

PROTOCOL

CUMULATIVE CONTAMINANT MIGRATION

The following describes SRS's approach to evaluate the impact of cumulative contaminant migration (CM) in groundwater from units in proximity to each other. The cumulative impact will be evaluated by preparing a list of preliminary CM constituents of concern (COCs) from each unit. The basic approach to be applied is as follows:

- 1) Concentration-Based Standards. For any constituent that has a concentration-based regulatory limit for groundwater, any preliminary CM COC from any of the individual basins will be listed as a preliminary CM COC for the basins as a group. The regulatory limits include maximum concentration limits (MCLs) and risk-based concentrations or activities. Concentration-based standards includes metals, organics, inorganics and alpha-emitting radionuclides. The MCL for gross alpha particle activity is 15 pCi/L, exclusive of radon and uranium. Additionally, if the gross alpha particle activity is greater than 5 pCi/L, the activity of radium-226 and radium-228 must be determined.
- 2) Dose-Based Standards. The principal exception from concentration-based standards beta-emitting radionuclides. Gross beta particle activity is a dose-based MCL to which a suite of radionuclides may contribute, Safe Drinking Water Act, (40 CFR 141.16). The average annual dose of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or an internal organ greater than 4 mrem/year).

CONSTITUENTS WITH CONCENTRATION-BASED STANDARDS

For constituents with concentration-based regulatory limits, there is no additive increase to groundwater contamination from adjacent units since the maximum predicted groundwater concentration from any single basin would not be exceeded by the combined leachate from all the basins due to dilution. The combined outcome is controlled by the volume and concentration mixing ratios as presented in the equation:

$$C_1V_1 + C_2V_2 = C_3V_3$$

where:

C_1 = the predicted concentration below unit 1

V_1 = the volume of the leachate below unit 1

C_2 = the predicted concentration below unit 2

V_2 = the volume of the leachate below unit 2

C_3 = aggregated concentration at a well in close proximity to unit 1 and 2

V_3 = the total volume of leachate below the aggregated units

Solving for C_3 (the aggregated concentration):

$$C_3 = \frac{C_1V_1 + C_2V_2}{V_3}$$

The total leachate volume is equal to the sum of the two leachate volumes, so

$$V_3 = V_1 + V_2$$

Substituting,

$$C_3 = \frac{C_1V_1 + C_2V_2}{V_1 + V_2}$$

As indicated by this equation, the aggregated concentration (C_3) will not exceed the maximum concentration from the particular unit contributing the highest concentration (C_{max}). Attachment A provides a visual representation of the above. Thus, constituents with concentration-based regulatory limits can be dropped from the cumulative analysis.

DOSE-BASED REGULATORY STANDARDS

For those constituents with a dose-based MCL, i.e., beta-emitters, separate radionuclides could contribute to a combined dose or radioactivity that exceeds the level of the individual radionuclides. Therefore, it is appropriate to sum the activities of beta-emitting radionuclides in the modeled release to determine if the total dose exceeds regulatory limits. The applicable MCL is the 4 mrem/year limit for beta-emitting radionuclides in groundwater. The process for evaluating the additive effect is described below.

The cumulative effect of the constituents with a dose-based limit is evaluated to determine if the combined release will result in an exceedance of the regulatory standard for groundwater.

Consideration is given to those constituents that were identified as CM-COPCs and are predicted to reach the water table within 1,000 years. To assess the effect from beta-emitting radionuclides that appear at more than one unit, only the maximum predicted groundwater activity for a given radionuclide from each waste unit in the group would be selected. Adding the dose, utilizing the maximum predicted activities for each radionuclide from all units, will provide the most conservative estimate of the total radioactivity that could be released in the groundwater. Beta-emitters present in the aquifer at the current time, also need to be factored into the summation as well as any modeled releases. This assumption is only valid if the waste units are oriented parallel to the groundwater flow direction and are adjacent to each other, and if leachate below all units would actually mix into a co-mingled plume.

If the additive groundwater activities exceed the regulatory standard, the data is re-evaluated to assess predicted travel times from the bottom of the waste unit through the vadose zone to the aquifer. The dose of each of the predicted radionuclides (if they are ever present in the groundwater simultaneously) are summed to determine their combined activities and then compared to the regulatory standard.

If consideration of the temporal effects on leachate activities still indicates a potential problem, the scenario is re-evaluated to determine which exposure units actually lie parallel to the groundwater flow path. The data would be re-sorted for only those units that have the potential to successively contribute leachate to a single volume of groundwater, i.e. a co-mingled plume. Attachment B is a flow chart depicting the process of addressing dose as a result of contaminant migration from units in proximity to one another.

The doses resulting from all the manmade beta-emitting radionuclides cannot exceed 4 mrem/yr. The concentrations of the more important manmade isotopes that result in a 4 mrem/yr dose have previously been calculated by USEPA (USEPA, Radioactivity in Drinking Water, EPA-570/9-76-003, Appendix III, January 1981).

Consider the following example. Two waste units are contiguous to one another. Both are oriented parallel to the groundwater flow direction. Modeling indicates that a hypothetical receptor well, in common and downgradient from both waste units, will yield the following results, as depicted in Tables 1 and 2.

Table 1. Example of Model Predictions for Concentrations and Travel Times

Beta-Emitting- CM-COPC	Predicted Maximum Concentration, pCi/L	Predicted Travel Time, years
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Cesium-137	0	>1,000
Iodine-129	.2	4
Strontium-90	6	170
Technetium-99	180	5.5

Table 2. Example for Calculation of Additive Dose

Beta-Emitting- CM-COPC	Concentration, pCi/L	Concentration Yielding a Dose of 4 mrem/yr	Resulting Dose, mrem/yr
Cesium-137	0	200	0
Iodine-129	.2	1	.8
Strontium-90	6	8	3
Technetium-99	180	900	.8
Additive Dose			4.6

The equation used to calculate the dose for the individual radionuclide is:

$$C_w/E_q * 4\text{mrem/yr} = \text{mrem/yr}$$

Where:

C_w = Radionuclide concentration in groundwater (pCi/L)

E_q = Radionuclide-specific 4 mrem/yr equivalent dose (pCi/L)

The additive dose is then calculated by summing the doses for each of the individual beta-emitting radionuclides.

Because the additive dose of beta-emitting radionuclides (4.6 mrem/yr) exceeds the regulatory standard (4 mrem/yr), a temporal analysis of the travel times must be performed to determine if any of the radionuclides will ever be present in the aquifer simultaneously. Please refer to the graph in Attachment C.

Temporal Analysis

Based upon the data in the graph (Attachment C) it will be noted that the Sr-90 dose is predicted to peak at 3 mrem/yr in approximately 180 years. Because no other beta-emitting radionuclides are present within the Sr-90 rise-fall time and the predicted peak does not exceed 4 mrem/yr, Sr-90 could not be considered a CM-COC. Similarly, no Cs-137 is predicted to leach to the aquifer, so it could not be considered as a CM-COC either.

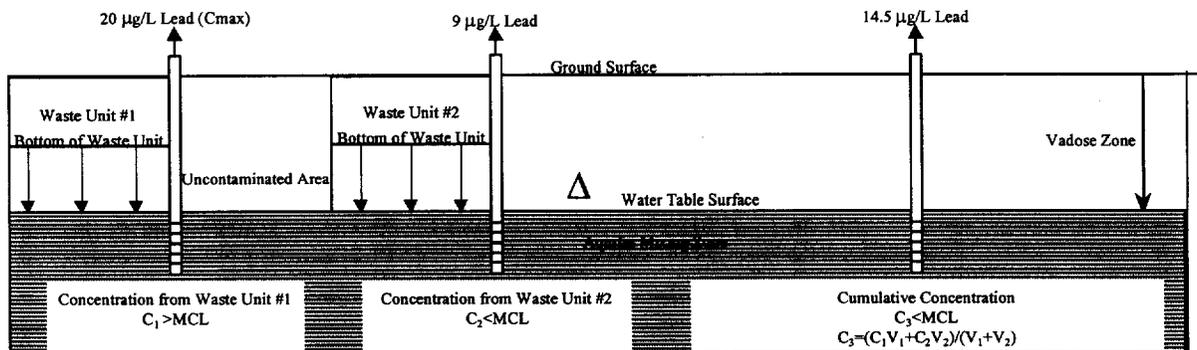
However, the temporal analysis of the rise-fall times for I-129 and Tc-99 indicate an overlapping of their respective curves. The midpoint of the overlap occurs at approximately 8 years when both I-129 and Tc-99 occur simultaneously within the aquifer. In this case, the temporal analysis requires that the two radionuclides be evaluated for additive dose to determine if the 4 mrem/yr regulatory standard is exceeded. Summing the maximum doses at the overlap will yield the maximum dose possible for contributions from both radionuclides. In this case, the additive dose is 1.2 mrem/yr, which still does not exceed the regulatory standard.

ATTACHMENT A: CUMULATIVE LEAD CONCENTRATIONS LEACHED FROM ADJACENT WASTE UNITS

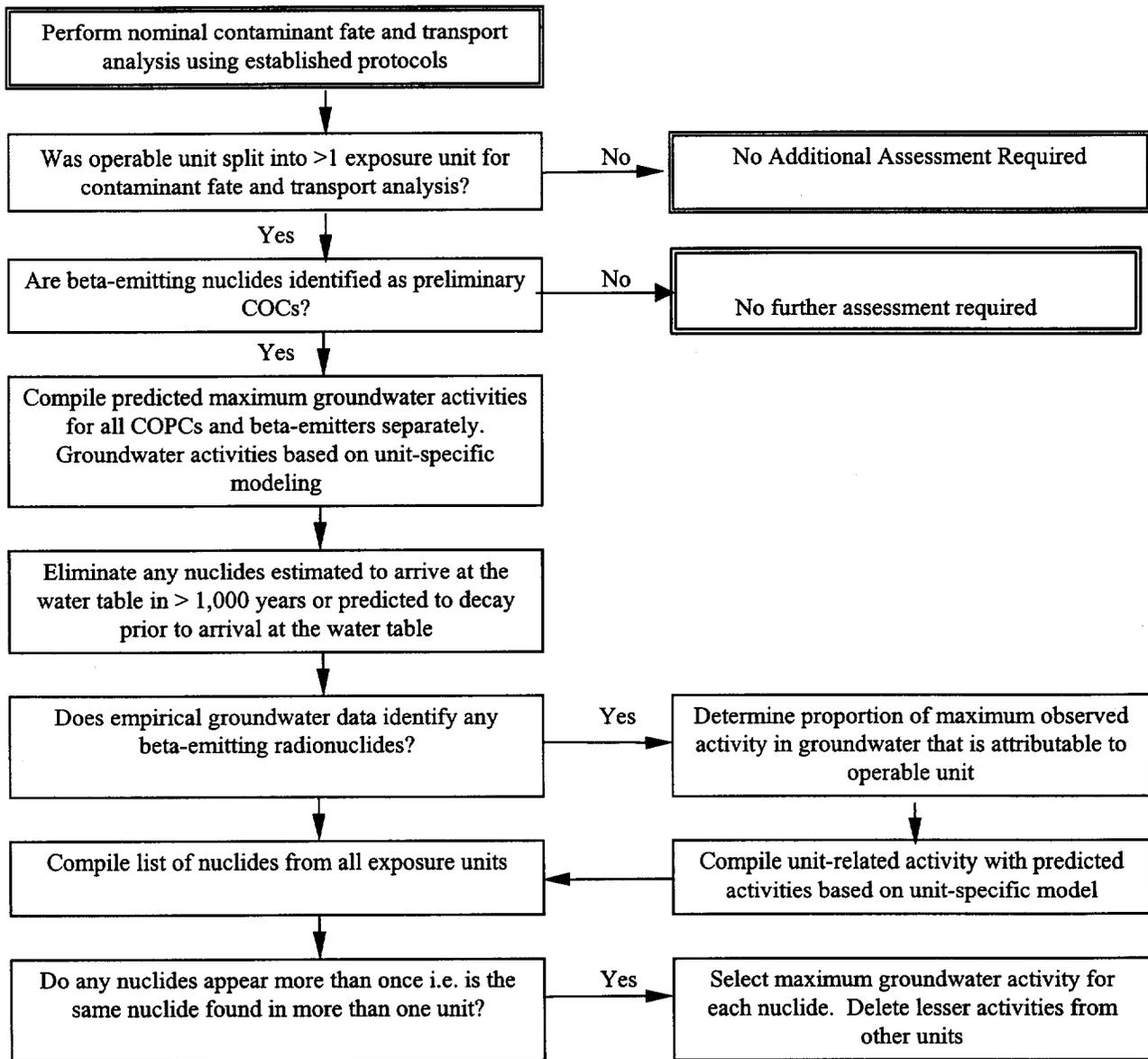
$$C_3 = \frac{C_1V_1 + C_2V_2}{V_1 + V_2}$$

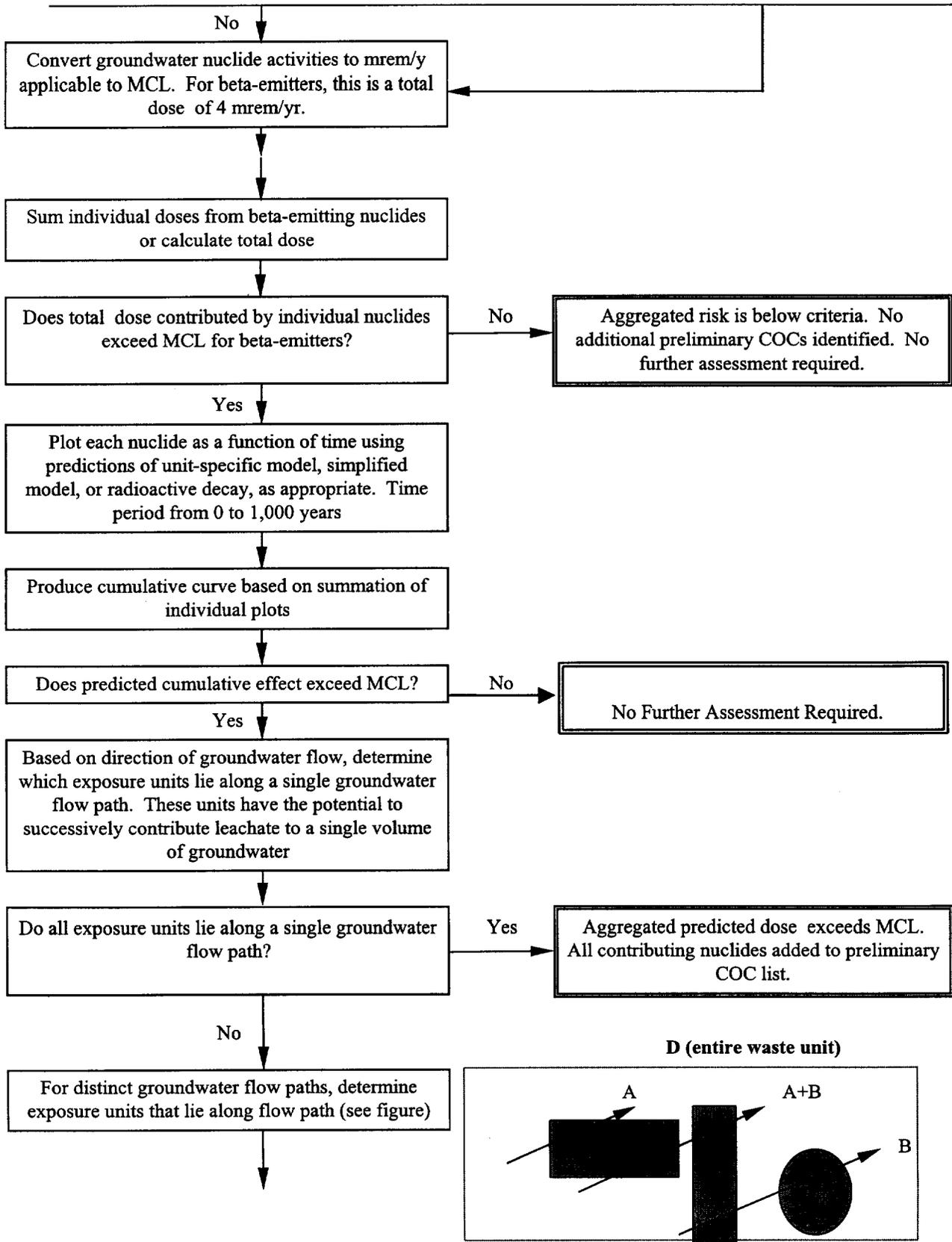
If: $C_1=20 \mu\text{g/L}$
 $V_1=500,000 \text{ Liters}$
 $C_2=9 \mu\text{g/L}$
 $V_2=500,000 \text{ Liters}$
 $C_3=14.5 \mu\text{g/L}$

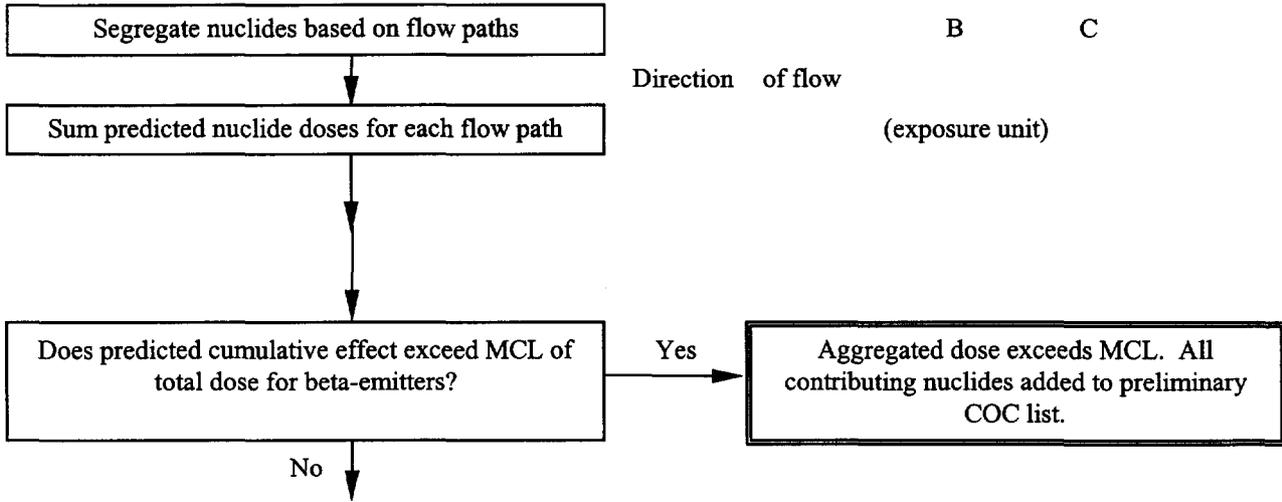
Background = 0.0 $\mu\text{g/L}$ Lead
 MCL = 15 $\mu\text{g/L}$ Lead



ATTACHMENT B. DRAFT PROCEDURE FOR AGGREGATING CONTAMINANT FATE AND TRANSPORT ANALYSIS RESULTS FOR AN OPERABLE UNIT







No additional preliminary COCs identified. No further assessment

Attachment C: Example of Additive Dose for Temporal Analysis

