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PROBCON-HDW: A Probability and Consequence System of Codes for Long-Term Analysis of Hanford Defense Wastes

**M. G. Piepho
T. H. Nguyen**

December 1988

**Prepared for the U.S. Department of Energy
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Richland, Washington 99352

ABSTRACT

The PROBCON-HDW (PROBability and CONsequence analysis for Hanford defense waste) computer code system calculates the long-term cumulative releases of radionuclides from the Hanford defense wastes (HDW) to the accessible environment and compares the releases to environmental release limits as defined in 40 CFR 191. PROBCON-HDW takes into account the variability of input parameter values used in models to calculate HDW release and transport in the vadose zone to the accessible environment (taken here as groundwater). A human intrusion scenario, which consists of drilling boreholes into the waste beneath the waste sites and bringing waste to the surface, is also included in PROBCON-HDW. PROBCON-HDW also includes the capability to combine the cumulative releases according to various long-term (10,000 year) scenarios into a composite risk curve or complementary cumulative distribution function (CCDF). The system structure of the PROBCON-HDW codes, the mathematical models in PROBCON-HDW, the input files, the input formats, the command files, and the graphical output results of several HDW release scenarios are described in the report.

SUMMARY

The PROBCON-HDW system of computer codes was written to perform a probability and consequence analysis of the Hanford defense waste (HDW) disposal alternatives' performances over the long term of 10,000 years as part of the Hanford Defense Waste Environmental Impact Statement (HDW-EIS 1987). The PROBCON-HDW code system consists of six computer programs: PROBCON, CMCCDF, COMHUM, PRAPLT, WBCCDF, and W8PLOT. Each program is described in this document. All programs were developed in FORTRAN on a Digital Equipment Corporation VAX 11/780 computer. The PROBCON-HDW system is an analysis tool that permits quantitative comparison of the potential long-term impacts of the HDW relative to release limits as defined by the U.S. Environmental Protection Agency (EPA) 40 CFR 191.13 standard.

PROBCON-HDW uses the Monte Carlo approach, in which key model parameters are sampled from probability density functions and the deterministic performance assessment models are run once for each set of parameter values sampled. Since no confirmed basis is available for the values of such key parameters as retardation coefficients for nuclide transport in soils and protective barrier parameters, it is necessary to assume such values in order to perform the analysis called for in 40 CFR 191.13. Until more experimental data are available, the calculations performed by PROBCON-HDW are useful for illustration of the relative features of each disposal alternative. However, the calculational results from PROBCON-HDW are not intended to be used to demonstrate compliance, or lack thereof, with the EPA standard.

The HDW disposal alternatives that can be analyzed by PROBCON-HDW consist of the in-place stabilization and disposal alternative (waste is disposed of near surface), the geologic alternative (high-level waste is removed for disposal in a geologic repository, and low-activity waste residuals are disposed of near surface), and the reference alternative (a combination of the previous two alternatives in that some waste is removed for disposal and some waste is disposed of near surface). The long-term performances of the disposal alternatives can also be compared to the performance of the no disposal action alternative (continued storage).

PROBCON-HDW calculates the EPA release limits for each radionuclide. The limits are based on the limits shown in Table 1 of 40 CFR 191, the number of metric tons of heavy metal represented in waste, and the fuel burnup. PROBCON-HDW further determines two sets of release limits. One set (total release limits) is based on the total waste activity; the other set (partitioned release limits) is based on the remaining amount of radionuclide inventory that is disposed of near surface. The amount of radionuclide activity that potentially reaches the accessible environment is then calculated by PROBCON-HDW for each radionuclide and is divided by the appropriate release limit to form a release ratio. The release ratios for all radionuclides included in PROBCON-HDW's data base are summed to form the consequence measure for comparative analyses. Since a Monte Carlo approach is used in PROBCON-HDW, a distribution of summed release ratios is obtained for each scenario.

The default release scenarios include two different distributions of recharge values to the groundwater: one distribution each for a current climate and a much wetter climate. The default scenarios also include protective barrier failures and drilling intrusions. The barrier failures are assumed to occur 500 years after disposal.

Two major release mechanisms are modeled in PROBCON-HDW. One is the leaching of the waste source followed by transport to the groundwater. The other is an intrusive mechanism, drilling, by which the radioactive materials are brought to the surface. Five leaching mechanisms are included:

- adsorption-controlled release
- solubility-controlled release
- dissolution-controlled release (linear release)
- diffusion-controlled release
- hybrid releases (combinations of the above).

The type of release is governed principally by physical and chemical characteristics of the waste form.

The PROBCON-HDW results are summarized as a complementary cumulative distribution function (CCDF) of the release-ratio consequences. Sample CCDFs are shown in Section 3.3.

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PROBCON-HDW: A PROBABILITY AND CONSEQUENCE SYSTEM OF CODES
FOR LONG-TERM ANALYSIS OF HANFORD DEFENSE WASTES

1.0 INTRODUCTION

The PROBCON-HDW system of codes was developed at Pacific Northwest Laboratory(a) for use in the Hanford defense waste environmental impact statement, or HDW-EIS (DOE 1987). PROBCON-HDW was motivated by the 40 CFR 191.13 standard (EPA 1985). This standard requires not only a consequence analysis, but also a probabilistic analysis. The consequence defined by the standard is the sum of ratios of each radionuclide's release from the waste disposal site to the accessible environment during the 10,000 years after disposal over each radionuclide's release limits. The release limit is the allowed amount of activity that can be released to the accessible environment during the 10,000 years after disposal. The consequence C is defined as

$$C = Q_1/RL_1 + Q_2/RL_2 + Q_3/RL_3 + \dots + Q_N/RL_N \quad (1.1)$$

where C = the release-ratio consequence

Q_n = the quantity of the nth nuclide released to the accessible environment over the 10,000 year time period following disposal

RL_n = release limit for the nth radionuclide (EPA 1985)

n = radionuclide index and has integer values from 1 to N

N = the total number of radionuclides considered in analysis.

The release limit for each radionuclide is based on the values in Table 1 of 40 CF 191, on the total amount of fuel throughput, and on the burnup rate of the fuel. The basis of the release limit derivations for each alternative of Hanford defense waste is described in Appendix A of this report.

(a) Operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

The 40 CFR 191.13 standard states that the probability (P) of the release-ratio consequence (C) in excess of 1 ($C > 1$) should be less than 0.1, as shown in Equation (1.2):

$$P(C > 1) < 0.1 \quad (1.2)$$

In other words, the 90th percentile value of C's distribution should not exceed 1. In addition, the standard requires that the probability of the release-ratio consequence in excess of 10 ($C > 10$) should be less than 0.001, as shown below:

$$P(C > 10) < 0.001 \quad (1.3)$$

In other words, the 99.9th percentile value of C's distribution should not be greater than 10.

The PROBCON-HDW system is operational on a DEC VAX 11/780 computer with the VMS operating system. PROBCON-HDW was written for the performance assessment of the Hanford defense wastes, but could be easily modified for other near-surface waste disposal systems that require a probability and consequence analysis.

The mathematical models used in PROBCON-HDW for risk analysis and the releases to the accessible environment (both natural and human intrusion releases) are described in Section 2.0, Mathematical Models. The computer codes in the PROBCON-HDW system are described in Section 3.0, which includes a system flow chart, a listing of the input and output files, the input description for the main user input file, and examples of run command files. Section 3.3 contains example graphical output of PROBCON-HDW. Appendix A describes the derivation of the release limit values for each alternative. Appendix B summarizes the parameter values used in the HDW-EIS (DOE 1987); these parameter values are the default values used in PROBCON-HDW. The listings of the computer programs in the PROBCON-HDW system are shown in the Appendices C through H.

2.0 MATHEMATICAL MODELS

The mathematical models used in PROBCON-HDW are described in this section. The probabilistic risk analysis methodology used by PROBCON-HDW is described first, to set the stage for the mathematical models of release mechanisms that follow. The risk analysis method acts as an integrator and ties everything together.

2.1 PROBABILITY RISK ANALYSIS METHODOLOGY

The PROBCON-HDW system utilizes a probabilistic risk analysis (PRA) method that is based on a scenario analysis defined by event trees. A chain of events along each branch of an event tree defines the scenario that is represented by that branch. A Monte Carlo simulation of each scenario's consequences is performed; i.e., the parameters with uncertainty associated with their values are sampled many times, and a range of consequences is calculated (see Figure 2.1), where one consequence value is obtained for each set of sampled parameter values. The range of consequence values is shown graphically, with the consequence values represented along the x-axis and the complementary cumulative distribution function (CCDF) of the consequence values represented along the y-axis.

The CCDF of a consequence value is the probability that a consequence is greater than or equal to the consequence value. The CCDF curve is sometimes called the "risk curve." Since the consequences calculated by PROBCON-HDW are defined as the ratio of calculated releases to the accessible environment to the amount of release allowed by 40 CFR 191 (i.e., as release ratios), the CCDF curve is referred to here as the release-ratio curve or, more simply, the release curve.

A release curve is calculated for each branch or scenario on the scenario event tree. As an example, Figure 2.2 shows an event tree representing eight scenarios; these scenarios were assumed in the HDW-EIS (DOE 1987) and they are used to illustrate the capabilities of PROBCON-HDW. After a release curve is calculated for each scenario, all of the curves are summed, with the probability of each scenario used to weight each scenario as shown in Equation (2.1):

FIGURE 2.1. Natural Release Simulation Model in PROBCON-HDW for Calculating Probabilities and Consequences (DOE 1987)

$$\text{Composite CCDF}(C) = \sum_j P(S_j) \cdot \text{CCDF}(C|S_j) \quad (2.1)$$

where $\text{CCDF}(C|S_j)$ is the release curve or CCDF for scenario S_j (j is the scenario index), and $P(S_j)$ is the probability of the scenario occurring over a defined time period (in this case, 10,000 years). Of course, by probability theory the sum of scenario probabilities must equal 1.0 as shown in Equation (2.2).

FIGURE 2.2. Probabilistic Scenario Event Tree (DOE 1987)

$$\sum_j P(S_j) = 1.0 \quad (2.2)$$

In the PROBCON-HDW system, the scenario probabilities can be varied. In fact, since there is a chance of no release (i.e., 100% containment), the scenarios that are included in the release analysis do not require their probabilities

to add to 1.0. In other words, Equation (2.2) includes all the release scenarios and the scenario with no release.

2.2 LONG-TERM NATURAL RELEASE MECHANISMS

The natural release mechanisms in the PROBCON code include the following types: 1) dissolution-controlled release, 2) solubility-controlled release, 3) adsorption-controlled release, 4) diffusion-controlled release, and 5) a combination of the above releases. Each waste form is assigned only one release mechanism except when the scenario includes a barrier failure for a fraction of the waste form. In that case, the fraction with barrier failure may have a different release model than the fraction without a barrier failure. For example, for intact barriers, the diffusion-controlled release would apply; however, for the portion where a barrier admitted water, the release may be controlled by dissolution, solubility, or adsorption.

2.2.1 Dissolution-Controlled Release

The dissolution-controlled release process (linear-release model) is used for calculating the release of radionuclides from existing and future grout waste for postulated protective barrier failures that result in infiltration of water. The linear release model assumes that infiltrating water directly contacts the waste form, becomes saturated with the dissolving chemicals and radionuclides in the waste, and carries the entire solution downward. The activity in curies of nuclide n reaching the groundwater per year, Q_n' , is given for grout by the following equation (DOE 1987, Appendix P):

$$Q_n' = Q_{0n} \cdot [\exp(-\lambda_n \cdot t)]/T_L \quad (2.3)$$

$$\text{for } T_I < t < T_F$$

where λ_n = the radioactive decay constant, $0.693/\text{half-life}$, yr^{-1} , of the n th radionuclide

Q_{0n} = the initial inventory of nuclide n , Ci

T_I = minimum of $T_n + T_H$ and 10,000 years = initial arrival time of radionuclide n to groundwater; 10,000 yrs is the time period of interest

T_F = minimum of $T_n + T_H + T_L$ and 10,000 years (for grout, 10,000 years is always the minimum) = final arrival time

T_H = the holdup time before leaching starts (taken as 505 years from the year 1995 for barrier failure cases)

T_n = the nuclide travel time from waste site to groundwater, year

T_L = the time required to dissolve (leach) all of the radionuclides from the waste form, year (14,000 years is used for grout waste).

Integrating the release rate [Equation (2.3)] over time from the initial radionuclide arrival time at the groundwater, T_I , to the time of final radionuclide arrival, T_F , yields the following expression for the activity in curies of nuclide n accumulated in the groundwater under the waste sites over the next 10,000 years:

$$Q_n \text{ (Dissolution)} = Q_{0n} \cdot \exp(-\lambda_n \cdot T_I) \cdot [1 - \exp(-\lambda_n \cdot T_D)] / T_L \cdot \lambda_n \quad (2.4)$$

where $T_D = T_F - T_I$. If $T_D = 0$, then $Q_n = 0$. Equation (2.4) is used for only the grout waste for scenarios with a barrier failure.

2.2.2 Solubility-Controlled Release

The solubility-controlled release model is used here to model the radionuclide release from the single-shell tank waste and the double-shell tank waste residuals to the groundwater. The solubility-controlled release assumes that the solute (radionuclide) concentration remains constant (except for radionuclide decay) in the waste form. The activity in curies of radionuclide n reaching the groundwater per year, Q_n' , at time t , for the solubility-controlled release is given by

$$Q_n' = A_w \cdot q \cdot C_n \cdot C_v \cdot \exp(-\lambda_n \cdot t) \quad (2.5)$$

for $T_I < t < T_F$

where A_W = surface area of waste for waste class W, km^2

q = annual recharge infiltrating waste and reaching groundwater, cm/yr

C_n = fixed maximum concentration of radionuclide n in tank waste, $\mu\text{Ci/L}$

C_v = units conversion factor = 10 (10 liters = 1 m^3), L/m^3 ;

λ_n = radioactive decay constant, $1/\text{yr}$

T_I = initial arrival time to groundwater = minimum of $T_n + T_H$ and 10,000 years

T_n = nth radionuclide travel time from waste site to groundwater, yr

T_H = holdup time before leaching starts [taken as 505 years for barrier failure (the year 2500), and 155 years for no barrier (the year 2150)]

T_F = minimum of $T_I + T_R$ and 10,000 years = final arrival time to groundwater

T_R = time duration of solubility-controlled release, year, and is given by

$$T_R = \ln \left[Q_{0n} \cdot \lambda_n \cdot \exp(-\lambda_n \cdot T_H) / (A_W q C_n C_v) + 1 \right] / \lambda_n \quad (2.6)$$

where $\ln$ is the natural logarithm (see Appendix P of DOE 1987).

Integrating the arrival rate of radionuclide n to the groundwater [Equation (2.5)] over time, from the initial arrival time, T_I , to the final arrival time, T_F , yields the following integrated release to the groundwater:

$$Q_n(\text{solubility}) = A_W \cdot q \cdot C_n \cdot C_v \cdot \exp(-\lambda_n \cdot T_I) \cdot \left\{ 1 - \exp \left[-\lambda_n \cdot (T_F - T_I) \right] \right\} / \lambda_n \quad (2.7)$$

If $T_I = T_F$, then $Q_n = 0$.

2.2.3 Adsorption-Controlled Release

An adsorption-controlled release model is used here to model the radionuclide release from the double-shell tank wastes for the no action alternative. The adsorption-controlled release assumes that infiltrating water comes into contact with the waste form and carries the solute (radionuclides) downward. The concentration of the solute varies with time, even if the radioactive decay is negligible. The adsorption-controlled release model, which is most appropriate for the liquid waste form, was used under the no action alternative for double-shell tank wastes, which are primarily liquids. The activity in curies of radionuclide n reaching the groundwater per year, Q'_n , for the adsorption-controlled release is given by

$$Q'_n = \lambda_{Ln} \cdot Q_{0n} \cdot \exp \left[-\lambda_n \cdot t - \lambda_{Ln} \cdot (t - T_H - T_n) \right] \quad (2.8)$$

for $T_I < t < 10,000$

where λ_{Ln} = leach rate parameter, 1/yr, $[q \cdot C_L / (R_n \cdot \theta \cdot h)]$, of nuclide n

q = annual recharge infiltrating waste and reaching groundwater, cm/yr

C_L = unit conversion factor = 0.01, m/cm

R_n = retardation factor for radionuclide n [see Equation (S.6) of DOE 1987]

θ = soil moisture content fraction (0.078 for the wetter climate, 0.064 for the current climate)

h = effective waste class thickness (taken as 64 m for double-shell tank waste (no-action alternative only) and 1 m for double-shell tank residuals (see Table P.24 of DOE 1987))

T_I = initial arrival time of radionuclide n to groundwater = minimum of $T_H + T_n$ (holdup time plus nuclide travel time) and 10,000 years

T_H = holdup time before leaching starts (taken as 155 years from 1995 for no barrier cases)

T_n = nth radionuclide's travel time to groundwater, years.

Integrating Equation (2.8) from the initial arrival time, T_I , to the final arrival time of 10,000 years yields the following accumulated release:

$$Q_n \text{ (adsorption)} = \lambda_{Ln} \cdot Q_{On} \cdot \exp(-\lambda_n \cdot T_I) \cdot \{1 - \exp[-(\lambda_n + \lambda_{Ln}) \cdot (10,000 - T_I)]\} / (\lambda_n + \lambda_{Ln}) \quad (2.9)$$

If $T_I = 10,000$, then $Q_n = 0$.

2.2.4 Diffusion-Controlled Release

The analysis here summarizes the diffusion model results presented in Appendix P of DOE 1987. The simplified model includes only the most transportable radionuclides, ^{14}C , ^{99}Tc , ^{129}I , and ^{238}U (each was given a zero K_d value for analysis of movement under the barrier for the diffusion model). These are the only radionuclides calculated to diffuse to the barrier's edge in less than 10,000 years.

In the simplified diffusion model a fraction of the waste, F , is assumed to diffuse out at a constant rate (if radioactive decay is ignored) over a time period, T . This period starts from the time that the diffusion of nuclides at the barrier's edge is non-zero, which is about 4,800 years (for zero K_d) after the year 2150, and ends when the diffusion of nuclides is zero [see Appendix P, T_0 defined after Equation (P.24) is approximately 4,800 years and is equal to T here (DOE 1987)]. In summary, the rate at which the most transportable radionuclides reach the groundwater (radioactive decay is included) at time t , is:

$$Q_n' = F \cdot Q_{On} \cdot \exp(-\lambda_n \cdot t) / T \quad (2.10)$$

for $T_I < t < 10,000$

where $T_I = T_n + T_H + 4,800$ years and the exponential function is the radioactive decay term.

The fraction F is 0.03 and time period T is 6,000 years for the tank waste (single-shell tank, double-shell tank, future double-shell tank). The fraction and time period for grout waste were equal to 0.05 and 19,000 years, respectively. These values are based on the results of the more sophisticated diffusion release analysis in Appendix P of DOE (1987). Equation (2.10) is integrated from T_I years (the initial arrival time of radionuclides to the groundwater) to 10,000 years.

$$Q_n(\text{diffusion}) = F \cdot Q_{0n} \cdot \exp(-\lambda_n \cdot T_I) \cdot \{1 - \exp[-\lambda_n \cdot (10,000 - T_I)]\} / (T \cdot \lambda_n) \quad (2.11)$$

2.2.5 Combination Releases

For the scenarios with postulated barrier failures (for the three disposal alternatives), a combination of two release models is required because the barrier failure is modeled to affect only a fraction, F_L , of the waste class. This fraction, F_L , of waste requires a non-diffusive or leaching release model, and the complementary part of this waste, $1-F_L$, requires the diffusion-release model. F_L is a random variable assumed to have a log-normal distribution (see Table B.2 of this report).

The two releases are modeled by dividing the waste classes into two parts, one part with fraction F_L , described by the leaching-release models, and the other with fraction $1-F_L$, described by the diffusion-release model. Such a model ignores any interaction or coupling of the two parts, which would require a much more complicated model. The simple combined release model described here should be considered as a first-order approximation to more complicated combination releases. The combined integrated release from the waste to the groundwater for radionuclide n for the barrier failure scenarios is

$$Q_n(\text{tank waste}) = F_L \cdot Q_n(\text{solubility}) + (1 - F_L) \cdot Q_n(\text{tank diffusion}) \quad (2.12)$$

for the tank waste classes with a barrier [see Equations (2.7) and (2.11)], and

$$Q_n(\text{grout}) = F_L \cdot Q_n(\text{dissolution}) + (1 - F_L) \cdot Q_n(\text{grout diffusion}) \quad (2.13)$$

for the grout waste classes with a barrier [see Equations (2.4) and (2.11)]. For the scenarios with no barrier failure, F_L is set to 0 and only diffusion occurs.

For the no disposal action alternative, the integrated release to the groundwater is just Q_n (adsorption), Equation (2.9), for double-shell tank wastes, and Q_n (solubility), Equation (2.7), for the single-shell tank waste.

The radionuclides in waste categories other than tank and grout wastes contribute almost nothing to the integrated releases over 10,000 years. The travel times to groundwater for the radionuclides in other waste categories are longer than 10,000 years or the activities in curies of the radionuclides are significantly smaller than the nuclide activities in tank and grout wastes. Hence, release models for the nuclides in other categories (i.e., other than tank and grout wastes) are not included in PROBCON-HDW.

2.3 HUMAN INTRUSION RELEASE MECHANISMS

Representative human intrusion events include borehole drilling and excavation. The marker system is assumed to prevent any systematic intrusion, excavation, or habitation. If the mitigating effect of the marker system is assumed (Appendix M of DOE 1987), then the probability of a major excavation occurring over the waste over the next 10,000 years is less than 0.0001. The 40 CFR 191 guidelines do not require inclusion of events with probabilities less than 10^{-4} over 10,000 years; hence, major excavation was not included in the probabilistic analysis capability of the PROBCON code.

The borehole event, however is considered representative of the more probable human intrusion events and is cited in the 40 CFR 191 standard. PROBCON-HDW uses the Poisson distribution as the probability distribution for boreholes. Other distributions could have been chosen, but the Poisson distribution was initially tried. Since the intrusion consequences or releases are extremely small relative to the leaching releases, the initial intrusion model was never changed.

The Poisson distribution is well suited for calculating the probability of an event occurring randomly within a period of m years if the annual probability^(a) of the event, p , is known. The probability of i events, $P(i)$, occurring over m years is

$$P(i) = \exp(-L) \cdot L^i / i! \quad (2.14)$$

where $L = m \cdot p$ ($m = 9,900$ years here)

p = the annual probability of a borehole intercepting a waste category

i = the number of boreholes drilled in m years.

The probability of more than i events occurring over time period m is

$$P(j > i) = \sum_{j=i+1}^{\infty} \exp(-L) \cdot L^j / j! \quad (2.15)$$

where j = the number of boreholes drilled in m years.

Equation (2.14) was used to calculate the probability of 0, 1, 2, and so on boreholes for each waste category. Equation (2.15) was used to determine how many boreholes should be included in the analysis. The maximum number of boreholes included in the PROBCON-HDW analysis is the value of i for which $P(j > i)$ is less than 0.0001. This maximum number is the 99.99 percentile value of the number of boreholes expected to occur over m years.

(a) "Annual probability" as used here is the probability per year that a borehole will intercept a given waste class.

The annual probability for each waste class is derived by multiplying an annual borehole frequency per square kilometer (obtained from literature) by the surface area occupied by each waste class. Annual drilling frequencies per unit area vary from $0.0002/\text{km}^2/\text{yr}$ to $0.012/\text{km}^2/\text{yr}$ as given in Little (1980); a value of $0.01/\text{km}^2/\text{yr}$ is chosen for the default value in PROBCON-HDW. This number is more than three times higher (more conservative) than the number recommended in EPA standard 40 CFR 191. Estimates of annual frequencies or annual probabilities for borehole drilling on each of the waste classes are calculated and given in Table 2.1. These annual frequencies are used with the Poisson distribution to generate 10,000-year probabilities in PROBCON-HDW.

Even though the drilling borehole is not expected to be random but somewhat clustered in time, the random-based Poisson distribution should be adequate here. The Poisson distribution is adequate partly because the clustering effects from the past are included in the annual borehole probabilities (Table 2.1). Furthermore, a large number of boreholes result during the long time period of 10,000 years, which tends to make the Poisson distribution a conservative choice. After the various numbers of boreholes that could intercept each waste category over the next 10,000 years is determined, the simplified model assumes that all the boreholes occur in one year. The year of drilling is an input parameter; 400 and 1,000 years after disposal were the values used in the HDW-EIS (DOE 1987). Since the model assumes that all the boreholes occur in one year, this is extreme clustering in time and certainly not random. Furthermore, if only the rather early years (400 and 1,000) of the 10,000-year period are chosen as the drilling years, then the mitigating effects of radioactive decay are minimized in these early years and the results are conservative in this sense.

The source terms (inventories) per borehole were calculated for each waste class listed in Table 2.1 by dividing the waste class inventory (for each alternative) per radionuclide by the surface area of that class, and then multiplying this result (an inventory areal density) by the area of a 30-cm-diameter borehole, $7 \times 10^{-8} \text{ km}^2$ (0.07 m^2). The resulting product is the initial inventory per borehole for each radionuclide in each waste class or category for each disposal alternative. The following equation was used for calculating the

yth percentile value of the accumulated release of radionuclide n from waste category W to the land surface due to drilling:

$$Q_n[I_W(y)] = [Q_{In} \cdot \exp(-\lambda_n \cdot T_{DRILL}) / A_W] \cdot A_{BH} \cdot I_W(y) \quad (2.16)$$

where Q_{In} = initial inventory (Ci) of radionuclide n in waste category W;
W = 1 to 11 (see Table 2.1)

T_{DRILL} = time of drilling (year) after the year 1995; T_{DRILL} has three values in this study: 155 years, 455 years, and 1,055 years(a)

A_W = surface area of waste class W (km^2) (see Table 2.1)

A_{BH} = area of borehole (km^2) = $7 \times 10^{-8} \text{ km}^2$

$I_W(y)$ = the yth percentile value of the number of boreholes in waste category W where $0 < y \leq 99.99$.

$I_W(y)$ must satisfy the following relationship with the probabilities for i boreholes in waste class W, $P(i)$, (Equation 2.14):

$$\sum_{i=0}^{I_W(y)-1} P(i) < 0.01y \leq \sum_{i=0}^{I_W(y)} P(i) \quad (2.17)$$

which says that the yth percentile value of the number of boreholes in waste category W, $I_W(y)$, is the first integer number which causes the sum of probabilities for each borehole to exceed the probability value $0.01y$. The 0.01 factor converts percentile values into probability values.

The yth percentile value of the release-ratio consequence (summed release ratios) for waste category W for each alternative A (each alternative has a different set of waste categories) due to drilling boreholes is given by

-
- (a) The 55 years included in the drilling time is the time between the reference inventory year (1995) and the year of disposal (2050), and accounts for radioactive decay during that period.

TABLE 2.1. Annual Probabilities of Boreholes in Waste Categories and Waste-Class Surface Areas

Waste Index, W	Waste Class/Category	Annual Probability, intrusions/yr	Surface Area, A _W , km ²
1	Single-shell tanks	5.5×10^{-4}	0.055
2	Double-shell tanks	5.8×10^{-5}	0.0058
3a	Grout of existing waste (ISD and reference)	5.8×10^{-4}	0.058
3b	Grout of existing waste (geologic)	2.5×10^{-3}	0.25
4	Future double-shell tanks	5.8×10^{-5}	0.0058
5	Grout of future waste	3.3×10^{-4}	0.033
6	DWSF(a)/ ⁹⁰ Sr canisters	1.0×10^{-6}	0.00010
7a	DWSF/ ¹³⁷ Cs canisters (in-place stabilization and disposal)	2.4×10^{-6}	0.00024
7b	DWSF/ ¹³⁷ Cs canisters (no disposal action)	1.3×10^{-6}	0.00013
8	TRU-contaminated soil	1.2×10^{-4}	0.012
9	Pre-1970 buried TRU	7.5×10^{-4}	0.075
10	Retrievable TRU	2.5×10^{-4}	0.025
11	Future TRU	1.7×10^{-4}	0.017

(a) Drywell storage facility.

$$C_W(y) = \sum_n Q_n [I_W(y)] / RL_{n,A} \quad (2.18)$$

The yth percentile value of the release-ratio consequence for all waste categories is calculated by

$$C(y) = \sum_W C_W(y) \quad (2.19)$$

Equation (2.19) assumes that the yth percentile consequence value of each waste class can simply be added to obtain the total consequence value at the yth percentile. This total distribution of consequence values, Equation (2.19), is not the same as the total distribution found by adding Poisson distributions. In general, the yth percentile value of the distribution of the sum of random variables is not equal to the sum of the yth percentile value of the distribution of each random variable. The distribution defined by Equation (2.19) is conservative in the sense that $C(y)$ is greater than or equal to the yth percentile value of the distribution found from the sum of random variables. The drilling model in PROBCON-HDW is only approximate, which is, however, sufficient for purposes such as comparison of waste disposal alternatives. Furthermore, the releases from the drilling model were found to be very much smaller than the releases from the leaching models; thus, refinements to the drilling model were not necessary.

The complementary cumulative distribution function of the yth percentile consequence value, $CCDF[C(y)]$, is defined by

$$CCDF[C(y)] = 1.0 - 0.01y \quad (2.20)$$

Since the consequences due to drilling are discrete [depending on the integer number of boreholes in Equation (2.16)], the corresponding CCDF will be a step function indicating the discrete nature of the borehole model.

Special note should be made of Equation (2.16) and the drywell storage facility (DWSF) waste category ($W = 6, 7a, 7b$) of strontium and cesium

canisters. This is the only waste class/category that has a target waste area smaller than the borehole area. Each canister is about 6 cm in diameter, and the borehole is assumed to have a 30-cm diameter. Hence, a larger area for the canisters was calculated, with the use of Figure 2.3 for use in Equation (2.16) and for finding the annual probabilities of a borehole intrusion of a canister (Table 2.1). The calculated canister area for the drilling model, $3.4 \times 10^{-7} \text{ km}^2$, is based on a 33-cm radius. If a borehole intercepts anywhere within this 33-cm-radius circle, as shown in Figure 2.3, then the canister is at least grazed by the borehole and, for conservatism, is assumed to release all its inventory to the accessible environment. That is, the borehole area, A_{BH} , is set to $3.4 \times 10^{-7} \text{ km}^2$ (0.34 m^2) for the DWSF canisters instead of $7 \times 10^{-8} \text{ km}^2$ (0.07 m^2). The area for the DWSF canisters, A_W , in Table 2.1 is the calculated larger area, A_{BH} (Figure 2.3), multiplied by the number of canisters. For all other waste categories, the area of the borehole is negligible compared to the target waste area; hence, the borehole area is not included in the other waste class/category areas.

FIGURE 2.3. Drywell Storage Facility Canister Area for Borehole Model (DOE 1987)

3.0 DESCRIPTION OF SYSTEM AND COMPUTER CODES

This section describes the different components of the PROBCON-HDW system, which includes the computer codes, the input files, and the output files. The user input instructions for the key input that is essential to meaningful simulations are also included.

3.1 SYSTEM OF COMPUTER CODES

The PROBCON-HDW code system contains six different computer codes: 1) PROBCON, 2) CMCCDF, 3) COMHUM, 4) PRAPLT, 5) W8CCDF, and 6) W8PLOT. The complete PROBCON-HDW system of codes, their interfaces, and their files are shown in Figure 3.1.

3.1.1 PROBCON Code

The PROBCON code (PROBability and CONsequence analysis), which contains the natural (leaching) release models and human intrusion model, is the main code of the system. The mathematical models used in this code were described in Section 2.0; the input instructions are included in Section 3.2. The PROBCON code runs in two modes, the natural (leaching) release mode and the human intrusion release mode. The release modes cannot be exercised simultaneously, nor can more than one waste alternative be run or simulated at the same time; i.e., PROBCON is run once for each waste disposal alternative simulation for each set of scenario conditions and assumptions.

Because of the potentially large number of PROBCON runs, the user is advised to develop a bookkeeping system for tracking the many input and output files that result. Many of the output files of PROBCON are used as input files for the post-processing codes and plotting codes. The bookkeeping system that was used for the HDW-EIS simulations is described in Sections 3.2 and 3.3. A listing of the PROBCON code is displayed in Appendix C.

3.1.2 COMHUM Code

COMHUM (COMbines HUMAN intrusion CCDFs) is a post-processing code that combines the CCDFs from human intrusion for each waste class and writes

FIGURE 3.1. PROBCON-HDW System

the human intrusion CCDF for each waste alternative to a file that can be used for further processing. The additional processing consists of plotting and/or combining the human intrusion CCDFs with the natural release CCDFs. The COMHUM code listing is displayed in Appendix D.

3.1.3 CMCCDF Code

CMCCDF (CoMbine human intrusion and natural release CCDFs) combines the human intrusion CCDF (CCDFjk.DAT file, j=waste alternative index, k=human intrusion date index) with the natural release CCDF (RAN ℓ ij.DAT file, n=model or simulation index, ℓ =barrier failure indicator, i=climate index, and j=waste alternative index); these indices are described further in Section 3.2. The output data file from CMCCDF is the CCnijk.SUM file, which contains the total CCDF for a given scenario (described by indices k, ℓ , and i) and for a given waste alternative (denoted by index j). The CCnijk.SUM file is processed by the plotting program PRAPLT. The CMCCDF code listing is displayed in Appendix E.

3.1.4 PRAPLT Code

PRAPLT is the main plotting program in the PROBCON-HDW system. PRAPLT plots the CCDF files (natural release only, human intrusion only, or combined), and/or the probability density functions (PDFs) of the water recharge parameter, the radionuclide distribution coefficients, and waste area fraction or percentage affected by barrier failure. The PRAPLT code listing is displayed in Appendix F.

3.1.5 W8CCDF Code

The W8CCDF (Weight 8 CCDFs) code calculates the combined or weighted CCDF from the CCDF of each scenario and an estimated probability of each scenario's occurrence over the next 10,000 years. In other words, W8CCDF combines all the scenario CCDFs (eight were used for the HDW-EIS; see Figure 2.2) according to Equation (2.1) in order to get the composite CCDF for each waste alternative. The composite CCDF data is on output file W8CCDF.SUM. The W8CCDF code listing is displayed in Appendix G.

3.1.6 W8PLOT Code

The W8PLOT (Weight 8 PLOTS) code plots the composite CCDFs, one for each alternative. This code is essentially the PRAPLT code except for seven extra lines of coding, which fix the scale of the x-axis of the composite CCDF plots. The W8PLOT code listing is displayed in Appendix H.

3.2 INPUT FILES AND FORMATS: INPUT INSTRUCTIONS

The main user input (internal file name INPT.IN) for the PROBCON-HDW system is read by the PROBCON program. The other programs primarily read the output files generated by PROBCON or other programs in the PROBCON-HDW system. The user input for the PROBCON program is described in detail in the next subsection. Although the internal file name for this input is INPT.IN, the file name that is used for storage purposes must be more descriptive since a separate input file is needed for each scenario and for each alternative with natural long-term releases. As shown in Figure 3.1, the file name convention that was used in the HDW-EIS for file storage contains five descriptive indices:

1. i = climate index, = 1 for current climate, = 3 for wetter climate
2. j = disposal alternative index, see Table 3.2 for values and definitions
3. k = time of human intrusion index, = 1 for 100 years after disposal, = 2 for 400 years after disposal, = 3 for 1000 years after disposal
4. l = barrier failure index, = 2 for no barrier failure, = 3 for barrier failure in the year 2500 A.D. (One, 1, was not used as index value.)
5. n = simulation index, = 1 for models described in this report, can equal any other number for different models that are tried out. This last index was useful during the model development phase when changes were made to the models.

Each user of PROBCON-HDW can choose an index scheme for keeping track of the potentially large number of files generated by the system.

3.2.1 PROBCON Input

The PROBCON program contains all necessary model data for a "default" run (a standard run). Default data values can be altered as desired via input to the program. Only a title card with some trailing options is necessary to run PROBCON with the default data values.

Input to the PROBCON program must be done through an input file called INPT.IN, which is created in the same directory as PROBCON. The input file must be named INPT.IN, and the construction of such a file requires knowledge

of the "option cards" or "option records," which are described below. For filing purposes, descriptive file names should be used. Before the time of PROBCON execution, each of these input files must be assigned or copied to local file name INPT.IN. An example of a file-naming convention is described in Section 3.4.

To run PROBCON, an INPT.IN file containing at least the "TITL>" option card (explained below) is required, since a title and certain mode selections are necessary for a run.

3.2.1.1 INPT.IN File Format

The INPT.IN file should consist of a list of option records, commented with the "****" option (explained below) and separated by any number of blank records as desired for easier reading. The first option record should have option card "TITL>," since this option specifies necessary information for the PROBCON program.

The following is a complete list of the allowable option cards:

****	CINV>
AINV>	DLYT>
AISO>	HINT>
AKDV>	ISON>
AREA>	NATR>
BARR>	RCHG>
BFRD>	TITL>
CAWF>	

All option cards should constitute the first five positions of their associated records. The ">" is a mandatory entry on the option cards except for the comment card.

The data values following most option cards can be entered in a free format just as for list-directed input/output. However, the data values must be separated by commas, and the last data value must not be followed by a comma.

3.2.1.2 Option Cards and Option Record Formats

The construction of an INPT.IN file is made simple and logical through the use of option records, each one consisting of an option card and data values, which are entered in an almost free format. Each option card is associated with the changing of specific data values from their default values normally used by PROBCON. Default values can be obtained by running the PROBCON program with no changes specified in the INPT.IN file (only the "TITL>" card should be used) and then inspecting the PROBCON.OUT file, which includes formatted outputs of all data values used by PROBCON. The following INPT.IN file with four card images is recommended for this purpose:

```
****INPT.IN file for showing default values in PROBCON.OUT
TITL>NAT. REL:  IPSD      ALT., WET CLIMATE,W/BAR.FAIL @  505 YRS
N
2,2
```

All the option cards, the associated data values, and the required format are described next.

"***": [comment]**

This option reserves the associated record for comments. It follows the same restriction as all other option cards in that it must occupy the first (in this case, four) positions of a record. Thus, whole lines must be reserved for commenting; one particular line cannot be used for both record-changing information and a comment.

"AINV>": [Add INVENTORY values]

The inventory values for an additional nuclide may be added to the existing collection via this option. Since a large amount of data is involved here [44 (4 alternatives times 11 waste categories) inventory values per added nuclide], the format for this option has some special features. The precise format is as follows:

```
AINV> isonum
      arg11, arg12, arg13, arg14, arg15, arg16, arg17, arg18, arg19, arg1a, arg1b
```


arg21, arg22, arg23, arg24, arg25, arg26, arg27, arg28, arg29, arg2a, arg2b
arg31, arg32, arg33, arg34, arg35, arg36, arg37, arg38, arg39, arg3a, arg3b
arg41, arg42, arg43, arg44, arg45, arg46, arg47, arg48, arg49, arg4a, arg4b

where

- `isonum` = index number of the nuclide to be added. "isonum" is restricted to the number immediately following the index number for the last nuclide currently on the list of nuclides for the run (Table 3.1 gives the nuclide index numbers).
- `argij` = the inventory value in curies (Ci) of the activity of the nuclide for the *i*th waste disposal alternative and in the *j*th waste category (Table 3.2 gives the disposal alternatives indices "i=1 to 4" and Table 3.3 gives the waste category indices "j = 1 to 11").

When adding a new nuclide, "isonum" must be the number immediately following the last "isonum" used. For instance, I-129 is the last listed nuclide in the unaltered (default) data base of the PROBCON program. Since its "isonum" is "11" (see Table 3.3), the "isonum" for the next added nuclide should be "12". If "12" is not presented, PROBCON will print an error message on the screen and stop. This restriction is necessary to ensure clarity in output.

The inventory values should appear as presented above, where there is separate record for each waste disposal alternative, and there are no blank records between them. None of the values should be left blank unless the value to be stored is a zero. (Blanks are read in as "0" for the "AINV>" option.) In addition, although commas are probably the safest to use in terms of avoiding errors, blanks may also be used as delimiters between inventory values. (NOTE: This is a special feature of "AINV>" that should not be attempted for other options that require commas as delimiters.)

"AIS0>": [Add IS0tope]

When adding a nuclide, several miscellaneous parameters must also be included that normally need not be changed for already existing nuclides.

TABLE 3.1. Indices for Nuclides

<u>Index</u>	<u>Nuclide</u>
1	⁹⁰ Sr
2	¹³⁷ Cs
3	¹⁵¹ Sm
4	²³⁹⁻²⁴⁰ Pu
5	²⁴¹ Am
6	⁶³ Ni
7	¹⁴ C
8	²³⁸ U
9	⁹³ Zr
10	⁹⁹ Tc
11	¹²⁹ I

TABLE 3.2. Indices for Waste Disposal Alternatives

<u>Index</u>	<u>Waste Disposal Alternative</u>
1	Geologic disposal
2	In-place stabilization and disposal
3	Reference
4	No action

This option allows the necessary inclusion of such data via the following format:

AISO> isonum, decay_constant, solubility_concentration, 40_CFR_191_value
multfact1, multfact2, multfact3, multfact4

where

- isonum = index number of the nuclide to be added. "isonum" is restricted to the number immediately following the index number for the last nuclide currently on the list of nuclides for the run (Table 3.1 gives the nuclide index numbers)

TABLE 3.3. Indices for Waste Categories

Index	Waste Category
1	Single-shell tank
2	Double-shell tank
3	Grout--existing tank waste
4	Double-shelled tank, future
5	Grout--future tank waste
6	Strontium drywell waste
7	Cesium drywell waste
8	TRU contaminated soil
9	Pre-1970 buried TRU site
10	Existing stored TRU site
11	Future TRU site

- decay_constant = $\ln(2)/\text{half-life}$ for nuclide "isonum" (1/yr)
- solubility_concentration = concentration of nuclide "isonum" in single-shell tank waste - used for solubility controlled leaching model (microcuries/liter)
- 40_CFR_191_value = release limit rates from Table 3.1 of 40 CFR 191 for radionuclide "isonum" per 1000 metric tons of heavy metal (MTHM) of fuel throughput (Ci)
- multfacti = factor for modified release limits for nuclide "isonum" and waste disposal alternative "i"

All multfact's are set to 1.0 on default.

All values must be specified for this option; a blank in a data slot will be read in as zero.

All four factors must be entered in the record immediately following the "AISO>" record; they cannot appear in the "AISO>" record, and no blank records may separate the two records.

When adding a new nuclide, "isonum" must be the number immediately following the last "isonum" used. For instance, ¹²⁹I is the last listed

nuclide in the unaltered (default) data base of the PROBCON program. Since its "isonum" is "11" (see the documentation), the "isonum" for the next added nuclide should be "12". If "12" is not presented, PROBCON will print an error message on the CRT and stop. This restriction is necessary to assure clarity in output.

"AKDV>": [Alter (or Add) KD Value]

Kd distribution parameters may be altered or added for an already existing nuclide or for a new nuclide, respectively, via this option. The necessary format is as follows:

AKDV> isonum, Kd_median, Kd_variance, Kd_low, Kd_high

where

- isonum = index number of the nuclide involved (already existing or added)... when adding an nuclide, "isonum" is restricted to the number immediately following the index number for the last nuclide currently on the list of nuclides used for the run (Table 3.1 gives the nuclide index numbers)
- Kd_median = median of the Kd pdf for nuclide "isonum"
- Kd_variance = variance of the Kd pdf for nuclide "isonum"
- Kd_low = minimum Kd pdf value for nuclide "isonum"
- Kd_high = maximum Kd pdf value for nuclide "isonum"
- pdf = probability density function

Adding only the Kd_median value and leaving the rest of the Kd pdf information blank (but retaining the proper "AKDV>" format) will suffice when a new nuclide is added. The reason for this involves difficulty (time constraints) in modifying the PROBCON code into a modular and general one. As it appears now, PROBCON will only fully account for the Kd pdfs of strontium, plutonium, americium, and uranium. The pdfs for other nuclides are not accounted for; rather, only median values are used. New nuclides are treated in a manner similar to the nuclides in the "other" category. It is quite possible to generalize the code, so that it can

account either for the Kd distributions of all the nuclides involved or for a selected few.

"AREA>": [change AREA value]

Waste area default values may be changed using this option with the following format:

AREA> waste_disposal_alternative, waste_class, area_value

where

- waste_disposal_alternative = index of the waste disposal alternative associated with the area value
- waste_class = number of the waste category associated with the area waste category (Table 3.2 below gives the disposal alternatives indices "i = 1 to 4" and the waste category indices "j = 1 to 11" are shown in Table 3.3)
- area_value = surface area of waste class for borehole model (km^2) and the solubility-controlled release model

None of the data slots may be left blank for this option.

"BARR>": [BARRier in place? answer]

The PROBCON program assumes that a barrier is in place, unless this option is used with the following format to indicate that a barrier is not in place:

BARR>barrier_in_place? answer

where

- barrier_in_place? answer = Y for "yes," N for "no"

The "Y" option is usually redundant, but can be used to negate a previous "BARR> N".

"BFRD>": [change Barrier Failure Recharge Distribution parameters]

Functional-barrier-failure recharge and disruptive-barrier-failure recharge distribution default parameters may be altered via this option card, which requires the following format:

BFRD> fbfrmn, fbfrmx, dbfrmn, dbfrmx, fdbprob

where

- fbfrmn = functional-barrier-failure recharge minimum (cm)
- fbfrmx = functional-barrier-failure recharge maximum (cm)
- dbfrmn = disruptive-barrier-failure recharge minimum (cm)
- dbfrmx = disruptive-barrier-failure recharge maximum (cm)
- fdbprob = probability of functional barrier failure

Any of the data slots may be left blank to indicate no change in the respective PROBCON default values.

"CAWF>": [Change Affected Waste Fraction pdf parameters]

The affected waste fraction is actually the percentage of the waste inventory that is affected by the barrier failure. The assumed barrier failure will not change the recharge for 100% of the waste, but for some x% where x is an uncertain parameter; the variability of x (affected waste percentage) is described by this input option. The affected waste fraction pdf default parameters may be altered via this option, which requires the following format:

CAWF> awf_low, awf_high, awf_median, awf_variance

where

- awf_low = minimum value for the affected waste fraction pdf (%)
- awf_high = maximum value for the affected waste fraction pdf (%)
- awf_median = affected waste fraction pdf median (%)
- awf_variance = affected waste fraction pdf variance (%)

Any of the data slots may be left blank to indicate no change in the respective PROBCON default values.

"CINV>": [Change INVENTORY value]

This option allows one to change an inventory value for an already existing nuclide. Its format is as follows:

CINV> waste_disposal_alternative, isonum, waste_class, inventory_value

where

- waste_disposal_alternative = index of the waste disposal alternative associated with the inventory value (Table 3.2 gives the indices of the waste disposal alternatives "i = 1 to 4").
- isonum = index number of the isotope involved (Table 3.1 gives the nuclide index numbers)
- waste_class = index of the waste category associated with the inventory value (Table 3.3 gives the indices for the waste categories).
- inventory_value = the inventory activity of nuclide "isonum" (Ci)

None of the data slots may be left blank for this option.

"DLYT>": [change DeLaY Time]

The default diffusion time delay for an nuclide may be altered via this option, which requires the following format:

DLYT> isonum, diffusion_dly_time

where

- isonum = index number of the nuclide involved (Table 3.1 gives the nuclide index numbers)
- diffusion_dly_time = diffusion time delay associated with nuclide "isonum"; i.e., the time it takes for the initial molecules to diffuse to the outer edge of barrier where advection takes place.

None of the data slots may be left blank for this option.

"HINT>": [change miscellaneous Human INTrusion data]

This option allows one to alter miscellaneous data values associated with the Human Intrusion PROBCON option from their PROBCON default values. The following format is required:

HINT> disposal_time, period, intrusion_time

where

- disposal_time = disposal time after 1995 (years)
- period = time period for drilling boreholes (about 9900 years)
- intrusion_time = assumed intrusion time after disposal (years) when all boreholes are assumed to occur - model simplification

Any of the data slots may be left blank to indicate no change in the respective PROBCON default values.

"ISON>": [change ISOtope (nuclide) Name]

When a nuclide is added to the existing list of nuclides, PROBCON should know its name so it can provide a readable output. A name may be entered via this option in the following format:

ISON> isonum, nuclide_name

where

- isonum = index number of the nuclide to be added..."isonum" is restricted to the number immediately following the index number for the last nuclide currently on the list of nuclides for the run (Table 3.1 gives the nuclide index numbers)
- nuclide_name = name of nuclide "isonum". This name should be a character string containing no blanks. Some of the nuclide names already stored in PROBCON do, indeed, contain spaces, e.g., Sr 90. However, any new nuclide names should not contain a space.

"NATR>": [change NATuRal release miscellaneous data]

Miscellaneous data associated with the natural release option of the PROBCON program may be altered via this option, which requires the following format:

NATR> random, samples, bft, tshell, leach_time, bulk_dens, vol_mois, thick
where

- random = number of random numbers to be discarded prior to run
- samples = number of samples to be run
- bft = number of years after 1995 to barrier failure
- tshell = steel shell tank lifetime (years)
- leach_time = leaching time parameter for non-grout; used in dissolution-controlled release model; this is the time that is required to completely dissolve waste (years)
- bulk_dens = bulk density of soil (grams per milliliter, 1.8)
- vol_mois = volumetric moisture content of soil (%)
- thick = waste deposit thickness for double-shell tank liquids or residuals to be used in adsorption-controlled release model (64 m was effective thickness of liquids assuming soils would soak up liquids for 64 m, 1 m for residuals in double shell tanks).

Any of the data slots may be left blank to indicate no change in respective PROBCON default values.

"RCHG>": [change ReCHArGe pdf parameters]

The main descriptors of the recharge pdf may be altered via this option, which requires the following format:

RCHG> rchrg_low, rchrg_high, rchrg_median, rchrg_variance

where

- rchrg_low = recharge pdf minimum value (cm)
- rchrg_high = recharge pdf maximum value (cm)

- rchrg_median == recharge pdf median (cm)
- rchrg_variance = recharge histogram variance (cm²)

Any of the data slots may be left blank to indicate no change in the respective PROBCON default values.

"TITL>": [TITLE and necessary information card]

The INPT.IN file must contain this card and the two cards that follow, since it specifies information required by the PROBCON program. The special multiple-card format appears as follows:

```
TITL>title
release_type
waste_disposal_alternative, release_limits_index
where
```

- title = the title for the run (no more than 60 characters)
- release_type = either natural (enter N) or human intrusion (enter H)...the letter must be entered in the very first position of the record
- waste_disposal_alternative = the number associated with the waste disposal alternative for the run (Table 3.2 gives the disposal alternatives indices "i=1 to 4").
- release_limits_index = the index of the waste disposal alternative from which release limit values will be taken (Table 3.2 gives the disposal alternatives indices "i=1 to 4").

Normally the two fields are the same, except when the geologic alternative or reference alternative is to be run or modeled with the "total release limits" instead of the "partitioned release limits." The total release limits are the ones calculated for the in-place stabilization and disposal alternative or no action alternative and is based on the entire or total HDW fuel throughput (past and future).

The records must appear, in order and format, as in the format module above; the release type (N or H) must occupy the first position of the

record immediately below that of the title, and the "waste_disposal_alternative, release_limits_index" record must be the next record. The information for the latter record can be entered in a free format. None of the data slots may be left blank for this option.

Unchanged Data Values:

For many of the options, a data value can be left unchanged by merely leaving its "slot" blank. An example is shown below for the following option record:

```
BFRD> 1.      ,      ,9.      ,21.      ,
```

After this record is processed, the functional-barrier-failure recharge minimum will be 1.0, the functional-barrier-failure recharge maximum will remain unchanged, the disruptive-barrier-failure recharge minimum will be 9.0, and the disruptive-barrier-failure recharge maximum will be 21.0, the functional-barrier-failure recharge minimum and probability for functional barrier failure will both retain their previous values. An option record with the format

```
BFRD>      ,      ,9.      ,21.      ,
```

will bring about the same changes as the above, except the disruptive-barrier-failure recharge minimum will remain the same, in addition to the other two.

Changeable Default Data Values:

The following Table 3.4 tells which default data values are changeable and which can be added. The option cards necessary for changing and adding particular data values are also indicated. Hopefully, this table should prove convenient in changing default data values.

Adding a Nuclide:

A nuclide may be added to the existing PROBCON list if it is one which does not require special Kd distribution treatment. The reason for this involves time that is necessary to modify the PROBCON code into a general one.

TABLE 3.4. Option Card Summary

Default Data Type	Card
Affected waste fraction pdf maximum (change)	CAWF>
Affected waste fraction pdf median (change)	CAWF>
Affected waste fraction pdf minimum (change)	CAWF>
Affected waste fraction pdf variance (change)	CAWF>
Area value (change)	AREA>
Barrier not in place specification	BARR>
Bulk density of soil (change)	NATR>
Decay constant value for an nuclide (add)	AISO>
Diffusion delay time (add or change)	DLYT>
Disposal time after 1995 (change)	HINT>
Disruptive-barrier-recharge pdf maximum (change)	BFRD>
Disruptive-barrier-recharge pdf minimum (change)	BFRD>
Functional-barrier-recharge pdf maximum (change)	BFRD>
functional-barrier-recharge pdf minimum (change)	BFRD>
Intrusion time after disposal (change)	HINT>
Inventory value (add)	AINV>
Inventory value (change)	CINV>
Kd distribution maximum for an nuclide (add or change)	AKDV>
Kd distribution median for an nuclide (add or change)	AKDV>
Kd distribution minimum for an nuclide (add or change)	AKDV>
Kd distribution variance for an nuclide (add or change)	AKDV>
Leaching time parameter for non-grout (change)	NATR>
Factors for modified release limits (add)	AISO>
Name of a new nuclide (add)	ISON>
Number of random numbers discarded prior to run (change)	NATR>
Number of samples run (change)	NATR>
Number of years after 1995 to barrier failure (change)	NATR>
Probability of functional barrier failure (change)	BFRD>
Recharge pdf maximum (change)	RCHG>
Recharge pdf median (change)	RCHG>
Recharge pdf minimum (change)	RCHG>
Recharge pdf variance (change)	RCHG>
Release limit from Table 3.1 of 40 CFR 191 for a nuclide (add)	AISO>
Release limits for the run	TITL>
Release type for the run	TITL>
Solubility limit for an nuclide (add)	AISO>
Steel shell tank lifetime (change)	NATR>
Time period (change)	HINT>
Title for the run	TITL>
Volumetric moisture content of soil (change)	NATR>
Waste deposit thickness (change)	NATR>

As it appears now, PROBCON will fully account for the Kd pdfs of only strontium, plutonium, americium, and uranium. The pdfs for other nuclides are not accounted for; rather, only median values are used. New nuclides are treated in a manner similar to the nuclides in the "other" category. Thus, as long as a nuclide has a Kd distribution which is not very crucial for calculations (i.e., its median value) it can be added to the existing list without impairing results.

Several option cards must be involved when adding a nuclide. A list of the necessary options follows:

AINV>
AKDV>
DLYT>
AISO>
ISON>

3.2.2 CMCCDF Input

This program reads the standard input file (default file TAPES) that follows the program execution in the standard VAX .COM file (see example in next section). The input format is

<u>Line No.</u>	<u>Format</u>	<u>Field Description</u>
1	I5	Graph index = 1 for log y-axis, = 2 for linear y-axis
2	A40	Output file name, CC2ijk.SUM, goes to PRAPLT program
3	A40	Input file name, RAN2ij.DAT from PROBCON program
4	A40	Input file name, CCDFkj.OUT from COMHUM program
5	A40	Blank card image
6	A60	Title card that describes scenario disposal alternative
-3+5m	A60	Repeat of lines 2 to 6 for m different combinations of
⋮	⋮	↓
1+5m	A60	alternatives and scenarios, where m = 2 to M.
2+5M	A40	Blank card image for end of input; M = total number of combinations.

CMCCDF reads each data file RAN2ij.DAT, which contains the CCDF for the natural release scenario (2,i) for the jth waste disposal alternative.

CMCCDF also reads each data file CCDFjk.OUT, which contains the CCDF for the human intrusion scenario k (the kth date of occurrence) for the jth waste disposal alternative.

3.2.3 COMHUM Input

<u>Line No.</u>	<u>Format</u>	<u>Field Description</u>
1	I5	Graph type index, = 1 for log y-axis, = 2 for linear y-axis
2	A40	Input file name
3	I5	Disposal alternative index (see Table 3.2)
4	A40	Output file name, CCDFjk.out
-1+3m	A40	Repeat lines 2 to 4 for m = 2 to M, where m is the ordinal
3m	I5	↓
1+3m	A40	number of output files.
2+3M	A40	Blank card image, end of input; M = total number of output files.

COMHUM reads the data file CCDFhk.DAT which contains the CCDF due to the human intrusion scenario for the kth date of occurrence. This file contains the CCDF for each of the four waste alternatives used in the HDW-EIS.

3.2.4 PRAPLT Input

PRAPLT is usually run in an interactive mode where the user is prompted for input on the terminal screen.

<u>Line No.</u>	<u>Format</u>	<u>Field Description</u>
1	I5	Plotter index. = 1 for CALCOMP = 2 for HP7221T = 3 for HP7550A
2	A40	Input file name (blanks end the run)
3	A1	Correct input file? Yes or No answer.
4	I5	Plot type index = 1 for single pdf plot = 2 for multiple CCDF plot.
5	A1	Are more curves to be plotted? Yes or No answer.

PRAPLT reads the probability density function (pdf) files which consist of the KDSR.OUT file (strontium Kd pdf), KDPU.OUT file (plutonium Kd pdf), KDAM.OUT file (americium Kd pdf), KDU.OUT file (uranium Kd pdf), AWF.OUT file (area of waste affected by barrier failure pdf), and the RECHRG.OUT file (water recharge to groundwater pdf).

PRAPLT also reads the CCDFHK.DAT data file which contains the CCDF due to the human intrusion scenario for the kth date of occurrence.

PRAPLT also reads the CC2ijk.SUM data file which contains the CCDF for scenario (2,i,k) for the jth disposal alternative.

3.2.5 W8CCDF Input

<u>Line No.</u>	<u>Format</u>	<u>Field Description</u>
1	I5	Graph type index = 1 for log y-axis, = 2 for linear y-axis.
2	A40	Output file name, NH00j0.sum.
3	A40	Input file name, CC2ijk.sum from CMCCDF program.
4	E15.7	Scenario probability (multiplier weight) for CCDF.
1+2m	A40	Repeat of lines 3 and 4 for m = 2 to M, where
2+2m	E15.7	m = the number of input files or scenarios for each alternative (8 scenarios were in HDW-EIS).
3+2M	A40	Blank card image, indicating end of input files; M = total number of input files or scenarios.
4+2M	A60	Title for composite CCDF for a particular disposal alternative.
5+2M	A40	Blank card image, end of run.

W8CCDF reads the CC2ijk.SUM data files which contain the CCDF for the (2,i,k) scenario for the jth disposal alternative.

3.2.6 W8PLOT Input

The input file for W8PLOT is interactive and the same as PRAPLT input.

W8PLOT reads the W8PLOT.SUM data file, which is the total composite CCDF of all the scenarios combined.

3.3 OUTPUT FILES

The index scheme described in Section 3.2 is used in this section. Recall that i = climate index, j = disposal alternative, k = date of human intrusion, l = barrier failure index, and n = simulation index. The reader should also refer to Figure 3.1, which shows all of the output files in the system.

3.3.1 PROBCON Output

The PROBCON output files for the Natural (Leaching) Release option are the following:

PROBCON.OUT
PROBCON.SUM
KDAM.OUT
KDPU.OUT
KDSR.OUT
KDU.OUT
AWF.OUT
RECHRG.OUT
REL RAT.OUT

PROBCON.OUT contains tables of all data values used by PROBCON and all important results. It is an essential file for the user.

PROBCON.SUM is an executive summary of PROBCON.OUT.

Kd pdf plot files are made for ^{90}Sr , ^{239}Pu , ^{241}Am , and ^{238}U . They have a format suitable for processing by PRAPLT, the plotting program.

AWF.OUT is a plot file for the affected waste fraction distribution. Data are presented in a format suitable for processing by PRAPLT.

RECHRG.OUT is a plot file for the recharge distribution. Data is presented in a format suitable for processing by PRAPLT.

REL RAT.OUT is a standard output file for further processing by the CMCCDF code.

When PROBCON is run using the Human Intrusion option, the following files are produced:

PROBCON.OUT
PROBCON.SUM
HICCDF.OUT.

PROBCON.OUT contains tables of all data values used by PROBCON and all important results. It is the most convenient file for review of results.

PROBCON.SUM is an executive summary of PROBCON.OUT.

HICCDF.OUT is a standard output data file for further processing by COMHUM after several files have been stored as CCDFHk.DAT where k denotes the date of occurrence for the human intrusion.

3.3.2 CMCCDF Output

The main output file from program CMCCDF is the data file CC2ijk.SUM, which contains the CCDF for each scenario (2,i,k) for the jth disposal alternative. The CCDF on this file includes release-ratio consequences from both the natural release mode and the human intrusion mode. The purpose of this data file is to provide the CCDF curve information to the plotting program PRAPLT and/or to be read by the W8CCDF program so that it can be combined with other CCDFs into the total composite CCDF for all scenarios.

Two additional output files are the document files CMCCDF.OUT and CMCCDF.SUM. File CMCCDF.SUM is an executive output file that summarizes the CMCCDF.OUT file.

3.3.3 COMHUM Output

The main output file from program COMHUM is the data file CCDFjk.OUT, which contains the CCDF for the kth date of human intrusion for the jth disposal alternative. The CCDF on this file contains only the releases caused by human intrusion. The purpose of this file is to provide the human intrusion release data for the CMCCDF program, which will combine the human intrusion release data with the release data from the natural release mode.

3.3.4 PRAPLT Output

The main output of program PRAPLT is plots of probability density functions and CCDFs. An example plot of a probability density function is shown in Figure 3.2, and an example plot of a CCDF or release-ratio consequence curve is shown in Figure 3.3.

3.3.5 W8CCDF Output

The W8CCDF program has the output data file NH00j0.SUM which contains the total composite CCDF of all scenarios for the jth alternative. These files are read by program W8PLOT for plotting purposes.

W8CCDF also has the standard document output files W8CCDF.OUT and W8CCDF.SUM where the *.SUM file is the executive summary file and the *.OUT file is the more detailed output.

3.3.6 W8PLOT Output

The program W8PLOT's only output is the plot of the total composite CCDF curve for each alternative. An example plot is shown in Figure 3.4.

3.4 COMMAND FILES FOR CODE EXECUTION

The command files for execution of each program are stored in *.COM files on the VAX 11/780 computer. Some example command files are shown for each program except for the plotting programs, which are run interactively.

3.4.1 PROBCON Command File

The following command file executes the PROBCON program in the natural release mode for the scenario that includes a barrier failure (3 index in filename), the current climate recharge (second 1 index in filename), for the in-place stabilization and disposal alternative (2 index in filename). The first index of 1 (simulation number) in the file names (NR****. and RA****. files) in the command file indicates that the current models (as described in this document) are used. The temporary file FOR007 is a scratch file that contains additional information about each of the 2000 trials that is performed

FIGURE 3.2. Assumed Probability Density Function of the K_d Values for Plutonium in Single-Shell and Double-Shell Tank Waste (DOE 1987)

FIGURE 3.3. Release-Ratio Curves for Alternatives for the Scenario of Current Climate, No Barrier Failure, and 400-Year Intrusion (DOE 1987)

FIGURE 3.4. Preliminary Composite CCDFs for All Alternatives Based on All Scenarios for Wastes Disposed of Near Surface (DOE 1987)

in PROBCON on default. The scratch file is large and detailed, and is not commonly used, but it can be useful for verification or review. \$ASSIGN

NR1312.DAT INPT.IN

\$ASSIGN RA1312.DAT RELRAT.OUT

\$ASSIGN NR1312.OUT PROBCON.OUT

\$ASSIGN NR1312.SUM PROBCON.SUM

\$ASSIGN NR1312.TMP FOR007

\$RUN PROBCON

The "NR" in the above files stands for "Natural Release mode", and the "RA" stands for "Release rAtes." A similar command file for the human intrusion scenario of drilling boreholes 1000 years after disposal ($k=3$) is shown below.

\$ASSIGN HI3.DAT INPT.IN

\$ASSIGN HIOUT3.OUT PROBCON.OUT

```

$ASSIGN HISUM3.SUM PROBCON.SUM
$ASSIGN CCDFH3.DAT HICCDF.OUT
$RUN PROBCON

```

The "HI" in the above files stands for "Human Intrusion mode."

3.4.2 CMCCDF Command File

The following command file executes the CMCCDF code, reads both the human intrusion CCDF files (one for each alternative) and the natural release files (one for each alternative) for the same scenario as above (barrier failure with current climate):

```

$ASSIGN CMCCDF.SUM FOR004
$ASSIGN CMCCDF.OUT FOR006
$RUN CMCCDF
1,                                ,LOG Y-AXIS
CC3113.SUM                        ,OUTPUT FILE NAME
RA1311.DAT                        ,INPUT FILE NAME
CCDF13.DAT                        ,INPUT FILE NAME
                                ,END OF INPUT FILES
GEO. ALT.;CUR. CLIM. BF @2500 A.D.; BH @ 1000YR. TITLE FOR ABOVE
CC3123.SUM                        ,OUTPUT FILE NAME
RA1312.DAT                        ,INPUT FILE NAME
CCDF23.OUT                        ,INPUT FILE NAME
                                ,END OF INPUT FILES
IPSD ALT.;CUR. CLIM. BF @2500 A.D.; BH @ 1000 YR. TITLE FOR ABOVE
CC3133.SUM                        ,OUTPUT FILE NAME
RA1313.DAT                        ,INPUT FILE NAME
CCDF33.OUT                        ,INPUT FILE NAME
                                ,END OF INPUT FILES
REF. ALT.;CUR. CLIM. BF @2500 A.D.; BH @1000 YR. TITLE FOR ABOVE
                                ,END OF RUN INDICATOR

```

3.4.3 COMHUM Command File

The following command file executes the COMHUM code, reads the human intrusion CCDF for 1000 years after disposal (k=3), and creates 4 new files with the CCDF for each alternative on each file.

```
$ASSIGN COMHUM.OUT FOR006
$RUN COMHUM
1,                                ,LOG Y-AXIX
CCDFH3.DAT                        ,INPUT FILE NAME
1,                                ,ALTERNATIVE SELECTION
CCDF13.OUT                        ,OUTPUT FILE NAME
2,                                ,ALTERNATIVE SELECTION
CCDF23.OUT                        ,OUTPUT FILE NAME
3,                                ,ALTERNATIVE SELECTION
CCDF33.OUT                        ,OUTPUT FILE NAME
4,                                ,ALTERNATIVE SELECTION
CCDF43.OUT                        ,OUTPUT FILE NAME
0,                                ,END OF RUN INDICATOR
```

3.4.4 PRAPLT Command File

This program is run interactively. The user just needs to interactively answer the questions on the terminal screen.

3.4.5 W8CCDF Command File

The following command file executes program W8CCDF, reads the CCDF files for each scenario for the geologic disposal alternative, and reads the corresponding scenario probability for each scenario:

```
$ASSIGN W8CCDF.SUM FOR004
$ASSIGN W8CCDF.OUT FOR006
$RUN W8CCDF
1,                                ,LOG Y-AXIS
NH0010.SUM                        ,OUTPUT FILE NAME
CC2312.SUM                        ,INPUT FILE NAME-SCENARIO (2,3,2)
0.025                             ,SCENARIO PROBABILITY
```

CC2313.SUM	,INPUT FILE NAME-SCENARIO (2,3,3)
0.025	,SCENARIO PROBABILITY
CC3312.SUM	,INPUT FILE NAME-SCENARIO (3,3,2)
0.025	,SCENARIO PROBABILITY
CC3313.SUM	,INPUT FILE NAME-SCENARIO (3,3,3)
0.025	,SCENARIO PROBABILITY
CC2112.SUM	,INPUT FILE NAME-SCENARIO (2,2,2)
0.225	,SCENARIO PROBABILITY
CC2113.SUM	,INPUT FILE NAME-SCENARIO (2,1,3)
0.225	,SCENARIO PROBABILITY
CC3112.SUM	,INPUT FILE NAME-SCENARIO (3,1,2)
0.225	,SCENARIO PROBABILITY
CC3113.SUM	,INPUT FILE NAME-SCENARIO (3,1,3)
0.225	,SCENARIO PROBABILITY
	,END OF INPUT FILES INDICATOR
GEOLOGIC ALT. COMPOSITE CCDF FOR 8 SCENARIOS . TITLE FOR ABOVE	
	,END OF RUN INDICATOR

3.4.6 W8PLOT Command File

This program is run interactively. The user must answer the questions on the terminal screen.

4.0 REFERENCES

Department of Energy (DOE). 1987. Final Environmental Impact Statement-- Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes. DOE/EIS-0113, U.S. Department of Energy, Washington, D.C.

Environmental Protection Agency (EPA). 1985. High-Level and Transuranic Radioactive Waste--Background Information Document Final Rule. EPA 520/1-85-023, U.S. Environmental Protection Agency, Office of Radiation Protection Programs, Washington, D.C.

Little, A. D. 1980. Release Mechanisms. Volume D: Technical Support of Standards for High-Level Radioactive Waste Management. EPA 520/4-79-007D (PB81-106254), Office of Radiation Protection Programs, Washington, D.C.

APPENDIX A

ENVIRONMENTAL RELEASE LIMITS (40 CFR 191)

APPENDIX A
ENVIRONMENTAL RELEASE LIMITS (40 CFR 191)

The release limits used in Equation (1.1) are defined in this Appendix. Since the release limits for Hanford defense wastes depend on the disposal alternative being simulated, the disposal alternative index, A, will be used as a subscript; e.g., $RL_{N,A}$. $RL_{N,A}$ is the release limit for the nth radionuclide in curies for waste alternative A. N is the total number of radionuclides in the waste that are modeled. Eleven radionuclides were used on default in program PROBCON ($N = 11$). Their selection was based primarily on the inventory of each radionuclide divided by its release limit (i.e., the inventory-to-release-limit ratio). The radionuclides corresponding to the ten largest inventory-to-release-limit ratios were selected. The radionuclides included in PROBCON are ^{90}Sr , ^{137}Cs , ^{151}Sm , $^{239-240}\text{Pu}$, ^{241}Am , ^{63}Ni , ^{14}C , ^{238}U , ^{93}Zr , ^{99}Tc , and ^{129}I . ^{129}I was also included because it is highly soluble and transportable. The radionuclides that were omitted from PROBCON are not expected to contribute significantly to the release-ratio consequence over the next 10,000 years. This expectation is based on the knowledge that at least one of the following statements is true: the inventories of the remaining radionuclides are small relative to their allowed release limits; their high retardation factors cause their travel times to the groundwater to be greater than 10,000 years; or their radioactive decay half-lives are short compared to their travel times.

The release limits for the reprocessed irradiated fuel throughput used as default in PROBCON are based on approximately 94,000 metric tons of heavy metal (MTHM), before processing, represented in existing waste and 12,000 MTHM projected for future waste. Release limits (in curies) are calculated for each radionuclide from Table 1 of EPA standard 40 CFR 191 (EPA 1985), the fuel throughputs, the fuel burnup, and the amount of radionuclide inventory that is disposed of near surface on site for each disposal alternative.

For the reference and geologic disposal alternatives, the majority of the radionuclide inventories are disposed of in a geologic repository. The

EPA release limits for the radionuclides disposed of near surface in these two alternatives are lower than for the other alternatives when the release limits are proportioned by the amount of inventory disposed of on site.

The release limit, $RL_{n,A}$, for each radionuclide, n , for each alternative, A , is calculated by the following equation:

$$RL_{n,A} = C_n \cdot B \cdot (M_e \cdot E_{n,A} + M_f \cdot F_{n,A}) \quad (A.1)$$

where C_n = the release limit from Table 1 of 40 CFR 191 for each radionuclide n per 1,000 MTHM of fuel throughput

B = burnup correction factor = $5,000 \text{ MWd}/30,000 \text{ MWd} = 1/6$
(see Note 3 of 40 CFR 191; 5000 MWd/MTHM may be used when the average burnup is below 5000 MWd/MTHM)

M_e = number of thousand MTHM already processed and existing as waste at Hanford

M_f = number of thousand MTHM projected to be processed in the future at Hanford
= 12; i.e., 12,000 MTHM in future waste

$E_{n,A}$ = existing inventory of radionuclide n disposed of by alternative A divided by the total existing inventory of radionuclide n before disposal; i.e., the fraction of existing waste that will be disposed of near surface on site by disposal alternative A (see Equation A.2).

$$E_{n,A} = \frac{Q_{n,A,e}}{Q_{n,e}} \quad (A.2)$$

where $Q_{n,A,e}$ = existing inventory (Ci) of radionuclide n disposed of near surface by disposal alternative A

$Q_{n,e}$ = total existing inventory (Ci) of radionuclide n before disposal

$F_{n,A}$ = total existing inventory (Ci) of radionuclide n to be disposed of by alternative A divided by the total future inventory of radionuclide n before disposal; i.e., the fraction of future waste remaining on site with disposal alternative A (see Equation A.3).

$$F_{n,A} = \frac{Q_{n,A,f}}{Q_{n,f}} \quad (A.3)$$

where $Q_{n,A,f}$ = future inventory (Ci) of radionuclide n disposed of near surface by alternative A
 $Q_{n,f}$ = total future inventory (Ci) of radionuclide n before disposal.

Both the existing and future inventory-remaining fractions defined above are all equal to 1 for the no disposal action and the in-place stabilization and disposal alternatives. For these alternatives all radionuclide inventories remain near surface on site. Hence, these alternatives use the "total" release limits, which are not "partitioned." The radionuclide inventory fractions for the geologic disposal and reference alternatives, shown in Table A.1, are used in Equation A.1 to calculate the partitioned release limits for each radionuclide. The inventory-remaining fraction of each radionuclide is directly proportional to the partitioned release limit for each. The partitioned release limits were motivated by Note 4 of the 40 CFR 191, which states that a different release limit allocation may be used as long as the total release limit remains unchanged. The calculated release limits, as used here, for each radionuclide for each alternative are shown in Table A.2.

The burnup correction factor ($B = 1/6$) effectively reduces the existing fuel throughput from 94,000 MTHM to about 16,000 equivalent MTHM (eMTHM), and the future fuel throughput from 12,000 MTHM to 2,000 eMTHM (i.e., 18,000 eMTHM in total) for calculating the EPA release limits. The burnup correction factor used here is based on 5,000 MWd/MTHM, a value permitted by the EPA in Note 3 of 40 CFR 191 when the average burnup is below 5000 MWd/MTHM.

TABLE A.1. Fractions of Existing and Future Radionuclide Inventories Disposed of Near Surface for Geologic Disposal and Reference Alternatives

n	Radionuclide	Geologic Disposal		Reference (combination Disposal)	
		$E_{n,A=1}$	$F_{n,A=1}$	$E_{n,A=2}$	$F_{n,A=2}$
1	^{90}Sr	0.029	0.006	0.53	0.034
2	^{137}Cs	0.010	0.03	0.29	0.081
3	^{151}Sm	0.045	0.006	0.81	0.031
4	$^{239-240}\text{Pu}$	0.017	0.009	0.72	0.02
5	^{241}Am	0.029	0.009	0.72	0.048
6	^{63}Ni	0.051	0.001	0.93	0.001
7	^{14}C	1.0	1.0	1.0	1.0
8	^{238}U	0.046	0.75	1.0	0.75
9	^{93}Zr	0.053	0.032	1.0	0.075
10	^{99}Tc	0.037	0.034	1.0	1.0
11	^{129}I	1.0	1.0	1.0	1.0

TABLE A.2. 40 CFR 191 Table 1 Values and Partitioned Release Limits (Equation A.1) for Each Radionuclide Disposed of Near Surface for Each Alternative (Ci)

n	Radionuclide	Table 1	Geologic Disposal	Reference (combination Disposal)	In-Place Stabilization and Disposal	No Disposal Action
		191 C _n	RL _{n,A=1}	RL _{n,A=2}	RL _{n,A=3}	RL _{n,A=4}
1	⁹⁰ Sr	1,000	470	8,300	18,000	18,000
2	¹³⁷ Cs	1,000	210	4,750	18,000	18,000
3	¹⁵¹ Sm	1,000	720	12,500	18,000	18,000
4	²³⁹⁻²⁴⁰ Pu	100	28	1,000	1,800	1,800
5	²⁴¹ Am	100	47	1,100	1,800	1,800
6	⁶³ Ni	1,000	800	14,500	18,000	18,000
7	¹⁴ C	100	1,800	1,800	1,800	1,800
8	²³⁸ U	100	220	1,700	1,800	1,800
9	⁹³ Zr	1,000	900	15,800	18,000	18,000
10	⁹⁹ Tc	10,000	6,500	180,000	180,000	180,000
11	¹²⁹ I	100	1,800	1,800	1,800	1,800

REFERENCE

Environmental Protection Agency (EPA). 1985. High-Level and Transuranic Radioactive Waste -- Background Information Document Final Rule. EPA 52011-85-023, Office of Radiation Protection Programs, Washington, D.C.

APPENDIX B
DEFAULT PARAMETER VALUES

APPENDIX B
DEFAULT PARAMETER VALUES

The PROBCON code includes default values for all the model parameters as mentioned in the input section (Section 3.0). The parameter values consist primarily of inventory values for 11 radionuclides, transport parameter (Kd distribution coefficient) values for each radionuclide, and barrier and leaching parameter values. This appendix provides additional information on many of the default parameter values. The output file PROBCON.OUT lists all of the parameter values used for each sum. The scratch file FOR007.DAT gives actual values of key parameters used for each trial or sample (2000 samples are run on default in PROBCON).

The total radionuclide inventory values (including future waste) used on default in PROBCON are given in Table B.1.

The initial inventories of each radionuclide in each waste class for each alternative are listed in Tables P.19 through P.22 of the Hanford Defense Waste Environmental Impact Statement (DOE 1987). The inventory of ^{240}Pu ,

TABLE B.1. Total Radionuclide Inventories

<u>n</u>	<u>Radionuclide</u>	<u>Inventory, Ci</u>
1	^{90}Sr	123,000,000
2	^{137}Cs	126,000,000
3	^{151}Sm	1,220,000
4	$^{239-240}\text{Pu}$	123,000
5	^{241}Am	392,000
6	^{63}Ni	320,000
7	^{14}C	5,290
8	^{238}U	580
9	^{93}Zr	6,380
10	^{99}Tc	34,800
11	^{129}I	58

small in comparison to ^{239}Pu , is added to that of ^{239}Pu because their transport and release properties are expected to be the same; both have long radioactive half-lives and are usually taken together for dosimetry calculations. The longer half-life of ^{239}Pu is used on default in program PROBCON.

Fixed single-valued K_d values were used for grout waste and TRU wastes. For the single-shell and double-shell tank wastes, PROBCON uses these values for all the radionuclides except plutonium, americium, uranium, strontium, and nickel where pdfs are used. Log-normal pdfs of K_d values are used for plutonium, americium, strontium, and nickel, and a uniform pdf was used for uranium. Adopting a range or distribution of K_d values permits a realistic analysis that includes provision for uncertainty. The default minimum K_d values in the pdfs are the K_d values listed in Appendix P of the HDW-EIS for concentrated and complexed nuclides. The maximum sampled K_d values in the pdfs are chosen to be those for dilute noncomplexed values of soils reported by Delegard and Barney (1983). Nickel is assumed to have the same K_d values as ^{90}Sr , and ^{93}Zr is assumed to have a K_d value of 20mL/g. The default median K_d values are reported in Delegard and Barney (1983) except for plutonium in the no action alternative, where a median value closer to the concentrated complexed value was used. The plutonium K_d value is very important to the release-ratio consequence. For ^{238}U , a uniform pdf of K_d values was used for all waste classes with a low K_d value of 0 and high K_d value of 16mL/g. The K_d pdfs for single-shell and double-shell tank waste are summarized in Table B.2.

Input parameters that are described by pdfs are shown in Table B.2 with the assumed pdfs. The bimodal uniform (two-step) pdfs for the barrier failure recharges have a probability for the functional barrier failure of 0.95 (i.e., the area under the uniform section with the lower recharge values of the pdf is 0.95) and a probability of disruptive barrier failure of 0.05 (i.e., the area under the uniform section with the higher recharge values of the pdf is 0.05).

TABLE B.2. Summary of Probability Density Functions and Corresponding Parameters

Parameter (Unit)	pdf Type	Median	Parametric Values		
			Low	High	Deviation
1. Current Climate Recharge (cm/yr)	log-normal	1.5	0	5	0.9
2. Wetter Climate Recharge (cm/yr)	log-normal	5.0	1.5	15	2.5
3. Current Climate Recharge Under Barrier Failure (cm/yr)	bimodal (0.95)	0.05	0	0.1	1.7
	uniform (0.05)	7.5	5	10	
4. Wetter Climate Recharge Under Barrier Failure (cm/yr)	bimodal (0.95)	0.1	0	0.2	3.3
	uniform (0.05)	15	10	20	
5a. Plutonium K_d for Disposal Alternatives (mL/g)	log-normal	26.0	0.63	71	17.0
5b. Plutonium K_d for No Disposal Action (mL/g)	log-normal	6.0	0.63	71	10.7
6. Americium K_d (mL/g)	log-normal	15.5	5.6	130	15.0
7. Uranium K_d (mL/g)	uniform	8.0	0	16	4.6
8. Strontium, Nickel K_d (mL/g)	log-normal	1.5	0.02	21	3.0
9. Waste Fraction Under Barrier Failure, F_L	log-normal	0.08	0	1.0	0.25

REFERENCES

Delegard, C. H., and G. S. Barney. 1983. Effect of Hanford High-Level Waste Components on Sorption of Cobalt, Strontium, Neptunium, Plutonium, and Americium on Hanford Sediments. RHO-RE-ST-IP, Rockwell Hanford Operations, Richland, Washington.

APPENDIX C

PROBCON CODE LISTING

APPENDIX C

PROBCON CODE LISTING

```
C---- PROGRAM PROBCON CALCULATES THE PROBABILITY AND CONSEQUENCES OF THE
C      HANFORD DEFENSE WASTE DISPOSAL ALTERNATIVES OVER THE LONG TERM-10,000 YRS
C      PROGRAM PROBCON IS THE MAIN PROGRAM OF THE PROBCON-HDW SYSTEM OF CODES
C
C CODE CUSTODIAN:          MEL PIEPHO, (509)375-2049
C                          Fluid and Thermal Science Section (FTS)
C                          Pacific Northwest Laboratories (Battelle)
C
C      DATE: 1985
C
C Complete I/O revision by Tu-Cuong(Clark) H. Nguyen
C                          Fluid and Thermal Science Section (FTS)
C                          Pacific Northwest Laboratories (Battelle)
C
C NOTE: The input instructions are not listed here, but are contained in the
C FORTRAN code. The instructions were left out here because they are displayed
C in Section 3.2.1.
C
C      INCLUDE 'INCLUD.FOR/LIST'
C
C      COMMON /DUMMY /IDUMY
C      COMMON /LEACH /CONLTP
C
C      CHARACTER*1 REPLY,BLANK,LINE(99)
C      CHARACTER*40 KDFILE,OUTFIL,BLANKS,CHRGFL,QFILE,AREAF
1      ,KDSRFL,KDPUFL,KDAMFL,KDUFL,AWFFIL
C
C      LOGICAL MANINT,BARRIER,OUTHST,OUTCRG,OUTCCC,OUTKDS,OUTKDP,OUTKDA
1      ,OUTKDU,OUTAWF,TEST
C
C      DATA BLANK /' '/
C      DATA BLANKS/' '
C      INPT = 2
C
C---- LEACH TIME FOR GROUT
C      TLGROT=14000.
C
C      RT2PI=SQRT(2.*3.141592654)
C
C.....Open default output and summary files:
C      OPEN (UNIT=3,NAME='PROBCON.OUT',STATUS='NEW',FORM='FORMATTED')
C      OPEN (UNIT=4,NAME='PROBCON.SUM',STATUS='NEW',FORM='FORMATTED')
```



```

C.....Read in the title and the default data changes:
      CALL RDINPT(INPT)
C
C.....Make sure that the 'TITL>' card is in 'INPT.IN':
      DO 3 I=1,60
      IF (TITLE(I).NE.' ') GOTO 1
3 CONTINUE
      PRINT *, 'PROBCON: title not given in ''INPT.IN''
      PRINT *, '           use the ''TITL>'' option card!'
      STOP
1 MANINT = TYPE.EQ.'H'
2 FORMAT(60A1)
14 FORMAT(' OPENING ERROR ENCOUNTERED FOR FILE: ',A40)
      DO 9 GALT=1,4
      IF(GALT.EQ.1) WRITE (3,500)
      IF(GALT.EQ.4) WRITE (3,500)
      WRITE (3,522)
      WRITE (3, 4) ALTERN(GALT)
4 FORMAT('OALTERNATIVE: ',A35)
      WRITE (3, 7) (NAMEWC(J),J=1,MAXWST)
1      , (IFIX(YROI(J)),J=1,MAXWST)
7 FORMAT('O',39X,'ISOTOPE INVENTORIES [Ci] BY WASTE CLASS'/
1      53X,'W A S T E   C L A S S'/
2      ' N ISOTOPE ',11(A6,3X),2X,'TOTAL   N'/
3      16X,11('(',I4,')',3X)/)
      DO 9 N=1,NSTOPE
      DO 19 J=1,99
19 LINE(J)=BLANK
      SUM=0.
      DO 8 J=1,MAXWST
      IF(RQ(N,J,GALT).LE.0.) GO TO 8
      K=9*(J-1)+1
      ENCODE(9,21,LINE(K)) RQ(N,J,GALT)
21 FORMAT(1PE9.2)
      SUM=SUM+RQ(N,J,GALT)
8 CONTINUE
      WRITE (3,10) N,NAME(N),LINE,SUM,N
9 CONTINUE
10 FORMAT(I3,2X,A6,2X,99A1,1PE11.2,I4)
C
C---- CALCULATE RELEASE LIMITS
      CALL CALCR1
C
C
C
32 FORMAT(4E8.0)
C
      IF(MANINT) GO TO 114
C
C---- NATURAL RELEASE

```

```

C
17 IF((JALT.LE.0) .OR. (JALT.GT.4)) JALT=IALT
C
    IDUMY=32767
18 FORMAT(16I5)
    IF(NORANO.LT.0) GO TO 20
    IF(NORANO.EQ.0) GO TO 25
    DO 15 I=1,NORANO
    XX=RAN(IDUMY)
15 CONTINUE
    GO TO 25
C
C---- NORANO IS NEGATIVE OF NEW SEED FOR RANDOM NO. GENERATOR
C
20 IDUMY=NORANO/4
    IDUMY=2+4*IDUMY
    XX=RAN(IDUMY)
25 CONTINUE
C
41 FORMAT(A40)
42 FORMAT(10E8.0)
43 FORMAT(11E7.0)
C
36 DO 44 I=1,NSTOPE
    KD(I)=KDMED(I)
    IF(KDLO(I).EQ.KDHI(I)) GO TO 44
    VARH=(1.+SQRT(1.+4./KDMED(I)*KDVAR(I)/KDMED(I)))/2.
    PARAKD(1,I)=ALOG(KDMED(I))
    PARAKD(2,I)=SQRT(ALOG(VARH))
44 CONTINUE
C
    BARRIER=BARR.EQ.'Y'
    IF(.NOT.BARRIER) THEN
        DO 48 N=1,NSTOPE
48     DELAYT(N)=0.
        TBARFL = 0.
        GO TO 51
    END IF
    REBFLO=PARABF(1)
    REBFHI=PARABF(4)
    TEST=REBFLO.EQ.REBFHI
    IF(TEST) GO TO 51
    TEST=(PARABF(1).LT.PARABF(2)) .AND.
1      (PARABF(2).LE.PARABF(3)) .AND.
2      (PARABF(3).LT.PARABF(4)) .AND.
3      (      0..LE.PARABF(5)) .AND.
4      (PARABF(5).LE.      1.)
    IF(TEST) GO TO 51
51 CONTINUE
C

```

```

C
  55 FORMAT(8E10.0)
C
  79 FORMAT(10X,I3,2X,A22)
  81 FORMAT(' ',I5,2X,A6,I5)
  82 FORMAT(10I5)
 110 CONTINUE
C
C----- ENSURE THAT RETARDATION IS BOUNDED
        THETAR=.33
        BDO THE=BD /THETAR
C
C----- VARIANCE OF RECHARGE AND AFFECTED WASTE FRACTION
C LOGNORMAL DENSITY FUNCTIONS
C
        VARH= (1.+SQRT(1.+4./RMH*VAR/RMH))/2.
        PARAM (1)=ALOG(RMH)
        PARAM (2)=SQRT(ALOG(VARH))
        IF(AWFLO.EQ.AWFHI) GO TO 109
        IF(AWFVAR.EQ.0.) GO TO 109
        VARH= (1.+SQRT(1.+4./AWFMED*AWFVAR/AWFMED))/2.
        PARAWF(1)=ALOG(AWFMED)
        PARAWF(2)=SQRT(ALOG(AWFVAR))
 109 CONTINUE
C
        NPCTIL=0
        GOTO 200
C
C----- HUMAN INTRUSION
 114 CONTINUE
        OUTCCC = .TRUE.
        OPEN (UNIT=2,NAME='HICCDF.OUT',TYPE='NEW',
 1  FORM='FORMATTED')
C
C
C 116 PRINT *, ' ENTER TIME TO INTRUSION AFTER DISPOSAL TIME (YEARS)'
C      READ (5,55) TINTRU
C      IF(TINTRU.GE.0.) GO TO 120
C      PRINT *, ' INTRUSION TIME MUST BE => 0. '
C      PRINT *, ' DO YOU WANT TO TRY AGAIN? (Y OR N)'
C      READ (5,2) REPLY
C      IF(REPLY.EQ.'Y') GO TO 116
C      STOP ' RUN DISCONTINUED: INTRUSION TIME'
C
C      CALL MANIN(OUTCCC)
C      IF(.NOT.OUTCCC) GO TO 1
C      CLOSE(UNIT=2,DISPOSE='SAVE')
C      WRITE (3,125)
 125 FORMAT ('OHUMAN INTRUSION CCDF DATA SAVED ON FILE:
 1 HICCDF.OUT')

```

```

C      WRITE (3,125) OUTFIL
C 125 FORMAT('OHUMAN INTRUSION OUTPUT SAVED ON FILE: ',A40)
      CLOSE (UNIT=3,DISPOSE='SAVE')
      CLOSE (UNIT=4,DISPOSE='SAVE')
      STOP
C      GO TO 1
C
C---- ZERO OUT HISTOGRAM BINS
C
200 CONTINUE
      DO 201 I=1,MAXWST
201 CEWSTC(I)=0.
      DO 203 J=1,5
      DO 203 I=1,NSAMPL
203 WSTCLS(I,J)=0.
      DO 215 I=1,NHIST
      THISTN(I)=0.
215 CONTINUE
      DO 216 N=1,NSTOPE
      STATIS(N,1)=0.
      STATIS(N,2)=0.
      STATIS(N,3)= 1.E38
      STATIS(N,4)=-1.E38
      IF(KDHI(N).EQ.KDLO(N)) GO TO 216
      IF(N.EQ.1) GO TO 214
      IF(N.EQ.4) GO TO 214
      IF(N.EQ.5) GO TO 214
      IF(N.EQ.8) GO TO 216
C---- TREAT ANY UNIFORMLY DISTRIBUTED Kd'S
      RANGE=KDHI(N)-KDLO(N)
      IF(RANGE.EQ.0.) RANGE=1.
      XMXPDF(N)=1./RANGE
      XMNPDF(N)=XMXPDF(N)
      GO TO 216
214 XX=KDHI(N)
      TWOSIG=2.*PARAKD(2,N)**2
      XMXPDF(N)=EXP(-(ALOG(XX/KDMED(N))))**2/TWOSIG)
1      /(XX*PARAKD(2,N)*RT2PI)
      XMNPDF(N)=0.
      XX=KDLO(N)
      IF(XX.LE.0.) GO TO 216
      XMNPDF(N)=EXP(-(ALOG(XX/KDMED(N))))**2/TWOSIG)
1      /(XX*PARAKD(2,N)*RT2PI)
216 NCOUNT(N)=0
      DO 217 I=1,KDHSTS
217 FRKDSR(I)=0.
      DO 218 I=1,KDHSTP
218 FRKDPU(I)=0.
      DO 219 I=1,KDHSTA
219 FRKDAM(I)=0.

```

```

DO 220 I=1,KDHSTU
220 FRKDU (I)=0.
DO 221 I=1,NH20HS
221 RHIST(I)=0.
DO 222 N=1,NSTOPE
DO 222 I=1,MAXSAM
222 RELISO(I,N)=0.
DO 213 I=1,AWFHST
213 FRAWF (I)=0.
C
C----- RECHARGE DISTRIBUTION
C
IF(RECHHI.EQ.RECHLO) GO TO 223
XX=RECHHI
TWOSIG=2.*PARAM(2)**2
RCXPDF=EXP(-(ALOG(XX/RMH))**2/TWOSIG)/(XX*PARAM(2)*RT2PI)
XX=RECHLO
RCNPDF=0.
IF(XX.LE.0.) GO TO 223
RCNPDF=EXP(-(ALOG(XX/RMH))**2/TWOSIG)/(XX*PARAM(2)*RT2PI)
C
C----- AFFECTED WASTE FRACTION DISTRIBUTION
C
223 AWXPDF=0.
AWNPDF=0.
IF(AWFLO .EQ.AWFHI) GO TO 240
IF(AWFVAR.EQ.0. ) GO TO 240
XX=AWFHI
TWOSIG=2.*PARAWF(2)**2
AWXPDF=EXP(-(ALOG(XX/AWFMED))**2/TWOSIG)
1 / (XX*PARAWF(2)*RT2PI)
XX=AWFLO
IF(XX.LE.0.) GO TO 240
AWNPDF=EXP(-(ALOG(XX/AWFMED))**2/TWOSIG)
1 / (XX*PARAWF(2)*RT2PI)
C
C----- SET UP HISTOGRAM BIN BOUNDARIES
C
240 NO=2
IF(KDLO(1).EQ.KDHI(1)) NO=0
CALL MAKBIN(NO,PARAKD(1,1),KDLO(1),KDHI(1),KDHSTS,BNKDSR)
NO=2
IF(KOLO(4).EQ.KDHI(4)) NO=0
CALL MAKBIN(NO,PARAKD(1,4),KDLO(4),KDHI(4),KDHSTP,BNKDPU)
NO=2
IF(KDLO(5).EQ.KDHI(5)) NO=0
CALL MAKBIN(NO,PARAKD(1,5),KOLO(5),KDHI(5),KDHSTA,BNKDAM)
CALL MAKBIN( 0,PARAKD(1,8),KDLO(8),KDHI(8),KDHSTU,BNKDU )
NO=2
IF(RECHLO .EQ.RECHHI ) NO=0

```

```

      CALL MAKBIN(NO,PARAM      ,RECHLO ,RECHHI ,NH2OHS,BINREC)
      NO=5
      IF(REBFLO .EQ.REBFHI ) NO=0
      IF(BARRIER)
1CALL MAKBIN(NO,PARABF      ,REBFLO ,REBFHI ,NH2OBF,BINRBF)
      NO=2
      IF(AWFLO .EQ.AWFHI ) NO=0
      IF(AWFVAR.GT.0.)
1CALL MAKBIN(NO,PARAWF      ,AWFLO ,AWFHI ,AWFHST,BINAWF)
C
C---- GENERATE RANDOM NUMBERS SO AS TO GET CORRELATION BETWEEN KD'S
C      AND BETWEEN RECHARGE AND BARRIER-FAIL-RECHARGE.
      DO 225 I=1,NSAMPL
      COMON (I)=RAN(IDUMY)
      RELVAL(I)=RAN(IDUMY)
      IF(KDLO(1).EQ.KDHI(1)) AKDSR(I)=KDMED(1)
      IF(KDLO(4).EQ.KDHI(4)) AKDPU(I)=KDMED(4)
      IF(KDLO(5).EQ.KDHI(5)) AKDAM(I)=KDMED(5)
      IF(KDLO(8).EQ.KDHI(8)) AKDU (I)=KDMED(8)
      IF(RECHLO .EQ.RECHHI) RECHRG(I)=RMH
      IF(REBFLO .EQ.REBFHI) RECHBF(I)=REBFLO
      IF(AWFLO .EQ.AWFHI ) AWF (I)=AWFMED
225 CONTINUE
C
      IF(KDLO(1).NE.KDHI(1))
1CALL FILLUP(2,PARAKD(1,1),KDLO(1),KDHI(1),NSAMPL,AKDSR ,RELVAL,1)
      IF(KDLO(4).NE.KDHI(4))
1CALL FILLUP(2,PARAKD(1,4),KDLO(4),KDHI(4),NSAMPL,AKDPU ,RELVAL,1)
      IF(KDLO(5).NE.KDHI(5))
1CALL FILLUP(2,PARAKD(1,5),KDLO(5),KDHI(5),NSAMPL,AKDAM ,RELVAL,1)
      IF(KDLO(8).NE.KDHI(8))
1CALL FILLUP(0,PARAKD(1,8),KDLO(8),KDHI(8),NSAMPL,AKDU ,RELVAL,1)
      IF(RECHLO.NE.RECHHI)
1CALL FILLUP(2,PARAM      ,RECHLO ,RECHHI ,NSAMPL,RECHRG,COMON ,1)
      IF(BARRIER .AND. (REBFLO.NE.REBFHI))
1CALL FILLUP(5,PARABF      ,REBFLO ,REBFHI ,NSAMPL,RECHBF,COMON ,1)
      IF((AWFVAR.GT.0.) .AND. (AWFLO.NE.AWFHI))
1CALL FILLUP(2,PARAWF      ,AWFLO ,AWFHI ,NSAMPL,AWF ,RELVAL,2)
C
C---- COMPUTE CORRELATION BETWEEN ABOVE VARIABLES
      DO 248 I=1,7
248 AVE(I)=0.
      DO 249 I=1,NSAMPL
      AVE(1)=AVE(1)+AKDSR (I)
      AVE(2)=AVE(2)+AKDPU (I)
      AVE(3)=AVE(3)+AKDAM (I)
      AVE(4)=AVE(4)+AKDU (I)
      AVE(5)=AVE(5)+RECHRG(I)
      IF(.NOT.BARRIER) RECHBF(I)=0.
      AVE(6)=AVE(6)+RECHBF(I)

```

```

      IF(AWFVAR.LE.0.) AWF(I)=100.
249 AVE(7)=AVE(7)+AWF(I)
      SAMPLN=NSAMPL
      DO 247 I=1,7
247 AVE(I)=AVE(I)/SAMPLN
      SSQ(1,1)=DOTPRD(AKDSR,AKDSR,NSAMPL,AVE(1),AVE(1))
      SSQ(2,1)=DOTPRD(AKDPU,AKDSR,NSAMPL,AVE(2),AVE(1))
      SSQ(3,1)=DOTPRD(AKDAM,AKDSR,NSAMPL,AVE(3),AVE(1))
      SSQ(4,1)=DOTPRD(AKDU,AKDSR,NSAMPL,AVE(4),AVE(1))
      SSQ(5,1)=DOTPRD(RECHRG,AKDSR,NSAMPL,AVE(5),AVE(1))
      SSQ(6,1)=DOTPRD(RECHBF,AKDSR,NSAMPL,AVE(6),AVE(1))
      SSQ(7,1)=DOTPRD(AWF,AKDSR,NSAMPL,AVE(7),AVE(1))
      SSQ(2,2)=DOTPRD(AKDPU,AKDPU,NSAMPL,AVE(2),AVE(2))
      SSQ(3,2)=DOTPRD(AKDAM,AKDPU,NSAMPL,AVE(3),AVE(2))
      SSQ(4,2)=DOTPRD(AKDU,AKDPU,NSAMPL,AVE(4),AVE(2))
      SSQ(5,2)=DOTPRD(RECHRG,AKDPU,NSAMPL,AVE(5),AVE(2))
      SSQ(6,2)=DOTPRD(RECHBF,AKDPU,NSAMPL,AVE(6),AVE(2))
      SSQ(7,2)=DOTPRD(AWF,AKDPU,NSAMPL,AVE(7),AVE(2))
      SSQ(3,3)=DOTPRD(AKDAM,AKDAM,NSAMPL,AVE(3),AVE(3))
      SSQ(4,3)=DOTPRD(AKDU,AKDAM,NSAMPL,AVE(4),AVE(3))
      SSQ(5,3)=DOTPRD(RECHRG,AKDAM,NSAMPL,AVE(5),AVE(3))
      SSQ(6,3)=DOTPRD(RECHBF,AKDAM,NSAMPL,AVE(6),AVE(3))
      SSQ(7,3)=DOTPRD(AWF,AKDAM,NSAMPL,AVE(7),AVE(3))
      SSQ(4,4)=DOTPRD(AKDU,AKDU,NSAMPL,AVE(4),AVE(4))
      SSQ(5,4)=DOTPRD(RECHRG,AKDU,NSAMPL,AVE(5),AVE(4))
      SSQ(6,4)=DOTPRD(RECHBF,AKDU,NSAMPL,AVE(6),AVE(4))
      SSQ(7,4)=DOTPRD(AWF,AKDU,NSAMPL,AVE(7),AVE(4))
      SSQ(5,5)=DOTPRD(RECHRG,RECHRG,NSAMPL,AVE(5),AVE(5))
      SSQ(6,5)=DOTPRD(RECHBF,RECHRG,NSAMPL,AVE(6),AVE(5))
      SSQ(7,5)=DOTPRD(AWF,RECHRG,NSAMPL,AVE(7),AVE(5))
      SSQ(6,6)=DOTPRD(RECHBF,RECHBF,NSAMPL,AVE(6),AVE(6))
      SSQ(7,6)=DOTPRD(AWF,RECHBF,NSAMPL,AVE(7),AVE(6))
      SSQ(7,7)=DOTPRD(AWF,AWF,NSAMPL,AVE(7),AVE(7))
      DO 250 I=1,7
      SDN(I)=0.
      IF(SSQ(I,I).GT.0.) SDN(I)=SQRT(SSQ(I,I))
250 CONTINUE
      DO 254 J=1,7
      DO 254 I=J,7
      SDNIJ=SDN(I)*SDN(J)
      IF(SDNIJ.GT.0.) GO TO 253
      SSQ(I,J)=0.
      GO TO 254
253 SSQ(I,J)=SSQ(I,J)/SDNIJ
254 CONTINUE
      TSUM=SQRT(SAMPLN-1.)
      IF(NSAMPL.LE.1) GO TO 256
      DO 255 I=1,7
255 SDN(I)=SDN(I)/TSUM

```

C

```

C----- START OF SAMPLE LOOP
C
256 WRITE (7,500) TITLE
    WRITE (7,226) (NAME(N),N=1,NSTOPE)
226 FORMAT(' SMPL ',11(A6,4X),4X,'TOTAL'/)
    TSUM =0.
    TSQSUM=0.
    DO 300 I=1,NSAMPL
        KD(1)=AKDSR (I)
        KD(4)=AKDPU (I)
        KD(5)=AKDAM (I)
C----- ENSURE THAT Ni-63 HAS Kd VALUE IDENTICAL TO THAT OF Sr-90
        KD(6)=KD (1)
        KD(8)=AKDU (I)
        RCHRG=RECHRG(I)
        IF(BARRIER ) RCHBF=RECHBF(I)
        FL =AWF (I)
        IF(AWFVAR.EQ.0.) FL =AWFMED
        CALL BINNER(KD(1),BNKDSR,FRKDSR,KDHSTS)
        CALL BINNER(KD(4),BNKDPU,FRKDPU,KDHSTP)
        CALL BINNER(KD(5),BNKDAM,FRKDAM,KDHSTA)
        CALL BINNER(KD(8),BNKDU ,FRKDU ,KDHSTU)
        CALL BINNER(RCHRG,BINREC,RHIST ,NH20HS)
        IF(BARRIER)
1CALL BINNER(RCHBF,BINRBF,RBFHST,NH20BF)
        IF(AWFVAR.GT.0.)
1CALL BINNER(FL ,BINAWF,FRAWF ,AWFHST)
        RCHRG=RCHRG/2.54
        RCHBF=RCHBF/2.54
        FL =FL/100.
C----- GET TIME FOR RECHARGE WATER TO REACH WATER TABLE
        CALL INTRP(RCHRG,BINR,TWATIM,NWATER,TWAT)
        CALL LECHTM(RCHRG,TLSAVE)
        IF(.NOT.BARRIER) GO TO 227
        CALL INTRP(RCHBF,BINR,TWATIM,NWATER,TWATBF)
        CALL LECHTM(RCHBF,TLABF)
227 TOTAL=0.
        DO 235 N=1,NSTOPE
            TRVLT(N)=TWAT*(1.+BDOHE*KD(N))
            TRVLBF(N)=TRVLT(N)
            TDELAZ=TSHELL
            IF(.NOT.BARRIER ) GO TO 228
            IF(TBARFL.GE.BIGT) GO TO 228
C
C----- GET TRAVEL TIMES UNDER THE BARRIER, ASSUMING BARRIER FAILURE.
            TRVLBF(N)=TWATBF*(1.+BDOHE*KD(N))
            TDELAZ=AMAX1(TSHELL,TBARFL)
228 TDELAZ=TRVLT(N)+TDELAZ
C
C----- PROCESS ONLY THE FIRST 5 WASTE CLASSES, OTHERS HAVE LARGE Kd VALUES

```



```

C      DO 238 J=1,MAXWST
      DO 238 J=1,5
      IF(((J.EQ.3) .OR. (J.EQ.5)) .AND. (N.LE.6)) GO TO 238
      IF(RQ(N,J,IALT).LE.0.) GO TO 238
      RATIO=RQ(N,J,IALT)/RL(N,JALT)
      CEN =0.
      TL  =TSAVE
      IF(BARRIER .AND. (TBARFL.LT.BIGT)) TL=TLSABF
      IF((J.EQ.3) .OR. (J .EQ.5 )) TL=TLGROT
      TDELAY=AMAX1(TDELAX-YROI(J)+1995.,0.)
      IF(.NOT.BARRIER ) GO TO 224

C
C----- DIFFUSION RELEASE MODEL
      TDELAD=TDELAY+DELAJT(N)
      IF(TDELAD.GT.BIGT) GO TO 229
      DENOM =LAMDA(N)
      EXPDK =EXP(-LAMDA(N) *TDELAD)
      EXPARG=LAMDA(N)*(BIGT-TDELAD)
      EXPDIF=ONEMEX(EXPARG)
      CEN  =FR(J)/TP(J)*EXPDK*EXPDIF/DENOM*RATIO
229  IF(LEACHM(J,IALT).EQ.1 ) GO TO 234
      IF(TBARFL .GT.BIGT) GO TO 234
      CEN=(1.-FL)*CEN
224  TDELAY=AMAX1(TRVLBF(N)+TDELAZ-YROI(J)+1995.,0.)
      IF(TDELAY .GT.BIGT) GO TO 234
      CHRGR =RCHRG
      IF(BARRIER .AND. (TBARFL.LT.BIGT)) CHRGR=RCHBF
      IF(LEACHM(J,IALT).GT.2 ) GO TO 230

C
C----- DISSOLUTION-CONTROLLED RELEASE MODEL (LINEAR RELEASE MODEL)
      DENOM =LAMDA(N)*TL
      EXPDK =EXP(-LAMDA(N)*TDELAY)
      EXPARG=LAMDA(N)*(AMIN1(BIGT,TDELAY+TL)-TDELAY)
      EXPDIF=ONEMEX(EXPARG)
      CEN  =CEN+FL*EXPDK*EXPDIF/DENOM*RATIO
      GO TO 234

C
230 IF(LEACHM(J,IALT).GT.3) GO TO 233
C
C----- SOLUBILITY-CONTROLLED RELEASE MODEL
      IF((TDELAZ+TRVLBF(N)).GE.BIGT) GO TO 234
      AREA =HIGA(J,IALT)
      BASE =CHRG*AREA*0.0254*CSOL(N)*1000.
      CI    =RQ(N,J,IALT)*EXP(-LAMDA(N)*TDELAZ)
      TRLEAS=10.*BIGT
      IF(BASE.NE.0.) TRLEAS=ALOG(CI*LAMDA(N)/BASE+1.)/LAMDA(N)
      TUPPER=TRLEAS
      IF((TRLEAS+(TRVLBF(N)+TDELAZ)).GE.BIGT)
1      TUPPER=BIGT-(TRVLBF(N)+TDELAZ)
      EXPDK = EXP(-LAMDA(N)*TRVLBF(N))

```

```

EXPARG=LAMDA(N)*TUPPER
EXPDIF=ONEMEX(EXPARG)
DENOM =RQ(N,J,IALT)*LAMDA(N)
CEN   =CEN+FL*BASE*EXPDK*EXPDIF/DENOM*RATIO
GO TO 234

C
233 IF(LEACHM(J,IALT).GT.4) GO TO 234
C
C----- ADSORPTION-CONTROLLED RELEASE MODEL
RETARD=1.+BDOHE*KD(N)
ALAMD=0.0254*CHRG/(RETARD*THETA*H)
TOTLMD=ALAMD+LAMDA(N)
DENOM=TOTLMD
EXPDK=EXP(-LAMDA(N)*TDELAY)
EXPDIF=0.
EXPARG=TOTLMD*(BIGT-TDELAY)
EXPDIF=ONEMEX(EXPARG)
CEN   =CEN+FL*ALAMD*EXPDK*EXPDIF/DENOM*RATIO

C
C----- END OF NATURAL RELEASE MODELS
C
234 TOTAL=TOTAL+CEN
RELISO(I,N)=RELISO(I,N)+CEN
CEWSTC(J )=CEWSTC(J )+CEN
WSTCLS(I,J)=WSTCLS(I,J)+CEN
238 CONTINUE
IF(RELISO(I,N).LE.0.) GO TO 235
NCOUNT(N )=NCOUNT(N )+1
STATIS(N,1)=STATIS(N,1)+RELISO(I,N)
STATIS(N,2)=STATIS(N,2)+RELISO(I,N)**2
STATIS(N,3)=AMIN1(STATIS(N,3),RELISO(I,N))
STATIS(N,4)=AMAX1(STATIS(N,4),RELISO(I,N))
235 CONTINUE
WRITE (7,237) I,(RELISO(I,N),N=1,NSTOPE),TOTAL
237 FORMAT(' ',I4,1P11E10.3,5X,E10.3)
TSUM  =TSUM  +TOTAL
TSQSUM=TSQSUM+TOTAL**2
RELVAL(I)=TOTAL
300 CONTINUE
CALL SORT(RELVAL,1,1,1,NSAMPL)
I50  =SAMPLN*0.500+0.5
I90  =SAMPLN*0.900+0.5
I99  =SAMPLN*0.990+0.5
I999 =SAMPLN*0.999+0.5
IF(I50 .LT.1) I50 =1
IF(I90 .LT.1) I90 =1
IF(I99 .LT.1) I99 =1
IF(I999.LT.1) I999=1
TOTMIN=RELVAL(I)
TOTMAX=RELVAL(NSAMPL)

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```

TCENTN(1)=TOTMIN
J=NSAMPL/(NHIST-1)
K=J*(NHIST-2)
JJ=0
DO 301 I=3,NHISTO
IF((NSAMPL-JJ).LE.J) J=1
JJ=JJ+J
C TCENTN(I-1)=(RELVAL(JJ)+RELVAL(JJ+1))/2.
TCENTN(I-1)=RELVAL(JJ)
301 THISTN(I-2)=J
TCENTN(NHISTO)=TOTMAX
THISTN(NHISTO)=0
THISTN(NHISTO-1)=J
WRITE (7,303) NCOUNT
303 FORMAT('NUMBER OF NONZERO ENTRIES IN EACH COLUMN:'/1X,11I10)
AVERAG=TSUM/SAMPLN
VARINC=0.
IF(NSAMPL.GT.1) VARINC=(TSQSUM-SAMPLN*AVERAG**2)/(SAMPLN-1.)
VARINC=AMAX1(VARINC,0.)
SD=SQRT(VARINC)
C
TOTALS(1,1)=0.
TOTALS(2,1)=0.
TOTALS(3,1)=0.
TOTALS(4,1)=0.
DO 315 N=1,NSTOPE
IF(NCOUNT(N).LE.0) GO TO 315
CALL SORT(RELISO(1,N),1,1,1,NSAMPL)
DO 310 J=1,4
IF(J.EQ.1) X=0.500
IF(J.EQ.2) X=0.900
IF(J.EQ.3) X=0.990
IF(J.EQ.4) X=0.999
I=SAMPLN*X+0.5
IF(I.LT.1) I=1
QANTCS(J,N)=RELISO(I,N)
TOTALS(J,1)=TOTALS(J,1)+RELISO(I,N)
TOTALS(J,2)=TOTALS(J,2)+RELISO(I,N)*FBWIP(N,IALT)
310 QANTCI(J,N)=RELISO(I,N)*RL (N,JALT)
315 CONTINUE
C
DO 317 N=1,5
CALL SORT(WSTCLS(1,N),1,1,1,NSAMPL)
DO 316 J=1,4
IF(J.EQ.1) X=0.500
IF(J.EQ.2) X=0.900
IF(J.EQ.3) X=0.990
IF(J.EQ.4) X=0.999
I=SAMPLN*X+0.5
IF(I.LT.1) I=1

```

```

      WSTCQN(J,N)=WSTCLS(I,N)
316 CONTINUE
317 CONTINUE
C
C      IF(.NOT.OUTCRG) GO TO 370
      OPEN(UNIT=2,NAME='RECHRG.OUT',TYPE='NEW',FORM='FORMATTED',ERR=318)
      GO TO 320
318 WRITE (3,319)
C 318 WRITE (3,319) CHRGL
319 FORMAT(' OPENING ERROR ENCOUNTERED FOR FILE: ',A40/
1      ' NOTHING WRITTEN TO THIS FILE.  RUN CONTINUED.')
```

```

      GO TO 370
320 WRITE (2, 2) TITLE
      WRITE (2,330)
330 FORMAT('RECHARGE (cm)',58X)
      WRITE (2,340)
340 FORMAT('COUNT',66X)
      WRITE (2,350) BRCMIN,BRCMAX
      WRITE (2,350) RECHLO,RCNPDI
      WRITE (2,350) RECHHI,RCXPDF
350 FORMAT(1P2E15.7)
351 FORMAT(1PE15.7)
      CALL CCDFER(NH2OHS-1,RHIST,COMON)
      DO 360 I=1,NH2OHS
360 WRITE (2,350) BINREC(I),COMON(I)
      WRITE (2,361)
361 FORMAT(9X,'88888.',9X,'88888.'/9X,'99999.',9X,'99999.')
```

```

      CLOSE(UNIT=2,DISPOSE='SAVE')
370 CONTINUE
C 370 IF(.NOT.OUTKDS) GO TO 380
      OPEN(UNIT=2,NAME='KDSR.OUT',TYPE='NEW',FORM='FORMATTED',ERR=371)
      GO TO 372
371 WRITE (3,319)
C 371 WRITE (3,319) KDSRFL
C      GO TO 380
372 WRITE (2, 2) TITLE
      WRITE (2,374)
374 FORMAT('Kd(Sr) AND Kd(Ni)',54X)
      WRITE (2,340)
      WRITE (2,350) BKDSRN,BKDSRX
      WRITE (2,350) KDLO(1),XMNPDI(1)
      WRITE (2,350) KDHI(1),XMXPDI(1)
      CALL CCDFER(KDHSTS-1,FRKDSR,COMON)
      DO 378 I=1,KDHSTS
378 WRITE (2,350) BNKDSR(I),COMON(I)
      WRITE (2,361)
      CLOSE(UNIT=2,DISPOSE='SAVE')
```

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C 380 IF(.NOT.OUTKDP) GO TO 390
      OPEN(UNIT=2,NAME='KDPU.OUT',TYPE='NEW',FORM='FORMATTED',ERR=381)
      GO TO 382
```

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381 WRITE (3,319)
C 381 WRITE (3,319) KDPUFL
C GO TO 390
382 WRITE (2, 2) TITLE
WRITE (2,384)
384 FORMAT('Kd(Pu)',65X)
WRITE (2,340)
WRITE (2,350) BKDPUN,BKDPUX
WRITE (2,350) KDLO(4),XMNPDF(4)
WRITE (2,350) KDHI(4),XMXPDF(4)
CALL CCDFER(KDHSTP-1,FRKDPU,COMON)
DO 388 I=1,KDHSTP
388 WRITE (2,350) BNKDPU(I),COMON(I)
WRITE (2,361)
CLOSE(UNIT=2,DISPOSE='SAVE')
C 390 IF(.NOT.OUTKDA) GO TO 393
OPEN(UNIT=2,NAME='KAM.OUT',TYPE='NEW',FORM='FORMATTED',ERR=387)
GO TO 389
387 WRITE (3,319)
C 387 WRITE (3,319) KAMFL
C GO TO 393
389 WRITE (2, 2) TITLE
WRITE (2,391)
391 FORMAT('Kd(Am)',65X)
WRITE (2,340)
WRITE (2,350) BKDAMN,BKDAMX
WRITE (2,350) KDLO(5),XMNPDF(5)
WRITE (2,350) KDHI(5),XMXPDF(5)
CALL CCDFER(KDHSTA-1,FRKDAM,COMON)
DO 392 I=1,KDHSTA
392 WRITE (2,350) BNKDAM(I),COMON(I)
WRITE (2,361)
CLOSE(UNIT=2,DISPOSE='SAVE')
C 393 IF(.NOT.OUTKDP) GO TO 396
OPEN(UNIT=2,NAME='KDU.OUT',TYPE='NEW',FORM='FORMATTED',ERR=399)
GO TO 401
399 WRITE (3,319)
C 399 WRITE (3,319) KDUFL
C GO TO 396
401 WRITE (2, 2) TITLE
WRITE (2,394)
394 FORMAT('Kd(U)',66X)
WRITE (2,340)
WRITE (2,350) BKDUMN,BKDUMX
WRITE (2,350) KDLO(8),XMNPDF(8)
WRITE (2,350) KDHI(8),XMXPDF(8)
CALL CCDFER(KDHSTU-1,FRKDU,COMON)
DO 395 I=1,KDHSTU
395 WRITE (2,350) BNKOU(I),COMON(I)
WRITE (2,361)

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```

      CLOSE(UNIT=2,DISPOSE='SAVE')
C 396 IF(.NOT.OUTAWF) GO TO 400
      OPEN(UNIT=2,NAME='AWF.OUT',TYPE='NEW',FORM='FORMATTED',ERR=402)
      GO TO 403
402 WRITE (3,319)
C 402 WRITE (3,319) AWWFIL
C      GO TO 400
403 WRITE (2, 2) TITLE
      WRITE (2,397)
397 FORMAT('AFFECTED WASTE FRACTION (%)',44X)
      WRITE (2,340)
      WRITE (2,350) AWFMIN,AWFMAX
      WRITE (2,350) AWFLO ,AWNPDF
      WRITE (2,350) AWFHI ,AWXPDF
      CALL CCDFER(AWFHST-1,FRAWF,COMON)
      DO 398 I=1,AWFHST
398 WRITE (2,350) BINAWF(I),COMON(I)
      WRITE (2,361)
      CLOSE(UNIT=2,DISPOSE='SAVE')
C
C 400 IF(.NOT.OUTHST) GO TO 410
      OPEN (UNIT=2,NAME='RELAT.OUT',TYPE='NEW',FORM='FORMATTED',
1      ERR=404)
      GO TO 406
404 WRITE (3,319)
C 404 WRITE (3,319) OUTFIL
C      GO TO 410
406 WRITE (2, 2) TITLE
      WRITE (2,405)
405 FORMAT('CONSEQUENCE',60X)
      WRITE (2,340)
      WRITE (2,350) BTCMIN,BTCMAX
      ONENEG=-1.
      WRITE (2,350) ONENEG,ONENEG
      WRITE (2,350) ONENEG,ONENEG
      CALL CCDFER(NHISTO-1,THISTN,COMON)
      DO 407 I=1,NHISTO
407 WRITE (2,350) TCENTN(I),COMON(I)
      WRITE (2,361)
      CLOSE(UNIT=2,DISPOSE='SAVE')
C
410 WRITE (3,500) TITLE
500 FORMAT('1',60A1)
      WRITE (3,498) BIGT
497 FORMAT('0'///' ==> ==> ==> ==> RELEASE LIMITS WERE USED FROM'
1      , ' ALTERNATIVE: ',A35///)
498 FORMAT('OMAX TIME PERMITTED: ',F9.0
1      , ' [YEARS]')
      WRITE (3,499) ALTERN(IALT)
499 FORMAT('OALTERNATIVE USED: ',A35)

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      IF(IALT.NE.JALT) WRITE (3,497) ALTERN(JALT)
      WRITE (3,501) KDFILE
501  FORMAT('OKD DATA FILE NAME: ',A40,/)
      WRITE (3,502)
502  FORMAT('      ISOTOPE KD-MEDIAN KD-VAR.  KDLO'
1, '      KDHI COVER DELAY REL.LIMIT HALFLIFE  DECAY CONST.'
2, '      SOLUBILITY LIMITS')
      WRITE (3,503) (I,NAME(I)
1, '      KDMED(I),KDVAR(I),KDLO(I),KDHI(I),DELAYT(I)
2, '      RL(I,JALT),ALOG(2.)/LAMDA(I),LAMDA(I),CSOL(I),I=1,NSTOPE)
503  FORMAT(I3,3X,A6,0PF9.2,F9.2,2F9.2,F9.0,1PE14.3,1PE10.2,1PE13.2
1, '      F20.4)
      WRITE (3,510)
      DO 504 J=1,MAXWST
      K=LEACHM(J,IALT)
      AREA=HIGA(J,IALT)*1.E6
      IF((J.EQ.6) .AND. (NOCANS(IALT,1).EQ.0)) AREA=0.
      IF((J.EQ.7) .AND. (NOCANS(IALT,2).EQ.0)) AREA=0.
      WRITE (3,511) J,NAMEWC(J),AREA,K,LEACHN(K)
504  CONTINUE
      IF(NORANO.LT.0) WRITE (3,505) -NORAND
505  FORMAT('OSTARTING RANDOM NO. SEED: ',I10)
      IF(NORANO.GE.0) WRITE (3,506) NORANO
506  FORMAT('ORANDOM NOS. DISCARDED PRIOR TO RUN:      ',I10)
510  FORMAT('O      WASTE      AREA      LEACH'
1, '      /'      CLASS      [M**2]      MODEL'/)
511  FORMAT(I4,2X,A6,F11.2,I5,5X,A22)
      WRITE (3,520) NSAMPL
520  FORMAT(' NUMBER OF SAMPLES RUN:      ',I10)
      WRITE (3,522)
      IF(.NOT.BARRIER) GO TO 528
      WRITE (3,521)
521  FORMAT(' BARRIER ASSUMED.  DIFFUSION PARAMETERS ARE: '/
1, '      WASTE CLASS  FRACTION OF Q/TIME PERIOD [1/YEARS]')
522  FORMAT(' ')
      DO 523 J=1,5
      WRITE (3,524) NAMEWC(J),FR(J),TP(J)
523  CONTINUE
524  FORMAT(6X,A6,15X,F4.2,'/',F6.0)
      WRITE (3,522)
      WRITE (3,525) TBARFL
525  FORMAT(' TIME TO BARRIER FAILURE:      ',F10.0
1, ' [YEARS]')
      WRITE (3,522)
      WRITE (3,526) PARABF(1),PARABF(2), PARABF(5)
1, '      ,PARABF(3),PARABF(4),1.-PARABF(5)
526  FORMAT('OBARRIER-FAILURE-RECHARGE DISTRIBUTION: '/
1, '      MIN [cm] MAX [cm] PROBABILITY' /
2, '      'O',F8.3,2X,F8.3,3X,F7.3/F9.3,2X,F8.3,3X,F7.3)
      WRITE (3,522)

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```

        WRITE (3,522)
528 WRITE (3,540) TSHELL
540 FORMAT(' STEEL SHELL TANK LIFE TIME:           ',F10.0
      1  , ' [YEARS]')
C
        WRITE (3,541) AWFLO
541 FORMAT(' OMIN VALUE FOR AWF DISTRIBUTION:       ',F10.3
      1  , ' [%]')
        WRITE (3,542) AWFHI
542 FORMAT(' MAX VALUE FOR AWF DISTRIBUTION:        ',F10.3
      1  , ' [%]')
        WRITE (3,543) AWFMED
543 FORMAT(' MEDIAN VALUE FOR AWF DISTRIBUTION:     ',F10.3
      1  , ' [%]')
        WRITE (3,544) AWFVAR
544 FORMAT(' VARIANCE FOR AWF DISTRIBUTION:         ',F10.3
      1  , ' [%**2]')
C
        WRITE (3,545) RECHLO
545 FORMAT(' OMIN VALUE FOR RECHARGE DISTRIBUTION:   ',F10.3
      1  , ' [CM]')
        WRITE (3,546) RECHHI
546 FORMAT(' MAX VALUE FOR RECHARGE DISTRIBUTION:    ',F10.3
      1  , ' [CM]')
        WRITE (3,550) RMH
550 FORMAT(' MEDIAN VALUE FOR RECHARGE DISTRIBUTION: ',F10.3
      1  , ' [CM]')
        WRITE (3,560) VAR
560 FORMAT(' VARIANCE FOR RECHARGE DISTRIBUTION:    ',F10.3
      1  , ' [CM**2]')
        WRITE (3,561) CONLTP
561 FORMAT(' OLEACHING TIME PARAMETER FOR NON-GROUT: ',F10.3)
        WRITE (3,562) TLGROT
562 FORMAT(' LEACHING TIME PARAMETER FOR GROUT:      ',F10.2)
        WRITE (3,570) BD
570 FORMAT(' OBULK DENSITY OF SOIL:                 ',F10.3
      1  , ' [M/L**3]')
        WRITE (3,580) THETA*100.
580 FORMAT(' VOLUMETRIC MOISTURE CONTENT OF SOIL:    ',F10.3
      1  , ' [%]')
        WRITE (3,584) H
584 FORMAT(' THICKNESS OF WASTE DEPOSIT:            ',F10.3
      1  , ' [M]')
C
        WRITE (3,600) NAME(1)
        CALL HSTPRN(NSAMPL,BNKDSR,FRKDSR,KDHSTS)
        WRITE (3,610)
        WRITE (3,600) NAME(4)
        CALL HSTPRN(NSAMPL,BNKOPU,FRKOPU,KDHSTP)
        WRITE (3,610)

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WRITE (3,600) NAME(5)
CALL HSTPRN (NSAMPL,BNKDAM,FRKDAM,KDHSTA)
WRITE (3,610)
WRITE (3,600) NAME(8)
CALL HSTPRN(NSAMPL,BNKDU ,FRKDU,KDHSTU)
WRITE (3,620)
CALL HSTPRN(NSAMPL,BINREC,RHIST,NH2OHS)
WRITE (3,610)
IF(.NOT.BARRIER ) GO TO 585
WRITE (3,618)
CALL HSTPRN(NSAMPL,BINRBF,RBFHST,NH2OBF)
WRITE (3,610)
585 IF(AWFVAR.LE.0.) GO TO 586
WRITE (3,622)
CALL HSTPRN(NSAMPL,BINAWF,FRAWF,AWFHST)
WRITE (3,610)
C
586 WRITE (3,581)
581 FORMAT('OSTAN.DEV. AND CORRELATION MATRIX FOR: Kd(Sr),Kd(Pu)'
1  ',Kd(Am),Kd(U),recharge,barr.fail-rechrg, and affected'
2  ',-waste-fraction'//)
DO 582 I=1,7
WRITE (3,583) I,SDN(I),(SSQ(I,J),J=1,I)
582 CONTINUE
583 FORMAT(I3,F14.4,3X,7F12.4)
WRITE (3,610)
C
WRITE (3,627) TITLE
627 FORMAT ('IFINAL STATISTICS FOR A CALCULATED RELEASE-RATIO',
1  ' CONSEQUENCE FOR'/' CASE (title): ',60A1)
WRITE (3,590) AVERAG,SD,TOTMIN,TOTMAX
590 FORMAT('OMEAN =',1PE15.7/' S.D. =',E15.7
1  '/' MIN =', E15.7/' MAX =',E15.7)
WRITE (3,591) RELVAL(I50),RELVAL(I90),RELVAL(I99),RELVAL(I999)
591 FORMAT('OQUANTILE VALUES OF RELEASE-RATIO CONSEQUENCE'//
1  ' 50 -TH =',1PE15.7/
2  ' 90 -TH =', E15.7/
3  ' 99 -TH =', E15.7/
4  ' 99.9-TH =', E15.7)
IF(NPCTIL.LE.0) GO TO 589
DO 588 I=1,NPCTIL
J=SAMPLN*PERCEN(I)/100.+0.5
IF(J.LT.1) J=1
WRITE (3,587) PERCEN(1),RELVAL(J)
587 FORMAT('O',F3.1,'-TH =',1PE15.7)
588 CONTINUE
589 WRITE (3,592)
592 FORMAT('O STATISTICS FOR THOSE ISOTOPES REACHING THE BIOSPHERE'/'
1  'O N ISOTOPE NUMBER MEAN S.D. MINIMUM '
2  ', 'MAXIMUM'//)

```

```

DO 597 N=1,NSTOPE
IF(NCOUNT(N).GT.0) GO TO 595
WRITE (3,593) N,NAME(N)
593 FORMAT(I3,3X,A6,I8,1P4E11.3)
GO TO 597
C
595 COUNT=NCOUNT(N)
AVERAG=STATIS(N,1)/COUNT
SD=0.
IF(COUNT.GT.1.) SD=(STATIS(N,2)-COUNT*AVERAG**2)/(COUNT-1.)
SD=AMAX1(SD,0.)
SD=SQRT(SD)
WRITE (3,593) N,NAME(N),NCOUNT(N),AVERAG,SD,STATIS(N,3)
1 ,STATIS(N,4)
597 CONTINUE
C
WRITE (3,610)
TOTAL=0.
DO 598 J=1,MAXWST
CEWSTC(J)=CEWSTC(J)/SAMPLN
598 TOTAL=TOTAL+CEWSTC(J)
IF(TOTAL.GT.0.) GO TO 594
WRITE (3,596)
596 FORMAT('ONOTHING ESCAPED.... END OF REPORT!')
GO TO 1
C
594 WRITE (3,601)
DO 599 J=1,MAXWST
PERCTL=CEWSTC(J)/TOTAL
WRITE (3,602) J,NAMEWC(J),CEWSTC(J),PERCTL
599 CONTINUE
WRITE (3,603) TOTAL
C
600 FORMAT('OHISTOGRAM FOR KD(' ,A6,')')
601 FORMAT('O AVERAGE CONSEQUENCE BY WASTE CLASS'//
1 ' NAME CONSEQUENCE %'//)
602 FORMAT(I4,2X,A6,1PE11.2;2PF7.2)
603 FORMAT('O TOTAL ' ,1PE11.2,' 100.00')
C
WRITE (3,604)
604 FORMAT('O MAJOR INDIVIDUAL WASTE CLASS QUANTILE CONSEQUENCES'//
1 ' NAME 50 % 90 % 99 % 99.9 %'//)
DO 605 I=1,5
WRITE (3,606) I,NAMEWC(I),(WSTCQN(J,I),J=1,4)
605 CONTINUE
606 FORMAT(I4,2X,A6,1P4E10.2)
C
610 FORMAT('O')
618 FORMAT('OHISTOGRAM FOR BARRIER-FAILURE-RECHARGE [cm]')
620 FORMAT('OHISTOGRAM FOR RECHARGE [CM]')
622 FORMAT('OHISTOGRAM FOR AFFECTED WASTE FRACTION')

```

```

        WRITE (3,610)
        WRITE (3,630)
630  FORMAT('OHISTOGRAM FOR TOTAL CONSEQUENCE')
        CALL HSTPRN(NSAMPL,TCENTN,THISTN,NHISTO)
        WRITE (3,610)
C
C---- WRITE OUT INDIVIDUAL ISOTOPE QUANTILE RELEASES [CURIES].
C
        LUNIT=3
        DO 720 K=1,2
        IF(K.EQ.2) LUNIT=4
        WRITE (LUNIT,500) TITLE
        WRITE (LUNIT,610)
        WRITE (LUNIT,610)
        WRITE (LUNIT,635)
635  FORMAT('OINDIVIDUAL ISOTOPE QUANTILE RELEASES [CURIES]')
        WRITE (LUNIT,640)
640  FORMAT('O N ISOTOPE INIT. Q REL.LIMIT'
1      , ' 50 % 90 % 99 % 99.9 %/')
        DO 660 N=1,NSTOPE
        SUM=0.
        DO 642 J=1,MAXWST
642  SUM=SUM+RQ(N,J,IALT)
        IF(NCOUNT(N).GT.0) GO TO 650
        WRITE (LUNIT,645) N,NAME(N),SUM,RL(N,JALT)
645  FORMAT(I3,3X,A6,1P6E10.2)
        GO TO 660
650  WRITE (LUNIT,645) N,NAME(N),SUM,RL(N,JALT),(QANTCI(J,N),J=1,4)
660  CONTINUE
C
        WRITE (LUNIT,610)
        WRITE (LUNIT,610)
        WRITE (LUNIT,661)
661  FORMAT('OINDIVIDUAL ISOTOPE RELEASE RATIO CONSEQUENCE')
        WRITE (LUNIT,662)
662  FORMAT('O',23X,'50 % QUANTILE',5X,'90 % QUANTILE',5X,
1      , '99 % QUANTILE',4X,'99.9 % QUANTILE'/35X,'% ',17X,'% ',17X
2      , '% ',17X,'% ')
        DO 670 N=1,NSTOPE
        IF(NCOUNT(N).GT.0) GO TO 665
        WRITE (LUNIT,664) N,NAME(N)
664  FORMAT(I3,3X,A6,8X,4(1PE11.2,0PF7.2))
        GO TO 670
665  WRITE (LUNIT,664) N,NAME(N),(QANTCS(J,N)
1      , QANTCS(J,N)/TOTALS(J,1)*100.,J=1,4)
670  CONTINUE
        WRITE (LUNIT,671) (TOTALS(J,1),J=1,4)
671  FORMAT('OTOTAL CONSEQUENCE ',1PE10.2,' 100.00'
1      ,3(E11.2,' 100.00'))
720  CONTINUE

```

```

C      GO TO 1
      CLOSE (UNIT=3,DISPOSE='SAVE')
      CLOSE (UNIT=4,DISPOSE='SAVE')
      STOP
      END
      BLOCK DATA
      INCLUDE 'INCLUD.FOR/LIST'

C
      DATA NSTOPE / 11 /

C
C---- ISOTOPE DATA
      DATA (NAME(I),I=1,11) / 'Sr- 90', 'Cs-137', 'Sm-151', 'Pu-239'
1      , 'Am-241', 'Ni- 63', 'C - 14', 'U -238', 'Zr- 93', 'Tc- 99'
2      , 'I -129'/

C---- DECAY CONSTANTS = LOG(2)/(HALF LIFE)
      DATA (LAMDA(I),I=1,11) / 2.4E-2, 2.3E-2, 7.5E-3, 2.9E-5
1      , 1.6E-3, 6.9E-3, 1.2E-4, 0.15E-9, 7.3E-7, 3.3E-6
2      , 4.3E-8/

C
C---- SOLUBILITY CONCENTRATIONS IN SST (MAX) [microcurries/liter]
      DATA (CSOL(I),I=1,11) /160000.,670000., 7200., 1.6, 1300.
1      , 1500., 7.6, 0.0012, 35., 340., 0.20 /

C
C---- TABLE 1 FROM 40 CFR 191
      DATA (CFRT1(I),I=1,11) / 1000., 1000., 1000., 100.
1      , 100., 1000., 100., 100., 1000., 10000.
2      , 100./

C
C---- MULTIPLICATIVE FACTOR FOR MODIFIED RELEASE LIMITS
C
      DATA ((FBWIP(I,J),I=1,11),J=1,4) / 44 * 1.0 /

C
C---- (E,F)KMTHM = (EXISTING,FUTURE) TONNAGE OF HEAVY METAL
C              IN TOTAL INVENTORIES [METRIC TONS/1000.]
      DATA EKMTHM,FKMTHM/94.000,12.000/

C
C---- WASTE CLASS DATA
C
      DATA NAMEWC/'SST90 ', 'DST90 ', 'TG ', 'DSTF95', 'TGF '
1      , 'DWSF-1', 'DWSF-2', 'TRU-S ', 'TRU-P ', 'TRU-R ', 'TRU-F '/

C
C---- YROI(.) = (YEAR OF INVENTORY FOR WASTE CLASS)
      DATA YROI / 1995. , 1995. , 1995. , 1995. , 1995.
1      , 1995. , 1995. , 1995. , 1995. , 1995. , 1995. /

C
C---- LEACH MODEL USED FOR NATURAL RELEASES
C
      DATA LEACHN/'DIFFUSION '
1      , 'DISSOLUTION-CONTROLLED'

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```

2          , 'SOLUBILITY -CONTROLLED'
3          , 'ADSORPTION -CONTROLLED' /
C
  DATA LEACHM/ 3, 3, 2, 3, 2, 2, 2, 2, 2, 2, 2
1          , 3, 3, 2, 3, 2, 2, 2, 2, 2, 2, 2
2          , 3, 3, 2, 3, 2, 2, 2, 2, 2, 2, 2
3          , 3, 4, 2, 4, 2, 2, 2, 2, 2, 2, 2/
C
C----- FR AND TP VALUES (FOR 1ST 5 WASTE CLASSES ONLY).
C      FR = FRACTION OF WASTE DIFFUSED OUT OVER TIME PERIOD TP.
C      SEE DIFFUSION AND DISSOLUTION MODELS.
C
  DATA FR/ 0.03, 0.03, 0.05, 0.03, 0.05/
  DATA TP/ 6000., 6000., 19000., 6000., 19000./
C
C----- HUMAN INTRUSION DATA
C
C----- CASE TITLES
  DATA CH1 / 'A BORE HOLE'
1          , 'A BASEMENT '
2          , 'A CANAL ' /
C
  DATA CH2 / 'IN A SINGLE SHELLLED TANK (1990)
1          , 'IN A DOUBLE SHELLLED TANK (1990)
2          , 'IN TRENCH GROUT
3          , 'IN A DOUBLE SHELLLED TANK, FUTURE (1995)
4          , 'IN TRENCH GROUT, FUTURE
5          , 'IN STRONTIUM DRYWELL WASTE
6          , 'IN CESIUM DRYWELL WASTE
7          , 'IN TRU CONTAMINATED SOIL
8          , 'IN A PRE-1970 BURIED TRU SITE
9          , 'IN AN EXISTING STORED TRU SITE
A          , 'IN A FUTURE TRU SITE
C
C
C
C----- HISTOGRAM DATA
C
C----- TOTAL CONSEQUENCE
  DATA BTCMIN, BTCMAX/ 0.01, 100./
C
C----- WATER DATA [INCHES, YEARS]
C
  DATA BINR / 0.049, 0.20, 0.50, 1.00, 1.50, 2.00
1          , 2.50, 3.00, 4.00, 6.00, 11.81/
C
  DATA TWATIM/ 4200., 925., 500., 220., 140., 100.
1          , 92., 85., 67., 50., 40./
C
C----- LIST OF ALTERNATIVES

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```

DATA ALTERN/'GEOLOGIC DISPOSAL
1          ,'IN-PLACE STABILIZATION AND DISPOSAL'
2          ,'REFERENCE
3          ,'NO ACTION
'/

C
C---- BIGT = MAX TIME [YEARS]
DATA BIGT/10000./

C
C---- STRONTIUM AND CESIUM CAPSULE DATA
DATA NOCANS/ 0, 304, 0, 304
1          , 0, 688, 0, 368/

C
C
C.....AREA data (km**2):
DATA ((HIGA(I,J),J=1,4),I=1,MAXWST) /
1          .055, .055, .055, .055
2          , .0058, .0058, .0058, .0058
3          , .250, .058, .058, .058
4          , .0058, .0058, .0058, .0058
5          , .033, .033, .033, .033
6          , 0., .00010, 0., .00010
7          , 0., .00024, 0., .00013
8          , .012, .012, .012, .012
9          , .075, .075, .075, .075
A          , .025, .025, .025, .025
B          , .017, .017, .017, .017
C          /

C
C
C.....KD data:
DATA
1 (KDMED(I),I=1,11) / 1.5,26.,5.6,32.,14.,1.5,0.,8.,20.,0.,0. /, median
2 (KDVAR(I),I=1,11) /25.,0.,0.,2500.,250.,25.,0.,341.33,0.,0.,0./, variance
3 (KDLO(I),I=1,11) /0.022,26.,5.6,0.63,5.6,0.022,0.,0.,20.,0.,0./, low
4 (KDHI(I),I=1,11) / 21.,26.,5.6,71.0,130.0,21.,0.,16.,20.,0.,0. / high

C
C
C.....GEOLOGIC DISPOSAL INVENTORY data:
DATA ((RQ(N,I,1),I=1,MAXWST),N=1,11) /
1          2.10E6,4100.,2.50E5,21000.,2.40E5,0.,0.,0.,0.,0.,0.
2          ,5.30E5,5300.,2.10E5,25000.,1.50E6,0.,0.,0.,0.,0.,0.
3          ,33000.,87.,4100.,200.,2300.,0.,0.,0.,0.,0.,0.
4          ,1400.,0.,140.,3.,290.,0.,0.,0.,0.,0.,0.
5          ,1400.,8.,220.,160.,3000.,0.,0.,0.,0.,0.,0.
6          ,14500.,12.,1600.,3.,0.,0.,0.,0.,0.,0.,0.
7          ,150.,1.,4850.,0.,280.,0.,0.,0.,0.,0.,0.
8          ,24.,0.,0.,0.,39.,0.,0.,0.,0.,0.,0.
9          ,210.,0.,22.,1.,63.,0.,0.,0.,0.,0.,0.
A          ,800.,7.,300.,2.,160.,0.,0.,0.,0.,0.,0.
B          ,1.,0.,45.,0.,12.,0.,0.,0.,0.,0.,0.

gSr
gCs
gSm
gPu
gAm
gNi
gC
gU
gZr
gTc
gI

```

```

C      /
C
C.....IN-PLACE STABILIZATION AND DISPOSAL INVENTORY data:
DATA ((RQ(N,I,2),I=1,MAXWST),N=1,11) /
1      4.20E7,4100.,8.20E6,21000.,4.20E7,3.10E7,0.,3400.,20000.      iSr
2      ,22000.,44000.
3      ,1.10E7,5300.,1.10E7,25000.,3.90E6,0.,1.000E8,1800.,21000.      iCs
4      ,23000.,46000.
5      ,6.50E5,88.,1.70E5,200.,4.00E5,0.,0.,0.,0.,0.,0.      iSm
6      ,27000.,0.,110.,3.,6200.,0.,0.,14000.,25000.,24000.,27000.      iPu
7      ,28000.,8.,16000.,160.,3.30E5,0.,0.,3900.,7200.,1400.,5400.      iAm
8      ,2.90E5,12.,24000.,3.,5700.,0.,0.,0.,0.,0.,0.,0.      iNi
9      ,3000.,1.,2000.,0.,280.,0.,0.,0.,1.,2.,2.      iC
A      ,470.,2.,2.,0.,47.,0.,0.,2.,49.,4.,5.      iU
B      ,4200.,0.,180.,1.,2000.,0.,0.,0.,0.,0.,0.,0.      iZr
C      ,16000.,7.,14000.,2.,4800.,0.,0.,0.,0.,0.,0.,0.      iTc
0      ,24.,0.,22.,0.,12.,0.,0.,0.,0.,0.,0.,0.      iI
E      /

C
C.....REFERENCE INVENTORY data:
DATA ((RQ(N,I,3),I=1,MAXWST),N=1,11) /
1      4.20E7,4100.,8.20E5,21000.,1.40E6,0.,0.,3400.,19000.,0.,0.      rSr
2      ,1.10E7,5300.,1.10E7,25000.,4.10E6,0.,0.,1800.,19000.,0.,0.      rCs
3      ,6.50E5,90.,1.70E4,200.,1.20E4,0.,0.,0.,0.,0.,0.,0.      rSm
4      ,27000.,0.,11.,3.,650.,0.,0.,14000.,24000.,0.,0.      rPu
5      ,28000.,8.,1600.,165.,16000.,0.,0.,3900.,6900.,0.,0.      rAm
6      ,2.90E5,12.,2400.,3.,0.,0.,0.,0.,0.,0.,0.,0.      rNi
7      ,3000.,1.,2000.,0.,280.,0.,0.,0.,1.,0.,0.      rC
8      ,470.,2.,0.,0.,39.,0.,0.,2.,49.,0.,0.      rU
9      ,4200.,0.,180.,1.,150.,0.,0.,0.,0.,0.,0.,0.      rZr
A      ,16000.,7.,14000.,2.,4800.,0.,0.,0.,0.,0.,0.,0.      rTc
B      ,24.,0.,22.,0.,12.,0.,0.,0.,0.,0.,0.,0.      rI
C      /

C
C.....NO ACTION INVENTORY data:
DATA ((RQ(N,I,4),I=1,MAXWST),N=1,11) /
1      4.20E7,8.20E6,0.,4.20E7,0.,3.10E7,0.,3400.,20000.,22000.      nSr
2      ,44000.
3      ,1.10E7,1.10E7,0.,5.10E7,0.,0.,5.30E7,1800.,21000.,23000.      nCs
4      ,46000.
5      ,6.50E5,1.70E5,0.,4.00E5,0.,0.,0.,0.,0.,0.,0.      nSm
6      ,27000.,110.,0.,6200.,0.,0.,0.,14000.,25000.,24000.,27000.      nPu
7      ,28000.,16000.,0.,3.30E5,0.,0.,0.,3900.,7200.,1400.,5400.      nAm
8      ,2.90E5,24000.,0.,5700.,0.,0.,0.,0.,0.,0.,0.,0.      nNi
9      ,3000.,2000.,0.,280.,0.,0.,0.,0.,1.,2.,2.      nC
A      ,470.,2.,0.,47.,0.,0.,0.,2.,49.,4.,5.      nU
B      ,4200.,180.,0.,2000.,0.,0.,0.,0.,0.,0.,0.,0.      nZr

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```

C      ,16000.,14000.,0.,4800.,0.,0.,0.,0.,0.,0.
D      ,24.,22.,0.,12.,0.,0.,0.,0.,0.,0.
E      /

```

nTc
ngI

```

C
C
C*****BARRIER-FAILURE-RECHARGE DISTRIBUTION PARAMETERS:
C.....PARABF(1) == functional barrier recharge minimum value (cm)
C.....PARABF(2) == functional barrier failure recharge maximum value (cm)
C.....PARABF(3) == disruptive barrier failure recharge minimum value (cm)
C.....PARABF(4) == disruptive barrier failure recharge maximum value (cm)
C.....PARABF(5) == probability of functional barrier failure
      DATA PARABF / 0.,.2,10.,20.,.95 /
C
C
C.....DIFFUSION TIME DELAYS FOR ISOTOPES:
C.....The diffusion time delays for the different isotopes are stored in an
C.....array 'DELAYT(NSTOPE)'. Indexing is as follows:
C.....DELAYT(1) -> Sr-90
C.....DELAYT(2) -> Cs-137
C.....DELAYT(3) -> Sm-151
C.....DELAYT(4) -> Pu-239
C.....DELAYT(5) -> Am-241
C.....DELAYT(6) -> Ni-63
C.....DELAYT(7) -> C-14
C.....DELAYT(8) -> U-238
C.....DELAYT(9) -> Zr-93
C.....DELAYT(10) -> Tc-99
C.....DELAYT(11) -> I-129
      DATA (DELAYT(I),I=1,11) / 10001.,10001.,10001.,10001.,10001.
1      ,10001.,4800.,4800.,10001.,4800.,4800. /
C
C
C.....STEEL SHELL TANK LIFETIME (YEARS):
      DATA TSHLL / 155. /
C
C
C*****Data Section for HUMAN INTRUSION:
C
C
C.....DISPOSAL TIME AFTER 1995 (years):
      DATA TDISPO / 55. /
C
C
C.....TIME PERIOD (years):
      DATA T / 9900. /
C
C
C.....NUMBER OF RANDOM NUMBERS TO BE DISCARDED:

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DATA NORANO / 5 /
C
C
C*****Section for HISTOGRAM X-AXIS PLOT LIMITS:A
C
C.....Recharge Histogram X-AXIS PLOT LIMITS:
DATA BRCMIN,BRCMAX / 0.,30. /
C
C.....Affected Waste Fraction Histogram X-AXIS PLOT LIMITS:
DATA AWFMIN,AWFMAX / 0.,100. /
C
C.....Kd(Sr) Histogram X-AXIS PLOT LIMITS:
DATA BKDSRN,BKDSRX / 0.,1.5 /
C
C.....Kd(Pu) Histogram X-AXIS PLOT LIMITS:
DATA BKDPUN,BKDPUX / 0.,100. /
C
C.....Kd(Am) Histogram X-AXIS PLOT LIMITS:
DATA BKDAMN,BKDAMX / 0.,100. /
C
C.....Kd(U) Histogram X-AXIS PLOT LIMITS:
DATA BKDUMN,BKDUMX / 0.,16. /
C
C*****End of section for X-AXIS PLOT LIMITS.
C
C
C*****AFFECTED WASTE FRACTION HISTOGRAM MAIN DESCRIPTORS:
C.....Minimum value (%):
DATA AWFLO / 0. /
C.....Maximum value (%):
DATA AWFHI / 100. /
C.....Median (%):
DATA AWMED / 25. /
C.....Variance (%**2):
DATA AWFVAR / 2500. /
C*****End of AWF MAIN DESCRIPTORS Section.
C
C
C*****RECHARGE HISTOGRAM MAIN DESCRIPTORS:
C.....Minumum value (cm):
DATA RECHLO / 1.5 /
C.....Maximum value (cm):
DATA RECHHI / 15. /
C.....Median (cm):
DATA RMH / 5. /
C.....Variance (cm**2):
DATA VAR / 7.5 /
C*****End of AWF MAIN DESCRIPTORS Section.
C
C

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C.....NUMBER OF YEARS AFTER 1995 TO BARRIER FAILURE:
      DATA TBARFL / 505. /
C
C
C.....NUMBER OF SAMPLES TO BE USED:
      DATA NSAMPL / 2000 /
C
C
C.....LEACHING TIME PARAMETER FOR NON-GROUT:
      DATA CONLTP / 440.0 /
C
C
C.....BULK DENSITY OF SOIL:
      DATA BD / 1.8 /
C
C
C.....VOLUMETRIC MOISTURE CONTENT OF SOIL (%):
      DATA THETA / 7.8 /
C
C
C.....WASTE DEPOSIT THICKNESS (meters):
      DATA H / 1. /
C
C
C.....INTRUSION TIME AFTER DISPOSAL (years):
      DATA TINTRU / 100. /
C
C
C.....IS A BARRIER IN PLACE? (default value is yes)
      DATA BARR / 'Y' /
      END
C
C
C
      SUBROUTINE RDINPT(INPT)
C
C.....This is the same include file used for the 'PROBCON.FOR' program:
      INCLUDE 'INCLUD.FOR/LIST'
C
C.....These are "must declare" variables...all others are implicitly typed.
      INTEGER WASTCS,ALTRN,C
C
C.....Variables for input record storage:
      CHARACTER*80 RECORD,CHRREC,FORERR
C
C.....Dummy character variables for testing whether or not particular default
C.....data values are to be changed:
      CHARACTER*10 FBFRMN,FBFRMX,DBFRMN,DBFRMX,FBPROB,
1          PLOTMN,PLOTMX,MINVAL,MAXVAL,MEDIAN,VARYNC,CISONM,

```

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2          RNDMND,NMSMPL,BFAILT,SSTLIF,LCHTP,SLDENS,SLMOIS,
3          WDTCK,ARLSEL,DISPOT,TPER,INTRUT,BLANK,DUMCHR

      BLANK = ' '
C.....Dummy constant for record counting:
      C = 1

      OPEN (UNIT=INPT,NAME='INPT.IN',STATUS='OLD',FORM='FORMATTED')
C
C.....Write out the header for the 'INPT.IN' echo:
      WRITE (3,109)
      WRITE (3,110)
      WRITE (3,111)
C.....Write out the record number column header:
      WRITE (3,112)
C
C.....Start of large input loop:
      10 READ (INPT,20,END=40) RECORD
C.....Echo record:
      WRITE (3,*) RECORD
C.....Write record number:
      WRITE (3,115) C
      C = C + 1
C.....Make a copy of the original record for error printing purposes...the
C.....original record will be changed by 'INSQUOTES'.
      FORERR = RECORD
C.....Read the option card:
      READ (RECORD,30) OPTION
      30 FORMAT (A4)
C
C.....Process the record...prepare it for list-directed I/O and for "no data
C.....change" options: (essentially, remove the option card from the original
C.....record, and insert quotes around data values (even blanks) to allow for
C.....list-directed character reading)
      CALL INSQUOTES(RECORD,CHRREC)
C
C
      IF (OPTION.EQ.' ' .OR.OPTION.EQ.'****') THEN
        GOTO 10
C
C
      ELSE IF (OPTION.EQ.'TITL') THEN
        READ (RECORD,100) TITLE
        READ (INPT,20) RECORD
        READ (RECORD,100) TYPE
C.....Echo the record:
        WRITE (3,*) RECORD
C.....Write record number:
        WRITE (3,115) C
        C = C + 1

```

```

        READ (INPT,20) RECORD
        READ (RECORD,*) IALT,JALT
C.....Echo the record:
        WRITE (3,*) RECORD
C.....Write record number:
        WRITE (3,115) C
        C = C + 1
        GOTO 10
C
C
        ELSE IF (OPTION.EQ.'BARR') THEN
            READ (CHRREC,*) BARR
            GOTO 10
C
C
        ELSE IF (OPTION.EQ.'AREA') THEN
            READ (RECORD,*) ALTRN,WASTCS,HIGA(WASTCS,ALTRN)
C.....Error checking:
            IF (ALTRN.GT.4) THEN
                PRINT 80
                PRINT *,FORERR
            CLOSE (UNIT=INPT)
            STOP
        END IF
            IF (WASTCS.GT.11) THEN
                PRINT 90
                PRINT *,FORERR
            CLOSE (UNIT=INPT)
            STOP
        END IF
        GOTO 10
C
C
        READ (RECORD,*) DUM1,DUM2,DUM3,DUM4,DUM5
        READ (CHRREC,*) FBFRMN,FBFRMX,DBFRMN,DBFRMX,FBPROB
        IF (FBFRMN.NE.BLANK) PARABF(1) = DUM1
        IF (FBFRMX.NE.BLANK) PARABF(2) = DUM2
        IF (DBFRMN.NE.BLANK) PARABF(3) = DUM3
        IF (DBFRMX.NE.BLANK) PARABF(4) = DUM4
        IF (FBPROB.NE.BLANK) PARABF(5) = DUM5
        GOTO 10
C
C
        ELSE IF (OPTION.EQ.'CAWF') THEN
            READ (RECORD,*) DUM1,DUM2,DUM3,DUM4
            READ (CHRREC,*) MINVAL,MAXVAL,MEDIAN,VARYNC
            IF (MINVAL.NE.BLANK) AWFLO = DUM1
            IF (MAXVAL.NE.BLANK) AWFHI = DUM2
            IF (MEDIAN.NE.BLANK) AWMED = DUM3
            IF (VARYNC.NE.BLANK) AWFVAR = DUM4

```

```

      GOTO 10
C
C
      ELSE IF (OPTION.EQ.'AKDV') THEN
        READ (RECORD,*) ISONUM,DUM2,DUM3,DUM4,DUM5
        READ (CHRRREC,*) CISONM,MEDIAN,VARYNC,MINVAL,MAXVAL
C.....Make sure 'isonum' is legal for isotope addition cases:
        IF (ISONUM.GT.NSTOPE) THEN
          IF (ISONUM.LE.(NSTOPE+1)) THEN
            NSTOPE = ISONUM
          ELSE
            PRINT 50
            PRINT *,FORERR
            PRINT 70, ISONUM,NSTOPE
            CLOSE (UNIT=INPT)
            STOP
          END IF
        END IF

        IF (MEDIAN.NE.BLANK) KDMED(ISONUM) = DUM2
        IF (VARYNC.NE.BLANK) KDVAR(ISONUM) = DUM3
        IF (MINVAL.NE.BLANK) KDLO(ISONUM) = DUM4
        IF (MAXVAL.NE.BLANK) KDHI(ISONUM) = DUM5
      GOTO 10
C
C
      ELSE IF (OPTION.EQ.'CINV') THEN
        READ (RECORD,*) ALTRN,ISONUM,WASTCS,RQ(ISONUM,WASTCS,ALTRN)
C.....Error checking:
        IF (ALTRN.GT.4) THEN
          PRINT 80
          PRINT *,FORERR
          CLOSE (UNIT=INPT)
          STOP
        END IF
        IF (WASTCS.GT.11) THEN
          PRINT 90
          PRINT *,FORERR
          CLOSE (UNIT=INPT)
          STOP
        END IF
      GOTO 10
C
C
      ELSE IF (OPTION.EQ.'DLYT') THEN
        READ (RECORD,*) ISONUM
C.....Make sure 'isonum' is legal for isotope addition cases:
        IF (ISONUM.GT.NSTOPE) THEN

```

```

        IF (ISONUM.LE.(NSTOPE+1)) THEN
            NSTOPE = ISONUM
        ELSE
            PRINT 50
            PRINT *,FORERR
            PRINT 70, ISONUM,NSTOPE
            CLOSE (UNIT=INPT)
            STOP
        END IF
    END IF

    READ (RECORD,*) ISONUM,DELAYT(ISONUM)
GOTO 10

C
C
    ELSE IF (OPTION.EQ.'RCHG') THEN
        READ (RECORD,*) DUM1,DUM2,DUM3,DUM4
        READ (CHRREC,*) MINVAL,MAXVAL,MEDIAN,VARYNC
        IF (MINVAL.NE.BLANK) RECHLO = DUM1
        IF (MAXVAL.NE.BLANK) RECHHI = DUM2
        IF (MEDIAN.NE.BLANK) RMH = DUM3
        IF (VARYNC.NE.BLANK) VAR = DUM4
GOTO 10

C
C
    ELSE IF (OPTION.EQ.'AINV') THEN
        READ (RECORD,*) ISONUM

C.....Make sure 'isonum' is legal:
        IF (ISONUM.GT.NSTOPE) THEN
            IF (ISONUM.LE.(NSTOPE+1)) THEN
                NSTOPE = ISONUM
            ELSE
                PRINT 50
                PRINT *,FORERR
                PRINT 70, ISONUM,NSTOPE
                CLOSE (UNIT=INPT)
                STOP
            END IF
        END IF

        DO 15 J=1,4
            READ (INPT,20) RECORD
            READ (RECORD,*) (RQ(NSTOPE,I,J),I=1,MAXWST)
C.....Echo record:
            WRITE (3,*) RECORD
C.....Write record number:
            WRITE (3,115) C
            C = C + 1
15      CONTINUE

```

```

GOTO 10
C
C
ELSE IF (OPTION.EQ.'NATR') THEN
  READ (RECORD,*) DUM1,DUM2,DUM3,DUM4,DUM5,DUM6,DUM7,DUM8
  READ (CHRREC,*) RNDMND,NMSMPL,BFAILT,SSTLIF,LCHTP,SLDENS,
1  SLMOIS,WDTHCK
  IF (RNDMND.NE.BLANK) NORANO = DUM1
  IF (NMSMPL.NE.BLANK) NSAMPL = DUM2
  IF (BFAILT.NE.BLANK) TBARFL = DUM3
  IF (SSTLIF.NE.BLANK) TSHELL = DUM4
  IF (LCHTP.NE.BLANK) CONLTP = DUM5
  IF (SLDENS.NE.BLANK) BD = DUM6
  IF (SLMOIS.NE.BLANK) THETA = DUM7
  IF (WDTHCK.NE.BLANK) H = DUM8
GOTO 10
C
C
ELSE IF (OPTION.EQ.'HINT') THEN
  READ (RECORD,*) DUM1,DUM2,DUM3
  READ (CHRREC,*) DISPO,TPER,INTRUT
  IF (DISPO.NE.BLANK) TDISPO = DUM1
  IF (TPER.NE.BLANK) T = DUM2
  IF (INTRUT.NE.BLANK) TINTRU = DUM3
GOTO 10
C
C
ELSE IF (OPTION.EQ.'AISO') THEN
  READ (RECORD,*) ISONUM
C.....Make sure 'isonum' is legal:
  IF (ISONUM.GT.NSTOPE) THEN
    IF (ISONUM.LE.(NSTOPE+1)) THEN
      NSTOPE = ISONUM
    ELSE
      PRINT 50
      PRINT *,FORERR
      PRINT 70, ISONUM,NSTOPE
      CLOSE (UNIT=INPT)
      STOP
    END IF
  END IF

  READ (RECORD,*) ISONUM,LAMDA(ISONUM),CSOL(ISONUM)
1  ,CFRT1(ISONUM)
  READ (INPT,20) RECORD
  READ (RECORD,*) (FBWIP(ISONUM,J),J=1,4)
C.....Echo record:
  WRITE (3,*) RECORD

```

```

C.....Write record number:
      WRITE (3,115) C
      C = C + 1
      GOTO 10
C
C
      ELSE IF (OPTION.EQ.'ISON') THEN
        READ (RECORD,*) ISONUM
C.....Make sure 'isonum' is legal:
      IF (ISONUM.GT.NSTOPE) THEN
        IF (ISONUM.LE.(NSTOPE+1)) THEN
          NSTOPE = ISONUM
        ELSE
          PRINT 50
          PRINT *,FORERR
          PRINT 70, ISONUM,NSTOPE
          CLOSE (UNIT=INPT)
          STOP
        END IF
      END IF

      READ (CHRREC,*) DUMCHR,NAME(ISONUM)
      GOTO 10

      ELSE
        PRINT *,'PROBCON: illegal option in ''INPT.IN'' record-->'
        PRINT *,FORERR
        CLOSE (UNIT=INPT)
        STOP
      END IF

40 CLOSE (UNIT=INPT)
20 FORMAT (A80)
50 FORMAT (' PROBCON: input error in ''INPT.IN'' record-->')
70 FORMAT (' isotope number ',I3,' is not in sequence...',
1      I3,' is currently the largest number')
80 FORMAT (' PROBCON: illegal alternative in ''INPT.IN'' record-->')
90 FORMAT (' PROBCON: illegal waste class in ''INPT.IN'' record-->')
100 FORMAT (60A1)
109 FORMAT ('1*****')
110 FORMAT (' ECHO OF THE ''INPUT.IN'' FILE')
111 FORMAT (' *****')
112 FORMAT (84X,'RECORD'/84X,'NUMBER'/)
115 FORMAT ('+',85X,I2)
      RETURN
      END
C
C
C 'INSQUOTES' [INSert QUOTES] Subroutine

```


C Coded by Tu-Cuong(Clark) H. Nguyen on June 17, 1987

C

* This subroutine accepts as arguments a character variable (80 chars long)
* holding the entry string to be "quoted" 'ENTRY' and a character variable (also
* 80 chars long) 'QENTRY' to hold the newly "quoted" string. 'ENTRY' must have
* the form

*
* card> arg1,arg2,arg3,arg4,...
*

* where 'card' is the input option indicator, and the arguments are data values
* (which can be blanks for some options). The commas between arguments are
* required, but the arguments may be spaced as desired. For example, the
* following is legal:

*
* card> arg1 ,arg2 ,arg3 ,arg4
*

C

*
* The 'card' is removed from 'ENTRY' and a comma is appended to it (in case the
* last argument is a blank) , preparing it for a REAL variable READ. When
* 'INSQUOTES' returns control to the calling program, 'QENTRY' will contain the
* information from 'ENTRY' adjusted so that it can be read into character
* variables, i.e. quotes will be inserted in the appropriate places. For
* example, 'ENTRY' will contain the following after 'INSQUOTES' has been
* called with the examples above:

*
* arg1 ,arg2 ,arg3 ,arg4,
*

* Note that 'card>' is removed and a comma has been appended. 'QENTRY' will
* contain the following:

* 'arg1','arg2','arg3','arg4'
*

C

*
* Variable Identification:

* AFTGSN == position in 'ENTRY' after the '>' sign
* COMLOC == position of a comma in a string
* CONCAT == char variable to hold the initial string in 'NENTRY' to be
* concatenated to 'QENTRY'
* ENTRY == char variable holding the string to be "quoted"
* LSNCHR == position of the last character before blanks in 'NENTRY'
* LSQCHR == position of the last character before blanks in 'QENTRY'
* NENTRY == char variable holding the reduced form of 'ENTRY'...it's necessary
* since 'ENTRY' must not be changed
* NXTLOC == position of the character after a comma in a string
* PRELOC == position of the character before a comma in a string
* QENTRY == char variable for manufacture of a newly "quoted" 'ENTRY'
*

```

C
C
C
SUBROUTINE INSQUOTES(ENTRY,QENTRY)

INTEGER COMLOC,PRELOC,NXTLOC,LSQCHR,LSNCHR,AFTGSN
CHARACTER*80 ENTRY,NENTRY,QENTRY,CONCAT

QENTRY = ' '

C
C.....Initialize 'NENTRY' to contain all the information after the 'card' in
C.....the original 'ENTRY':
AFTGSN = INDEX(ENTRY,'>') + 1
NENTRY = ENTRY(AFTGSN:)
C.....Adjust 'ENTRY' to contain all its original information after the 'card'
C.....plus a following comma:
ENTRY = NENTRY(:79)//','
C
C.....Loop for manufacture of 'QENTRY':
10 I = 1
C
C.....Remove initial blanks from 'NENTRY' and append and initial "" to
it:
20 IF (NENTRY(I:I).EQ.' ') THEN
I = I + 1
GO TO 20
END IF
NENTRY = ''//NENTRY(I:)
C
C.....Find location of the next comma in 'NENTRY'
COMLOC = INDEX(NENTRY,',')
C
C.....If there are no commas, contatenate the last argument in 'NENTRY'
C.....with a "" following, and return to the calling program...'QENTRY'
C.....contains the "quoted" string:
IF (COMLOC.EQ.0) THEN
LSQCHR = INDEX(QENTRY,' ') - 1
LSNCHR = INDEX(NENTRY,' ') - 1
QENTRY = QENTRY(:LSQCHR)//NENTRY(:LSNCHR)//''
RETURN
END IF
C
PRELOC = COMLOC - 1
NXTLOC = COMLOC + 1
LSQCHR = INDEX(QENTRY,' ') - 1
C
C.....Initialize 'LSNCHR' so that when used in production of 'QENTRY',
C.....trailing blanks are removed from 'CONCAT':
CONCAT = NENTRY(:PRELOC)
LSNCHR = INDEX(CONCAT,' ') - 1

```

```

C
C.....'QENTRY' is a concatenation of itself (with trailing blanks removed),
C.....'CONCAT' (with trailing blanks removed), and "':":
      QENTRY = QENTRY(:LSQCHR)//CONCAT(:LSNCHR)//' ',
C
C.....Remove the already concatenated argument from 'NENTRY':
      NENTRY = NENTRY(NXTLOC:)
      GOTO 10
      END
C
C
      SUBROUTINE CALCRL
C---- THIS SUBROUTINE COMPUTES THE ISOTOPE RELEASE LIMITS BASED
C      UPON 40 CFR 191 USING THE METHOD DESCRIBED IN APPENDIX S
C      OF THE EIS.
C
      INCLUDE 'INCLUD.FOR/LIST'
C
      DIMENSION EFRAC(MXNISO,4),FFRAK(MXNISO,4)
C
C---- BCF = BURNUP CORRECTION FACTOR
      DATA BCF/6./
C
C---- ALTERNATIVE LOOP
      DO 40 IA=1,4
      DO 40 N=1,NSTOPE
      ETQ=0.
      FTQ=0.
      EQ =0.
      FQ =0.
      DO 30 I=1,MAXWST
      GO TO (10,10,10,20,20,10,10,10,10,10,20),I
C
C---- PRESENT OR EXISTING INVENTORIES (NO ACTION ALTERNATIVE)
      10 EQ =EQ +RQ(N,I,IA)
      ETQ=ETQ+RQ(N,I, 4)
      GO TO 30
C
C---- FUTURE INVENTORIES (NO ACTION ALTERNATIVE)
      20 FQ =FQ +RQ(N,I,IA)
      FTQ=FTQ+RQ(N,I, 4)
C
      30 CONTINUE
C
      EFRAC=0.
      FFRAC=0.
      IF(ETQ.NE.0.) EFRAC=EQ/ETQ
      IF(FTQ.NE.0.) FFRAC=FQ/FTQ
C
      IF(N .NE.2) GO TO 35

```

```

      IF(IA.NE.2) GO TO 35
      EFRAC=1.
      FFRAC=1.
C
35  IF(EFRAC.GT.1.) EFRAC=1.
      IF(FFRAC.GT.1.) FFRAC=1.
      EFRAC(N,IA)=EFRAC
      FFRAC(N,IA)=FFRAC
C
      RL(N,IA)=CFRT1(N)*(EKMTHM*EFRAC+FKMTHM*FFRAC)/BCF
40  CONTINUE
C
C---- WRITE OUT FRACTIONS AND RELEASE LIMITS
C
      WRITE (3,50)
50  FORMAT('1FRACTIONS OF EXISTING AND FUTURE RADIONUCLIDE '
1    ',INVENTORIES REMAINING IN HDW FOR EACH ALTERNATIVE')
      WRITE (3,60)
60  FORMAT('0',14X,'GEOLOGIC',7X,'IPSD',9X,'REFERENCE',5X,'NO ACTION'/
1    ' ' N NUCLIDE',4(' EXIST. FUTURE'))
      WRITE (3,70)
70  FORMAT(' ')
      DO 90 N=1,NSTOPE
      WRITE (3,80) N,NAME(N),(EFRAC(N,J),FFRAC(N,J),J=1,4)
80  FORMAT(I3,2X,A6,F7.3,F6.3,3(F8.3,F6.3))
90  CONTINUE
C
      WRITE (3,70)
      WRITE (3,70)
      WRITE (3,100)
100  FORMAT('040 CFR 191 TABLE 1 VALUES AND RELEASE LIMITS')
      WRITE (3,110)
110  FORMAT('0',11X,'TABLE 1'/' ' N NUCLIDE 40CFR191 GEOLOGIC
1    ', 'IPSD ' 'REFERENCE ' 'NO ACTION')
      DO 130 N=1,NSTOPE
      WRITE (3,120) N,NAME(N),CFRT1(N),(RL(N,I),I=1,4)
120  FORMAT(I3,2X,A6,F8.0,1P4E10.2)
130  CONTINUE
      RETURN
      END
      SUBROUTINE MANIN(OUTCCC)
C
      INCLUDE 'INCLUD.FOR/LIST'
      LOGICAL OUTCCC,IJALT
C
      INTEGER D,S
C
      DIMENSION GEOFA(3)
C
C---- ASSUME A 12 INCH BORE HOLE

```

```

      GEOFA(1)=3.141592654*(6.*0.0254)**2
C
      IF(OUTCCC) WRITE (2,5) TITLE
5  FORMAT(60A1)
      IF(OUTCCC) WRITE (2,6) TINTRU
6  FORMAT(' INTRUSION TIME =',F6.0,' YEARS')
C
      IJALT=(JALT.GE.1) .AND. (JALT.LE.4)
C
      DO 200 IALT=1,4
      KALT=IALT
      IF(IJALT) KALT=JALT
      SUMPC =0.
      SUM500=0.
      SUM900=0.
      SUM990=0.
      SUM999=0.
      DO 7 I=1,4
      DO 7 N=1,NSTOPE
      CONSEQ(N,I)=0.
      7  CURIEN(N,I)=0.
C
      DO 81 D=1,3
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
      D=1
      IF(D.NE.1) GO TO 81
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
      DO 80 S=1,MAXWST
C---- AREA IS IN [M**2] AFTER THIS
      AREA=HIGA(S,IALT)*1.E6
      IF(AREA.LE.0.) GO TO 80
      PDS=CALCP(D,S)
      ALAMDA=PDS*T
      YROID=YROI(S)-1995.
      8  CONTINUE
      GEOFAG=GEOFA(D)/AREA
C---- THE 0.45 DEPENDS ON THE BOREHOLE DIAMETER. SHOULD THE
C      BOREHOLE DIAMETER CHANGE, THE 0.45 SHOULD ALSO CHANGE.
      IF((S.EQ.6) .OR. (S.EQ.7)) GEOFAG=0.45/AREA
C
      NOISO=0
      DO 9 N=1,NSTOPE
      IF(RQ(N,S,IALT).GT.0.) NOISO=NOISO+1
      9  CONTINUE
      IF(NOISO.LE.0) GO TO 80
      WRITE (3,10) TITLE
10  FORMAT('1',80A1)
      WRITE (3,15) CH1(D),CH2(S)
15  FORMAT('/',1,A11,1X,A44)
      WRITE (3,17) IALT,ALTERN(IALT)
      IF(IJALT) WRITE (3,93) ALTERN(KALT)

```

```

WRITE (3,18) AREA/1.E6
WRITE (3,22) TDISPO,TINTRU
17 FORMAT('OALTERNATIVE:',I4,5X,A35)
18 FORMAT('OTOTAL AREA OF WASTE CLASS: ',F11.8,' (Km**2)')
WRITE (3,20) PDS,T,ALAMDA
20 FORMAT(' ANNUAL FREQUENCY=',1PE10.3,3X,'TIME PERIOD (YEARS)=' ,
1 OPF6.0/' LAMDA = P*T      =' ,F10.5)
22 FORMAT('ODISPOSAL TIME =' ,F6.0,' YEARS AFTER 1995'/
1 'OINTRUSION OCCURS AT TIME =' ,F6.0,' YEARS AFTER DISPOSAL',/)
WRITE (3,28)
28 FORMAT('O ISOTOPE INIT. INV.(Ci) INV.(Ci)'
1 ' BH-INV.(Ci) CONSEQ. % REL.LIMIT'/)
CM(1) =0.
CCDF(1)=1.
IMAX =1
INDEX=0
CALL POISON(ALAMDA,MAXPRO,PROB,CCDF)
SUMCE =0.
SUMCUR=0.
DO 35 N=1,NSTOPE
IF(RQ(N,S,IALT).GT.0.) GO TO 30
CE(N)=0.
GO TO 35
30 DENOM=RL(N,KALT)
CDUM=RQ(N,S,IALT)*EXP(-LAMDA(N)*(TDISPO+TINTRU-YROID))
CE(N)=CDUM/DENOM*GEOFAG
SUMCE =SUMCE +CE(N)
SUMCUR=SUMCUR+CE(N)*DENOM
35 CONTINUE
DO 40 N=1,NSTOPE
IF(RQ(N,S,IALT).GT.0.) GO TO 37
WRITE (3,38) N,NAME(N),RQ(N,S,IALT)
GO TO 40
37 DENOM=RL(N,KALT)
CDUM=RQ(N,S,IALT)*EXP(-LAMDA(N)*(TDISPO+TINTRU-YROID))
PERCNT=0.
IF(SUMCE.NE.0.) PERCNT=100.*CE(N)/SUMCE
WRITE (3,38) N,NAME(N),RQ(N,S,IALT),CDUM,CDUM*GEOFAG,CE(N)
1 ,PERCNT,DENOM
38 FORMAT(I3,3X,A6,2X,1P4E15.7,OPF8.3,1PE15.7)
40 CONTINUE
WRITE (3,41) SUMCE
41 FORMAT(' ',53X,'TOTAL',1PE15.7,' 100.000')
KEY=0
CON500=0.
CON900=0.
CON990=0.
CON999=0.
I500 =1
I900 =1

```

```

1990 =1
1999 =1
SMPC =0.
EM500 =0.
EM900 =0.
EM990 =0.
EM999 =0.
SUMTIL=PROB(1)
DO 55 I=2,MAXPRO
IMAX=I-1
INDEX=INDEX+1
M(INDEX)=IMAX
EMINDX =IMAX
C =0.
PE=CCDF(I)
IF(PE.LT.0.0001) GO TO 60
C=SUMCE*EMINDX
TOTCUR=SUMCUR*EMINDX
CM(I)=C
CONE=C*PROB(I)
SMPC =SMPC +CONE
SUMPC =SUMPC +CONE
CONE =TOTCUR*PROB(I)
IF(SUMTIL.GE.0.500) GO TO 44
I500 =I
CON500=C
EM500 =EMINDX
44 IF(SUMTIL.GE.0.900) GO TO 46
I900 =I
CON900=C
EM900 =EMINDX
46 IF(SUMTIL.GE.0.990) GO TO 47
I990 =I
CON990=C
EM990 =EMINDX
47 IF(SUMTIL.GE.0.999) GO TO 48
I999 =I
CON999=C
EM999 =EMINDX
48 SUMTIL=SUMTIL+PROB(I)
IF(KEY.EQ.0) WRITE (3,49) CCDF(1),PROB(1),PROB(1)
49 FORMAT('ONUM= 0',18X,'CCDF=',F7.4,' ',P=',F7.4,' 0',1PE15.7)
KEY=KEY+1
WRITE (3,50) I-1,C,CCDF(I),PROB(1),INDEX,SUMTIL
50 FORMAT(' NUM=',I4,' C=',F12.9,' CCDF=',F7.4,' ',P=',F7.4,I5
1 ,1PE15.7)
55 CONTINUE
60 CONTINUE
SUM500=SUM500+CON500
SUM900=SUM900+CON900

```

```

SUM990=SUM990+CON990
SUM999=SUM999+CON999
WRITE (3,88)
WRITE (3,53)
53 FORMAT('OSUMMARY'/' ISOTOPE RELEASES (Ci)')//
1 ' ISOTOPE 50 %-TILE 90 %-TILE 99 %-TILE'
2 ', 99.9 %-TILE')
54 FORMAT('OCONSEQUENCE ',1PE14.7,3E15.7)
51 FORMAT('OCONSEQUENCE*35',1PE14.7,3E15.7)
00 58 N=1,NSTOPE
IF((EM500+EM900+EM990+EM999) .EQ. 0.) GO TO 56
IF(CE(N).GT.0.) GO TO 57
56 WRITE (3,38) N,NAME(N)
GO TO 58
57 CEN=CE(N)
VCL500=CEN*EM500
VCL900=CEN*EM900
VCL990=CEN*EM990
VCL999=CEN*EM999
VAL500=RL(N,KALT)*VCL500
VAL900=RL(N,KALT)*VCL900
VAL990=RL(N,KALT)*VCL990
VAL999=RL(N,KALT)*VCL999
CONSEQ(N,1)=CONSEQ(N,1)+VCL500
CONSEQ(N,2)=CONSEQ(N,2)+VCL900
CONSEQ(N,3)=CONSEQ(N,3)+VCL990
CONSEQ(N,4)=CONSEQ(N,4)+VCL999
CURIES(N,1)=CURIES(N,1)+VAL500
CURIES(N,2)=CURIES(N,2)+VAL900
CURIES(N,3)=CURIES(N,3)+VAL990
CURIES(N,4)=CURIES(N,4)+VAL999
WRITE (3,38) N,NAME(N),VAL500,VAL900,VAL990,VAL999
58 CONTINUE
WRITE (3,54) CON500 ,CON900 ,CON990 ,CON999
WRITE (3,51) CON500*35.,CON900*35.,CON990*35.,CON999*35.
WRITE (3,88)
WRITE (3,89) SMP
IF(IMAX.LT.2 ) GO TO 80
IF(.NOT.OUTCCC) GO TO 80
WRITE (2,59) IALT,ALTERN(IALT)
59 FORMAT(I5,5X,A35)
WRITE (2,61) CH1(O),CH2(S)
61 FORMAT(A11,1X,A44)
WRITE (2,62)
WRITE (2,63)
62 FORMAT('CONSEQUENCE, C')
63 FORMAT('PROBABILITY OF CONSEQUENCE => C')
C
WRITE (2,76) IMAX
76 FORMAT(I5)

```



```

      DO 78 I=1,IMAX
      WRITE (2,77) CM(I),CCDF(I)
77  FORMAT(1P2E15.7)
78  CONTINUE
C
80  CONTINUE
81  CONTINUE
C
      DO 83 L=1,4
      SUM1=0.
      SUM2=0.
      DO 82 N=1,NSTOPE
      SUM1=SUM1+CONSEQ(N,L)
82  SUM2=SUM2+CONSEQ(N,L)*FBWIP(N,IALT)
      TOTALS(L,1)=SUM1
83  TOTALS(L,2)=SUM2
C
      LUNIT=3
      DO 120 K=1,2
      IF(K.EQ.2) LUNIT=4
      WRITE (LUNIT,10) TITLE
      WRITE (LUNIT,87)
      WRITE (LUNIT,88)
      WRITE (LUNIT,17) IALT,ALTERN(IALT)
93  FORMAT('0'///' ===> ===> ===> ===> RELEASE LIMITS WERE USED FROM'
1    ' , ' ALTERNATIVE: ' ,A35///)
      IF(IJALT) WRITE (LUNIT,93) ALTERN(KALT)
      WRITE (LUNIT,95)
      DO 86 N=1,NSTOPE
      DO 79 L=1,4
      IF(CURIES(N,L).GT.0.) GO TO 85
      IF(CONSEQ(N,L).GT.0.) GO TO 85
79  CONTINUE
      WRITE (LUNIT,84) N,NAME(N)
      WRITE (LUNIT,91) RL(N,KALT)
91  FORMAT('+' ,95X,1PE11.2)
84  FORMAT(I3,3X,A6,12X,4(1PE11.2,0PF7.2),1PE11.2)
      GO TO 86
85  WRITE (LUNIT,84) N,NAME(N)
      1      , (CURIES(N,I),CONSEQ(N,I)/TOTALS(I,1)*100.,I=1,4)
      2      , RL(N,KALT)
86  CONTINUE
      WRITE (LUNIT,96) SUM500      ,SUM900      ,SUM990      ,SUM999
      WRITE (LUNIT,97) SUM500*35.,SUM900*35.,SUM990*35.,SUM999*35.
      WRITE (LUNIT,89) SUMPC
87  FORMAT('0===> ===> ===> ===> ===> ===> <=== <=== <=== '
1    ' , ' <=== <=== <=== ')
88  FORMAT('0')
89  FORMAT('0MEAN CONSEQUENCE (SUM      P*C): ' ,1PE10.2)
94  FORMAT('1')

```

```

95 FORMAT('OSUMMARY'///' ISOTOPE RELEASES (Ci)'//
1  ' ISOTOPE 50 % QUANTILE',5X,'90 % QUANTILE'
2  ',5X,'99 % QUANTILE',4X,'99.9 % QUANTILE REL.LIMIT'
3  '/39X,'% ',17X,'% ',17X,'% ',17X,'% ')
96 FORMAT('OCONSEQUENCE',4(1PE11.2,' 100.00'))
97 FORMAT('OCONSEQUENCE*35',4(1PE11.2,' 100.00'))
98 FORMAT(///'OAUXILIARY SUMMARY'///' ISOTOPE RELEASES (Ci)'//
1  ' ISOTOPE MULT. 50 % QUANTILE',5X,'90 % QUANTILE'
2  ',5X,'99 % QUANTILE',4X,'99.9 % QUANTILE'
3  '/39X,'% ',17X,'% ',17X,'% ',17X,'% ')
C
WRITE (LUNIT,98)
DO 115 N=1,NSTOPE
DO 100 L=1,4
IF(CURIES(N,L).GT.0.) GO TO 110
IF(CONSEQ(N,L).GT.0.) GO TO 110
100 CONTINUE
WRITE (LUNIT,105) N,NAME(N),FBWIP(N,IALT)
105 FORMAT(I3,3X,A6,F10.1,2X,4(1PE11.2,OPF7.2))
GO TO 115
110 WRITE (LUNIT,105) N,NAME(N),FBWIP(N,IALT)
1, (CURIES(N,I),CONSEQ(N,I)*FBWIP(N,IALT)/TOTALS(I,2)*100.,I=1,4)
115 CONTINUE
WRITE (LUNIT,96) (TOTALS(I,2),I=1,4)
120 CONTINUE
200 CONTINUE
RETURN
END
FUNCTION CALCP(I,J)
C
C---- THIS FUNCTION COMPUTES ANNUAL PROBABILITY FOR (HUMAN) INTRUSION I,
C INTO WASTE TYPE J.
C
INCLUDE 'INCLUD.FOR/LIST'
C
GO TO (100,200,300),I
C
C---- BORE HOLE
C
100 GO TO (110,110,110,110,110,140,150,110,110,110,110),J
110 AREA=HIGA(J,IALT)
C
0.01 = [FREQUENCY/UNIT AREA/YEAR]
P=AREA*0.01
GO TO 2000
C
C---- Sr- 90 CANNISTERS
140 AREA=HIGA(J,IALT)
P=AREA*0.01
GO TO 2000
C

```

```

C---- Cs-137 CANNISTERS
150 AREA=HIGA(J,IALT)
    P=AREA*0.01
    GO TO 2000
200 CONTINUE
300 CONTINUE
C
2000 CALCP=P
    RETURN
    END
    SUBROUTINE CCDFER(N,B,C)
C
C---- THIS PROGRAM CONSTRUCTS A CCDF FROM THE HISTOGRAM STORED IN B(.).
C    THE CCDF IS RETURNED IN C(.).
C
    DIMENSION B(1),C(1)
C
    IF(N.EQ.0) GO TO 30
    SUM=0.
    DO 10 I=1,N
10  SUM=SUM+B(I)
    IF(SUM.LE.0.) GO TO 30
    C(1)=1.
    DO 20 I=2,N
20  C(I)=C(I-1)-B(I-1)/SUM
    C(N+1)=0.
30  RETURN
    END
    SUBROUTINE POISON(LAMDA,N,PROB,CCDF)
    REAL LAMDA
    DIMENSION PROB(N),CCDF(N)
C
    IF(N.LE.0) GO TO 20
    PROB(1)=EXP(-LAMDA)
    CPROB=PROB(1)
    CCDF(1)=1.
    IF(N.LE.1) GO TO 20
    DO 10 J=2,N
    PROB(J)=LAMDA/FLOAT(J-1)*PROB(J-1)
C---- PROBABILITY OF NUMBER OF HOLES .GE. J
    CCDF(J)=1.-CPROB
10  CPROB=CPROB+PROB(J)
20  RETURN
    END
    SUBROUTINE INTRP(X,XTAB,YTAB,N,Y)
C
C---- THIS SUBROUTINE INTERPOLATES YTAB(.) TO GET Y(X).
C
    DIMENSION XTAB(N),YTAB(N)
C

```

```

      DO 10 I=2,N
      IF(X.LT.XTAB(I)) GO TO 20
10  CONTINUE
      I=N+1
20  IF(I.GT.N) I=N
      Y=YTAB(I-1)+(X-XTAB(I-1))/(XTAB(I)-XTAB(I-1))*(YTAB(I)-YTAB(I-1))
      RETURN
      END
      SUBROUTINE BINNER(X,XTAB,BINS,N)
C
C----- THIS SUBROUTINE DETERMINES WHICH BIN X BELONGS TO AND INCREMENTS
C          THE CORRESPONDING BIN COUNT
C
      DIMENSION XTAB(N),BINS(N)
C
      DO 10 I=2,N
      IF(X.LT.XTAB(I)) GO TO 20
10  CONTINUE
      I=N+1
20  BINS(I-1)=BINS(I-1)+1.
      RETURN
      END
      FUNCTION ONEMEX(XS)
C----- COMPUTE 1-EXP(-X) WITH A MINIMUM LOSS OF PRECISION
C
      DOUBLE PRECISION EXPDIF,X
C
      X=XS
      IF(X.GT.1.D-3) GO TO 10
      EXPDIF=X*(1.D0-X/2.D0*(1.-X/3.D0))
      GO TO 20
10  EXPDIF=1.D0-DEXP(-X)
20  ONEMEX=EXPDIF
      RETURN
      END
      SUBROUTINE LECHTM(RECHRG,TL)
C
C----- THIS SUBROUTINE CALCULATES TL [YEARS], THE LEACHING TIME
C          AS A FUNCTION OF RECHRG [INCHES].
C
      COMMON /LEACH /CONLTP
C
      TL=CONLTP/(2.54*RECHRG+0.01)
      RETURN
      END
      SUBROUTINE HSTPRN(N,XTAB,FRAC,M)
C
C----- THIS SUBROUTINE PRINTS THE HISTOGRAM STORED IN XTAB(.)AND FRAC(.)
C
      DIMENSION XTAB(M),FRAC(M)

```

```

C      CHARACTER*1 STAR
C
C      DATA STAR/'*'/
C
C      IF(N.LE.1) GO TO 70
C
      FN=N
      BIG=FRAC(1)
      SUM=FRAC(1)
      MM1=M-1
      DO 10 I=2,MM1
      BIG=AMAX1(BIG,FRAC(I))
      SUM=SUM+FRAC(I)
10  CONTINUE
      IF(SUM.EQ.0.) SUM=1.
      A=BIG/SUM*FN/50.
      A=AMAX1(A,1.)
      WRITE (3,20) A
20  FORMAT('OBIN LOWER EDGE FRAC. %-TILE COUNT PDF',10X
1    ' ,EACH * DENOTES',F5.2,' COUNTS'/)
      SUM100=SUM/100.
      CUM=0.
      ITO=N
      DO 50 I=1,MM1
      PERCNT=CUM/SUM100
      FRAK=FRAC(I)/SUM
      PDF=FRAK/(XTAB(I+1)-XTAB(I))
      COUNT=FN*FRAK
      KOUNT=COUNT+0.5001
      IF(I.NE.MM1) ITO =ITO-KOUNT
      IF(I.EQ.MM1) KOUNT=ITO
      NSTARS=COUNT/A+0.5001
      IF(NSTARS.GE.1) GO TO 40
      WRITE (3,30) I,XTAB(I),FRAK,PERCNT,KOUNT,PDF
30  FORMAT(' ',I3,F10.4,F7.3,F8.2,I6,1PE9.2,1X,50A1)
      GO TO 50
40  WRITE (3,30) I,XTAB(I),FRAK,PERCNT,KOUNT,PDF,(STAR,J=1,NSTARS)
50  CUM=CUM+FRAC(I)
      WRITE (3,60) M,XTAB(M)
60  FORMAT(' ',I3,F10.4,8X,' 100.00')
C
C      70 RETURN
C      END
C      SUBROUTINE LNNPPF(NOPRAM,PARAM,P,PPF)
C
C----- THIS SUBROUTINE COMPUTES THE PERCENT POINT FUNCTION (QUANTILE)
C      FOR THE LOGNORMAL DISTRIBUTION WITH MEAN amean AND STANDARD
C      DEVIATION sigma, GIVEN A PROBABILITY P.
C      amean IS CONTAINED IN PARAM(1)

```

```

C      sigma IS CONTAINED IN PARAM(2).
C
C----- IF NOPRAM IS ZERO DEFAULT VALUES ARE USED FOR amean AND sigma
C      DEFAULT VALUES ARE amean=0. AND sigma=1.
C
C      DIMENSION PARAM(2)
C
C      CALL NORPPF(NOPRAM,PARAM,P,PPP)
C      PPF=EXP(PPP)
C      RETURN
C      END
C      SUBROUTINE NORPPF(NOPRAM,PARAM,P,PPF)
C
C----- THIS SUBROUTINE COMPUTES THE PERCENT POINT FUNCTION (QUANTILE)
C      FOR THE NORMAL DISTRIBUTION WITH MEAN amean AND STANDARD
C      DEVIATION sigma, GIVEN A PROBABILITY P.
C      amean IS CONTAINED IN PARAM(1)
C      sigma IS CONTAINED IN PARAM(2).
C
C----- PROCEDURE USES A RATIONAL APPROXIMATION GIVEN BY
C      EQ. 26.2.23 IN ABRAMOWITZ AND STEGUN
C
C      DIMENSION PARAM(2)
C
C      DATA C0,C1,C2,D1,D2,D3/2.515517,0.802853,0.010328
C      1      ,1.432788,0.189269,0.001308/
C
C      IF(NOPRAM) 2,1,2
C----- DEFAULT VALUES
C      1 AMEAN=0.
C      SIGMA=1.
C      GO TO 3
C
C      2 AMEAN=PARAM(1)
C      SIGMA=PARAM(2)
C
C      3 X=0.
C      IF((P.LE.0.) .OR. (P.GE.1.0)) GO TO 50
C      R=P
C      IF(P.EQ.0.5) GO TO 40
C      IF(P.GT.0.5) R=1.-R
C      T=SQRT(-2.*ALOG(R))
C      ANUM=C0+T*(C1+T* C2)
C      ADEN=1.+T*(D1+T*(D2+T*D3))
C      X=T-ANUM/ADEN
C      IF(P.LT.0.5) X=-X
C      40 PPF=X*SIGMA+AMEAN
C      RETURN
C
C      50 PPF=0.

```

```

        RETURN
        END
        SUBROUTINE MAKBIN(NOPRAM,PARAM,XMIN,XMAX,N,BINS)
C----- THIS SUBROUTINE DETERMINES N-1 BIN BOUNDARIES BETWEEN
C        XMIN AND XMAX, SUCH THAT EACH OF THE N-1 BINS HAS EQUAL
C        PROBABILITY ASSOCIATED WITH IT.  THE UNDERLYING DISTRIBUTION IS
C        LOGNORMAL.
C
        DIMENSION PARAM(2),BINS(N)
C
        LOGICAL NONEQ
C
C----- NOPRAM .EQ. 0  ==> X IS UNIFORMLY  DISTRIBUTED BETWEEN XMIN AND XMAX
C        .EQ. 5      ==> X IS DISTRIBUTED BETWEEN XMIN AND XMAX AS TWO
C                        DISTINCT UNIFORM DISTRIBUTIONS.
C        ANY OTHER VALUE ==> X IS LOGNORMALLY DISTRIBUTED BETWEEN XMIN AND XMAX
C
        IF(NOPRAM.EQ.5) GO TO 30
        NONEQ=NOPRAM.NE.0
C
        IF(NONEQ) GO TO 3
        PHIGH=XMAX
        PLOW =XMIN
        GO TO 6
C
3 PLOW =0.
  IF(XMIN.LE.0.) GO TO 5
  XLOW =ALOG(XMIN)
  CALL NORCUM(NOPRAM,PARAM,XLOW ,PLOW )
5 XHIGH=ALOG(XMAX)
  CALL NORCUM(NOPRAM,PARAM,XHIGH,PHIGH)
6 BINS(1)=XMIN
  IF(N.LE.2) GO TO 20
  NM1=N-1
  DELTAP=(PHIGH-PLOW)/FLOAT(NM1)
  DO 10 I=2,NM1
    P=PLOW+FLOAT(I-1)*DELTAP
C
    IF(NONEQ) GO TO 8
    PPF=P
    GO TO 10
C
8 CALL LNNPPF(NOPRAM,PARAM,P,PPF)
10 BINS(I)=PPF
20 BINS(N)=XMAX
25 RETURN
C
C----- TWO UNIFORM DISTRIBUTIONS
C
30 NN=PARAM(5)*FLOAT(N)+0.5

```

```

      IF(NN.LT.2) NN=2
      MM=N-NN
      IF(MM.LT.2) MM=2
      NN=N-MM
      BINS(1)=XMIN
      PLOW =XMIN
      PHIGH=PARAM(2)
      IF(PLOW.GE.PHIGH) GO TO 45
      IF(NN .LE.2 ) GO TO 45
      NM1=NN-1
      DELTAP=(PHIGH-PLOW)/FLOAT(NM1)
      DO 40 I=2,NM1
40  BINS(I)=PLOW+FLOAT(I-1)*DELTAP
      BINS(NN)=PARAM(2)
45  I=NN+1
      IF(I.GT.N) GO TO 25
      BINS(I)=PARAM(3)
      PLOW =PARAM(3)
      PHIGH =XMAX
      IF(PLOW.LT.PHIGH) GO TO 60
50  IF(MM .LE.2 ) GO TO 60
      NM1=MM-1
      DELTAP=(PHIGH-PLOW)/FLOAT(NM1)
      DO 55 J=2,NM1
      I=I+1
55  BINS(I)=PLOW+FLOAT(J-1)*DELTAP
60  BINS(N)=XMAX
      GO TO 25
      END
      SUBROUTINE NORCUM(NOPRAM,PARAM,X,P)
C
C---- CORCUM COMPUTES THE CUMULATIVE (-INFINITY, X) PROBABILITY
C      P FOR THE NORMAL DISTRIBUTION WITH MEAN amean AND STANTARD
C      DEVIATION sigma. amean AND sigma ARE CONTAINED IN PARAM(1) AND
C      PARAM(2) RESPECTIVELY.
C
C---- IF NOPRAM IS ZERO THEN THE DEFAULT VALUES FOR amean AND sigma
C      ARE USED. THAT IS PARAM(1)=0. AND PARAM(2)=1.
C
C---- PROCEDURE USES A POWER SERIES EXPANSION FOR 0. LE. Z .LE. 1
C      GIVEN BY EQ. 7.1.6 IN ABRAMOWITZ AND STEGUN. FOR Z .GT. 1
C      THE CONTINUED FRACTION EXPANSION IN EQ. 7.1.14 IN
C      ABRAMOWITZ AND STEGUN IS USED.
C
C---- PROGRAMMED AND CHECKED BY AR(TONY) OLSEN
C      DATE: OCTOBER 2, 1978
C      MODIFIED BY CA OSTER
C
      DIMENSION PARAM(2)
C

```



```

DATA ERR/1.0E-8/
DATA SQRT2,SQRTPI/1.414213562,1.772453851/
C
  IF(NOPRAM) 2,1,2
C
C---- DEFAULT VALUES
1 AMEAN=0.
  SIGMA=1.
  GO TO 3
C
2 AMEAN=PARAM(1)
  SIGMA=PARAM(2)
C
3 Y=(X-AMEAN)/SIGMA
  AY=ABS(Y)/SQRT2
  IF(AY.GT.1.) GO TO 30
  A1=AY
  A2=AY
  DO 10 L=1,50
    A2=A2*AY*AY/(FLOAT(L)+0.5)
    IF(A2.LT.ERR) GO TO 20
10 A1=A1+A2
20 ERF=2.*EXP(-AY*AY)*A1/SQRTPI
  GO TO 50
30 L=12.*AY+15.
  A1=FLOAT(L)/(2.*AY)
  DO 40 I=2,L
    A2=L-I+1
40 A1=(A2/2.)/(AY+A1)
  A1=AY+A1
  ERF=1.-EXP(-AY*AY)/A1/SQRTPI
50 S=-1.
  IF(Y.GE.0.) S=1.
  P=(1.+S*ERF)/2.
  RETURN
  END
SUBROUTINE FILLUP(NOPRAM,PARAM,XMIN,XMAX,N,A,B,K)
COMMON /DUMMY /IDUMY
DIMENSION PARAM(2),A(N),B(N)
LOGICAL KNE1,NONEO
DATA EPSILN/0.01/
C
C---- NOPRAM .EQ. 0 ==> X IS UNIFORMLY DISTRIBUTED BETWEEN XMIN AND XMAX
C      .EQ. 5 ==> X IS DISTRIBUTED BETWEEN XMIN AND XMAX AS TWO
C                DISTINCT UNIFORM DISTRIBUTIONS.
C      ANY OTHER VALUE ==> X IS LOGNORMALLY DISTRIBUTED BETWEEN XMIN AND XMAX
C
C---- K .EQ. 1 ==> RANDOM NUMBERS ARE ALREADY STORED IN B(.)
C      .NE. 1 ==> GENERATE NEW RANDOM NUMBERS WHEN THEY ARE NEEDED.
C      KNE1=K.NE.1

```

```

C      IF(NOPRAM.EQ.5) GO TO 50
      NONEQ=NOPRAM.NE.0
C
      IF(NONEQ) GO TO 3
      PLO=XMIN
      PHI=XMAX
      GO TO 7
C
3     PLO=0.
      IF(XMIN.LE.0.) GO TO 5
      XLO=ALOG(XMIN)
      CALL NORCUM(NOPRAM,PARAM,XLO,PLO)
5     XHI=ALOG(XMAX)
      CALL NORCUM(NOPRAM,PARAM,XHI,PHI)
7     DX=(PHI-PLO)/FLOAT(N-1)
      DO 10 I=1,N
10    A(I)=-1.
      EN=N
      DO 40 I=1,N
      X=PLO+FLOAT(I-1)*DX
      IF(NONEQ) GO TO 14
      PPF=X
      GO TO 16
C
14    CALL LNNPPF(NOPRAM,PARAM,X,PPF)
C
16    XI=B(I)
      IF(KNE1) XI=RAN(IDUMY)
      IX=EN*XI+.5
      IF(IX.LT.1) IX=N
20    IF(IX.GT.N) IX=1
      IF(A(IX).LT.0.) GO TO 30
      IX=IX+1
      GO TO 20
30    A(IX)=PPF
40    CONTINUE
45    RETURN
C
C----- TWO UNIFORM DISTRIBUTIONS
C
50    NN=PARAM(5)*FLOAT(N)+0.5
      NN=MAX0( 2,NN)
      NN=MIN0(N-1,NN)
      PLOL=AMAX1(XMIN,PARAM(1))
      PHIL=PARAM(2)
      DXL =(PHIL-PLOL)/FLOAT(NN-1)
      PLOR=PARAM(3)
      PHIR=AMIN1(XMAX,PARAM(4))
      DXR =(PHIR-PLOR)/FLOAT(N-NN-1)

```

```

DO 54 I=1,N
54 A(I)=-1.
   EN=N
   DO 75 I=1,N
   IF(I.GT.NN) GO TO 55
   PPF=PLOL+FLOAT(I-1)*DXL
   IF(I.EQ.1) PPF=PLOL+DXL*EPSILN
   IF(I.EQ.NN) PPF=PHIL-DXL*EPSILN
   GO TO 60
55 PPF=PLOR+FLOAT(I-NN-1)*DXR
   IF(I.EQ.NN+1) PPF=PLOR+DXR*EPSILN
   IF(I.EQ.N) PPF=PHIR-DXR*EPSILN
60 XI=B(I)
   IF(KNE1) XI=RAN(IDUMY)
   IX=EN*XI+.5
   IF(IX.LT.1) IX=N
65 IF(IX.GT.N) IX=1
   IF(A(IX).LT.0.) GO TO 70
   IX=IX+1
   GO TO 65
70 A(IX)=PPF
75 CONTINUE
   GO TO 45
END
FUNCTION DOTPRD(X,Y,N,XBAR,YBAR)
  DIMENSION X(N),Y(N)
  DOUBLE PRECISION SUM
  SUM=(X(1)-XBAR)*(Y(1)-YBAR)
  IF(N.LT.2) GO TO 20
  DO 10 I=2,N
  SUM=SUM+(X(I)-XBAR)*(Y(I)-YBAR)
10 CONTINUE
20 DOTPRD=SUM
  RETURN
END
SUBROUTINE SORT(A,NN,NNN,II,JJ)
C
C----- SEE ALGORITHM 347 IN COMM OF ACM,VOL 12,NO 3,MARCH 1969 PP 185-187
C          SORTS ARRAY A ON WORDS NN THRU NNN (A(NN,.) THRU A(NNN,.))
C          INTO INCREASING ORDER, FROM A(.,II) TO A(.,JJ)
C          ORDERING IS BY THE FUNCTION KOMPR( , , , ).
C----- THE FUNCTION KOMPR(X,YI,J) MUST BE CODED SO THAT IF THE ARRAY
C          (X(K),K=I,J) IS TO BE SORTED ABOVE (Y(K),K=I,J) I.E. X.GT.Y
C          THEN KOMPR.GT.0. IF X IS TO BE SORTED BELOW Y I.E. X.LT.Y
C          THEN KOMPR.LT.0. IF X IS ORDER-EQUIVALENT TO Y I.E. X=Y
C          THEN KOMPR=0.
C----- ARRAYS IU(KK) AND IL(KK) PERMIT SORTING UP TO 2**(KK+1)-1 ELEMENTS
C----- THE ARRAY A CONSISTS OF RECORDS MN WORDS IN LENGTH. IF THIS
C          LENGTH IS MODIFIED THEN THE DIMENSION STATEMENT FOR A,T,AND TT
C          MUST BE MODIFIED TOO.

```

```

C
C   INTEGER A,T,TT,0
      INTEGER      0
      DIMENSION IU(16),IL(16),T( 1),TT( 1),A( 1, 1)
      DATA MN/1/
      I=II
      J=JJ
      M=1
      N=NN
      O=NNN
5   IF(I.GE.J) GO TO 70
10  K=I
      IJ=(J+I)/2
      DO 11 MM=1,MN
11  T(MM)=A(MM,IJ)
      IF(KOMPR(A(1,I),T,N,0)) 20,20,111
111 DO 12 MM=1,MN
      A(MM,IJ)=A(MM,I )
      A(MM,I )=T(MM )
12  T(MM )=A(MM,IJ)
20  L=J
      IF(KOMPR(A(1,J),T,N,0)) 120,40,40
120 DO 21 MM=1,MN
      A(MM,IJ)=A(MM, J)
      A(MM, J)=T(MM )
21  T(MM )=A(MM,IJ)
      IF(KOMPR(A(1,I),T,N,0)) 40,40,121
121 DO 22 MM=1,MN
      A(MM,IJ)=A(MM,I )
      A(MM,I )=T(MM )
22  T(MM )=A(MM,IJ)
      GO TO 40
30  DO 31 MM=1,MN
      A(MM,L)=A (MM,K)
31  A(MM,K)=TT(MM)
40  L=L-1
      IF(KOMPR(A(1,L),T,N,0)) 140,140,40
140 DO 41 MM=1,MN
41  TT(MM)=A(MM,L)
50  K=K+1
      IF(KOMPR(A(1,K),T,N,0)) 50,150,150
150 IF(K.LE.L) GO TO 30
      IF((L-I) .LE. (J-K)) GO TO 60
      IL(M)=I
      IU(M)=L
      I =K
      M =M+1
      GO TO 80
60  IL(M)=K
      IU(M)=J

```

```

      J      =L
      M      =M+1
      GO TO 80
70  M=M-1
      IF(M.EQ.0) RETURN
      I=IL(M)
      J=IU(M)
80  IF((J-I) .GE. 11) GO TO 10
      IF(      I      .EQ. 11) GO TO 5
      I=I-1
90  I=I+1
      IF(I.EQ.J) GO TO 70
      DO 91 MM=1,MN
91  T(MM)=A(MM,I+1)
      IF(KOMPR(A(1,I),T,N,0)) 90,90,191
191 K=I
100 DO 101 MM=1,MN
101 A(MM,K+1)=A(MM,K)
      K=K-1
      IF(KOMPR(T,A(1,K),N,0)) 100,1101,1101
1101 DO 102 MM=1,MN
102 A(MM,K+1)=T(MM)
      GO TO 90
      END
      FUNCTION KOMPR(I,J,K,L)
C
C---- IF I.LT.J KOM=-1
C      IF I.EQ.J KOM= 0
C      IF I.GT.J KO=+1
C---- TO MAKE A DECENDING SORT SIMPLY SET KOM=1 AT STATEMENT 2 AND -1 AT
C      STATEMENT 3.
C
      DIMENSION I(1),J(1)
      REAL I,J
C
      DO 1 N=K,L
      IF(I(N)-J(N)) 2,1,3
1  CONTINUE
      KOM=0
      GO TO 4
2  KOM=-1
      GO TO 4
3  KOM=1
4  KOMPR=KOM
      RETURN
      END

```

APPENDIX D
CMCCDF CODE LISTING

APPENDIX D
CMCCDF CODE LISTING

```

C---- PROGRAM CMCCDF
C   THIS PROGRAM COMBINES SEVERAL CCDFs INTO ONE CCDF
C
C   PARAMETER MAXZ=27*90,MAXFIL= 10
1   ,MAXX1 = 51,MAXX2 = 50,MAXX3 =50,MAXX4 =50
2   ,MAXX  =MAXX1+MAXX2+MAXX3+MAXX4
3   ,JTOP  =MAXX-1,MAXCNT= 4
C
C   DIMENSION XIN(MAXX),CTOTAL(MAXX),CM(MAXZ),CCDF(MAXZ)
1   ,CO(MAXZ),X(MAXZ),XD(MAXZ),CD(MAXZ),PERCNT(MAXCNT)
C
C   CHARACTER*1 XTITL(60),YTITL(60),REPLY
C   CHARACTER*56 CH12
C   CHARACTER*40 INFILE,OUTFIL,BLANKS,INFYLS(MAXFIL)
C   CHARACTER*60 TYTLS(MAXFIL),TITL
C
C   LOGICAL LOGY,DISCR
C
C   PERCNT(1)=0.500
C   PERCNT(2)=0.900
C   PERCNT(3)=0.990
C   PERCNT(4)=0.999
C
C   BLANKS='
C
C   PRINT *, ' ENTER 1 FOR LOG    Y AXIS'
C   PRINT *, '      2 FOR LINEAR Y AXIS'
C   READ (5,5) I
5  FORMAT(I5)
C   LOGY=I.EQ.1
C   CCDFMN=0.1
C   H=1.-CCDFMN
C   IF(LOGY) H=ALOG(CCDFMN)
C   H=H/FLOAT(MAXX1-1)
C   XIN  (1)=1.
C   CTOTAL(1)=0.
C   DO 10 I=2,MAXX1
C   ARG=FLOAT(I-1)*H
C   Y=1.-ARG
C   IF(LOGY) Y=EXP(ARG)
10  XIN(I)=Y
C   YONE=CCDFMN
C   CCDFMN=0.01
C   H=YONE-CCDFMN
C   IF(LOGY) H=ALOG(CCDFMN/YONE)

```

```

H=H/FLOAT(MAXX2)
I1=MAXX1+1
I2=I1+MAXX2-1
DO 11 I=I1,I2
ARG=FLOAT(I-I1+1)*H
Y=YONE-ARG
IF(LOGY) Y=EXP(ARG)*YONE
11 XIN(I)=Y
YONE=CCDFMN
CCDFMN=0.001
H=YONE-CCDFMN
IF(LOGY) H=ALOG(CCDFMN/YONE)
H=H/FLOAT(MAXX3)
I1=I2+1
I2=I2+MAXX3
DO 12 I=I1,I2
ARG=FLOAT(I-I1+1)*H
Y=YONE-ARG
IF(LOGY) Y=EXP(ARG)*YONE
12 XIN(I)=Y
YONE=CCDFMN
CCDFMN=0.0001
H=YONE-CCDFMN
IF(LOGY) H=ALOG(CCDFMN/YONE)
H=H/FLOAT(MAXX4)
I1=I2+1
I2=I2+MAXX4
DO 13 I=I1,I2
ARG=FLOAT(I-I1+1)*H
Y=YONE-ARG
IF(LOGY) Y=EXP(ARG)*YONE
13 XIN(I)=Y
C
14 DO 15 I=1,MAXX
15 CTOTAL(I)=0.
NOFILE=0
PRINT *, ' ENTER OUTPUT FILE NAME'
PRINT *, '          BLANKS ==> RUN IS STOPPED'
READ (5,25) OUTFIL
IF(OUTFIL.EQ.BLANKS) GO TO 200
C
XPLMIN= 1.E35
XPLMAX=-1.E35
XXPDFN= 1.E35
XXPDFX=-1.E35
FXPDFN=-1.
FXPDFX=-1.
IMAXD =0
DISCR =.TRUE.
ALARM =.FALSE.

```



```

C
20 PRINT *, ' ENTER INPUT FILE NAME'
   PRINT *, '          BLANKS ==> WRITE OUTPUT FILE AND STOP'
   READ (5,25) INFILE
25  FORMAT(A40)
   IF(INFILE.EQ.BLANKS) GO TO 110
   OPEN(UNIT=2,NAME=INFILE,TYPE='OLD',FORM='FORMATTED')

C
C
   READ (2,31) TITL
32  FORMAT(60A1)
31  FORMAT(A60)
   NOFILE=NOFILE+1
   INFYLS(NOFILE)=INFILE
   TYTLS (NOFILE)=TITL

C
   READ (2,32) XTITL
   READ (2,32) YTITL
   READ (2,75) XPLMI,XPLMA
   READ (2,75) XNPDP,FNPDP
   READ (2,75) XXPDP,FXPDP
   IF(XNPDP.NE.-1.) XXPDPN=AMIN1(XXPDPN,XNPDP)
   IF(FNPDP.NE.-1.) FXPDPN=AMAX1(FXPDPN,FNPDP)
   IF(XXPDP.NE.-1.) XXPDPX=AMAX1(XXPDPX,XXPDP)
   IF(FXPDP.NE.-1.) FXPDPX=AMAX1(FXPDPX,FXPDP)
   IMAX=0
   DO 70 I=1,MAXZ
   READ (2,75,END=76) X(I),CO(I)
   IF((X(I).EQ.88888.) .AND. (CO(I).EQ.88888.)) GO TO 76
75  FORMAT(2E15.7)
70  IMAX=I
76  DO 74 I=1,MAXZ
   READ (2,75,END=73) XDI,CDI
   IF((XDI.EQ.99999.) .AND. (CDI.EQ.99999.)) GO TO 73
   IF(IMAXD.GE.MAXZ) GO TO 73
   IMAXD=IMAXD+1
   XD(IMAXD)=XDI
   CD(IMAXD)=CDI
74  CONTINUE
73  CLOSE(UNIT=2,DISPOSE='SAVE')
   XPLMIN=AMIN1(XPLMIN,XPLMI)
   XPLMAX=AMAX1(XPLMAX,XPLMA)
   MAXDI=IMAXD

C
C---- CONSTRUCT WORKING CCDF FOR INPUT CCDF
   IF(IMAX.LE.0) GO TO 105
   SUMC=0.
   DO 77 I=2,IMAX
77  SUMC=SUMC+(X(I)-X(I-1))*(CO(I-1)+CO(I))
   SUMC=SUMC/2.

```

```

        IF(SUMC.EQ.0.) GO TO 20
        IMAX=IMAX+1
        CM(1)=X(1)
        CCDF(1)=1.
        DO 78 I=1,IMAX
        CM(I)=X(I)
78      CCDF(I)=CO(I)
        CCDF(IMAX)=0.
65      C=0.
        DO 100 J=1,MAXX
        XINJ=XIN(J)
        DO 90 I=2,IMAX
        IF(I .EQ.IMAX ) GO TO 79
        IF(XINJ .LT.CCDF(I)) GO TO 90
79      IF(IMAXD.EQ.0 ) GO TO 80
C
C----- DISCRETE CCDF
        C=CM(I)
        GO TO 95
C
C----- CONTINUOUS CCDF
80      DISCR=.FALSE.
        IF(CCDF(I).GE.1.000001*CCDF(I-1)) GO TO 88
        IF(CCDF(I).LE.0.999990*CCDF(I-1)) GO TO 88
        SLOPE=0.
        GO TO 89
88      SLOPE=(CM(I)-CM(I-1))/(CCDF(I)-CCDF(I-1))
89      C=(XINJ-CCDF(I-1))*SLOPE+CM(I-1)
        C=AMAX1(C,0.)
        GO TO 95
90      CONTINUE
C
95      CTOTAL(J)=CTOTAL(J)+C
100     CONTINUE
105     IF(MAXDI.LE.D) GO TO 109
C
C----- DISCRETE CCDF
        DO 106 I=1,IMAXD
        CM (I)=XD(I)
106     CCDF(I)=CD(I)
        MAXDI=-1
        IMAX=IMAXD
        GO TO 65
C
109     IF(NOFIL.LT.MAXFIL) GO TO 20
C
110     SUM=XIN(1)-XIN(MAXX)
        OPEN(UNIT=3,FILE=OUTFIL,TYPE='NEW',FORM='FORMATTED')
        PRINT *, ' ENTER TITLE FOR OUTPUT FILE'
        READ (5,31) TITL

```

```

WRITE (3,31) TITL
WRITE (3,32) XTITL
WRITE (3,115)
C 115 FORMAT('COUNTS',54X)
115 FORMAT('CONSEQUENCE, C',46X)
WRITE (3,125) XPLMIN,XPLMAX
IF(XXPDFN.EQ. 1.E35) XXPDFN=-1.
IF(XXPDFX.EQ.-1.E35) XXPDFX=-1.
WRITE (3,125) XXPDFN,FXPDFN
WRITE (3,125) XXPDFX,FXPDFX
IF(DISCR) WRITE (3,124)
DO 120 J=1,MAXX
120 WRITE (3,125) CTOTAL(J),XIN(J)
125 FORMAT(1P2E15.7)
IF(.NOT.DISCR) WRITE (3,124)
124 FORMAT(9X,'88888.',9X,'88888.')
WRITE (3,121)
121 FORMAT(9X,'99999.',9X,'99999.')
IF(NOFIL.LE.0) GO TO 14
WRITE (4,127)
127 FORMAT('////' '===> ===> ===> ===> ===> ===> <===')
1 ' <=== <=== <=== <=== <===')
WRITE (4,126)
WRITE (6,126)
126 FORMAT('OTHE FOLLOWING FILES, WITH THEIR TITLE LINES'/
1' WERE COMBINED TO FORM ONE CCDF.'/)
DO 129 I=1,NOFIL
WRITE (4,128) I,INFYLS(I),TYTLS(I)
WRITE (6,128) I,INFYLS(I),TYTLS(I)
128 FORMAT(I5,' FILE: ',A40,' TITLE: ',A60)
129 CONTINUE
C
DO 130 J=1,JTOP
DXJ =CTOTAL(J+1)-CTOTAL(J)
XINJ=(CTOTAL(J)+CTOTAL(J+1))/2.
YINJ=XIN(J)-XIN(J+1)
YPDF=0.
IF(DXJ.NE.0.) YPDF=YINJ/DXJ/SUM
130 WRITE (6,135) J,CTOTAL(J),XIN(J),XINJ,YPDF
J=MAXX
WRITE (6,135) J,CTOTAL(J),XIN(J)
131 FORMAT('O',4X,1PE15.7)
135 FORMAT(15,1P5E15.7)
WRITE (6,185) MAXX,XIN(MAXX)
WRITE (4,150)
WRITE (6,150)
150 FORMAT('OQUANTILE VALUES'//)
DO 175 J=1,MAXCNT
C=0.
XINJ=1.-PERCNT(J)

```

```

DO 170 I=2,JTOP
  IF( I .EQ.JTOP ) GO TO 155
  IF(XINJ.LT.XIN(I)) GO TO 170
155 IF(XIN(I).GE.1.000001*XIN(I-1)) GO TO 160
  IF(XIN(I).LE.0.999990*XIN(I-1)) GO TO 160
  SLOPE=0.
  GO TO 165
160 SLOPE=(CTOTAL(I)-CTOTAL(I-1))/(XIN(I)-XIN(I-1))
165 QANTIL=CTOTAL(I-1)+SLOPE*(XINJ-XIN(I-1))
  GO TO 174
170 CONTINUE
174 WRITE (4,180) J,PERCNT(J),QANTIL
175 WRITE (6,180) J,PERCNT(J),QANTIL
180 FORMAT(I5,2PF5.1,'% ',1PE15.7)
C
185 FORMAT(I5,45X,1PE15.7)
  CLOSE(UNIT=3,DISPOSE='SAVE')
  WRITE (4,190) OUTFIL,TITL
  WRITE (6,190) OUTFIL,TITL
190 FORMAT('OTHE OUTPUT CCDF IS WRITTEN TO: '/
1  'O',4X,' FILE: ',A40,' TITLE: ',A60)
  GO TO 14
C
200 STOP 'END OF RUN'
  END

```

APPENDIX E
COMHUM CODE LISTING

APPENDIX E
COMHUM CODE LISTING

```

C---- PROGRAM COMHUM
C   THIS PROGRAM COMBINES SEVERAL HUMAN INTRUSION CCDF'S
C   IN ONE FILE, INTO A SINGLE CCDF AND WRITES IT TO A
C   SECOND FILE IN THE FORMAT ACCEPTABLE TO PRAPLT.
C
C   PARAMETER MAXZ=27*90
1  ,MAXX1 = 51,MAXX2 = 50,MAXX3 =50,MAXX4 =50
2  ,MAXX  =MAXX1+MAXX2+MAXX3+MAXX4
C
C
C   DIMENSION XIN(MAXX),CTOTAL(MAXX),CM(MAXZ),CCDF(MAXZ)
C
C   CHARACTER*1  TITL(60),XTITL(60),YTITL(60)
C   CHARACTER*56 CH12,CHALT
C   CHARACTER*40 INFILE,OUTFIL,BLANKS
C   CHARACTER*60 SUBTIT
C
C   LOGICAL LOGY
C
C   BLANKS='
C
C   PRINT *, ' ENTER 1 FOR LOG    Y AXIS'
C   PRINT *, '      2 FOR LINEAR Y AXIS'
C   READ (5,5) I
5  FORMAT(I5)
C   LOGY=I.EQ.1
C   CCDFMN=0.1
C   H=1.-CCDFMN
C   IF(LOGY) H=ALOG(CCDFMN)
C   H=H/FLOAT(MAXX1-1)
C   XIN(1)=1.
C   CTOTAL(1)=0.
C   DO 10 I=2,MAXX1
C   ARG=FLOAT(I-1)*H
C   Y=1.-ARG
C   IF(LOGY) Y=EXP(ARG)
C   XIN(I)=Y
10  CTOTAL(I)=0.
C   YONE=CCDFMN
C   CCDFMN=0.01
C   H=YONE-CCDFMN
C   IF(LOGY) H=ALOG(CCDFMN/YONE)
C   H=H/FLOAT(MAXX2)
C   I1=MAXX1+1
C   I2=I1+MAXX2-1

```

```

DO 11 I=I1,I2
ARG=FLOAT(I-I1+1)*H
Y=YONE-ARG
IF(LOGY) Y=EXP(ARG)*YONE
XIN(I)=Y
11 CTOTAL(I)=0.
YONE=CCDFMN
CCDFMN=0.001
H=YONE-CCDFMN
IF(LOGY) H=ALOG(CCDFMN/YONE)
H=H/FLOAT(MAXX3)
I1=I2+1
I2=I2+MAXX3
DO 12 I=I1,I2
ARG=FLOAT(I-I1+1)*H
Y=YONE-ARG
IF(LOGY) Y=EXP(ARG)*YONE
XIN(I)=Y
12 CTOTAL(I)=0.
YONE=CCDFMN
CCDFMN=0.0001
H=YONE-CCDFMN
IF(LOGY) H=ALOG(CCDFMN/YONE)
H=H/FLOAT(MAXX4)
I1=I2+1
I2=I2+MAXX4
DO 13 I=I1,I2
ARG=FLOAT(I-I1+1)*H
Y=YONE-ARG
IF(LOGY) Y=EXP(ARG)*YONE
XIN(I)=Y
13 CTOTAL(I)=0.
C
20 PRINT *, ' ENTER INPUT FILE NAME'
PRINT *, '          BLANKS STOP THE RUN'
READ (5,25) INFILE
25 FORMAT(A40)
IF(INFILE.EQ.BLANKS) GO TO 150
OPEN(UNIT=2,NAME=INFILE,TYPE='OLD',FORM='FORMATTED')
26 PRINT *, ' THE FOLLOWING ALTERNATIVES EXIST:'
PRINT 27
PRINT 28
PRINT 29
PRINT 30
PRINT *, ' '
PRINT *, ' ENTER NUMBER OF ALTERNATIVE SELECTED'
PRINT *, '          0 CLOSSES INPUT FILE AND SEEKS A NEW ONE'
READ (5,51) IALT
IF(IALT.NE.0) GO TO 33
CLOSE(UNIT=2,DISPOSE='SAVE')

```

```

      GO TO 20
27  FORMAT(' 1.  GEOLOGIC DISPOSAL')
28  FORMAT(' 2.  IN-PLACE STABILIZATION AND DISPOSAL')
29  FORMAT(' 3.  REFERENCE')
30  FORMAT(' 4.  NO ACTION')
C
33  REWIND 2
    PRINT *, ' ENTER OUTPUT FILE NAME'
    READ (5,25) OUTFIL
    OPEN(UNIT=3,NAME=OUTFIL,TYPE='NEW',FORM='FORMATTED')
C
    READ (2,32) TITL
32  FORMAT(60A1)
31  FORMAT(A60)
    WRITE (6,35) INFILE,OUTFIL,TITL
35  FORMAT('1PROGRAM COMHUM USED TO COMBINE THE CCDFs ON FILE: '
1    ,A40/' THE OUTPUT FILE HISTOGRAM IS ON FILE: '
2    ,A40//' ',60A1)
    READ (2,31) SUBTIT
    WRITE (6,36) SUBTIT
36  FORMAT('0',A60)
    WRITE (6,37)
37  FORMAT('0ALTERNATIVE CHOSEN:')
    IF(IALT.EQ.1) WRITE (6,27)
    IF(IALT.EQ.2) WRITE (6,28)
    IF(IALT.EQ.3) WRITE (6,29)
    IF(IALT.EQ.4) WRITE (6,30)
C
    DO 40 I=1,MAXX
40  CTOTAL(I)=0.
C
    NOPROC=0
50  READ (2,51,END=110) JALT,CHALT
51  FORMAT(I5,5X,A35)
    READ (2,55) CH12
55  FORMAT(A56)
    WRITE (6,60) CH12
60  FORMAT('0',A56)
    READ (2,32) XTITL
    READ (2,32) YTITL
    READ (2,65) IMAX
65  FORMAT(I5)
    DO 70 I=1,IMAX
70  READ (2,75) CM(I),CCDF(I)
75  FORMAT(2E15.7)
    IF(JALT.NE.IALT) GO TO 50
    NOPROC=NOPROC+1
    C=0.
    DO 100 J=1,MAXX
    XINJ=XIN(J)

```



```

      DO 90 I=1,IMAX
      IF(XINJ.NE.CCDF(I)) GO TO 85
      C=CM(I)
      GO TO 95
85  IF(XINJ.LT.CCDF(I)) GO TO 90
      IF(I.EQ.1) GO TO 95
      C=CM(I-1)
      GO TO 95
90  CONTINUE
      C=CM(IMAX)
95  CTOTAL(J)=CTOTAL(J)+C
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C   WRITE (6,96) J,CTOTAL(J)-C,C,CTOTAL(J),XINJ
C 96  FORMAT(I5,1P4E15.7)
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
100 CONTINUE
      GO TO 50
C
110 IF(NOPROC.GT.0) GO TO 113
      WRITE (6,111)
111  FORMAT('ONO CCDFs FOUND FOR CHOSEN ALTERNATIVE')
      GO TO 138
113 CONTINUE
      IF(CTOTAL(1).EQ.0.) CTOTAL(1)=CTOTAL(2)/10.
114  FORMAT(9X,'1.E+38',8X,'-1.E+38'
1    /12X,'-1.',12X,'-1.'/12X,'-1.',12X,'-1.')
115  FORMAT('PROBABILITY OF CONSEQUENCE => C',29X)
      IF(IALT.EQ.1) WRITE (3,27)
      IF(IALT.EQ.2) WRITE (3,28)
      IF(IALT.EQ.3) WRITE (3,29)
      IF(IALT.EQ.4) WRITE (3,30)
      WRITE (3,116)
116  FORMAT('CONSEQUENCE, C',46X)
      WRITE (3,115)
      WRITE (3,114)
      WRITE (3,122)
      DO 120 J=1,MAXX
120  WRITE (3,125) CTOTAL(J),XIN(J)
      WRITE (3,123)
122  FORMAT(9X,'88888.' ,9X,'88888.')
123  FORMAT(9X,'99999.' ,9X,'99999.')
125  FORMAT(1P2E15.7)
      DO 130 J=1,MAXX
130  WRITE (6,135) J,CTOTAL(J),XIN(J)
135  FORMAT(I5,1P5E15.7)
138  CLOSE(UNIT=3,DISPOSE='SAVE')
      GO TO 26
C
150 STOP 'END OF RUN'
      ENO

```

APPENDIX F
PRAPLT CODE LISTING

APPENDIX F

PRAPLT CODE LISTING

```

C---- PRAPLT IS A PROGRAM TO PLOT PRA HISTOGRAMS AS pdf'S OR CCDF'S
C
C   PARAMETER   MAXXY=27*90,MAXXY4=MAXXY+4
C
C   DIMENSION X(MAXXY4,4),Y(MAXXY4,4),XTAB(MAXXY4,4),YTAB(MAXXY4,4)
1  ,XPLOT(MAXXY4),YPLOT(MAXXY4)
C
C   DIMENSION NOX(4),NOY(4),NO(4),NOH(4)
1  ,XPLMIN(4),XPLMAX(4),FXPDFX(4),XPL(2),YPL(2)
2  ,FXPDFN(4),SLLX(5),SLLY(5),XXPDFN(4),XXPDFX(4)
C
C   CHARACTER*1 XTITLE(60,4),YTITLE(60,4),TITL(60,4)
1  ,REPLY
C   CHARACTER*60 XLABEL,HLABEL(4)
C   CHARACTER*40 INFILE(4),BLANKS
C
C   DIMENSION REALXL(15),REALHL(15,4)
C
C   EQUIVALENCE (REALXL,XLABEL),(REALHL,HLABEL)
C
C   LOGICAL CNTRPT,NSLL
C
C   BLANKS='
C
C   IPLOT=0
C
2  PRINT *, ' ENTER PLOTTER NOMINATION INDEX'
PRINT *, '      1 ==> CALCOMP'
PRINT *, '      2 ==> HP7221T'
PRINT *, '      3 ==> HP7550A'
READ (5,65) IPLOTR
IF(IPLOTR.EQ.1) GO TO 1
IF(IPLOTR.EQ.2) GO TO 1
IF(IPLOTR.EQ.3) GO TO 1
PRINT *, ' PLOTTER NOMINATED IS NOT PERMITTED'
PRINT *, '      DO YOU WANT TO TRY AGAIN? (Y OR N)'
READ (5,20) REPLY
IF(REPLY.EQ.'Y') GO TO 2
STOP 'PLOTTER NOMINATION INVALID'
C
1  NOCURV=0
C
C---- SPECIAL LIMIT LINES
SLLX(1)= 1.
SLLX(2)= 1.

```

```

SLLX(3)=10.
SLLX(4)=10.
SLLX(5)=100.
SLLY(1)= 1.
SLLY(2)= 0.1
SLLY(3)= 0.1
SLLY(4)= 0.001
SLLY(5)= 0.001
C
  ITYPE =0
  5 J      =NOCURV+1
  NODISC=0
  PRINT *, ' ENTER NAME OF INPUT FILE'
  PRINT *, '          BLANK NAME ==> STOPS RUN'
  READ (5,10) INFILE(J)
  IF(INFILE(J).EQ.BLANKS) GO TO 325
10  FORMAT(A40)
  OPEN(UNIT=2,NAME=INFILE(J),TYPE='OLD',FORM='FORMATTED',ERR=11)
  GO TO 15
11  PRINT *, ' OPEN ERROR FOR INPUT FILE.  TRY AGAIN!'
  GO TO 5
C
  15 READ (2,20) (TITL(I,J),I=1,60)
  READ (2,20) (XTITLE(1,J),I=1,60)
  READ (2,20) (YTITLE(1,J),I=1,60)
20  FORMAT(80A1)
  NOH(J)=1
  NOX(J)=1
  NOY(J)=1
  DO 25 I=1,60
  IF( TITL (I,J).NE.' ') NOH(J)=I
  IF(XTITLE(I,J).NE.' ') NOX(J)=I
  IF(YTITLE(I,J).NE.' ') NOY(J)=I
25  CONTINUE
  PRINT 30,INFILE(J)
30  FORMAT('OINPUT FILE NAME: ',A40)
  PRINT 35,( TITL (I,J),I=1,60)
  1      ,(XTITLE(I,J),I=1,60)
  2      ,(YTITLE(I,J),I=1,60)
35  FORMAT('          TITLE: ',60A1/
  1      '          X-TITLE: ',60A1/
  2      '          Y-TITLE: ',60A1)
  PRINT *, ' '
  PRINT *, ' IS THIS THE CORRECT FILE? (Y OR N)'
  READ (5,20) REPLY
  IF(REPLY.EQ.'Y') GO TO 40
  CLOSE(UNIT=2,DISPOSE='SAVE')
  GO TO 5
C
40  READ (2,45) XPLMIN(J),XPLMAX(J)

```

```

      READ (2,45) XXPDFN(J),FXPDFN(J)
      READ (2,45) XXPDFX(J),FXPDFX(J)
45  FORMAT(2E15.7)
      NDISC=0
      NODISC=0
      DO 50 I=1,MAXXY
      READ (2,45,END=53) X(I,J),Y(I,J)
      IF((X(I,J).EQ.88888.) .AND. (Y(I,J).EQ.88888.)) GO TO 55
50  CONTINUE
      I=MAXXY+1
55  NO(J)=I-1
C
      IF(I.GT.1) GO TO 52
      DO 54 I=1,MAXXY
      READ (2,45,END=53) XDI,CDI
      IF((XDI.EQ.99999.) .AND. (CDI.EQ.99999.)) GO TO 53
      NDISC =NDISC +1
      NODISC=NODISC+1
      X(I,J)=XDI
      Y(I,J)=CDI
54  CONTINUE
53  NO(J)=NODISC
52  CLOSE(UNIT=2,DISPOSE='SAVE')
      IF(NO(J).GT.1) GO TO 60
      PRINT *, ' NO DATA TO PLOT ON FILE NAMED: '
      PRINT 56,INFILE(J)
56  FORMAT(' ',A40)
      GO TO 5
C
60  NOCURV=NOCURV+1
      IF(ITYPE.NE.0) GO TO 70
      PRINT *, ' ENTER 1 FOR SINGLE pdf PLOT'
      PRINT *, '      2 FOR MULTIPLE CCDF PLOT'
      READ (5,65) ITYPE
65  FORMAT(I5)
      IF(ITYPE.NE.1) GO TO 70
      PRINT *, ' ENTER 0 IF POINTS ARE AT CENTER  OF DELTA X'
      PRINT *, '      1 IF POINTS ARE AT LEFT END OF DELTA X'
      READ (5,65) I
      CNTRPT=I.EQ.0
      GO TO 200
C
C----- READ MORE DATA FOR MULTIPLE CCDF PLOT
C
70  IF(NOCURV.EQ.4) GO TO 200
      PRINT *, ' MULTIPLE CCDF PLOT: '
75  PRINT *, ' ARE MORE CURVES TO BE PLOTTED? (Y OR N)'
      READ (5,20) REPLY
      IF(REPLY.EQ.'Y') GO TO 5
      IF(REPLY.NE.'N') GO TO 75

```

```

C
200 PRINT *, ' ENTER 1 FOR LINEAR X-AXIS'
PRINT *, '      2 FOR LOG      X-AXIS'
READ (5,65) LXAXIS
PRINT *, ' ENTER 1 FOR LINEAR Y-AXIS'
PRINT *, '      2 FOR LOG      Y-AXIS'
READ (5,65) LYAXIS
YMIN= 1.E35
YMAX=-1.E35
XMIN= 1.E35
XMAX=-1.E35
XMAX=XMAX
XMNN=XMIN
DO 224 J=1,NOCURV
NO1=NO(J)
XMNN=AMIN1(XMNN,X(1,J))
NO1=NO1+2
DO 220 I=3,NO1
IF(ITYPE.EQ.1) GO TO 217
C----- CCDF PLOTS
XTAB(I,J)=X(I-2,J)
YTAB(I,J)=Y(I-2,J)
GO TO 220
C----- pdf PLOTS
217 XTAB(I,J)=X(I-2,J)
IF(CNTRPT) XTAB(I,J)=(X(I-1,J)+X(I-2,J))/2.
DX=X(I-1,J)-X(I-2,J)
YTAB(I,J)=Y(I-2,J)
IF(DX.NE.0.) YTAB(I,J)=(Y(I-2,J)-Y(I-1,J))/DX
YTAB(I,J)=AMAX1(0.,YTAB(I,J))
YMAX=AMAX1(YMAX,YTAB(I,J))
IF((YTAB(I,J).LE.0.) .AND. (LYAXIS.EQ.2)) GO TO 220
YMIN=AMIN1(YMIN,YTAB(I,J))
220 CONTINUE
XMAX=AMAX1(XMAX,X(NO1-2,J))
XMIN=AMIN1(XMIN,XPLMIN(J))
XMAX=AMAX1(XMAX,XPLMAX(J))
IF(LYAXIS .EQ.2 ) GO TO 224
IF(ITYPE .EQ.2 ) GO TO 224
IF(FXPDFX(J).GT.0.) YMIN=AMIN1(YMIN,FXPDFX(J))
IF(FXPDFN(J).GT.0.) YMIN=AMIN1(YMIN,FXPDFN(J))
IF(FXPDFN(J).GT.0.) YMAX=AMAX1(YMAX,FXPDFN(J))
IF(FXPDFX(J).GT.0.) YMAX=AMAX1(YMAX,FXPDFX(J))
224 CONTINUE
IF(XMIN.GE. 1.E34) XMIN=XMNN
IF(XMAX.LE.-1.E34) XMAX=XMAX
IF(ITYPE.EQ.1) GO TO 225
YMAX=1.
YMIN=0.0001
225 DO 230 J=1,NOCURV

```

```

C---- ADD INITIAL AND TERMINAL POINTS
      NO1=NO(J)+2
      IF(ITYPE.EQ.1) GO TO 226
C---- CCDF PLOT
      XTAB(1,J)=XMIN
      XTAB(2,J)=XMIN
      YTAB(1,J)=1.
      YTAB(2,J)=1.
      NO1=NO1+1
      XTAB(NO1,J)=XTAB(NO1-1,J)
      YTAB(NO1,J)=YMIN
      GO TO 229
C---- pdf PLOT
226  XTAB(1,J)=XXPDFN(J)
      XTAB(2,J)=XXPDFN(J)
      YTAB(1,J)=YMIN
      YTAB(2,J)=FXPDFN(J)
      XTAB(NO1-1,J)=XXPDFX(J)
      YTAB(NO1-1,J)=FXPDFX(J)
      XTAB(NO1,J)=XXPDFX(J)
      YTAB(NO1,J)=YMIN
229  NO(J)=NO1
      NOH1=NOH(J)
      ENCODE(NO1,20,HLABEL(J)) (TITL(I,J),I=1,NOH1)
230  CONTINUE
      J=1
      NOX1=NOX(J)
      ENCODE(NO1,20,XLABEL) (XTITLE(I,J),I=1,NOX1)
C
      PRINT *, ' ARE SPECIAL LIMIT LINES WANTED? (Y OR N)'
      READ (5,20) REPLY
      NSLL=REPLY.NE.'Y'
C
      XAXIS=6.
      YAXIS=4.
      IF(IPLLOT.NE.0) GO TO 233
C
      IF(IPLOTR.EQ.1) CALL CALCMP
      IF(IPLOTR.EQ.2) CALL H7221C
      IF(IPLOTR.EQ.3) CALL HP7550
      IF(IPLOTR.NE.2) GO TO 233
C---- SPECIAL FOR HP7221 SERIES PLOTTERS
      CALL HWSPEC(24., 'PEN')
C
233  CALL RESET('ALL')
      CALL AREA2D(XAXIS,YAXIS)
      DO 235 J=1,NOCURV
      CALL HEADIN(REALHL(1,J),NOH(J),1.,NOCURV)
235  CONTINUE
      J=1

```

```

        IF(ITYPE.EQ.2) GO TO 238
        CALL XNAME(REALXL,NOX1)
        CALL YNAME('pdf$',100)
        GO TO 240
    238 CALL XNAME('RELEASE RATIO CONSEQUENCE, C$',100)
        CALL YNAME('PROBABILITY OF CONSEQUENCE => C$',100)
    240 IF(LXAXIS.NE.2) GO TO 255
C
C----- LOG X-AXIS
        CALL ALGPLT(XMIN,XMAX,XAXIS,ORGX,XCYCLE)
        IF(LYAXIS.NE.2) GO TO 250
C
C----- LOG X-AXIS AND LOG Y-AXIS
        CALL ALGPLT(YMIN,YMAX,YAXIS,ORGY,YCYCLE)
        CALL LOGLOG(ORGX,XCYCLE,ORGY,YCYCLE)
        GO TO 270
C
C----- LOG X-AXIS AND LINEAR Y-AXIS
    250 CALL AXSPLT(YMIN,YMAX,YAXIS,ORGY,YSTEP,YAXISL)
        CALL XLOG(ORGX,XCYCLE,ORGY,YSSTEP)
        GO TO 270
C
C----- LINEAR X-AXIS
    255 CALL AXSPLT(XMIN,XMAX,XAXIS,ORGX,XSTEP,XAXISL)
        IF(LYAXIS.NE.2) GO TO 260
C
C----- LINEAR X-AXIS AND LOG Y-AXIS
        CALL ALGPLT(YMIN,YMAX,YAXIS,ORGY,YCYCLE)
        CALL YLOG(ORGX,XSTEP,ORGY,YCYCLE)
        GO TO 270
C
C----- LINEAR X-AXIS AND LINEAR Y-AXIS
    260 CALL AXSPLT(YMIN,YMAX,YAXIS,ORGY,YSSTEP,YAXISL)
        XAXISM=ORGX+XSTEP*XAXISL
        YAXISM=ORGY+YSSTEP*YAXISL
        CALL GRAF(ORGX,XSTEP,XAXISM,ORGY,YSSTEP,YAXISM)
C
    270 IF(ITYPE.EQ.2) GO TO 280
        NO1=NO(1)
        DO 275 I=1,NO1
            XPLOT(I)=XTAB(I,1)
            YPLOT(I)=YTAB(I,1)
    275 CONTINUE
        II=NO1+1
        XPLOT(II)=XPLOT(II-1)
        YPLOT(II)=YMIN
        IF(NDISC.NE.0) GO TO 276
C
        CALL MARKER(15)
        CALL CURVE(XPLOT,YPLOT,II,0)
        GO TO 300

```



```

276 CALL DOT
    DO 277 I=1,II
    XPL(1)=XPLOT(I)
    XPL(2)=XPLOT(I)
    YPL(1)=YMIN
    YPL(2)=YPLOT(I)
    CALL CURVE(XPL,YPL,2,0)
277 CONTINUE
    GO TO 300

C
C---- MAKE MULTIPLE CCDF PLOT
C
280 JMOD=0
    DO 290 J=1,NOCURV
    NO1=NO(J)
    II=0
    DO 279 I=1,NO1
    IF(XTAB(I,J).LT.XMIN) GO TO 279
    IF(XTAB(I,J).GT.XMAX) GO TO 279
    IF(YTAB(I,J).LT.YMIN) GO TO 279
    IF(YTAB(I,J).GT.YMAX) GO TO 279
    II=II+1
    XPLOT(II)=XTAB(I,J)
    YPLOT(II)=YTAB(I,J)
    IF(I.EQ.NO1) GO TO 279
    IF(NDISC.EQ.0) GO TO 279
    IF(XTAB(I+1,J).LT.XMIN) GO TO 279
    IF(XTAB(I+1,J).GT.XMAX) GO TO 279
    II=II+1
    XPLOT(II)=XTAB(I+1,J)
    YPLOT(II)=YTAB(I,J)
279 CONTINUE
    JMOD=JMOD+1
    IF(JMOD.GT.5) JMOD=1
C    CALL MARKER(J+14)
    GO TO (281,282,283,284,285),JMOD
C---- USE SOLID LINES
281 CALL CHNDOT
    CALL RESET('CHNDOT')
    GO TO 289
C---- USE DOTTED LINES
282 CALL DOT
    GO TO 289
C---- USE DASHED LINES
283 CALL DASH
    GO TO 289
C---- USE CHAIN DOTS
284 CALL CHNDOT
    GO TO 289
C---- USE CHAIN DASHES

```

```

285 CALL CHNDSH
289 CONTINUE
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C    DO 288 I=1,II
C    WRITE (6,301) I,XPLOT(I),YPLOT(I)
C 288 CONTINUE
C 301 FORMAT(I5,1P2E15.7)
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C    CALL CURVE(XPLOT,YPLOT,II,0)
290 CONTINUE
C
300 IF(NSLL) GO TO 320
C
C---- PLOT SPECIAL LIMIT LINES
      DO 319 I=1,5
      SLLX(I)=AMIN1(SLLX(I),XMAX)
319 CONTINUE
      CALL CHNDOT
      CALL RESET('CHNDOT')
      CALL CURVE(SLLX,SLLY,5,0)
C
320 IPLOT=IPLOT+1
      CALL ENDPL(IPLOT)
      GO TO 1
C
325 CALL DONEPL
      STOP 7777
      END

```

APPENDIX G

W8CCDF CODE LISTING

APPENDIX G
W8CCDF CODE LISTING

```

C---- PROGRAM W8CCDF
C   THIS PROGRAM MAKES A LINEAR COMBINATION OF CCDFs INTO ONE CCDF
C   (PROVIDED THE WEIGHTS ARE ALL NONEGATIVE AND SUM TO UNITY)
C
C   PARAMETER MAXZ=27*90,MAXFIL= 10
C   1 ,MAXX1 = 51,MAXDEC= 5
C   2 ,MAXX  =(MAXX1-1)*MAXDEC
C   3 ,JTOP  =MAXX-1,MAXCNT= 4
C
C   DIMENSION XIN(MAXX),CTOTAL(MAXX),CM(MAXZ),CCDF(MAXZ)
C   1 ,CO(MAXZ),X(MAXZ),XD(MAXZ),CD(MAXZ),PERCNT(MAXCNT)
C   2 ,W8(MAXFIL)
C
C   CHARACTER*1 XTITL(60),YTITL(60),REPLY
C   CHARACTER*56 CH12
C   CHARACTER*40 INFILE,OUTFIL,BLANKS,INFYLS(MAXFIL)
C   CHARACTER*60 TYTLS(MAXFIL),TITL
C
C   LOGICAL LOGX,DISCR,ALARM
C
C   PERCNT(1)=0.500
C   PERCNT(2)=0.900
C   PERCNT(3)=0.990
C   PERCNT(4)=0.999
C
C   BLANKS='
C
C   FNOXX=MAXX1-1
C
C   PRINT *, ' ENTER 1 FOR LOG    Y AXIS'
C   PRINT *, '          2 FOR LINEAR Y AXIS'
C   READ (5,5) I
C   5 FORMAT(I5)
C   LOGX=I.EQ.1
C   CONSMX=0.001
C   I2    =0
C   XIN(1)=CONSMX
C   DO 11 K=1,MAXDEC
C   CONSMN=CONSMX
C   CONSMX=CONSMX*10.
C   I1    =I2+1
C   I2    =I2+MAXX1-1
C   H=CONSMX-CONSMN
C   IF (LOGX) H=ALOG (CONSMX/CONSMN)
C   H=H/FNOXX

```

```

DO 10 I=I1,I2
ARG=FLOAT(I-I1+1)*H
EX=CONSMN+ARG
IF(LOGX) EX=EXP(ARG)*CONSMN
10 XIN(I)=EX
11 CONTINUE
C
14 DO 15 I=1,MAXX
15 CTOTAL(I)=0.
NOFILE=0
PRINT *, ' ENTER OUTPUT FILE NAME'
PRINT *, '      BLANKS ==> RUN IS STOPPED'
READ (5,25) OUTFIL
IF(OUTFIL.EQ.BLANKS) GO TO 200
C
XPLMIN= 1.E35
XPLMAX=-1.E35
XXPDFN= 1.E35
XXPDFX=-1.E35
FXPDFN=-1.
FXPDFX=-1.
IMAXD =0
DISCR =.TRUE.
SUMW8S=0.
ALARM =.FALSE.
C
20 PRINT *, ' ENTER INPUT FILE NAME'
PRINT *, '      BLANKS ==> WRITE OUTPUT FILE AND STOP'
READ (5,25) INFILE
25 FORMAT(A40)
IF(INFILE.EQ.BLANKS) GO TO 110
C
26 PRINT *, ' ENTER MULTIPLIER WEIGHT FOR THIS CCDF'
READ (5,75) W8F
IF((W8F.GE.0.) .AND. (W8F.LE.1.0)) GO TO 28
PRINT *, ' MULTIPLIER WEIGHT IS NOT IN UNIT INTERVAL [0.,1.]'
PRINT *, '      DO YOU WANT TO CHANGE IT? (Y OR N)'
READ (5,27) REPLY
27 FORMAT(A1)
IF(REPLY.EQ.'Y') GO TO 26
ALARM=.TRUE.
28 SUMW8S=SUMW8S+W8F
C
OPEN(UNIT=2,NAME=INFILE,TYPE='OLD',FORM='FORMATTED')
C
C
READ (2,31) TITL
32 FORMAT(60A1)
31 FORMAT(A60)
NOFILE=NOFILE+1

```

```

W8      (NOFILE)=W8F
INFYLS(NOFILE)=INFILE
TYTLS (NOFILE)=TITL

```

C

```

READ (2,32) XTITL
READ (2,32) YTITL
READ (2,75) XPLMI,XPLMA
READ (2,75) XNPDP,FNPDP
READ (2,75) XXPDP,FXPDF
IF(XNPDP.NE.-1.) XXPDPN=AMIN1(XXPDPN,XNPDP)
IF(FNPDP.NE.-1.) FXPDFN=AMAX1(FXPDFN,FNPDP)
IF(XXPDP.NE.-1.) XXPDFX=AMAX1(XXPDFX,XXPDF)
IF(FXPDF.NE.-1.) FXPDFX=AMAX1(FXPDFX,FXPDF)
IMAX=0
DO 70 I=1,MAXZ
READ (2,75,END=76) X(I),CO(I)
IF((X(I).EQ.88888.) .AND. (CO(I).EQ.88888.)) GO TO 76
75 FORMAT(2E15.7)
70 IMAX=I
76 DO 74 I=1,MAXZ
READ (2,75,END=73) XDI,CDI
IF((XDI.EQ.99999.) .AND. (CDI.EQ.99999.)) GO TO 73
IF(IMAXD.GE.MAXZ) GO TO 73
IMAXD=IMAXD+1
XD(IMAXD)=XDI
CD(IMAXD)=CDI
74 CONTINUE
73 CLOSE(UNIT=2,DISPOSE='SAVE')
XPLMIN=AMIN1(XPLMIN,XPLMI)
XPLMAX=AMAX1(XPLMAX,XPLMA)
MAXDI=IMAXD

```

C

```

C---- CONSTRUCT WORKING CCDF FOR INPUT CCDF
IF(IMAX.LE.0) GO TO 105
SUMC=0.
DO 77 I=2,IMAX
77 SUMC=SUMC+(X(I)-X(I-1))*(CO(I-1)+CO(I))
SUMC=SUMC/2.
IF(SUMC.EQ.0.) GO TO 20
IMAX=IMAX+1
CM(1)=X(1)
CCDF(1)=1.
DO 78 I=2,IMAX
CM(I)=X(I)
78 CCDF(I)=CO(I)
CCDF(IMAX)=0.
65 C=0.
DO 100 J=1,MAXX
XINJ=XIN(J)
DO 90 I=2,IMAX

```

```

      IF(I .EQ. IMAX ) GO TO 79
      IF(XINJ .GT. CM(I)) GO TO 90
79  IF(IMAXD.EQ.0 ) GO TO 80
C
C---- DISCRETE CCDF
      C=CCDF(I)
      GO TO 95
C
C---- CONTINUOUS CCDF
80  DISCR=.FALSE.
      IF(CM(I).GE.1.000001*CM(I-1)) GO TO 88
      IF(CM(I).LE.0.999990*CM(I-1)) GO TO 88
      SLOPE=0.
      GO TO 89
88  SLOPE=(CCDF(I)-CCDF(I-1))/(CM(I)-CM(I-1))
89  C=(XINJ-CM(I-1))*SLOPE+CCDF(I-1)
      C=AMAX1(C,0.)
      C=AMIN1(C,1.)
      GO TO 95
C
90  CONTINUE
C
95  CTOTAL(J)=CTOTAL(J)+C*W8F
100 CONTINUE
105 IF(MAXDI.LE.0) GO TO 109
C
C---- DISCRETE CCDF
      DO 106 I=1,IMAXD
      CM (I)=XD(I)
106  CCDF(I)=CD(I)
      MAXDI=-1
      IMAX=IMAXD
      GO TO 65
C
109 IF(NOFILE.LT.MAXFIL) GO TO 20
C
110 SUM=XIN(MAXX)-XIN(1)
      OPEN(UNIT=3,FILE=OUTFIL,TYPE='NEW',FORM='FORMATTED')
      PRINT *, ' ENTER TITLE FOR OUTPUT FILE'
      READ (5,31) TITL
      WRITE (3,31) TITL
      WRITE (3,32) XTITL
      WRITE (3,115)
C 115 FORMAT('COUNTS',54X)
115  FORMAT('CONSEQUENCE, C',46X)
      WRITE (3,125) XPLMIN,XPLMAX
      IF(XXPDFN.EQ. 1.E35) XXPDFN=-1.
      IF(XXPDFX.EQ.-1.E35) XXPDFX=-1.
      WRITE (3,125) XXPDFN,FXPDFN
      WRITE (3,125) XXPDFX,FXPDFX

```

```

        IF(DISCR) WRITE (3,124)
        DO 120 J=1,MAXX
120 WRITE (3,125) XIN(J),CTOTAL(J)
125 FORMAT(1P2E15.7)
        IF(.NOT.DISCR) WRITE (3,124)
124 FORMAT(9X,'88888.',9X,'88888.')
        WRITE (3,121)
121 FORMAT(9X,'99999.',9X,'99999.')
        IF(NOFIL.LE.0) GO TO 14
        WRITE (4,127)
127 FORMAT('////' ===> ===> ===> ===> ===> ===> <===')
1   ' <=== <=== <=== <=== <===')
        WRITE (4,126)
        WRITE (6,126)
126 FORMAT('OTHE FOLLOWING FILES, WITH THEIR TITLE LINES'/
1   ' WERE COMBINED TO FORM ONE CCDF.//')
        DO 129 I=1,NOFILE
        WRITE (4,128) I,INFYLS(I),TYTLS(I)
        WRITE (6,128) I,INFYLS(I),TYTLS(I)
128 FORMAT(15,' FILE: ',A40,' TITLE: ',A60)
129 CONTINUE
C
        WRITE (4,140)
        WRITE (6,140)
140 FORMAT('OMULTIPLIER WEIGHTS ARE: '//)
        DO 141 I=1,NOFILE
        WRITE (4,142) I,W8(I)
141 WRITE (6,142) I,W8(I)
142 FORMAT(15,F10.6)
        WRITE (4,143) SUMW8S
        WRITE (6,143) SUMW8S
143 FORMAT('-----'/5X,F10.6)
        IF((SUMW8S.LE.0.) .OR. (SUMW8S.GT.1.)) ALARM=.TRUE.
        IF(ALARM) WRITE (4,144)
        IF(ALARM) WRITE (6,144)
144 FORMAT('O***** ONE OR MORE MULTIPLIER WEIGHT IS OUTSIDE'
1   ' , ' THE UNIT INTERVAL OR THEIR SUM EXCEEDS UNITY. *****')
        WRITE (4,145)
        WRITE (6,145)
145 FORMAT('O')
        DO 130 J=1,JTOP
        DXJ =XIN(J+1)-XIN(J)
        XINJ=(XIN (J)+XIN (J+1))/2.
        YINJ= CTOTAL(J)-CTOTAL(J+1)
        YPDF=0.
        IF(DXJ.NE.0.) YPDF=YINJ/DXJ/SUM
130 WRITE (6,135) J,XIN(J),CTOTAL(J),XINJ,YPDF
        J=MAXX
        WRITE (6,135) J,XIN(J),CTOTAL(J)
131 FORMAT('O',4X,1PE15.7)

```



```

135 FORMAT(15,1P5E15.7)
    WRITE (4,150)
    WRITE (6,150)
150 FORMAT('QUANTILE VALUES'//)
    DO 175 J=1,MAXCNT
        C=0.
        XINJ=1.-PERCNT(J)
        DO 170 I=2,JTOP
            IF( I .EQ.JTOP ) GO TO 155
            IF(XINJ.LT.CTOTAL(I)) GO TO 170
155 IF(CTOTAL(I).GE.1.000001*CTOTAL(I-1)) GO TO 160
            IF(CTOTAL(I).LE.0.999990*CTOTAL(I-1)) GO TO 160
            SLOPE=0.
            GO TO 165
160 SLOPE=(XIN(I)-XIN(I-1))/(CTOTAL(I)-CTOTAL(I-1))
165 QANTIL=XIN(I-1)+SLOPE*(XINJ-CTOTAL(I-1))
            GO TO 174
170 CONTINUE
174 WRITE (4,180) J,PERCNT(J),QANTIL
175 WRITE (6,180) J,PERCNT(J),QANTIL
180 FORMAT(15,2PF5.1,'% ',1PE15.7)
C
    CLOSE(UNIT=3,DISPOSE='SAVE')
    WRITE (4,190) OUTFIL,TITL
    WRITE (6,190) OUTFIL,TITL
190 FORMAT('OTHE OUTPUT CCDF IS WRITTEN TO: '/
1    'O',4X,' FILE: ',A40,' TITLE: ',A60)
    GO TO 14
C
200 STOP 'END OF RUN'
    END

```

APPENDIX H
W8PLOT CODE LISTING

APPENDIX H

W8PLOT CODE LISTING

```

C---- W8PLOT IS A PROGRAM TO PLOT PRA HISTOGRAMS AS pdf'S OR CCDF'S
C-----W8PLOT IS BASICALLY THE PRAPLOT PROGRAM EXCEPT FOR 7 ADDITIONAL LINES
C-----W8PLOT GRAPHICS ARE GEARED FOR SCALES OF THE COMPOSITE CCDF & EPA STAND.
C
C      PARAMETER   MAXXY=27*90,MAXXY4=MAXXY+4
C
C      DIMENSION X(MAXXY4,4),Y(MAXXY4,4),XTAB(MAXXY4,4),YTAB(MAXXY4,4)
1      ,XPLT(MAXXY4),YPLT(MAXXY4)
C
C      DIMENSION NOX(4),NOY(4),NO(4),NOH(4)
1      ,XPLMIN(4),XPLMAX(4),FXPDFX(4),XPL(2),YPL(2)
2      ,FXPDFN(4),SLLX(5),SLLY(5),XXPDFN(4),XXPDFX(4)
C
C      CHARACTER*1 XTITLE(60,4),YTITLE(60,4),TITL(60,4)
1      ,REPLY
C      CHARACTER*60 XLABEL,HLABEL(4)
C      CHARACTER*40 INFILE(4),BLANKS
C
C      DIMENSION REALXL(15),REALHL(15,4)
C
C      EQUIVALENCE (REALXL,XLABEL),(REALHL,HLABEL)
C
C      LOGICAL CNTRPT,NSLL
C
C      BLANKS='
C
C      IPLOT=0
C
2  PRINT *, ' ENTER PLOTTER NOMINATION INDEX'
PRINT *, '      1  ==> CALCOMP'
PRINT *, '      2  ==> HP7221T'
PRINT *, '      3  ==> HP7550A'
READ (5,65) IPLOTR
IF(IPLOTR.EQ.1) GO TO 1
IF(IPLOTR.EQ.2) GO TO 1
IF(IPLOTR.EQ.3) GO TO 1
PRINT *, ' PLOTTER NOMINATED IS NOT PERMITTED'
PRINT *, '      DO YOU WANT TO TRY AGAIN? (Y OR N)'
READ (5,20) REPLY
IF(REPLY.EQ.'Y') GO TO 2
STOP 'PLOTTER NOMINATION INVALID'
C
1  NOCURV=0
C
C---- SPECIAL LIMIT LINES

```

```

SLLX(1)= 1.
SLLX(2)= 1.
SLLX(3)=10.
SLLX(4)=10.
SLLX(5)=100.
SLLY(1)= 1.
SLLY(2)= 0.1
SLLY(3)= 0.1
SLLY(4)= 0.001
SLLY(5)= 0.001

```

C

```

      ITYPE =0
5  J      =NOCURV+1
      NODISC=0
      PRINT *, ' ENTER NAME OF INPUT FILE'
      PRINT *, '          BLANK NAME ==> STOPS RUN'
      READ (5,10) INFILE(J)
      IF(INFILE(J).EQ.BLANKS) GO TO 325
10  FORMAT(A40)
      OPEN(UNIT=2,NAME=INFILE(J),TYPE='OLD',FORM='FORMATTED',ERR=11)
      GO TO 15
11  PRINT *, ' OPEN ERROR FOR INPUT FILE. TRY AGAIN!'
      GO TO 5

```

C

```

15  READ (2,20) (TITL(I,J),I=1,60)
      READ (2,20) (XTITLE(I,J),I=1,60)
      READ (2,20) (YTITLE(I,J),I=1,60)
20  FORMAT(80A1)
      NOH(J)=1
      NOX(J)=1
      NOY(J)=1
      DO 25 I=1,60
      IF( TITL (I,J).NE.' ') NOH(J)=I
      IF(XTITLE(I,J).NE.' ') NOX(J)=I
      IF(YTITLE(I,J).NE.' ') NOY(J)=I
25  CONTINUE
      PRINT 30,INFILE(J)
30  FORMAT('OINPUT FILE NAME: ',A40)
      PRINT 35,( TITL (I,J),I=1,60)
1      ,(XTITLE(I,J),I=1,60)
2      ,(YTITLE(I,J),I=1,60)
35  FORMAT('          TITLE: ',60A1/
1      '          X-TITLE: ',60A1/
2      '          Y-TITLE: ',60A1)
      PRINT *, ' '
      PRINT *, ' IS THIS THE CORRECT FILE? (Y OR N)'
      READ (5,20) REPLY
      IF(REPLY.EQ.'Y') GO TO 40
      CLOSE(UNIT=2,DISPOSE='SAVE')
      GO TO 5

```

```

C
40 READ (2,45) XPLMIN(J),XPLMAX(J)
   READ (2,45) XXPDFN(J),FXPDFN(J)
   READ (2,45) XXPDFX(J),FXPDFX(J)
45 FORMAT(2E15.7)
   NDISC=0
   NODISC=0
   DO 50 I=1,MAXXY
     READ (2,45,END=53) X(I,J),Y(I,J)
     IF((X(I,J).EQ.88888.) .AND. (Y(I,J).EQ.88888.)) GO TO 55
50 CONTINUE
   I=MAXXY+1
55 NO(J)=I-1

C
   IF(I.GT.1) GO TO 52
   DO 54 I=1,MAXXY
     READ (2,45,END=53) XDI,CDI
     IF((XDI.EQ.99999.) .AND. (CDI.EQ.99999.)) GO TO 53
     NDISC =NDISC +1
     NODISC=NODISC+1
     X(I,J)=XDI
     Y(I,J)=CDI
54 CONTINUE
53 NO(J)=NODISC
52 CLOSE(UNIT=2,DISPOSE='SAVE')
   IF(NO(J).GT.1) GO TO 60
   PRINT *, ' NO DATA TO PLOT ON FILE NAMED: '
   PRINT 56,INFILE(J)
56 FORMAT(' ',A40)
   GO TO 5

C
60 NOCURV=NOCURV+1
   IF(ITYPE.NE.0) GO TO 70
   PRINT *, ' ENTER 1 FOR SINGLE pdf PLOT'
   PRINT *, '          2 FOR MULTIPLE CCDF PLOT'
   READ (5,65) ITYPE
65 FORMAT(I5)
   IF(ITYPE.NE.1) GO TO 70
   PRINT *, ' ENTER 0 IF POINTS ARE AT CENTER  OF DELTA X'
   PRINT *, '          1 IF POINTS ARE AT LEFT END OF DELTA X'
   READ (5,65) I
   CNTRPT=I.EQ.D
   GO TO 200

C
C---- READ MORE DATA FOR MULTIPLE CCDF PLOT
C
70 IF(NOCURV.EQ.4) GO TO 200
   PRINT *, ' MULTIPLE CCDF PLOT: '
75 PRINT *, ' ARE MORE CURVES TO BE PLOTTED? (Y OR N)'
   READ (5,20) REPLY

```

```

      IF(REPLY.EQ.'Y') GO TO 5
      IF(REPLY.NE.'N') GO TO 75
C
200 PRINT *, ' ENTER 1 FOR LINEAR X-AXIS'
   PRINT *, '          2 FOR LOG    X-AXIS'
   READ (5,65) LXAXIS
   PRINT *, ' ENTER 1 FOR LINEAR Y-AXIS'
   PRINT *, '          2 FOR LOG    Y-AXIS'
   READ (5,65) LYAXIS
   YMIN= 1.E35
   YMAX=-1.E35
   XMIN= 1.E35
   XMAX=-1.E35
   XMXX=XMAX
   XMNN=XMIN
   DO 224 J=1,NOCURV
   NO1=NO(J)
   XMNN=AMIN1(XMNN,X(1,J))
   NO1=NO1+2
   DO 220 I=3,NO1
   IF(ITYPE.EQ.1) GO TO 217
C---- CCDF PLOTS
   XTAB(I,J)=X(I-2,J)
   YTAB(I,J)=Y(I-2,J)
   GO TO 220
C---- pdf PLOTS
217 XTAB(I,J)=X(I-2,J)
   IF(CNTRPT) XTAB(I,J)=(X(I-1,J)+X(I-2,J))/2.
   DX=X(I-1,J)-X(I-2,J)
   YTAB(I,J)=Y(I-2,J)
   IF(DX.NE.0.) YTAB(I,J)=(Y(I-2,J)-Y(I-1,J))/DX
   YTAB(I,J)=AMAX1(0.,YTAB(I,J))
   YMAX=AMAX1(YMAX,YTAB(I,J))
   IF((YTAB(I,J).LE.0.) .AND. (LYAXIS.EQ.2)) GO TO 220
   YMIN=AMIN1(YMIN,YTAB(I,J))
220 CONTINUE
   XMXX=AMAX1(XMXX,X(NO1-2,J))
   XMIN=AMIN1(XMIN,XPLMIN(J))
   XMAX=AMAX1(XMAX,XPLMAX(J))
   IF(LYAXIS .EQ.2 ) GO TO 224
   IF(ITYPE .EQ.2 ) GO TO 224
   IF(FXPDX(J).GT.0.) YMIN=AMIN1(YMIN,FXPDFX(J))
   IF(FXPDX(J).GT.0.) YMIN=AMIN1(YMIN,FXPDFN(J))
   IF(FXPDX(J).GT.0.) YMAX=AMAX1(YMAX,FXPDFX(J))
   IF(FXPDX(J).GT.0.) YMAX=AMAX1(YMAX,FXPDFN(J))
224 CONTINUE
   IF(XMIN.GE. 1.E34) XMIN=XMNN
   IF(XMAX.LE.-1.E34) XMAX=XMXX
   IF(ITYPE.EQ.1) GO TO 225
   YMAX=1.

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      YMIN=0.0001
225 IF((LYAXIS.EQ.2) .AND. (YMIN.LE.0.)) YMIN=YMAX/1.E10
      DO 230 J=1,NOCURV
C----- ADD INITIAL AND TERMINAL POINTS
      NO1=NO(J)+2
      IF(ITYPE.EQ.1) GO TO 226
C----- CCDF PLOT
      XTAB(1,J)=XMIN
      XTAB(2,J)=XMIN
      YTAB(1,J)=1.
      YTAB(2,J)=1.
      NO1=NO1+1
      XTAB(NO1,J)=XTAB(NO1-1,J)
      YTAB(NO1,J)=YMIN
      GO TO 229
C----- pdf PLOT
226 XTAB(1,J)=XXPDFN(J)
      XTAB(2,J)=XXPDFN(J)
      YTAB(1,J)=YMIN
      YTAB(2,J)=FXPDFN(J)
      XTAB(NO1-1,J)=XXPDFX(J)
      YTAB(NO1-1,J)=FXPDFX(J)
      XTAB(NO1,J)=XXPDFX(J)
      YTAB(NO1,J)=YMIN
      DO 228 I=1,NO1
228 YTAB(I,J)=AMAX1(YTAB(I,J),YMIN)
229 NO(J)=NO1
      NOH1=NOH(J)
      ENCODE(NO1,20,HLABEL(J)) (TITL(I,J),I=1,NOH1)
230 CONTINUE
      J=1
      NOX1=NOX(J)
      ENCODE(NO1,20,XLABEL) (XTITLE(I,J),I=1,NOX1)
C
      PRINT *, ' ARE SPECIAL LIMIT LINES WANTED? (Y OR N) '
      READ (5,20) REPLY
      NSLL=REPLY.NE.'Y'
C
      XAXIS=6.
      YAXIS=4.
      IF(IPLLOT.NE.0) GO TO 233
C
      IF(IPLOTR.EQ.1) CALL CALCMP
      IF(IPLOTR.EQ.2) CALL H7221C
      IF(IPLOTR.EQ.3) CALL HP7550
      IF(IPLOTR.NE.2) GO TO 233
C----- SPECIAL FOR HP7221 SERIES PLOTTERS
      CALL HWSPEC(24., 'PEN')
C
233 CALL RESET('ALL')

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      CALL AREA2D(XAXIS,YAXIS)
      DO 235 J=1,NOCURV
      CALL HEADIN(REALHL(1,J),NOH(J),1.,NOCURV)
235  CONTINUE
      J=1
      IF(ITYPE.EQ.2) GO TO 238
      CALL XNAME(REALXL,NOX1)
      CALL YNAME('pdf$',100)
      GO TO 240
238  CALL XNAME('RELEASE RATIO CONSEQUENCE, C$',100)
      CALL YNAME('PROBABILITY OF CONSEQUENCE => C$',100)
240  IF(LXAXIS.NE.2) GO TO 255
C
C---- LOG X-AXIS
      CALL ALGPLT(XMIN,XMAX,XAXIS,ORGX,XCYLE)
      IF(LYAXIS.NE.2) GO TO 250
C
C---- LOG X-AXIS AND LOG Y-AXIS
      CALL ALGPLT(YMIN,YMAX,YAXIS,ORGY,YCYCLE)
      CALL LOGLOG(ORGX,XCYLE,ORGY,YCYCLE)
      GO TO 270
C
C---- LOG X-AXIS AND LINEAR Y-AXIS
250  CALL AXSPLT(YMIN,YMAX,YAXIS,ORGY,YSTEP,YAXISL)
      CALL XLOG(ORGX,XCYLE,ORGY,YSSTEP)
      GO TO 270
C
C---- LINEAR X-AXIS
255  CALL AXSPLT(XMIN,XMAX,XAXIS,ORGX,XSTEP,XAXISL)
      IF(LYAXIS.NE.2) GO TO 260
C
C---- LINEAR X-AXIS AND LOG Y-AXIS
      CALL ALGPLT(YMIN,YMAX,YAXIS,ORGY,YCYCLE)
      CALL YLOG(ORGX,XSTEP,ORGY,YCYCLE)
      GO TO 270
C
C---- LINEAR X-AXIS AND LINEAR Y-AXIS
260  CALL AXSPLT(YMIN,YMAX,YAXIS,ORGY,YSSTEP,YAXISL)
      XAXISM=ORGX+XSTEP*XAXISL
      YAXISM=ORGY+YSSTEP*YAXISL
      CALL GRAF(ORGX,XSTEP,XAXISM,ORGY,YSSTEP,YAXISM)
C
270  IF(ITYPE.EQ.2) GO TO 280
      NO1=NO(1)
      IIII=0
      DO 275 I=1,NO1
      IF(XTAB(I,1).LT.XPLMIN(1)) GO TO 275
      IF(XTAB(I,1).GT.XPLMAX(1)) GO TO 275
      IIII=IIII+1
      XPLOT(IIII)=XTAB(I,1)

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      YPLOT(IIII)=YTAB(I,1)
275  CONTINUE
      II=IIII+1
      XPLOT(II)=XPLOT(II-1)
      YPLOT(II)=YMIN
      IF(NDISC.NE.0) GO TO 276
C    CALL MARKER(15)
      CALL CURVE(XPLOT,YPLOT,II,0)
      GO TO 300
276  CALL DOT
      DO 277 I=1,II
      XPL(1)=XPLOT(I)
      XPL(2)=XPLOT(I)
      YPL(1)=YMIN
      YPL(2)=YPLOT(I)
      CALL CURVE(XPL,YPL,2,0)
277  CONTINUE
      GO TO 300
C
C---- MAKE MULTIPLE CCDF PLOT
C
280  JMOD=0
      DO 290 J=1,NOCURV
      NO1=NO(J)
      II=0
      DO 279 I=1,NO1
      IF(XTAB(I ,J).LT.XMIN) GO TO 279
      IF(XTAB(I ,J).GT.XMAX) GO TO 279
      IF(YTAB(I ,J).LT.YMIN) GO TO 279
      IF(YTAB(I ,J).GT.YMAX) GO TO 279
      II=II+1
      XPLOT(II)=XTAB(I,J)
      YPLOT(II)=YTAB(I,J)
      IF(I .EQ. NO1) GO TO 279
      IF(NDISC .EQ. 0) GO TO 279
      IF(XTAB(I+1,J).LT.XMIN) GO TO 279
      IF(XTAB(I+1,J).GT.XMAX) GO TO 279
      II=II+1
      XPLOT(II)=XTAB(I+1,J)
      YPLOT(II)=YTAB(I ,J)
279  CONTINUE
      JMOD=JMOD+1
      IF(JMOD.GT.5) JMOD=1
C    CALL MARKER(J+14)
      GO TO (281,282,283,284,285),JMOD
C---- USE SOLID LINES
281  CALL CHNDOT
      CALL RESET('CHNDOT')
      GO TO 289
C---- USE DOTTED LINES

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282 CALL DOT
GO TO 289
C----- USE DASHED LINES
283 CALL DASH
GO TO 289
C----- USE CHAIN DOTS
284 CALL CHNDOT
GO TO 289
C----- USE CHAIN DASHES
285 CALL CHNSH
289 CONTINUE
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
C      DO 288 I=1,II
C      WRITE (6,301) I,XPLOT(I),YPLOT(I)
C 288 CONTINUE
C 301 FORMAT(I5,1P2E15.7)
C$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$$
      CALL CURVE(XPLOT,YPLOT,II,0)
290 CONTINUE
C
300 IF(NSLL) GO TO 320
C
C----- PLOT SPECIAL LIMIT LINES
      DO 319 I=1,5
      SLLX(I)=AMIN1(SLLX(I),XMAX)
319 CONTINUE
      CALL CHNDOT
      CALL RESET('CHNDOT')
      CALL CURVE(SLLX,SLLY,5,0)
C
320 IPLOT=IPLOT+1
      CALL ENDPL(IPLOT)
      GO TO 1
C
325 CALL DONEPL
      STOP 7777
      END

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