-01
	Nb-95m	3.00E-05	0.010	0.0E+00	2.0E-07	6.60E-03	1.98E-07	6.60E-03	7.03E-09	2.34E-04			7.03E-09	2.34E-04	7.28E-03
	Nb-95	3.00E-05	0.096	9.3E-05	4.8E-05	1.59E+00	4.76E-05	1.59E+00	1.69E-06	5.64E-02			1.69E-06	5.64E-02	1.96E+00
Mo-99		2.00E-05	0.008	1.1E-01	2.8E-14	1.42E-09							2.84E-14	1.42E-09	2.57E-09
	Tc-99m	1.00E-03	0.001	4.6E-02	2.7E-14	2.73E-11							2.73E-14	2.73E-11	4.97E-11
Ru-103		3.00E-05	0.108	7.7E-05	1.0E-05	3.37E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-103m	6.00E-03	0.000	6.8E-05	1.0E-05	1.68E-03	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ru-106		3.00E-06	1.008	2.7E-05	2.2E-05	7.25E+00	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Rh-106	NaN	0.000	2.7E-05	2.2E-05		0.00E+00						0.00E+00		0.00E+00
Ag-110m		6.00E-06	0.684	2.0E-07	1.5E-07	2.42E-02	1.45E-07	2.42E-02	5.16E-09	8.60E-04			5.16E-09	8.60E-04	1.97E-02
	Ag-110	NaN	0.000	0.0E+00	1.9E-09		1.93E-09		6.86E-11				6.86E-11		0.00E+00

Table 2.4-211 – {Transport Analysis for Pathway to Branch 2 through Fill}

(Page 2 of 2)

Parent Radio-nuclide	Progeny in Chain	ECL[a] (µCi/cm³)	Half-life[b] $t_{1/2}$ (years)	Reactor Coolant Activity[c] (µCi/cm³)	Advection & Radioactive Decay[d]		+ Retardation[e]		+ Dilution[f]		+ Dispersion[g]		Final Activity (µCi/cm³)	Final Activity / ECL	Bio-Accumulation Total Dose – Aquatic Ingestion (mrem/year)
					Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Ground Water Activity (µCi/cm³)	Ground Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL	Surface Water Activity (µCi/cm³)	Surface Water Activity / ECL			
Te-127m		9.00E-06	0.298	4.4E-04	2.1E-04	2.35E+01	2.12E-04	2.35E+01	7.52E-06	8.35E-01	8.13E-07	9.03E-02	8.13E-07	9.03E-02	3.85E+00
	Te-127	1.00E-04	0.001	0.0E+00	2.1E-04	2.07E+00	2.07E-04	2.07E+00	7.36E-06	7.36E-02	7.93E-07	7.93E-03	7.93E-07	7.93E-03	3.15E-01
I-129		2.00E-07	15700000	4.6E-08	4.6E-08	2.30E-01	4.60E-08	2.30E-01	1.63E-09	8.16E-03			1.63E-09	8.16E-03	2.54E-02
I-130		2.00E-05	0.001	5.0E-02	3.0E-69	1.51E-64							3.01E-69	1.51E-64	8.02E-64
Te-129m		7.00E-06	0.092	1.5E-03	1.4E-04	2.00E+01	1.40E-04	2.00E+01	4.97E-06	7.09E-01	6.77E-07	9.67E-02	6.77E-07	9.67E-02	4.15E+00
	Te-129	4.00E-04	0.000	2.4E-03	9.1E-05	2.28E-01	9.11E-05	2.28E-01	3.23E-06	8.08E-03			3.23E-06	8.08E-03	3.74E-01
Te-131m		8.00E-06	0.003	3.7E-03	7.5E-31	9.34E-26	7.47E-31	9.34E-26	2.65E-32	3.32E-27			2.65E-32	3.32E-27	1.39E-25
	Te-131	8.00E-05	0.000	2.6E-03	1.7E-31	2.10E-27	1.68E-31	2.10E-27	5.97E-33	7.46E-29			5.97E-33	7.46E-29	3.09E-27
	I-131	1.00E-06	0.022	7.4E-01	3.7E-05	3.66E+01	3.66E-05	3.66E+01	1.30E-06	1.30E+00			1.30E-06	1.30E+00	3.90E+00
Te-132		9.00E-06	0.009	4.1E-02	9.7E-13	1.08E-07							9.73E-13	1.08E-07	5.25E-06
	I-132	1.00E-04	0.000	3.7E-01	1.0E-12	1.00E-08							1.00E-12	1.00E-08	3.80E-08
I-133		7.00E-06	0.002	1.3E+00	1.5E-40	2.11E-35							1.48E-40	2.11E-35	8.61E-35
	Xe-133m	NaN	0.006	0.0E+00	3.7E-18								3.73E-18		
	Xe-133	NaN	0.014	0.0E+00	6.6E-08								6.59E-08		
Te-134		3.00E-04	0.000	6.7E-03	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
	I-134	4.00E-04	0.000	2.4E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
I-135		3.00E-05	0.001	7.9E-01	1.6E-126	5.32E-122							1.60E-126	5.32E-122	2.02E-121
	Xe-135m	NaN	0.000	0.0E+00	2.6E-127								2.56E-127		
	Xe-135	NaN	0.001	0.0E+00	8.4E-92								8.38E-92		
Cs-134		9.00E-07	2.062	1.7E-01	1.5E-01	1.70E+05	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-136		6.00E-06	0.036	5.3E-02	1.2E-04	2.01E+01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Cs-137		1.00E-06	30	1.1E-01	1.1E-01	1.09E+05	1.74E-49	1.74E-43					1.74E-49	1.74E-43	2.38E-41
	Ba-137m	NaN	0.000	1.0E-01	1.0E-01		1.64E-49						1.64E-49		0.00E+00
Cs-138		4.00E-04	0.000	2.2E-01	0.0E+00	0.00E+00							0.00E+00	0.00E+00	0.00E+00
Ba-140		8.00E-06	0.035	6.2E-04	1.2E-06	1.49E-01	1.19E-06	1.49E-01	4.22E-08	5.28E-03			4.22E-08	5.28E-03	3.81E-02
	La-140	9.00E-06	0.005	1.6E-04	1.4E-06	1.52E-01	1.37E-06	1.52E-01	4.86E-08	5.40E-03			4.86E-08	5.40E-03	2.01E-01
Ce-141		3.00E-05	0.089	8.9E-05	7.7E-06	2.55E-01	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-143		2.00E-05	0.004	7.6E-05	5.1E-30	2.53E-25	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
	Pr-143	2.00E-05	0.037	8.8E-05	2.7E-07	1.35E-02	0.00E+00	0.00E+00					0.00E+00	0.00E+00	0.00E+00
Ce-144		3.00E-06	0.778	6.9E-05	5.2E-05	1.74E+01	6.73E-122	2.24E-116					6.73E-122	2.24E-116	6.97E-115
	Pr-144m	NaN	0.000	0.0E+00	9.3E-07		1.20E-123						1.20E-123		0.00E+00
	Pr-144	6.00E-04	0.000	6.9E-05	5.2E-05	8.69E-02	6.73E-122	1.12E-118					6.73E-122	1.12E-118	0.00E+00
W-187		3.00E-05	0.003	1.8E-03	3.1E-38	1.03E-33							3.10E-38	1.03E-33	1.39E-31
Np-239		2.00E-05	0.006	8.7E-04	1.736E-18	8.68E-14	1.74E-18	8.68E-14	6.16E-20	3.08E-15			6.16E-20	3.08E-15	4.43E-14
	Pu-239	2.00E-08	24,065	0.0E+00	2.331E-10	1.17E-02	2.33E-10	1.17E-02	8.27E-12	4.14E-04			8.27E-12	4.14E-04	2.50E-03
Highlighted values exceed one percent of the ECL.													**Sum =**	**5.20**	**23.02**

Footnotes to Tables 2.4-206 through 2.4-211:

a. *ECL* values were derived from 10 CFR Part 20, Appendix B, Table 2, Column 2 (Title 10, Code of Federal Regulations, U.S. Nuclear Regulatory Commission). The term "NaN" represents "Not a Number" and indicates that a Maximum Effluent Concentration Limit (*ECL*) was not available.
b. Half-lives were obtained from ICRP (1983) and Kennedy and Strenge (1992), and converted from days to years.
c. Source term activity concentrations were obtained from Reference AREVA, 2007.
d. "Advection and Radioactive Decay" values were calculated from Eq. (2.4.13-9), (2.4.13-14), or (2.4.13-21) depending on the position in decay chain. These calculations assume that the retardation factor (Equation 2.4.13-2) is equal to 1 (R=1).
e. "Retardation" values were calculated from Eq. (2.4.13-9), (2.4.13-14), or (2.4.13-21) depending on their position in the decay chain using retardation factors derived from Equation 2.4.13-2. Retardation factors were calculated for elements for which site-specific distribution coefficients were available (Table 2.4-45). For elements which site-specific distribution coefficients are not available, the retardation factor was assumed to be equal to 1 (i.e., corresponding with K_d=0).
f. Dilution was accounted for using Eq. (26) and the dilution factors in Table 2.4-201. Dilution factors for contaminated groundwater discharges to surface water were calculated based on the 100-year low annual mean flow in the receiving stream.
g. Dispersion was accounted for using Codell and Duguid (1983). The dispersion values that are shown in the tables have been multiplied by the dilution factors.

FSAR Section 2.4.13 is supplemented by the addition of Figure 2.4-108 and Figure 2.4-109, and Figures 2.4-102, 2.4-103, 2.4-105 and 2.4-106 are being replaced with the following figures:

Figure 2.4-102 – {Conceptual Model of Subsurface Pathways through the Upper Chesapeake Unit to Surface Streams}

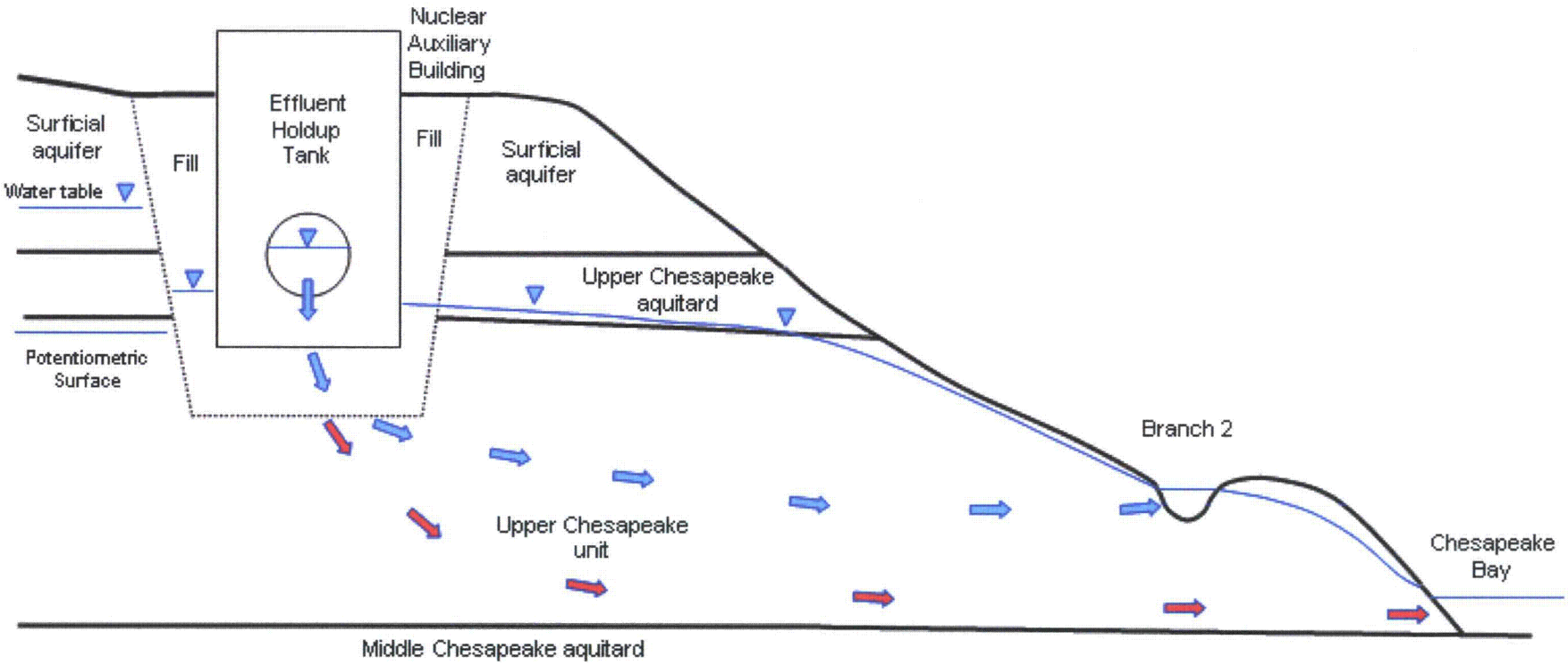


Figure 2.4-103 – {Plan View of Subsurface Contaminant Pathways}

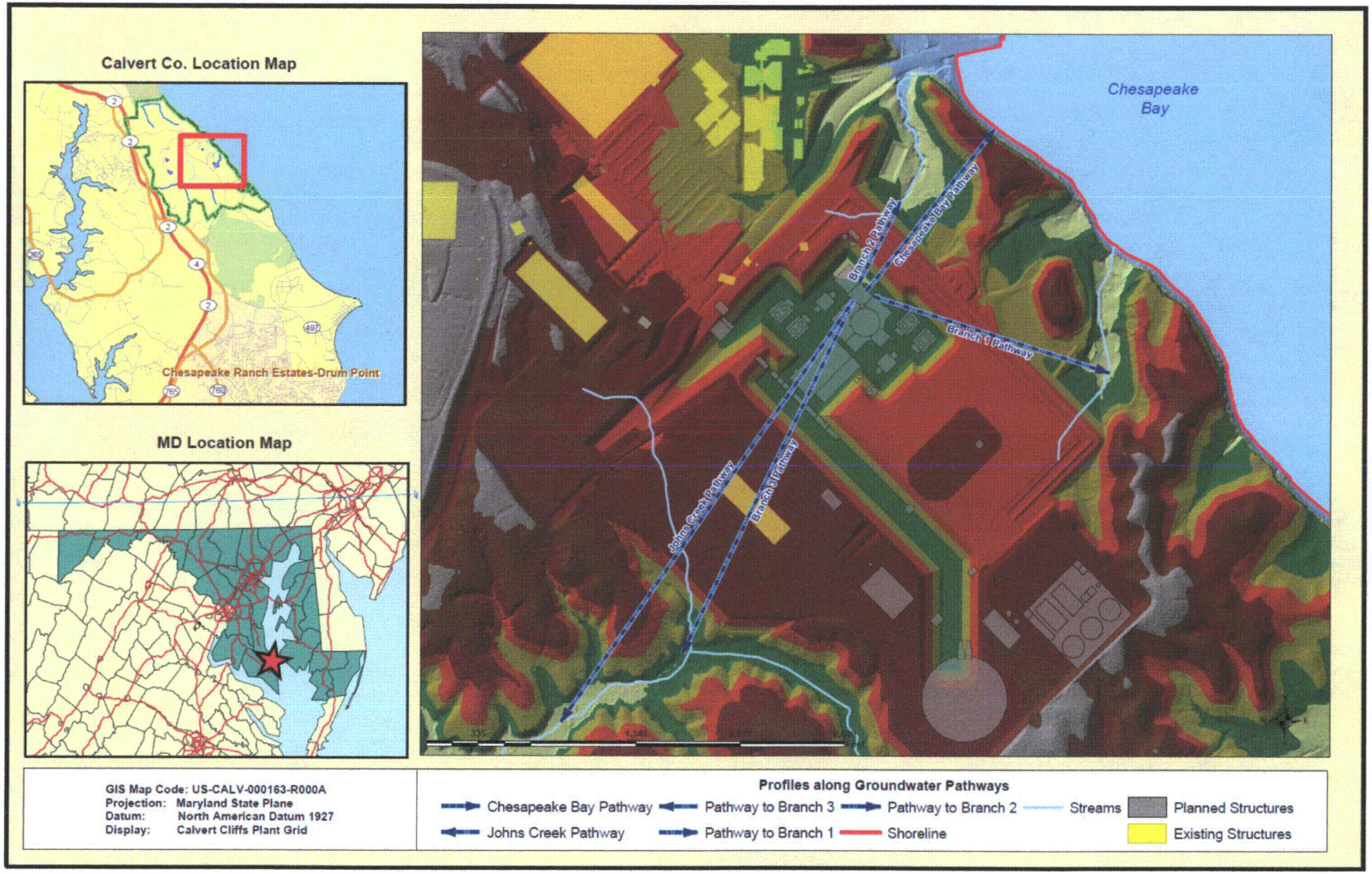


Figure 2.4-105 – {Potentiometric Surface Contours from Groundwater Model of Post-Construction Conditions}

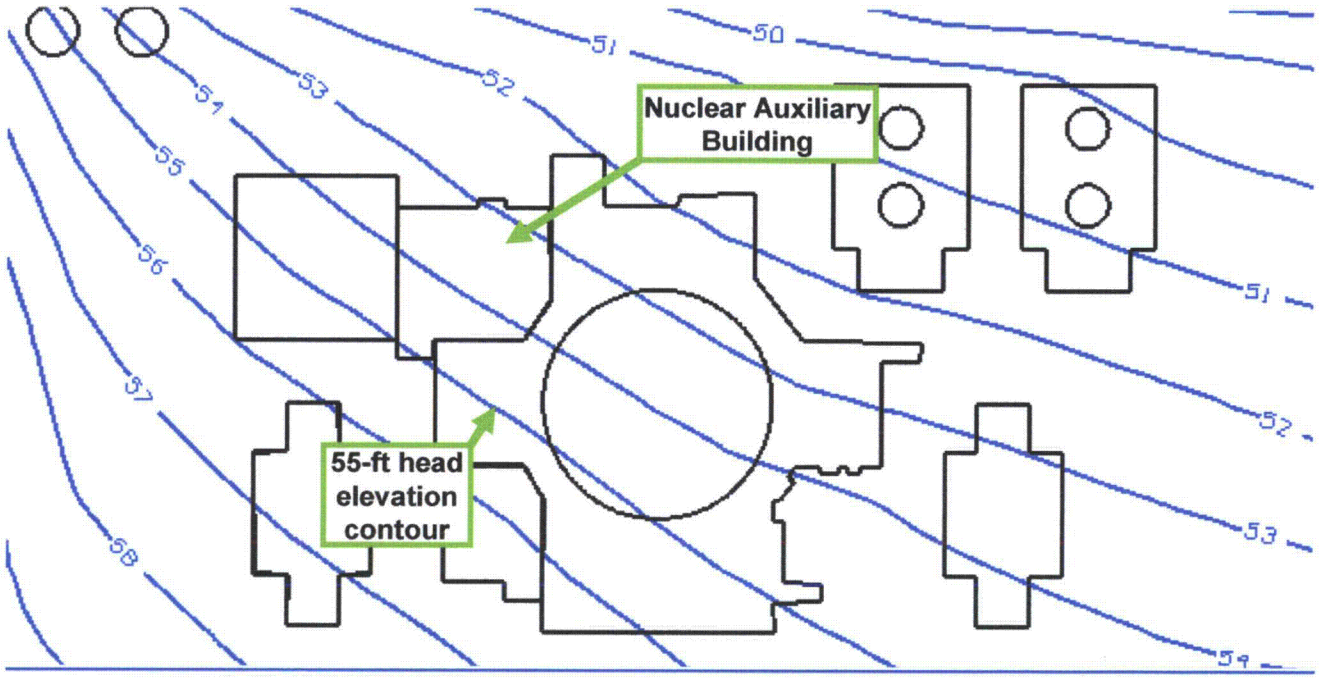
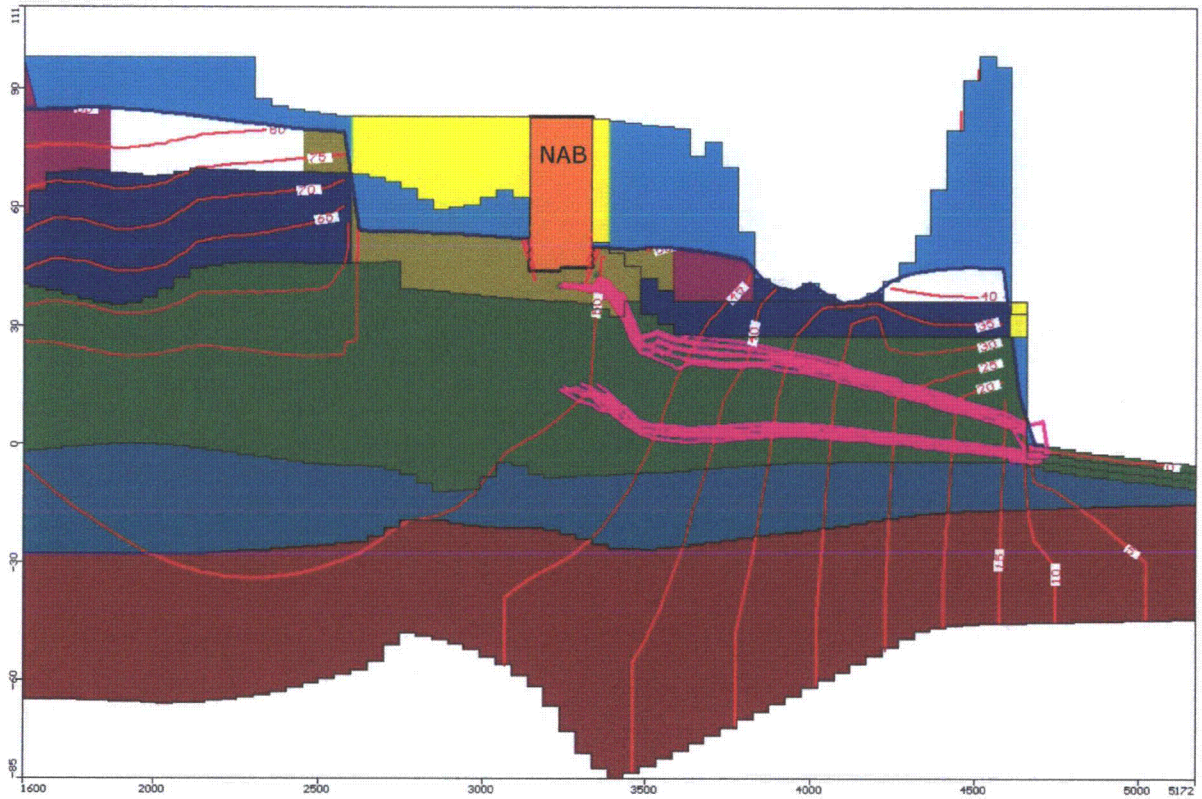


Figure 2.4-106 – {Cross Section Showing Pathlines through the Upper Chesapeake Unit in the Post-Construction Groundwater Model}

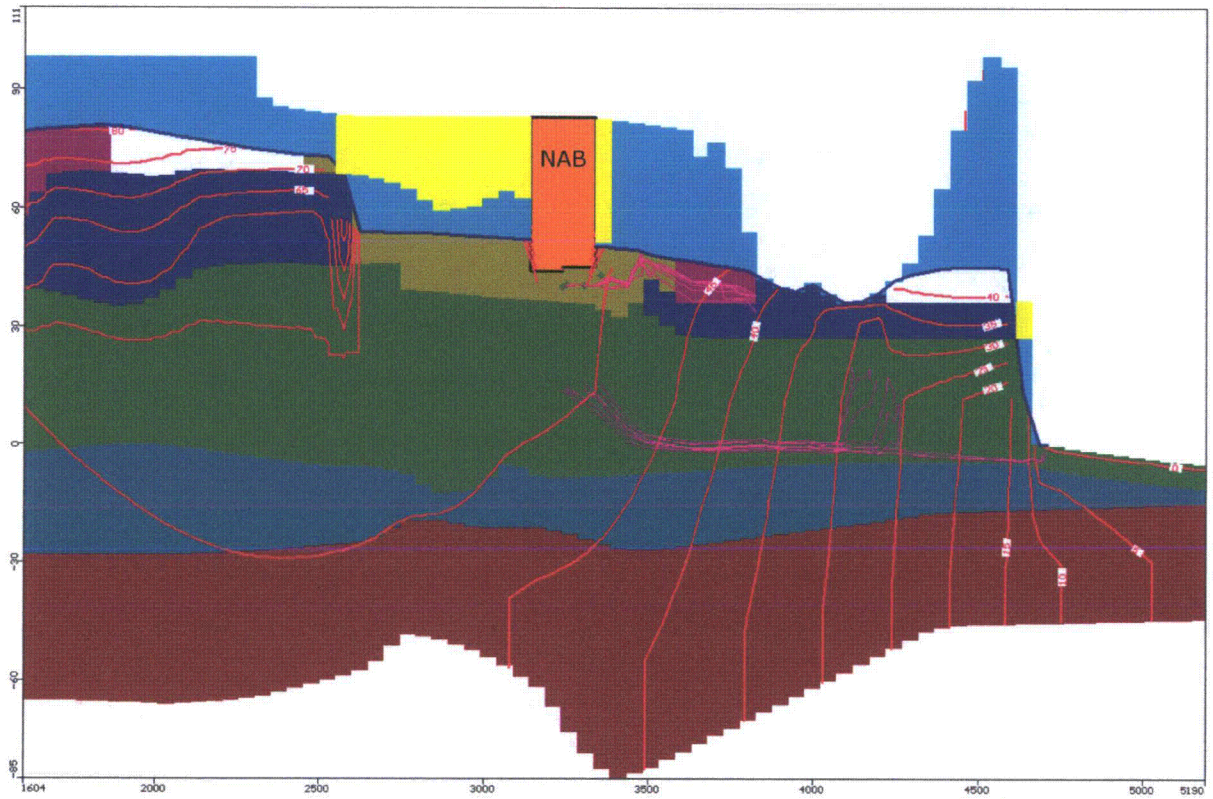


Legend

Vertical and horizontal scales in feet

Surficial aquifer	Lower Chesapeake unit	Fill beyond the excavation area
Upper Chesapeake aquitard	Backfill in the excavation area	Materials above the water table
Upper Chesapeake unit	Transition zone 1 (fill to aquitard)	Dry cells
Middle Chesapeake aquitard	Transition zone 2 (fill to aquitard)	Inactive cells (buildings)
Piezometric contour	Pathlines of tracked particles	Water table

Figure 2.4-108 – {Cross-Section Showing Pathlines through Engineered Fill in Post-Construction Groundwater Model, for the Simulation Using the Maximum Hydraulic Conductivity of the Fill Material}



Legend

Vertical and horizontal scales in feet

Surficial aquifer	Lower Chesapeake unit	Fill beyond the excavation area
Upper Chesapeake aquitard	Backfill in the excavation area	Materials above the water table
Upper Chesapeake unit	Transition zone 1 (fill to aquitard)	Dry cells
Middle Chesapeake aquitard	Transition zone 2 (fill to aquitard)	Inactive cells (buildings)
Piezometric contour	Pathlines of tracked particles	Water table

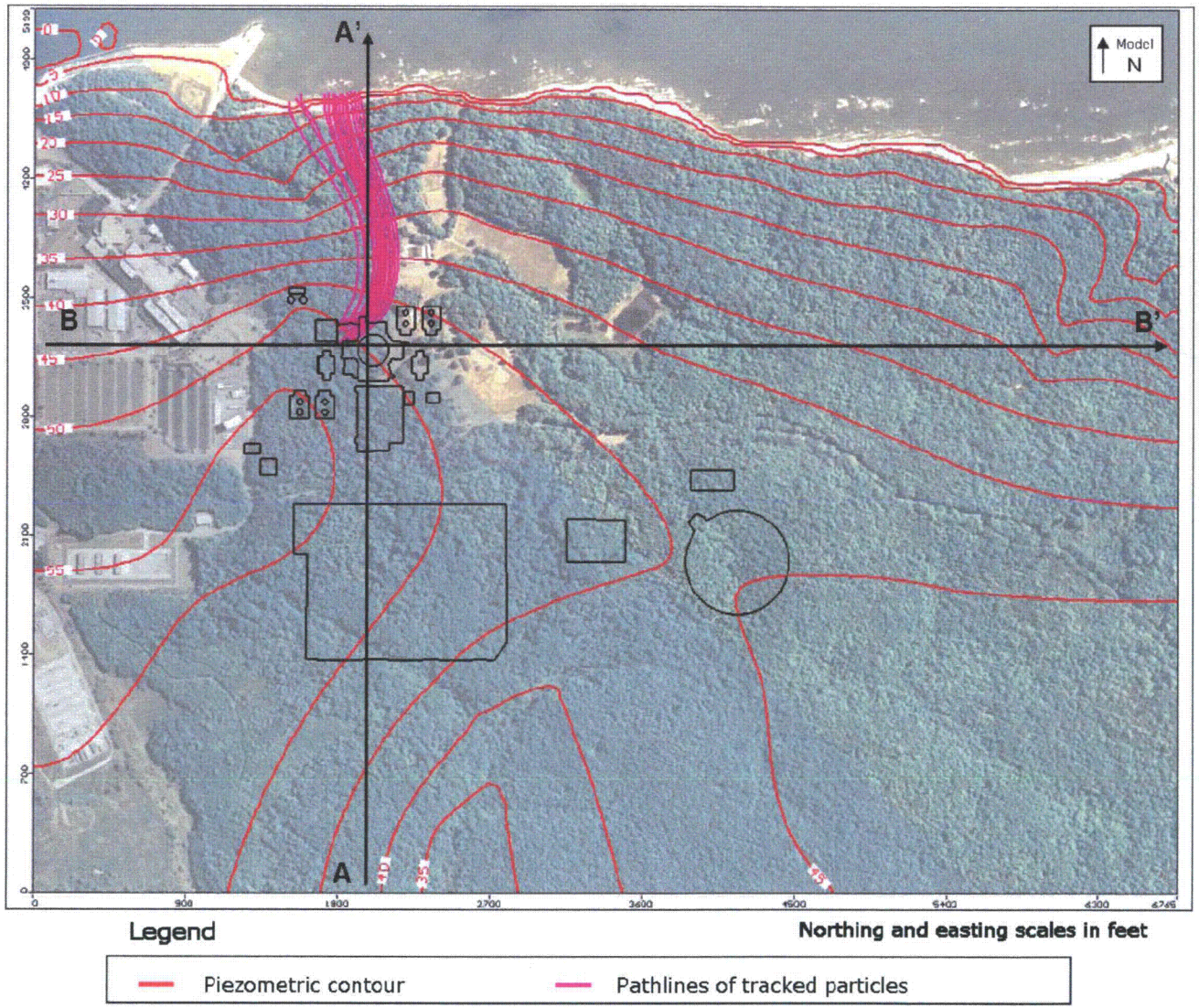



Figure 2.4-109 – {Pathlines from Nuclear Auxiliary Building Obtained from Groundwater Model of Post-Construction Conditions}