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D. E. Stephenson, C. M. King, B. B. Looney,
W. G. Holmes, and D. E. Gordon

E. I. du Pont de Nemours and Company
Savannah River Laboratory
Aiken, SC 29808

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ABSTRACT

Remedial action at hazardous waste sites must be designed to minimize the risk to human health. Additionally, such remedial action should be achieved in the most cost-effective manner. A risk assessment strategy consistent with these objectives has been developed for closure of waste sites which may potentially contain hazardous substances at the Savannah River Plant. The strategy consists of 1) site characterization, 2) contaminant transport modeling, and 3) determination of relative merits of alternative remedial actions according to the degree of health protection they provide.

The evaluation process for assessing human health risk requires several types of data and analysis. Information needs to be available on the likely residual concentration of contaminants in the environmental media (soil, groundwater) for each of the remedial action alternatives proposed for a given waste site or

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facility. A prediction of potential transport or movement of contaminants must be performed using field data and computer codes which model transport in the unsaturated and saturated zones. Where data are lacking for each calculation, the worst case assumption is used. Input to such numerical models should be able to distinguish between alternative remedial action plans proposed for the site; however, the uncertainties associated with these data may preclude meeting this objective.

The solute transport calculation leads to an estimate of contaminant concentration in the environmental media to which human populations could be exposed. This concentration information is then used to estimate health effects by considering potential for human intake. This is a function of the human exposure pathway under evaluation. Completion of the human health risk evaluation process requires information on the toxicological properties of the various contaminants and a means to assess the likelihood of adverse effects projected for each remedial action alternative.

INTRODUCTION

The Savannah River Plant (SRP), a major Department of Energy facility for the production of nuclear materials, is located along the Savannah River in South Carolina (Figure 1). During the years of operation (1954-present) a large number of sites have been used for the disposal of hazardous, low-level radioactive, and mixed wastes (Figure 2). There are currently ongoing programs being conducted at these waste sites which include monitoring, characterization, and assessment and where necessary the implementation of remedial action projects including closure of these sites. Using this approach, it was determined that there are eighty-two waste sites at 48 distinct geographical locations which will require a risk assessment for evaluating various closure and remedial action options. Because of the diverse situations in which the waste has been disposed and the specific nature of the various wastes, each disposal site can present a unique case. Therefore, a strategy for waste site closure and contaminated groundwater cleanup has been developed (Figure 3).

DISCUSSION

The purpose of risk assessment at SRP is to characterize the environmental impacts and associated health effects from the proposed remedial action at each waste site. Risk assessment may be divided into three major components: hazard assessment, exposure assessment, and risk characterization. This is being accomplished at SRP through a systematic process (Figure 4):

characterizing the waste site to determine what, if any, potential hazardous material is present; identifying potential exposure pathways; performing transport modeling to estimate the concentrations of hazardous materials at receptor locations to which humans might be exposed from the various remedial actions; and determining the human health effect risk from the concentrations.

The first task in the risk assessment is to identify the hazard. This involves determining the hazardous materials which are present at the waste site and in what amounts. This is a tedious task in a number of instances because of the diverse materials and substances which have been disposed of at the waste sites. At SRP this is accomplished principally by a program of site characterizations. The SRP waste sites are being carefully characterized based on the following:

- An estimate of the waste inventory at the site if one is not available
- A groundwater monitoring and analysis program to determine if contaminants have reached the water table
- An engineering survey of the site
- Collection of geologic and hydrogeologic data to determine the physical setting
- Soil sampling and analysis to identify contaminants in the soil below the site
- A review of the toxicity of the materials available for potential transport through subsurface and atmospheric environments.

The characterization phase is then followed by the analysis of potential transport. This may be semi-quantitative or involve detailed numerical calculations. Once the contaminant transport

calculation is completed to obtain an estimate of concentration in an environmental media to which the human population could be exposed, this information is used to estimate health effects. This is done by considering the daily human intake of the residual concentration of potential contaminants from the specific pathway. This exposure assessment is referred to as the daily human dose (DHD).

Completion of the human health risk evaluation or risk characterization process requires information on the toxicological properties of the potential concentration of contaminants and means to assess the likelihood of adverse effects at the DHD levels. Two measures of toxicity cited in the literature and used in risk assessments at waste sites are:

- Acceptable Daily Intake (ADI) for noncarcinogens
- Unit Carcinogen Risk (UCR) for carcinogens (i.e., the risk at a unit dose, measured in mg/kg body weight/day).

Both ADI and UCR values are based upon clinical toxicology studies on laboratory animals and models of dose-response relationships applicable to humans. These are then translated to a health effect expressed as chronic risk index (CRI) or carcinogenic risk (CR):

(1) Chronic Risk Index = $\log \left(\frac{\text{daily human dose}}{\text{acceptable daily intake}} \right)$

(2) Carcinogenic Risk = daily human dose x unit carcinogenic risk.

Limits were established for the evaluation of the closure options so that the CRI will be less than zero and the CR less than or equal to 10^{-6}.

At SRP the principal criteria being used in risk assessments associated with remedial action alternatives are: (1) comparison of residual soil contamination to guidelines to evaluate the presence of potential hazards; (2) transport of potential contaminants; (3) pathway analysis; and (4) the potential for health effects. As an example of this methodology the risk assessment for the closure of a settling basin using three remedial options is presented. The remedial actions considered were: a) backfill the basin, b) backfill the basin and cap the site, and c) excavate the basin, backfill, and cap the site with the excavated material transported to a disposal site.

In considering the potential risk at the waste facilities at SRP relative to the performance of remedial actions, the groundwater is considered as the significant pathway for human exposure. Infiltrating water carries the waste through the vadose zone to the water table and then eventually to surface streams. A prediction of the potential for contamination and transport within the groundwater system is accomplished by modeling.

Based upon data obtained from characterization studies for the settling basin, five key contaminants were identified. Using these key contaminants as the source term along with existing soil chemistry and geohydrologic parameters, values of the flux to the water table and transport in the saturated zone were calculated for each contaminant using the DOSTOMAN code (King, 1985). The results obtained are expressed as parts per billion (ppb) of predicted

concentration in the groundwater and Savannah River (assuming outcrop and discharge with no sediment sorption). The results are given for each remedial action (Table 1). These results were converted to health effects as a function of closure option (Table 2).

The results in Table 2 illustrate that backfilling the site only is not acceptable since the CRI and CR exceed the established acceptable level. Capping the site is sufficient to meet public health requirements based upon transport and CRI/CR analysis.

A cleanup program to remove chlorocarbons from the groundwater using pumping/air stripping is in place at this site. This active cleanup addresses the compounds which result in the largest component of calculated risk. The increased cost for excavation of the contaminated material is not warranted based upon (1) meeting the absolute health effect risk goals described above, or (2) assuring responsible use of funds to maximize benefits (the incremental reduction in calculated risk is low relative to costs of excavation and disposal). Capping or excavation/capping combined with the existing groundwater cleanup will result in an effective closure/ remedial action for this example site.

CONCLUSIONS

The criterion of maximum achievable health protection at lowest cost requires consideration of the relative degree of health protection offered by the alternative plan. As the evaluation scheme is now defined, this determination is relatively straightforward, at least in concept, and can be summarized as follows.

- Site characterization required to define potential hazardous materials at waste disposal location
- Pathway analysis identifies possible routes for exposure to human population
- Contaminant transport modeling calculates concentrations at human receptor locations
- Health effects based on toxicological properties and exposure concentrations of contaminants

TABLE 1

Predicted Contaminant Concentrations in Groundwater (GW) and Surface Water (SW), µg/L

Contaminant	Closure Alternatives					
	Option a		Option b		Option c	
	GW	SW	GW	SW	GW	SW
Nickel	30	10^{-4}	10^{-1}	10^{-5}	10^{-3}	10^{-7}
Nitrate	500	10^{-1}	50	10^{-2}	<1	10^{-4}
Perclene	400	10^{-1}	10^{-4}	10^{-3}	10^{-3}	10^{-7}
Triclene	10	10^{-3}	10^{-1}	10^{-5}	10^{-3}	10^{-7}
Trichloroethane	1	10^{-4}	10^{-2}	10^{-6}	10^{-4}	10^{-8}

TABLE 2

Health Risk Assessment for the Closure Options, 1/yr

Contaminant	Closure Alternatives					
	Option a		Option b		Option c	
	CRI	CR	CRI	CR	CRI	CR
Nickel	0	10^{-3}	-2	10^{-7}	-4	10^{-9}
Nitrate	-2	-	-4	-	-6	-
Perclene	2	10^{-2}	0	10^{-9}	-2	10^{-8}
Triclene	0	10^{-4}	-2	10^{-7}	-4	10^{-9}
Trichloroethane	-3	10^{-7}	-5	10^{-9}	-7	10^{-11}

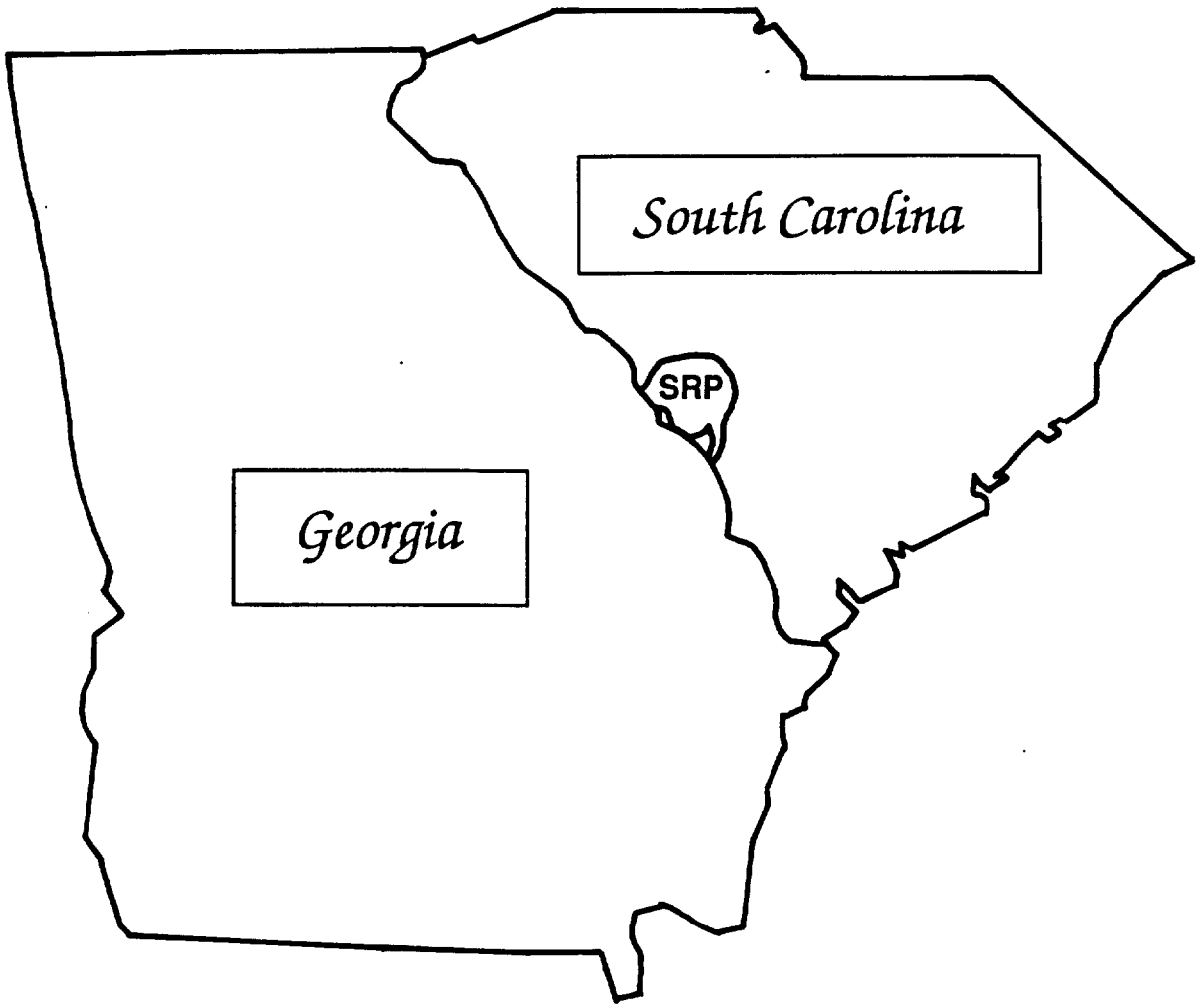

FIGURE 1. Location of Savannah River Plant

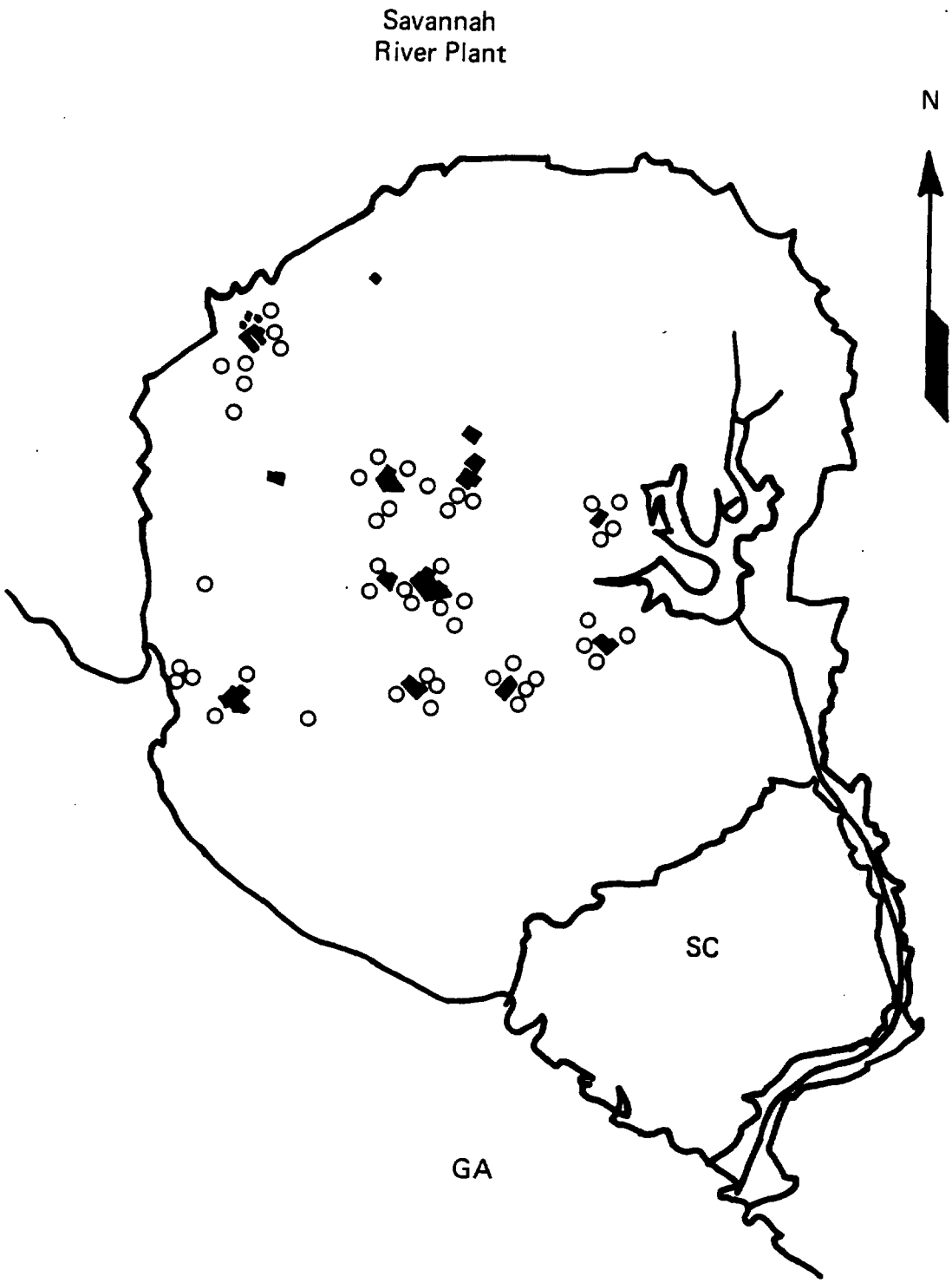

FIGURE 2. SRP Waste Sites

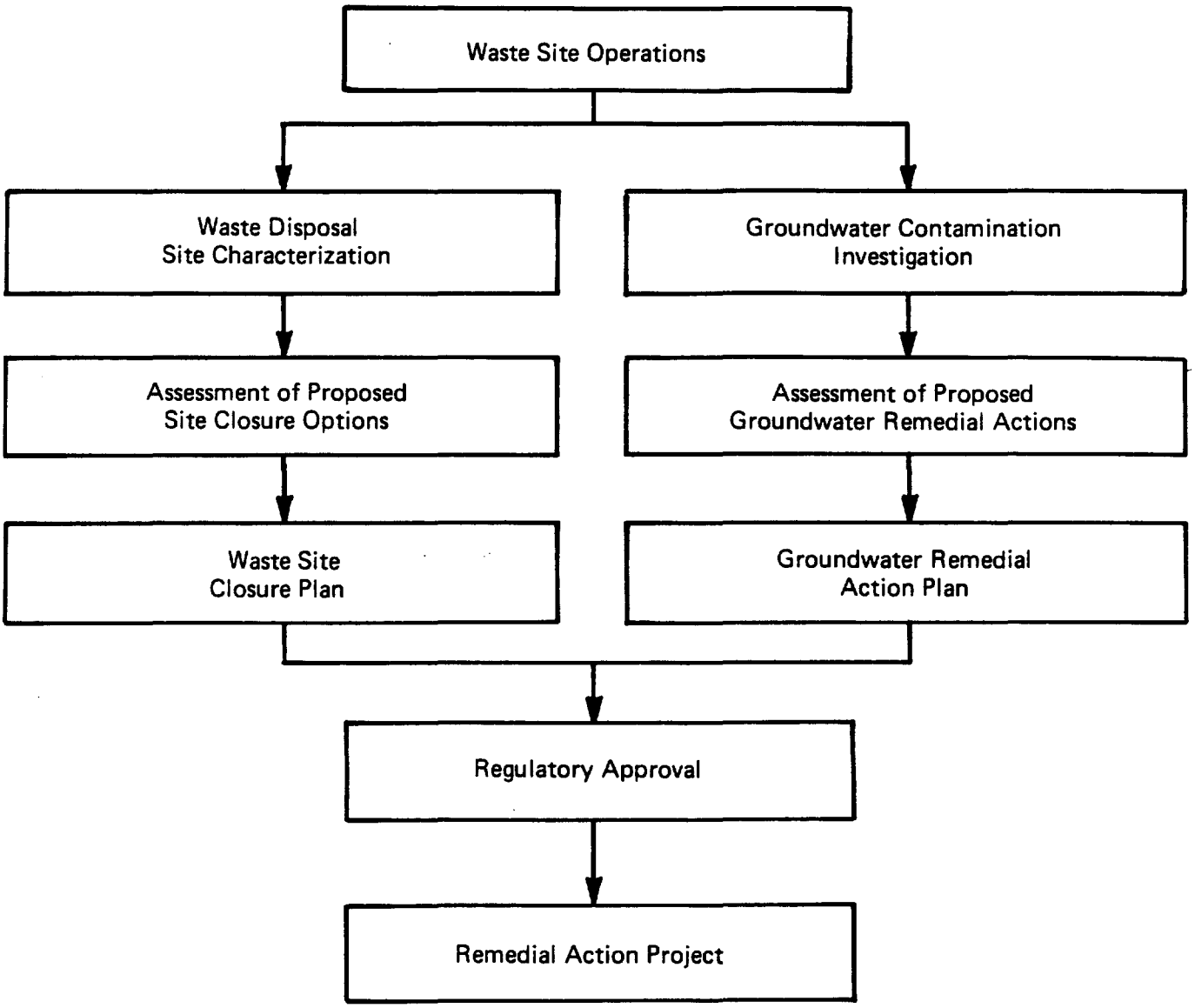

FIGURE 3. Waste Site Closure and Groundwater Protection Strategy

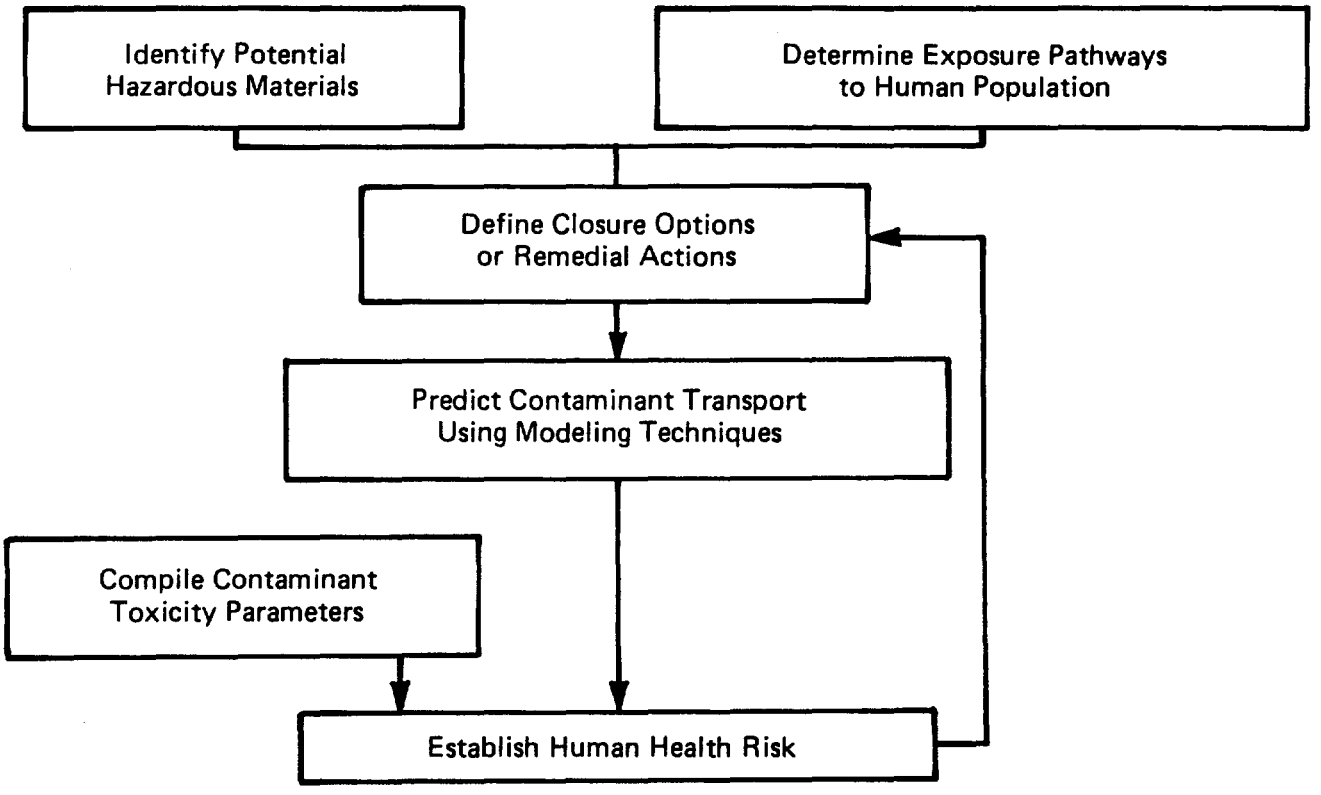

FIGURE 4. Health Risk Assessment Approach