Environmental Radiological Analysis

Fate and Transport Modeling of Residual Contaminants and Human Health Impacts from the F-Area High-Level Waste Tank Farm

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1.0 INTRODUCTION

Fate and transport modeling was performed to support closure of the SRS High-Level Waste (HLW) tanks. This modeling estimates the potential human health impacts of residual contamination remaining in closed HLW tanks in the F-Area Tank Farm. The modeling also estimates the concentrations and dose levels at the groundwater seepline, which is the point of exposure. This modeling was performed to support Revision 2 of the "Industrial Wastewater Closure Plan for F- and H-Area High-Level Waste Systems, Savannah River Site, Construction Permit Numbers 14,338, 14,520, 17,424-1W," (Pending Approval September 1997).

The F-Area Tank Farm tanks were modeled assuming conditions that will exist after tank closure for the analyzed tank closure scenario. The specific closure scenario modeled was filling the tanks with reducing grout and no engineered structures will be used to reduce the infiltration of rain water.

The modeling assumed (1) institutional control for 100 years and subsequent industrial land use; (2) the area immediately around the F-Area Tank Farm remains in commercial/industrial use for the entire 10,000-year period of analysis; and (3) the area of commercial/industrial land use extends between Fourmile Branch and Upper Three Runs in the vicinity of the F-Area Tank Farm.

Potential impacts to the following receptors were analyzed:

Worker: an adult who has authorized access to, and works at, the tank farm and surrounding areas but is considered to be a member of the public for compliance purposes. This analysis assumes that the worker remains on the shores of Fourmile Branch or Upper Three Runs during working hours.

Intruder: a teenager who gains unauthorized access to the F-Area Tank Farm and is potentially exposed to contaminants.

Nearby adult resident: an adult who lives in a dwelling across Fourmile Branch downgradient of the F-Area Tank Farm, near the location of the seepline.

Nearby child resident: a child who lives in a dwelling across Fourmile Branch downgradient of the F-Area Tank Farm, near the location of the seepline.

For informational purposes, concentrations and dose levels were also calculated in the groundwater at 1 meter and 100 meters downgradient from the edge of F-Area Tank Farm.

The identity and level of residual contaminants in F-Tank Farm were derived from data provided in d'Entremont (1996b). The calculated impacts from the residual contamination in these tanks can be used in conjunction with results from modeling of other sources in the Groundwater Transport Segment (GTS) to account for F-Tank Farm impacts against the GTS performance objectives.

2.0 ANALYZED SCENARIO

In the analyzed scenario, the mobile contaminants in the tanks will gradually migrate downward through unsaturated soil to the hydrogeologic units comprising the Shallow Aquifer underlying the F-Area Tank Farm. The first hydrogeologic unit encountered will be the Water Table Aquifer. Some contaminants will be transported by groundwater through the Water Table Aquifer to the seepline and subsequently to Fourmile Branch. Upon reaching the surface water, the contaminants will contaminate the seepline, sediments at the bottom of Fourmile Branch, and the shoreline. Aquatic organisms in the streams and plants along the shoreline will become exposed to the contaminants. Terrestrial organisms might ingest the contaminated vegetation and obtain their drinking water from the contaminated stream. Human receptors could be exposed to contaminants through various pathways associated with the surface water.

Due to vertical leakage through the Tan Clay layer, a portion of the contaminants will migrate further downward into the underlying Barnwell-McBean Aquifer which predominantly discharges along Fourmile Branch. These contaminants will affect organisms and human receptors in and along Fourmile Branch in the same manner as those contaminants transported through the Water Table Aquifer.

Variability in the Green Clay layer underlying the Barnwell-McBean Aquifer results in flow from the Barnwell-McBean down to the Congaree Aquifer. Thus, a portion of those contaminants reaching the Barnwell-McBean Aquifer will move further downward into the Congaree Aquifer which predominantly discharges along Upper Three Runs. However, since there is minimal interchange between these two aquifers and the volume of water in the Congaree is quite large, impacts to humans and aquatic and terrestrial organisms at this location will be negligible. More details on the hydrogeology of the tank farm area can be found in Appendix E of the *High-Level Waste Tank Closure Program Plan* (DOE 1996a).

The closure scenario assumes that the tanks will be filled with grout and no engineered structures will be used to reduce the infiltration of rain water. Based on the E-Area Vaults radiological performance

assessment (WSRC 1994a), the concrete tank structure could enter a period of degraded performance due to cracking around 1,400 years post closure. Assuming that the approximately 34 feet of grout continues to support the tank roof and provide an additional barrier to infiltration for an indefinite period of time [Z-Area radiological performance assessment (WSRC 1992)], water infiltration should occur much later than 1,400 years. For this scenario, the conservative assumption is made that the tank top, grout, and basemat will fail (in terms of their ability to retard water infiltration) at 1,000 years, with a corresponding increase in their respective hydraulic conductivities.

Previous modeling of tank closure scenarios (DOE 1996b) has demonstrated that placing a cap over a grout-filled tank has little effect on the magnitude of the impact at the point of exposure. The cap does succeed in detaining the movement of contaminants until failure of the cap occurs. Thus, impacts due to leaching contaminants from a grout-filled tank with a cover can be assumed to be the same as for a grout-filled tank with no cover but occurring later in time. For this reason, separate modeling runs were not performed for a closure with an engineered cover. Impacts can be assumed to be equivalent to those from the analyzed scenario but separated by about 500 years.

3.0 METHODOLOGY

3.1 General Methodology

Utilizing the Multimedia Environmental Pollutant Assessment System (MEPAS) computer code (Droppo et al. 1995), a multipathway risk model developed by Pacific Northwest Laboratory, this assessment performed calculations to assess the impacts of the leaching of contaminants to the groundwater for the tank closure scenario. To model the grout-filled tank, an infiltration rate was selected that represents the vertical moisture flux passing through the tank bottom. The infiltration rate depends on the chemical and physical characteristics of the tank and the fill material.

Based on the calculated inventories of chemical and radioactive contaminants remaining after bulk waste removal and spray washing in the tanks (d'Entremont 1996b), the model was set up to simulate the transport of contaminants from the contaminated zone (residual waste layer), through the concrete basemat, the vadose zone directly beneath the basemat, and into the underlying Shallow Aquifer. As previously stated, the Shallow Aquifer is comprised of three interacting aquifers, the Water Table, the Barnwell-McBean, and the Congaree. Model runs were completed for contaminant transport through each of these aquifers for both early (before failure) and late (after failure) conditions.

Modeling was also performed for contaminants remaining in the ancillary equipment and piping above the tank. In this calculation, the piping and equipment were considered to be the contaminated zone while the partially saturated (vadose) zone was defined as the layer of soil extending from the surface to the saturated zone.

For both the Water Table and Barnwell-McBean Aquifers, calculated contaminant concentrations, dose levels, and peak times of occurrence are provided at 1 meter and 100 meters downgradient from the edge of the F-Area Tank Farm, at the seepline, and at Fourmile Branch for the receptors discussed in Section 3.2. Results for the Congaree Aquifer are reported at the seepline of Upper Three Runs.

3.2 Receptors

The potential receptors and exposure pathways are identified in the following sections and illustrated in Figure 1.

3.2.1 WORKER

The worker is assumed to be in the area including and surrounding the F-Area Tank Farm. Because institutional controls are in place, the potential for exposure of the worker to the primary source (residual at the bottom of the tanks) will be minimal due to the barrier provided by the cover over the tanks, the structural integrity of the tank, the lack of any industrial work over the tanks, and safety measures that DOE will take to reduce potential exposure further. Therefore, this analysis assumes that the worker is constantly at the nearest place where contaminants will be accessible (i.e., on the banks of Fourmile Branch or Upper Three Runs as part of his work duties). The assumption is conservative because the worker has a greater potential for exposure to contaminants at the seepline. For compliance purposes, the worker is assumed to be a member of the public at all points in time, which means the dose limits applicable to members of the public will be applied to the worker. However, the fact that he is a worker limits, and hence, eliminates pathways that might be considered if he were identified as a resident. The potential exposure pathways for the seepline worker are:

- Direct irradiation from shoreline deposits (radioactive contaminants only)
- Incidental ingestion of the soil from shoreline deposits

- Dermal contact with shoreline deposits

The assessment did not evaluate exposure from the inhalation of resuspended soil because the soil conditions at the seepline (i.e., the soil is very damp) are such that the amount of soil resuspended and potentially inhaled would be minimal.

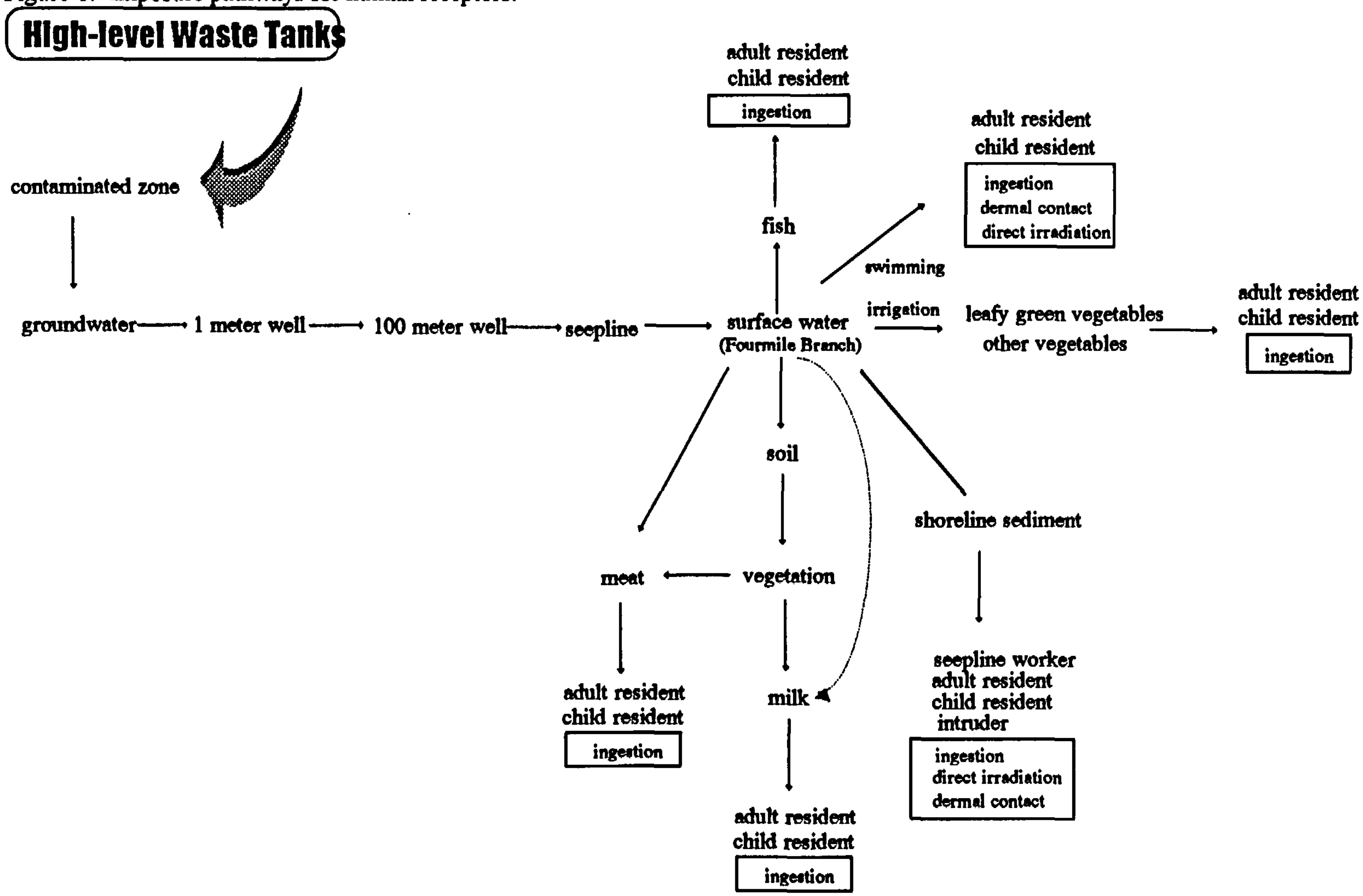
3.2.2 INTRUDER

Another potential receptor is the intruder, a person who gains unauthorized access to the tank farm site and becomes exposed to the contaminants. The intruder scenario is analyzed as if institutional controls have ceased. Because the intruder will not have residential habits, he will not have exposure pathways similar to those of a resident (the intruder does not build a house, grow produce, etc.); rather, the intruder could be exposed to the same pathways as the seepline worker but for a shorter duration (4 hours per day, as noted in Section 4.2.5).

3.2.3 NEARBY ADULT RESIDENT/NEARBY CHILD RESIDENT

Nearby residents could be exposed to contaminants from the F-Area Tank Farm. Under this scenario, members of the public are assumed to construct a dwelling near (but outside) the tank farm and surrounding industrial land use area. The dwelling is assumed to be downgradient near Fourmile Branch on the side opposite the F-Area Tank Farm 100 meters downstream of the groundwater outcropping in Fourmile Branch. The residents of this dwelling will include adults and children. The adult resident will be modeled separately from the child because of different body weights and consumption rates. A residential scenario was not analyzed for Upper Three Runs since the impacts from Fourmile Branch are greater and thus more limiting, as evidenced by the results at the seeplines.

Figure 1. Exposure pathways for human receptors.



The resident is assumed to use Fourmile Branch for recreational purposes; to grow and consume produce irrigated with water from Fourmile Branch; to obtain milk from cows raised on the residential property; and to consume meat from cattle that was fed contaminated vegetation from the area. Therefore, the potential exposure pathways for both the nearby adult and nearby child resident would be the following:

- Incidental ingestion of contaminated soil from shoreline deposits
- Inhalation of contaminated soil from shoreline deposits
- Direct irradiation from shoreline deposits (radioactive contaminants only)
- Direct irradiation from surface water (radioactive contaminants only - recreation)
- Dermal contact with surface water
- Incidental ingestion of surface water
- Ingestion of contaminated meat
- Ingestion of produce grown on contaminated soil irrigated with water from Fourmile Branch
- Ingestion of milk from cows that are fed contaminated vegetation
- Ingestion of aquatic foods (e.g., fish) from Fourmile Branch

3.2.4 ATMOSPHERIC PATHWAY RECEPTORS

The analyzed scenario does not present a credible mechanism for material to be released from the tank to the atmosphere. Since the residual contamination will be covered with grout, the possibility of suspended particulates containing contaminants is eliminated. Therefore, the direct transport of material via the atmospheric pathway was not analyzed.

3.3 Description of Computational Code

Groundwater and surface water concentrations and human health impacts were calculated using the MEPAS computer code. MEPAS integrates source-term, transport, and exposure models for contaminants. In the MEPAS code, contaminants are transported from a contaminated area to potential human receptors through various transport pathways (groundwater, surface water, soils, food, etc.). Human receptors then receive doses, both chemical and radiation, through exposure or intake routes (ingestion, dermal contact, inhalation, etc.) and numerous exposure pathways (drinking water, leafy vegetables, meat, etc.).

MEPAS includes models to estimate human health impacts from radiation exposure (radionuclides and direct radiation), carcinogenic chemicals, and noncarcinogenic chemicals. Health effects resulting from

radiation are reported as lifetime cancer risk and radionuclide exposures are calculated as annual dose (mrem/yr). Cancer incidence rates are calculated for nonradiological carcinogens.

The MEPAS code is widely used and accepted throughout the DOE complex and has been presented to and accepted by other regulatory agencies such as EPA. Examples of its use by DOE include the EH-Environmental Survey Risk Assessment and the Complex-Wide Programmatic Waste Management EIS Impact Analysis. This code has been used to demonstrate environmental impacts in RCRA-Subpart X permit applications to various EPA regions; these analyses were accepted and were the basis for permits that were issued.

3.4 Calculational Methodology

The modeling results presented in this document are based on the amount of contaminants remaining in each tank in the F-Tank Farm after bulk waste removal and spray washing. The inventory assumed is based on 1,000 gallons of residual solids remaining in each tank except Tank 17, and 2,000 gallons of residual solids in Tank 17 (d'Entremont 1996b). For purposes of modeling, the inventory is distributed over a square with area corresponding to that of the tank bottom. The results can generally be scaled to differing amounts of residual contaminants in a tank.

Because MEPAS was not specifically designed to model rainwater runoff efficiencies afforded by engineered caps or thick covers such as the grout fill, analyses were performed specifying infiltration rates that relate to the closure scenario. For example, an infiltration rate of 2 centimeters per year relates to an intact engineered cap such as those previously designed and evaluated at SRS (WSRC 1993). Since the grout fill in this closure scenario would hinder infiltration but to a lesser degree than a grout and cap combination, an infiltration rate of 4 centimeters per year was chosen to represent before failure conditions. Similarly, an infiltration rate of 40 centimeters per year (average infiltration rate for SRS soils) would correspond to the infiltration rate occurring after grout and basemat failure (WSRC 1994a).

For the F-Tank Farm analysis, the impacts at the point of exposure from groups of tanks that are similar in location and structure were calculated. For the F-Area analysis, all Type I tanks (Tanks 1-8) were grouped together, all the Type III tanks (Tanks 25-28, 33,34, and 44-47) were grouped together, and all the Type IV tanks (Tanks 17-20) were grouped together. These groupings are appropriate because the tanks in each grouping have approximately the same basemat thickness (an important consideration in calculating the retardation effects on contaminants).

DOE has performed a sensitivity analysis to ensure that the distance between tanks within a grouping (e.g., all the Type III tanks in F-Area Tank Farm are not adjacent to each other) did not substantially affect the projected results at the point of exposure for a given GTS. The analysis involved comparing the results of combining four relatively far apart tanks (Tanks 33,34,46 and 47) with modeling the tanks separately. The composite run resulted in maximum drinking water dose rates that were within 5% of the individual run dose rates. The results of this analysis indicate that the distance from F-Area Tank Farm to the point of exposure is relatively large compared to the dimensions of the tank farm so that projected impacts at the point of exposure vary little as the source term is moved within F-Area Tank Farm.

Separate MEPAS calculations were performed for each grouping of tanks. For each calculation, the source term data (in both concentration and total inventory) for the grouping distributed over a square with area equal to that of the tank bottoms in the grouping was entered. For instance, for the Type I tanks, the source term for the MEPAS calculation would consist of the total inventory of the affected tanks and the concentration of contaminants in the grouping (i.e., the total inventory of the affected tanks divided by the total solids in these tanks) distributed over a square with area equal to the area of the eight Type I tanks.

To account for overlapping of the contaminant plumes from the three separate groupings of tanks, the calculations were performed with the three groupings at the same initial physical location (as discussed above, location of the source within the F-Area Tank Farm boundary has little influence on the calculated concentration at the point of exposure). The centerline concentrations were summed from each plume at the point of exposure to ensure that the highest concentration is reported. Therefore, although the plumes from the groupings may not overlap entirely, this calculation methodology provides an upper estimate for the projected impacts.

MEPAS runs were performed for early (before structural failure) and late (after structural failure) conditions for the tanks. As previously discussed, a failure time was assumed based on the anticipated performance of the tank fill material and concrete basemat. Failure would be catastrophic: that is, the tank fill and basemat would fail simultaneously. For modeling purposes, failure was simulated by increasing the infiltration rate to 40 cm/yr and increasing the hydraulic conductivity of the concrete basemat to that of sand. Because radionuclide and chemical pollutants could leach though imperfections in the concrete before catastrophic failure occurs, the original source term was reduced by an amount equal to the quantities released to the Water Table Aquifer during the prefailure period. In addition, radionuclides continually decay, further diminishing the source term. Thus, for late runs, in addition to changing the infiltration rates and hydraulic conductivities, the source term concentrations were adjusted to reflect losses and decay occurring before failure.

To obtain a continous analysis of the release of pollutants over the two periods, it was necessary to perform three sets of MEPAS runs per scenario. First, MEPAS runs were executed with all parameters simulating pre-failure conditions including the entire contaminant inventory and the release period (MEPAS parameter WS-TLIFE) was set equal to the time to failure (i.e., 1000 years). The model calculated transport of the released material for 10,000 years after the initial release.

Next, using the results from the initial runs, the auxiliary FORTRAN program FF.FOR (see Attachment A) was used to calculate the quantity of contaminants which actually reaches the aquifer during the prefailure period. A second set of runs was performed using as the source term only the amount of contaminants that reached the aquifer during prefailure time period. The remaining contaminants (those not reaching the aquifer during the early runs) are then the source or inventory for the late runs (the third set of runs). It is assumed that the sludge remains behind so that the source concentration for the late runs is reduced (from the early runs) by the same ratio as is the inventory. The second set of early runs and the late runs were combined to obtain the final answer (see Section 5.2 for a discussion of how results were combined).

In the groundwater transport pathway, infiltration causes leaching of pollutants from the tank through distinct media below the waste unit down to the groundwater in the three uppermost aquifers. To model the movement of the pollutants from the waste unit to the aquifers, MEPAS requires identification of the distinct strata that the pollutants encounter.

To model the tanks in F-Tank Farm, the residual solids remaining at the bottom of the tank were considered to be the contaminated zone. Between the contaminated zone and the Water Table Aquifer, two discernible layers were identified: the concrete basemat of the tank and the unsaturated (vadose) zone. Parameters describing the concrete layer were defined for both pre- and post-failure conditions because values for such parameters as porosity, field capacity, and hydraulic conductivity change with degradation state. Flow through the vadose zone is complicated in that movement varies with soil-moisture content and wetting and drying conditions. Therefore, soil parameters values (e.g., density, porosity) for the Water Table Aquifer were conservatively used to describe the unsaturated zone.

Once contaminants reach the Water Table Aquifer, they may follow one of three possible routes: (1) they will be transported through the water table and outcrop at the seepline and Fourmile Branch; (2) they will leak from the Water Table Aquifer through the underlying Tan Clay layer into the Barnwell-McBean Aquifer which also outcrops at the seepline and Fourmile Branch; or (3) they will continue downward from

the Barnwell-McBean Aquifer though the Green Clay layer, into the Congaree, and appear in Upper Three Runs.

The total flux to each aquifer indicates the distribution of contaminants among the three aquifers. Hydrologic studies (WSRC 1994b) indicate that the water budget or percent flow to each aquifer below the F- and H-Tank Farm areas is 31 percent to the Water Table Aquifer, 65 percent to the Barnwell-McBean Aquifer, and 4 percent to the Congaree Aquifer. Thus, 31 percent of the leachate from Tank 17 will remain in the Water Table Aquifer, while 65 percent is transferred through the Barnwell-McBean Aquifer, and 4 percent will reach the Congaree Aquifer.

In MEPAS, only one of these groundwater paths may be analyzed at a time; thus, three separate runs were performed both for early and late conditions. In MEPAS, the aquifer being analyzed in a particular run is considered to be the saturated zone; all the layers between the contaminated zone and this saturated zone are recognized by the code as partially saturated zones. For example, in modeling contaminant transport through the Barnwell-McBean Aquifer, the Barnwell-McBean is identified as the saturated zone while the concrete basemat, vadose zone, Water Table Aquifer, and Tan Clay layer are all modeled as partially saturated zones. Thus, depending on whether an aquifer is being recognized as the saturated zone or a partially saturated zone for a particular run, parameters may change or additional ones may be necessary. The parameters used for modeling the various strata in the model are further discussed in Section 4.2.

For each of the eight layers modeled (contaminated zone, concrete basemat, vadose zone, Water Table Aquifer, Tan Clay layer, Barnwell-McBean Aquifer, Green Clay layer, and Congaree Aquifer), surface distribution coefficients, K_ds, were selected for each radionuclide and chemical. Because distribution coefficients are a chemical property, the K_d values were not changed for degraded or failed materials. The identification and derivation of the K_d values are described in Section 4.2.1.

As contaminants are transported from the contaminated zone to the seepline, they are dispersed longitudinally (along the streamline of fluid flow), vertically, and transversely (out sideways) by the transporting medium. MEPAS incorporates longitudinal dispersivity of pollutants moving downward through the partially saturated zone layers (i.e., concrete basemat and vadose zone) into concentration calculations. In the saturated zone, concentration calculations include the three-dimensional dispersion along the length of travel. Dispersion distances were calculated through each of the layers encountered by the contaminants. As expected, dispersion increases with longer travel distances.

Groundwater concentrations and doses due to ingestion of water were calculated at hypothetical wells at 1 meter and 100 meters downgradient from the edge of the F-Area Tank Farm, at the seeplines of Fourmile

Branch and Upper Three Runs, and in Fourmile Branch. No human receptors would be exposed to the groundwater pathway at these locations, but the calculations were performed for information purposes.

Impacts to adult and child residential receptors were evaluated at a point 100 meters downstream of the groundwater outcropping in Fourmile Branch. The concentrations of contaminants in Fourmile Branch were also calculated. Based on the dimensions, flow rate, and stream velocity of Fourmile Branch, MEPAS accounts for the mixing of the contaminant-containing water from the aquifer with stream water and other groundwater contributions. For both adult and child residents, ingestion rates were based on site-specific parameters. Parameters and associated assumptions used in calculating human impacts are presented in Section 4.2.5.

In addition to the tank contents, MEPAS runs were performed to determine the impacts of residual pollutants contained in ancillary equipment and piping. The piping and other outside equipment were assumed to be filled with grout (where possible). For modeling in MEPAS, the ancillary equipment was considered to be the contaminated zone, and the entire distance between the contaminated zone and the saturated zone was characterized as one layer of typical SRS soil. Therefore, no credit was taken for the additional reduction of leachate afforded by the tank structure in its closed configuration, thus, providing conservative results.

4.0 ASSUMPTIONS AND INPUTS

4.1 Source Term

4.1.1 WASTE VOLUMES

The individual tank inventories after bulk waste removal and spray washing were totaled to determine cumulative waste volumes. The inventory (see Table 1) assumed is based on 1,000 gallons of residual solids remaining in each tank except Tank 17, and 2,000 gallons of residual solids in Tank 17 (d'Entremont 1996b). Although the waste volume is present as damp saltcake, sludge, and zeolite, the total waste volume was assumed, conservatively, to be sludge. Concentrations then were calculated for each radionuclide and chemical constituent of concern based on the total volume and the inventories.

Table 1. F-Tank Farm residual waste volumes after bulk waste removal and spray washing, gallons.[a]

	17-20	25-28,33-34,44-47	1-8	Total
Sludge (gal)	5,000	10,000	8,000	22,000

a. From d'Entremont (1996b).

4.1.2 RADIONUCLIDES

The radioactive material inventory for F-Tank Farm used for the modeling is listed in Table 2. As discussed in Section 6.0, the radiological dose can be contributed to a small fraction of the total inventory of radionuclides shown in Table 2. Modeling for radiological dose was therefore only performed using the major contributors for input (beta-gamma emitters: Se-79, Tc-99, C-14, I-129, and the alpha emitting isotopes of Uranium, Neptunium, Plutonium, Amercium, and Curium and their decay products). Both the radioactive and chemical inventories relate to quantities remaining after bulk waste removal and spray water washing, estimated to be 1,000 gallons of residuals for all tanks except for Tank 17 and 2,000 gallons of residual solids in Tank 17 (d'Entremont 1996b). DOE conservatively assumed that an additional 20 percent of the radioactive contaminants remaining in each tank after bulk waste removal and spray washing will be distributed in the ancillary equipment and piping associated with the tank system (d'Entremont 1996a).

Table 2. F-Tank Farm residuals inventory of radionuclides (curies)[a]

	Inventory by Tank Group			
Radionuclide	17-20	25-28,33-34,44-47	1-8	Total
C-14	5.87E-03	2.66E-02	7.45E-04	3.32E-02
Co-60	4.53E+00	3.63E+02	5.66E+01	4.24E+02
Ni-59	3.45E-01	1.92E+00	1.11E+00	3.38E+00
Se-79	2.86E-02	3.84E-01	7.65E-01	1.18E+00
Sr-90	1.57E+03	3.00E+04	3.53E+04	6.69E+04
Y-90	1.57E+03	3.00E+04	3.53E+04	6.69E+04
Tc-99	4.96E-01	6.65E+00	1.32E+01	2.03E+01
Ru-106	3.72E-03	4.47E+02	1.11E-01	4.47E+02
Rh-106	3.72E-03	4.47E+02	1.11E-01	4.47E+02
Sb-125	2.89E+00	1.12E+03	3.04E+01	1.15E+03
Sn-126	5.31E-02	7.14E-01	1.42E+00	2.19E+00

I-129	2.35E-06	3.16E-05	6.31E-05	9.71E-05
Cs-134	1.29E-02	1.46E+01	1.50E-01	1.48E+01
Cs-135	3.27E-04	4.39E-03	8.76E-03	1.35E-02
Cs-137	1.09E+02	2.03E+03	2.46E+03	4.60E+03
Ba-137m	1.03E+02	1.92E+03	2.33E+03	4.35E+03
Ce-144	2.09E-04	5.17E+02	1.17E-02	5.17E+02
Pr-144	2.09E-04	5.17E+02	1.17E-02	5.17E+02
Pm-147	4.88E+01	2.17E+04	5.16E+02	2.23E+04
Eu-154	7.54E+00	3.03E+02	1.20E+02	4.31E+02
U-232	8.80E-05	7.26E-04	6.43E-04	1.46E-03
U-235	5.93E-04	1.24E-03	8.15E-04	2.65E-03
U-238	3.82E-02	1.12E-01	2.54E-02	1.76E-01
Np-237	0.00E+00	1.72E-02	4.36E-02	6.08E-02
Pu-239	2.27E+01	1.13E+02	6.70E+00	1.42E+02
Pu-240	5.65E+00	2.53E+01	1.60E+00	3.26E+01
Pu-241	1.26E+02	5.54E+02	4.77E+00	6.85E+02
Pu-242	8.69E-03	5.20E-03	9.63E-04	1.49E-02
Am-241	5.43E+01	3.82E+02	1.15E+02	5.51E+02
Am-242m	0.00E+00	4.79E-02	1.29E-01	1.77E-01
Cm-244	1.38E-03	3.21E-02	2.83E-02	6.18E-02
Cm-245	8.18E-10	1.09E-08	2.17E-08	3.34E-08

a. Source. d'Entremont 1996b.

4.1.3 CHEMICALS

The chemical source inventory used in this modeling is listed in Table 3. As with the radioactive source term, the ancillary piping and evaporator residuals were conservatively estimated to be equal to 20 percent of the tank inventory.

Table 3. F-Tank Farm residuals inventory of chemical constituents (kilograms)[a]

	Inventory by Tank Group			
Constituent	17-20	25-28,33-34,44-47	1-8	Total
Silver	1.51E+01	2.00E+01	1.04E+00	3.61E+01
Aluminum	2.64E+02	6.82E+02	2.90E+01	9.75E+02
Barium	8.79E+00	1.21E+01	1.65E+00	2.25E+01

Fluoride	7.96E+00	1.05E+01	5.14E-01	1.90E+01
Chromium	1.06E+01	1.44E+01	1.46E+00	2.65E+01
Copper	7.54E+00	1.01E+01	6.86E-01	1.83E+01
Iron	1.22E+03	1.63E+03	1.33E+02	2.98E+03
Mercury	3.10E+00	4.31E+00	7.23E-01	8.13E+00
Nitrate	8.17E+01	1.09E+02	7.52E+00	1.98E+02
Manganese	5.65E+01	1.52E+02	6.61E+01	2.75E+02
Nickel	0.00E+00	1.35E+01	4.15E+01	5.50E+01
Lead	1.26E+01	1.71E+01	1.83E+00	3.15E+01
Uranium	1.14E+02	3.33E+02	7.58E+01	5.23E+02
Zinc	1.51E+01	2.01E+01	1.26E+00	3.65E+01

a. Source: d'Entremont 1996b

4.2 Calculational Parameters

The modeling is designed to be specific to F-Tank Farm; this is accomplished by utilizing site-specific data where available. For the hundreds of MEPAS input parameters, default values were used only for the distribution coefficients for chemical constituents (except selenium).

For the analyzed scenario, the majority of the MEPAS input parameters remain constant. Examples of constant parameters include contaminants of concern (radionuclide and chemical) and their respective initial source terms, spatial dimensions and elevation of the contaminated zone, strata thicknesses, chemical and physical properties (distribution coefficients, hydraulic conductivity and gradient) of SRS soil, exposure pathways, dose conversion factors, and downgradient distances to compliance points.

Input parameters that changed with tank groupings and were shown by sensitivity analyses to markedly affect the breakthrough times and peak concentrations include constituent and strata specific distribution factors, rainwater infiltration factors, and concrete basemat hydraulic conductivities. See Attachment A for a listing of these MEPAS parameters and the MEPAS input values presented by tank grouping and saturated zone. These and other important parameters are discussed in the following sections.

4.2.1 DISTRIBUTION COEFFICIENTS

The distribution coefficient, K_d, is defined for two-phased systems as the ratio of the constituent concentration in the solid (soil) to the concentration of the constituent in the interstitial liquid (leachate). For a given element, this parameter can vary over several orders of magnitude depending on such conditions as soil pH and clay content. Experiments (Bradbury and Sarott 1995) have demonstrated that strong oxidizing or reducing environments tend to affect the K_d values markedly. Because this parameter is highly sensitive in relation to breakthrough and peak times (but not necessarily peak concentration), careful selection is imperative to achieve reasonable results. For this reason, several literature sources were used to ensure that the most current and appropriate K_ds were selected.

The solubility limit for plutonium, 4.4E-13 M/liter, is used to calculate the distribution coefficient for plutonium-239. The plutonium and uranium isotopes were the only contaminants present in the F-Tank Farm that were limited by solubility and thus were the only contaminants for which the K_d values were calculated in this manner. For plutonium and uranium isotopes, the K_d values were derived such that the solubility limit is considered to be the concentration of the contaminant dissolved in the water or leachate. As an example the Pu-239 distribution coefficient calculation performed is shown below. The distribution coefficients for uranium were derived in a similar manner.

K_d = Cs/Cw = (adsorbed contaminant per weight of solid)/(dissolved concentration)

K_d = (2.61x10^{-7} Ci/g)/[6.13x10^{-2} Ci/g)*(4.4x10^{-13} moles/L)*(239 g/mole)/10^3 mL/L)]

where:

2.61x10^{-7} Ci/g = concentration of Pu-239 in sludge

6.13x10^{-2} Ci/g = specific activity of Pu-239

4.4x10^{-13} moles/liter = solubility limit of Pu-239

K_d = (2.61x10^{-7} Ci/g)/ (6.44x10^{-15} Ci/mL)

K_d = 4.05x10^7 mL/g

For purposes of modeling the transport of contaminants from the tank bottom though the three affected aquifers, a maximum of eight distinct strata were identified. These eight strata are (1) the contaminated zone; (2) the concrete basemat; (3) the vadose zone; (4) the Water Table Aquifer; (5) the Tan Clay layer; (6) the Barnwell-McBean Aquifer; (7) the Green Clay layer; and (8) the Congaree Aquifer. Distribution coefficients for each of these zones differ depending on the chemical and physical characteristics of the material comprising the layer.

The modeling of the ancillary equipment/piping in F-Tank Farm was similar, except the concrete basemat was conservatively assumed to have no effect on reducing the transport rate of contaminants to the saturated zone. In this instance, the grout-filled equipment/piping is modeled as the contaminated zone and the thickness of the vadose zone was increased to reflect the higher elevation of the piping in relation to the Water Table.

Distribution coefficients for each stratum under various conditions are listed in Table 4.

Under the analyzed scenario, both the tank and piping will be filled with a strongly reducing grout. Therefore, the K_ds selected for the contaminated zone and the tank basemat reflect this reducing environment; these are listed in Columns II and III, respectively. The vadose zone, Water Table Aquifer, and Congaree Aquifer distribution coefficients are assumed to have K_ds which are characteristics of typical SRS soil as listed under Column I of Table 4. The Tan Clay layer and Green Clay layer are assumed to have physical and chemical characteristics of clay with K_ds provided under Column IV.

Similarly, for the piping model, K_ds for the contaminated zone and the vadose zone are given in Columns II, and I, respectively. The Water Table Aquifer, Barnwell-McBean Aquifer, and Congaree Aquifer distribution coefficients are listed under Column I of Table 4. The Tan Clay layer and Green Clay layer K_ds are provided under Column IV.

4.2.2 MEPAS GROUNDWATER INPUT PARAMETERS

Table 5 presents input parameters used for the partially saturated zones for the various closure scenarios.

Table 6 presents input parameters for the saturated zone. These values are constant for all closure scenarios.

Table 4. Radionuclide and chemical distribution coefficients (cm^3/gram).

	I		II		III		IV	
Constituent	SRS soil	Note	Reducing contaminated zone	Note	Reducing concrete	Note	Clay	Note
Americium	150	a	5,000	c	5,000	c	8,400	d
Carbon-14	2	a	0.1[b]	c	0.1[b]	c	1	d
Curium-244, -245	150	a	5,000	c	5,000	c	8,400	d
Iodine-129	0.6	a	2	c	2	c	1	d
Tritium	0	a	0	c	0	c	0	d
Neptunium-237	10	a	5,000	c	5,000	c	55	d
Plutonium-238,-239, -240, -241, -242	100	a	NA	j	NA	j	5,100	d
Selenium-79	5	a	0.1	c	0.1	c	740	d
Technetium-99	0.36	a	1,000	c	1,000	c	1	d
Aluminum	35,300	e	353	f	353	f	35,300	g
Barium	530	e	1[h]	c	1[h]	c	16,000	g
Chromium VI[i]	16.8	e	7.9	f	7.9	f	360	g
Copper	41.9	e	33.6	f	33.6	f	336	g
Fluoride	0	e	0	f	0	f	0	g
Iron	15	e	1.5	c	1.5	f	15	g
Lead	234	e	500	c	500	c	1,830	g
Manganese	16.5	e	100	c	100	c	36.9	g
Mercury	322	e	5,280	f	5,280	f	5,280	g
Nickel	300	e	100	c	100	c	650	g
Nitrate	0	e	0	f	0	f	0	g
Silver	0.4	e	1	c	1	c	40	g
Uranium[l]	50	a	NA	k	NA	k	1,600	d
Zinc	12.7	e	1,460	f	1,460	f	1,460	g

a. WSRC (1994a), Table 3.3-2, page 3-69, value for soil.
b. Characteristics similar to selenium (Bradbury and Sarott 1995, Table 3, page 16).
(Bradbury and Sarott 1995, Table 3, page 16).
c. Bradbury and Sarott (1995), Table 4, Region 1, page 42.
d. WSRC (1994a), Table 3.3-2, page 3-69, value for clay.
e. MEPAS default for soil <10% clay and pH from 5-9.
f. MEPAS default for soil >30% clay and pH >9
g. MEPAS default for soil >30% clay and pH from 5-9.
h. Characteristics similar to strontium
i. For conservatism, all chromium modeled as VI valence.
j. Solubility limit of 4.4E-13 M/liter used to determine K_d, E-Area RPA (WSRC 1994a, page D-32).
k. Solubility limit of 3.0E-10 M/liter used to determine K_d, E-Area RPA (WSRC 1994a, page D-34).
l. Uranium distribution coefficient applicable for U-233, and U-234.

Table 5. MEPAS input parameters for partially saturated zones.

	Concrete Basemat						
	Intact	Failed	Vadose zone	Water Table Aquifer	Tan Clay layer	Barnwell-McBean Aquifer	Green Clay layer
Strata thickness (ft)	3.54[a] (Type 1) 2.74[a] (Type 3) 0.58[a] (Type 4)	3.54[a] (Type 1) 2.74[a] (Type 3) 0.58[a] (Type 4)	15.9[b] (Type 1) 24.8[b] (Type 3) 5.94[b] (Type 4)	40.0[c]	3.0[c]	60.0[c]	5.0[c]
Bulk density (g/cm^3)	2.21[d]	1.64[e]	1.59[d]	1.59[d]	1.36[e]	1.59[d]	1.39[e]
Total porosity	15%[d]	38%[e]	35%[f]	35%[f]	40%[f]	35%[f]	40%[f]
Field capacity	15%[d]	9%[e]	12%[e]	35%[e]	33.4%[e]	35%[e]	32.5%[e]
Longitudinal dispersion (ft)	0.0058[g]	0.0058[g]	0.054[g]	0.40[g]	0.030[g]	0.60[g]	0.050[g]
Vertical hydraulic conductivity (cm/s)	9.6E-09[d]	6.6E-03[e]	7.1E-03[h]	7.1E-03[h]	1.6E-06[h]	5.6E-04[h]	4.4E-09[h]

a. WSRC, Drawing #W202091, 1991.
b. Based on distance between bottom of tank (elevation from WSRC, Drawing #202091, 1991) to groundwater.
c. GeoTrans (1987).
d. WSRC (1994a).
e. Droppo (1995), Table 2.1.
f. Aadland (1995).
g. Calculated using MEPAS formula for longitudinal dispersivity.
h. GeoTrans (1993).

Table 6. MEPAS input parameters for saturated zone.

	Water Table Aquifer	Barnwell-McBean Aquifer	Congaree Aquifer
Thickness (ft)	40[a]	60.0[a]	100.0[a]
Bulk Density (g/cm^3)	1.59[b]	1.59[b]	1.64[c]
Total Porosity	35%[d]	35%[d]	34%[d]
Effective Porosity	20%[d]	20%[d]	25%[d]
Pore Velocity (ft/day)	0.12	0.064	0.23

a. Geotrans (1987).
b. WSRC (1994a).
c. Droppo (1995).
d. Aadland (1995).

4.2.3 HYDRAULIC CONDUCTIVITIES

Due to the fact that leach rate is ultimately limited by the lowest hydraulic conductivity of the strata and structures above and below the contaminated zone, this parameter is highly sensitivity in its effect on breakthrough times and peak concentrations at the receptor locations. Table 7 shows the changes in hydraulic conductivities due to failure as a function of time for the concrete basemat. For modeling purposes, it was assumed that excess water has a place to run off (over the sides of the basemat or cover) and that ponding above the contaminated zone does not occur.

Table 7. Concrete basemat hydraulic conductivities (centimeters per second).

Time (yrs)	Hydraulic conductivity
0-1,000	9.6E-09
1,000-10,000	6.6E-03 (failure at 1,000 years)

4.2.4 INFILTRATION RATES

As discussed in Section 2.0, infiltration rates are a function of time to failures of tank top, grout, and concrete basemat. Infiltration rates as a function of time are presented in Table 8.

Table 8. Infiltration rates (centimeters per year).

Time (yrs)	Rate
0-1,000	4
1,000-10,000	40 (failure at 1,000 years)

4.2.5 HUMAN HEALTH EXPOSURE PARAMETERS AND ASSUMED VALUES

Because the impact on a given receptor depends in large part on the physical characteristics and habits of the receptor, it is necessary to stipulate certain values to obtain meaningful results. Certain of these values are included as default values in MEPAS; however, others must be specified so that the receptors are modeled appropriately for the scenario being described.

For this modeling effort, site-specific values were used as much as possible: that is, values that had been used in other modeling efforts for the SRS were incorporated when available and appropriate. Table 9 lists the major parameters that were used in assigning characteristics to the receptors used in the calculations.

Table 9. Assumed human health exposure parameters.

Parameter	Applicable Receptor	Value	Comments
Body Mass	Adult	70 kg	This value is taken directly from ICRP 23, *Report of the Task Group on Reference Man*. In radiological dose calculations, this is the standard value in the industry.
	Child	30 kg	This value was obtained from ICRP 23, *Report of the Task Group on Reference Man*. Both a male and female child of age 9 have an average mass of 30 kg.
Exposure Period	All	1 year	This value is necessary so that MEPAS will calculate an annual radiation dose. Lifetime doses can be calculated by multiplying the annual dose by the assumed life of the individual.
Leafy Vegetable Ingestion Rate	Adult	21 kg/yr	This value was taken from Hamby (1993), which was used previously in other modeling work at SRS.
	Child	8.53 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC Regulatory Guide 1.109.
Other Vegetables Ingestion Rate	Adult	163 kg/yr	This value was taken from Hamby (1993), which was used previously in other modeling work at SRS.
	Child	163 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC Regulatory Guide 1.109.
Meat Ingestion Rate	Adult	43 kg/yr	This value was taken from Hamby (1993), which was used previously in other modeling work at SRS.
	Child	16 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC Regulatory Guide 1.109.
Milk Ingestion Rate	Adult	120 L/yr	This value was taken from Hamby (1993), which was used previously in other modeling work at SRS.
	Child	128 L/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC Regulatory Guide 1.109.
Water Ingestion Rate	All	2 L/day	This value is standard in MEPAS and is consistent with maximum drinking water rates in NRC Regulatory Guide 1.109.
Finfish Ingestion Rate	Adult	9 kg/yr	This value was taken from Hamby (1993), which was used previously in other modeling work at SRS.

	Child	2.96 kg/yr	This value was calculated based on the adult ingestion rate from Hamby (1993) and the ratio of child to adult ingestion rates for maximum individuals in NRC Regulatory Guide 1.109.
Time Spent at Shoreline	Adult Resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC Regulatory Guide 1.109.
	Child Resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC Regulatory Guide 1.109.
	Seepline Worker	2080 hrs/yr	This value is based on the assumption of continuous exposure of the seepline worker during each working day.
	Intruder	1040 hrs/yr	This value is based on the conservative assumption of half-time exposure during each working day.
Time Spent Swimming	Adult Resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC Regulatory Guide 1.109.
	Child Resident	12 hrs/yr	This is a default value from MEPAS and is consistent with NRC Regulatory Guide 1.109.

5.0 CALCULATION OF HUMAN HEALTH IMPACTS FROM MEPAS OUTPUT DATA

5.1 MEPAS Output File Structure

MEPAS generates several ASCII result files for each run that it calculates. Three files of particular importance are the *.hhi, *.wat, and *.wls files. Files with an "hhi" extension provide maximum dose information for each receptor by pathway and contaminant. The time period during which the maximum dose occurs is also listed, although this time period is not an absolute time: that is, the time periods in the *.hhi files are expressed relative to the point in time when nonzero concentrations are observed in the water body serving as the source of pathways for a given receptor and not from the start of the release.

Files with a "wat" extension list the concentrations of contaminants in the specified water locations (i.e., 1-meter well, 100-meter well, seepline, surface water) as a function of time by contaminant. Finally, the *.wls files contain an "echo" of the input data related to water concentrations as well as intermediate and final concentration results for each receptor.

5.2 Reduction of MEPAS Data

The MEPAS modeling runs for the analyzed scenario and the ancillary equipment with early and late conditions generated an immense quantity of data and information describing the fate and transport of the

radiological and nonradiological residual contaminants. This output data from MEPAS was not readily usable for several reasons:

- Data within the various ASCII output files were arranged in different formats for each file type, making extraction of needed information difficult and time-consuming.
- No single output file contained all the data necessary for a complete analysis for impacts (e.g., the *.hhi file had maximum dose information but did not have dose profiles over time while the *.wat file had water concentrations over time but did not have any doses).
- Data from early and late MEPAS runs needed to be combined to give results as a continuous function of time.

The solution to overcoming these difficulties was twofold: the design of a FORTRAN program to extract necessary data from the needed files and the design of a spreadsheet that would take the output file from the FORTRAN program and perform all necessary subsequent calculations. The FORTRAN program named ECOCONC.EXE (Attachment C) was written to extract water concentrations as a function of time for all the water locations of interest: the 1-meter well, the 100-meter well, the seepline, Upper Three Runs and Fourmile Branch. This program combined the results of the early (second MEPAS runs) and late runs (with appropriate offset for failure times in the late runs) for both the tanks and the ancillary equipment and produced an output file (with extension "ECO") with concentrations as a function of time that could be imported into an EXCEL® spreadsheet for additional calculations as described in the next section.

5.3 Calculations Using the Reduced MEPAS Data

The spreadsheet RA_TMPLT.XLS was used to calculate radiation doses as a function of time based on data in the *.ECO files. Dose conversion factors (DCFs) for the various pathways and receptors were calculated using the HLWDCF.XLS spreadsheet as described in its calculation package. These DCFs were then multiplied by the appropriate concentrations to determine the dose at any time. The basic makeup of the RA_TMPLT.XLS spreadsheet is as follows:

- Worksheet 1 - "Data": Data from the *.ECO files were pasted into this sheet. To accomplish this, the *.ECO files were opened in a separate EXCEL file, the entire sheet was copied, and then the image from the clipboard was pasted into the "Data" worksheet of RA_TMPLT.XLS.

- Worksheet 2 - "Dose Calcs.": This worksheet was designed to read data from the "Data" worksheet, calculate doses, identify the maximum dose for each radionuclide, and identify the time when the maximum dose occurred. This was accomplished by using standard EXCEL formulas and commands so that no human intervention was needed on this worksheet once it was set up.

- Worksheet 3 - "Maximum Doses": This worksheet read maximum dose values from the "Dose Calcs." worksheet and formatted the values (e.g., significant digits, order of contaminants) to facilitate efficient pasting of the results into a Microsoft Word document. This operation was accomplished using standard EXCEL formulas, commands, and features so that, once set up, no human manipulation was needed on this worksheet.

- Worksheet 4 - "Lookup": This worksheet was designed to allow doses to be calculated for all receptors at a given point in time. The intent of this spreadsheet was to allow the user to input a single time point (in years) into a cell for which the spreadsheet would then display doses for all radionuclides at that time using EXCEL lookup functions executed on the "Dose Calcs." worksheet.

Another EXCEL spreadsheet, NR_TMPLT.XLS, was used to calculate concentrations of nonradiological contaminants as a function of time. The basic structure of NR_TMPLT.XLS is the same as RA_TMPLT.XLS, except that the "Dose Calcs" worksheet calculates concentrations in mg/L instead of calculating a dose. A third spreadsheet, ALPH_TMP.XLS is constructed similarly to allow calculation of gross alpha concentrations. Because of the sheer number of alpha-emitting radionuclides that are present in the tanks, it was necessary to divide the source term information into two further sets of calculations (denoted as "A" and "B"). The spreadsheet combines the concentrations from all radionuclides and contains a lookup function to determine the alpha concentration at times entered by the user.

5.4 QA/Technical Review of MEPAS Files and Auxiliary Calculations

Because of the structure of the MEPAS output and input files, the input values for MEPAS are echoed in several locations. Therefore, it is possible to verify input parameters in any of several ASCII files, although the ease of interpretation of the values in the files varies with the file type. For instance, the *.PRM files have all variable names (as defined by the MEPAS user's manual) and values associated with them but no units on the values. The *.WLS files have certain input parameters listed in common

descriptive terms (e.g., "leach rate" as opposed to the MEPAS variable name for leach rate) with associated units that are usually different from the original input parameter units (conversions need to be performed to verify values). The *.WIN files are raw ASCII input files and have the input values but do not have variable names or units associated with the values. However, the *.WIN files have a structured format so that once the order in which variables are listed are understood, it is relatively easy and efficient to verify values in the *.WIN files.

Because of the nature of the input and output files, as described above, the MEPAS files for previous initial modeling runs were reviewed through a combination of automated and manual processes to verify the input parameters. These previous reviews involved dividing the computer runs into four groups: radiological tank ("rad tank") calculations, nonradiological tank calculations ("nonrad tank"), radiological piping and ancillary calculations ("rad piping"), and nonradiological piping and ancillary calculations ("nonrad piping").

For the radiological tank calculations, all the *.WLS files were printed out and checked manually to ensure that all parameters had been entered correctly.

For the remaining groups of calculations, a more automated approach was adopted. It was recognized that most of the parameters do not change for each separate computer run. Therefore, a method was devised whereby only differences between the various computer files would need to be checked to ensure that the changes were appropriate to the scenario and conditions.

Due to the rigorous checking conducted previously to ensure that entries for all MEPAS input parameters were peformed appropriately, the QA review process was less intensive for this set of modeling runs. It was only necessary at this point to review the differences between the file being checked and the benchmark files to ensure that all changes were appropriate.

6.0 HUMAN HEALTH ASSESSMENT RESULTS

6.1 Impacts from Contaminant Transport

For each scenario, the maximum concentration or dose was identified for each receptor and for each contaminant along with the period during which the maximum occurred within a 10,000-year performance period. In addition, for radiological constituents, the total dose was calculated to enable the evaluation of the impacts of all radiological constituents. Because the maximum doses for each radionuclide do not necessarily occur simultaneously, it is not appropriate to add the maximum doses. Rather, it is more appropriate to assess the doses as a function of time, sum the doses from all radionuclides for each time increment, and then select the maximum total dose from this compilation. Therefore, the total dose reported in Tables 10 through 12 for radiological constituents might not correlate to the maximum dose or period for any individual radionuclide because of the contributions from all radionuclides at a given time. In addition to total dose, the gross alpha concentration , the beta-gamma dose, and the lifetime risk of incidence of excess cancer were calculated to allow comparisons to the appropriate performance objectives.

Nonradiological constituent concentrations in the various water bodies were calculated to enable direct comparisons to performance objectives. For each constituent, the maximum concentration was calculated along with the period during which the maximum concentration occurred (Tables 13 through Table 15). None of the nonradiological constituents are known ingestion carcinogens; therefore, cancer risk was not calculated for these contaminants.

Tables 10 through 15 list impact estimates due to transport of contaminants in the three aquifers described in Section 3.0. All contaminants listed in Tables 2 and 3 were used in the calculations; however, contaminants with exceedingly small impacts at the locations of interest were not listed in Tables 10 through 15. The tables that list radiological impacts include doses for postulated receptors (i.e., Adult Resident, Child Resident, Seepline Worker, and Intruder) and at the seepline.

Additional calculations were performed for groundwater locations close to the tank farm (i.e., the 1 m well and the 100 m well) for informational purposes. For nonradiological constituents, the maximum concentration of each contaminant is listed for each water location.

Although calculational results are presented for the three aquifers, the maximum concentration of a contaminant to which a person could potentially be exposed is the highest concentration among the three aquifers (i.e., the doses and concentrations from the three aquifers are not additive). For example, the maximum dose a person could get by ingesting water at the seepline location is due to contaminant

transport in the Barnwell-McBean Aquifer. In reality, the water at the seepline may be a mixture of the groundwater that outcrops from the Barnwell-McBean Aquifer and the Water Table Aquifer, resulting in an average seepline concentration. DOE did not take credit for this possibility but has instead assumed that a person could ingest the maximum contaminant concentration from a single aquifer.

Inspection of Tables 10 through 15 shows that Tc-99 is the dominant radiation dose contributor. These tables show dose estimates from several other constituents; however, it is apparent that Tc-99 is the limiting constituent. The tables also indicate that gross alpha concentration in the groundwater and surface water will be much less than any of the performance objectives during the 10,000 year period.

Tables 13 through 15 indicate that the seepline concentrations of all nonradiological contaminants will be quite low throughout the 10,000 year period. None of the contaminants are projected to exceed any performance objectives.

Table 10. F-Tank Farm radiological results due to contaminant transport in the Water Table Aquifer.

Location		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Lifetime risk	Gross alpha concentration (pCi/L)
Adult resident	Maximum value	(a)	1.9E-02	(a)	(a)	N/A	1.9E-02	4.2E-07	N/A
	Time of maximum (yr)	(a)	385	(a)	(a)	N/A	385		N/A
Child resident	Maximum value	(a)	1.8E-02	(a)	(a)	N/A	1.8E-02	1.3E-07	N/A
	Time of maximum (yr)	(a)	385	(a)	(a)	N/A	385		N/A
Seepline worker	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
Intruder	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
1-meter well	Maximum value	8.3E+00	4.3E+01	1.8E-01	4.8E-02	4.3E+01	4.3E+01	9.5E-04	5.2E+00
	Time of maximum (yr)	1155	385	1085	1015	385	385		1855
100-meter well	Maximum value	2.0E+00	1.6E+01	3.4E-02	1.2E-02	1.6E+01	1.6E+01	3.5E-04	1.8E+00
	Time of maximum (yr)	1225	315	1085	1015	315	315		1995
Seepline	Maximum value	3.4E-02	1.0E+00	(a)	(a)	1.0E+00	1.0E+00	2.2E-05	2.6E-02
	Time of maximum (yr)	2205	385	(a)	(a)	385	385		3815
Surface water (Drinking)	Maximum value	(a)	7.1E-03	(a)	(a)	7.1E-03	7.1E-03	1.5E-07	1.8E-04
	Time of maximum (yr)	(a)	385	(a)	(a)	385	385		3885

a. Radiation dose is less than 0.001 mrem/yr.
b. Concentration is less than 1×10^{-13} pCi/L.
c. Risk is less than 1×10^{-7}.

Table 11. F-Tank Farm radiological results due to contaminant transport in the Barnwell-McBean Aquifer.

Location		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Lifetime risk	Gross alpha concentration (pCi/L)
Adult resident	Maximum value	(a)	2.7E-02	(a)	(a)	N/A	2.7E-02	5.9E-07	N/A
	Time of maximum (yr)	(a)	805	(a)	(a)	N/A	805		N/A
Child resident	Maximum value	(a)	2.5E-02	(a)	(a)	N/A	2.5E-02	1.8E-07	N/A
	Time of maximum (yr)	(a)	805	(a)	(a)	N/A	805		N/A
Seepline worker	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
Intruder	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
1-meter well	Maximum value	3.2E+00	1.3E+02	4.1E-01	1.7E-01	1.3E+02	1.3E+02	2.9E-03	1.3E+01
	Time of maximum (yr)	3815	665	1225	1085	665	665		2695
100-meter well	Maximum value	1.0E+00	5.2E+01	8.4E-02	4.6E-02	5.2E+01	5.2E+01	1.1E-03	4.6E+00
	Time of maximum (yr)	3815	665	1225	1085	665	665		2905
Seepline	Maximum value	3.6E-02	1.9E+00	(a)	(a)	1.9E+00	1.9E+00	4.1E-05	3.9E-02
	Time of maximum (yr)	5705	805	(a)	(a)	805	805		6405
Surface water (Drinking)	Maximum value	(a)	9.9E-03	(a)	(a)	9.9E-03	9.9E-03	2.2E-07	2.2E-04
	Time of maximum (yr)	(a)	805	(a)	(a)	805	805		6265

a. Radiation dose is less than 0.001 mrem/yr.
b. Concentration is less than 1×10^{-13} pCi/L.
c. Risk is less than 1×10^{-7}.

Table 12. F-Tank Farm radiological results due to contaminant transport in the Congaree Aquifer.

Location		Se-79 dose (mrem/yr)	Tc-99 dose (mrem/yr)	C-14 dose (mrem/yr)	I-129 dose (mrem/yr)	Beta-Gamma dose (mrem/yr)	Total dose (mrem/yr)	Lifetime risk	Gross alpha concentration (pCi/L)
Adult resident	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
Child resident	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
Seepline worker	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
Intruder	Maximum value	(a)	(a)	(a)	(a)	N/A	(a)	(c)	N/A
	Time of maximum (yr)	(a)	(a)	(a)	(a)	N/A	(a)		N/A
1-meter well	Maximum value	(a)	9.1E-01	1.2E-03	(a)	9.1E-01	9.1E-01	2.0E-05	3.1E-03
	Time of maximum (yr)	(a)	4935	1505	(a)	4935	4935		8785
100-meter well	Maximum value	(a)	2.3E-01	(a)	(a)	2.3E-01	2.3E-01	5.1E-06	1.2E-03
	Time of maximum (yr)	(a)	1225	(a)	(a)	1225	1225		9135
Seepline	Maximum value	(a)	6.5E-03	(a)	(a)	6.5E-03	6.5E-03	1.4E-07	3.7E-05
	Time of maximum (yr)	(a)	5495	(a)	(a)	5495	5495		9275
Surface water (Drinking)	Maximum value	(a)	(a)	(a)	(a)	(a)	(a)	(c)	1.0E-06
	Time of maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)		8995

a. Radiation dose is less than 0.001 mrem/yr.
b. Concentration is less than 1×10^{-13} pCi/L.
c. Risk is less than 1×10^{-7}.

Table 13. F-Tank Farm nonradiological results due to contaminant transport in the Water Table Aquifer.

Receptor		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
1-meter well	Maximum concentration (mg/L)	1.3E-01	(a)	7.7E-05	1.4E-02	2.1E-02	6.2E-03	2.7E+00	3.7E-05	1.4E-01	1.9E-01	1.5E-04	6.1E-04	2.1E-05	6.0E-03
	Time of Maximum (yr)	1015	(a)	9975	105	1645	2765	1575	9975	105	1995	9975	9975	8365	2065
100-meter well	Maximum concentration (mg/L)	2.7E-02	(a)	(a)	4.7E-03	3.0E-03	8.3E-04	3.8E-01	1.1E-06	4.9E-02	2.9E-02	(a)	1.6E-04	8.5E-06	2.2E-03
	Time of Maximum (yr)	1015	(a)	(a)	105	1855	3185	1715	9975	105	2205	(a)	8435	9345	2205
Seepline well	Maximum concentration (mg/L)	9.0E-04	(a)	(a)	2.6E-04	4.0E-05	1.1E-05	5.1E-03	(a)	2.7E-03	4.3E-04	(a)	(a)	(a)	3.6E-05
	Time of Maximum (yr)	1085	(a)	(a)	105	4795	9905	4445	(a)	105	5145	(a)	(a)	(a)	4585
Surface Water	Maximum concentration (mg/L)	5.8E-06	(a)	(a)	1.8E-06	(a)	(a)	3.3E-05	(a)	1.8E-05	2.8E-06	(a)	(a)	(a)	(a)
	Time of Maximum (yr)	1085	(a)	(a)	105	(a)	(a)	4375	(a)	105	5075	(a)	(a)	(a)	(a)

a. Concentration is less than 1×10^{-6} mg/L.

Table 14. F-Tank Farm nonradiological results due to contaminant transport in the Barnwell-McBean Aquifer.

Receptor		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
1-meter well	Maximum concentration (mg/L)	3.7E-01	(a)	(a)	2.3E-01	2.6E-02	1.0E-02	5.2E+00	(a)	2.3E+00	3.7E-01	(a)	(a)	(a)	4.7E-03
	Time of maximum (yr)	1155	(a)	(a)	1015	3745	6055	2485	(a)	1015	3045	(a)	(a)	(a)	7385
100-meter well	Maximum concentration (mg/L)	8.7E-02	(a)	(a)	5.7E-02	5.6E-03	2.0E-03	9.4E-01	(a)	5.9E-01	6.7E-02	(a)	(a)	(a)	2.0E-03
	Time of maximum (yr)	1155	(a)	(a)	1015	4095	7035	2765	(a)	1015	3465	(a)	(a)	(a)	7455
Seepline well	Maximum concentration (mg/L)	2.2E-03	(a)	(a)	1.5E-03	6.0E-05	(a)	7.7E-03	(a)	1.5E-02	6.4E-04	(a)	(a)	(a)	1.7E-05
	Time of maximum (yr)	1365	(a)	(a)	1015	9555	(a)	7735	(a)	1015	8925	(a)	(a)	(a)	9975
Surface water	Maximum concentration (mg/L)	1.2E-05	(a)	(a)	7.5E-06	(a)	(a)	4.0E-05	(a)	7.8E-05	3.3E-06	(a)	(a)	(a)	(a)
	Time of maximum (yr)	1365	(a)	(a)	1015	(a)	(a)	7805	(a)	1015	8785	(a)	(a)	(a)	(a)

a. Concentration is less than 1×10^{-6} mg/L.

Table 15. F-Tank Farm nonradiological results due to contaminant transport in the Congaree Aquifer.

Receptor		Silver	Aluminum	Barium	Fluoride	Chromium	Copper	Iron	Mercury	Nitrate	Manganese	Nickel	Lead	Uranium	Zinc
1-meter well	Maximum concentration (mg/L)	3.4E-05	(a)	(a)	1.2E-03	(a)	(a)	6.6E-03	(a)	1.3E-02	2.6E-04	(a)	(a)	(a)	(a)
	Time of Maximum (yr)	4025	(a)	(a)	1085	(a)	(a)	4725	(a)	1085	6615	(a)	(a)	(a)	(a)
100-meter well	Maximum concentration (mg/L)	7.3E-06	(a)	(a)	2.5E-04	(a)	(a)	1.4E-03	(a)	2.6E-03	5.2E-05	(a)	(a)	(a)	(a)
	Time of Maximum (yr)	4235	(a)	(a)	1085	(a)	(a)	4795	(a)	1085	6755	(a)	(a)	(a)	(a)
Seepline well	Maximum concentration (mg/L)	(a)	(a)	(a)	7.5E-06	(a)	(a)	3.3E-05	(a)	7.9E-05	1.4E-06	(a)	(a)	(a)	(a)
	Time of Maximum (yr)	(a)	(a)	(a)	1085	(a)	(a)	6475	(a)	1085	8365	(a)	(a)	(a)	(a)
Surface Water	Maximum concentration (mg/L)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	2.1E-06	(a)	(a)	(a)	(a)	(a)
	Time of Maximum (yr)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	1085	(a)	(a)	(a)	(a)	(a)

a. Concentration is less than 1×10^{-6} mg/L.

6.2 Summary of Results

The maximum radiological dose at the seepline (the point of exposure) was calculated to be 1.9 mrem per year from the Barnwell-McBean Aquifer. Essentially all of this dose is due to selenium-79 and technetium-99 because the other radionuclides either decay en route or do not migrate at a sufficient rate to reach the seepline within the 10,000-year period of analysis. The calculated gross alpha concentration at the seepline demonstrates that appreciable amounts of alpha-emitting radionuclides do not arrive at the seepline within the 10,000-year period. For nonradiological constituents, none of the contaminants reach the seepline in quantities that could exceed the maximum contaminant level.

7.0 UNCERTAINTY/SENSITIVITY ANALYSIS

The principal parameters that affect modeling results are the following:

Inventory: The amount of material in the tank directly affects the concentrations at any given location, unless the amount of material is so great that the solubility limit is exceeded. Once the solubility limit is exceeded, greater amounts of source material do not necessarily result in increased concentrations at receptor locations. In this modeling effort, both plutonium and uranium were assumed to be limited by solubility.

Hydraulic conductivity: The actual rate of water movement through the material is ultimately affected by the hydraulic conductivity of the strata underneath the source. For both scenarios, the concrete basemat is the limiting layer with regard to water infiltration. At the time of basemat failure, the hydraulic conductivity is increased dramatically, making more water available to carry contaminants to the aquifer. In general, this will result in greater doses/concentrations due to the increased movement of material.

Distribution coefficient: The distribution coefficient (K_d) affects the rate at which contaminates moves through strata. Large K_d values provide significant holdup time for short-lived radionuclides.

Vadose zone thickness: The thickness of the strata between the contaminated region and the aquifer does not necessarily reduce the concentration so much as it slows the progress toward the aquifer.

Therefore, for shorter-lived radionuclides, extra time granted by thicker strata can decrease the activity before they reach the aquifer.

Dispersion coefficient: The dispersion coefficient affects the degree to which the plume "spreads" as it moves toward receptor locations. Less dispersion would understandably cause greater concentrations to be calculated for a given point, while greater dispersion would result in lower concentration estimates.

Distance downgradient to receptor location: The distance to a given receptor location affects (a) the time at which contaminants will arrive at the location and (b) how much dispersion occurs. For greater distances, longer travel times will be encountered, resulting in lower activity values for short-lived radioactive constituents and greater dispersion for all constituents.

As described in Sections 3 and 4, a number of conservative assumptions were included as part of this modeling effort. This has the effect of providing dose/concentration estimates that may be greater than values that might actually be measured. The relative lack of sensitivity of the magnitude of the results to many of the parameters listed above, however, suggests that the estimates depend on a limited few key parameters, such as source term, assumed strata layering, and the amount of dispersion. Therefore, the impact estimates in this appendix could be high by an order of magnitude (or more). That is, it is expected that the "true" value is less than the estimates presented in this document because of the conservative assumptions. The uncertainties associated with this modeling are comparable to those typically performed elsewhere to estimate potential environmental impacts. The initial modeling as presented in the general closure plan, underwent an independent sensitivity and uncertainty analysis by Sandia National Laboratories. An evaluation of the Sandia analysis (Cook 1996) concluded that the results were "... similar enough to conclude that the problem has been addressed properly."

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ATTACHMENT A

Auxiliary FORTRAN Program (FF.FOR)

```
C  MEPAS  -  FIND TOTAL MATERIAL EXITING LOWEST PSZ.
      DIMENSION HL( 20), S( 20), C( 20), AINV( 20), NCON( 20)
      CHARACTER FILEN*8, LB*1, NAME( 20)*10
      OPEN( 7, FILE= 'F.IN', STATUS = 'UNKNOWN')
      READ( 7, *) NVAD
      OPEN( 9, FILE= 'F.OUT', STATUS = 'UNKNOWN')
      AL2= ALOG( 2.)
20    WRITE( *,1)
1     FORMAT( ' CASE NAME (FILE W/O EXTENSION) = ?')
      READ( 7, 2, END = 23) FILEN
2     FORMAT( A8)
      IF( FILEN( 1:1) .EQ. '-')STOP 2
      CLOSE( 5)
      CLOSE( 6)
      WRITE( *, 21)
21    FORMAT( ' TIME OF FAILURE (YRS) = ?')
      READ( 7, *) TIME
      OPEN( 5, FILE= FILEN//'.POL')
      OPEN( 6, FILE= FILEN//'.WIN')
C  FIND HALF LIVES FROM WIN
C  SKIP 7 LINES
      DO 22 I = 1, 7
C     WRITE( *, 3)
22    READ( 6, 3)
3     FORMAT( 1X)
C  READ # PARENTS
      READ( 6, 4) N
C     WRITE( *, 4)
4     FORMAT( 30X, I5)
      READ( 6, 3)
C     WRITE( *, 3)
C  READ HALF LIVES
      M = 0
      DO 5 I = 1, N
      READ( 6, 6) NAME(I), HL(I), ND, C(I), AINV( I)
C     WRITE( *, 6) NAME(I), HL(I), ND, C(I), AINV( I)
```

```
<      FORMAT( 10X, A10, E10.3, I5, E10.3, 25X, E10.3)
       NCON( I) = M + 1
       M = M + ND
       READ( 6, 3)
C      WRITE(*, 3)
       IF( ND .GT. 1) THEN
        DO 7 J = 1, ND-1
C       WRITE( *, 3)
7       READ( 6, 3)
       ENDIF
5      CONTINUE
C  SKIP FIRST MEDIUM
       L = 0
10     READ( 5, 8) LB
C      WRITE( 9, 8) LB
8      FORMAT( 5X, A1)
       IF( LB .EQ. '#') L = L + 1
       IF( L .EQ. NVAD) GO TO 9
       GO TO 10
9      READ( 5, 3)
       READ( 5, 3)
       READ( 5, 3)
       DO 11 I= 1, N
C
C      WRITE(9, 3)
       E = AL2/ HL( I)
       S( I) = 0.
C  CALCULATE RELEASE THROUGH SECOND LAYER
15     READ( 5, 12) ICON, IT1, T1, F1, U1
C      WRITE( 9, 12) ICON, IT1, T1, F1, U1
12     FORMAT( 2X, 2I5, 20X, 3E10.3)
       FF = F1 * U1
       FP = F1 * U1
       TF = T1
       TP = T1
       IF( ICON .NE. NCON( I)) GO TO 15
```

```
      IF( T1 .GE. TIME) GO TO 11
      READ( 5, 12) ICON, IT2, T2, F2, U2
      IF( T1 .GE. TIME) GO TO 11
      IF( S( I) .GE. .99 * AINV( I)) THEN
       S( I) = AINV( I)
       GO TO 11
      ENDIF
      IF( ICON .NE. NCON(I)) THEN
       BACKSPACE( 5)
C  EXTRAPOLATE FLUX BASED ON LOG-LOG STRAIGHT LINE
C
C     IJ = 1
C     WRITE( *,*)FILEN,I,IJ, FP, FF, TP, TF, S( I), AINV( I)
       B= ALOG( FP/ FF)/ ALOG( TP/ TF)
       A= FF/ TF** B
       S( I)= S( I) + ( TIME** ( B + 1.) - TF** ( B + 1.))* A/ (B + 1.)
C
-     IJ = 11
      WRITE( *,*)FILEN,I,IJ
       GO TO 11
      ENDIF
      FF = F2 * U2
      TF = T2
      IF( F2 * U2 .GT. FP) THEN
       FP = F2 * U2
       TP = T2
      ENDIF
      IF( T2 .LE. TIME) THEN
       READ( 5, 12) ICON, IT3, T3, F3, U3
       IF( ICON .NE. NCON(I)  .OR.  T3 .GT. TIME) THEN
        BACKSPACE( 5)
C
C     IJ = 2
C     WRITE( *,*)FILEN,I,IJ
        S( I) = S( I) + ( T2 - T1) * ( F1* U1* EXP( E * T1) + F2* U2*
     a  EXP( E * T2))/ 2.
```

```
C
      IJ = 22
C     WRITE( *,*)FILEN,I,IJ
        IF( S( I) .GE. AINV( I)) GO TO 11
C     WRITE( 9, 99) I, S( I), T1, T2, F1, F2, E
99    FORMAT( ' 99 I, S( I), T1, T2, F1, F2, E ='/I5, 1P6E11.3)
        T1 = T2
        U1 = U2
        F1 = F2
        GO TO 16
       ELSE
      FF = F3 * U3
      TF = T3
      IF( F3 * U3 .GT. FP) THEN
       FP = F3 * U3
       TP = T3
      ENDIF
-
.     IJ = 3
C     WRITE( *,*)FILEN,I,IJ
        S( I) = S( I) + ( T2 - T1) * ( F1* U1* EXP( E * T1) + 4.* F2* U2
     a  * EXP( E * T2) + F3* U3* EXP( E* T3))/ 3.
C
C     IJ = 33
C     WRITE( *,*)FILEN,I,IJ
        IF( S( I) .GE. AINV( I)) GO TO 11
C     WRITE( 9, 98) I, S( I), T1, T2, T3, F1, F2, F3, E
98    FORMAT( ' 98 I, S( I), T1, T2, T3, F1, F2, F3, E ='/I5, 1P6E11.3/
     a5X, 2E11.3)
        T1 = T3
        U1 = U3
        F1 = F3
        GO TO 16
       ENDIF
      ELSE
C  INTERPOLATE TO TIME
```

```
      IJ = 5
      WRITE( *, *)NAME( I), IJ, TIME, T1, F2, E, F1, U1, T2
       E2 = E* T2
       E1 = E* T1
       IF( E1 .GT. 35.  .OR.  E2 .GT. 35.)THEN
        E1 = 1
        E2 = 1
       ELSE
        E1 = EXP( E1)
        E2 = EXP( E2)
       ENDIF
       FU = (TIME - T1) * (F2* U2* E2 - F1* U1* E1)/
     a ( T2 -T1) + F1* U1* E1
C      IJ = 55
C      WRITE( *, *)NAME( I), IJ, TIME, T1, F2, E, F1, U1, T2
C
C      IJ = 4
      WRITE( *,*)FILEN,I,IJ
       S( I) = S( I) + ( TIME - T1) * ( F1* U1* EXP( E * T1) + FU) / 2.
C
C      IJ = 44
C      WRITE( *,*)FILEN,I,IJ
       IF( S( I) .GE. AINV( I)) GO TO 11
C      WRITE( 9, 97) I, S( I), T1, T2, TIME, F1, F2, FU, E
97     FORMAT( ' 98 I, S( I), T1, T2, TIME, F1, F2, FU, E ='/I5, 1P6E11.3
     a/ 5X, 2E11.3)
       T1 = T2
       U1 = U2
       F1 = F2
      ENDIF
11    CONTINUE
      WRITE( 9, 19) FILEN
19    FORMAT( ///' FOR FILE = ', A8/)
C     WRITE( *, 19) FILEN
      DO 18 I = 1, N
      AN = (AINV(I) - S( I))
```

```
C  DECAY NEW INVENTORY
      AOLD = AINV( I) - AN
      CHG = 100. * AOLD/ AINV( I)
      AN = AN * EXP( -AL2 * TIME/ HL( I))
      IF( AN . LT. 1.E-32) AN = 1.E-32
      CH1 = 100. * (AINV( I) - AN)/ AINV( I)
C     IF( CH1 .LT. 10.) GO TO 18
      CN = C( I) * AN/ AINV( I)
C     WRITE( *, 17) NAME(I), I, C( I), AINV(I), CHG, CN, AN
      WRITE( 9, 17) I, NAME(I), C( I), AINV(I), AOLD, CHG, CN, AN,
     aNAME(I)
17    FORMAT( I3, 2X, A8, ' : OLD CONC, INV=', 1P2E10.2, 5X, '(', E10.2,
     z' early rel.)'/
     a1X, 0PF5.1,' % CHANGE - W/O DECAY', 9X,
     b'NEW CONC, INV= ', 1P2E10.2, 3X, A8)
18    CONTINUE
      GO TO 20
23    STOP 2
      END
```

ATTACHMENT B

MEPAS Input Parameters for F-Tank Farm for the Partially Saturated and Saturated Zones

Ty Tanks
(Saturated Zone - Water Table Aquifer)

Input Parameter	PSZ1 Concrete Intact	PSZ1 Basemat Failed	PSZ2 Vadose zone	SZ Water Table Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	0.019
Strata thickness (ft)	3.54	3.54	15.9	40
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59
Total porosity (%)	15	38	35	35
Field capacity (%)	15	9	12	N/A
Vertical hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	N/A
Longitudinal dispersivity (ft)				
1 meter	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	260
Transverse dispersivity (ft)				
1 meter	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	26
Vertical dispersivity (ft)				
1 meter	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	0.12
Effective Porosity (%)	N/A	N/A	N/A	20
Soil classification	clay	sand	sandy loam	loamy sand
Sand (%)	20	92	65	83
Silt (%)	20	5	25	11
Clay (%)	60	3	10	6
Organic Matter (%)	0	0	0.1	0.1
Iron (%)	0	0	1.3	1.3
pH	8	8	7	6

N/A = Not Applicable

Type I Tanks - ng and Equipment
(Saturated Zone - Water Table Aquifer)

Input Parameter	PSZ1 Vadose zone	SZ Water Table Aquifer
Darcy velocity (ft/day)	N/A	0.019
Strata thickness (ft)	45.44	40
Bulk density (g/cm^3)	1.59	1.59
Total porosity (%)	35	35
Field capacity (%)	12	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	N/A
Longitudinal dispersion (ft)	0.454	N/A
Longitudinal dispersivity (ft)		
1 meter	N/A	27.5
100 meter	N/A	43.7
Seepline	N/A	255
Surface Water	N/A	260
Transverse dispersivity (ft)		
1 meter	N/A	2.75
100 meter	N/A	4.37
Seepline	N/A	25.5
Surface Water	N/A	26
Vertical dispersivity (ft)		
1 meter	N/A	0.07
100 meter	N/A	0.11
Seepline	N/A	0.64
Surface Water	N/A	0.65
Pore velocity (ft/day)	-	0.12
Effective Porosity (%)	-	20
Soil classification	sandy loam	loamy sand
Sand (%)	65	83
Silt (%)	25	11
Clay (%)	10	6
Organic Matter (%)	0.1	0.1
Iron (%)	1.3	1.3
pH	7	6

N/A = Not Applicable

Ty, Tanks
(Saturated Zone - Barnwell McBean Aquifer)

Input Parameter	PSZ1 Concrete Basemat Intact	PSZ1 Concrete Basemat Failed	PSZ2 Vadose zone	PSZ3 Water Table Aquifer	PSZ4 Tan Clay Layer	SZ Barn-McBean Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.064
Strata thickness (ft)	3.54	3.54	15.9	40	3	60
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59	1.36	1.59
Total porosity (%)	15	38	35	35	40	35
Field capacity (%)	15	9	12	35	33.4	N/A
Vertical hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	7.10E-03	1.60E-06	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	0.4	0.03	N/A
Longitudinal dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	N/A	N/A	260
Transverse dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	N/A	N/A	26
Vertical dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.064
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	20
Soil classification	clay	sand	sandy loam	loamy sand	silty clay	loamy sand
Sand (%)	20	92	65	83	7	83
Silt (%)	20	5	25	11	46	11
Clay (%)	60	3	10	6	47	6
Organic Matter (%)	0	0	0.1	0.1	0.1	0.1
Iron (%)	0	0	1.3	1.3	0	0
pH	8	8	7	6	7	7

N/A = Not Applicable

Type I Tanks - .ng and Equipment
(Saturated Zone - Barnwell McBean Aquifer)

Input Parameter	PSZ1 Vadose zone	PSZ2 Water Table Aquifer	PSZ3 Tan Clay Layer	SZ Barn.-McBean Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	0.064
Strata thickness (ft)	45.44	40	3	60
Bulk density (g/cm^3)	1.59	1.59	1.36	1.59
Total porosity (%)	35	35	40	35
Field capacity (%)	12	35	33.4	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	7.10E-03	1.60E-06	N/A
Longitudinal dispersion (ft)	0.454	0.4	0.03	N/A
Longitudinal dispersivity (ft)				
1 meter	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	260
Transverse dispersivity (ft)				
1 meter	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	26
Vertical dispersivity (ft)				
1 meter	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	0.064
Effective Porosity (%)	N/A	N/A	N/A	20
Soil classification	sandy loam	loamy sand	silty clay	loamy sand
Sand (%)	65	83	7	83
Silt (%)	25	11	46	11
Clay (%)	10	6	47	6
Organic Matter (%)	0.1	0.1	0.1	0.1
Iron (%)	1.3	1.3	0	0
pH	7	6	7	7

N/A = Not Applicable

T; Tanks
(Saturated Zone - Congaree Aquifer)

Input Parameter	PSZ1 Concrete Basemat Intact	PSZ1 Concrete Basemat Failed	PSZ2 Vadose zone	PSZ3 Water Table Aquifer	PSZ4 Tan Clay Layer	PSZ5 Barn.-McBea Aquifer	PSZ6 Green Clay Layer	SZ Congaree Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23
Strata thickness (ft)	3.54	3.54	15.9	40	3	60	5	100
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59	1.36	1.59	1.39	1.64
Total porosity (%)	15	38	35	35	40	35	40	34
Field capacity (%)	15	9	12	35	33.4	35	32.5	N/A
Vert. hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	7.10E-03	1.60E-06	5.60E-04	4.40E-09	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	0.4	0.03	0.6	0.05	N/A
Longitudinal dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27.45
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	285
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	290
Transverse dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28.5
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29
Vertical dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.71
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.73
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25
Soil classification	clay	sand	sandy loam	loamy sand	silty clay	loamy sand	clay	sand
Sand (%)	20	92	65	83	7	83	20	92
Silt (%)	20	5	25	11	46	11	20	5
Clay (%)	60	3	10	6	47	6	60	3
Organic Matter (%)	0	0	0.1	0.1	0.1	0.1	0.1	0.1
Iron (%)	0	0	1.3	1.3	0	0	0	0
pH	8	8	7	6	7	7	7	7

N/A = Not Applicable

Type I Tanks - .ng and Equipment
(Saturated Zone - Congaree Aquifer)

Input Parameter	PSZ1 Vadose zone	PSZ2 Water Table Aquifer	PSZ3 Tan Clay Layer	PSZ4 Barn.-McBean Aquifer	PSZ5 Green Clay Layer	SZ Congaree Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.23
Strata thickness (ft)	45.44	40	3	60	5	100
Bulk density (g/cm^3)	1.59	1.59	1.36	1.59	1.39	1.64
Total porosity (%)	35	35	40	35	40	34
Field capacity (%)	12	35	33.4	35	32.5	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	7.10E-03	1.60E-06	5.60E-04	4.40E-09	N/A
Longitudinal dispersion (ft)	0.454	0.4	0.03	0.6	0.05	N/A
Longitudinal dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	27.45
100 meter	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	285
Surface Water	N/A	N/A	N/A	N/A	N/A	290
Transverse dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	28.5
Surface Water	N/A	N/A	N/A	N/A	N/A	29
Vertical dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	0.71
Surface Water	N/A	N/A	N/A	N/A	N/A	0.73
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.23
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	25
Soil classification	sandy loam	loamy sand	silty clay	loamy sand	clay	sand
Sand (%)	65	83	7	83	20	92
Silt (%)	25	11	46	11	20	5
Clay (%)	10	6	47	6	60	3
Organic Matter (%)	0.1	0.1	0.1	0.1	0.1	0.1
Iron (%)	1.3	1.3	0	0	0	0
pH	7	6	7	7	7	7

N/A = Not Applicable

Ty‚ . Tanks
(Saturated Zone - Water Table Aquifer)

Input Parameter	PSZ1 Concrete Intact	PSZ1 Basemat Failed	PSZ2 Vadose zone	SZ Water Table Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	0.019
Strata thickness (ft)	2.74	2.74	24.8	40
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59
Total porosity (%)	15	38	35	35
Field capacity (%)	15	9	12	N/A
Vertical hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	N/A
Longitudinal dispersivity (ft)				
1 meter	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	260
Transverse dispersivity (ft)				
1 meter	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	26
Vertical dispersivity (ft)				
1 meter	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	0.12
Effective Porosity (%)	N/A	N/A	N/A	20
Soil classification	clay	sand	sandy loam	loamy sand
Sand (%)	20	92	65	83
Silt (%)	20	5	25	11
Clay (%)	60	3	10	6
Organic Matter (%)	0	0	0.1	0.1
Iron (%)	0	0	1.3	1.3
pH	8	8	7	6

N/A = Not Applicable

Type III Tanks . ing and Equipmnet
(Saturated Zone - Water Table Aquifer)

Input Parameter	PSZ1 Vadose zone	SZ Water Table Aquifer
Darcy velocity (ft/day)	N/A	0.019
Strata thickness (ft)	64.54	40
Bulk density (g/cm^3)	1.59	1.59
Total porosity (%)	35	35
Field capacity (%)	12	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	N/A
Longitudinal dispersion (ft)	0.645	N/A
Longitudinal dispersivity (ft)		
1 meter	N/A	27.5
100 meter	N/A	43.7
Seepline	N/A	255
Surface Water	N/A	260
Transverse dispersivity (ft)		
1 meter	N/A	2.75
100 meter	N/A	4.37
Seepline	N/A	25.5
Surface Water	N/A	26
Vertical dispersivity (ft)		
1 meter	N/A	0.07
100 meter	N/A	0.11
Seepline	N/A	0.64
Surface Water	N/A	0.65
Pore velocity (ft/day)	N/A	0.12
Effective Porosity (%)	N/A	20
Soil classification	sandy loam	loamy sand
Sand (%)	65	83
Silt (%)	25	11
Clay (%)	10	6
Organic Matter (%)	0.1	0.1
Iron (%)	1.3	1.3
pH	7	6

N/A = Not Applicable

Tyı , Tanks
(Saturated Zone - Barnwell McBean Aquifer)

Input Parameter	PSZ1 Concrete Basemat Intact	PSZ1 Concrete Basemat Failed	PSZ2 Vadose zone	PSZ3 Water Table Aquifer	PSZ4 Tan Clay Layer	SZ Barn.-McBean Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.064
Strata thickness (ft)	2.74	2.74	24.8	40	3	60
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59	1.36	1.59
Total porosity (%)	15	38	35	35	40	35
Field capacity (%)	15	9	12	35	33.4	N/A
Vertical hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	7.10E-03	1.60E-06	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	0.4	0.03	N/A
Longitudinal dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	N/A	N/A	260
Transverse dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	N/A	N/A	26
Vertical dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.064
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	20
Soil classification	clay	sand	sandy loam	loamy sand	silty clay	loamy sand
Sand (%)	20	92	65	83	7	83
Silt (%)	20	5	25	11	46	11
Clay (%)	60	3	10	6	47	6
Organic Matter (%)	0	0	0.1	0.1	0.1	0.1
Iron (%)	0	0	1.3	1.3	0	0
pH	8	8	7	6	7	7

N/A = Not Applicable

Type III Tanks .ing and Equipment
(Saturated Zone - Barnwell McBean Aquifer)

Input Parameter	PSZ1 Vadose zone	PSZ2 Water Table Aquifer	PSZ3 Tan Clay Layer	SZ Barnwell-McBean Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	0.064
Strata thickness (ft)	64.54	40	3	60
Bulk density (g/cm^3)	1.59	1.59	1.36	1.59
Total porosity (%)	35	35	40	35
Field capacity (%)	12	35	33.4	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	7.10E-03	1.60E-06	N/A
Longitudinal dispersion (ft)	0.645	0.4	0.03	N/A
Longitudinal dispersivity (ft)				
1 meter	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	260
Transverse dispersivity (ft)				
1 meter	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	26
Vertical dispersivity (ft)				
1 meter	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	0.064
Effective Porosity (%)	N/A	N/A	N/A	20
Soil classification	sandy loam	loamy sand	silty clay	loamy sand
Sand (%)	65	83	7	83
Silt (%)	25	11	46	11
Clay (%)	10	6	47	6
Organic Matter (%)	0.1	0.1	0.1	0.1
Iron (%)	1.3	1.3	0	0
pH	7	6	7	7

N/A = Not Applicable

Typ. . Tanks
(Saturated Zone -Congaree Aquifer)

Input Parameter	PSZ1 Concrete Basemat Intact	PSZ1 Concrete Basemat Failed	PSZ2 Vadose zone	PSZ3 Water Table Aquifer	PSZ4 Tan Clay Layer	PSZ5 Barn.-McB. Aquifer	PSZ6 Green Clay Layer	SZ Congaree Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23
Strata thickness (ft)	2.74	2.74	24.8	40	3	60	5	100
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59	1.36	1.59	1.39	1.64
Total porosity (%)	15	38	35	35	40	35	40	34
Field capacity (%)	15	9	12	35	33.4	35	32.5	N/A
Vert. hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	7.10E-03	1.60E-06	5.60E-04	4.40E-09	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	0.4	0.03	0.6	0.05	N/A
Longitudinal dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27.45
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	285
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	290
Transverse dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28.5
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29
Vertical dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.71
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.73
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25
Soil classification	clay	sand	sandy loam	loamy sand	silty clay	loamy sand	clay	sand
Sand (%)	20	92	65	83	7	83	20	92
Silt (%)	20	5	25	11	46	11	20	5
Clay (%)	60	3	10	6	47	6	60	3
Organic Matter (%)	0	0	0.1	0.1	0.1	0.1	0.1	0.1
Iron (%)	0	0	1.3	1.3	0	0	0	0
pH	8	8	7	6	7	7	7	7

N/A = Not Applicable

Type III Tanks ,ing and Equipment
(Saturated Zone - Congaree Aquifer)

Input Parameter	PSZ1 Vadose zone	PSZ2 Water Table Aquifer	PSZ3 Tan Clay Layer	PSZ4 Barn.-McBean Aquifer	PSZ5 Green Clay Layer	SZ Congaree Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.23
Strata thickness (ft)	64.54	40	3	60	5	100
Bulk density (g/cm^3)	1.59	1.59	1.36	1.59	1.39	1.64
Total porosity (%)	35	35	40	35	40	34
Field capacity (%)	12	35	33.4	35	32.5	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	7.10E-03	1.60E-06	5.60E-04	4.40E-09	N/A
Longitudinal dispersion (ft)	0.645	0.4	0.03	0.6	0.05	N/A
Longitudinal dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	27.45
100 meter	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	285
Surface Water	N/A	N/A	N/A	N/A	N/A	290
Transverse dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	28.5
Surface Water	N/A	N/A	N/A	N/A	N/A	29
Vertical dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	0.71
Surface Water	N/A	N/A	N/A	N/A	N/A	0.73
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.23
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	25
Soil classification	sandy loam	loamy sand	silty clay	loamy sand	clay	sand
Sand (%)	65	83	7	83	20	92
Silt (%)	25	11	46	11	20	5
Clay (%)	10	6	47	6	60	3
Organic Matter (%)	0.1	0.1	0.1	0.1	0.1	0.1
Iron (%)	1.3	1.3	0	0	0	0
pH	7	6	7	7	7	7

N/A = Not Applicable

Typ. . / Tanks
(Saturated Zone - Water Table Aquifer)

Input Parameter	PSZ1 Concrete Intact	PSZ1 Basemat Failed	PSZ2 Vadose zone	SZ Water Table Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	0.019
Strata thickness (ft)	0.58	0.58	5.94	40
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59
Total porosity (%)	15	38	35	35
Field capacity (%)	15	9	12	N/A
Vertical hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	N/A
Longitudinal dispersivity (ft)				
1 meter	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	260
Transverse dispersivity (ft)				
1 meter	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	26
Vertical dispersivity (ft)				
1 meter	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	0.12
Effective Porosity (%)	N/A	N/A	N/A	20
Soil classification	clay	sand	sandy loam	loamy sand
Sand (%)	20	92	65	83
Silt (%)	20	5	25	11
Clay (%)	60	3	10	6
Organic Matter (%)	0	0	0.1	0.1
Iron (%)	0	0	1.3	1.3
pH	8	8	7	6

N/A = Not Applicable

Type IV Tanks ,ing and Equipment
(Saturated Zone - Water Table Aquifer)

Input Parameter	PSZ1 Vadose zone	SZ Water Table Aquifer
Darcy velocity (ft/day)	N/A	0.019
Strata thickness (ft)	52.52	40
Bulk density (g/cm^3)	1.59	1.59
Total porosity (%)	35	35
Field capacity (%)	12	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	N/A
Longitudinal dispersion (ft)	0.525	N/A
Longitudinal dispersivity (ft)		
1 meter	N/A	27.5
100 meter	N/A	43.7
Seepline	N/A	255
Surface Water	N/A	260
Transverse dispersivity (ft)		
1 meter	N/A	2.75
100 meter	N/A	4.37
Seepline	N/A	25.5
Surface Water	N/A	26
Vertical dispersivity (ft)		
1 meter	N/A	0.07
100 meter	N/A	0.11
Seepline	N/A	0.64
Surface Water	N/A	0.65
Pore velocity (ft/day)	N/A	-
Effective Porosity (%)	N/A	-
Soil classification	sandy loam	loamy sand
Sand (%)	65	83
Silt (%)	25	11
Clay (%)	10	6
Organic Matter (%)	0.1	0.1
Iron (%)	1.3	1.3
pH	7	6

N/A = Not Applicable

Ty… / Tanks
(Saturated Zone - Barnwell McBean Aquifer)

Input Parameter	PSZ1 Concrete Basemat Intact	PSZ1 Concrete Basemat Failed	PSZ2 Vadose zone	PSZ3 Water Table Aquifer	PSZ4 Tan Clay Layer	SZ Barn.-McBean Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.064
Strata thickness (ft)	0.58	0.58	5.94	40	3	60
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59	1.36	1.59
Total porosity (%)	15	38	35	35	40	35
Field capacity (%)	15	9	12	35	33.4	N/A
Vertical hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	7.10E-03	1.60E-06	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	0.4	0.03	N/A
Longitudinal dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	N/A	N/A	260
Transverse dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	N/A	N/A	26
Vertical dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	N/A	N/A	0.65
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.064
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	20
Soil classification	clay	sand	sandy loam	loamy sand	silty clay	loamy sand
Sand (%)	20	92	65	83	7	83
Silt (%)	20	5	25	11	46	11
Clay (%)	60	3	10	6	47	6
Organic Matter (%)	0	0	0.1	0.1	0.1	0.1
Iron (%)	0	0	1.3	1.3	0	0
pH	8	8	7	6	7	7

N/A = Not Applicable

Type IV Tanks ,ing and Equipment
(Saturated Zone - Barnwell McBean Aquifer)

Input Parameter	PSZ1 Vadose zone	PSZ2 Water Table Aquifer	PSZ3 Tan Clay Layer	SZ Barnwell-McBean Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	0.064
Strata thickness (ft)	52.52	40	3	60
Bulk density (g/cm^3)	1.59	1.59	1.36	1.59
Total porosity (%)	35	35	40	35
Field capacity (%)	12	35	33.4	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	7.10E-03	1.60E-06	N/A
Longitudinal dispersion (ft)	0.525	0.4	0.03	N/A
Longitudinal dispersivity (ft)				
1 meter	N/A	N/A	N/A	27.5
100 meter	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	255
Surface Water	N/A	N/A	N/A	260
Transverse dispersivity (ft)				
1 meter	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	25.5
Surface Water	N/A	N/A	N/A	26
Vertical dispersivity (ft)				
1 meter	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	0.64
Surface Water	N/A	N/A	N/A	0.65
Pore velocity (cm/s)	N/A	N/A	N/A	0.064
Effective Porosity (%)	N/A	N/A	N/A	20
Soil classification	sandy loam	loamy sand	silty clay	loamy sand
Sand (%)	65	83	7	83
Silt (%)	25	11	46	11
Clay (%)	10	6	47	6
Organic Matter (%)	0.1	0.1	0.1	0.1
Iron (%)	1.3	1.3	0	0
pH	7	6	7	7

N/A = Not Applicable

Tyι . Tanks
(Saturated Zone -Congaree Aquifer)

Input Parameter	PSZ1 Concrete Basemat Intact	PSZ1 Concrete Basemat Failed	PSZ2 Vadose zone	PSZ3 Water Table Aquifer	PSZ4 Tan Clay Layer	PSZ5 Barn.-McB Aquifer	PSZ6 Green Clay Layer	SZ Congaree Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23
Strata thickness (ft)	0.58	0.58	5.94	40	3	60	5	100
Bulk density (g/cm^3)	2.21	1.64	1.59	1.59	1.36	1.59	1.39	1.64
Total porosity (%)	15	38	35	35	40	35	40	34
Field capacity (%)	15	9	12	35	33.4	35	32.5	N/A
Vert. hydraulic conductivity (cm/s)	9.60E-09	6.60E-03	7.10E-03	7.10E-03	1.60E-06	5.60E-04	4.40E-09	N/A
Longitudinal dispersion (ft)	0.0058	0.0058	0.054	0.4	0.03	0.6	0.05	N/A
Longitudinal dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	27.45
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	285
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	290
Transverse dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	28.5
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	29
Vertical dispersivity (ft)								
1 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.71
Surface Water	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.73
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25
Soil classification	clay	sand	sandy loam	loamy sand	silty clay	loamy sand	clay	sand
Sand (%)	20	92	65	83	7	83	20	92
Silt (%)	20	5	25	11	46	11	20	5
Clay (%)	60	3	10	6	47	6	60	3
Organic Matter (%)	0	0	0.1	0.1	0.1	0.1	0.1	0.1
Iron (%)	0	0	1.3	1.3	0	0	0	0
pH	8	8	7	6	7	7	7	7

N/A = Not Applicable

Type IV Tanks ,ping and Equipment
(Saturated Zone - Water Table)

Input Parameter	PSZ1 Vadose zone	PSZ2 Water Table Aquifer	PSZ3 Tan Clay Layer	PSZ4 Barnwell-McBean Aquifer	PSZ5 Green Clay Layer	SZ Congaree Aquifer
Darcy velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.23
Strata thickness (ft)	52.52	40	3	60	5	100
Bulk density (g/cm^3)	1.59	1.59	1.36	1.59	1.39	1.64
Total porosity (%)	35	35	40	35	40	34
Field capacity (%)	12	35	33.4	35	32.5	N/A
Vertical hydraulic conductivity (cm/s)	7.10E-03	7.10E-03	1.60E-06	5.60E-04	4.40E-09	N/A
Longitudinal dispersion (ft)	0.525	0.4	0.03	0.6	0.05	N/A
Longitudinal dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	27.45
100 meter	N/A	N/A	N/A	N/A	N/A	43.7
Seepline	N/A	N/A	N/A	N/A	N/A	285
Surface Water	N/A	N/A	N/A	N/A	N/A	290
Transverse dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	2.75
100 meter	N/A	N/A	N/A	N/A	N/A	4.37
Seepline	N/A	N/A	N/A	N/A	N/A	28.5
Surface Water	N/A	N/A	N/A	N/A	N/A	29
Vertical dispersivity (ft)						
1 meter	N/A	N/A	N/A	N/A	N/A	0.07
100 meter	N/A	N/A	N/A	N/A	N/A	0.11
Seepline	N/A	N/A	N/A	N/A	N/A	0.71
Surface Water	N/A	N/A	N/A	N/A	N/A	0.73
Pore velocity (ft/day)	N/A	N/A	N/A	N/A	N/A	0.23
Effective Porosity (%)	N/A	N/A	N/A	N/A	N/A	25
Soil classification	sandy loam	loamy sand	silty clay	loamy sand	clay	sand
Sand (%)	65	83	7	83	20	92
Silt (%)	25	11	46	11	20	5
Clay (%)	10	6	47	6	60	3
Organic Matter (%)	0.1	0.1	0.1	0.1	0.1	0.1
Iron (%)	1.3	1.3	0	0	0	0
pH	7	6	7	7	7	7

N/A = Not Applicable

ATTACHMENT C

MEPAS Output File Nomenclature

MEPAS OUTPUT FILES NOMENCLATURE

Input and output files are named VWXX(E or L)YYY.*,

where V = N for Non-radiological
= R for Radiological

W = A for grout filled tanks (radiological)
= R for grout filled tanks(nonradiological)
= G for grouted piping/ancillary equipment

XX = failure time (of cover and basemat) in hundreds of years
= 10 = Failure at 1,000 years

E = early (pre-failure) runs
L = late (post-failure) runs

YYY = Infiltration rate in cm/year
= 004 = 4 cm/year
= 040 = 40 cm/year

There are also a set of runs (V-1)WXXEYYY, where V-1 is one letter prior to V. These runs are the same as VWXXE except that the inventory reflects only material reaching aquifer prior to failure. (V-1)WXXEYYY results are combined with late results in *.ECO files (concentration vs. time + dose).

MEPAS file extentions are as follows:

*.WIN = FORTRAN input file to water transport code (RADCON)
*.HIN = FORTRAN input file to exposure code (HAZ)
*.CHM = FORTRAN input file containing chemical property information
*.WAT = 70-year average concentrations (output file)
*.POL = Fluxes and concentrations through each layer (output file)
*.HHI = Peak doses at each receptor by pathway (output file)
*.WLS = Listing of input information used by code and peak concentrations (output file)

ATTACHMENT D

FORTRAN Program ECOCONC.EXE

```
C  OVERLAY 70 YEAR CONCENTRATIONS FROM EARLY/LATE TANKS/PIPES
      CHARACTER FILEN*8, NFILE(6)*8, LOC(6)*24, ELEM(20)*8, CON(20)*8
      CHARACTER E*8
      DIMENSION C( 8, 20, 180), NP( 7)
      DATA NI, NJ, NK, NL/ 8, 20, 180, 6/
      OPEN( 5, FILE= 'ECOCONC.IN', STATUS= 'OLD')
C  I= PATHWAYS  J= CONSTITUENT  K= TIME STEP  L= ANALYSIS (EARLY/LATE
C                                                        TANKS/PIPES)
      L = 0
      IEND = 1
      KMAX = 1
24    READ( 5, 2, END= 1) FILEN
2     FORMAT( A8)
      IF( FILEN( 1: 1) .EQ. '-') THEN
       IEND = 0
       GO TO 1
      ENDIF
C  KADD IS INCREMENT ON TIME FOR THIS CASE
      KADD = 0
      L = L + 1
      NFILE( L) = FILEN
      IF( L .GT. NL) STOP 4
      BACKSPACE( 5)
C  READ DEGRADATION TIME (100s YRS)  AND  INFILTRATION RATE (CM/YR)
      READ( 5, 3) IT, IR
3     FORMAT( 2X, I2, 1X, I3)
      IF( FILEN( 5: 5) .EQ. 'L')THEN
       IT = IT * 100 + 35
       KADD = IT / 70
      ENDIF
      CLOSE( 9)
      CLOSE( 7)
      CLOSE( 6)
      OPEN( 9, FILE= FILEN//'.WIN', STATUS='OLD')
      OPEN( 7, FILE= FILEN//'.HIN', STATUS='OLD')
      OPEN( 6, FILE= FILEN//'.WAT', STATUS='OLD')
```

```
C  ECO FILE WILL HAVE NAME OF FIRST FILE ON LIST
      IF( L .EQ. 1) THEN
       OPEN( 8, FILE= FILEN//'.ECO', STATUS='UNKNOWN')
      ENDIF
      READ( 7, 4)
      READ( 7, 4)
4     FORMAT( A1)
      READ( 7, 5) NCON
5     FORMAT( I3)
      IF( NCON .GT. NJ) STOP 1
      DO 6 M = 1, NCON
6     READ( 7, 2) CON( M)
C  READ LOCATION NAMES
      READ( 7, 12) NP
12    FORMAT( 7I3)
      NPT= NP( 1) + NP( 3)
      IF( NPT .GT. NI) STOP 2
      MP = 0
      READ( 9, 2, END = 30) E
      DO 28 M = 1, 8
      IF( E( M: M) .EQ. 'N'  .OR.  E( M: M) .EQ. 'Y') GO TO 28
      GO TO 29
28    CONTINUE
      MP = MP + 1
      READ( 9, 31) LOC( MP)
31    FORMAT( 15X, A24)
      GO TO 29
30    IF( MP .NE. NPT) STOP 7
      READ( 6, 4)
C  READ WAT FILE
      DO 13 I= 1, NPT
      READ( 6, 4)
      READ( 6, 4)
      DO 13 J= 1, NCON
      READ( 6, 14, END= 22) K, JJ, E, CC, U
14    FORMAT( 4X, I3, 3X, I2, 2X, A8, 22X, 2E10.3)
```

```
      IF( K .EQ. -88) GO TO 13
      IF( J .NE. JJ) STOP 3
      ELEM( J) = E
      C( I, J, K + KADD) = C( I, J, K + KADD) + CC * U
      IF( K + KADD .GT. KMAX) THEN
       KMAX = K + KADD
       IF( KMAX. GT. NK) STOP 6
      ENDIF
      GO TO 21
13    CONTINUE
      GO TO 24
C  WRITE RESULTS
1     CONTINUE
      IF( L .EQ. 0) STOP
      DO 16 I= 1, NPT
      IF( L .GT. 1) THEN
       WRITE( 8, 27)
       WRITE( 8, 17) LOC( I), NFILE( 1), NFILE( 1),
     a (NFILE( LL), LL = 2, L)
       IF( I .EQ. 1) WRITE( *, 26) NFILE( 1), NFILE( 1),
     a (NFILE( LL), LL = 2, L)
      ELSE
       WRITE( 8, 27)
       WRITE( 8, 17) LOC( I), NFILE( 1), NFILE( 1)
       IF( I .EQ. 1) WRITE( *, 26) NFILE( 1), NFILE( 1)
      ENDIF
      WRITE( 8, 25) ( ELEM( J), J= 1, NCON)
      WRITE( 8, 18)  (CON( J), J= 1, NCON)
27    FORMAT( 78( '='))
17    FORMAT(/ 1X, 'LOCATION = ', A24, 4X, 'FILE IS : ', A8, '.ECO = ',
     aA8, 6(' + ', A8))
26    FORMAT( 1X, '  FILE IS : ', A8, '.ECO = ', A8,
     a 6(' + ', A8))
25    FORMAT(/ '  70'/ ' YEAR', 1X, 20( A8, 1X))
      FORMAT( ' PER.', 1X, 20( A8, 1X)/)
      KWRIT = KMAX
```

```
C  LIMIT OUTPUT TO 157 LINES ( FOR CONSISTENCY WITH FULMER SPREAD SHEETS)
       KWRIT = 157
       DO 16 K = 1, KWRIT
       WRITE( 8, 20) K, ( C( I, J, K), J= 1, NCON)
20     FORMAT( 1X, I3, 1P20E9.1)
16     CONTINUE
C  ZERO OUT C, CON, LOC, ELEM
       DO 15 I = 1, NI
       LOC( I) = '                   '
       DO 15 J = 1, NJ
       ELEM( J) = '          '
       CON( J) = '          '
       DO 15 K = 1, NK
15     C( I, J, K) = 0.
       IF( IEND .EQ. 1) STOP
       KMAX = 1
       L = 0
       IEND = 1
       GO TO 24
22     STOP 5
       END
```