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Mr. Jay Adler
Entergy Nuclear Northeast
Indian Point Energy Center
450 Broadway
Buchanan, NY 10511

REVIEW OF PRELIMINARY GROUNDWATER DOSE ASSESSMENT FOR INDIAN POINT

Dear Mr. Adler:

This letter documents an independent review of *Water Mass Balance and Dose Assessment from Groundwater and Storm Water, An Assessment of 2005 Effluent Impact* dated March 21, 2006. The review also included some supporting information. This review was performed by Dade Moeller & Associates and Environmental Resources Management (ERM) at the request of Entergy Indian Point Energy Center (IPEC). The subject dose assessment report documents the initial efforts at estimating the potential radiation dose that could be received by a maximally exposed member of the public from uncontrolled groundwater transport of radionuclides from the IPEC site to the Hudson River. The purpose of this independent review was to assess the appropriateness of the approach and methods used in the groundwater modeling and dose assessment, and the reasonableness of the initial dose estimate. This review did not include a detailed evaluation and verification of all data and parameter values.

The review determined that based upon information available at the time the report was prepared the methods used are reasonable and appropriate. The review of groundwater modeling determined that while the method is conservative there is potential that the groundwater flow rate to the Hudson River may be underestimated and the total release of radionuclides could potentially be higher. The review of dose assessment methods found these to be conservative and consistent with guidance of Nuclear Regulatory Commission Regulatory Guide 1.109. Calculation of the radionuclide dilution in the Hudson River also appears to be conservative.

Considering all of the above factors, the radiation dose estimate is conservative, but potentially without the degree of conservatism that may have originally been thought to exist because of the potential for higher radionuclide releases to the river. Any dose received by an actual member of the public from release of radionuclides in groundwater from the IPEC site would likely be less than that estimated in the report. Additional information on the specific areas of the review is presented in the attached pages.

Sincerely,

Tracy A. Ikenberry

Tracy A. Ikenberry, CHP
Associate
Dade Moeller & Associates

Review of the Preliminary Groundwater Dose Assessment for Indian Point Energy Center

An independent review of *Water Mass Balance and Dose Assessment from Groundwater and Storm Water, An Assessment of 2005 Effluent Impact* (Sandike 2006). The review also included some additional supporting information. This review was performed by Dade Moeller & Associates and Environmental Resources Management (ERM) at the request of Entergy Indian Point Energy Center (IPEC). The subject dose assessment report documents the initial efforts at estimating the potential radiation dose that could be received by a maximally exposed member of the public from uncontrolled groundwater transport of radionuclides from the IPEC site to the Hudson River. The purpose of this independent review was to assess the appropriateness of the approach and methods used in the groundwater modeling and dose assessment, and the reasonableness of the initial dose estimate. This review did not include a detailed evaluation and verification of all data and parameter values. Specific comments on the subject dose assessment report are provided below.

Groundwater Modeling. The initial activity was to review the methodologies and results of calculations for the flux of tritium in groundwater and storm water that potentially discharges to the Hudson River. Since ERM currently has minimal knowledge of the site conditions and history, the review focused on the approach, validity and limitations of using the water mass balance method for estimating groundwater flow rates. The following comments are offered:

- The approach for calculating groundwater flow using the water balance method appears reasonable, and is based on the steady-state conservation of mass (i.e. no aquifer storage effects).
- The water balance equation applied does not incorporate a flux term for the release of tritium-impacted water into the groundwater. If there is currently an active release of tritium at the site, a flux term should be incorporated into the mass balance equation by estimating the steady state release rate and concentration of tritium within the release.
- The estimated groundwater flow rates for each catchment area using the water balance method are intuitively low for the scale of the catchment areas and preliminary understanding of groundwater flow at the Indian Point Energy Center site. The following table presents the estimated groundwater flow rate, in gallons per minute (GPM), calculated from the water mass balance method (spreadsheets page 1 and 3):

Summary of Water Balance Catchments and Calculated Groundwater Flow Rates

Catchment ID	*Catchment surface area (ft^2)*	*Groundwater flow rate from water balance method (GPM)*
1 (Northern Excluded Area)	250,529	1.65
2 (Unit 2)	571,681	3.37
3 (Unit 1/3)	1,668,370	13.81
4 (Southern Excluded Area)	674,416	3.12

Using an approach consistent with the water mass balance, these calculations suggest that containment of the tritium plume may be achieved by pumping groundwater from within each catchment area using the above flow rates. These flow rates appear unrealistically low given the size of the catchment areas and nature of groundwater flow in fractured bedrock.

- An upper bound average tritium concentration of 200,000 pCi/L was used for groundwater flow in Area 2. Although this could be a conservative estimate of tritium in this area, tritium concentrations as high as 600,000 pCi/L have been reported for site monitoring well MW-30. Therefore, the use of 200,000 pCi/L may not be as overly conservative as the model intended, because higher concentrations have been detected in site groundwater and the tritium plume may not be vertically or linearly delineated in this area. However, based on the information reviewed by ERM, no conclusion can be made at this time.

Additional comments related to the future direction of groundwater modeling efforts are provided in the Addendum at the end of this review.

Dose Assessment Method Unlike groundwater modeling, there is existing guidance for dose assessment at IPEC. The dose assessment methods used are those documented in the Offsite Dose Calculation Manuals (ODCM) for the Indian Point Units 1 and 2, and Unit 3 (Entergy Nuclear Northeast, 2005a, 2005b). These calculations are consistent with the equations and parameter values for a maximally exposed individual in Regulatory Guide 1.109 (NRC 1977). The exposure scenarios of consumption of fresh fish and saltwater invertebrates in the Hudson River estuary are consistent with the methods of the ODCM. This is a reasonable and conservative approach, consistent with current IPEC methods to demonstrate regulatory compliance.

Site-specific calculations are used to develop dilution factors for liquid effluent release to the Hudson River estuary at Indian Point, and these were examined in greater detail. The earliest description of the dilution factors is presented in a calculation for Indian Point Unit 3 (NYPA 1994). A brief description is provided in ABS 2006:

> *The activity released during the entire quarter was further assumed to get released into the river during a single 6-hour half-tidal cycle, and to mix uniformly with the average water mass that traverses the Indian Point site during the same time interval. This dilution volume is equal to 5.49×10^7 m^3 (1.45×10^{10} gallons) when there is no fresh-water inflow from the estuaries. The scenario is equivalent to a slug of water, equal to 5.47×10^7 m^3, moving back and forth by the Indian Point site carrying the same concentration for an entire quarter, without additional dilution.*

The Hudson River at Indian Point is approximately 1,300 m wide and averages 12 m depth (Blumberg & Hellweger 2004). The volume of water assumed for dilution would fill a river length of approximately 3,500 m.

Consideration of fresh water input and the net river flow downstream may provide significantly greater estimates of dilution. Blumberg and Hellweger (2004) note that net river flow is a small fraction of tidal flow, net river flow being about an order of magnitude lower than tidal flow at

Indian Point. However, net river flow still provides significant dilution. The *Radioactive Effluent Release Report: 2005* (Entergy Nuclear Northeast 2006) reports USGS data showing the quarterly river flow rate at Indian Point from 4th quarter 2003 through 3rd quarter 2004 to range from 19,133 to 38,133 cfs (ft^3/s) with an assumed annual average of 25,600 cfs (1.15×10^7 gpm). This is generally consistent with net river flow estimates provided by Blumberg and Hellweger (2004) and the NYPA (1994) calculation. Even if only a small portion of the Hudson River is considered for dilution, as was done in a calculation by Kinneson cited in NYPA 1994, there is significant flow for dilution. Kinneson cited minimum river flow rates and used 15% of the cross-sectional area of the river at 48% of the midstream river velocity. Using these values, dilution factors approximately 10 times higher than those used in the subject dose assessment report can be derived. Therefore, the method used to estimate dilution in the Hudson River is a conservative approach.

Overall the dose assessment methodology is appropriate and represents a reasonable and conservative approach.

Radiation Dose Estimate Based on the reviews documented above for groundwater modeling and dose assessment methods, the radiation dose estimate is conservative, but potentially without the degree of conservatism that may have originally been thought to exist. Any dose received by an actual member of the public from release of radionuclides in groundwater from the IPEC site would likely be less than that estimated in the report. Areas of clear conservatism seem to be present in the consumption rates for fish and shellfish, and also in the dilution of radionuclides in the Hudson River. Potentially less conservatism may be present in the estimates of groundwater flow rates and radionuclide discharge to the Hudson River. The data to be collected in the ongoing groundwater monitoring effort will assist in resolving some of these uncertainties.

References

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Blumberg, A. F. and F. L. Hellweger. 2004. *Hydrodynamics of the Hudson River Estuary*. In: Hudson River Fishes and their Environment, Waldman, J., K. Limburg, and D. Strayer, Eds. American Fisheries Society, Alpharetta, Georgia, (accepted), 2005. http://www1.coe.neu.edu/~ferdi/files/hres2004.pdf

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Addendum: Additional Comments to Assist Groundwater Modeling

1. The groundwater area descriptions use the phrase "appears to move" when describing groundwater flow directions through a given area, implying that groundwater flow is not very well defined and inferred from groundwater quality data and topographic setting, but not based on water table elevations. While the mass balance approach is sufficiently conservative, it treats groundwater flow as somewhat linear toward the river, like a porous media. It is ERM's understanding that the groundwater beneath the site flows through fractured crystalline bedrock (granite). Hence, the direction of groundwater flow beneath the site would be controlled by the attitude and orientation of water-bearing fractures and may not be directly towards the river. If the bedrock structure and flow regime is not well understood, future site-specific efforts should be directed at this definition (e.g. fluorescent dye testing, pulse testing, etc.).

2. The water mass balance equation assumes there are no on-site pumping wells, injection wells or other sources/sinks to groundwater (i.e. springs, loosing or gaining streams, etc.). This assumption needs to be verified, or corresponding flux terms should be incorporated into the water balance equation.

3. The groundwater flow rate within each catchment area (top of page 3 in spreadsheet) should be independently verified using a Darcy's Law calculation. For example, Darcy's Law can be used to calculate an approximate groundwater flow within each catchment area using the following equation and variables:

   $$Q = KA\frac{dh}{dl}$$

   where:

   Q = groundwater discharge rate to the river at the base of the catchment (ft^3/year);

   K = representative horizontal hydraulic conductivity of the aquifer (ft/year);

   A = cross sectional area perpendicular to groundwater flow and through which groundwater discharges ($feet^2$); and

   dh/dl = horizontal hydraulic gradient calculated from on-site wells (unit-less).

   Using site-specific hydrogeologic parameters from each catchment area, the Darcy flow calculation should be consistent with the flow rates estimated using the water balance method. One alternative is to re-arrange the Darcy equation to solve for K, and compare the calculated K to field estimates of K (i.e. from slug tests and/or pumping tests). Agreement of the Darcy flow or K estimates with field estimates would verify the water mass balance approach used.

4. Recharge and infiltration estimates were obtained from a 2004 USGS report on water use. Since these estimates drive the groundwater flux calculation in the water mass balance approach, they should be independently verified against other recharge/infiltration estimates for the Indian Point site. If possible, these recharge estimates should be adjusted for site- and catchment-specific soil and topographic conditions.

5. The topographic contours of the site suggest that there could be localized groundwater and/or overland flow during storm events that may cross from Areas 1 and 4 into Areas 2 and 3. This may need to be considered in future models.

6. Estimates for the amount of water remaining in the storm drains and discharging to the canal (bottom of spreadsheet page 3) should be checked against plant records of storm water runoff that may be monitored under NPDES or other discharge permits. If these estimates are consistent with plant records, the water mass balance approach is verified. Consideration should also be made as to whether the tritium in the surface system comes entirely from infiltrating groundwater or if there are other contributing sources.