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**GWSCREEN: A Semi-Analytical
Model for Assessment of the
Groundwater Pathway from
Surface or Buried Contamination:
Version 2.0 Theory and User's
Manual**

Arthur S. Rood

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**GWSCREEN: A Semi-Analytical Model for
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Version 2.0 Theory and User's Manual**

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May, 1993

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ABSTRACT

GWSCREEN was developed for assessment of the groundwater pathway from leaching of radioactive and non radioactive substances from surface or buried sources. The code was designed for implementation in the Track I and Track II assessment of CERCLA (Comprehensive Environmental Response, Compensation and Liability Act) sites identified as low probability hazard at the Idaho National Engineering Laboratory (DOE, 1992).

The code calculates the limiting soil concentration such that, after leaching and transport to the aquifer, regulatory contaminant levels in groundwater are not exceeded. The code uses a mass conservation approach to model three processes: Contaminant release from a source volume, contaminant transport in the unsaturated zone, and contaminant transport in the saturated zone. The source model considers the sorptive properties and solubility of the contaminant. Transport in the unsaturated zone is described by a plug flow model. Transport in the saturated zone is calculated with a semi-analytical solution to the advection dispersion equation in groundwater.

In Version 2.0, GWSCREEN has incorporated an additional source model to calculate the impacts to groundwater resulting from the release to percolation ponds. In addition, transport of radioactive progeny has also been incorporated.

GWSCREEN has shown comparable results when compared against other codes using similar algorithms and techniques. This code was designed for assessment and screening of the groundwater pathway when field data is limited. It was not intended to be a predictive tool.

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1. Introduction

Multimedia exposure assessment of hazardous chemicals and radionuclides requires that all pathways of exposure be investigated. In the assessment process, limited data is often encountered, and the primary purpose for performing initial screening is to identify priority contaminants and data needs. This process is accomplished by using simplified models that make best use of the available data and conservative assumptions. The GWSCREEN model was designed to perform initial screening calculations for groundwater pathway impacts resulting from the leaching of surficial and buried contamination at CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) sites identified as low probability hazard at the Idaho National Engineering Laboratory (DOE, 1992). In version 2.0, an additional model was added to calculate impacts to groundwater from the operation of a percolation pond. The model was designed to make best use of the data that would potentially be available. These data include the area and depth of contamination, sorptive properties and solubility limit of the contaminant, depth to aquifer, and the physical properties of the aquifer (porosity, velocity and dispersivity). For the pond model, data on effluent flow rates and operation time is required.

The modeling approach used in GWSCREEN is a mass balance approach that has its roots in the methodology presented by the Nuclear Regulatory Commission (Codell et al., 1982; Kozak et al., 1989). Similar methodologies have also been employed in a number of other assessment codes including the Remedial Action Priority System (Whelan et al., 1987) and DECHEMA (Killogh et al., 1991). The groundwater transport model used in GWSCREEN has been used at the Idaho National Engineering Laboratory (INEL) for scoping and assessment purposes (Codell et al., 1982; Rood et al., 1989) and has been shown to give reasonable results when calibrated to measured data.

Model output includes the limiting soil concentration such that, after leaching and

transport to the aquifer, regulatory contaminant levels in groundwater are not exceeded. Also groundwater concentration as a function of time may be calculated. The model only considers drinking water consumption and does not include the transfer of contamination to food products due to irrigation with contaminated water. However, these pathways may be taken into account by adjusting the water consumption rate. Both radiological and non-radiological contaminants are considered in GWSCREEN.

GWSCREEN was not intended to be a predictive tool, rather, it was intended to provide the framework to calculate bounding impacts to groundwater from the leaching of surficial and buried contamination. The conservatism of the results are dependent on the choice of input parameters used in the evaluation.

1.1 Summary of Changes in Version 2.0

Differences between GWSCREEN, version 1.5 (Rood, 1992) and GWSCREEN version 2.0 are as follows.

- Concentrations of radioactive progeny in groundwater are calculated.
- Carcinogenic risk for radionuclides are calculated.
- A model to simulate releases from percolation ponds and subsequent impacts to groundwater was added.
- Radiological dose, carcinogenic risk, and the hazard quotient are calculated for the peak time using the user defined input mass (or activity).
- A user defined tabulated source function may be used instead of the GWSCREEN source models.
- Number of Gaussian Quadrature points was increased from 24 to 34.
- Numerical integration may be performed by Simpson's rule or Gaussian Quadrature.
- Up to nine time periods may be calculated for concentration as a function of time output.

- Solubility release time for decaying source terms was changed.
- Rate constants for additional loss mechanisms were added.

2. Methodology

There are three primary models employed in GWSCREEN (Figure 1); the source model, the unsaturated zone mass transport model and the saturated zone (aquifer) mass transport model. These models are coupled together by the contaminant fluxes across the interface between source, unsaturated, and saturated zone boundaries. Three types of source release models may be employed in GWSCREEN. These are the surficial or buried source model, the percolation pond release model, and the tabulated source model. GWSCREEN calculates the source mass fluxes for the surficial or buried source model and the percolation pond release model. The user provides the source mass fluxes for the tabulated source model by generating an ASCII file containing mass flux at the source volume - unsaturated zone interface as a function of time. The unsaturated zone model uses a simplified plug flow model and the saturated zone model uses a semi-analytical solution to the advection-dispersion equation for transient mass flux as described by Codell (1982).

2.1 Source Modeling

2.1.1 Surface or Buried Source Model -- The source volume for the surface or buried source model is defined as the zone in which contaminants have been observed or are suspected to be present. This zone, in most cases, occupies the volume bounded by the soil surface to some finite depth below the soil surface, but may also include buried waste. Release from the source volume is modeled as a first order leaching process which accounts for decay and sorption. The contaminant is assumed to be homogeneously mixed in a finite volume and a steady state infiltration rate is assumed. The leaching process is described mathematically by a first order leach rate constant. The differential equation which describes the mass balance of contaminant in the source volume is given by

Figure 1. Conceptual model of GWSCREEN for the source volume, unsaturated zone, and aquifer.

$$\frac{dQ}{dt} = -(\lambda_L + \lambda_d + \lambda_o) Q \quad (1)$$

where λ_d = decay rate constant (y^{-1})

λ_L = leach rate constant (y^{-1})

λ_o = rate constant for other loss mechanisms (y^{-1})

Q = mass (or activity) in the source volume (mg or Ci)

The solution to Equation 1 is

$$Q(t) = Q_o e^{-(\lambda_L + \lambda_d + \lambda_o)t} \quad (2)$$

where Q_o = the initial mass or activity in the source volume (mg or Ci)

t = time (years).

The initial mass or activity in the source volume (Q_o) is given by

$$Q_o = C_o \times L \times W \times T \quad (3)$$

where L, W, T = the length, width and thickness of the source volume (m)

C_o = the initial concentration (Ci or $mg\ m^{-3}$) in the solid and liquid phases.

The leach rate constant (λ_L) and decay rate (λ_d) constant are given by the following.

$$\lambda_L = \frac{P}{\theta_c R_{dc} T} \quad \lambda_d = \frac{\ln(2)}{T_{1/2}} \quad (4)$$

where P = the net water percolation rate ($m\ y^{-1}$)

θ_c = the volumetric moisture content in the source volume ($m^3\ m^{-3}$)

R_{dc} = the retardation factor in the source volume.

$T_{1/2}$ = the contaminant half life (y^{-1})

The leach rate constant was originally described by Baes and Sharp (1983). The formulation given in Equation 4 was taken from Gilbert (1989).

The net water percolation rate (P) is the amount of water that enters the soil per unit time that is not lost to evapotranspiration or runoff. Under steady state condition (no net storage) this can be approximated by

$$P = P_r - R - E \quad (5)$$

where P_r = precipitation ($m\ y^{-1}$)

R = runoff ($m\ y^{-1}$)

E = evapotranspiration ($m\ y^{-1}$).

The value P/θ_c represents the pore velocity in the contaminated zone and is based on the unit gradient model which assumes the hydraulic conductivity is equal to the net percolation rate. Darcy's law states

$$q_w = K \frac{dH}{dX} \quad (6)$$

where q_w = net water infiltration rate (percolation rate, P) or Darcy flux ($m\ y^{-1}$)

dH/dX = change in hydraulic head with respect to distance ($m\ m^{-1}$)

K = hydraulic conductivity of the contaminated zone ($m\ y^{-1}$).

In the unit gradient model, $dH/dX = 1.0$, thus, $q_w = K = P$. Saturated hydraulic conductivity and the volumetric moisture content differ for different rock types. When a porous media is saturated (i.e. all the pore spaces are filled with water), the volumetric moisture content is equal to the effective porosity of the media. (In this model, the effective porosity is assumed equal to the total porosity.) The volumetric moisture content is related to the effective porosity by the fraction of the pore spaces that are saturated. The volumetric

water content for a given material and a given water flux is usually determined using equations that have been fitted to field data relating suction head to volumetric moisture content and hydraulic conductivity. Curves generated using the van Genuchten (1978) fitting parameters for basalt and surface sediment at the Idaho National Engineering Laboratory (INEL), Radioactive Waste Management Complex (RWMC) are presented in Figures 2 and 3. These materials were characterized in detail by Bishop (1991) and McElroy (1990) and van Genuchten fitting parameters were given by Baca (1992).

The retardation factor in the source volume (R_{dc}) is given by

$$R_{dc} = 1 + \frac{K_{dc} \rho_c}{\theta_c} \quad (7)$$

where K_{dc} = the distribution coefficient in the source volume (ml g⁻¹)

ρ_c = the bulk density of the source volume (g cm⁻³).

For organic contaminants, the sorption coefficient is derived from the organic carbon partitioning coefficient (K_{oc}) and the fraction of organic material in the medium (f_{oc}). The sorption coefficient for organics is given by Equation 8.

$$K_d = f_{oc} K_{oc} \quad (8)$$

The contaminant flux out the base of the source volume can now be calculated. The contaminant flux is given by

$$q_c(t) = \lambda_L Q(t) \quad (9)$$

where $q_c(t)$ = the contaminant flux out the bottom of the source volume (mg or Ci y⁻¹).

The concentration of the leachate ($C_{leachate}(t)$) is given by Equation 10.

Figure 2. Volumetric moisture content vs hydraulic conductivity for vesicular basalt at the INEL. van Genuchten parameters, α and n were obtained from Baca (1992).

$$C_{leachate}(t) = \frac{Q(t)}{LxWxTx\theta_c x R_{dc}} \quad (10)$$

For some contaminants, the initial concentration of the leachate exceeds the solubility limit of the contaminant. In this case, the concentration of the leachate and the mass flux from the source volume will be governed by the solubility limit of the contaminant. The mass balance of the contaminant in the source volume is then given by Equation 11.

$$\frac{dQ}{dt} = -(\lambda_d + \lambda_o)Q - R \quad (11)$$

where $R = C_{sl} \times P \times L \times W$ (mg y^{-1}) (contaminant flux out bottom of source)

C_{sl} = the solubility limit of the contaminant (mg m^{-3})

The solution to Equation 11 for the initial conditions $Q = Q_o$ at $t=0$ is

$$Q(t) = Q_o e^{-(\lambda_d + \lambda_o)t} - \frac{R}{\lambda_d + \lambda_o} (1 - e^{-(\lambda_d + \lambda_o)t}) \quad (12)$$

After a period of time, the mass in the source volume is depleted sufficiently to allow for leaching to be controlled by the contaminant sorptive properties and not the solubility limit. The amount of mass in the source volume (Q_{sl}) where leaching by sorptive properties takes over is given by Equation 13.

$$Q_{sl} = C_{sl} \times L \times W \times T \times \theta_c R_{dc} \quad (13)$$

When decay or other first order loss processes are insignificant, the time required for the mass in the source volume to decrease to Q_{sl} is simply $t_{sl} = (Q_o - Q_{sl})/R$ and the mass balance equation is $Q(t) = Q_o - Rt$. Decay and degradation are considered significant if the sum of the rate constants ($\lambda_d + \lambda_o$) is less than $6.93E-11 y^{-1}$ (effective half time of 1×10^{10} years). If decay is significant during the release, then the solubility limited release time is given by the following.

Figure 3. Volumetric moisture content vs hydraulic conductivity for sediment at the INEL. van Genchten parameters, α and n were obtained from Baca (1992).

$$t_{sl} = \frac{-\ln \left(\frac{Q_{sl} + \frac{R}{\lambda_d + \lambda_o}}{Q_o + \frac{R}{\lambda_d + \lambda_o}} \right)}{\lambda_d + \lambda_o} \quad \text{for } \lambda_d + \lambda_o > 6.93 \times 10^{-11} \quad (14)$$

$$t_{sl} = \frac{Q_o - Q_{sl}}{R} \quad \text{for } \lambda_d + \lambda_o < 6.93 \times 10^{-11}$$

For radionuclides, total activity in the source volume must be converted to mass so that the quantity of the radionuclide may be related to its solubility limit. The conversion from activity to mass is given by the following.

$$Q_{(mass)} = \frac{Q_{(activity)} (3.7 \times 10^{10} \text{ dps Ci}^{-1}) (3.1536 \times 10^7 \text{ s y}^{-1}) (MW)}{\lambda_d N_A} \quad (15)$$

where $Q_{(mass)}$ = the mass of the radionuclide in the source volume (g)

N_A = Avogadro's number (6.023×10^{23} atoms mole⁻¹)

$Q_{(activity)}$ = the total activity of the radionuclide in the source volume (Ci)

dps = number of nuclear transformations per second

MW = the molecular weight of the radionuclide (g mole⁻¹)

Solubility limited releases for radionuclides usually only affects nuclides with large half-lives since little mass is associated with nuclides with short half-lives.

Output from the source model is then given by Equation 9 for releases not controlled by the contaminant's solubility, and by the term, R , in Equation 11 and 12 for solubility limited releases. These releases provide the contaminant flux at the boundary between source volume and unsaturated zone for the surficial or buried source model.

2.1.2 Pond Release Model -- The percolation pond conceptual model (Figure 4) accounts for the flow rate of water into the pond, the concentration of the contaminant in the water, sorption and decay of the contaminant in the pond sediments (or underlying alluvium) and the operational lifetime of the pond. The contaminant flux into the pond is assumed to be equal to the contaminant flux out of the pond and into the pond sediments or alluvium. Equilibrium between the pond water and sediments is assumed to occur instantaneously. Release from the pond sediments is modeled then as a first order process with constant input. The mass balance equation that describes the mass of contaminant in the pond sediments is

$$\frac{dM}{dt} = R_p - (\lambda_L + \lambda_d + \lambda_E)Q \quad (16)$$

where Q = mass or activity of contaminant in the pond sediments (Ci or mg)

λ_L = leach rate constant from pond sediments (y^{-1})

λ_E = rate constant for other loss processes from the pond sediments (y^{-1})

R_p = mass flux of the contaminant into the pond (Ci or mg y^{-1})

The leach rate constant for pond sediments (λ_L) is given by

$$\lambda_L = \frac{q_{pond}}{\theta_p T R_{dp} L W} \quad (17)$$

where q_{pond} = net water input rate into the pond ($m^3 y^{-1}$)

θ_p = volumetric moisture content in the pond sediments ($m^3 m^{-3}$)

R_{dp} = retardation factor in the pond sediments

T = pond sediment thickness (m).

L, W = length and width of the pond (m).

The width of the pond is defined as the dimension of the pond that lies perpendicular to groundwater flow. The retardation factor for the pond sediments is given by Equation 7, substituting θ_p for θ_c . The solution to Equation 16 for the initial conditions, $Q=Q_0$ when $t=0$ is:

$$Q(t) = \frac{R_p}{\lambda_L + \lambda_d + \lambda_E} (1 - e^{-(\lambda_L + \lambda_d + \lambda_E)t}) + Q_o e^{-(\lambda_L + \lambda_d + \lambda_E)t} \quad (18)$$

After operation of the pond ceases, the contaminant inventory remaining in the pond sediments are subsequently leached by percolating rainwater and snow melt. The inventory of contaminant in the pond sediments at the end of operation is given by $Q(t)$ in Equation 18 evaluated at time t_{op} , the operational lifetime of the pond. Post pond operation leaching is evaluated using Equation 2 where $Q_o = Q(t_{op})$, and $\lambda_E = 0$.

The flux to the unsaturated zone (q_c) during the operation period of the pond is given by

$$q_c(t) = \lambda_L \left(\frac{R_p}{\lambda_L + \lambda_d + \lambda_E} (1 - e^{-(\lambda_L + \lambda_d + \lambda_E)t}) + Q_o e^{-(\lambda_L + \lambda_d + \lambda_E)t} \right) \quad (19)$$

and the flux to the unsaturated zone after the operational period is given by Equation 9.

The pond model ignores additional dilution in the aquifer from percolating pond water. In most cases, the volume of water derived from rain and snow melt that reaches the aquifer from the source area is insignificant compared to the volume of water flowing in the aquifer across the same area. For the pond model, this assumption may not be true, and therefore caution must be exercised when using this model. The value of q_{pond} should be compared to the flow rate in the aquifer across the a cross sectional area of the source (the source width) that is perpendicular to the groundwater flow. If q_{pond} is greater than the aquifer flow across the cross sectional area of the source, then an "effective" pond width should be calculated. The effective pond width is the width such that q_{pond} plus the aquifer flow across the actual width of the pond is equal to, or less than, the aquifer flow across the cross sectional area of the aquifer using the effective width. For example, suppose the liquid effluent flow rate into a 20 m x 20 m pond is $1 \times 10^4 \text{ m}^3/\text{y}$ and the Darcy velocity in a 10 m thick aquifer lying below the pond is 20 m/y. The aquifer flow across the cross sectional

GWSCREEN Pond Model

Figure 4. GWSCREEN percolation pond source conceptual model.

area of the source is $20 \text{ m/y} \times 20 \text{ m} \times 10 \text{ m} = 5,000 \text{ m}^3/\text{y}$. Since the flow out of the pond is significant compared to the flow in the aquifer, the effective pond width should be calculated. The effective pond width is then

$$\text{Effective Width} = \frac{1 \times 10^4 \text{ m}^3/\text{y} + 5 \times 10^3 \text{ m}^3/\text{y}}{20 \text{ m/y} \times 10 \text{ m}} = 75 \text{ m}.$$

The effective width of the pond is a user required input variable in GWSCREEN and if the flow from the pond is insignificant, the effective width can be set equal to the true width of the pond.

2.2.3 Tabulated Source Model – The user may chose to calculate a mass flux from the source volume using another model. In such cases, the user provides contaminant mass fluxes as a function of time from the source volume and only the saturated zone and unsaturated zone model employed in GWSCREEN are used to calculate groundwater concentrations at the receptor point. The unsaturated zone model may also be ignored by setting its thickness equal to zero.

2.2 Unsaturated Zone Model

The unsaturated zone is defined as the zone between the base of the source volume and top of the aquifer. The unsaturated zone is assumed to be a homogeneous, isotropic, porous media with constant, unidirectional flow in the vertical (downward) direction. The model allows for differences in the transport properties between the unsaturated zone, source volume, and saturated zone. Due to the complexities and inherent uncertainties in modeling unsaturated flow and transport, a simplified plug-flow model was adapted that does not account for dispersion. In the plug flow model, non-sorbing contaminants move with the vertical velocity of the water. This velocity is calculated assuming the unit gradient condition as discussed previously. For most contaminants, the plug flow model is a

conservative assumption since the peak flux to the aquifer exceeds the peak flux when dispersion is considered. For contaminants with short half-lives relative to their residence time in the unsaturated zone, the plug flow assumption may not be conservative since, the contaminant will arrive sooner (lower residence time in the unsaturated zone) when dispersion is considered, therefore, allowing less time to decay. This observation was noted by Seitz (1991) and may become a significant factor when the unsaturated transit time (see Equation 20) is greater than ten times the half-life of the contaminant. Dispersion coefficients in the unsaturated zone would not be data readily available during the initial groundwater assessment process. Since other conservative assumptions, such as increasing the percolation rate and reducing the unsaturated zone thickness, may be assumed to compensate for the effect of dispersion on short half-lived contaminants, dispersion was not considered and the simpler plug-flow model was used. A rule of thumb to assure conservatism is to make sure the contaminant transit time in the unsaturated zone (T_u) does not exceed 10 times the half-life of the contaminant. If T_u exceeds 10 times the half-life, then the unsaturated thickness can be reduced such that T_u is equal to $10 \times T_{1/2}$. If radioactive contaminants with progeny are being modeled, then other factors may also have to be considered. These factors include the half lives and equilibrium conditions of the progeny at the time of maximum parent concentration, and the dose conversion and slope factors for the parent and progeny. See discussion in Section 3.3.

The amount of decay which occurs during transit is a function of the contaminant transit time in the unsaturated zone. The transit time in the unsaturated zone (T_u) is given by

$$T_u = \frac{X_u}{U_u} R_{du} \quad (20)$$

where X_u = the distance from the base of the source volume to the top of the aquifer (m)

U_u = the unsaturated pore velocity (m y^{-1})

R_{du} = the retardation factor in the *unsaturated* zone

The unsaturated pore velocity (U_u) is given by

$$U_u = \frac{P}{\theta_u} \quad (21)$$

where θ_u = the volumetric water content in the unsaturated zone ($\text{m}^3 \text{ m}^{-3}$).

For the pond model, P is given by $q_{\text{pond}} + (AL \times WA)$. The retardation factor (R_{du}) in the unsaturated zone is given by

$$R_{du} = 1 + K_{du} \frac{\rho_u}{\theta_u} \quad (22)$$

where K_{du} = the distribution coefficient in the unsaturated zone (ml g^{-1})

ρ_u = the bulk density in the unsaturated zone (g cm^{-3}).

The volumetric water content in the unsaturated zone may be determined in a similar manner to the volumetric water content in the source volume (See Figures 2 and 3). The fraction of mass or activity that remains after transit through the unsaturated zone (f) is given by Equation 23.

$$f = e^{-\lambda_u T_u} \quad (23)$$

The contaminant flux to the aquifer (q_a) is given by Equation 24 and it is through this term that the unsaturated zone and saturated zone models are coupled.

$$\begin{aligned} q_a &= f \lambda_L Q(t) \text{ (leaching releases)} \\ q_a &= f R \text{ (solubility limited releases)} \end{aligned} \quad (24)$$

For the pond model, the unsaturated travel time is different before and after the

operational period. After discharge to the pond ceases, leaching is by rainwater or snow melt and this usually results in lower contaminant flux to the groundwater and longer transit times in the unsaturated zone because the net percolation rate is lower. For simplicity and conservatism in GWSCREEN, the transit time in the unsaturated zone was assumed to remain the same both before and after the operational period of the pond.

2.3 Saturated Zone Model

The saturated zone model is based on an analytic solution to the advection dispersion equation for contaminants in a saturated porous media. These solutions were originally developed by Codell et al. (1982) and have been used for assessment of radionuclide transport in groundwater. These solutions apply equally as well to non-radiological contaminants. The model contains the following assumptions and limitations:

1. The model uses a cartesian coordinate system (x,y,z) as a frame of reference. The positive x direction is in the direction of flow.
2. The flow is uniform and unidirectional. No sources or sinks are accounted for.
3. The aquifer is modeled as an isotropic, homogeneous porous media of infinite lateral extent and finite thickness.
4. Molecular diffusion is assumed to be negligible.
5. The source can be represented by a rectangular area of length L and width W and centered at the origin (0,0,0).
6. The dispersion coefficients remain constant over the domain.

7. Transport is limited to a single specie which may decay or degrade as a function of time. Radioactive progeny are assumed to travel at the same rate as their parent.
8. The contaminant is assumed to move as a dissolved substance. Transport in liquid organic and vapor phases are not considered.
9. Solid and liquid phases are in equilibrium and concentrations are related by the linear sorption coefficient (K_d).
10. The contaminant is assumed to be mixed vertically (z direction) in a zone defined by the length of a typical well screen for a drinking water well.

Assumption 10 states that groundwater concentrations will be averaged (mixed) over the thickness of the well screen. This assumption is reasonable for receptor wells close to the source since contaminants poorly mixed in the vertical direction will be diluted by water drawn over the *entire* well screen interval. For receptor wells located farther downgradient from the source, the estimated concentration will be conservative since the contaminant plume will likely extend to greater depths than the assumed well screen thickness.

Calibration studies at the INEL using the groundwater model described in this document have been performed by Codell et al. (1982) and Rood (1989). Tritium plumes from the Idaho Chemical Processing Plant injection well and the Test Reactor Area percolation ponds were modeled. The predicted concentration matched measured data reasonably well considering the simplifications and assumptions of the model; however, the results were not as accurate as those made by a finite difference model (Robertson, 1974). The differences were attributed to the ability of the finite difference model to incorporate spatial differences in the flow field. This problem is reduced in problems where the hypothetical well to be modeled is relatively close (approximately 100 m) thereby reducing the effect of spatial variability in the groundwater flow.

The mass balance equation which describes contaminant transport for the stated assumptions is

$$\frac{\partial C}{\partial t} + \frac{U}{R_d} \frac{\partial C}{\partial x} = \frac{D_x}{R_d} \frac{\partial^2 C}{\partial x^2} + \frac{D_y}{R_d} \frac{\partial^2 C}{\partial y^2} - \lambda_d C \quad (25)$$

where C = concentration (mg or Ci m^{-3})

U = groundwater pore velocity ($m\ y^{-1}$)

$D_x\ D_y$ = dispersion coefficient in the x and y direction ($m^2\ y^{-1}$)

R_d = retardation factor in the aquifer

t = time (y)

x = distance from the center of the area source to the receptor parallel to groundwater flow (m)

y = distance from the center of the area source to the receptor perpendicular to groundwater flow (m).

The retardation factor in the aquifer is given by

$$R_d = 1 + K_{da} \frac{\rho_s}{\eta} \quad (26)$$

where η = the effective porosity of the aquifer

K_{da} = the distribution coefficient in the aquifer ($ml\ g^{-1}$)

ρ_s = the bulk density in the aquifer ($g\ cm^{-3}$).

The dispersion coefficients (D_x, D_y) are given by

$$D_x = \alpha_L U \quad (27)$$

$$D_y = \alpha_T U \quad (28)$$

where α_L = the longitudinal dispersivity (m)

α_T = the transverse dispersivity (m).

The Green's function solution to Equation 25 for the initial conditions $C = C_0$ at $t = 0$ in the source area and $C = 0$ everywhere else is given by

$$C(x,y,t) = \frac{Q_a}{\eta R_d b} \frac{1}{2L} \left(\operatorname{erf} \left(\frac{x + \frac{L}{2} - \frac{Ut}{R_d}}{\sqrt{\frac{4D_x t}{R_d}}} \right) - \operatorname{erf} \left(\frac{x - \frac{L}{2} - \frac{Ut}{R_d}}{\sqrt{\frac{4D_x t}{R_d}}} \right) \right) \times \frac{1}{2W} \left(\operatorname{erf} \left(\frac{\frac{W}{2} + y}{\sqrt{\frac{4D_y t}{R_d}}} \right) + \operatorname{erf} \left(\frac{\frac{W}{2} - y}{\sqrt{\frac{4D_y t}{R_d}}} \right) \right) e^{-\lambda_d t} \quad (29)$$

where b = the well screen thickness or mixing depth (m)

Q_a = the initial total mass in the volume defined by $L \times W \times b$

erf = the error function

L = length of source parallel to groundwater flow (m)

W = width of source perpendicular to groundwater flow (m).

The terms, L and W are identical to those defined in Equation 3. For an arbitrary release, the concentration may be found by the convolution integral.

$$C(x,y,t) = \int_0^t C_i(x,y,t-\tau) F(\tau) d\tau \quad (30)$$

where $C(t)$ = the concentration at time t for the arbitrary release (mg or Ci m^{-3}).

$C_i(t - \tau)$ = the concentration at time, $t - \tau$, for an instantaneous release at time $t - \tau = 0$ (mg or Ci m^{-3}).

$F(\tau)$ = the mass flux of the contaminant at time τ (mg or Ci m^{-3}).

$F(\tau)$ is given by Equation 24. Equation 30 gives the instantaneous concentration at

time t . For some contaminants, the average concentration over a period of exposure is desired. If the peak concentration (maximum concentration observed at the specified receptor point) is bounded by the time periods, T_a and T_b , then the maximum average concentration is given by the following.

$$C_{avg} = \frac{\int_{T_a}^{T_b} C(x,y,t) dt}{T_b - T_a} \quad (31)$$

where T_a, T_b = averaging time period (years).

2.4 Radioactive Decay and Ingrowth

To evaluate the movement of radioactive progeny, the model makes the simplifying assumption that radioactive progeny travel at the same rate as the parent. This assumption has been shown to be conservative (Codell et al., 1982) and greatly simplifies the calculations. The assumption is also made that no progeny exist at the time of waste emplacement. The concentration of the i^{th} progeny in a decay chain at the receptor location is

$$C_i = C_{parent} \frac{DIF_i R_{d_{parent}}}{DIF_{parent} R_{d_i}} \quad (32)$$

where DIF_i = decay-ingrowth factor of the i^{th} progeny

DIF_{parent} = decay-ingrowth factor of the parent

R_{di} = retardation factor of the i^{th} progeny

$R_{d_{parent}}$ = retardation factor of the parent

C_{parent} = groundwater concentration of the parent ($Ci\ m^{-3}$).

The decay ingrowth factor is given by (Scrabble et al., 1974)

$$DIF_i(t) = \frac{\lambda_i}{\lambda_1} \left[\left(\prod_{m=1}^{i-1} \lambda_m \right) \sum_{j=1}^i \left(\frac{e^{-\lambda_j t}}{\prod_{k \neq j} (\lambda_k - \lambda_j)} \right) \right] \quad (33)$$

where λ_1 = decay constant for the parent (y^{-1})
 λ_i = decay constant for the i^{th} progeny (y^{-1}).
 t = time from waste emplacement (years)

2.4 Limiting Soil Concentration

Assessment of groundwater at a contaminated site usually involves evaluation of following criteria:

- Maximum Contaminant Limits (MCLs) in groundwater
- Chemical toxicity (carcinogenic and non-carcinogenic) from the ingestion of contaminated groundwater
- Committed effective dose equivalent (CEDE) from the ingestion of contaminated groundwater (radionuclides only).

Maximum contaminant limits and CEDE limits are listed in 40 CFR 141 and associated amendments. The CEDE limit of 4 mrem y^{-1} for community drinking water systems only applies to beta-gamma emitters derived from man made sources. For alpha emitters, the gross activity limit is 15 pCi L^{-1} excluding uranium isotopes and $^{226-228}\text{Ra}$. These nuclides are limited to maximum concentrations of 20 $\mu\text{g } L^{-1}$ and 5 pCi L^{-1} respectively. At sites identified under CERCLA, maximum allowable concentrations are based on chemical toxicity. Toxicity is quantified in terms of carcinogenic risk and non-carcinogenic effects. Carcinogenic risk represents the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the potential carcinogen (EPA, 1989). Chronic exposure to radionuclides are considered a carcinogenic risk. Non-

carcinogenic effects are evaluated based on a hazard quotient that relates an exposure level over a lifetime with a reference dose derived for a similar exposure period. Other dose and risk criteria may be implemented depending on site-specific considerations.

The limiting soil concentration is the soil concentration such that, after leaching and transport, MCLs, toxicity, and CEDE limits are not exceeded. Because the concentration in groundwater is proportional to the soil concentration (excluding solubility limited releases), the limiting soil concentration may be found by a simple ratio.

$$C_s = \frac{C_L}{C_u} C_{us} \quad (34)$$

where C_s = limiting soil concentration (Ci or mg in aqueous and solid phases m^{-3})

C_L = limiting groundwater concentration (Ci or mg m^{-3})

C_u = groundwater concentration for a unit inventory source (Ci or mg m^{-3})

C_{us} = soil concentration (Ci or mg in aqueous, solid, and vapor phases m^{-3}) for a unit inventory source

For the pond model, a limiting effluent concentration is calculated. The limiting effluent concentration is given by

$$C_E = \frac{C_L R}{q_{pond} C_x} \quad (35)$$

where C_x = the maximum groundwater concentration calculated using the user input contaminant mass flux rate into the pond (Ci or mg m^{-3})

C_E = the limiting concentration in the pond effluent (Ci or mg m^{-3}).

If the release is solubility limited, then the limiting soil concentration is calculated with Equation 30, using the leaching model (Equation 9) or the pond release model (Equation 19) to provide the mass flux, and the user is warned that the solubility limit of the

contaminant was exceeded.

The limiting *groundwater* concentration (C_L) may be based on carcinogenic risk, non-carcinogenic toxicity, radiological dose, or a maximum contaminant limit. Calculation of the limiting soil concentration based on a maximum groundwater contaminant limit involves setting C_L equal to the MCL and calculating C_s using Equation 30 or 31. If radionuclides with progeny are modeled, then the maximum contaminant limit of the parent is adjusted for the maximum contaminant limits of the progeny. See sample problem #1 for the adjustment calculation. For a limiting soil concentration based on carcinogenic risk, non-carcinogenic toxicity or radiological dose, the limiting groundwater concentration (C_L) must first be calculated. For chronic exposure scenarios (greater than one year), such as the lifetime cancer risk, the maximum average concentration integrated over the exposure period (Equation 31) is calculated and set equal to C_u , otherwise (for exposure periods one year or less), the maximum concentration is set equal to C_u .

The limiting groundwater concentration for a radionuclide based on a maximum CEDE limit is

$$C_L = \frac{D_L}{\left(DCF_{parent} + \sum_{i=1}^n \frac{DIF_i R_{d_{parent}}}{DIF_{parent} R_{d_i}} DCF_i \right) I EF} \quad (36)$$

where D_L = applicable CEDE limit, (rem y^{-1})

DCF_i = dose conversion factor for the i^{th} progeny (rem Ci^{-1})

DCF_{parent} = dose conversion factor for the parent (rem Ci^{-1})

I = water intake rate ($L d^{-1}$).

C_L = limiting *parent* groundwater concentration ($Ci L^{-1}$)

EF = exposure frequency ($d y^{-1}$).

The limiting groundwater concentration for a radionuclide based on carcinogenic risk is formulated slightly different since the average concentration over the exposure period must

be considered. The limiting groundwater concentration for a nuclide with "n" members in the decay chain is given by

$$C_L = \frac{C_{risk} C_{parent}}{\left(\sum_{i=1}^n C_i SF_i \right) I EF ED} \quad (37)$$

where SF_i = slope factor for i^{th} member of the decay chain (Ci^{-1})

C_{parent} = parent groundwater concentration averaged over the exposure period ($Ci\ L^{-1}$)

C_i = groundwater concentration averaged over the exposure period for the i^{th} member of the decay chain ($Ci\ L^{-1}$)

I = water intake rate ($L\ d^{-1}$)

ED = exposure duration (y)

C_{risk} = acceptable carcinogenic risk factor (1×10^{-4} to 1×10^{-6} , see EPA, 1989).

The quantity in parentheses in the denominator of Equation 36 has been given the term, the "composite dose conversion factor". Progeny that are in secular equilibrium (activity of the parent equals activity of the progeny) with their parent can be treated simply by summing the dose conversion factors or the slope factors of the parent and progeny.

The limiting groundwater concentration for non-radiological carcinogens was derived from EPA (1989).

$$C_L = \frac{C_{risk} BW AT}{SF I EF ED} \quad (38)$$

where BW = body weight (kg)

AT = averaging time (d)

SF = slope factor ($mg/kg/d$)⁻¹

For non-carcinogenic toxicity assessment, the point of departure from an acceptable concentration is given by the hazard quotient, HQ (EPA, 1989).

$$HQ = \frac{E}{RfD} \quad (39)$$

where RfD = reference dose (mg/kg/d)

E = contaminant exposure or intake (mg/kg/d)

Contaminant intake or exposure is given by Equation 40.

$$E = \frac{C_L I E F E D}{B W A T} \quad (40)$$

An HQ of unity is considered acceptable (EPA, 1989); therefore, the limiting groundwater concentration for non-carcinogens is given by Equation 41.

$$C_L = \frac{H Q B W A T R f D}{I E F E D} \quad (41)$$

The methodology presented so-far is applicable for sites that contain single contaminants. Some sites may contain multiple contaminants having the same regulatory criteria endpoint (radiological dose, carcinogenic risk or hazard quotient). In these cases, several approaches are recommended. First, the transit time of each contaminant should be considered. If the contaminant transit times are significantly different, then the contaminants can be treated separately because the maximum concentrations will not overlap. For contaminants that have approximately the same transit time, then the regulatory criteria limit can be scaled for each contaminant. The general form of the scaling equation for n number of radionuclides limited by CEDE is

$$D_{L_j} = \frac{DCF_j}{\sum_{i=1}^n DCF_i} \times D_L \quad (42)$$

where D_{L_j} = CEDE limit for the j^{th} nuclide (rem y^{-1}).

DCF_j = dose conversion factor for the j^{th} nuclide (rem Ci⁻¹).

The general form of the scaling equation for carcinogens is

$$C_{risk,j} = \frac{SL_j}{\sum_{i=1}^n SL_i} \times C_{risk} \quad (43)$$

where $C_{risk,j}$ = probability risk factor for the j^{th} contaminant

SL_j = slope factor for the j^{th} contaminant (mg/kg/day)⁻¹.

The general form of the scaling equation for non-carcinogens is

$$HQ_j = \frac{RfD_j}{\sum_{i=1}^n RfD_i} \times HQ \quad (44)$$

where HQ_j = hazard quotient for the j^{th} contaminant

RfD_j = reference dose for the j^{th} contaminant (mg/kg/day).

3. Code Implementation

GWSCREEN is written for the most part, in standard FORTRAN and compiled for operation on a personnel computer with a DOS operating system. Non-standard extensions are mainly violations of the 6 character limit used for naming variables. The FORTRAN source code is also compatible with most FORTRAN compilers on UNIX operating systems. Input to GWSCREEN is through one, free format ASCII file. This file contains the contaminant and site specific data such as sorption coefficients and regulatory limits and exposure scenario data such as drinking water consumption rates and standard body weight. This file is assigned a name by the user and the user is prompted for this file name during execution of the program. The default input file name is "GWSCREEN.PAR" and the

default output file name is "GWSCREEN.OUT". Line by line input for the user defined input file is found in Section 3.2, Table 2.

Equations 1 to 47 are implemented in numerous subroutines in the code. These subroutines and the equations embedded in them are cross referenced and briefly described in Table 1. The program flow and execution, and an explanation of output from several sample problems are described in Section 3.3. Nine sample problems that demonstrate the options in GWSCREEN are presented in Appendix A. Appendix B contains the source code listing.

Table 1. A brief description of the GWSCREEN subroutines.

Subroutine	Description
AREA	Calculates Green's function for an area source. Called by FUNC. Equations used: 27,28,29
ASSIGN	Assigns a value to the dummy variable, XDUMMY and selects the units of the calculation. Called by GWS6
CARCIN	Calculates limiting soil and pond effluent concentration for non-radiological carcinogenic effects. Called by GWS6. Equations used: 33,34,37
CHECKN	Checks parameter values in input file with acceptable limits. Called by INPUT
CRAD	Calculates limiting soil concentration for radiological carcinogenic effects. Called by GWS6. Equations used: 34,35,37
CTIME	Calls FUNC to calculate concentration as a function of time. Called by GWS6
ERF	Exponential and error function subroutines. Includes functions ERX, EXPPF, ERRORF, GAMMP, GCF, GAMMLN; Called by AREA
FLUXES	Calculates cumulative source flux and aquifer flux at each print step. Called by CTIME. Equations used: 24
FUNC	Calls SIMPSON or QGAUS2 to compute the convolution integral. Called by CTIME, GOLDEN, QGAUS1
GOLDEN	Determines the maximum concentration and the time of maximum. Called by PEAK
GWINT	Calculates the average integrated concentration. Called by GWS6. Equations used: 31
GWS6	Main program unit. calls INPUT, ASSIGN, CTIME, CARCIN, CRAD, MAXRAD, MAXNRAD, NCARCIN
INPUT	Reads GWSCREEN input file and calls CHECKIN. Called by GWS6
LICENSE	Writes disclaimer and licensing agreement (if any) to output file.
LIMITS	Calculates integration limits. Called by SIMPSON and QGAUS2. Equations used: 45
LINT	Linear interpolates the tabulated source function. Called by SRCTERM
MAXNRAD	Calculates the limiting soil and pond concentration for a nonradiological contaminant based on MCL. Called by GWS6. Equations used: 34,35
MAXRAD	Calculates the limiting soil and pond concentration for a radiological contaminant based on MCL. Called by GWS6. Equations used: 34, 35
NCARCIN	Calculates the limiting soil and pond concentration for a nonradiological contaminant based on HQ. Called by GWS6. Equations used: 39, 40, 41
PEAK	Calculates the maximum groundwater concentration. Called by GWS6
QGAUS1	Performs Gauss Legendre integration on groundwater concentration as a function of time. Called by GWINT. Equations used: 31
QGAUS2	Performs Gauss Legendre integration to compute the convolution integral. Called by FUNC. Equations used: 30
RAD	Calculates the limiting soil and pond concentration for a radiological contaminant based of CEDE. Called by GWS6. Equations used: 34,36
RDKGWS	Computes the decay-ingrowth factors. Called by CTIME, RAD, CRAD, MAXRAD. Equations used: 33
ROOT	Computes the solubility limited mass release time. Called by SOURCX. Equations used: 14
SIMPSON	Performs Simpson rule integration to compute the convolution integral (includes subroutine TRAPZ). Called by FUNC. Equations used: 30
SOURCEX	Calculates fixed transport parameter values. Called by GWS6. Equations used: 4,7,10,12,13,15,17,20,21,22
SRCPOND	Calculates flux from pond to unsaturated zone. Called by SRCTERM. Equations used: 19
SRCTERM	Calculate flux from surface or buried source to unsaturated zone. Called by QGAUS2, SIMPSON. Equations used 9, 12, 18.
WRITEO	Writes limiting soil or pond concentration to output file. Called by GWS6.

3.1 Computational Methods

The methodology presented in Section 2 requires numerical integration to calculate the instantaneous groundwater concentration (Equation 30) and the average integrated concentration (Equation 31). GWSCREEN version 2.0 uses two algorithms, Gauss-Legendre and Simpson's rule, to integrate Equation 30. (Press et al. 1986). Equation 31 is calculated using Gauss-Legendre only. Gauss-Legendre routines are computationally efficient for relatively smooth integrals and, if a preselected number of weight points are used, integration variables are not needed, thereby simplifying the required input for the user. For integrands that are not approximated very well by polynomials or that are unpredictable and erratic, the Gaussian-Legendre algorithms may become unstable and produce erroneous results. The Simpson rule routine, which is a more robust solver, may be used in such cases. The computational time using the Simpson's rule routine however, is usually longer and also requires the user to input integration variables. In general, Gauss-Legendre integration should be used for the surface and buried source model and Simpson rule integration should be used for the pond model. For a source defined by a tabulation of contaminant mass fluxes, the integration routine selected should be based on the smoothness of the flux versus time curve. If the flux versus time curve is relatively smooth, then the Gauss-Legendre routine can be used otherwise, the Simpson's rule routine should be used.

Variations of the Gauss-Legendre integration routine are found in the subroutines, QGAUS1 and QGAUS2. In QGAUS1, an eight point (8 pairs of abscissas and weights) are used to integrate the instantaneous groundwater concentration over time. In QGAUS2, a 17 point Gauss-Legendre integration routine is used to compute the convolution integral and calculate the instantaneous groundwater concentration. The abscissas and weights for these routines were calculated using a FORTRAN routine adapted from Press et al., (1986). It was necessary to use more weight points in the QGAUS2 subroutine in order to achieve a stable solution to the convolution integral.

The integration limits in Equation 30 often result in values of the function $C(x,y,t-\tau)$ that are near zero, add little to the integrand, and decrease the overall accuracy of the solution. Codell derived expressions for the integration limits, T_1 and T_2 , such that for each function call of $C(x,y,t-\tau)$, significant values to the integrand were added. These limits were presented (in Codell) for a line source with a decay term and for an area source without a decay term. The limits for an area source were modified to include a decay term in GWSCREEN. The limits, T_1 , T_2 are given by the following.

$$T_1, T_2 = t - \frac{1}{2} \left(\frac{\frac{2U(x \pm L/2) + 4D_x \gamma}{R_d}}{\left(\frac{U}{R_d}\right)^2 + \frac{4D_x \lambda}{R_d}} \right) \quad (45)$$

$$\pm \frac{1}{2} \left(\sqrt{\frac{\left(\frac{2U(x \pm L/2) + 4D_x \gamma}{R_d}\right)^2}{\left(\frac{U}{R_d}\right)^2 + \frac{4D_x \lambda}{R_d}}} - \frac{4(x - L/2)^2}{\left(\frac{U}{R_d}\right)^2 + \frac{4D_x \lambda}{R_d}} \right)$$

where T_1 , T_2 = the upper and lower limits of integration (years)

γ = and arbitrary value such that $e^{-\gamma} \approx 0.0$

and $T_1 < (t-\tau) < T_2$.

A value of 50 was found to be adequate for γ . These limits are calculated in the subroutine LIMITS.

Equation 30 in subroutine AREA, requires evaluation of error functions. The error function routine was also adapted from Numerical Recipes (Press et al., 1986) and contained in subroutines ERROR, GAMMP, GSER, GCF and GAMLIN.

Maximum concentration is determined in the subroutines, PEAK and GOLDEN. The

subroutine, PEAK uses Equation 46 to calculate points that are known to lie on either side of the peak.

$$ZMIN = \frac{\left(T_{oper} + \left((x-L) \frac{R_d}{U} \right) \right)}{5} \times \frac{T_{1/2} U}{(0.1+x) R_d} \quad (46)$$

$$ZMAX = \left(T_{oper} + (x+L) \frac{R_d}{U} \right) 5$$

where ZMIN = minimum bound (y)

ZMAX = maximum bound (y)

T_{oper} = operational time of pond, $T_{oper} = 0$ if surface or buried source model is used (y).

These points, along with their midpoint, are passed to the subroutine, GOLDEN (golden section routine adapted from Press et al., 1986) that calculates the maximum concentration and the time the maximum concentration occurred at.

3.2 Contaminant and Site Specific Data File

Variables and structure for the required input file are presented in Table 2. A value for each variable must be included in the input file whether or not that value is used in the calculation. If more than one value is read on a line, then the values must be separated by spaces or commas. Comments may follow the last value on a line.

Line 15 lists 6 variables, however, only one value is read. The first value read on line 15 is assigned to one of the following variables, DCF, RCSF, SFACTOR, RFD, RADMAX, or ZRADMAX depending on the value of IMODE (see Table 2). Units of the contaminant (Ci or mg) are also selected by the IMODE variable. If the IMODE variable is 1, then the first value on line 15 is read as DCF, the ingestion dose conversion factor (rem

Ci^{-1}) and the units of the contaminant are curies. If $\text{IMODE}=2$, then the first value on line 15 is read as RCSF, the radiological carcinogenic slope factor (Ci^{-1}) and the units of the contaminant are curies. If $\text{IMODE}=3$, then the first value on line 15 is read as RADMAX, the maximum radionuclide concentration in groundwater (Ci L^{-1}) and the units of the contaminant are curies. If the IMODE variable is 4, then the first value on line 15 is read as ZRADMAX, the maximum allowable non-radiological contaminant concentration in groundwater (mg L^{-1}), and the units of the contaminant are mg. If the IMODE variable is 5, then the first value on line 15 is read as SFACTOR, the carcinogenic slope factor kg d mg^{-1} , and the units of the contaminant are mg. If the IMODE variable is 6, then the first value on line 15 is read as RFD, the reference dose for non-carcinogens (mg/kg/d), and the units of the contaminant are mg.

In general, the Simpsons rule integration routine is a more robust solver and is recommended for the pond model and when a user defined release function is used, however the routine usually requires more computational time. The variables JMAX, JSTART and EPS are used with the Simpsons rule integration routine. The routine evaluates the integral for a variable number points and monitors the accuracy of the solution. The accuracy is checked by computing the integral using 2^n number of middle points plus the two end points and then adding 2^{n+1} number of middle points and comparing the result with the previous evaluation. A maximum of JMAX number of iterations is performed. On the first iteration, the crudest approximation to the integral is performed by evaluating the function at the upper and lower limits. On each successive iteration, the number of middle points (points between the upper and lower limits of integration) evaluated are increased by a factor of 2 starting with one middle point added during the second iteration. The number of additional middle points is given by 2^{n-2} where n =the iteration number. The routine evaluates the integral for at least JSTART number iterations before the " $n-1$ " solution is checked for convergence with the n^{th} solution. For example, if the variable JSTART is set equal to 6 (its minimum allowable value) then 6 iterations are performed before convergence checking occurs. The number of middle points added on the 6th iteration is $2^{6-2} = 16$. Convergence is checked by calculating the EPS value and comparing it to the user input EPS value. The EPS variable is

given by

$$EPS = \frac{|f_p - f_c|}{f_c} \quad (47)$$

where f_p = previous evaluation of the integral (Equation 30)

f_c = current evaluation of the integral.

If the calculated EPS is less than the user input EPS, then the routine is terminated and the current evaluation of the integral is returned. If the calculated EPS is greater than the user input EPS, then 2^{n-2+1} number of middle points are added and a new value of the integral is calculated and checked. If convergence is not achieved in JMAX number of iterations, then the routine is terminated and the current value of the integral is returned. The user is warned of non-convergence by a message printed to the screen and the current EPS value is also printed. An adequate solution does not necessarily require convergence to be met and depends on the values of the integration variables, JMAX, JSTART, and EPS. Unacceptable solutions are usually detected by observing the concentration verses time output. If there are *significant* fluctuations in the curve, then the EPS value should be set lower and JMAX increased. In the samples problems presented in Appendix A, adequate solutions were obtained using an EPS value of 5.0×10^{-3} and a JMAX value of 12. The JSTART variable, which must be less than JMAX, was set equal to 6. Decreasing the EPS value and increasing JMAX is not without cost, however since computational time is significantly increased when these values are changed.

When a tabulated source function is used, the release function, $F(\tau)$ in Equation 30 is linearly interpolated from the data provided by the user. Linear interpolation is performed in the subroutine, LINT.

Table 2. The GWSCREEN input file for contaminant and site specific data. Variables given the same line number must appear in the same order on the line as presented in this Table. A value for each variable listed must be present whether or not that variable is used in the calculation. Minimum and maximum acceptable values are noted by MIN and MAX designations.

LINE NUMBER	VARIABLE	CODE VARIABLE	TYPE	DESCRIPTION
1	—	TITLE	CHARACTER	80 character title of project
2	—	KFLAG	INTEGER	Flag variable to select the type of calculation. If KFLAG=0, then concentration vs. time is calculated. If KFLAG=1, then peak concentration and limiting soil concentration is calculated. KFLAG must equal 0 if IMODEL = 3. MIN:0 MAX:1
2	—	NPROG	INTEGER	Number of radioactive progeny. MIN:0 MAX:9
3	$T_b - T_a$	INTIME	INTEGER	Groundwater concentration integration time for calculation of average concentration (y). If INTIME equals zero, then integration is not performed. MIN:0 MAX:1000
4	L	AL	REAL	Length of source parallel to groundwater flow (m). MIN:1 MAX:1E4
4	W	WA	REAL	Width of source perpendicular to groundwater flow (m). MIN:1 MAX:1E4
4	T	THICKS	REAL	Thickness of source volume (m) if IMODEL=1 or thickness of pond sediments if IMODEL=2. This variable is ignored if IMODEL=3. MIN:1E-3 MAX:1E4
5	P	PERC	REAL	The net water percolation rate (m y ⁻¹). MIN:1E-4 MAX:1E6
5	θ_s	THETAS	REAL	Volumetric moisture content in contaminated zone (m m ⁻¹). MIN:1E-8 MAX:0.9999999
5	θ_u	THETAU	REAL	Volumetric moisture content in the unsaturated zone (m m ⁻¹). MIN:1E-8 MAX:0.9999999
6	ρ_c	RHOS	REAL	Bulk density in the contaminated zone (g cm ⁻³). MIN:0.01 MAX:10.0
6	K_{dc}	ZKDS	REAL	Sorption coefficient in contaminated zone (ml g ⁻¹) MIN:0 MAX:1.0E18
6	λ_o	RC2	REAL	Loss rate constant from source zone for mechanisms other than decay (y ⁻¹). MIN:0 MAX:1.0E18
7	ρ_u	RHOU	REAL	Bulk density in unsaturated zone (g cm ⁻³) MIN:0.01 MAX:10.

Table 2. (continued)

LINE NUMBER	VARIABLE	CODE VARIABLE	TYPE	DESCRIPTION
7	K_{du}	ZKDU	REAL	Sorption coefficient in unsaturated zone (ml g^{-1}) MIN:0 MAX:1.0E18.
8	$T_{1/2}$	ATHALF(I)	REAL	Half Life(s) of contaminant and radioactive progeny. Array of NPROG+1 number of elements (years). MIN:0 MAX:1E38 Note: value of ATHALF reset to 1.0E38 if ATHALF=0.
9	Q_s	QI	REAL	Initial mass in source volume or in pond sediment (Ci or mg)
9	MW	ZMW	REAL	Molecular weight of contaminant (g mole^{-1})
9	C_d	SL	REAL	Contaminant solubility limit (mg L^{-1})
10	ρ_s	RHOA	REAL	Bulk density in saturated zone (g cm^{-3}) MIN:0.01 MAX:10
10	η	PHI	REAL	Porosity of saturated zone (m m^{-1}) MIN:1E-10 MAX:0.999999
10	K_{ds}	AKD(I)	REAL	Sorption coefficient(s) in the saturated zone of contaminant and radioactive progeny. Array of NPROG+1 number of elements (ml g^{-1}). Code variable ZKDA=AKD(1). MIN:0 MAX:1.0E18
11	α_L	AX	REAL	Longitudinal dispersivity (m) MIN:1E-10 MAX:1E6
11	α_T	AY	REAL	Transverse Dispersivity (m) MIN:1E-10 MAX:1E6
11	U	VX	REAL	Saturated pore velocity (m y^{-1}) MIN:1E-10 MAX:1E6
12	b	THICK	REAL	Well screen (mixing) thickness (m) MIN:1E-10 MAX:1E6
12	X_u	DEPTH	REAL	Thickness of unsaturated zone (m) MIN:1E-10 MAX:1E6
13	—	IMODE	INTEGER	Flag variable to select type of groundwater criteria. IMODE=1 Radiological dose; IMODE=2 Radioactive carcinogenic risk; IMODE=3 Maximum radionuclide concentration; IMODE=4 Maximum non-radiological groundwater concentration; IMODE=5 Carcinogenic risk; IMODE=6 Non-carcinogenic reference dose MIN:1 MAX:6
13	—	IMODEL	INTEGER	Flag variable to indicate what source model to run. IMODEL=1, surface or buried source leaching model, IMODEL=2, pond release model, IMODEL=3, tabulated source function MIN:1 MAX:3

Table 2. (continued)

LINE NUMBER	VARIABLE	CODE VARIABLE	TYPE	DESCRIPTION
NOTE: Line 14 variables are used only in the pond model (IMODEL=3)				
14	Q_{pond}	RMI	REAL	Rate of mass input into disposal pond (Ci or mg y ⁻¹).
14	t_{op}	TOPER	REAL	Operation time of pond facility (y)
14	q_{pond}	PNDFLX	REAL	Water flux into pond (m ³ y ⁻¹)
14	Θ_p	THETAP	REAL	Volumetric water content of pond sediments (m ³ m ⁻³)
14	λ_c	EVAP	REAL	Evaporation or other loss rate constant for the contaminant in the pond (y ⁻¹)
14	W_e	WAEFF	REAL	Effective pond width at aquifer (m)
15	DCF	DCF ^a	REAL	Radiological dose conversion factor (rem Ci ⁻¹)
15	SF	RCSF ^a	REAL	Radiological carcinogenic slope factor (Ci ⁻¹)
15	C_L	RADMAX ^a	REAL	Maximum allowable radionuclide concentration in groundwater (Ci L ⁻¹)
15	C_L	ZRADMAX ^a	REAL	Maximum allowable non-radiological groundwater contaminant concentration (mg L ⁻¹)
15	SF	SFACTOR ^a	REAL	Carcinogenic risk slope factor (mg/kg/d) ⁻¹
15	RfD	RFD ^a	REAL	Reference dose for non-radiological contaminants (mg/kg/d)
16	x	XD	REAL	Receptor distance from center of source parallel to groundwater flow (m)
16	y	YD	REAL	Receptor distance from center of source perpendicular to groundwater flow (m)
17	BW	BW	REAL	Body weight of standard man (kg)
17	AT	AT	REAL	Averaging time (days)
17	I	WI	REAL	Water intake rate (L d ⁻¹)
17	EF	EF	REAL	Exposure frequency (d y ⁻¹)
17	ED	ED	REAL	Exposure duration (y)
17	D_L	DLIM	REAL	Radiological CEDE limit (rem y ⁻¹)

Table 2. (continued)

LINE NUMBER	VARIABLE	CODE VARIABLE	TYPE	DESCRIPTION
17	—	CRISK	REAL	Acceptable carcinogenic risk factor (unitless)
17	HQ	HQ	REAL	Hazard quotient (unitless)
18	—	ISOLVE	INTEGRER	Flag variable to select numerical integration method. ISOLVE=1, Gaussian Quadrature; ISOLVE=2, Simpson Rule MIN:1 MAX:2
18	—	JSTART	INTEGRER	Number of iterations to perform in the Simpson rule integration routine before convergence checking is to begin. JMAX must be greater than JSTART. See discussion in Section 3.2. MIN:6 MAX:14
18	—	JMAX	INTEGRER	Maximum number of iterations to perform for the Simpson rule integration routine. The maximum number of point evaluations = $[2^{JMAX-1}]$. See discussion in Section 3.2. MIN:7 MAX:15
18	—	EPS	REAL	Convergence criteria for Simpson rule integration. See discussion in Section 3.2 MIN:1.0E-6 MAX:1.0
19	—	NTIMES	INTEGER	Number of time periods to calculate concentration over. Read only if KFLAG is 0 or IMODEL is 3. MIN:1 MAX:9
19 + I		T1(I)	REAL	Beginning time of the I th time period to calculate concentration as a function of time ^b
19 + I		T2(I)	REAL	Ending time of the I th time period to calculate concentration as a function of time ^b
19 + I		TP(I)	REAL	Print time step for the I th time period (y) ^b
19 + NTIMES + J		ATIME(J)	REAL	Time of the J th release for tabulated source function. Maximum of 1000 points allowed (y)
19 + NTIMES + J		QREL(J)	REAL	Mass flux of J th release for the tabulated source function (Ci or mg y ⁻¹)

^a Only one variable is read on line 15. The variable read depends on the value of IMODE (line 13). If IMODE=1, then line 15 variable is DCF and units are in Ci. If IMODE=2, then line 15 variable is RCSF and units are in Ci. If IMODE=3, then line 15 variable is RADMAX and units are in Ci. If IMODE=4, then line 15 variable is ZRADMAX and units are in mg. If IMODE=5, then line 15 variable is SFACTOR and units are in mg. If IMODE=6, then line 15 variable is RFD and units are in mg.

^b Time from waste emplacement.

3.3 Code Execution and Output

Overall program flow (Figure 5) is controlled by the user input variables, IMODE, IMODEL, and KFLAG. These variables determine the regulatory option to use, units of the calculation, the release model to use, and whether concentration vs time or the limiting soil concentration is calculated. When executing GWSCREEN, the user is prompted for the name of the user defined input file (Table 2) and the name of the file the output is to be written to. The default names for these files are GWSCREEN.PAR and GWSCREEN.OUT and the user may select them by simply pressing the return key at the prompt.

All input data is printed to the output file along with the date and time of the run. If the contaminant being modeled is radioactive with radioactive progeny, then the progeny half lives, aquifer sorption coefficients, dose conversion factors and slope factors are printed to the right of the parent value beginning with the first decay chain member. Space has been provided for the input data to be checked and reviewed by additional personnel. Fixed parameter values calculated in the code, such as the leach rate constant (λ_L) and the retardation factor (R_d), are also printed in the output file. Aquifer retardation factors and decay rate constants for radioactive progeny are printed to the right of the parent values.

3.3.1 KFLAG, IMODEL, IMODE, INTIME -- The variable, KFLAG determines whether concentration vs time or limiting soil concentration are calculated. If KFLAG equals 0, then groundwater concentration and source flux are calculated as a function of time and printed to the output file. Up to 9 separate time periods for output may be selected. For each time period, concentration may be printed for unlimited number of specific times within that time period. If KFLAG equals 1, then the limiting soil concentration is calculated and, depending on the option selected, the maximum radiological dose, carcinogenic risk, or noncarcinogenic hazard quotient are calculated. Unlike GWSCREEN version 1.3 - 1.5, the peak concentration reported is based on the mass (or activity) input as the QI variable and not a unit inventory.

The IMODEL variable selects what type of release model is used. If IMODEL is equals to 1, then the surficial or buried source model is used. If IMODEL=2, then the pond model is used and if IMODEL=3, then the tabulated source function is used. The tabulated source function requires a time history of flux to the unsaturated zone be appended to the end of the input file. Each time period consists of one line, in the first column is the time of the release and in the second column, the mass release rate (mg or Ci per year).

Appropriate units are selected automatically with the IMODE variable. If concentration vs time mode (KFLAG=0) has been selected, then the output file contains the contaminant fluxes and groundwater concentrations for the output times specified by the NTIMES, T1, T2 and TP variables. These output times are the time from waste emplacement. If KFLAG=1, then the limiting soil concentration and limiting contaminant mass are calculated and printed to the output file. The code also compares the limiting contaminant mass with the solubility limited mass (Q_{sl}). If the limiting mass exceeds the solubility limited mass as given by Equation 13, then a warning is printed at the bottom of the output file. If the solubility limit is unknown, then the variable, SL should be set to 1×10^6 mg/L or greater. This will basically eliminate a solubility limited release from being considered.

The INTIME variable controls the concentration averaging time when KFLAG=1. If INTIME is less than or equal to 1, then the maximum concentration is reported as the average concentration. When KFLAG equals zero (concentration vs time mode) and INTIME is greater than zero, GWSCREEN calculates the average concentration over the output time period defined by the variables T1(I), T2(I). If INTIME equals zero, then average concentrations are not calculated when KFLAG=0.

3.3.2 Solubility Limited Releases -- Limiting soil inventories for contaminants with relatively short half-lives compared to their unsaturated transit times, are usually quite large, and often exceed the solubility limited mass (Equation 13). This situation may occur even when the solubility limit is set artificially high. The user should be aware that the limiting

GWSCREEN VERSION 2.0 FLOWCHART

Figure 5. Flow chart for the GWSCREEN code. Note: Not all subroutines are shown on this figure.

contaminant inventory calculated under these conditions is unreasonably high and sometimes not physically possible. For radionuclides, the specific activity of the nuclide is also computed and compared to the limiting soil concentration. The specific activity is given by

$$S_p = \frac{N_A \lambda_d 3.1536 \times 10^7 \text{ s/y}}{MW 3.7 \times 10^{10} \text{ dps/Ci}} \quad (48)$$

Limiting soil concentrations that exceed the specific activity of the nuclide are also noted in the output.

3.3.3 Radioactive Progeny -- Groundwater concentrations for radioactive progeny (when KFLAG=0) are designated by columns labeled "member #1", "member #2", "member #3", ... "member n". If the limiting soil concentration is selected, then the maximum parent groundwater concentration and the corresponding radiological dose or carcinogenic risk is printed to the output file. The concentration of each of the remaining members of the decay chain at the time of maximum concentration of the parent is also printed in the output file along with the corresponding radiological dose or carcinogenic risk for each member. The groundwater concentration, dose, and risk values are based on the user input activity (or mass) in the source volume as defined by the QI variable. Concentration of the progeny are reported at the time of the maximum parent concentration. In most cases, the maximum progeny concentration occurs at the same time as the parent, however, there are cases where the maximum progeny concentration occurs at a different time than that of the parent's. This generally happens when "no equilibrium conditions" exists between parent and progeny and is illustrated in example problem #8 (Figure 6). In example problem #8, the maximum ²⁴¹Pu concentration (parent nuclide) occurs at 318 years (compare output for sample problem #8 with Figure 6), the maximum ²⁴¹Am concentration occurs at 376 years, and the maximum ²³⁷Np concentration occurs at 388 years. In the output for limiting soil concentration, the maximum concentrations for ²⁴¹Am (4.0×10^{-13} Ci L⁻¹) and ²³⁷Np (3.2×10^{-13} Ci L⁻¹) are calculated at 318 years, the time of maximum concentration for ²⁴¹Pu. Note that these

concentrations are lower than the actual maximum concentration presented in Figure 6. Also note in the output that the average concentrations for the progeny are higher than the reported maximum concentration for the progeny. This indicates that the peak progeny concentration did not occur at the same time as the peak parent concentration. The user should be aware when non-equilibrium conditions occur and run the code in both the limiting soil concentration and concentration vs time modes to assure a conservative answer has been calculated.

The ^{241}Pu flux to the aquifer and the unsaturated transit time (251 years) are also shown in Figure 6. Since the unsaturated transit time exceeds ten times the half life (14.4 years) then, as suggested in Section 2.2, the thickness in the unsaturated zone may be decreased such that $[10 \times T_{1/2}] \leq T_{\text{unsat}}$ for conservatism. In this problem however, the limiting soil concentration is driven by ^{241}Am and ^{237}Np since the carcinogenic slope factors for these nuclides are about 2 orders of magnitude greater than ^{241}Pu and their groundwater concentrations at the receptor are higher. Longer unsaturated transit times allow for more radioactive progeny ingrowth and therefore, higher progeny groundwater concentrations and greater risk. Therefore, it is more conservative in this particular case, to use the longer unsaturated transit time.

Figure 6. Concentration as a function of time for sample problem #8.

4. References

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APPENDIX A: GWSCREEN SAMPLE PROBLEMS

The input and output files for nine sample problems are presented in this appendix. Each sample problem was intended to demonstrate a different aspect of the GWSCREEN code. The sample problems were run on an IBM® PS/2 486 SX personal computer. Code execution time ranged from one to 12 seconds.

The output file for sample problem #1 has been annotated for additional explanation. Annotation in the output file for sample problem #1 are as follows. Redlined text indicates a comment or additional information or explanation of the output and bold text indicates an input value that has been echoed back in the output. A brief description of each problem follows.

Sample Problem 1.

Limiting soil concentration for Pu-239 in a 50 m x 50 m x 2.5 m source volume located in an environment similar to eastern Idaho and using the default parameters presented in DOE/ID-1-340(92), Revision 1. The maximum allowable groundwater concentration was based on a carcinogenic target risk of 1×10^{-6} and is given by

$$C_{\max} = \frac{1 \times 10^{-6}}{SF \times I \times ED \times EF}.$$

where $C_{\max}$ = the maximum allowable groundwater concentration (pCi L⁻¹)

SF = the slope factor pCi⁻¹

I = intake rate (2 L d⁻¹)

ED = exposure duration (30 years)

EF = exposure frequency (350 d y⁻¹)

The slope factor for ²³⁹Pu is 3.1×10^{-11} pCi⁻¹ therefore the maximum allowable groundwater concentration is

$$\frac{1 \times 10^{-6}}{(3.1 \times 10^{-11} \text{ pCi}^{-1}) (2 \text{ L/d}) (30 \text{ y}) (350 \text{ d/y})} = 1.5 \times 10^{-12} \text{ Ci L}^{-1}$$

The ^{235}U maximum allowable groundwater activity concentration based in carcinogenic risk (slope factor = $1.3 \times 10^{-10} \text{ pCi}^{-1}$) was 0.37 pCi L^{-1} . The maximum ^{239}Pu groundwater concentration adjusted for progeny is given by the following.

$$C_L = \frac{1}{\frac{1}{MCL_p} + \sum_{i=1}^n \frac{DIF_i R_{d_{parent}}}{DIF_{parent} R_{d_i} MCL_i}} \quad (\text{A-1})$$

where D_L = applicable CODE limit, (rem y^{-1})

MCL_i = maximum contaminant limit for i^{th} progeny (Ci L^{-1})

MCL_{parent} = maximum contaminant limit for the parent (Ci L^{-1})

Rd_i = retardation factor for i^{th} progeny (Ci L^{-1})

Rd_{parent} = retardation factor for the parent (Ci L^{-1})

I = water intake rate (L d^{-1}).

C_L = maximum allowable *parent* groundwater concentration adjusted for progeny (Ci L^{-1})

This value is printed in the output file under the heading, "Results of the Calculation".

The ^{235}U progeny had little impact on the results since very little ingrowth occurred during transit.

Sample Problem 2.

Limiting soil concentration for Sr-90 in a 25 m x 25 m x 1.0 m source volume located in an environment similar to eastern Idaho and using the default parameters presented in DOE/ID-1-340(92), Revision 1. The limiting soil concentration was based on the maximum permissible drinking water concentration in 40 CFR 141, Subpart B, Table A, of 8 pCi L^{-1} .

Sample Problem 3a.

Limiting soil concentration for a mercury carbonate (Hg_2CO_3) source in a 25 m x 25 m x 1.0 m source volume located in an environment similar to eastern Idaho and using the default parameters presented in DOE/ID-1-340(92), Revision 1. The limiting soil concentration was based on subchronic noncarcinogenic toxicity (1 year exposure period) using an RfD value of $3.0\text{E}4$ mg/kg/day. Sample problem 3 illustrate the solubility release model in GWSCREEN. In this example, the solubility limit was provided as input. This value was based on the carbonate form of mercury and was obtained from the CRC Handbook of Chemistry and Physics. Also, an estimate of the source mass was provided as input. GWSCREEN was run in the "backwards" direction for this problem (Example problems 1 and 2 were also run in the backwards direction). That is, the limiting soil concentration and limiting contaminant mass were calculated. "Backward" calculations are performed in GWSCREEN by setting the KFLAG variable to 1.

A limiting soil contaminant mass of 2.4×10^8 and a limiting soil concentration of 256 mg kg^{-1} were calculated for this example. This mass was less than the estimated contaminant mass in the source volume of 2.81×10^8 mg (equivalent to 300 ppm soil concentration) and therefore the site would require further evaluation or cleanup. However, at the bottom of the output, a warning statement is printed stating that the limiting soil mass exceeds the solubility limited source mass. This statement indicates the following:

- The initial concentration of the leachate exceeds the solubility limit of the contaminant
- Release of the contaminant from the source volume is controlled by the solubility limit of the contaminant.

At this point in the analysis, a forward calculation should be performed and the maximum groundwater concentration should be evaluated for risk. The forward calculation and risk calculation are illustrated in Example 3b.

Sample Problem 3b.

Concentration vs time for the 281 kg mercury carbonate source described in problem 3a. Note that the mass used in the simulation exceeds the solubility limited mass calculated in sample problem 3a and therefore, the release is solubility limited. Contaminant flux to the unsaturated zone is constant until the source mass is depleted to the solubility limited mass of 4.23×10^6 mg. After that, release from the source volume occurs by first order leaching. The solubility limited release time was 9841 years.

In this example, concentration as a function of time is printed to the output file following the printout of the input parameter values and values calculated in the SOURCE subroutine. The first column lists the time from the start of waste emplacement. In the second and third columns, cumulative source flux and cumulative aquifer flux from the time of waste emplacement are printed. The fourth and fifth columns contain the current aquifer flux and the groundwater concentration. For this example, the groundwater concentration reaches a steady state value.

Sample Problem 4.

Limiting soil concentration for 2,3,7,8-tetrachlorodibenzo-p-dioxine (TCDD) in a remediated storage site in Biloxi, Mississippi. The limiting soil concentration was based on a carcinogenic slope factor of $1.5E5$ (mg/kg/day)⁻¹. In this example, the optional loss rate constant for the source was employed. Data from the literature (Schaum, 1984) indicate that TCDD degrades in soil with a half life of around 100 years and near the surface with a half life of 12 years. Degradation rates of TCDD in groundwater were unknown. Since degradation only affects TCDD in the source compartment (soil), the half life of TCDD in soil (100 years) was converted to a first order rate constant using Equation 4. This value was set equal to the code variable, RC2 and the contaminant half life was set equal to infinity (by setting THALF=0.0). The K_d value used in the example was based on an organic partitioning coefficient (K_{oc}) of 3.3×10^6 mL g⁻¹ and a fraction of organic carbon of 5.0×10^{-4} .

Sample Problem 5

Limiting ^{226}Ra soil concentration for a hypothetical uranium mill tailings pile containing an average ^{226}Ra concentration of 500 pCi g^{-1} . The limiting soil concentration was based on a maximum proposed groundwater concentration limit of 20 pCi L^{-1} for ^{226}Ra and (40 CRF 141) and 1.0 pCi L^{-1} for ^{210}Pb (proposed). Note that the maximum ^{226}Ra concentration in groundwater was adjusted for the ^{210}Pb progeny and is lower than 20 pCi/L (see Equation A-1).

Sample Problem 6a

Limiting soil concentration for a Ni-59 source at a hypothetical site. The limiting soil mass exceeds the solubility limit of Ni-59 therefore, a warning statement is printed to the output file. Limiting soil concentration was based on a annual dose equivalent of 4 mrem/y .

Sample Problem 6b

Concentration vs time for a 1000 Ci inventory (11 nCi/g) Ni-59 source at a hypothetical site. The release is solubility limited for a time period given by Equation 14. The maximum dose can be computed from the maximum concentration ($6.5\text{E-}9 \text{ Ci L}^{-1}$) by multiplying by an annual water ingestion rate and dose conversion factor.

$$\text{Dose} = 6.5\text{E-}9 \text{ Ci/L} \times 730 \text{ L/y} \times 200 \text{ rem/Ci} \times 1000 \text{ mrem/rem} = 0.95 \text{ mrem/y.}$$

Since this value is below the 4 mrem y^{-1} criteria, then the hypothetical inventory is would be considered acceptable in terms of groundwater protection.

Sample Problem 7a

Limiting pond effluent concentration for a hypothetical percolation pond receiving $4000 \text{ m}^3 \text{ y}^{-1}$ liquid effluent containing $0.25 \mu\text{Ci L}^{-1}$ of ^{90}Sr . The output for the pond model includes the limiting pond effluent concentration and the contaminant mass in the pond sediments at the end of the operational lifetime of the pond. In this example, the unsaturated

thickness was set very thin so that transit time from the base of the pond sediments to the top of the aquifer was insignificant. Since residence time in the unsaturated zone is low, the flux leaving the source compartment is essentially equal to the flux to the aquifer

Sample Problem 7b

Concentration as a function of time for the pond described in problem 7a. In this example, the tabulated source function was used. The mass flux from the pond as a function of time was calculated using Equation 19 for time periods less than 30 years and Equation 9 for time periods > 30 years. These data were calculated on a spreadsheet and exported to an ASCII file. This file was then appended to the end of the GWSCREEN input file. Note that the flux to the aquifer after 32 years (95.7 Ci y^{-1}) does not equal the mass input rate to the pond (100 Ci y^{-1}) indicating that the pond sediment compartment has not equilibrated during the 30 year operational period. The aquifer flux after 30 years (0.62 Ci y^{-1}) is significantly lower than the flux at 30 years and is a result of the lower percolation rate after the operation of the pond is terminated.

Sample Problem 8

Limiting soil concentration for a ^{241}Pu source in an environment similar to eastern Idaho. The limiting soil concentration is based carcinogenic risk. This example shows the importance of including radioactive progeny in the assessment. The risk resulting from ^{241}Pu alone is insignificant ($6.0\text{E-}12$). However the risk from the progeny, ^{241}Am ($2.4\text{E-}6$), is significant and the site may be in need of further evaluation. Also note the discussion in Section 3.3 of this document concerning this example.

Sample Problem 9

Limiting soil concentration for a 25 m x 15 m hydrocarbon spill containing benzene. The optional loss rate constant (λ_o) was used to model volatilization losses from the source volume. Volatilization loss from groundwater was not accounted for. The volatilization rate constant ($1.13\text{E-}2 \text{ y}^{-1}$) and the degradation half life (0.95 years) were calculated using a methodology and data obtained in Ünlü (1992). Limiting soil concentration was based the

carcinogenic risk associated with benzene exposure and sorption coefficients were based on a K_{oc} value of 83 mL g⁻¹ and a f_{oc} of 0.003. Note: The volatilization rate constant is dependent on the geometry of the source and the type of hydrocarbon spilled. The volatilization rate constant should not be used with other problems since it is a site and scenario specific value.

References

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Sample Problem 1: Input File

EXAMPLE PROBLEM #1; Pu-239 for GWSCREEN Ver 2.0. INCLUDE U-235 PROGENY

```
1 1 KFLAG NPROG
1 INTIME
50.0 50.0 2.50 AL WA THICKS
1.0 0.35 0.090 PERC THETAS THETAU
1.5 22.0 0.0 RHOS ZKDS RC2
1.9 22.0 RHOU ZKDU
2.41E+04 7.04E8 THALF(I)
1.00 239.0 7.11E6 QI ZMW SL
1.9 0.10 22.0 6.0 RHQA PHI ZKDA
1.0E-3 5.0E-4 570.0 AX AY VX
15.0 50.0 THICK DEPTH
3 1 IMODE IMODEL
1. 1. 1. 1. 1. RMI TOPER PNDPLX THETAP EVAP WAEFF
1.5E-12 3.7E-13 DCF-crad-radmax-NRADMAX-SFACTOR-RFD
0.0, 0. XD YD
70.0 2.555E+04 2.0 350. 70. 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
1 6 11 1.0E-2 ISOLVE,JMAX,EPS
2 NTIMES
```

Output File

TIME OF RUN 16:52:53.9
DATE OF RUN 06/21/93
INPUT FILE NAME: pb-1.par
OUTPUT FILE NAME: pb-1.out

time GWSCREEN run was performed
date GWSCREEN run was performed
file containing input data
file where output data is written to

ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND LIMITATION OF LIABILITY

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Energy, Office of Environmental Restoration and Waste Management, and licensing statement
DOE Field Office, Idaho, Contract Number DE-AC07-76ID01570.

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or assumes any legal liability or responsibility for the accuracy,
completeness, or usefulness of any information, apparatus, product,
or process disclosed, or represents that its use would not infringe on
privately owned rights.

```
*****
*
* This output was produced by the model:
*
* GWSCREEN
* Version Control Copy, Version 2.0
* A semi-analytical model for the assessment
* of the groundwater pathway from the leaching
* of surficial and buried contamination and
* release of contaminants from percolation ponds
* 6-20-93
* Arthur S. Rood
* Idaho National Engineering Laboratory
* EG&G Idaho Inc.
* Subsurface and Environmental Modeling Unit
* PO Box 1625
* Idaho Falls, Idaho 83415
*****
```

header and code version identification

>>> TITLE OF PROJECT:

EXAMPLE PROBLEM #1; Pu-239 for GWScreen Ver 2.0. INCLUDE U-235 PROGENY

GAUSSIAN QUADRATURE SOLUTION Numerical integration will be performed by Gaussian Quadrature
MODEL OPTIONS

IMODE: 3 Limiting soil concentration will be based on maximum radionuclide concentration in groundwater
KFLAG: 1 (0) CONC VS TIME; (1) PEAK CONC AND LIMITING SOIL CONC The peak conc. and limiting soil conc option
IMODEL: 1 (1) SURF OR BURIED SOURCE; (2) POND SOURCE; (3) TABULATED SOURCE FUNCTION surface source model

>>> INPUT DATA

```
*****
NUMBER OF RADIOACTIVE PROGENY          1
LENGTH OF SOURCE PARALLEL TO GW FLOW (m) 5.00E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m) 5.00E+01
THICKNESS OF SOURCE (m) 2.50E+00
PERCOLATION RATE (darcy vel m/y) 1.00E+00
VOLUMETRIC WATER CONTENT IN SOURCE 3.50E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE 9.00E-02
BULK DENSITY AT SOURCE (g/cm**3) 1.50E+00
SORPTION COEFFICIENT AT SOURCE (ml/g) 2.20E+01
BULK DENSITY IN UNSAT ZONE (g/cm**3) 1.90E+00
UNSATURATED ZONE THICKNESS (m) 5.00E+01
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g) 2.20E+01
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1) 0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci) 1.00E+00
MOLECULAR WEIGHT (g/mole) 2.39E+02
SOLUBILITY LIMIT (mg/L) 7.11E+06
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y) 2.41E+04 7.04E+08
BULK DENSITY OF AQUIFER (g/cm**3) 1.90E+00
POROSITY OF AQUIFER 1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g) 2.20E+01 6.00E+00
DISPERSIVITY X DIRECTION (m) 1.00E-03
DISPERSIVITY Y DIRECTION (m) 5.00E-04
PORE VELOCITY (m/y) 5.70E+02
WELL SCREEN THICKNESS (m) 1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS (m) 0.10E+00
DISTANCE TO RECEPTOR ALONG Y AXIS (m) 0.00E+00
LIMITING RADIONUCLIDE GW CONCENTRATION (Ci/L) 1.50E-12 3.70E-13
UNITS OF CONTAMINANT Ci
```

```
HPROB
AQ
UN
THICK
PERG
THETA
THETAU
RHOS
ZKDS
RHOU
DEPTH
ZKDU
RC2
Q1
ZIN
SE
ATHALF(1), ATHALF(2)
RHOA
PHI
AKDA(1), AKDA(2)
AX
AY
VX
THICK
XQ
YD
RADMAX(1), RADMAX(2)
```

INPUT DATA FILE CREATED BY: _____ DATE / / space provided for input to be validated.

INPUT DATA CHECKED BY: _____ DATE / /

LIMITING SOIL CONCENTRATION CALCULATION

KFLAG variable set to 1

>>> INITIAL ACTIVITY CONVERTED TO MASS (mg) 1.61E+04 Q1 variable converted to mass using Equation 15

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

```
*****
LEACH RATE CONSTANT (1/y) 1.1994E-02 calculated with equation 4
UNSATURATED PORE VELOCITY (m/y) 1.1111E+01 calculated with equation 21
DECAY CONSTANT(S) (1/y) 2.8761E-05 9.8458E-10 calculated with equation 4
RETARDATION FACTOR(S) (SATURATED) 4.1900E+02 1.1500E+02 calculated with equation 26
RETARDATION FACTOR (UNSATURATED) 4.6544E+02 calculated with equation 22
SOLUBILITY LIMITED MASS (mg) 1.4820E+15 calculated with equation 13
SOLUBILITY LIMITED ACTIVITY (Ci) 9.2058E+10 calculated with equation 15 solved for activity
TRANSIT TIME IN UNSAT ZONE (years) 2.0945E+03 calculate with equation 20
FRACTION DECAYED DURING UNSAT TRANSPORT 5.8462E-02 calculated with equation 23
```

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

```
*****
INTEGRATION TIME (years) 1 NTIME
BODY WEIGHT (kg) 7.000E+01 BW
AVERAGING TIME (days) 2.555E+04 AT
WATER INTAKE RATE (L/d) 2.000E+00 WI
EXPOSURE FREQUENCY (days/year) 3.500E+02 EF
EXPOSURE DURATION (years) 7.000E+01 ED
```

RADIOLOGICAL DOSE LIMIT (rem/y) 4.000E-03
 CARCINOGENIC RISK CRITERIA 1.000E-06
 HAZARD QUOTIENT 1.000E+00

DLIM
 CRISK
 HQ

>>> RESULTS OF CALCULATIONS

MAXIMUM RADIONUCLIDE CONCENTRATION CALCULATION

DECAY-INGROWTH FACTORS 9.4104E-01 2.0185E-06

MAXIMUM PARENT CONCENTRATION ADJUSTED FOR PROGENY = 1.50E-12 Ci/L

NOTE: PROGENY CONCENTRATIONS ARE REPORTED AT THE TIME OF THE MAXIMUM PARENT CONCENTRATION

MAXIMUM CONCENTRATION FOR MBR #1: 1.18E-10 Ci/L

AVERAGE CONCENTRATION FOR MBR #1: 1.18E-10 Ci/L

MAXIMUM CONCENTRATION FOR MBR #2: 9.23E-16 Ci/L

AVERAGE CONCENTRATION FOR MBR #2: 9.23E-16 Ci/L

PEAK TIME (y): 2.113015E+03

LIMITING SOIL CONCENTRATION (Ci/m³): 2.031E-06

LIMITING SOIL CONCENTRATION (Ci/kg): 1.354E-09

LIMITING SOIL AMOUNT (Ci): 1.270E-02

LIMITING SOIL AMOUNT (mg): 2.044E+02

SPECIFIC ACTIVITY (Ci/g): 6.212E-02

EXECUTION TIME (seconds) 0

decay ingrowth factors calculated with Equation 33

see Equation A-1

maximum concentration for number #1 at the peak time

concentration averaged over consumption period

maximum concentration for number #2 at time 2113 y

concentration averaged over consumption period

time of maximum parent (number #1) concentration

limiting soil concentration as given by equation 34

limiting soil concentration in activity per kg

limiting inventory of activity in the source volume

limiting inventory converted to mass

activity of the nuclide per mass of its element.

computer run time, zero if less than 1 second

Sample Problem 2: Input File

EXAMPLE PROBLEM #2; Sr-90 limit based on MCL of 8 pCi/L in 40 CFR 141

1 0	KFLAG
30	INTIME
25.0 25.0 1.00	AL WA THICKS
1.0 0.35 0.090	PERC THETAS THETAU
1.5 24.0 0.0	RHOS zKDS RC2
1.9 24.0	RHOU zKDU
28.5	THALF
1.0 90.0 1.0e6	QI ZMW SL
2.0 0.10 24.0	RHOA PHI zKDA
1.0e-3 5.0e-4 570.	AX AY VX
15.0 5.0	THICK DEPTH
3 1	IMODE IMODEL
1. 1. 1. 1. 1. 25.	RMI TOPER PNOFLX THETAP EVAP WAEFF
1.44e-12	DCF-RADMAX-NRADMAX-SFACTOR-RFD
0.0, 0.	XD YD
70.0 2.555E+04 2.0 350. 30. 0.004 1.0E-6 1.0	BW AT WI EF ED DLIM CRISK HQ
1 6 11 1.0E-2	ISOLVE JMAX EPS

Output File

TIME OF RUN 16:52:54.8

DATE OF RUN 06/21/93

INPUT FILE NAME: pb-2.par

OUTPUT FILE NAME: pb-2.out

ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND LIMITATION OF LIABILITY

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```
*****
*
*   This output was produced by the model:
*
*   GWScreen
*   Version Control Copy, Version 2.0
*   A semi-analytical model for the assessment
*   of the groundwater pathway from the leaching
*   of surficial and buried contamination and
*   release of contaminants from percolation ponds
*   6-20-93
*   Arthur S. Rood
*   Idaho National Engineering Laboratory
*   EG&G Idaho Inc.
*   Subsurface and Environmental Modeling Unit
*   PO Box 1625
*   Idaho Falls, Idaho 83415
*****
```

>>> TITLE OF PROJECT:
'EXAMPLE PROBLEM #2; Sr-90 limit based on MCL of 8 pCi/L in 40 CFR 141

GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 3

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

```
*****
NUMBER OF RADIOACTIVE PROGENY          0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)  2.50E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)  2.50E+01
THICKNESS OF SOURCE (m)  1.00E+00
PERCOLATION RATE (darcy vel m/y)  1.00E+00
VOLUMETRIC WATER CONTENT IN SOURCE  3.50E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE  9.00E-02
BULK DENSITY AT SOURCE (g/cm**3)  1.50E+00
SORPTION COEFFICIENT AT SOURCE (ml/g)  2.40E+01
BULK DENSITY IN UNSAT ZONE (g/cm**3)  1.90E+00
UNSATURATED ZONE THICKNESS (m)  5.00E+00
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)  2.40E+01
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**(-1))  0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci)  1.00E+00
MOLECULAR WEIGHT (g/mole)  9.00E+01
SOLUBILITY LIMIT (mg/L)  1.00E+06
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)  2.85E+01
BULK DENSITY OF AQUIFER (g/cm**3)  2.00E+00
POROSITY OF AQUIFER  1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)  2.40E+01
DISPERSIVITY X DIRECTION (m)  1.00E-03
DISPERSIVITY Y DIRECTION (m)  5.00E-04
PORE VELOCITY (m/y)  5.70E+02
WELL SCREEN THICKNESS (m)  1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS (m)  0.00E+00
DISTANCE TO RECEPTOR ALONG Y AXIS (m)  0.00E+00
LIMITING RADIONUCLIDE GW CONCENTRATION (Ci/L)  1.44E-12
UNITS OF CONTAMINANT  Ci
```

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

LIMITING SOIL CONCENTRATION CALCULATION
 >>> INITIAL ACTIVITY CONVERTED TO MASS (mg) 7.17E+00
 >>> VALUES CALCULATED IN SOURCE SUBROUTINE

 LEACH RATE CONSTANT (1/y) 2.7510E-02
 UNSATURATED PORE VELOCITY (m/y) 1.1111E+01
 DECAY CONSTANT(S) (1/y) 2.4321E-02
 RETARDATION FACTOR(S) (SATURATED) 4.8100E+02
 RETARDATION FACTOR (UNSATURATED) 5.0767E+02
 SOLUBILITY LIMITED MASS (mg) 2.2719E+13
 SOLUBILITY LIMITED ACTIVITY (Ci) 3.1690E+12
 TRANSIT TIME IN UNSAT ZONE (years) 2.2845E+02
 FRACTION DECAYED DURING UNSAT TRANSPORT 9.9614E-01

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

 INTEGRATION TIME (years) 30
 BODY WEIGHT (kg) 7.000E+01
 AVERAGING TIME (days) 2.555E+04
 WATER INTAKE RATE (L/d) 2.000E+00
 EXPOSURE FREQUENCY (days/year) 3.500E+02
 EXPOSURE DURATION (years) 3.000E+01
 RADIOLOGICAL DOSE LIMIT (rem/y) 4.000E-03
 CARCINOGENIC RISK CRITERIA 1.000E-06
 HAZARD QUOTIENT 1.000E+00

>>> RESULTS OF CALCULATIONS

 MAXIMUM RADIONUCLIDE CONCENTRATION CALCULATION
 MAXIMUM PARENT CONCENTRATION ADJUSTED FOR PROGENY = 1.44E-12 Ci/L
 MAXIMUM CONCENTRATION FOR MBR #1: 1.66E-12 Ci/L
 AVERAGE CONCENTRATION FOR MBR #1: 1.02E-12 Ci/L
 PEAK TIME (y): 2.390078E+02
 LIMITING SOIL CONCENTRATION (Ci/m**3): 2.258E-03
 LIMITING SOIL CONCENTRATION (Ci/kg): 1.505E-06
 LIMITING SOIL AMOUNT (Ci): 1.411E+00
 LIMITING SOIL AMOUNT (mg): 1.012E+01
 SPECIFIC ACTIVITY (Ci/g): 1.395E+02
 EXECUTION TIME (seconds) 0

Sample Problem 3a: Input File

EXAMPLE #3A, Hg (Hg2CO3);30 year chronic exposure;50 m interbeds;Flood Scenario
 1 0 KFLAG NPROG
 30 INTIME
 25.0 25.0 1.00 AL WA THICKS
 1.0 0.40 0.40 PERC THETAS THETAU
 1.5 100.0 0.0 RHOS zKDS RC2
 1.9 100.0 RHOU zKDU
 0.0E00 THALF
 2.81e8 461.0 4.5E-02 QI ZMW SL (based on Hg2CO3 form) 1.125e8
 1.9 0.10 100.0 RHOA PHI zKDA
 9.00 4.000 570. AX AY VX
 15.0 50.0 THICK DEPTH
 6 1 IMODE IMODEL
 1. 1. 1. 1. 1. 25. RMI TOPER PNDFLX THETAP EVAP WAEFF
 3.0e-04 DCF-RADMAX-NRADMAX-SFACTOR-RFD
 12.5, 0. XD YD
 70.0 25550. 2.0 350. 30.0 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
 1 6 11 1.0E-2 ISOLVE,JMAX,EPS

Output File

TIME OF RUN 16:52:55.8
DATE OF RUN 06/21/93
INPUT FILE NAME: pb-3a.par
OUTPUT FILE NAME: pb-3a.out

ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND
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*
* This output was produced by the model: *
*
* GWSCREEN *
* Version Control Copy, Version 2.0 *
* A semi-analytical model for the assessment *
* of the groundwater pathway from the leaching *
* of surficial and buried contamination and *
* release of contaminants from percolation ponds *
* 6-20-93 *
* Arthur S. Rood *
* Idaho National Engineering Laboratory *
* EG&G Idaho Inc. *
* Subsurface and Environmental Modeling Unit *
* PO Box 1625 *
* Idaho Falls, Idaho 83415 *

>>> TITLE OF PROJECT:
EXAMPLE #3A, Hg (Hg2CO3);30 year chronic exposure;50 m interbeds;Flood Scenari

GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 6

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY 0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m) 2.50E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m) 2.50E+01
THICKNESS OF SOURCE (m) 1.00E+00
PERCOLATION RATE (darcy vel m/y) 1.00E+00
VOLUMETRIC WATER CONTENT IN SOURCE 4.00E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE 4.00E-01
BULK DENSITY AT SOURCE (g/cm**3) 1.50E+00
SORPTION COEFFICIENT AT SOURCE (ml/g) 1.00E+02
BULK DENSITY IN UNSAT ZONE (g/cm**3) 1.90E+00
UNSATURATED ZONE THICKNESS (m) 5.00E+01
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g) 1.00E+02
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1) 0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci) 2.81E+08

MOLECULAR WEIGHT (g/mole)	4.61E+02
SOLUBILITY LIMIT (mg/L)	4.50E-02
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)	1.00E+38
BULK DENSITY OF AQUIFER (g/cm ³)	1.90E+00
POROSITY OF AQUIFER	1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)	1.00E+02
DISPERSIVITY X DIRECTION (m)	9.00E+00
DISPERSIVITY Y DIRECTION (m)	4.00E+00
PORE VELOCITY (m/y)	5.70E+02
WELL SCREEN THICKNESS (m)	1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS (m)	1.25E+01
DISTANCE TO RECEPTOR ALONG Y AXIS (m)	0.00E+00
NON-CARCINOGENIC REFERENCE DOSE RfD (mg/kg/d)	3.00E-04
UNITS OF CONTAMINANT	mg

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

LIMITING SOIL CONCENTRATION CALCULATION

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y)	6.6489E-03
UNSATURATED PORE VELOCITY (m/y)	2.5000E+00
DECAY CONSTANT(S) (1/y)	0.0000E+00
RETARDATION FACTOR(S) (SATURATED)	1.9010E+03
RETARDATION FACTOR (UNSATURATED)	4.7600E+02
SOLUBILITY LIMITED MASS (mg)	4.2300E+06
SOLUBILITY LIMITED ACTIVITY (Ci)	0.0000E+00
TRANSIT TIME IN UNSAT ZONE (years)	9.5200E+03
FRACTION DECAYED DURING UNSAT TRANSPORT	0.0000E+00

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

INTEGRATION TIME (years)	30
BODY WEIGHT (kg)	7.000E+01
AVERAGING TIME (days)	2.555E+04
WATER INTAKE RATE (L/d)	2.000E+00
EXPOSURE FREQUENCY (days/year)	3.500E+02
EXPOSURE DURATION (years)	3.000E+01
RADIOLOGICAL DOSE LIMIT (rem/y)	4.000E-03
CARCINOGENIC RISK CRITERIA	1.000E-06
HAZARD QUOTIENT	1.000E+00

>>> RESULTS OF CALCULATIONS

LIMITING GROUNDWATER CONCENTRATION (mg/L):	2.55E-02
MAXIMUM GROUNDWATER CONCENTRATION (mg/L):	3.01E-02
AVERAGE GROUNDWATER CONCENTRATION (mg/L):	3.00E-02
HAZARD QUOTIENT FOR INPUT MASS:	1.17E+00
PEAK TIME (y):	9.617586E+03
LIMITING SOIL CONCENTRATION (mg/m ³):	3.835E+05
LIMITING SOIL CONCENTRATION (mg/kg):	2.557E+02
LIMITING SOIL AMOUNT (mg):	2.397E+08
WARNING !!! THE LIMITING SOIL MASS OF 2.397E+08 mg	
EXCEEDS THE SOLUBILITY LIMITED SOURCE MASS OF 4.230E+06 mg	
EXECUTION TIME (seconds)	1

Sample Problem 3b: Input File

EXAMPLE #3A, Hg (Hg2CO3);30 year chronic exposure;50 m interbeds;Flood Scenario	
0 0	KFLAG NPROG
30	INTIME
25.0 25.0 1.00	AL WA THICKS

```

1.0 0.40 0.40      PERC THETAS THETAU
1.5 100.0 0.0      RHOS ZKDS RC2
1.9 100.0          RHOU ZKDU
0.0800            THALF
2.81e8 441.0 4.5E-02  QI ZMW SL (based on Hg2CO3 form) 1.125e8
1.9 0.10 100.0      RHQA PHI ZKDA
9.00 4.000 570.      AX AY VX
15.0 50.0           THICK DEPTH
6 1                INODE INODEL
1. 1. 1. 1. 1. 25.  RMI TOPER PNOFLX THETAP EVAP
3.0e-04            DCF-RADMAX-NRADMAX-SFACTOR-RFD
12.5, 0.           XD YD
70.0 25550. 2.0 350. 30.0 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HG
1 6 11 1.0E-2       ISOLVE,JMAX,EPS
1                  ntimes
19000.,1.952e4 ,10.  t1 t2 tp

```

Output File

TIME OF RUN 16:52:57.8
DATE OF RUN 06/21/93
INPUT FILE NAME: pb-3b.par
OUTPUT FILE NAME: pb-3b.lst

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```

*****
*
*   This output was produced by the model:
*
*   GWSCREEN
*   Version Control Copy, Version 2.0
*   A semi-analytical model for the assessment
*   of the groundwater pathway from the leaching
*   of surficial and buried contamination and
*   release of contaminants from percolation ponds
*   6-20-93
*   Arthur S. Rood
*   Idaho National Engineering Laboratory
*   EG&G Idaho Inc.
*   Subsurface and Environmental Modeling Unit
*   PO Box 1625
*   Idaho Falls, Idaho 83415
*****

```

>>> TITLE OF PROJECT:
EXAMPLE #3A, Hg (Hg2CO3);30 year chronic exposure;50 m interbeds;Flood Scenari

GAUSSIAN QUADRATURE SOLUTION
MODEL OPTIONS
IMODE: 6
KFLAG: 0 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY 0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m) 2.50E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m) 2.50E+01
THICKNESS OF SOURCE (m) 1.00E+00
PERCOLATION RATE (darcy vel m/y) 1.00E+00
VOLUMETRIC WATER CONTENT IN SOURCE 4.00E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE 4.00E-01
BULK DENSITY AT SOURCE (g/cm**3) 1.50E+00
SORPTION COEFFICIENT AT SOURCE (ml/g) 1.00E+02
BULK DENSITY IN UNSAT ZONE (g/cm**3) 1.90E+00
UNSATURATED ZONE THICKNESS (m) 5.00E+01
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g) 1.00E+02
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1) 0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci) 2.81E+08
MOLECULAR WEIGHT (g/mole) 4.61E+02
SOLUBILITY LIMIT (mg/L) 4.50E-02
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y) 1.00E+38
BULK DENSITY OF AQUIFER (g/cm**3) 1.90E+00
POROSITY OF AQUIFER 1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g) 1.00E+02
DISPERSIVITY X DIRECTION (m) 9.00E+00
DISPERSIVITY Y DIRECTION (m) 4.00E+00
PORE VELOCITY (m/y) 5.70E+02
WELL SCREEN THICKNESS (m) 1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS (m) 1.25E+01
DISTANCE TO RECEPTOR ALONG Y AXIS (m) 0.00E+00
NON-CARCINOGENIC REFERENCE DOSE RfD (mg/kg/d) 3.00E-04
UNITS OF CONTAMINANT mg

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y) 6.6489E-03
UNSATURATED PORE VELOCITY (m/y) 2.5000E+00
DECAY CONSTANT(S) (1/y) 0.0000E+00
RETARDATION FACTOR(S) (SATURATED) 1.9010E+03
RETARDATION FACTOR (UNSATURATED) 4.7600E+02
SOLUBILITY LIMITED MASS (mg) 4.2300E+06
SOLUBILITY LIMITED ACTIVITY (Ci) 0.0000E+00
TRANSIT TIME IN UNSAT ZONE (years) 9.5200E+03
FRACTION DECAYED DURING UNSAT TRANSPORT 0.0000E+00

>>> SOLUBILITY LIMITED RELEASE FOR 9.8407E+03 YEARS

>>> CONCENTRATION VS TIME MODE

TIME (years)	CUMULATIVE SOURCE FLUX (mg)	CUMULATIVE AQUIFER FLUX (mg)	AQUIFER FLUX (mg/year)	GW CONC ... member #1 (mg/m**3)
1.9000E+04	2.8100E+08	2.6663E+08	2.8125E+04	8.8504E-01
1.9010E+04	2.8100E+08	2.6691E+08	2.8125E+04	8.8504E-01
1.9020E+04	2.8100E+08	2.6719E+08	2.8125E+04	8.8504E-01
1.9030E+04	2.8100E+08	2.6747E+08	2.8125E+04	8.8504E-01
1.9040E+04	2.8100E+08	2.6775E+08	2.8125E+04	8.8504E-01
1.9050E+04	2.8100E+08	2.6803E+08	2.8125E+04	8.8504E-01
1.9060E+04	2.8100E+08	2.6831E+08	2.8125E+04	8.8504E-01
1.9070E+04	2.8100E+08	2.6859E+08	2.8125E+04	8.8504E-01
1.9080E+04	2.8100E+08	2.6888E+08	2.8125E+04	8.8504E-01

1.9090E+04	2.8100E+08	2.6916E+08	2.8125E+04	8.8504E-01
1.9100E+04	2.8100E+08	2.6944E+08	2.8125E+04	8.8504E-01
1.9110E+04	2.8100E+08	2.6972E+08	2.8125E+04	8.8504E-01
1.9120E+04	2.8100E+08	2.7000E+08	2.8125E+04	8.8504E-01
1.9130E+04	2.8100E+08	2.7028E+08	2.8125E+04	8.8504E-01
1.9140E+04	2.8100E+08	2.7056E+08	2.8125E+04	8.8504E-01
1.9150E+04	2.8100E+08	2.7084E+08	2.8125E+04	8.8504E-01
1.9160E+04	2.8100E+08	2.7113E+08	2.8125E+04	8.8504E-01
1.9170E+04	2.8100E+08	2.7141E+08	2.8125E+04	8.8504E-01
1.9180E+04	2.8100E+08	2.7169E+08	2.8125E+04	8.8504E-01
1.9190E+04	2.8100E+08	2.7197E+08	2.8125E+04	8.8504E-01
1.9200E+04	2.8100E+08	2.7225E+08	2.8125E+04	8.8504E-01
1.9210E+04	2.8100E+08	2.7253E+08	2.8125E+04	8.8504E-01
1.9220E+04	2.8100E+08	2.7281E+08	2.8125E+04	8.8504E-01
1.9230E+04	2.8100E+08	2.7309E+08	2.8125E+04	8.8504E-01
1.9240E+04	2.8100E+08	2.7338E+08	2.8125E+04	8.8504E-01
1.9250E+04	2.8100E+08	2.7366E+08	2.8125E+04	8.8504E-01
1.9260E+04	2.8100E+08	2.7394E+08	2.8125E+04	8.8504E-01
1.9270E+04	2.8100E+08	2.7422E+08	2.8125E+04	8.8504E-01
1.9280E+04	2.8100E+08	2.7450E+08	2.8125E+04	8.8504E-01
1.9290E+04	2.8100E+08	2.7478E+08	2.8125E+04	8.8504E-01
1.9300E+04	2.8100E+08	2.7506E+08	2.8125E+04	8.8504E-01
1.9310E+04	2.8100E+08	2.7534E+08	2.8125E+04	8.8504E-01
1.9320E+04	2.8100E+08	2.7563E+08	2.8125E+04	8.8504E-01
1.9330E+04	2.8100E+08	2.7591E+08	2.8125E+04	8.8504E-01
1.9340E+04	2.8100E+08	2.7619E+08	2.8125E+04	8.8504E-01
1.9350E+04	2.8100E+08	2.7647E+08	2.8125E+04	8.8504E-01
1.9360E+04	2.8100E+08	2.7675E+08	2.8125E+04	8.8504E-01
1.9370E+04	2.8100E+08	2.7702E+08	2.6441E+04	8.8275E-01
1.9380E+04	2.8100E+08	2.7728E+08	2.4740E+04	8.7049E-01
1.9390E+04	2.8100E+08	2.7752E+08	2.3148E+04	8.5902E-01
1.9400E+04	2.8100E+08	2.7774E+08	2.1659E+04	8.4829E-01
1.9410E+04	2.8100E+08	2.7795E+08	2.0266E+04	8.1644E-01
1.9420E+04	2.8100E+08	2.7815E+08	1.8962E+04	7.8640E-01
1.9430E+04	2.8100E+08	2.7833E+08	1.7742E+04	7.5829E-01
1.9440E+04	2.8100E+08	2.7850E+08	1.6601E+04	7.3198E-01
1.9450E+04	2.8100E+08	2.7866E+08	1.5533E+04	7.0737E-01
1.9460E+04	2.8100E+08	2.7881E+08	1.4534E+04	6.8048E-01
1.9470E+04	2.8100E+08	2.7895E+08	1.3599E+04	6.4551E-01
1.9480E+04	2.8100E+08	2.7909E+08	1.2724E+04	6.1278E-01
1.9490E+04	2.8100E+08	2.7921E+08	1.1906E+04	5.8215E-01
1.9500E+04	2.8100E+08	2.7932E+08	1.1140E+04	5.5350E-01
1.9510E+04	2.8100E+08	2.7943E+08	1.0423E+04	5.2669E-01
1.9520E+04	2.8100E+08	2.7953E+08	9.7528E+03	5.0160E-01

AVERAGE INTEGRATED CONCENTRATION FROM 1.9000E+04 TO 1.9520E+04 YEARS = 8.35E-01 mg/m**3
 MAXIMUM CONCENTRATION(S) mg/m**3
 8.85E-01
 TIME(S) OF MAXIMUM CONCENTRATIONS (years)
 1.90E+04
 EXECUTION TIME (seconds) 3

Sample problem 4: Input File

'EXAMPLE PROBLEM #4 TCDD dioxin storage at Biloxi Mississippi GWS V 2.0'					TITLE
1	0				KFLAG
30					INTIME
250.0	250.0	0.61			AL WA THICKS
0.58	0.125	0.125			PERC THETAS THETAU
2.0	1.65E+03	0.00693			RHOS zKDS RC2
2.0	1.65E+03				RHOJ zKDU
0.0E+00					THALF
7.6e4	322.0	2.0E-04			QI ZMW SL
2.0	0.25	1.65E+03			RHOA PHI zKDA
30.9	9.0	50.6			AX AY VX
5.0	1.0				THICK DEPTH

5 1 IMODE IMODEL
 1. 1. 1. 1. 1. 250. RMI TOPER PNDFLX THETAP EVAP WAEFF
 1.50e5 DCF-RADMAX-NRADMAX-SFACTOR-RFD
 152.0, 0. XD YD
 70.0 2.555E+04 2.0 350. 30. 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
 1 6 10 1.0E-2 ISOLVE,JMAX,EPS
 Degredation rate of TCDD in soil based on 100 year half time. No degradation
 assumed for groundwater.
 Kd based on Koc of 3.3E6 ml/g and foc of 5E-4

Output File

TIME OF RUN 16:53:01.5
 DATE OF RUN 06/21/93
 INPUT FILE NAME: pb-4.par
 OUTPUT FILE NAME: pb-4.out

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 *
 * This output was produced by the model: *
 * *
 * GWSCREEN *
 * Version Control Copy, Version 2.0 *
 * A semi-analytical model for the assessment *
 * of the groundwater pathway from the leaching *
 * of surficial and buried contamination and *
 * release of contaminants from percolation ponds *
 * 6-20-93 *
 * Arthur S. Rood *
 * Idaho National Engineering Laboratory *
 * EG&G Idaho Inc. *
 * Subsurface and Environmental Modeling Unit *
 * PO Box 1625 *
 * Idaho Falls, Idaho 83415 *

>>> TITLE OF PROJECT:
 'EXAMPLE PROBLEM #4 TCDD dioxin storage at Biloxi Mississippi GWS V 2.0' TIT

----- GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 5

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY 0
 LENGTH OF SOURCE PARALLEL TO GW FLOW (m) 2.50E+02
 WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m) 2.50E+02
 THICKNESS OF SOURCE (m) 6.10E-01

PERCOLATION RATE (darcy vel m/y)	5.80E-01
VOLUMETRIC WATER CONTENT IN SOURCE	1.25E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE	1.25E-01
BULK DENSITY AT SOURCE (g/cm**3)	2.00E+00
SORPTION COEFFICIENT AT SOURCE (ml/g)	1.65E+03
BULK DENSITY IN UNSAT ZONE (g/cm**3)	2.00E+00
UNSATURATED ZONE THICKNESS (m)	1.00E+00
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)	1.65E+03
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1)	6.93E-03
INITIAL MASS OR ACTIVITY (mg or Ci)	7.60E+04
MOLECULAR WEIGHT (g/mole)	3.22E+02
SOLUBILITY LIMIT (mg/L)	2.00E-04
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)	1.00E+38
BULK DENSITY OF AQUIFER (g/cm**3)	2.00E+00
POROSITY OF AQUIFER	2.50E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)	1.65E+03
DISPERSIVITY X DIRECTION (m)	3.09E+01
DISPERSIVITY Y DIRECTION (m)	9.00E+00
PORE VELOCITY (m/y)	5.06E+01
WELL SCREEN THICKNESS (m)	5.00E+00
DISTANCE TO RECEPTOR ALONG X AXIS (m)	1.52E+02
DISTANCE TO RECEPTOR ALONG Y AXIS (m)	0.00E+00
CARCINOGENIC SLOPE FACTOR (mg/kg/d)**-1	1.50E+05
UNITS OF CONTAMINANT	mg

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

***** LIMITING SOIL CONCENTRATION CALCULATION

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y)	2.8812E-04
UNSATURATED PORE VELOCITY (m/y)	4.6400E+00
DECAY CONSTANT(S) (1/y)	0.0000E+00
RETARDATION FACTOR(S) (SATURATED)	1.3201E+04
RETARDATION FACTOR (UNSATURATED)	2.6401E+04
SOLUBILITY LIMITED MASS (mg)	2.5163E+07
SOLUBILITY LIMITED ACTIVITY (Ci)	0.0000E+00
TRANSIT TIME IN UNSAT ZONE (years)	5.6899E+03
FRACTION DECAYED DURING UNSAT TRANSPORT	0.0000E+00

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

INTEGRATION TIME (years)	30
BODY WEIGHT (kg)	7.000E+01
AVERAGING TIME (days)	2.555E+04
WATER INTAKE RATE (L/d)	2.000E+00
EXPOSURE FREQUENCY (days/year)	3.500E+02
EXPOSURE DURATION (years)	3.000E+01
RADIOLOGICAL DOSE LIMIT (rem/y)	4.000E-03
CARCINOGENIC RISK CRITERIA	1.000E-06
HAZARD QUOTIENT	1.000E+00

>>> RESULTS OF CALCULATIONS

CARCINOGENIC RISK CALCULATION

LIMITING GROUNDWATER CONCENTRATION (mg/L):	5.68E-10
MAXIMUM GROUNDWATER CONCENTRATION (mg/L):	2.41E-09
AVERAGE GROUNDWATER CONCENTRATION (mg/L):	2.41E-09
CARCINOGENIC RISK FOR USER INPUT MASS:	4.25E-06
PEAK TIME (y):	3.682187E+04
LIMITING SOIL CONCENTRATION (mg/m**3):	4.693E-01
LIMITING SOIL CONCENTRATION (mg/kg):	2.347E-04

LIMITING SOIL AMOUNT (mg): 1.789E+04
 EXECUTION TIME (seconds) 1

Sample Problem 5: Input File

EXAMPLE PROBLEM #5	Re-226 limiting soil conc INCLUDING Pb-210 GWS V 2.0	TITLE
1 1	KFLAG NPROG	
1	INTIME	
100.0 100.0 5.0	AL WA THICKS	
0.10 0.10 0.15	PERC THETAS THETAU	
1.8 1.0E+02 0.0	RHOS zKDS RC2	
2.0 1.0E+01	RHOU zKDU	
1.60E+03 21.0	THALF(I)	
9.00 226. 1.0	QI ZMW SL	
2.0 0.30 10.0 20	RHOA PHI zKDA(I)	
10.0 1.0 300	AX AY VX	
5.0 25.0	THICK DEPTH	
3 1	IMODE IMODEL	
1. 1. 1. 1. 1. 100.	RMI TOPER PNDFLX THETAP EVAP WAEFF	
20.0E-12 1.0E-12	DCF-RADMAX-NRADMAX-SFACTOR-RFD	
50.0, 0.	XD YD	
70.0 2.555E+04 2.0 350. 70. 0.004	1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ	
1 6 11 1.0E-2	ISOLVE,JMAX,EPS	

Output File

TIME OF RUN 16:53:03.7
 DATE OF RUN 06/21/93
 INPUT FILE NAME: pb-5.par
 OUTPUT FILE NAME: pb-5.out

=====
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=====

 * This output was produced by the model: *
 * *
 * GWSCREEN *
 * Version Control Copy, Version 2.0 *
 * A semi-analytical model for the assessment *
 * of the groundwater pathway from the leaching *
 * of surficial and buried contamination and *
 * release of contaminants from percolation ponds *
 * 6-20-93 *
 * Arthur S. Rood *
 * Idaho National Engineering Laboratory *
 * EG&G Idaho Inc. *
 * Subsurface and Environmental Modeling Unit *
 * PO Box 1625 *

```

*                Idaho Falls, Idaho 83415                *
*****
>>> TITLE OF PROJECT:
EXAMPLE PROBLEM #5  Ra-226 limiting soil conc INCLUDING Pb-210 GWS V 2.0
-----
GAUSSIAN QUADRATURE SOLUTION
MODEL OPTIONS
IMODE: 3
KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC
IMODE:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION
>>> INPUT DATA
*****
NUMBER OF RADIOACTIVE PROGENY                1
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)      1.00E+02
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)   1.00E+02
THICKNESS OF SOURCE (m)                       5.00E+00
PERCOLATION RATE (darcy vel m/y)              1.00E-01
VOLUMETRIC WATER CONTENT IN SOURCE            1.00E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE  1.50E-01
BULK DENSITY AT SOURCE (g/cm**3)              1.80E+00
SORPTION COEFFICIENT AT SOURCE (ml/g)          1.00E+02
BULK DENSITY IN UNSAT ZONE (g/cm**3)          2.00E+00
UNSATURATED ZONE THICKNESS (m)                2.50E+01
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)      1.00E+01
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1) 0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci)            9.00E+00
MOLECULAR WEIGHT (g/mole)                     2.26E+02
SOLUBILITY LIMIT (mg/L)                       1.00E+00
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)    1.60E+03 2.10E+01
BULK DENSITY OF AQUIFER (g/cm**3)             2.00E+00
POROSITY OF AQUIFER                          3.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)      1.00E+01 2.00E+01
DISPERSIVITY X DIRECTION (m)                  1.00E+01
DISPERSIVITY Y DIRECTION (m)                  1.00E+00
PORE VELOCITY (m/y)                           3.00E+02
WELL SCREEN THICKNESS (m)                     5.00E+00
DISTANCE TO RECEPTOR ALONG X AXIS (m)        5.00E+01
DISTANCE TO RECEPTOR ALONG Y AXIS (m)        0.00E+00
LIMITING RADIONUCLIDE GW CONCENTRATION (Ci/L) 2.00E-11 1.00E-12
UNITS OF CONTAMINANT                          Ci

```

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

```

-----
LIMITING SOIL CONCENTRATION CALCULATION
>>> INITIAL ACTIVITY CONVERTED TO MASS (mg)  9.10E+03
>>> VALUES CALCULATED IN SOURCE SUBROUTINE
*****
LEACH RATE CONSTANT (1/y)                    1.1105E-04
UNSATURATED PORE VELOCITY (m/y)              6.6667E-01
DECAY CONSTANT(S) (1/y)                      4.3322E-04 3.3007E-02
RETARDATION FACTOR(S) (SATURATED)            6.7667E+01 1.3433E+02
RETARDATION FACTOR (UNSATURATED)             1.3433E+02
SOLUBILITY LIMITED MASS (mg)                  9.0050E+09
SOLUBILITY LIMITED ACTIVITY (Ci)              8.9102E+06
TRANSIT TIME IN UNSAT ZONE (years)            5.0375E+03
FRACTION DECAYED DURING UNSAT TRANSPORT      8.8722E-01

```

```

-----
>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION
*****
INTEGRATION TIME (years)                      1
BODY WEIGHT (kg)                              7.000E+01
AVERAGING TIME (days)                       2.555E+04

```

WATER INTAKE RATE (L/d)	2.000E+00
EXPOSURE FREQUENCY (days/year)	3.500E+02
EXPOSURE DURATION (years)	7.000E+01
RADIOLOGICAL DOSE LIMIT (rem/y)	4.000E-03
CARCINOGENIC RISK CRITERIA	1.000E-06
HAZARD QUOTIENT	1.000E+00

>>> RESULTS OF CALCULATIONS

MAXIMUM RADIONUCLIDE CONCENTRATION CALCULATION

DECAY-INGROWTH FACTORS 1.0995E-01 1.1141E-01

MAXIMUM PARENT CONCENTRATION ADJUSTED FOR PROGENY = 1.78E-12 Ci/L

NOTE: PROGENY CONCENTRATIONS ARE REPORTED AT THE TIME OF THE MAXIMUM PARENT CONCENTRATION

MAXIMUM CONCENTRATION FOR MBR #1: 2.42E-12 Ci/L

AVERAGE CONCENTRATION FOR MBR #1: 2.42E-12 Ci/L

MAXIMUM CONCENTRATION FOR MBR #2: 1.23E-12 Ci/L

AVERAGE CONCENTRATION FOR MBR #2: 1.23E-12 Ci/L

PEAK TIME (y): 5.096225E+03

LIMITING SOIL CONCENTRATION (Ci/m**3): 1.330E-04

LIMITING SOIL CONCENTRATION (Ci/kg): 7.388E-08

LIMITING SOIL AMOUNT (Ci): 6.649E+00

LIMITING SOIL AMOUNT (mg): 6.720E+03

SPECIFIC ACTIVITY (Ci/g): 9.895E-01

EXECUTION TIME (seconds) 0

Sample Problem 6a: Input File

EXAMPLE PROBLEM #6 for users manual Ni-59 solubility limited release GWS V 2.0

TITLE

1 0

KFLAG NPROG

1

INTIME

100.0 100.0 5.0

AL WA THICKS

0.10 0.10 0.15

PERC THETAS THETAU

1.8 2.0E-1 0.0

RHOS zKDS RC2

2.0 8.0

RHOU zKDU

7.5E+04

THALF(1)

1000.0 59. 3.6E-3

QI ZMW SL

2.0 0.30 10.0

RHOA PHI zKDA

10.0 1.0 300

AX AY VX

5.0 0.5

THICK DEPTH

1 1

IMODEL

1. 1. 1. 1. 100

RMI TOPER PNDFLX THETAP EVAP

2.0E+02

DCF- value includes Th-234 contribution

50.0, 0.

XD YD

70.0 2.555E+04 2.0 350. 70. 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ

ISOLVE,JMAX,EPS

1 6 11 1.0E-2

Output File

TIME OF RUN 16:53:05.2

DATE OF RUN 06/21/93

INPUT FILE NAME: pb-6a.par

OUTPUT FILE NAME: pb-6a.out

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```

*                                     *
*   This output was produced by the model:   *
*                                     *
*           GWSCREEN                     *
*   Version Control Copy, Version 2.0       *
*   A semi-analytical model for the assessment *
*   of the groundwater pathway from the leaching *
*   of surficial and buried contamination and *
*   release of contaminants from percolation ponds *
*           6-20-93                     *
*           Arthur S. Rood               *
*   Idaho National Engineering Laboratory   *
*           EG&G Idaho Inc.             *
*   Subsurface and Environmental Modeling Unit *
*           PO Box 1625                 *
*           Idaho Falls, Idaho 83415     *
*                                     *
*****

```

>>> TITLE OF PROJECT:

EXAMPLE PROBLEM #6 for users manual NI-59 solubility limited release GWS V 2.

GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 1

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY	0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)	1.00E+02
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)	1.00E+02
THICKNESS OF SOURCE (m)	5.00E+00
PERCOLATION RATE (darcy vel m/y)	1.00E-01
VOLUMETRIC WATER CONTENT IN SOURCE	1.00E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE	1.50E-01
BULK DENSITY AT SOURCE (g/cm**3)	1.80E+00
SORPTION COEFFICIENT AT SOURCE (ml/g)	2.00E-01
BULK DENSITY IN UNSAT ZONE (g/cm**3)	2.00E+00
UNSATURATED ZONE THICKNESS (m)	5.00E-01
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)	8.00E+00
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1)	0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci)	1.00E+03
MOLECULAR WEIGHT (g/mole)	5.90E+01
SOLUBILITY LIMIT (mg/L)	3.60E-03
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)	7.50E+04
BULK DENSITY OF AQUIFER (g/cm**3)	2.00E+00
POROSITY OF AQUIFER	3.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)	1.00E+01
DISPERSIVITY X DIRECTION (m)	1.00E+01
DISPERSIVITY Y DIRECTION (m)	1.00E+00
PORE VELOCITY (m/y)	3.00E+02
WELL SCREEN THICKNESS (m)	5.00E+00
DISTANCE TO RECEPTOR ALONG X AXIS (m)	5.00E+01
DISTANCE TO RECEPTOR ALONG Y AXIS (m)	0.00E+00
RADIOLOGICAL DOSE CONVERSION FACTOR (rem/Ci)	2.00E+02
UNITS OF CONTAMINANT	Ci

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

LIMITING SOIL CONCENTRATION CALCULATION

>>> INITIAL ACTIVITY CONVERTED TO MASS (mg) 1.24E+07

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y)	4.3478E-02
UNSATURATED PORE VELOCITY (m/y)	6.6667E-01
DECAY CONSTANT(S) (1/y)	9.2420E-06
RETARDATION FACTOR(S) (SATURATED)	6.7667E+01
RETARDATION FACTOR (UNSATURATED)	1.0767E+02
SOLUBILITY LIMITED MASS (mg)	8.2800E+04
SOLUBILITY LIMITED ACTIVITY (Ci)	6.6949E+00
TRANSIT TIME IN UNSAT ZONE (years)	8.0730E+01
FRACTION DECAYED DURING UNSAT TRANSPORT	7.4601E-04

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

INTEGRATION TIME (years)	1
BODY WEIGHT (kg)	7.000E+01
AVERAGING TIME (days)	2.535E+04
WATER INTAKE RATE (L/d)	2.000E+00
EXPOSURE FREQUENCY (days/year)	3.500E+02
EXPOSURE DURATION (years)	7.000E+01
RADIOLOGICAL DOSE LIMIT (rem/y)	4.000E-03
CARCINOGENIC RISK CRITERIA	1.000E-06
HAZARD QUOTIENT	1.000E+00

>>> RESULTS OF CALCULATIONS

COMMITTED EFFECTIVE DOSE EQUIVALENT CALCULATION

COMPOSITE DOSE CONVERSION FACTOR (rem/Ci): 2.00E+02

LIMITING GROUNDWATER CONCENTRATION (Ci/L): 2.86E-08

MAXIMUM CONCENTRATION FOR MBR #1: 4.59E-07 Ci/L CEDE = 6.43E-02 rem

MAXIMUM CEDE 6.43E-02 rem

PEAK TIME (y): 1.038484E+02

LIMITING SOIL CONCENTRATION (Ci/m**3): 1.245E-03

LIMITING SOIL CONCENTRATION (Ci/kg): 6.915E-07

LIMITING SOIL AMOUNT (Ci): 6.223E+01

LIMITING SOIL AMOUNT (mg): 7.696E+05

SPECIFIC ACTIVITY (Ci/g): 8.086E-02

WARNING !!! THE LIMITING SOIL MASS OF 7.696E+05 mg

EXCEEDS THE SOLUBILITY LIMITED SOURCE MASS OF 8.280E+04 mg

EXECUTION TIME (seconds) 0

Sample Problem 6b: Input File

EXAMPLE PROBLEM #6b for users manual M1-59 solu limited release GWS V 2.0

TITLE

0 0	KFLAG NPROG
1	INTIME
100.0 100.0 5.0	AL WA THICKS
0.10 0.10 0.15	PERC THETAS THETAU
1.8 2.0E-1 0.0	RHOS zKDS RC2
2.0 8.0	RHOU zKDU
7.5E+04	THALF
1000.0 59. 3.6E-3	Q1 ZMW SL
2.0 0.30 10.0	RHOA PHI zKDA
10.0 1.0 300	AX AY VX
5.0 0.5	THICK DEPTH
1 1	IMODE IMODEL
1. 1. 1. 1. 100.	RMI TOPER PNDFLX THETAP EVAP WAEFF
2.0E+02	DCF- value includes Th-234 contribution
50.0, 0.	XD YD

```

70.0 2.555E+04 2.0 350. 70. 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
1 6 11 1.0E-2 ISOLVE,JMAX,EPS
5 NTIMES
100. 130. 3. T1 T2 TP
130. 160. 3. T1 T2 TP
160. 190. 3. T1 T2 TP
210. 3000. 200. T1 T2 TP
3075. 5000. 75. T1 T2 TP

```

Output File

```

TIME OF RUN 16:53:06.7
DATE OF RUN 06/21/93
INPUT FILE NAME: pb-6b.par
OUTPUT FILE NAME: pb-6b.lst

```

***** ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND LIMITATION OF LIABILITY

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```

*****
*
*   This output was produced by the model:
*
*   GWSCREEN
*   Version Control Copy, Version 2.0
*   A semi-analytical model for the assessment
*   of the groundwater pathway from the leaching
*   of surficial and buried contamination and
*   release of contaminants from percolation ponds
*   6-20-93
*   Arthur S. Rood
*   Idaho National Engineering Laboratory
*   EG&G Idaho Inc.
*   Subsurface and Environmental Modeling Unit
*   PO Box 1625
*   Idaho Falls, Idaho 83415
*****

```

```

>>> TITLE OF PROJECT:
EXAMPLE PROBLEM #6b for users manual Ni-59 solubility limited release GWS V 2

```

----- GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 1

KFLAG: 0 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

```

*****
NUMBER OF RADIOACTIVE PROGENY          0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m) 1.00E+02
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m) 1.00E+02
THICKNESS OF SOURCE (m)                5.00E+00

```

PERCOLATION RATE (darcy vel m/y) 1.00E-01
 VOLUMETRIC WATER CONTENT IN SOURCE 1.00E-01
 VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE 1.50E-01
 BULK DENSITY AT SOURCE (g/cm**3) 1.80E+00
 SORPTION COEFFICIENT AT SOURCE (ml/g) 2.00E-01
 BULK DENSITY IN UNSAT ZONE (g/cm**3) 2.00E+00
 UNSATURATED ZONE THICKNESS (m) 5.00E-01
 SORPTION COEFFICIENT IN UNSAT ZONE (ml/g) 8.00E+00
 OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y** -1) 0.00E+00
 INITIAL MASS OR ACTIVITY (mg or Ci) 1.00E+03
 MOLECULAR WEIGHT (g/mole) 5.90E+01
 SOLUBILITY LIMIT (mg/L) 3.60E-03
 HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y) 7.50E+04
 BULK DENSITY OF AQUIFER (g/cm**3) 2.00E+00
 POROSITY OF AQUIFER 3.00E-01
 SORPTION COEFFICIENT(S) IN AQUIFER (ml/g) 1.00E+01
 DISPERSIVITY X DIRECTION (m) 1.00E+01
 DISPERSIVITY Y DIRECTION (m) 1.00E+00
 PORE VELOCITY (m/y) 3.00E+02
 WELL SCREEN THICKNESS (m) 5.00E+00
 DISTANCE TO RECEPTOR ALONG X AXIS (m) 5.00E+01
 DISTANCE TO RECEPTOR ALONG Y AXIS (m) 0.00E+00
 RADIOLOGICAL DOSE CONVERSION FACTOR (rem/Ci) 2.00E+02
 UNITS OF CONTAMINANT Ci

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

>>> INITIAL ACTIVITY CONVERTED TO MASS (mg) 1.24E+07
 >>> VALUES CALCULATED IN SOURCE SUBROUTINE

 LEACH RATE CONSTANT (1/y) 4.3478E-02
 UNSATURATED PORE VELOCITY (m/y) 6.6667E-01
 DECAY CONSTANT(S) (1/y) 9.2420E-06
 RETARDATION FACTOR(S) (SATURATED) 6.7667E+01
 RETARDATION FACTOR (UNSATURATED) 1.0767E+02
 SOLUBILITY LIMITED MASS (mg) 8.2800E+04
 SOLUBILITY LIMITED ACTIVITY (Ci) 6.6949E+00
 TRANSIT TIME IN UNSAT ZONE (years) 8.0750E+01
 FRACTION DECAYED DURING UNSAT TRANSPORT 7.4601E-04

>>> SOLUBILITY LIMITED RELEASE FOR 3.3590E+03 YEARS
 >>> CONCENTRATION VS TIME MODE

TIME (years)	CUMULATIVE SOURCE FLUX (Ci)	CUMULATIVE AQUIFER FLUX (Ci)	AQUIFER FLUX (Ci/year)	GW CONC ... member #1 (Ci/m**3)
1.0000E+02	2.9108E+01	5.5992E+00	2.9087E-01	4.4372E-06
1.0300E+02	2.9982E+01	6.4718E+00	2.9087E-01	4.9170E-06
1.0600E+02	3.0855E+01	7.3444E+00	2.9087E-01	5.2983E-06
1.0900E+02	3.1728E+01	8.2170E+00	2.9087E-01	5.5942E-06
1.1200E+02	3.2601E+01	9.0896E+00	2.9087E-01	5.8197E-06
1.1500E+02	3.3475E+01	9.9622E+00	2.9087E-01	5.9891E-06
1.1800E+02	3.4348E+01	1.0835E+01	2.9087E-01	6.1155E-06
1.2100E+02	3.5221E+01	1.1707E+01	2.9087E-01	6.2085E-06
1.2400E+02	3.6094E+01	1.2580E+01	2.9087E-01	6.2768E-06
1.2700E+02	3.6968E+01	1.3453E+01	2.9087E-01	6.3266E-06
1.3000E+02	3.7841E+01	1.4325E+01	2.9087E-01	6.3628E-06
1.3000E+02	3.7841E+01	1.4325E+01	2.9087E-01	6.3628E-06
1.3300E+02	3.8714E+01	1.5198E+01	2.9087E-01	6.3887E-06
1.3600E+02	3.9588E+01	1.6070E+01	2.9087E-01	6.4076E-06
1.3900E+02	4.0461E+01	1.6943E+01	2.9087E-01	6.4213E-06

1.4200E+02	4.1334E+01	1.7816E+01	2.9087E-01	6.4311E-06
1.4500E+02	4.2207E+01	1.8688E+01	2.9087E-01	6.4379E-06
1.4800E+02	4.3081E+01	1.9561E+01	2.9087E-01	6.4431E-06
1.5100E+02	4.3954E+01	2.0433E+01	2.9087E-01	6.4463E-06
1.5400E+02	4.4827E+01	2.1306E+01	2.9087E-01	6.4489E-06
1.5700E+02	4.5700E+01	2.2179E+01	2.9087E-01	6.4511E-06
1.6000E+02	4.6574E+01	2.3051E+01	2.9087E-01	6.4521E-06
1.6000E+02	4.6574E+01	2.3051E+01	2.9087E-01	6.4521E-06
1.6300E+02	4.7447E+01	2.3924E+01	2.9087E-01	6.4531E-06
1.6600E+02	4.8320E+01	2.4796E+01	2.9087E-01	6.4536E-06
1.6900E+02	4.9193E+01	2.5669E+01	2.9087E-01	6.4540E-06
1.7200E+02	5.0067E+01	2.6542E+01	2.9087E-01	6.4547E-06
1.7500E+02	5.0940E+01	2.7414E+01	2.9087E-01	6.4547E-06
1.7800E+02	5.1813E+01	2.8287E+01	2.9087E-01	6.4549E-06
1.8100E+02	5.2686E+01	2.9159E+01	2.9087E-01	6.4553E-06
1.8400E+02	5.3560E+01	3.0032E+01	2.9087E-01	6.4549E-06
1.8700E+02	5.4433E+01	3.0905E+01	2.9087E-01	6.4552E-06
1.9000E+02	5.5306E+01	3.1777E+01	2.9087E-01	6.4554E-06
2.1000E+02	6.1128E+01	3.7595E+01	2.9087E-01	6.4550E-06
4.1000E+02	1.1934E+02	9.5768E+01	2.9087E-01	6.4559E-06
6.1000E+02	1.7756E+02	1.5394E+02	2.9087E-01	6.4567E-06
8.1000E+02	2.3578E+02	2.1212E+02	2.9087E-01	6.4567E-06
1.0100E+03	2.9400E+02	2.7029E+02	2.9087E-01	6.4567E-06
1.2100E+03	3.5221E+02	3.2846E+02	2.9087E-01	6.4567E-06
1.4100E+03	4.1043E+02	3.8664E+02	2.9087E-01	6.4567E-06
1.6100E+03	4.6865E+02	4.4481E+02	2.9087E-01	6.4567E-06
1.8100E+03	5.2686E+02	5.0298E+02	2.9087E-01	6.4567E-06
2.0100E+03	5.8508E+02	5.6116E+02	2.9087E-01	6.4567E-06
2.2100E+03	6.4330E+02	6.1933E+02	2.9087E-01	6.4567E-06
2.4100E+03	7.0151E+02	6.7750E+02	2.9087E-01	6.4567E-06
2.6100E+03	7.5973E+02	7.3568E+02	2.9087E-01	6.4567E-06
2.8100E+03	8.1795E+02	7.9385E+02	2.9087E-01	6.4567E-06
3.0750E+03	8.9509E+02	8.7093E+02	2.9087E-01	6.4567E-06
3.1500E+03	9.1692E+02	8.9274E+02	2.9087E-01	6.4567E-06
3.2250E+03	9.3875E+02	9.1456E+02	2.9087E-01	6.4567E-06
3.3000E+03	9.6058E+02	9.3638E+02	2.9087E-01	6.4567E-06
3.3750E+03	9.8111E+02	9.5819E+02	2.9087E-01	6.4567E-06
3.4500E+03	9.8432E+02	9.7943E+02	1.8642E-01	5.9956E-06
3.5250E+03	9.8445E+02	9.8355E+02	7.1451E-03	3.6871E-07
3.6000E+03	9.8445E+02	9.8371E+02	2.7386E-04	1.4174E-08
3.6750E+03	9.8445E+02	9.8372E+02	1.0497E-05	5.4326E-10
3.7500E+03	9.8445E+02	9.8372E+02	4.0232E-07	2.0822E-11
3.8250E+03	9.8445E+02	9.8372E+02	1.5420E-08	7.9808E-13
3.9000E+03	9.8445E+02	9.8372E+02	5.9103E-10	3.0589E-14
3.9750E+03	9.8445E+02	9.8372E+02	2.2653E-11	1.1724E-15
4.0500E+03	9.8445E+02	9.8372E+02	8.6827E-13	4.4938E-17
4.1250E+03	9.8445E+02	9.8372E+02	3.3280E-14	1.7224E-18
4.2000E+03	9.8445E+02	9.8372E+02	1.2756E-15	6.6017E-20
4.2750E+03	9.8445E+02	9.8372E+02	4.8890E-17	2.5303E-21
4.3500E+03	9.8445E+02	9.8372E+02	1.8739E-18	9.6983E-23
4.4250E+03	9.8445E+02	9.8372E+02	7.1823E-20	3.7172E-24
4.5000E+03	9.8445E+02	9.8372E+02	2.7529E-21	1.4248E-25
4.5750E+03	9.8445E+02	9.8372E+02	1.0551E-22	5.4609E-27
4.6500E+03	9.8445E+02	9.8372E+02	4.0441E-24	2.0931E-28
4.7250E+03	9.8445E+02	9.8372E+02	1.5501E-25	8.0224E-30
4.8000E+03	9.8445E+02	9.8372E+02	5.9411E-27	3.0749E-31
4.8750E+03	9.8445E+02	9.8372E+02	2.2771E-28	1.1785E-32
4.9500E+03	9.8445E+02	9.8372E+02	8.7279E-30	4.5172E-34
AVERAGE INTEGRATED CONCENTRATION FROM 1.0000E+02 TO 1.3000E+02 YEARS = 5.80E-06 CI/m**3				
AVERAGE INTEGRATED CONCENTRATION FROM 1.3000E+02 TO 1.6000E+02 YEARS = 6.43E-06 CI/m**3				
AVERAGE INTEGRATED CONCENTRATION FROM 1.6000E+02 TO 1.9000E+02 YEARS = 6.45E-06 CI/m**3				
AVERAGE INTEGRATED CONCENTRATION FROM 2.1000E+02 TO 3.0000E+03 YEARS = 6.46E-06 CI/m**3				
AVERAGE INTEGRATED CONCENTRATION FROM 3.0750E+03 TO 5.0000E+03 YEARS = 1.48E-06 CI/m**3				
MAXIMUM CONCENTRATION(S) CI/m**3				
6.46E-06				

TIME(S) OF MAXIMUM CONCENTRATIONS (years)
 1.21E+03
 EXECUTION TIME (seconds) 7

Sample Problem 7a: Input File

```
EXAMPLE PROBLEM #7A; Sr-90 release to a pond LIMITING CONC CALC
1 0 KFLAG NPROG
1 INTIME
20.0 20.0 0.50 AL MA THICKS
0.20 0.36 0.120 PERC THETAS THETAU
1.5 24.0 0.0 RHOS XKDS
1.9 24.0 RHOU XKDU
2.85E1 THALF(1)
0.0 90.0 1.0 QI ZMW SL
1.9 0.10 22.0 24.0 RHOA PHI XKDA
9.0 4.0 570.0 AX AY VX
15.0 0.00001 THICK DEPTH
1 2 INODE IMODEL
100. 30. 4000. 0.4 0.0 20. RMI TOPER PMDFLX THETAP EVAP WAEFF
1.3E5 DCF-RADMAX-NRADMAX-SFACTOR-RFD
100.0, 0. XD YD
70.0 2.555E+04 2.0 365. 30. 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
2 6 11 1.0E-2 ISOLVE,JSTART,JMAX,EPS
```

Output File

TIME OF RUN 16:53:14.6
 DATE OF RUN 06/21/93
 INPUT FILE NAME: PB-7A.PAR
 OUTPUT FILE NAME: PB-7A.OUT

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 *
 * This output was produced by the model: *
 *
 * GWSCREEN *
 * Version Control Copy, Version 2.0 *
 * A semi-analytical model for the assessment *
 * of the groundwater pathway from the leaching *
 * of surficial and buried contamination and *
 * release of contaminants from percolation ponds *
 * 6-20-93 *
 * Arthur S. Rood *
 * Idaho National Engineering Laboratory *
 * EG&G Idaho Inc. *
 * Subsurface and Environmental Modeling Unit *
 * PO Box 1625 *
 * Idaho Falls, Idaho 83415 *

 >>> TITLE OF PROJECT:
 EXAMPLE PROBLEM #7A; Sr-90 release to a pond LIMITING CONC CALC

 SIMPSON RULE SOLUTION

JSTART = 6

JMAX = 11

EPS = 1.0000E-02

MODEL OPTIONS

IMODE: 1

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:2 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY	0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)	2.00E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)	2.00E+01
THICKNESS OF SOURCE (m)	5.00E-01
PERCOLATION RATE (darcy vel m/y)	2.00E-01
VOLUMETRIC WATER CONTENT IN SOURCE	3.60E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE	1.20E-01
BULK DENSITY AT SOURCE (g/cm**3)	1.50E+00
SORPTION COEFFICIENT AT SOURCE (ml/g)	2.40E+01
BULK DENSITY IN UNSAT ZONE (g/cm**3)	1.90E 0
UNSATURATED ZONE THICKNESS (m)	1.00E-05
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)	2.40E+01
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**(-1))	0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci)	0.00E+00
MOLECULAR WEIGHT (g/mole)	9.00E+01
SOLUBILITY LIMIT (mg/L)	1.00E+00
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)	2.85E+01
BULK DENSITY OF AQUIFER (g/cm**3)	1.90E+00
POROSITY OF AQUIFER	1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)	2.20E+01
DISPERSIVITY X DIRECTION (m)	9.00E+00
DISPERSIVITY Y DIRECTION (m)	4.00E+00
PORE VELOCITY (m/y)	5.70E+02
WELL SCREEN THICKNESS (m)	1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS (m)	1.00E+02
DISTANCE TO RECEPTOR ALONG Y AXIS (m)	0.00E+00
RADIOLOGICAL DOSE CONVERSION FACTOR (rem/Ci)	1.30E+05
MASS RELEASE RATE TO POND (mg or Ci per y)	1.00E+02
OPERATION TIME OF POND (years)	3.00E+01
LIQUID EFFLUENT FLOW RATE TO POND (m**3/y)	4.00E+03
MOISTURE CONTENT OF UNDERLYING SEDIMENTS	4.00E-01
EVAPORATION RATE CONSTANT FROM POND (y**(-1))	0.00E+00
EFFECTIVE WIDTH OF POND AT AQUIFER (m)	2.00E+01
UNITS OF CONTAMINANT	Ci

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

 LIMITING SOIL CONCENTRATION CALCULATION

>>> INITIAL ACTIVITY CONVERTED TO MASS (mg) 0.00E+00

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y)	1.1001E-02
UNSATURATED PORE VELOCITY (m/y)	8.3333E+01
DECAY CONSTANT(S) (1/y)	2.4321E-02
RETARDATION FACTOR(S) (SATURATED)	4.1900E+02
LEACH RATE CONSTANT FROM POND SEDIMENTS	5.4945E-01
RETARDATION FACTOR (UNSATURATED)	3.8100E+02
SOLUBILITY LIMITED MASS (mg)	7.2800E+06

SOLUBILITY LIMITED ACTIVITY (Ci) 1.0155E+06
 TRANSIT TIME IN UNSAT ZONE (years) 4.5720E-05
 FRACTION DECAYED DURING UNSAT TRANSPORT 1.1120E-06

=====

POND SEDIMENT INVENTORY AT END OF OPERATIONS: 1.74E+02 Ci

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

INTEGRATION TIME (years) 1
 BODY WEIGHT (kg) 7.000E+01
 AVERAGING TIME (days) 2.555E+04
 WATER INTAKE RATE (L/d) 2.000E+00
 EXPOSURE FREQUENCY (days/year) 3.650E+02
 EXPOSURE DURATION (years) 3.000E+01
 RADIOLOGICAL DOSE LIMIT (rem/y) 4.000E-03
 CARCINOGENIC RISK CRITERIA 1.000E-06
 HAZARD QUOTIENT 1.000E+00

=====

>>> RESULTS OF CALCULATIONS

COMMITTED EFFECTIVE DOSE EQUIVALENT CALCULATION

COMPOSITE DOSE CONVERSION FACTOR (rem/Ci): 1.30E+05

LIMITING GROUNDWATER CONCENTRATION (Ci/L): 4.21E-11

MAXIMUM CONCENTRATION FOR MBR #1: 1.46E-07 Ci/L CEDE = 1.39E+01 rem

MAXIMUM CEDE 1.39E+01 rem

PEAK TIME (y): 6.979928E+01

LIMITING POND EFFLUENT CONCENTRATION (Ci/L): 7.199E-09

EXECUTION TIME (seconds) 4

Sample Problem 7b: Input File

EXAMPLE PROBLEM #7B; Sr-90 release to a pond CONC VS TIME

```

0 0 KFLAG NPROG
1 INTIME
20.0 20.0 0.50 AL WA THICKS
0.20 0.36 0.12 PERC THETAS THETAU
1.5 24.0 0.0 RHOS ZKDS
1.9 24.0 RHOU ZKDU
2.85E1 THALF(I)
0.00 90.0 1.0 QI ZMW SL
1.9 0.10 22.0 24.0 RHOA PHI ZKDA
9.0 4.0 570.0 AX AY VX
15.0 0.00001 THICK DEPTH
1 3 IMODE IMODEL
100. 30. 4000. 0.4 0.0 20. RMI TOPER PNDFLX THETAP EVAP WAEFF
1.3e5 DCF-RADMAX-NRADMAX-SFACTOR-RFD
100.0, 0. XD YD
70.0 2.555E+04 2.0 365. 30. 0.004 1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
2 6 12 5.0E-3 ISOLVE,JSTART JMAX,EPS
3 NTIMES
0.0 30.0 2.0
32. 62.0 2.0
64. 94.0 1.0
0.0000E+00 0.0000E+00
1.0000E+00 4.1808E+01
2.0000E+00 6.5364E+01
3.0000E+00 7.8636E+01
4.0000E+00 8.6113E+01
5.0000E+00 9.0325E+01
6.0000E+00 9.2699E+01
7.0000E+00 9.4036E+01
8.0000E+00 9.4789E+01
9.0000E+00 9.5213E+01
1.0000E+01 9.5453E+01

```

1.1000E+01	9.5587E+01
1.2000E+01	9.5663E+01
1.3000E+01	9.5706E+01
1.4000E+01	9.5730E+01
1.5000E+01	9.5744E+01
1.6000E+01	9.5751E+01
1.7000E+01	9.5756E+01
1.8000E+01	9.5758E+01
1.9000E+01	9.5759E+01
2.0000E+01	9.5760E+01
2.1000E+01	9.5761E+01
2.2000E+01	9.5761E+01
2.3000E+01	9.5761E+01
2.4000E+01	9.5761E+01
2.5000E+01	9.5761E+01
2.6000E+01	9.5761E+01
2.7000E+01	9.5761E+01
2.8000E+01	9.5761E+01
2.9000E+01	9.5761E+01
3.0000E+01	9.5761E+01
3.2000E+01	1.7866E+00
3.3000E+01	1.7246E+00
3.4000E+01	1.6647E+00
3.5000E+01	1.6069E+00
3.6000E+01	1.5512E+00
3.7000E+01	1.4973E+00
3.8000E+01	1.4454E+00
3.9000E+01	1.3952E+00
4.0000E+01	1.3468E+00
4.1000E+01	1.3000E+00
4.2000E+01	1.2549E+00
4.3000E+01	1.2114E+00
4.4000E+01	1.1693E+00
4.5000E+01	1.1287E+00
4.6000E+01	1.0896E+00
4.7000E+01	1.0518E+00
4.8000E+01	1.0153E+00
4.9000E+01	9.8002E-01
5.0000E+01	9.4601E-01
5.1000E+01	9.1317E-01
5.2000E+01	8.8148E-01
5.3000E+01	8.5089E-01
5.4000E+01	8.2136E-01
5.5000E+01	7.9285E-01
5.6000E+01	7.6534E-01
5.7000E+01	7.3878E-01
5.8000E+01	7.1314E-01
5.9000E+01	6.8839E-01
6.0000E+01	6.6450E-01
6.1000E+01	6.4143E-01
6.2000E+01	6.1917E-01
6.4000E+01	5.7694E-01
6.6000E+01	5.3759E-01
6.8000E+01	5.0092E-01
7.0000E+01	4.6676E-01
7.2000E+01	4.3492E-01
7.4000E+01	4.0526E-01
7.6000E+01	3.7762E-01
7.8000E+01	3.5186E-01
8.0000E+01	3.2786E-01
8.2000E+01	3.0550E-01
8.4000E+01	2.8466E-01
8.6000E+01	2.6525E-01
8.8000E+01	2.4715E-01
9.0000E+01	2.3030E-01

9.2000E+01 2.1459E-01
9.4000E+01 1.9995E-01

Output File

TIME OF RUN 16:53:19.7
DATE OF RUN 06/21/93
INPUT FILE NAME: PB-7B.PAR
OUTPUT FILE NAME: PB-7B.LST

ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND
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*
* This output was produced by the model: *
*
* GWSCREEN *
* Version Control Copy, Version 2.0 *
* A semi-analytical model for the assessment *
* of the groundwater pathway from the leaching *
* of surficial and buried contamination and *
* release of contaminants from percolation ponds *
* 6-20-93 *
* Arthur S. Rood *
* Idaho National Engineering Laboratory *
* EG&G Idaho Inc. *
* Subsurface and Environmental Modeling Unit *
* PO Box 1625 *
* Idaho Falls, Idaho 83415 *

>>> TITLE OF PROJECT:
EXAMPLE PROBLEM #7; Sr-90 release to a pond CONC VS TIME

=====

SIMPSON RULE SOLUTION

JSTART = 6

JMAX = 12

EPS = 5.0000E-03

MODEL OPTIONS

IMODE: 1

KFLAG: 0 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:3 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY	0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)	2.00E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)	2.00E+01
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)	2.85E+01
BULK DENSITY OF AQUIFER (g/cm**3)	1.90E+00
POROSITY OF AQUIFER	1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)	2.20E+01

DISPERSIVITY X DIRECTION (m) 9.00E+00
 DISPERSIVITY Y DIRECTION (m) 4.00E+00
 PORE VELOCITY (m/y) 5.70E+02
 WELL SCREEN THICKNESS (m) 1.50E+01
 DISTANCE TO RECEPTOR ALONG X AXIS (m) 1.00E+02
 DISTANCE TO RECEPTOR ALONG Y AXIS (m) 0.00E+00
 RADIOLOGICAL DOSE CONVERSION FACTOR (rem/Ci) 1.30E+05
 UNITS OF CONTAMINANT Ci

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

=====
 >>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y) 0.0000E+00
 UNSATURATED PORE VELOCITY (m/y) 1.6667E+00
 DECAY CONSTANT(S) (1/y) 2.4321E-02
 RETARDATION FACTOR(S) (SATURATED) 4.1900E+02
 RETARDATION FACTOR (UNSATURATED) 3.8100E+02
 SOLUBILITY LIMITED MASS (mg) 0.0000E+00
 SOLUBILITY LIMITED ACTIVITY (Ci) 0.0000E+00
 TRANSIT TIME IN UNSAT ZONE (years) 2.2860E-03
 FRACTION DECAYED DURING UNSAT TRANSPORT 5.5596E-05

=====
 TABULATED SOURCE FUNCTION

TIME (years)	SOURCE FLUX Ci/year
0.0000E+00	0.0000E+00
1.0000E+00	4.1808E+01
2.0000E+00	6.5364E+01
3.0000E+00	7.8636E+01
4.0000E+00	8.6113E+01
5.0000E+00	9.0325E+01
6.0000E+00	9.2699E+01
7.0000E+00	9.4036E+01
8.0000E+00	9.4789E+01
9.0000E+00	9.5213E+01
1.0000E+01	9.5453E+01
1.1000E+01	9.5587E+01
1.2000E+01	9.5663E+01
1.3000E+01	9.5706E+01
1.4000E+01	9.5730E+01
1.5000E+01	9.5744E+01
1.6000E+01	9.5751E+01
1.7000E+01	9.5756E+01
1.8000E+01	9.5758E+01
1.9000E+01	9.5759E+01
2.0000E+01	9.5760E+01
2.1000E+01	9.5761E+01
2.2000E+01	9.5761E+01
2.3000E+01	9.5761E+01
2.4000E+01	9.5761E+01
2.5000E+01	9.5761E+01
2.6000E+01	9.5761E+01
2.7000E+01	9.5761E+01
2.8000E+01	9.5761E+01
2.9000E+01	9.5761E+01
3.0000E+01	9.5761E+01
3.2000E+01	1.7866E+00
3.3000E+01	1.7246E+00

3.4000E+01	1.6647E+00
3.5000E+01	1.6069E+00
3.6000E+01	1.5512E+00
3.7000E+01	1.4973E+00
3.8000E+01	1.4454E+00
3.9000E+01	1.3952E+00
4.0000E+01	1.3468E+00
4.1000E+01	1.3000E+00
4.2000E+01	1.2549E+00
4.3000E+01	1.2114E+00
4.4000E+01	1.1693E+00
4.5000E+01	1.1287E+00
4.6000E+01	1.0896E+00
4.7000E+01	1.0518E+00
4.8000E+01	1.0153E+00
4.9000E+01	9.8002E-01
5.0000E+01	9.4601E-01
5.1000E+01	9.1317E-01
5.2000E+01	8.8148E-01
5.3000E+01	8.5089E-01
5.4000E+01	8.2136E-01
5.5000E+01	7.9285E-01
5.6000E+01	7.6534E-01
5.7000E+01	7.3878E-01
5.8000E+01	7.1314E-01
5.9000E+01	6.8839E-01
6.0000E+01	6.6450E-01
6.1000E+01	6.4143E-01
6.2000E+01	6.1917E-01
6.4000E+01	5.7694E-01
6.6000E+01	5.3759E-01
6.8000E+01	5.0092E-01
7.0000E+01	4.6676E-01
7.2000E+01	4.3492E-01
7.4000E+01	4.0526E-01
7.6000E+01	3.7762E-01
7.8000E+01	3.5186E-01
8.0000E+01	3.2786E-01
8.2000E+01	3.0550E-01
8.4000E+01	2.8466E-01
8.6000E+01	2.6525E-01
8.8000E+01	2.4715E-01
9.0000E+01	2.3030E-01
9.2000E+01	2.1459E-01
9.4000E+01	1.9995E-01

>>> CONCENTRATION VS TIME MODE

TIME (years)	GW CONC. member #1 Ci/m ³
0.0000E+00	0.0000E+00
2.0000E+00	0.0000E+00
4.0000E+00	0.0000E+00
6.0000E+00	3.1743E-17
8.0000E+00	8.9224E-14
1.0000E+01	1.1816E-11
1.2000E+01	3.2641E-10
1.4000E+01	3.6036E-09
1.6000E+01	2.2194E-08
1.8000E+01	9.1885E-08
2.0000E+01	2.8695E-07
2.2000E+01	7.2733E-07
2.4000E+01	1.5703E-06
2.6000E+01	2.9987E-06

2.8000E+01 5.1887E-06
 3.0000E+01 8.3007E-06
 3.2000E+01 1.2444E-05
 3.4000E+01 1.7672E-05
 3.6000E+01 2.4012E-05
 3.8000E+01 3.1409E-05
 4.0000E+01 3.9755E-05
 4.2000E+01 4.8945E-05
 4.4000E+01 5.8810E-05
 4.6000E+01 6.9216E-05
 4.8000E+01 7.9949E-05
 5.0000E+01 9.0762E-05
 5.2000E+01 1.0144E-04
 5.4000E+01 1.1159E-04
 5.6000E+01 1.2096E-04
 5.8000E+01 1.2937E-04
 6.0000E+01 1.3641E-04
 6.2000E+01 1.4208E-04
 6.4000E+01 1.4593E-04
 6.5000E+01 1.4753E-04
 6.6000E+01 1.4854E-04
 6.7000E+01 1.4903E-04
 6.8000E+01 1.4938E-04
 6.9000E+01 1.4930E-04
 7.0000E+01 1.4888E-04
 7.1000E+01 1.4849E-04
 7.2000E+01 1.4741E-04
 7.3000E+01 1.4589E-04
 7.4000E+01 1.4429E-04
 7.5000E+01 1.4255E-04
 7.6000E+01 1.4008E-04
 7.7000E+01 1.3811E-04
 7.8000E+01 1.3583E-04
 7.9000E+01 1.3317E-04
 8.0000E+01 1.3035E-04
 8.1000E+01 1.2723E-04
 8.2000E+01 1.2378E-04
 8.3000E+01 1.2188E-04
 8.4000E+01 1.1900E-04
 8.5000E+01 1.1520E-04
 8.6000E+01 1.1199E-04
 8.7000E+01 1.0847E-04
 8.8000E+01 1.0535E-04
 8.9000E+01 1.0208E-04
 9.0000E+01 9.8873E-05
 9.1000E+01 9.5546E-05
 9.2000E+01 9.2272E-05
 9.3000E+01 8.9160E-05
 9.4000E+01 8.6129E-05

AVERAGE INTEGRATED CONCENTRATION FROM 0.0000E+00 TO 3.0000E+01 YEARS = 9.83E-07 ci/m**3

AVERAGE INTEGRATED CONCENTRATION FROM 3.2000E+01 TO 6.2000E+01 YEARS = 7.58E-05 ci/m**3

AVERAGE INTEGRATED CONCENTRATION FROM 6.4000E+01 TO 9.4000E+01 YEARS = 1.28E-04 ci/m**3

MAXIMUM CONCENTRATION(S) ci,m**3

1.49E-04

TIME(S) OF MAXIMUM CONCENTRATIONS (years)

6.80E+01

EXECUTION TIME (seconds) 11

Sample Problem 8: Input File

EXAMPLE PROBLEM #8; Pu-241 for GWS-2.0. Am-241 AND NP-237 PROG CARCIN RISK CALC

1 2

KFLAG NPROG

30

INTIME

70.0 30.0 2.0	AL WA THICKS
1.0 0.35 0.090	PERC THETAS THETAU
1.5 22.0 0.0	RHOS ZKDS
1.9 22.0	RHOU ZKDU
14.4 432.2 2.1E6	THALF(I)
10.00 239.0 7.11E6	QI ZMW SL
1.9 0.10 22.0 340.0 5.0	RHOA PHI ZKDA
9.0E-0 4.0E-0 570.0	AX AY VX
15.0 6.0	THICK DEPTH
2 1	IMODE IMODEL
1. 1. 1. 1. 1. 30.	RMI TOPER PNDFLX THETAP EVAP WAEFF
4.8 310. 270	DCF-RCSF-RADMAX-NRADMAX-SFACTOR-RFD
135.0, 0.	XD YD
70.0 2.555E+04 2.0 350. 30. 0.004 1.0E-6 1.0	BW AT WI EF ED DLIM CRISK HQ
1 6 11 1.0E-2	ISOLVE,JMAX,EPS
2	NTIMES
300.0, 400.0 2.	T1 T2 TP
400. 500. 5.	T1 T2 TP

Output File

TIME OF RUN 16:53:53.3
DATE OF RUN 06/21/93
INPUT FILE NAME: pb-8.par
OUTPUT FILE NAME: pb-8.out

***** ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND LIMITATION OF LIABILITY

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*
* This output was produced by the model: *
*
* GWSCREEN *
* Version Control Copy, Version 2.0 *
* A semi-analytical model for the assessment *
* of the groundwater pathway from the leaching *
* of surficial and buried contamination and *
* release of contaminants from percolation ponds *
* 6-20-93 *
* Arthur S. Rood *
* Idaho National Engineering Laboratory *
* EG&G Idaho Inc. *
* Subsurface and Environmental Modeling Unit *
* PO Box 1625 *
* Idaho Falls, Idaho 83415 *

>>> TITLE OF PROJECT:
EXAMPLE PROBLEM #8; Pu-241 for GWS-2.0. Am-241 AND NP-237 PROG CARLIN RISK CAL

GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 2

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

NUMBER OF RADIOACTIVE PROGENY	2
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)	7.00E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)	3.00E+01
THICKNESS OF SOURCE (m)	2.00E+00
PERCOLATION RATE (darcy vel m/y)	1.00E+00
VOLUMETRIC WATER CONTENT IN SOURCE	3.50E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE	9.00E-02
BULK DENSITY AT SOURCE (g/cm**3)	1.50E+00
SORPTION COEFFICIENT AT SOURCE (ml/g)	2.20E+01
BULK DENSITY IN UNSAT ZONE (g/cm**3)	1.90E+00
UNSATURATED ZONE THICKNESS (m)	6.00E+00
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)	2.20E+01
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1)	0.00E+00
INITIAL MASS OR ACTIVITY (mg or Ci)	1.00E+01
MOLECULAR WEIGHT (g/mole)	2.39E+02
SOLUBILITY LIMIT (mg/L)	7.11E+06
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y)	1.44E+01 4.32E+02 2.10E+06
BULK DENSITY OF AQUIFER (g/cm**3)	1.90E+00
POROSITY OF AQUIFER	1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)	2.20E+01 3.40E+02 5.00E+00
DISPERSIVITY X DIRECTION (m)	9.00E+00
DISPERSIVITY Y DIRECTION (m)	4.00E+00
PORE VELOCITY (m/y)	5.70E+02
WELL SCREEN THICKNESS (m)	1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS (m)	1.35E+02
DISTANCE TO RECEPTOR ALONG Y AXIS (m)	0.00E+00
RADIOLOGICAL CARCINOGENIC SLOPE FACTOR (1/Ci)	4.80E+00 3.10E+02 2.70E+02
UNITS OF CONTAMINANT	Ci

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

===== LIMITING SOIL CONCENTRATION CALCULATION

>>> INITIAL ACTIVITY CONVERTED TO MASS (mg) 9.62E+01

>>> VALUES CALCULATED IN SOURCE SUBROUTINE

LEACH RATE CONSTANT (1/y)	1.4993E-02
UNSATURATED PORE VELOCITY (m/y)	1.1111E+01
DECAY CONSTANT(S) (1/y)	4.8135E-02 1.6038E-03 3.3007E-07
RETARDATION FACTOR(S) (SATURATED)	4.1900E+02 6.4610E+03 9.6000E+01
RETARDATION FACTOR (UNSATURATED)	4.6544E+02
SOLUBILITY LIMITED MASS (mg)	9.9590E+14
SOLUBILITY LIMITED ACTIVITY (Ci)	1.0353E+14
TRANSIT TIME IN UNSAT ZONE (years)	2.5134E+02
FRACTION DECAYED DURING UNSAT TRANSPORT	9.9999E-01

=====

>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION

INTEGRATION TIME (years)	30
BODY WEIGHT (kg)	7.000E+01
AVERAGING TIME (days)	2.555E+04
WATER INTAKE RATE (L/d)	2.000E+00
EXPOSURE FREQUENCY (days/year)	3.500E+02
EXPOSURE DURATION (years)	3.000E+01
RADIOLOGICAL DOSE LIMIT (rem/y)	4.000E-03
CARCINOGENIC RISK CRITERIA	1.000E-06
HAZARD QUOTIENT	1.000E+00

=====

>>> RESULTS OF CALCULATIONS

CARCINOGENIC RISK CALCULATION FOR RADIONUCLIDES

DECAY-INGROWTH FACTORS: 2.1300E-07 2.0659E-02 2.6052E-06

NOTE: PROGENY CONCENTRATIONS ARE REPORTED AT THE TIME OF THE MAXIMUM PARENT CONCENTRATION

MAXIMUM CONCENTRATION FOR MBR #1: 6.36E-17 Ci/L

AVERAGE CONCENTRATION FOR MBR #1: 5.95E-17 Ci/L RISK = 6.00E-12

MAXIMUM CONCENTRATION FOR MBR #2: 4.00E-13 Ci/L

AVERAGE CONCENTRATION FOR MBR #2: 4.06E-13 Ci/L RISK = 2.64E-06

MAXIMUM CONCENTRATION FOR MBR #3: 3.40E-15 Ci/L

AVERAGE CONCENTRATION FOR MBR #3: 3.49E-15 Ci/L RISK = 1.98E-08

MAXIMUM CARCINOGENIC RISK: 2.66E-06

LIMITING PARENT GROUNDWATER CONC. (Ci/L): 2.24E-17

PEAK TIME (y): 3.191418E+02

LIMITING SOIL CONCENTRATION (Ci/m**3): 8.943E-04

LIMITING SOIL CONCENTRATION (Ci/kg): 5.962E-07

LIMITING SOIL AMOUNT (Ci): 3.756E+00

LIMITING SOIL AMOUNT (mg): 3.613E+01

SPECIFIC ACTIVITY (Ci/g): 1.040E+02

EXECUTION TIME (seconds) 2

Sample Problem 9: Input File

EXAMPLE PROBLEM #9; hydrocarbon benzene spill with vapor diffusion loss

1 0	KFLAG NPROG
30	INTIME
15.0 25.0 2.00	AL WA THICKS
0.10 0.30 0.090	PERC THETAS THETAU
1.5 0.25 1.13E-2	RHOS zKDS RC2
1.9 0.25	RHOU zKDU
0.95	THALF(I)
5.625E8 78.11 1780.	QI ZMW SL
1.9 0.10 0.25	RHOA PHI zKDA
9.0 4.0 570.0	AX AY VX
15.0 0.1	THICK DEPTH
5 1	IMODE IMODEL
100. 30. 4000. 0.4 0.0 25	RMI TOPER PNDFLX THETAP EVAP WAEFF
5.2E-2	DCF-RADMAX-NRADMAX-SFACTOR-RFD
25.0, 0.	XD YD
70.0 2.555E+04 2.0 350. 30. 0.004	1.0E-6 1.0 BW AT WI EF ED DLIM CRISK HQ
1 6 12 5.0E-3	ISOLVE,JMAX,EPS

Output File

TIME OF RUN 16:53:56.7

DATE OF RUN 06/21/93

INPUT FILE NAME: PB-9.PAR

OUTPUT FILE NAME: PB-9.OUT

=====

ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND
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```

*
*   This output was produced by the model:
*
*   GWScreen
*   Version Control Copy, Version 2.0
*   A semi-analytical model for the assessment
*   of the groundwater pathway from the leaching
*   of surficial and buried contamination and
*   release of contaminants from percolation ponds
*   6-20-93
*   Arthur S. Rood
*   Idaho National Engineering Laboratory
*   EG&G Idaho Inc.
*   Subsurface and Environmental Modeling Unit
*   PO Box 1625
*   Idaho Falls, Idaho 83415
*
*****

```

>>> TITLE OF PROJECT:

EXAMPLE PROBLEM #9; hydrocarbon benzene spill with vapor diffusion loss

GAUSSIAN QUADRATURE SOLUTION

MODEL OPTIONS

IMODE: 5

KFLAG: 1 (0)CONC VS TIME; (1)PEAK CONC AND LIMITING SOIL CONC

IMODEL:1 (1) SURF OR BURIED SOURCE; (2)POND SOURCE; (3) TABULATED SOURCE FUNCTION

>>> INPUT DATA

```

NUMBER OF RADIOACTIVE PROGENY          0
LENGTH OF SOURCE PARALLEL TO GW FLOW (m)  1.50E+01
WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m)  2.50E+01
THICKNESS OF SOURCE (m)                2.00E+00
PERCOLATION RATE (darcy vel m/y)        1.00E-01
VOLUMETRIC WATER CONTENT IN SOURCE       3.00E-01
VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE  9.00E-02
BULK DENSITY AT SOURCE (g/cm**3)        1.50E+00
SORPTION COEFFICIENT A* SOURCE (ml/g)    2.50E-01
BULK DENSITY IN UNSAT ZONE (g/cm**3)     1.90E+00
UNSATURATED ZONE THICKNESS (m)          1.00E-01
SORPTION COEFFICIENT IN UNSAT ZONE (ml/g)  2.50E-01
OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1) 1.13E-02
INITIAL MASS OR ACTIVITY (mg or Ci)      5.62E+08
MOLECULAR WEIGHT (g/mole)                7.81E+01
SOLUBILITY LIMIT (mg/L)                  1.78E+03
HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y) 9.50E-01
BULK DENSITY OF AQUIFER (g/cm**3)        1.90E+00
POROSITY OF AQUIFER                     1.00E-01
SORPTION COEFFICIENT(S) IN AQUIFER (ml/g)  2.50E-01
DISPERSIVITY X DIRECTION (m)             9.00E+00
DISPERSIVITY Y DIRECTION (m)             4.00E+00
PORE VELOCITY (m/y)                     5.70E+02
WELL SCREEN THICKNESS (m)                1.50E+01
DISTANCE TO RECEPTOR ALONG X AXIS      (m)  2.50E+01
DISTANCE TO RECEPTOR ALONG Y AXIS      (m)  0.00E+00
CARCINOGENIC SLOPE FACTOR (mg/kg/d)**-1  5.20E-02
UNITS OF CONTAMINANT                     mg

```

INPUT DATA FILE CREATED BY: _____ DATE / /

INPUT DATA CHECKED BY: _____ DATE / /

```

=====
LIMITING SOIL CONCENTRATION CALCULATION
>>> VALUES CALCULATED IN SOURCE SUBROUTINE
*****
LEACH RATE CONSTANT (1/y)          7.4074E-02
UNSATURATED PORE VELOCITY (m/y)    1.1111E+00
DECAY CONSTANT(S) (1/y)           7.2963E-01
RETARDATION FACTOR(S) (SATURATED)  5.7500E+00
RETARDATION FACTOR (UNSATURATED)   6.2778E+00
SOLUBILITY LIMITED MASS (mg)       9.0112E+08
SOLUBILITY LIMITED ACTIVITY (Ci)    0.0000E+00
TRANSIT TIME IN UNSAT ZONE (years)  5.6500E-01
FRACTION DECAYED DURING UNSAT TRANSPORT 3.3783E-01
=====
>>> EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION
*****
INTEGRATION TIME (years)           30
BODY WEIGHT (kg)                   7.000E+01
AVERAGING TIME (days)             2.555E+04
WATER INTAKE RATE (L/d)            2.000E+00
EXPOSURE FREQUENCY (days/year)    3.500E+02
EXPOSURE DURATION (years)          3.000E+01
RADIOLOGICAL DOSE LIMIT (rem/y)    4.000E-03
CARCINOGENIC RISK CRITERIA         1.000E-06
HAZARD QUOTIENT                    1.000E+00
=====
>>> RESULTS OF CALCULATIONS
*****
CARCINOGENIC RISK CALCULATION
LIMITING GROUNDWATER CONCENTRATION (mg/L):  1.64E-03
MAXIMUM GROUNDWATER CONCENTRATION (mg/L):   3.95E-01
AVERAGE GROUNDWATER CONCENTRATION (mg/L):   2.33E-02
CARCINOGENIC RISK FOR USER INPUT MASS:      1.42E-05
PEAK TIME (y):                             1.110318E+00
LIMITING SOIL CONCENTRATION (mg/m**3):      5.268E+04
LIMITING SOIL CONCENTRATION (mg/kg):        3.512E+01
LIMITING SOIL AMOUNT (mg):                 3.951E+07
EXECUTION TIME (seconds)                   1

```

APPENDIX B: GWSCREEN CODE LISTING

PROGRAM GWS6
 ***** Begin Prologue *****

•
 • Identification
 •
 • Program Name: GWScreen
 • Module Name: gws6.f Version: 1.3
 • Date: 6/21/83 Time: 16:37:03
 •

C
 C AUTHOR A.S. ROOD
 C APRIL, 1981

C ***** NOTE *****
 C FOR COMPILATION ON INEL CRAY, THE FUNCTION DEFINITION MUST CHANGE
 C FROM REAL*8 FUNCTION(XXXX) TO FUNCTION(XXXX). REAL*8 FUNCTION(XXXX)
 C IS THE LAHEY FORMAT AND FUNCTION(XXXX) IS CRAY UNIX. THE FOLLOWING
 C FUNCTIONS ARE AFFECTED; AREA, FUNC, ERP, GAMMP, GAMMLN
 C *****

C This program is designed to calculate the concentration of a contaminant
 C in the surface soil that results in a groundwater concentration that is
 C at the acceptable regulatory standard for either maximum concentration,
 C radiological dose or carcinogenic risk. The program also calculates the
 C groundwater concentration as a function of time for an initial inventory.

C The program uses a three stage approach:
 C First, the leach rate of the contaminant from the surface is
 C calculated. Next the transit time from the surface to the aquifer is
 C calculated. Any decay which occurs during transit is accounted for and plug
 C flow is assumed. The contaminant is then assumed to dissolve in the aquifer
 C and initially mix in an volume that is equivalent to the area of the source
 C on the surface times the thickness of the well screen. The peak, or an
 C average integrated concentration is then calculated and compared with the
 C appropriate regulatory limit.

C This program uses equation 4.37 in NUREG CR/3332 to calculate groundwater
 C concentrations. The leach rate from the source is determined using
 C methodology in the RESRAD code (DOE/CH/8901).
 C Solution for time variant releases
 C are taken from the Gaussian Quad integration. Limits of integration are
 C determined by Codell's method in NUREG-0868. Gaus Quad integration
 C was used in two routines in the code. The convolution integral which
 C describes groundwater concentration resulting from a non-steady state
 C release is solved using a modified Gaus Quad routine found in Numerical
 C Recipes (Press et al) and found in the QGAUS2 subroutine.

C
 C A second integration routine was taken also from Numerical Recipes (Press et al
 C 1987) and is used in the subroutine QGAUS. This routine calculates the
 C average integrated concentration.

IMPLICIT REAL*8 (A-H,O-Z)

C INPUT VARIABLES:

C TITLE = TITLE OF PROJECT
 C KFLAG (0) = CONCENTRATION VS TIME
 C (1) = LIMITING SOIL CONCENTRATION
 C INTIME = INTEGRATING TIME. INTIME MUST EQUAL THE EXPOSURE DURATION
 C FOR CARCINOGENIC CALCULATIONS
 C AL = LENGTH OF SOURCE PARALLEL TO FLOW (m)
 C WA = WIDTH OF SOURCE PERPENDICULAR TO FLOW (m)
 C THICKS = THICKNESS OF CONTAMINATED ZONE (m)
 C PERC = PERCOLATION RATE (m/y)
 C THETAS = VOLUMETRIC MOISTURE CONTENT IN CONTAMINATED ZONE
 C THETAU = VOLUMETRIC MOISTURE CONTENT IN UNSATURATED ZONE
 C RHOS = DENSITY OF SURFACE SOIL (g/cm3)

C ZKDS = SORPTION COEFFICIENT IN SOURCE (cm³/g)
 C RC2 = ADDITIONAL RATE CONSTANT FOR SOURCE DEPLETION (y⁻¹)
 C THALF = HALF LIFE (y)
 C QI = UNIT INITIAL MASS IN SOURCE COMPARTMENT (CI OR MG)
 C QX = INPUT INITIAL MASS IN SOURCE COMPARTMENT
 C ZMW = MOLECULAR WEIGHT (G/MOLE)
 C SL = SOLUBILITY LIMIT OF CONTAMINANT (MG/L)
 C RHOA = DENSITY OF AQUIFER (G/CM³)
 C PHI = POROSITY OF AQUIFER
 C ZKDA = SORPTION COEFFICIENT IN AQUIFER
 C AX = DISPERSIVITY IN THE X DIRECTION (m)
 C AY = DISPERSIVITY IN THE Y DIRECTION (m)
 C VX = PORE VELOCITY IN AQUIFER, (m/y)
 C THICK = THICKNESS OF WELL SCREEN (m)
 C DEPTH = DEPTH OF AQUIFER FROM BASE OF CONTAMINATED ZONE (m)
 C IMODE = (1) LIMIT BASED ON 4 MREM/Y
 C (2) LIMIT BASED ON REFERENCE DOSE
 C (3) LIMIT BASED ON MAXIMUM CONTAMINANT LIMIT FOR RADIONUCLIDES
 C (4) LIMIT BASED ON CARCINOGENIC RISK FOR RADIONUCLIDES
 C (5) LIMIT BASED ON MAXIMUM CONTAMINANT LIMIT FOR CHEMICALS
 C (6) LIMIT BASED ON CARCINOGENIC RISK (1.0E-6)
 C DCF = DOSE CONVERSION FACTOR (rem/CI)
 C DSLOPE = SLOPE FACTOR FOR RADIONUCLIDES (1/pCi)
 C RADMAX = GROUNDWATER CRITERIA LIMIT FOR RADIONUCLIDES (CI/L)
 C ZRADMAX = GROUNDWATER CRITERIA LIMIT FOR NON-RAD (mg/L)
 C SFACOR = SLOPE FACTOR FOR CARCINOGENIC RISK CALCULATION (MG/KG/D)**-1
 C RFD = REFERENCE DOSE FOR NON-CARCINOGENIC EFFECTS (MG/KG/D)
 C XD = RECEPTOR DISTANCE DOWNGRADE (m)
 C YD = RECEPTOR DISTANCE PERPENDICULAR TO GW FLOW (m)
 C T1 = START TIME FOR CALCULATIONS (KFLAG = 0) (y)
 C T2 = END TIME FOR CALCULATIONS (KFLAG = 0) (y)
 C TP = PRINT TIME STEP (y)
 C EXPOSURE DATA
 C BW = BODY WEIGHT (kg)
 C AT = AVERAGING TIME (days)
 C WI = WATER INTAKE RATE (L/d)
 C EF = EXPOSURE FREQUENCY (years)
 C ED = EXPOSURE DURATION THIS VALUE SHOULD BE THE SAME AS INTIME FOR
 ' CARCINOGEN CALCULATIONS (years)
 C RCSF = RADIOLOGICAL CARCINOGENIC SLOPE FACTOR (1/CI)
 C DLIM = RADIOLOGICAL DOSE LIMIT (rem/y)
 C CRISK = CARCINOGENIC RISK CRITERIA
 C HQ = HAZARD QUOTIENT
 C RMI = RATE OF MASS INPUT INTO PERCOLATION POND (MG OR CI PER YEAR)
 C TOPER = OPERATION TIME OF PERC POND FACILITY (YEARS)
 C PNDFLX = WATER FLUX INTO POND (M**3/Y)
 C EVAP = EVAPORATION RATE CONSTANT FOR POND (Y**-1)
 C WAEFF = EFFECTIVE WIDTH OF POND AT AQUIFER
 C FIXED VALUES
 C UNITS = MG OR CI
 C CALCULATED VARIABLES IN MAIN PROGRAM
 C QM = INITIAL SOURCE MASS FOR RADIONUCLIDES
 C TTIME = CHARACTER VARIABLE FOR HOLDING TIME OF RUN
 C DDATE = CHARACTER VARIABLE FOR HOLDING DATA OF RUN
 C CSD = LIMITING SOIL CONCENTRATION IN CI OR MG PER KG
 C QACT = SOLUBILITY LIMITED MASS CONVERTED TO ACTIVITY
 C QCS = LIMITING CONTAMINANT AMOUNT (CI OR MG)
 C QMCS = LIMITING CONTAMINANT MASS (MG)
 C DAIC = AVERAGE INTEGRATED CONC FOR PROGENY
 C CHARACTER VALUES
 CHARACTER*2 UNITS
 CHARACTER*45 MODE
 C COMMON STATEMENTS
 COMMON /GW/ AX, AY, VX, THICK, AL, WA, OWLIM, RD, PHI, DLR, QX,
 / SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD, ZMW, RC2, IMODE
 COMMON /SOURCE/ THETAS, THETAU, RHOS, THICKS, ZKDS,
 / DEPTH, PERC, THALF, RHOA, ZKDU, RHOV, QM
 COMMON /EXPOSURE/ BW, AT, WI, EF, ED, DLIM, CRISK, HQ
 COMMON /FILES/ FILEIN, FILEOU, TITLE


```

CHARACTER*40 FILEIN,FILEOU
CHARACTER*78 TITLE
COMMON /POND/ RMI,TOPE,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
PARAMETER (NSPEC=9,SEC=3.1536E7,A=6.023E23)
COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
,ARD(NSPEC),RCSF(NSPEC)
COMMON /TABLE/ ATIME,QREL,NP
PARAMETER (NPOINTS=1000)
DIMENSION ATIME(NPOINTS),QREL(NPOINTS)
DIMENSION ADLR(NSPEC),DAIC(NSPEC)
DIMENSION T1(NSPEC),T2(NSPEC),TP(NSPEC)
C ***** End prologue

Character idkeyw*72
Data idkeyw /'@(#)gws6.f 1.3 6/21/93 16:37:03\0'/
idkeyw = idkeyw

C ***** READ DATA IN SUBROUTINE INPUT *****
CALL INPUT(XDUMMY,T1,T2,TP,KFLAG,INTIME,IFLAG,IMODEL,ISOLVE,NN,
INPROG,NTIMES)

CALL TIMER(ITICK1)
C TICK1=SECOND() for INEL cray
IF(IFLAG.EQ.1)THEN
GOTO 999
ENDIF
C USE SUBROUTINE "ASSIGN" TO ASSIGN A VALUE TO XDUMMY BASED ON THE
C VALUE OF IMODE
CALL ASSIGN(XDUMMY,ZRADMAX,SFACTOR,RFD,INTIME,UNITS,
IMODE)
C WRITE INPUT DATA TO OUTPUT FILE
WRITE(*,*) TITLE
WRITE(2,1000) IMODE,KFLAG,IMODEL
WRITE(2,2000) NPROG,AL,WA
IF(IMODEL.LT.3)THEN
WRITE(2,2050) THICKS,PERC,THETAS,THETAU,RHOS,zKDS,RHOU,DEPTH,
! zKDU
IF(IMODEL.EQ.2)THEN
WRITE(2,2100) RC2,QI,ZMW,SL
ELSE
WRITE(2,2100) RC2,QX,ZMW,SL
ENDIF
ENDIF
WRITE(2,2075) (ATHALF(I),I=1,NN)
WRITE(2,2150) RHOA,PHI,(AKD(I),I=1,NN)
WRITE(2,2200) AX,AY,VX,THICK,XD,YD

IF(IMODE.GT.3)THEN
WRITE(2,2300) MODE,XDUMMY
ELSE
IF(IMODE.EQ.1)THEN
WRITE(2,2400) MODE,(ADCF(I),I=1,NN)
ENDIF
IF(IMODE.EQ.2)THEN
WRITE(2,2400) MODE,(RCSF(I),I=1,NN)
ENDIF
IF(IMODE.EQ.3)THEN
WRITE(2,2400) MODE,(ARADMAX(I),I=1,NN)
ENDIF
ENDIF

IF(IMODEL.EQ.2)THEN
WRITE(2,2500) RMI,TOPE,PNDFLX,THETAP,EVAP,WAEFF
ENDIF

WRITE(2,2550) UNITS
IF(KFLAG.GT.0)THEN
WRITE(2,352)

```

```

ENDIF
C convert initial activity to mass if a radionuclide for solubility check
C CONVERT CI TO MG. USE THE CONVERSIONS 1 CI=3.7E10 DPS, 3.1536 S/Y
C 6.023E23 ATOMS/MOLE AND 1000 MG/G
IF(IMODEL.EQ.2)THEN
  QTEMP=QI
ELSE
  QTEMP=QX
ENDIF
IF(IMODE,LE.3.AND.IMODEL.LT.3)THEN
  QM=(((QTEMP*3.7E10)*SEC*ZMW)/((LOG(2.)/THALF))/A)*1000
  WRITE(2,2600) QM
ELSE
  QM=QTEMP
ENDIF
C .....
C ..... CALCULATE SOURCE .....
C ..... RELEASE AND FIXED .....
C ..... VALUES .....
C .....

CALL SOURCEX(UX,RDU,TSL,TRANSIT,ADLR,KFLAG,IMODEL,NN,UNITS)

C .....
C ..... CALCULATE CONCENTRATION AS A FUNCTION .....
C ..... OF TIME .....
C .....

IF(KFLAG.EQ.0.OR.IMODEL.EQ.3)THEN
  IF(IMODEL.NE.2)THEN
    QI=QX
  ENDIF
  CALL CTIME(UNITS,TSL,TRANSIT,ADLR,T1,T2,TP,IMODEL,ISOLVE,
    INN,NTIMES,INTIME)
  CALL TIMER(ITICK2)
  ITICK=(ITICK2-ITICK1)/100
  WRITE(*,*) ' Normal Termination'
  WRITE(2,2700) ITICK
  CLOSE(2,STATUS='KEEP')
  GOTO 999
ENDIF
C .....
C ..... CALCULATE LIMITING SOIL CONCENTRATION .....
C .....

C WRITE EXPOSURE DATA TO OUTPUT FILE
  WRITE(2,400) INTIME,BW,AT,WI,EF,ED,DLIM,CRISK,HQ
C CHECK EXPOSURE DURATION TO MAKE SURE IT IS EQUAL TO INTEGRATION TIME
C FOR CARCINOGENIC CALCULATIONS
  IF(IMODE.EQ.2.OR.IMODE.EQ.5)THEN
    IF(ED.NE.INTIME)THEN
      WRITE(*,13)
      WRITE(2,13)
      GOTO 999
    ENDIF
  ENDIF

C CALCULATE PEAK GROUNDWATER CONCENTRATION
  CALL PEAK(GWPEAK,PKTIME,TSL,IMODEL,ISOLVE)
  PKTIMEA=PKTIME+TRANSIT
  GWMAXI=GWPEAK*QX
C CALCULATE AVERAGE INTEGRATED CONC. (AIC) OR IF 1 YEAR INTEGRATION TIME
C IS USED THEN USE THE PEAK CONCENTRATION
  X1=FLOAT(INTIME)
  CALL GWINT(X1,PKTIME,TRANSIT,TSL,AIC,DAIC,ADLR,GWPEAK,PKTIMEA,
    IMODEL,ISOLVE,NN)
  AIC=AIC*QX
  DO 10,I=1,NN
    DAIC(I)=DAIC(I)*QX
10 CONTINUE

  IF(AIC.LE.0.)THEN

```

```

        WRITE(2,201)
        WRITE(*,201)
        GOTO 999
    ENDIF
C ***** CALCULATE SOIL CONC FOR THE GIVEN CONTAMINANT *****
    VOL = THICKS*WA*AL
C IMODE = (1) LIMIT BASED ON 4 MREM/Y
C      (2) LIMIT BASED ON CARCINOGENIC RADIOLOGICAL RISK
C      (3) LIMIT BASED ON MAXIMUM CONTAMINANT LIMIT FOR RADIONUCLIDES
C      (4) LIMIT BASED ON MAXIMUM CONTAMINANT LIMIT FOR CHEMICALS
C      (5) LIMIT BASED ON CARCINOGENIC RISK (1.0E-6)
C      (6) LIMIT BASED ON REFERENCE DOSE
C ***** RADIOLOGICAL DOSE
C DAIC,GWMAXI,GWPEAK CONCENTRATION IN CI/M**3

    IF(IMODE.EQ.1)THEN
        CALL RAD(CS,CE,AIC,AICI,VOL,PKTIMEA,ADLR,NN,IMODE)
    ENDIF

C ***** CARCINOGENIC RADIOLOGICAL RISK
    IF(IMODE.EQ.2)THEN
        CALL CRAD(CS,CE,AIC,DAIC,VOL,GWMAXI,PKTIMEA,ADLR,NN,IMODE)
    ENDIF

C ***** RADIONUCLIDE CONCENTRATION IN GROUNDWATER
    IF(IMODE.EQ.3)THEN
        CALL MAXRAD(CS,CE,AIC,DAIC,VOL,GWMAXI,PKTIMEA,ADLR,NN,IMODE)
    ENDIF
C ***** NON-RAD CONCENTRATION IN GROUNDWATER
    IF(IMODE.EQ.4)THEN
        CALL MAXNRAD(CS,CE,AIC,AICI,GWMAXI,VOL,ZRADMAX,IMODE)
    ENDIF
C ***** CARCINOGENIC RISK
    IF(IMODE.EQ.5)THEN
        CALL CARCIN(CS,CE,AIC,VOL,SFACTOR,AICI,GWMAXI,IMODE)
    ENDIF

C ***** NON CARCINOGENIC CHRONIC EXPOSURE
    IF(IMODE.EQ.6)THEN
        CALL NCARCIN(CS,CE,AIC,VOL,RFD,AICI,GWMAXI,IMODE)
    ENDIF

    CALL WRITEO(PKTIMEA,CS,CE,UNITS,IMODE)

    CALL TIMER(ITICK2)
    ITICK = (ITICK2-ITICK1)/100
    WRITE(*,*) '      Normal Termination'
    WRITE(2,2700) ITICK
    CLOSE(2,STATUS='KEEP')

13 FORMAT(' '
    //,2X,'ERROR:EXPOSURE DURATION (ED) MUST EQUAL INTEGRATION TIME (IN
    ITIME'
    //,2X,'FOR CARCINOGENIC CALCULATION')
201 FORMAT(2X,'NO SOIL CONCENTRATION LIMITS CALCULATED SINCE THE'
    //,2X,'AVERAGE INTEGRATED CONCENTRATION IS ZERO')
352 FORMAT(2X,'LIMITING SOIL CONCENTRATION CALCULATION')
400 FORMAT(2X,'> > > EXPOSURE DATA FOR LIMITING SOIL CONCENTRATION'
    //,2X,'*****')
    //,2X,'INTEGRATION TIME (years)      ',I3
    //,2X,'BODY WEIGHT (kg)              ',1PE10.3
    //,2X,'AVERAGING TIME (days)         ',1PE10.3
    //,2X,'WATER INTAKE RATE (L/d)        ',1PE10.3
    //,2X,'EXPOSURE FREQUENCY (days/year) ',1PE10.3
    //,2X,'EXPOSURE DURATION (years)      ',1PE10.3
    //,2X,'RADIOLOGICAL DOSE LIMIT (rem/y) ',1PE10.3
    //,2X,'CARCINOGENIC RISK CRITERIA    ',1PE10.3
    //,2X,'HAZARD QUOTIENT                ',1PE10.3
    //,2X,'-----'

```

```

1/,2X,'>>> RESULTS OF CALCULATIONS
1/,2X,'.....')
1000 FORMAT(2X,'MODEL OPTIONS'
1/,2X,'IMODE: ',I1
1/,2X,'KFLAG: ',I1,1X,'(0)CONC VS TIME; (1)PEAK CONC AND LIMITING S
IOIL CONC'
1/,2X,'IMODE:',I1,1X,'(1) SURF OR BURIED SOURCE; (2)POND SOURCE; (
13) TABULATED SOURCE FUNCTION')

2000 FORMAT(2X,'>>> INPUT DATA '
1/,2X,'.....'
1/,2X,'NUMBER OF RADIOACTIVE PROGENY ',I2
1/,2X,'LENGTH OF SOURCE PARALLEL TO GW FLOW (m) ',1PE9.2
1/,2X,'WIDTH OF SOURCE PERPENDICULAR TO GW FLOW (m) ',1PE9.2)

2050 FORMAT(2X,'THICKNESS OF SOURCE (m) ',1PE9.2
1/,2X,'PERCOLATION RATE (darcy vel m/y) ',1PE9.2
1/,2X,'VOLUMETRIC WATER CONTENT IN SOURCE ',1PE9.2
1/,2X,'VOLUMETRIC WATER CONTENT IN UNSATURATED ZONE ',1PE9.2
1/,2X,'BULK DENSITY AT SOURCE (g/cm**3) ',1PE9.2
1/,2X,'SORPTION COEFFICIENT AT SOURCE (ml/g) ',1PE9.2
1/,2X,'BULK DENSITY IN UNSAT ZONE (g/cm**3) ',1PE9.2
1/,2X,'UNSATURATED ZONE THICKNESS (m) ',1PE9.2
1/,2X,'SORPTION COEFFICIENT IN UNSAT ZONE (ml/g) ',1PE9.2)

2075 FORMAT(2X,'HALF-LIFE(S) OF CONTAMINANT AND PROGENY (y) ',1PE9.2
1,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2)
2100 FORMAT(2X,'OPTIONAL LOSS RATE CONSTANT FOR SOURCE (y**-1)',1PE9.2
1/,2X,'INITIAL MASS OR ACTIVITY (mg or Ci) ',1PE9.2
1/,2X,'MOLECULAR WEIGHT (g/mole) ',1PE9.2
1/,2X,'SOLUBILITY LIMIT (mg/L) ',1PE9.2)

2150 FORMAT(2X,'BULK DENSITY OF AQUIFER (g/cm**3) ',1PE9.2
1/,2X,'POROSITY OF AQUIFER ',1PE9.2
1/,2X,'SORPTION COEFFICIENT(S) IN AQUIFER (ml/g) ',1PE9.2
1,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2)
2200 FORMAT(2X,'DISPERSIVITY X DIRECTION (m) ',1PE9.2
1/,2X,'DISPERSIVITY Y DIRECTION (m) ',1PE9.2
1/,2X,'PORE VELOCITY (m/y) ',1PE9.2
1/,2X,'WELL SCREEN THICKNESS (m) ',1PE9.2
1/,2X,'DISTANCE TO RECEPTOR ALONG X AXIS (m) ',1PE9.2
1/,2X,'DISTANCE TO RECEPTOR ALONG Y AXIS (m) ',1PE9.2)
2300 FORMAT(2X,A45,1X,1PE9.2)
2400 FORMAT(2X,A45,1X,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,1PE9.2,
1PE9.2,1PE9.2,1PE9.2)
2500 FORMAT(2X,'MASS RELEASE RATE TO POND (mg or Ci per y) ',1PE9.2
1/,2X,'OPERATION TIME OF POND (years) ',1PE9.2
1/,2X,'LIQUID EFFLUENT FLOW RATE TO POND (m**3/y) ',1PE9.2
1/,2X,'MOISTURE CONTENT OF UNDERLYING SEDIMENTS ',1PE9.2
1/,2X,'EVAPORATION RATE CONSTANT FROM POND (y**-1) ',1PE9.2
1/,2X,'EFFECTIVE WIDTH OF POND AT AQUIFER (m) ',1PE9.2)
2550 FORMAT(2X,'UNITS OF CONTAMINANT ',A2
1/,2X,'
1/,2X,'INPUT DATA FILE CREATED BY: _____ DATE / / '
1/,2X,'
1/,2X,'INPUT DATA CHECKED BY: _____ DATE / / '
1/,2X,'
1/,2X,'-----')
2600 FORMAT(2X,'>>> INITIAL ACTIVITY CONVERTED TO MASS (mg) ',1PE9.2)
2700 FORMAT(2X,'EXECUTION TIME (seconds) ',I6)
999 END
C .....
C SUBROUTINE INPUT
C .....
SUBROUTINE INPUT(XDUMMY,T1,T2,TP,KFLAG,INTIME,IFLAG,IMODEL,
IISOLVE,NN,NPROG,NTIMES)
implicit real*8 (a-h,o-z)
C THIS SUBROUTINE READS THE INPUT FILE

```

```

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: Input.f Version: 1.9
* Date: 6/21/93 Time: 16:43:04
*

```

```

COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD, ZMW, RC2, IMODE
COMMON /SOURCE/ THETAS, THETAU, RHOS, THICKS, zKDS,
I DEPTH, PERC, THALF, RHOA, zKDU, RHOU, QM
COMMON /POND/ RMI, TOPER, PNDFLX, THETAP, EVAP, PLEACH, WAEFF
PARAMETER (NSPEC = 9)
COMMON /DECAY/ ADCF, AKD, ATHALF, ARD, ARADMAX, RCSF
DIMENSION ADCF(NSPEC), AKD(NSPEC), ATHALF(NSPEC), ARADMAX(NSPEC)
I, ARD(NSPEC), RCSF(NSPEC)
COMMON /EXPOSURE/ BW, AT, WI, EF, ED, DLIM, CRISK, HQ
COMMON /FILES/ FILEIN, FILEOU, TITLE
CHARACTER*40 FILEIN, FILEOU
CHARACTER*78 TITLE
COMMON /SIMP/ EPS, JMAX, JSTART
COMMON /TABLE/ ATIME, QREL, NP
PARAMETER (NPOINTS = 1000)
DIMENSION ATIME(NPOINTS), QREL(NPOINTS)
DIMENSION T1(NSPEC), T2(NSPEC), TP(NSPEC)
CHARACTER*10 TTIME
CHARACTER*10 DDATE

```

```

Character idkeyw*72
Data idkeyw /'@(#)Input.f1.9 6/21/93 16:43:04\0'/
idkeyw = idkeyw
IFLAG = 0

```

```

C IFLAG CHECKS ERRORS IN INPUT DECK. IF AN ERROR IS DETECTED THEN
C IFLAG IS SET EQUAL TO 1 AND THE PROGRAM IS TERMINATED
C BL = THE MINIMUM ACCEPTABLE VALUE
C BH = MAXIMUM ACCEPTABLE VALUE
C KLINE = LINE NUMBER OF RECORD
C KREC = RECORD NUMBER

```

```

C .....
C .....
C ..... READ IN DATA .....
C .....
C .....

```

```

CALL TIME(TTIME)
CALL DATE(DDATE)
c CALL DATTIM(DDATE, TTIME, TIMNEW)
WRITE(*, 1500)
write(*, *)
WRITE(*, 1200)
1200 format(1x, 'ENTER FILE WHICH CONTAINS INPUT DATA (GWSCREEN.PAR) > > >
I ')
READ(*, 1201) FILEIN
IF(ICHAR(FILEIN(1:1)).EQ.32) THEN
FILEIN = 'GWSCREEN.PAR'
ENDIF
1201 format(a40)
3 WRITE(*, 1202)
1202 format(1x, 'ENTER FILE TO WRITE OUTPUT TO (GWSCREEN.OUT) > > >')
READ(*, 1201) FILEOU
IF(ICHAR(FILEOU(1:1)).EQ.32) THEN
FILEOU = 'GWSCREEN.OUT'
ENDIF
IF(FILEIN.EQ.FILEOU) THEN
WRITE(*, *) '*** OUTPUT FILE WILL OVERWRITE INPUT FILE !!!!!!!!'
GOTO 3
ENDIF

```

```

OPEN(unit = 1, file = FILEIN, STATUS = 'OLD')
OPEN(unit = 2, file = FILEOU, STATUS = 'UNKNOWN')
WRITE(2, *) 'TIME OF RUN ', TTIME
WRITE(2, *) 'DATE OF RUN ', DDATE
WRITE(2, *) 'INPUT FILE NAME: ', FILEIN
WRITE(2, *) 'OUTPUT FILE NAME: ', FILEOU
CALL LICENSE
C *****TITLE
  READ(1, 1205) TITLE
1205 format(a78)
  KLINE = 2
  KREC = 1
C ***** KFLAG, NPROG
  READ(1, *) KFLAG, NPROG
  VI = FLOAT(KFLAG)
  BL = 0.0
  BH = 1.0
  CALL CHECK(VI, KLINE, KREC, BL, BH, IFLAG)
  VI = FLOAT(NPROG)
  BL = 0.0
  BH = 8.0
  KREC = KREC + 1
  CALL CHECK(VI, KLINE, KREC, BL, BH, IFLAG)
  NN = NPROG + 1
C ***** INTIME
  READ(1, *) INTIME
  VI = FLOAT(INTIME)
  BL = 0.0
  BH = 1.0E3
  KLINE = KLINE + 1
  KREC = 1
  CALL CHECK(VI, KLINE, KREC, BL, BH, IFLAG)

C ***** AL WA THICKS
  KLINE = KLINE + 1
  READ(1, *) AL, WA, THICKS
  BL = 1.0
  BH = 1.0E4
  CALL CHECK(AL, KLINE, KREC, BL, BH, IFLAG)
  KREC = KREC + 1
  CALL CHECK(WA, KLINE, KREC, BL, BH, IFLAG)
  KREC = KREC + 1
  BL = 1.0E-3
  CALL CHECK(THICKS, KLINE, KREC, BL, BH, IFLAG)

C ***** PERC THETAS THETAU
  KLINE = KLINE + 1
  READ(1, *) PERC, THETAS, THETAU
  KREC = 1
  BL = 1.0E-4
  BH = 1.0E6
  CALL CHECK(PERC, KLINE, KREC, BL, BH, IFLAG)
  KREC = KREC + 1
  BL = 1.0E-8
  BH = 9.999999E-1
  CALL CHECK(THETAS, KLINE, KREC, BL, BH, IFLAG)
  KREC = KREC + 1
  CALL CHECK(THETAU, KLINE, KREC, BL, BH, IFLAG)

C ***** RHOS ZKDS RC2
  READ(1, *) RHOS, ZKDS, RC2
  KLINE = KLINE + 1
  KREC = 1
  BH = 1.0E1
  BL = 1.0E-2
  CALL CHECK(RHOS, KLINE, KREC, BL, BH, IFLAG)
  KREC = KREC + 1
  BL = 0.0
  BH = 1.0E18

```

```

      CALL CHECK(ZKDS,KLINE,KREC,BL,BH,IFLAG)
      KREC = KREC + 1
      CALL CHECK(IRC2,KLINE,KREC,BL,BH,IFLAG)

C ***** RHOZ ZKDU
      READ(1,*) RHOZ,ZKDU
      KLINE = KLINE + 1
      KREC = 1
      BH = 1.0E1
      BL = 1.0E-2
      CALL CHECK(RHOS,KLINE,KREC,BL,BH,IFLAG)
      KREC = KREC + 1
      BL = 0.0
      BH = 1.0E18
      CALL CHECK(ZKDS,KLINE,KREC,BL,BH,IFLAG)

C ***** THALF
      READ(1,*) (ATHALF(J),J=1,NN)
      KLINE = KLINE + 1
      DO 20,I=1,NN
         IF(ATHALF(I).LE.0.0)THEN
            ATHALF(I) = 1.0E38
         ENDIF
      20 CONTINUE
      THALF = ATHALF(1)
C ***** QX ZMW SL
      KLINE = KLINE + 1
      KREC = 1
      BH = 1.0E38
      BL = 0.0
      READ(1,*) QX,ZMW,SL
      CALL CHECK(QX,KLINE,KREC,BL,BH,IFLAG)
      QI = 1.0
      BL = 1.0E-18
      KREC = KREC + 1
      CALL CHECK(SL,KLINE,KREC,BL,BH,IFLAG)
      KREC = KREC + 1
      CALL CHECK(ZMW,KLINE,KREC,BL,BH,IFLAG)
C ***** RHOA PHI AKD
      READ(1,*) RHOA,PHI,(AKD(I),I=1,NN)
      KLINE = KLINE + 1
      KREC = 1
      BL = 0.01
      BH = 10.
      CALL CHECK(RHOA,KLINE,KREC,BL,BH,IFLAG)
      KREC = 2
      BL = 1.0E-10
      BH = 0.9999999999999999
      CALL CHECK(PHI,KLINE,KREC,BL,BH,IFLAG)
      BL = 0.0
      BH = 1E18
      KREC = 3
      DO 30,J=1,NN
         CALL CHECK(AKD(J),KLINE,KREC,BL,BH,IFLAG)
         KREC = KREC + 1
      30 CONTINUE
C ***** AX AY VX
      READ(1,*) AX,AY,VX
      KLINE = KLINE + 1
      KREC = 1
      BL = 1.0E-10
      BH = 1.0E8
      CALL CHECK(AX,KLINE,KREC,BL,BH,IFLAG)
      KREC = KREC + 1
      CALL CHECK(AY,KLINE,KREC,BL,BH,IFLAG)
      KREC = KREC + 1
      CALL CHECK(VX,KLINE,KREC,BL,BH,IFLAG)

C ***** THICK DEPTH

```

```

READ(1,*) THICK,DEPTH
KLINE = KLINE + 1
KREC = 1
CALL CHECK(THICK,KLINE,KREC,BL,BH,IFLAG)
KREC = KREC + 1
BL = 0.0
CALL CHECK(DEPTH,KLINE,KREC,BL,BH,IFLAG)
KREC = KREC + 1

C ***** IMODE IMODEL
READ(1,*) IMODE,IMODEL
KREC = 1
KLINE = KLINE + 1
VI = FLOAT(IMODE)
BL = 1.0
BH = 6.0
CALL CHECK(VI,KLINE,KREC,BL,BH,IFLAG)
IF(IMODE.GT.3.AND.NN.GT.1)THEN
  WRITE(*,*) 'ERROR: DECAY PRODUCTS ARE NOT CALCULATED FOR NON-
IRADIOLOGICAL SPECIES'
  IFLAG = 1
  RETURN
ENDIF
IF(IMODEL.GT.2.AND.KFLAG.GT.0)THEN
  WRITE(*,*) 'ERROR: PEAK CONCENTRATION ROUTINE NOT ALLOWED WHEN
IMODEL = 3 (TABULATED SOURCE FUNCTION)'
  IFLAG = 1
  RETURN
ENDIF
BH = 3
KREC = 2
VI = FLOAT(IMODEL)
CALL CHECK(VI,KLINE,KREC,BL,BH,IFLAG)
C SET VALUE OF QPOND AND RESET QX TO 1.0 FOR POND MODEL
IF(IMODEL.EQ.2)THEN
  QI = QX
  QX = 1.0
ENDIF
C ***** RMI, TOPER, PNDFLX, THETAP, EVAP, WAEFF

READ(1,*) RMI, TOPER, PNDFLX, THETAP, EVAP,WAEFF
KREC = 1
KLINE = KLINE + 1

C ***** DCF,RADMAX,ZRADMAX,SFACTOR,RFD
C READ AN ARRAY OF VALUES FOR RADIOLOGICAL DOSE CRITERIA
KLINE = KLINE + 1
IF(IMODE.LT.4)THEN
  IF(IMODE.EQ.1)THEN
    READ(1,*) (ADCF(I),I = 1,NN)
  ENDIF
  IF(IMODE.EQ.2)THEN
    READ(1,*) (RCSF(I),I = 1,NN)
  ENDIF
  IF(IMODE.EQ.3)THEN
    READ(1,*) (ARADMAX(I),I = 1,NN)
  ENDIF
  ELSE
    READ(1,*) XDUMMY
  ENDIF
C XDUMMY WILL BE CONVERTED TO THE PROPER VALUE IN SUBROUTINE ASSIGN
C ***** XD AND YD *****
KLINE = KLINE + 1
READ(1,*) XD,YD
C ***** EXPOSURE DATA *****
KLINE = KLINE + 1
READ(1,*) BW,AT,WI,EF,ED,DLIM,CRISK,HQ
C ***** NUMERICAL SOLVER DATA *****
KLINE = KLINE + 1

```



```

READ(1,*) ISOLVE,JSTART,JMAX,EPS
KREC = 1
BL = 1
BH = 2
VI = FLOAT(ISOLVE)
CALL CHECK(VI,KLINE,KREC,BL,BH,IFLAG)
IF(JSTART.GE.JMAX)THEN
  IFLAG = 1
  WRITE(*,*) 'ERROR: JSTART MUST BE LESS THAN JMAX'
  RETURN
ENDIF
KREC = 2
BL = 6
BH = 14
VI = FLOAT(JSTART)
CALL CHECK(VI,KLINE,KREC,BL,BH,IFLAG)
BL = 7
BH = 15
KREC = 3
VI = FLOAT(JMAX)
CALL CHECK(VI,KLINE,KREC,BL,BH,IFLAG)
KREC = 4
BL = 1E-6
BH = 1.0
CALL CHECK(EPS,KLINE,KREC,BL,BH,IFLAG)
C ***** READ TIME PRINT-OUT TIMES IF KFLAG = 0 AND SOURCE TABLE
IF(KFLAG.LT.1)THEN
  READ(1,*) NTIMES
  DO 50,I=1,NTIMES
    READ(1,*) T1(I),T2(I),TP(I)
50  CONTINUE
    IF(I.MODEL.GT.2)THEN
      NP = 0
      DO 60, I = 1,1000
        READ(1,*,END=09) ATIME(I),QREL(I)
        NP = NP + 1
60  CONTINUE
      ENDIF
    ENDIF

09 CLOSE(1,STATUS='KEEP')
1000 WRITE(2,1500)
  WRITE(2,*) ' >>> TITLE OF PROJECT:'
  WRITE(2,*) ' ',TITLE
  WRITE(2,*) ' -----'
  '-----'
  IF(ISOLVE.LT.2)THEN
    WRITE(2,2000)
  ELSE
    WRITE(2,2100) JSTART,JMAX,EPS
  ENDIF
  RETURN

1500 FORMAT(2X,' .....')
1/,2X,' '
1/,2x,' ' This output was produced by the model: ''
1/,2X,' '
1/,2X,' ' GWSCREEN ''
1/,2X,' ' Version Control Copy, Version 2.0 ''
1/,2X,' ' A semi-analytical model for the assessment ''
1/,2X,' ' of the groundwater pathway from the leaching ''
1/,2X,' ' of surficial and buried contamination and ''
1/,2X,' ' release of contaminants from percolation ponds ''
1/,2X,' ' 6-20-93 ''
1/,2X,' ' Arthur S. Rood ''
1/,2X,' ' Idaho National Engineering Laboratory ''
1/,2X,' ' EG&G Idaho Inc. ''
1/,2X,' ' Subsurface and Environmental Modeling Unit ''
1/,2X,' ' PO Box 1625 ''

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```

1/,2X,' *          Idaho Falls, Idaho 83415          *'
1/,2X,' .....')
2000 FORMAT(2X,'GAUSSIAN QUADRATURE SOLUTION')
2100 FORMAT(2X,'SIMPSON RULE SOLUTION')
1/,2X,'JSTART = ',I2
1/,2X,'JMAX = ',I2
1/,2X,'EPS = ',1PE11.4)
END
SUBROUTINE LICENSE

```

```

*
* Identification
*

```

```

* Program Name: GWSCREEN
* Module Name: license.f Version: 1.1
* Date: 5/14/93 Time: 14:30:52
*

```

```

Character idkeyw*72
Data idkeyw /'@(#)license.f1.1 5/14/93 14:30:52\0'/
idkeyw = idkeyw

```

```

WRITE(*,1000)
WRITE(*,2000)
WRITE(2,1000)
WRITE(2,2000)
RETURN

```

```

1000 FORMAT(2X,'=====')
1=====
1/9x,' ACKNOWLEDGEMENT OF GOVERNMENT SPONSORSHIP AND'
1/9x,' LIMITATION OF LIABILITY '
1/2X,'
1/2x,'This material resulted from work developed under U.S. Departm
lent of'
1/,2x,'Energy, Office of Environmental Restoration and Waste Manage
lment,'
1/,2x,'DOE Field Office, Idaho, Contract Number DE-AC07-76ID01570.'
1/,8x,'This material is subject to the following license:'
1/,17x,'(no license at this time)')

```

```

2000 FORMAT(2X,'Neither the United States nor the United States Departm
lent of Energy,'
1/,2x,'nor any of their employees, makes any warranty, expressed or
l implied,'
1/,2x,'or assumes any legal liability or responsibility for the acc
luracy,'
1/,2x,'completeness, or usefulness of any information, apparatus, p
lroduct,'
1/,2x,'or process disclosed, or represents that its use would not i
lfringe on'
1/,2x,'privately owned rights.'
1/,2x,'=====')
1=====
1/2x,'
1/2x,'
END

```

```

C .....
C SUBROUTINE CHECK
C .....
SUBROUTINE CHECK(VI,KLINE,KREC,BL,BH,IFLAG)
implicit real*8 (a-h,o-z)
C THIS SUBROUTINE CHECKS THE INPUT DATA
*
* Identification
*
* Program Name: GWSCREEN
* Module Name: checkn.f Version: 1.1

```

```

*   Date: 4/6/93   Time: 16:46:46
*
Character idkeyw*72
Date idkeyw /'@(#)checkn.f      1.1 4/6/93 16:46:46\0'/
idkeyw = idkeyw

IF(VI.GE.BL.AND.VI.LE.BH)THEN
  RETURN
ELSE
  WRITE(*,100) KLINE,KREC,VI,BH,BL
  IFLAG = 1
  PAUSE
ENDIF
100 FORMAT(1X,'ERROR: IN LINE NUMBER ',I3,' RECORD ',I2,
/,1X,'VALUE OUT OF ACCEPTED BOUNDS'
/,1X,'INPUT VALUE: ',1PE11.4
/,1X,'ACCEPTED UPPER VALUE: ',1PE11.4
/,1X,'ACCEPTED LOWER VALUE: ',1PE11.4)
      RETURN
END

C .....
C  SUBROUTINE CTIME
C .....
  SUBROUTINE CTIME(UNITS,TSL,TRANSIT,ADLR,T1,T2,TP,IMODEL,ISOLVE,
INN,NTIMES,INTIME)
  IMPLICIT REAL*8(A-H,O-Z)

*
*   Identification
*
*   Program Name: GWSCREEN
*   Module Name: ctime.f Version: 1.2
*   Date: 6/21/93   Time: 16:40:35
*
C  CMAX = VARIABLE TO HOLD MAXIMUM CONCENTRATION
PARAMETER (NSPEC=9)
COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
,ARD(NSPEC),RCSF(NSPEC)
DIMENSION ADLR(NSPEC),CONC(NSPEC),Q(NSPEC),QDX(NSPEC),DAIC(NSPEC)
DIMENSION T1(NSPEC),T2(NSPEC),TP(NSPEC),AC(NSPEC),DAC(NSPEC,NSPEC)
DIMENSION CMAX(NSPEC),TMAX(NSPEC)
CHARACTER*2 UNITS
CHARACTER SPC*12, MBR*8

Character idkeyw*72
Date idkeyw /'@(#)ctime.f 1.2 6/21/93 16:40:35\0'/
idkeyw = idkeyw

SPC = '-----'
MBR = 'member #'
DO 5, I = 1, NN
  CMAX(I) = 0.0
5  CONTINUE
WRITE(*,*) ' >>> CONCENTRATION VS TIME MODE '
WRITE(2,*) ' >>> CONCENTRATION VS TIME MODE '
IF(T2(INTIMES).LT.TRANSIT)THEN
  WRITE(*,300) T2(INTIMES),TRANSIT
  WRITE(2,300) T2(INTIMES),TRANSIT
  RETURN
ENDIF
write(2,*)
IF(IMODEL.LT.3)THEN
  WRITE(*,500) (MBR,I,I = 1,NN)
  WRITE(2,500) (MBR,I,I = 1,NN)
  write(*,700) units,units,units,units,(SPC,I = 1,NN)

```

```

        write(2,700) units,units,units,units,(SPC,I=1,NN)
        ELSE
            WRITE(2,3000) (MBR,I,I=1,NN)
            WRITE(2,3500) UNITS
            WRITE(2,4000) (SPC,I=1,NN)
        ENDIF

DO 10,I=1,NTIMES
    TSTART=T1(I)
    TEND=T2(I)
    TPRINT=TP(I)
    DO 41 T=TSTART,TEND,TPRINT
        TX=T-TRANSIT
        IF(TX.LE.0.)THEN
            DO 12,J=1,NN
                CONC(J)=0.0
            12 CONTINUE
        ELSE
            CONC(1)=FUNC(TX,TSL,IMODEL,ISOLVE)
            IF(NN.GT.1)THEN
                C      SET PARENT INITIAL ACTIVITY TO 1.0 CI FOR DECAY CALCULATION
                C      ALL OTHERS TO 0
                Q(1)=1.0
                DO 20,J=2,NN
                    Q(J)=0.0
                20 CONTINUE
                CALL RDK(T,ADLR,NN,Q,QDX)
                DO 30,J=2,NN
                    CONC(J)=(CONC(1)/QDX(1))*QDX(J)*ARD(1)/ARD(J)
                30 CONTINUE
            ENDIF
            DO 35,K=1,NN
                IF(CONC(K).GT.CMAX(K))THEN
                    CMAX(K)=CONC(K)
                    TMAX(K)=T
                ENDIF
            35 CONTINUE
        ENDIF
        IF(IMODEL.LT.3)THEN
            CALL FLUXES(RELSRC,RELAQU,FAQU,TSL,T,TRANSIT,IMODEL)
            WRITE(*,800) T,RELSRC,RELAQU,FAQU,(CONC(J),J=1,NN)
            WRITE(2,800) T,RELSRC,RELAQU,FAQU,(CONC(J),J=1,NN)
        ELSE
            WRITE(*,5000) T,(CONC(J),J=1,NN)
            WRITE(2,5000) T,(CONC(J),J=1,NN)
        ENDIF
    41 CONTINUE

C      INTEGRATE CONCENTRATION FOR OUTPUT YEARS; DUMMY IS VARIABLE FOR
C      HOLDING PEAK CONC AND TIME OF PEAK -- THESE OPTIONS ARE NOT UTILIZED
C      IN THIS SUBROUTINE.
    IF(TEND.GT.TRANSIT.AND.INTIME.GT.0)THEN
        DUMMY1=1.0
        DUMMY2=1.0
        TI1=TEND-TSTART
        TI2=TI1/2+TSTART-TRANSIT
        CALL GWINT(TI1,TI2,TRANSIT,TSL,AIC,DAIC,ADLR,DUMMY1,DUMMY2,
        I  IMODEL,ISOLVE,NN)
        AC(I)=AIC
        IF(NN.GT.1)THEN
            DO 15,J=2,NN
                DAC(I,J)=DAIC(J)
            15 CONTINUE
        ENDIF
    ENDIF
10 CONTINUE

    IF(INTIME.GT.0)THEN
        DO 60,I=1,NTIMES

```

```

        WRITE(2,1000) T1(I),T2(I),AC(I),units
        IF(NN.GT.1)THEN
            DO 50,J=2,NN
                WRITE(2,2000) J,DAC(I,J),UNITS
50          CONTINUE
        ENDIF
60      CONTINUE
    ENDIF
    WRITE(2,6000) UNITS, (CMAX(I),I=1,NN)
    WRITE(2,7000) (TMAX(I),I=1,NN)

300 FORMAT(2X,'CONCENTRATION IS ZERO FOR ALL TIME PERIODS REQUESTED'
//,2X,'LAST TIME PERIOD REQUESTED (T2): ',1PE11.4,' YEARS'
//,2X,'TRANSIT TIME IN UNSATURATED ZONE: ',1PE11.4,' YEARS')

500 FORMAT (3X,'TIME      CUMULATIVE CUMULATIVE AQUIFER  GW CO
INC ... '
//,3X,'          SOURCE FLUX AQUIFER FLUX  FLUX',6X,
IA8,I1,3X,A8,I1,3X,A8,I1,3X,A8,I1,3X,A8,I1,3X,A8,I1,3X,A8,
II1,3X,A8,I1)

700 FORMAT(2X,' (years)',7x,'( ',a2,')',9X,'( ',a2,')',6x,'( ',a2,')/year'
//,3X,'( ',a2,')/m**3)'
//,2x,'-----',
IA12,A12,A12,A12,A12,A12,A12,A12,A12,A12)

800 FORMAT(2X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1
1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,
11PE11.4,1X,1PE11.4)

1000 FORMAT(2X,'AVERAGE INTEGRATED CONCENTRATION FROM ',1PE11.4,1X,' TO'
1,1X,1PE11.4,1X,' YEARS = ',1PE9.2,1X,a2,')/m**3')

2000 FORMAT(2X,'AVERAGE INTEGRATED CONCENTRATION FOR MEMBER #',I1,1X,
11PE11.4,1X,a2,')/m**3')

3000 FORMAT(2X,' TIME  GW CONC.',
//,2X,' (years) ',A8,I1,3X,A8,I1,3X,A8,I1,3X,A8,I1,3X,A8,I1,3X,
IA8,I1,3X,A8,I1,3X,A8,I1)
3500 FORMAT(15X,a2,')/m**3')
4000 FORMAT(2x,'-----',A12,A12,A12,A12,A12,A12,A12,A12,A12,A12)
5000 FORMAT(2X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1
1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4)

6000 FORMAT(2X,'MAXIMUM CONCENTRATION(S)',1X,A2,')/m**3'
//,2X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,
11PE9.2,1X,1PE9.2,1X,1PE9.2)

7000 FORMAT(2X,'TIME(S) OF MAXIMUM CONCENTRATIONS (years)'
//,2X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,1PE9.2,1X,
11PE9.2,1X,1PE9.2,1X,1PE9.2)

RETURN
END
C .....
C * FUNCTION FUNC(TI,TSL,IMODEL,ISOLVE) *
C .....
C This function calls the QGAUS2 routine to calculate the groundwater
C concentration at a point in time

REAL*8 FUNCTION FUNC(TI,TSL,IMODEL,ISOLVE)
IMPLICIT REAL*8(A-H,O-Z)
*
* Identification
*
* Program Name: GWSCREEN
* Module Name: func.f Version: 1.1
* Date: 4/6/93 Time: 17:06:52
*

```

```

Character idkeyw*72
Data idkeyw /'@{#}func.f 1.1 4/6/93 17:06:52\0'/
idkeyw = idkeyw

IF(ISOLVE.LT.2)THEN
    CALL QGAUS2(TI,G,TSL,IMODEL)
ELSE
    CALL SIMPSON(TI,G,TSL,IMODEL)
ENDIF
FUNC=G
RETURN
END

C .....
C SUBROUTINE FLUXES
C .....
SUBROUTINE FLUXES(RELSRC,RELAQU,FAQU,TSL,T,TRANSIT,IMODEL)
Implicit real*8 (a-h,o-z)

C This subroutine calculates the fluxes from the source volume
C and to the aquifer. Corrected 11-92 for missing decay term in
C flux and cumulative flux terms.
C RELSRC = CUMULATIVE FLUX FROM SOURCE
C RELAU = CUMULATIVE FLUX TO AQUIFER
C TSRC = THE SOURCE RELEASE TIME FRAME
C TAQU = THE AQUIFER RELEASE TIME FRAME
C FAQU = FLUX OF CONTAMINANT TO AQUIFER
COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZMW,RC2,IMODE
COMMON /POND/ RMI,TOPER,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
PARAMETER (A=6.023E+23,CI=3.7E+10,SEC=3.1536E+7)

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: fluxes.f Version: 1.3
* Date: 6/21/93 Time: 16:45:47
*
Character idkeyw*72
Data idkeyw /'@{#}fluxes.f 1.3 6/21/93 16:45:47\0'/
idkeyw = idkeyw

R1=EVAP+DLR+PLEACH
R2=DLR+SLEACH+RC2

C CALCULATE FLUXES FOR POND MODEL
IF(IMODEL.GT.1)THEN
    IF(T.LE.TOPE)THEN
        RELSRC=PLEACH*RMI*T/R1+PLEACH*RMI*(EXPF(-R1*T)-1)/(R1**2)
        RELAU=FRAC*(PLEACH*RMI*T/R1+PLEACH*RMI*(EXPF(-R1*(T-TRANSIT))-1)/(R1**2)-PLEACH*QI*(EXPF(-R1*(T-TRANSIT))-1)/R1)
        FAQU=FRAC*PLEACH*(RMI/R1*(1-EXPF(-R1*(T-TRANSIT)))+QI*EXPF(-R1*(T-TRANSIT)))
    ELSE
        T is greater than TOPE
        QMASS=RMI/R1*(1-EXPF(-R1*TOPE))+QI*EXPF(-R1*TOPE)
        RELSRC=PLEACH*RMI*TOPE/R1+PLEACH*RMI*(EXPF(-R1*TOPE)-1)/(R1**2)-PLEACH*QI*(EXPF(-R1*TOPE)-1)/R1
        SLEACH*QMASS*(EXPF(-R2*(T-TOPE))-1)/R2
        IF(T.GT.(TOPE+TRANSIT))THEN
            T is greater than TOPE and T is greater than TRANSIT;
            Assume T is greater than TRANSIT since this case is taken care
            of later since RELAU=0 and FAQU=0
            RELAU=FRAC*(PLEACH*RMI*TOPE/R1+PLEACH*RMI*(EXPF(-R1*TOPE)-1)/(R1**2)-PLEACH*QI*(EXPF(-R1*TOPE)-1)/R1+SLEACH*QMASS*(1-EXPF(-R2*(T-(TOPE+TRANSIT))))/R2)
        
```

```

        FAQU = FRAC*SLEACH*QMASS*EXPF(-R2*(T-(TOPER + TRANSIT)))
    ELSE
C      T is greater than TOPER and T greater than TRANSIT
C      but TOPER + TRANSIT is less than T
        TX = ABS(TOPER-TRANSIT)
        RELAU = FRAC*(PLEACH*RMI*(T-TX)/R1 +
        PLEACH*RMI*(EXPF(-R1*(T-TX))-1)/(R1**2)-
        PLEACH*QI*(EXPF(-R1*(T-TX))-1)/R1)
        FAQU = FRAC*PLEACH*(RMI/R1*(1-EXPF(-R1*(T-TX)))
        + QI*EXPF(-R1*(T-TX)))
    ENDIF
    ENDIF
    IF(T.LE.TRANSIT)THEN
        FAQU = 0.0
        RELAU = 0.0
    ENDIF
    RETURN
ENDIF

C  CALCULATE FLUXES FOR INTITAL MASS MODEL, NO SOLUBIL CONTROL
IF(TSL.EQ.0.0)THEN
    IF(T.LE.TRANSIT)THEN
        FAQU = 0.0
        RELAU = 0.0
        RELSRC = QI*(SLEACH/R2)*(1-EXPF(-R2*T))
        RETURN
    ELSE
        RELSRC = QI*(SLEACH/R2)*(1-EXPF(-R2*T))
        RELAU = FRAC*QI*(SLEACH/R2)*(1-EXPF(-R2*(T-TRANSIT)))
        FAQU = FRAC*SLEACH*QI*EXPF(-R2*(T-TRANSIT))
    ENDIF
ENDIF

C  CALCULATE FLUXES FOR SOLUBILITY LIMITED CONTROLLED RELEASE
IF(TSL.GT.0.)THEN
    IF(TSL.GE.T)THEN
        RELSRC = WFLUX*SL*T
    ELSE
        RELSRC = WFLUX*SL*TSL + QSL*(SLEACH/R2)*(1-EXP(-R2*(T-TSL)))
    ENDIF
    IF(TSL.GT.(T-TRANSIT))THEN
        FAQU = FRAC*WFLUX*SL
        RELAU = FRAC*WFLUX*SL*(T-TRANSIT)
    ELSE
        FAQU = FRAC*SLEACH*QSL*EXPF(-R2*(T-TRANSIT-TSL))
        RELAU = FRAC*(WFLUX*SL*TSL + QSL*(SLEACH/R2)*
        (1-EXP(-R2*(T-TSL-TRANSIT))))
    ENDIF
ENDIF

C  Convert mass to activity if a radionuclide for solubility limited
C  RELEASE CONVERT MG TO CI. USE THE CONVERSIONS 1 CI=3.7E10 DPS,
C  3.1536 S/Y 6.023E23 ATOMS/MOLE AND 1000 MG/G
IF(IMODE.LE.3)THEN
    RELDUM = (RELSRC/(1000*ZMW)*A*(DLR/SEC))/CI
    RELADUM = (RELAU/(1000*ZMW)*A*(DLR/SEC))/CI
    FAQU = (FAQU/(1000*ZMW)*A*(DLR/SEC))/CI
    RELSRC = RELDUM
    FAQU = FAQU
    RELAU = RELADUM
ENDIF
ENDIF

IF(T.LE.TRANSIT)THEN
    FAQU = 0.0
    RELAU = 0.0
ENDIF

RETURN
END
C .....

```

```

C SUBROUTINE SOURCEX
C .....
SUBROUTINE SOURCEX(UX,RDU,TSL,TRANSIT,ADLR,KFLAG,IMODEL,NN,UNITS)
  Implicit real*8 (a-h,o-z)
  PARAMETER (A = 6.023E + 23, CI = 3.7E + 10, SEC = 3.1536E + 7)

  *
  * Identification
  *
  * Program Name: GWSCREEN
  * Module Name: sourcex.f Version: 1.4
  * Date: 6/22/93 Time: 17:11:36
  *

C CALCULATED VALUES IN SOURCE SUBROUTINE
C SLEACH = LEACH RATE CONSTANT (Y-1)
C UX = UNSATURATED PORE VELOCITY (M/Y)
C DLR = DECAY RATE CONSTANT (Y-1)
C RD = RETARDATION COEFFICIENT
C RDU = RETARDATION IN UNSATURATED ZONE
C TRANSIT = TRANSIT TIME IN UNSAT ZONE (Y)
C FRAC = FRACTION OF INVENTORY REMAINING AFTER UNSAT ZONE TRANSIT
C SL = SOLUBILITY LIMIT
C QSL = MASS IN SOURCE WHERE SOLUBILITY LIMIT WOULD BE EXCEEDED IN LEACHATE
C WFLUX = WATER FLUX THROUGH SOURCE COMPARTMENT (L/Y)
C RC = THE SUM OF THE DECAY RATE CONSTANT AND THE ADDITIONAL SOURCE LOSS RATE CONSTANT
COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
  I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD, ZMW, RC2, IMODE
COMMON /SOURCE/ THETAS, THETAU, RHOS, THICKS, zKDS,
  I DEPTH, PERC, THALF, RHOA, zKDU, RHOU, QM
PARAMETER (NSPEC = 9)
COMMON /DECAY/ ADCF, AKD, ATHALF, ARD, ARADMAX, RCSF
DIMENSION ADCF(NSPEC), AKD(NSPEC), ATHALF(NSPEC), ARADMAX(NSPEC)
  I, ARD(NSPEC), RCSF(NSPEC)
COMMON /POND/ RMI, TOPER, PNDFLX, THETAP, EVAP, PLEACH, WAEFF
COMMON /TABLE/ ATIME, QREL, NP
PARAMETER (NPOINTS = 1000)
DIMENSION ATIME(NPOINTS), QREL(NPOINTS)
DIMENSION ADLR(NSPEC)
Character idkeyw*72, UNITS*2
Data idkeyw /'@(#)sourcex.f' 1.4 6/22/93 17:11:36/'
idkeyw = idkeyw

C CALCULATE LEACH RATE CONSTANT (y-1)
SLEACH = PERC/(THETAS*THICKS*(1 + zKDS*RHOS/THETAS))
C CALCULATE POND LEACH RATE CONSTANT PORE VEL IN UNSAT
IF(IMODEL.EQ.2) THEN
  PLEACH = (PNDFLX/(AL*WA))/(THETAP*THICKS*(1 + zKDS*RHOS/THETAP))
  UX = PNDFLX/(AL*WA)/THETAU
  ELSE
  UX = PERC/THETAU
ENDIF
C CALCULATE DECAY RATE (y-1) IF THALF = 1E38 THEN DLR = 0
DO 20, I = 1, NN
  IF(ATHALF(I).EQ.1.0E+38) THEN
    ADLR(I) = 0.0
  ELSE
    ADLR(I) = LOG(2.)/ATHALF(I)
  ENDIF
20 CONTINUE
DLR = ADLR(1)
C CALCULATE RD IN AQUIFER
DO 30, I = 1, NN
  ARD(I) = 1 + AKD(I)*RHOA/PHI
30 CONTINUE
RD = ARD(1)
WRITE(2,3000)
C CALCULATE FRACTION DECAYED DURING UNSAT ZONE TRANSIT
C RDU = retardation in unsaturated zone.
C TRANSIT = UNSATURATED TRANSIT TIME
RDU = 1 + zKDU*RHOA/THETAU

```



```

TRANSIT = DEPTH * RDU / UX
ARG = -DLR * TRANSIT
FRAC = EXPF(ARG)
C   CALCULATE WATER FLUX
WFLUX = AL * WA * PERC * 1000
C   CALCULATE QSL FROM SL CONVERT LITERS TO M3 BY FACTOR OF 1000
IF (IMODEL.LT.2) THEN
  QSL = SL * AL * WA * THICKS * THETAS * (1 + ZKDS * RHOS / THETAS) * 1000
ENDIF
C   CALCULATE MAXIMUM MASS IN SEDIMENT COMPARTMENT FOR POND MODEL
IF (IMODEL.EQ.2) THEN
  QM = RM / (PLEACH + DLR + EVAP) * (1 - EXPF(-(PLEACH + DLR + EVAP) * TOPER))
  + Q1 * EXPF(-(EVAP + DLR + PLEACH) * TOPER)
C   CONVERT ACTIVITY TO MASS
IF (IMODEL.LE.3) THEN
  QMA = QM
  QM = (((QMA * CI) * SEC * ZMW) / (LOG(2.) / THALF)) / A * 1000
ENDIF
  QSL = SL * AL * WA * THICKS * THETAP * (1 + ZKDS * RHOS / THETAP) * 1000
C   CLS = MAXIMUM CONCENTRATION IN POND SEDIMENTS
  CSL = QSL / (AL * WA * THICKS * THETAP * 1000)
ENDIF
C   COMPARE QM TO QSL. IF QM IS GREATER QSL THEN CALCULATE TSL. THE TIME THE
C   SOLUBILITY LIMITED RELEASE DOMINATES ONLY IF CONC VS TIME IS DESIRED.
C   LET R = CONTAMINANT FLUX VIA SOLUBILITY = SOL LIMIT X WATER FLUX
IF (IMODEL.LT.2) THEN
  IF (QM.GT.QSL.AND.KFLAG.EQ.0) THEN
    R = WFLUX * SL
    RC = DLR + RC2
    CALL ROOT(R, RC, QM, QSL, TSL)
  ELSE
    TSL = 0.0
  ENDIF
C   CONVERT SOLUBILITY LIMITED MASS TO ACTIVITY
ENDIF
  IF (IMODEL.LE.3) THEN
    QACT = (QSL * DLR * (1 / 3.1536E + 07) * 6.023E23) / (3.7E10 * ZMW * 1000)
  ELSE
    QACT = 0.0
  ENDIF
  FRACD = 1.00 - FRAC
  IF (IMODEL.EQ.3) THEN
    SLEACH = 0.
    QSL = 0.0
    QACT = 0.0
  ENDIF
  WRITE(2,3025) SLEACH,UX
  WRITE(2,3050) (ADLR(I), I = 1, NN)
  WRITE(2,3100) (ARD(I), I = 1, NN)
  IF (IMODEL.EQ.2) THEN
    WRITE(2,3150) PLEACH
C   SET WA EQUAL TO EFFECTIVE POND WIDTH
    WA = WAEFF
  ENDIF
  WRITE(2,3200) RDU, QSL, QACT, TRANSIT, FRACD

  IF (IMODEL.EQ.3) THEN
    WRITE(2,6000) UNITS
    DO 35, I = 1, NP
      WRITE(2,7000) ATIME(I), QREL(I)
35    CONTINUE
  ENDIF

C   IF INITIAL MASS IS GREATER THAN SOLUBILITY LIMITED MASS THEN PRINT
C   SOLUBILITY LIMITED MASS FLUX IS IN CONTROL FOR THE TIME TSL ONLY FOR
C   NON POND MODEL else print maximum concentration in pond sediments
IF (TSL.GT.0.AND.IMODEL.LT.2) THEN
  WRITE(2,3300) TSL
  WRITE(*,3300) TSL

```

```

ENDIF

IF(IMODEL.EQ.2)THEN
  IF(IMODEL.LT.3)THEN
    WRITE(2,3350) QMA,UNITS
  ELSE
    WRITE(2,3350) QM,UNITS
  ENDIF
ENDIF

IF(QM.GT.QSL.AND.IMODEL.EQ.2)THEN
  WRITE(2,3400) CSL
ENDIF

3000 FORMAT(2X,'>>> VALUES CALCULATED IN SOURCE SUBROUTINE '
  //,2X,'.....')

3025 FORMAT(2X,'LEACH RATE CONSTANT (1/y)          ',1PE11.4
  //,2X,'UNSATURATED PORE VELOCITY (m/y)          ',1PE11.4)

3050 FORMAT(2X,'DECAY CONSTANT(S) (1/y)          ',1PE11.4,
  //,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4)

3100 FORMAT(2X,'RETARDATION FACTOR(S) (SATURATED)  ',1PE11.4,
  //,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4,1PE11.4)

3150 FORMAT(2X,'LEACH RATE CONSTANT FROM POND SEDIMENTS ',1PE11.4)

3200 FORMAT(2X,'RETARDATION FACTOR (UNSATURATED)    ',1PE11.4
  //,2X,'SOLUBILITY LIMITED MASS (mg)              ',1PE11.4
  //,2X,'SOLUBILITY LIMITED ACTIVITY (Ci)           ',1PE11.4
  //,2X,'TRANSIT TIME IN UNSAT ZONE (years)         ',1PE11.4
  //,2X,'FRACTION DECAYED DURING UNSAT TRANSPORT ',1PE11.4
  //,2X,'-----')

3300 FORMAT(2X,'>>> SOLUBILITY LIMITED RELEASE FOR ',1PE11.4,' YEARS')

3350 FORMAT(2X,'POND SEDIMENT INVENTORY AT END OF OPERATIONS: ',1PE9.2,
  //,1X,A2)

3400 FORMAT(2X,'WARNING: THE MAXIMUM CONCENTRATION OF POND SEDIMENT '
  //,2X,'LEACHATE OF ',1PE9.2,' mg/L EXCEEDS THE SOLUBILITY LIMIT OF'
  //,2X,'THE CONTAMINANT')

6000 FORMAT(2X,'-----'
  //,2X,'TABULATED SOURCE FUNCTION'
  //,2X,'-----'
  //,2X,' TIME          SOURCE FLUX '
  //,2X,' (years)      ',a2,'/year'
  //,2X,'-----')

7000 FORMAT(2X,1PE11.4,2X,1PE11.4)
  RETURN
  END

C .....
C SUBROUTINE ASSIGN
C .....
  SUBROUTINE ASSIGN(XDUMMY,ZRADMAX,SFACTOR,RFD,INTIME,
  IUNITS,MODE)
  Implicit real*8 (a-h,o-z)

  Identification

  Program Name: GWSCREEN
  Module Name: assign.f Version: 1.2
  Date: 4/6/93 Time: 17:26:29

  COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
  I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZMW,RC2,IMODE

```

```

CHARACTER*2 UNITS
CHARACTER*45 MODE
Character idkeyw*72
Data idkeyw /'@(!)assign.f 1.2 4/8/93 17:26:29\0'/
idkeyw = idkeyw

```

C ASSIGN A VALUE TO XDUMMY BASED ON THE VALUE OF IMODE

```

IF(IMODE.EQ.1)THEN
  UNITS = 'Ci'
  MODE = 'RADIOLOGICAL DOSE CONVERSION FACTOR (rem/Ci)'
C  USER IS WARNED THAT INTIME SHOULD BE SET TO 1.0 FOR RAD CALC
  IF(INTIME.GT.1)THEN
    WRITE(*,11)
    WRITE(2,11)
  ENDIF
ENDIF

IF(IMODE.EQ.2)THEN
  UNITS = 'Ci'
  MODE = 'RADIOLOGICAL CARCINOGENIC SLOPE FACTOR (1/Ci)'
ENDIF

IF(IMODE.EQ.3)THEN
  UNITS = 'Ci'
  MODE = 'LIMITING RADIONUCLIDE GW CONCENTRATION (Ci/L)'
ENDIF

IF(IMODE.EQ.4)THEN
  ZRADMAX = XDUMMY
  UNITS = 'mg'
  MODE = 'LIMITING CONTAMINANT GW CONCENTRATION (mg/L)'
ENDIF

IF(IMODE.EQ.5)THEN
  SFACTOR = XDUMMY
  UNITS = 'mg'
  MODE = 'CARCINOGENIC SLOPE FACTOR (mg/kg/d) * 10^-1'
ENDIF

IF(IMODE.EQ.6)THEN
  RFD = XDUMMY
  UNITS = 'mg'
  MODE = 'NON-CARCINOGENIC REFERENCE DOSE RfD (mg/kg/d)'
ENDIF

11 FORMAT('
//,2X,'WARNING: VARIABLE INTIME SHOULD BE EQUAL TO 1 YEAR'
//,12X,'FOR RADIOLOGICAL DOSE CALCULATION'
//,' ')
RETURN
END

```

```

C
C .....
C

```

```

REAL*8 FUNCTION ERF(X)
IMPLICIT REAL*8 (A-H,O-Z)

```

```

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: erf.f Version: 1.1
* Date: 6/8/93 Time: 17:40:53
*

```

Character idkeyw*72

```

Data ldkeyw /'Ⓢ(Ⓢ)erf.f 1.1 6/8/93 17:40:53\0'/
ldkeyw = ldkeyw
A=0.50
IF(X.LT.0.)THEN
  ERF=-GAMMP(A,X**2)
ELSE
  ERF=GAMMP(A,X**2)
ENDIF
RETURN
END

```

```

SUBROUTINE ERROR(X,ERX)
C .....
C * SUBROUTINE ERROR
C .....
C This subroutine calculates the error function for an argument, X
C Adapted from Press et al, Numerical RECIPES: modified by A. Rood for
C use with double precision variables. This routine includes the subroutines
C GAMMLN, GSER, GAMMP AND GCF
C

```

```

IMPLICIT REAL*8 (A-H,O-Z)

```

```

IF(X.GE.25.) THEN
  ERX = 1.0
ELSE
  IF(X.LE.-25.) THEN
    ERX = -1.0
  ELSE
    ERX = ERF(X)
  ENDIF
ENDIF
END

```

```

C .....
C * FUNCTION EXPF
C .....
REAL*8 FUNCTION EXPF(X)
IMPLICIT REAL*8 (A-H,O-Z)

```

```

IF(X.LT.-500)THEN
  X=-500
ENDIF
EXPX = EXP(X)
RETURN
END

```

```

C
C .....
C

```

```

SUBROUTINE GCF(GAMMCF,A,X,GLN)
IMPLICIT REAL*8 (A-H,O-Z)
PARAMETER (ITMAX=100,EP8=3.E-7)
C WRITE(*,*) 'GAMMCF, A, X, GLN =',GAMMCF,A,X,GLN

```

```

GLN=GAMMLN(A)
GOLD=0.
A0=1.
A1=X
B0=0.
B1=1.
FAC=1.
DO 11 N=1,ITMAX
  AN=FLOAT(N)
  ANA=AN-A
  A0=(A1+A0*ANA)*FAC
  B0=(B1+B0*ANA)*FAC
  ANF=AN*FAC
  A1=X*A0+ANF*A1
  B1=X*B0+ANF*B1

```

```

      IF(A1.NE.0.)THEN
        FAC = 1./A1
        G = B1 *FAC
        IF(ABS((G-GOLD)/G).LT.EPS)GO TO 1
        GOLD = G
      ENDIF
11  CONTINUE
      PAUSE 'A too large, ITMAX too small'
1   GAMMCF = EXPF(-X + A *LOG(X)-GLN)*G
      RETURN
      END
C
C .....
C
      SUBROUTINE GSER(GAMSER,A,X,GLN)
      IMPLICIT REAL*8 (A-H,O-Z)
      PARAMETER (ITMAX = 100, EPS = 3.E-3)

      GLN = GAMMLN(A)
C   WRITE(0,1) 'A =',A
      IF(X.LE.0.)THEN
        IF(X.LT.0.)PAUSE
        GAMSER = 0.
        RETURN
      ENDIF
      AP = A
      SUM = 1./A
      DEL = SUM
      DO 11 N = 1, ITMAX
        AP = AP + 1.
        DEL = DEL * X / AP
        SUM = SUM + DEL
        IF(ABS(DEL).LT.ABS(SUM)*EPS)GO TO 1
11  CONTINUE
      PAUSE 'A too large, ITMAX too small'

1   GAMSER = SUM * EXPF(-X + A *LOG(X)-GLN)
      RETURN
      END
C
      REAL*8 FUNCTION GAMMLN(XX)
C .....
C   FUNCTION GAMMLN
C .....

      REAL*8 COF(6),STP,HALF,ONE,FPF,X,TMP,SER,XX
      DATA COF,STP/76.1800917300,-88.5053203300,24.0140982200,
        * -1.23173951600,.1208580030D-2,-.536382D-5,2.50662827465D0/
      DATA HALF,ONE,FPF/0.5D0,1.0D0,5.5D0/

      X = XX-ONE
      TMP = X + FPF
      TMP = (X + HALF)*LOG(TMP)-TMP
      SER = ONE
      DO 11 J = 1,6
        X = X + ONE
        SER = SER + COF(J)/X
11  CONTINUE
      GAMMLN = TMP + LOG(STP*SER)
      RETURN
      END
C
C .....
C
      REAL*8 FUNCTION GAMMP(A,X)
      IMPLICIT REAL*8 (A-H,O-Z)
      IF (X.LT.0..OR.A.LE.0.)PAUSE
      IF(X.LT.A + 1.)THEN
        CALL GSER(GAMSER,A,X,GLN)

```

```

      GAMMP = GAMSER
    ELSE
C   WRITE(*,*) 'A, X, GLN ',A,X,GLN
      CALL GCF(GAMMCF,A,X,GLN)
      GAMMP = 1.-GAMMCF
    ENDIF
    RETURN
  END
C .....
C   SUBROUTINE WRITEO
C .....
      SUBROUTINE WRITEO(PKTIMEA,CS,CE,UNITS,IMODEL)
      IMPLICIT REAL*8 (A-H,O-Z)
      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: writoo.f Version: 1.1
      * Date: 4/6/93 Time: 17:15:19
      *
      COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
      * SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZMW,RC2,IMODE
      COMMON /SOURCE/ THETAS, THETAU, RHOS, THICKS, zKDS,
      * DEPTH, PERC, THALF,RHOA, zKDU, RHOU, QM
      PARAMETER(A = 6.023E23,SEC = 3.1536E7,Ci = 3.7E10)
      CHARACTER UNITS*2
C   SP = SPECIFIC ACTIVITY CI/KG
      Character Idkeyw*72
      Data Idkeyw /'@(#)writoo.f 1.1 4/6/93 17:15:19\O'/
      Idkeyw = Idkeyw

C ..... OUTPUT RESULTS AND EXIT .....

      WRITE(2,200) PKTIMEA

C CONVERT CONCENTRATION TO CI/kg OR mg/KG AND CALCULATE TOTAL AMOUNT IN
C SOURCE VOLUME
      IF(IMODEL.LT.2)THEN
        CSD = CS/(RHOS*1000)
        QCS = CS*AL*WA*THICKS
C   CONVERT LIMITING ACTIVITY TO AMOUNT TO MASS
      IF(IMODE.LE.3)THEN
C   CALCULATE SPECIFIC ACTIVITY
      SP = (A*DLR/SEC)/(ZMW*Ci)
      QMCS = (((QCS*Ci)*SEC*ZMW)/DLR)/A)*1000
      ELSE
        QMCS = QCS
      ENDIF
      WRITE(2,300) UNITS,CS
      WRITE(2,350) UNITS,CSD
      WRITE(2,301) UNITS,QCS
      WRITE(*,300) UNITS,CS
      WRITE(*,350) UNITS,CSD
      WRITE(*,301) UNITS,QCS

      IF(IMODE.LE.3)THEN
        WRITE(2,302) QMCS
        WRITE(2,500) SP
        IF(SP.LT.CSD/1000)THEN
          WRITE(2,700) CSD/1000
        ENDIF
      ENDIF

C   COMPARE TOTAL MASS IN SOURCE VOLUME WITH THE SOLUBILITY
C   LIMITED MASS
      IF(QMCS.GT.QSL)THEN
        WRITE(2,351) QMCS,QSL

```

```

ENDIF

ELSE
C   CONVERT TO AMOUNT TO LITERS
    CE = CE/1000
    WRITE(2,400) UNITS,CE
ENDIF

200 FORMAT(2X,'PEAK TIME (y):',1PE13.6)
300 FORMAT(2X,'LIMITING SOIL CONCENTRATION ('.a2,/'m**3): ',1PE10.3)
301 FORMAT(2X,'LIMITING SOIL AMOUNT ('.a2,'): ',1PE10.3)
302 FORMAT(2X,'LIMITING SOIL AMOUNT (mg): ',1PE10.3)
350 FORMAT(2X,'LIMITING SOIL CONCENTRATION ('.a2,/'kg): ',1PE10.3)
351 FORMAT(2X,'WARNING !!! THE LIMITING SOIL MASS OF ',1PE10.3,' mg'
//,2X,'EXCEEDS THE SOLUBILITY LIMITED SOURCE MASS OF ',1PE10.3,' mg'
//)

400 FORMAT(2X,'LIMITING POND EFFLUENT CONCENTRATION ('.a2,/'L): ',
1PE10.3)

500 FORMAT(2X,'SPECIFIC ACTIVITY (Ci/g): ',1PE10.3)
700 FORMAT(2X,'NOTE: THE LIMITING SOIL CONCENTRATION OF ',1PE10.3,
' Ci/g'
//,8X,'EXCEEDS THE SPECIFIC ACTIVITY OF THE NUCLIDE.')

RETURN
END

C .....
C SUBROUTINE GOLDEN
C .....
SUBROUTINE GOLDEN(AX,BX,CX,GMAX,TMAX,TSL,IMODEL,ISOLVE)
IMPLICIT REAL*8 (A-H,O-Z)

C THIS SUBROUTINE IS FROM NUMERICAL RECIPES ,PRESS ET AL. 1987

PARAMETER (R = .61803399,C = .38196602,TOL = 0.001)

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: golden.f Version: 1.1
* Date: 4/6/93 Time: 17:07:42
*
Character idkeyw*72
Date idkeyw '/'@(#)golden.f 1.1 4/6/93 17:07:42\O'/
idkeyw = idkeyw

X0 = AX
X3 = CX
IF(ABS(CX-BX).GT.ABS(BX-AX))THEN
    X1 = BX
    X2 = BX + C*(CX-BX)
ELSE
    X2 = BX
    X1 = BX - C*(BX-AX)
ENDIF
F1 = -FUNC(X1,TSL,IMODEL,ISOLVE)
F2 = -FUNC(X2,TSL,IMODEL,ISOLVE)
1 IF(ABS(X3-X0).GT.TOL*(ABS(X1) + ABS(X2)))THEN
    IF(F2.LT.F1)THEN
        X0 = X1
        X1 = X2
        X2 = R*X1 + C*X3
C    F0 = F1
        F1 = F2
        F2 = -FUNC(X2,TSL,IMODEL,ISOLVE)
    ELSE
        X3 = X2

```

```

      X2=X1
      X1=R*X2+C*X0
C      F3=F2
      F2=F1
      F1=-FUNC(X1,TSL,IMODEL,ISOLVE)
      ENDIF
      GOTO 1
      ENDIF
      IF(F1.LT.F2)THEN
        GMAX=-F1
        TMAX=X1
      ELSE
        GMAX=-F2
        TMAX=X2
      ENDIF
      RETURN
      END

C .....
C  SUBROUTINE GWINT
C .....
      SUBROUTINE GWINT(X1,X2,TRANSIT,TSL,AIC,DAIC,ADLR,GWPEAK,PKTIMEA,
      I IMODEL,ISOLVE,NN)
      IMPLICIT REAL*8 (A-H,O-Z)
      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: gwint.f Version: 1.2
      * Date: 6/21/93 Time: 16:39:53
      *
      C This subroutine calculates the limits of integration for
      C regulatory criteria and the average integrated concentration.

      C CALCULATED VALUES IN GWINT SUBROUTINE
      C S = INTEGRATED CONCENTRATION
      C AIC = AVERAGE INTEGRATED CONCENTRATION
      C X1 IS EQUIVALENT TO THE INTEGRATION TIME CONVERTED TO A REAL NUMBER
      C X2 IS THE PEAK TIME
      C T1 = LOWER LIMIT OF INTEGRATION (Y)
      C T2 = UPPER LIMIT OF INTEGRATION (Y)

      C CHECK TO SEE IF INTEGRATION TIME IS BOUNDED EQUALLY ON BOTH SIDES OF THE
      C OF THE PEAK T1 AND T2 ARE THE INTEGRATION LIMITS
      PARAMETER (NSPEC=9)
      COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
      DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
      I,ARD(NSPEC),RCSF(NSPEC)
      DIMENSION ADLR(NSPEC),DAIC(NSPEC),Q(NSPEC),QDX(NSPEC)

      Character idkeyw*72
      Date idkeyw/'@(#)gwint.f 1.2 6/21/93 16:39:53\0'/
      idkeyw = idkeyw

      IF(X1.LE.1.)THEN
        AIC = GWPEAK
        DAIC(1) = GWPEAK
        IF(NN.GT.1)THEN
          Q(1) = 1.0
          DO 10, I = 2, NN
            Q(I) = 0.0
          10 CONTINUE
          CALL RDK(PKTIMEA,ADLR,NN,Q,QDX)
          DO 20, I = 2, NN
            DAIC(I) = GWPEAK*(QDX(I)/QDX(1))*(ARD(1)/ARD(I))
          20 CONTINUE
        ENDIF
      RETURN

```



```

ENDIF
IF((X2-X1/2).LT.0.0)THEN
  T1 = 0
  T2 = X1
ELSE
  T1 = X2-X1/2
  T2 = X2+X1/2
ENDIF

C CALCULATE INTEGRATED CONCENTRATION USING GAUSSIAN QUAD FROM
C NUMERICAL RECIPES

DO 30, I=1,NN
  WRITE(*,1000) I

  CALL QGAUS1(T1,T2,S,TSL,TRANSIT,ADLR,IMODFL,ISOLVE,NN,I)

  DAIC(I) = S/(T2-T1)
30 CONTINUE
AIC = DAIC(1)

1000 FORMAT(2X,'CALCULATING AVERAGE INTEGRATED CONCENTRATION FOR MEMBER
I #',I1)

RETURN
END
C .....
C SUBROUTINE LIMITS
C .....
SUBROUTINE LIMITS(T1,T2,TI,IFLAG,IMODEL)
IMPLICIT REAL*8 (A-H,O-Z)
PARAMETER (ARB = 50)
*
* Identification
*
* Program Name: GWSCREEN
* Module Name: limits.f Version: 1.1
* Date: 4/6/93 Time: 17:09:13
*

C COMMON STATEMENTS
COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZMW,RC2,IMODE
Character idkeyw*72
Date idkeyw/'@(#)limits.f 1.1 4/6/93 17:09:13\O'/
idkeyw = idkeyw

C DETERMINE LIMITS FOR INTEGRATION
C T1 = LOWER LIMIT T2 = UPPER LIMIT THESE VALUES ARE IN UNITS OF SECONDS
C INTEGRATION LIMITS ARE SELECTED BY CODELL'S METHOD. THE LIMITS ARE
C BASED ON THE VALUE OF ARB WHEN EXP(-ARB) APPROACHES ZERO. DEPENDING
C ON THE MACHINE USED, ARB MAY BE -50 TO -200
C XC1 AND XC2 = THE X DISTANCE USED IN CALCULATION OF THE INTEGRATION LIMITS.
C XC1 = XD + AL/2 AND
C XC2 = XD - AL/2 FOR HORIZONTAL AREA SOURCES. THE TEMP VARIABLES STORE THE
C INTERMEDIATE VALUES
IFLAG = -1
DXX = ABS(AX*VX)
XC1 = XD + AL/2
XC2 = XD - AL/2

TEMP1 = (2*VX*XC1/RD + 4*DXX*ARB/RD)/((VX/RD)**2
+ 4*DXX*DLR/RD)

TEMP2 = TEMP1**2 - (2*XC2)**2/((VX/RD)**2
+ 4*DXX*DLR/RD)

C IF TEMP2 IS LESS THAN ZERO THEN DO NOT PROCEED WITH INTEGRATION

```

```

IF(TEMP2.LE.0.0)THEN
  IFLAG = 1
  RETURN
ENDIF

TEMP3 = (2*VX*XC2/RO + 4
I'DXX*ARB/RO)/(VX/RO)**2
I + 4*DXX*DLR/RO)

T2 = T1-(TEMP3-SQRT(TEMP2))/2

T1 = T1-(TEMP1 + SQRT(TEMP2))/2

C CONDITIONAL STATEMENTS
C IF THE UPPER LIMIT IS EQ TO 0 THEN RETURN
IF(T2.LE.0.) THEN
  IFLAG = 1
  RETURN
ENDIF
C CHECK LOWER LIMIT OF INTEGRATION TO MAKE SURE IS NOT LESS THAN 0
IF(T1.LE.0.) THEN
  T1 = 0.0
ENDIF
C CHECK TO SEE IF INTEGRATION LIMIT IS GREATER THAN DESIRED TIME
IF(T2.GE.T1) THEN
  T2 = T1
ENDIF
C CUT OFF SOURCE TERM AFTER EXPONENT ARGUMENT IS -500 (APP. 700 HALF LIVES)
IF(DLR.GT.0.AND.IMODEL.LT.2)THEN
  CUTOFF = 700*(LOG(2.)/DLR)
  IF(T2.GT.CUTOFF)THEN
    T2 = CUTOFF
  ENDIF
ENDIF
RETURN
END

C .....
C * SUBROUTINE LINT .....
C .....
SUBROUTINE LINT(X,Y)
*
* Identification
*
* Program Name: GWSCREEN
* Module Name: lint.f Version: 1.1
* Date: 4/6/93 Time: 17:09:30
*
* subroutine for linear interpolation
*
IMPLICIT REAL*8(A-H,O-Z)
COMMON /TABLE/ ATIME,QREL,NP
PARAMETER (NPPOINTS = 1000)
DIMENSION ATIME(NPPOINTS),QREL(NPPOINTS)
Character Idkeyw*72
Data Idkeyw /'@(#)lint.f 1.1 4/6/93 17:09:30\0'/
Idkeyw = Idkeyw
C IF RELEASE TIME IS GREATER THAN SOURCE INPUT TIME THEN FLUX = 0
IF(X.GT.ATIME(NP))THEN
  Y = 0.0
  RETURN
ENDIF
N = NP
KLO = 1
KHI = N
1 IF (KHI-KLO.GT.1) THEN
  K = (KHI + KLO)/2
  IF(ATIME(K).GT.X)THEN
    KHI = K

```

```

ELSE
  KLO = K
ENDIF
GOTO 1
ENDIF
H = ATIME(KHI) - A / TIME(KLO)
IF (H.EQ.0.) PAUSE 'Bad XA input.'
Y = QREL(klo) + (x-ATIME(klo))/h * (QREL(khi)-
  QREL(klo))
RETURN
END

REAL*8 FUNCTION AREA(TI,Q)
IMPLICIT REAL*8 (A-H,O-Z)
C .....
C *   FUNCTION AREA   *
C .....
C This subroutine calculates the ground water concentration for an area source
C ALL UNITS ARE IN METERS AND YEARS
C
C Identification
C
C Program Name: GWSCREEN
C Module Name: area.f Version: 1.1
C Date: 4/6/93 Time: 16:42:40
C
C COMMON STATEMENTS
COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
  SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZMW,RC2,IMODE
Character idkeyw*72
Data idkeyw /'@(#)area.f 1.1 4/6/93 16:42:40\0'/
idkeyw = idkeyw

IF(TI.LE.0.0) THEN
  AREA = 0.0
  RETURN
ENDIF

DX = ABS(AX*VX)
DY = ABS(AY*VX)

C X ARGUMENTS

ARG1 = ((XD + AL/2) - VX*TI/RD)/SQRT(4*DX*TI/RD)
ARG2 = ((XD - AL/2) - VX*TI/RD)/SQRT(4*DX*TI/RD)
CALL ERRORD(ARG1,EX1)
CALL ERRORD(ARG2,EX2)

X2 = (EX1-EX2)*EXP(-DLR*TI)/(2*AL)
C Y ARGUMENTS
ARG1 = (WA/2 + YD)/SQRT(4*DY*TI/RD)
CALL ERRORD(ARG1,EY1)
ARG2 = (WA/2 - YD)/SQRT(4*DY*TI/RD)
CALL ERRORD(ARG2,EY2)
Y2 = (EY1 + EY2)/(2*WA)

C CALCULATE Z PARAMETER FOR AVG SOLUTION

Z1 = 1/THICK

C CALCULATE GROUND WATER CONCENTRATION

GWCON = (Q*X2*Y2*Z1)/(PHI*RD)
AREA = GWCON
RETURN
END

C .....
C SUBROUTINE PEAK

```

```

C .....
SUBROUTINE PEAK(GWPEAK,PKTIME,TSL,IMODEL,ISOLVE)
IMPLICIT REAL*8 (A-H,O-Z)

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: peak.f Version: 1.4
* Date: 6/21/93 Time: 16:48:12
*

C This subroutine calculates the peak concentration
C Called by MAIN
C CALCULATED VALUES IN PEAK SUBROUTINE
C DEL = TIME INCREMENT FOR PEAK BRACKET LOCATION
C TI = TIME SLOPE IS CALCULATED AT
C GWPEAK = PEAK CONCENTRATION
C PKTIME = TIME OF PEAK CONCENTRATION (Y)
C THE MINIMUM-MAXIMUM BOUNDARIES ARE THE VARIABLES ZMIN AND ZMAX
C THE MIDDLE POINT IS VARIABLE ZMID
C TX=DUMMY VARIABLE TO HOLD OPERATION TIME OF POND FOR POND MODEL
C Routine was re-written 8-31-92 because problems developed when short
C half-lived contaminants were evaluated.
COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
1 SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZM*W,RC2,IMODE
COMMON /POND/ RMI,TOPE,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
PARAMETER (R1 = 1.1,R2 = 2.1)
Character idkeyw*72
Data idkeyw /'@(#)peak.f 1.4 6/21/93 16:48:12\0'/
idkeyw = idkeyw
WRITE(*,*) ' CALCULATING PEAK CONCENTRATION'
TX = 0.0
C CALCULATE PEAK FOR POND MODEL DURING STEADY STATE IF THERE IS NO INITIAL MASS
IF(IMODEL.GT.1.AND.QI.LE.0.)THEN
TEMP = 20. * (LOG(2.)/(PLEACH + DLR + EVAP)) + (XD + AL) * RD/VX
IF(TOPE.GT.TEMP)THEN
WRITE(2,1000) TEMP
GWPEAK = FUNC(TEMP,TSL,IMODEL,ISOLVE)
PKTIME = TEMP
RETURN
ENDIF
TX = TOPE
ENDIF
C BRACKET MAXIMUM AND MINIMUM VALUE
IF(DLR.GT.1.0E-20)THEN
ZHR = (LOG(2.)/DLR) * V.X/((0.1 + XD) * RD)
IF(ZHR.GT.1.)THEN
ZHR = 1.0
ENDIF
ELSE
ZHR = 1.0
ENDIF
ZMIN = ((TX + (XD-AL) * RD/VX)/5.) * ZHR
IF(ZMIN.LE.1.0E-20)THEN
ZMIN = 1.0E-20
ENDIF
ZMAX = (TX + (XD + AL) * RD/VX) * 3.
C CHECK THAT ZMAX IS NON ZERO
ZSTEP = (ZMAX-ZMIN)/100.
DO 20,I = 1,100
ZC = FUNC(ZMAX,TSL,IMODEL,ISOLVE)
IF(ZC.GT.0.)THEN
ZMID = ZMIN + (ZMAX-ZMIN)/2.
CALL GOLDEN(ZMAX,ZMID,ZMIN,GWPEAK,PKTIME,TSL,IMODEL,ISOLVE)
RETURN
ELSE
ZMAX = ZMAX-ZSTEP
ENDIF

```

```

20 CONTINUE
WRITE(2,2000)
WRITE(*,2000)
RETURN

```

```

1000 FORMAT(' POND OPERATION TIME EXCEEDS STEADY STATE CUTOFF TIME OF'
1,1X,1PE9.2,'YEARS ')

```

```

2000 FORMAT(2X,'PEAK CONCENTRATION CANNOT BE FOUND WITH PEAK FINDER ROUTINE:'
1/,2X,'USE CONCENTRATION VS TIME MODE TO DETERMINE PEAK')

```

END

```

C .....
C SUBROUTINE ROOT
C .....

```

```

SUBROUTINE ROOT(R,RCS,Q0,QL,T)

```

C This subroutine calculates the time roots of the solubility release function

```

IMPLICIT REAL*8(A-H,O-Z)
PARAMETER (MAXIT=100)

```

```

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: root.f Version: 1.3
* Date: 4/15/93 Time: 18:13:40
*

```

```

Character Idkeyw*72
Data Idkeyw/'@(#)root.f 1.3 4/15/93 18:13:40\0'/
Idkeyw = Idkeyw

```

```

C perform calculation for decaying source only if the sum of the half
C times is greater than 1E10 years

```

```

IF(RCS.GT.8.93E-11)THEN
T=-LOG((QSL+R/RCS)/(Q0+R/RCS))/RCS
ZMB=Q0*EXP(-RCS*T)-R/RCS*(1-EXP(-RCS*T))-QSL
ELSE
T=(Q0-QSL)/R
ZMB=Q0-R*T-QSL
ENDIF

```

```

WRITE(*,1000) ZMB

```

```

1000 FORMAT(2X,'SOLUBILITY MASS BALANCE (mg)',1PE11.4)

```

```

RETURN
END

```

```

C .....
C SUBROUTINE QGAUS1
C .....

```

```

SUBROUTINE QGAUS1(A,B,SS,TSL,TRANSIT,ADLR,IMODEL,ISOLVE,NN,K)
IMPLICIT REAL*8 (A-H,O-Z)

```

```

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: qgaus1.f Version: 1.1
* Date: 4/6/93 Time: 17:11:58
*

```

```

PARAMETER (NSPEC=9)
COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
1,ARD(NSPEC),RCSF(NSPEC)
DIMENSION X(8),W(8),ADLR(NSPEC),Q(NSPEC),QDX(NSPEC)

```

C ZEROS AND WEIGHTS FOR 16 POINT GAUSSIAN QUADRATURE: FROM NUMERICAL

DATA X/ 0.0950125098,0.281603558,0.4580167777,0.617876244
 *,0.755404484,0.8656312024,0.9445750231,0.9894009350/

DATA W/ 0.1894508105,0.1826034150,0.1691565194,0.149595988
 *,0.1246289713,0.0951585117,0.0622535239,0.0271524594/
 Character idkeyw *72
 Date idkeyw /'@(#)qgaus1.f 1.1 4/8/93 17:11:56\0'/
 idkeyw = idkeyw

```

      XM=0.5*(B+A)
      XR=0.5*(B-A)
      SS=0
      IF(NN.GT.1)THEN
        DO 10,I=1,NN
          Q(I)=0.0
10      CONTINUE
          Q(1)=1.0
        ENDIF

      DO 20 J=1,8
        DX=XR*X(J)
C      CALCULATE DECAY INGROWTH FACTORS
        IF(NN.GT.1)THEN
          T=XM+DX+TRANSIT
          CALL RDK(T,ADLR,NN,Q,QDX)
          F1=(QDX(K)/QDX(1))*ARD(1)/ARD(K)
          T=XM-DX+TRANSIT
          CALL RDK(T,ADLR,NN,Q,QDX)
          F2=(QDX(K)/QDX(1))*ARD(1)/ARD(K)
        ELSE
          F1=1.0
          F2=1.0
        ENDIF
        SS=SS+W(J)*(FUNC1(XM+DX),TSL,IMODEL,ISOLVE)*F1+FUNC1(XM-DX),TSL,
        IMODEL,ISOLVE)*F2)
20    CONTINUE
      SS=XR*SS
      RETURN
      END
C .....
C  SUBROUTINE QGAUS2
C .....
      SUBROUTINE QGAUS2(TI,SS,TSL,IMODEL)
      IMPLICIT REAL*8 (A-H,O-Z)

      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: qgaus2.f Version: 1.1
      * Date: 4/8/93 Time: 17:12:16
      *

```

DIMENSION X(17),W(17)

C TIME UNITS ARE YEARS, CONCENTRATION UNITS ARE AMOUNT/M3
 C This routine calculates the groundwater concentration at time TI. This
 C routine has been adapted from Numerical Recipes, Press et al.

C COMMON STATEMENTS
 COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
 I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD,ZMW,RC2,IMODE

C ZEROS AND WEIGHTS FOR 34 POINT GAUSSIAN QUADRATURE:
 C CALCULATED WITH GAUSLEG SUBROUTINE

DATA X/ 0.0455098220,0.1361523573,0.2256666916,0.3133110813
 *,0.3983592778,0.4801065452,0.5578755007,0.6310217271

```

*,0.6989391132,0.7610648766,0.8168842279,0.8659346383
*,0.9078096777,0.9421623974,0.9687062625,0.9872278164
*,0.9975717538/

```

```

DATA W/ 0.0909567403,0.0902030444,0.0887018978,0.0864657397
*,0.0835130997,0.0798684443,0.0755619747,0.0706293758
*,0.0651115216,0.0590541358,0.0525074146,0.0455256115
*,0.0381665938,0.0304913806,0.0225637220,0.0144501627
*,0.0062291406/

```

```

Character Idkeyw*72
Data Idkeyw /'@(#)qgaus2.f          1.1  4/6/93  17:12:16\0'/
Idkeyw = Idkeyw

```

C INITIALIZE VARIABLES IF T1=0.0 RETURN TO START

```

IF(T1.EQ.0) THEN
  SS = 0.0
  RETURN
ENDIF

```

C DETERMINE INTEGRATION LIMITS

```

CALL LIMITS(A,B,T1,IFLAG,IMODEL)
IF(IFLAG.GT.0)THEN
  SS = 0.0
  RETURN
ENDIF

```

```

XM = 0.5*(B + A)
XR = 0.5*(B-A)
SS = 0

```

```

DO 11 J = 1,17

```

C TX1 AND TX2 ARE THE TIMES TO BE USED IN THE AREA SUBROUTINE

```

DX = XR*X(J)
TX1 = T1-(XM+DX)
TX2 = T1-(XM-DX)

```

C CALCULATE SOURCE TERM

```

T = XM+DX
CALL SRCTERM(T,TSL,Q1,IMODEL)

T = XM-DX
CALL SRCTERM(T,TSL,Q2,IMODEL)
SS = SS + W(J)*(AREA(TX1,Q1) + AREA(TX2,Q2))
11 CONTINUE
SS = XR*SS

```

```

RETURN
END
SUBROUTINE SIMPSON(T1,S,TSL,IMODEL)

```

```

C .....
C * SUBROUTINE SIMPSON
C .....

```

```

  IMPLICIT REAL*8(A-H,O-Z)

```

```

  *
  * Identification
  *

```

```

  * Program Name: GWSCREEN
  * Module Name: simpson.f Version: 1.2
  * Date: 4/7/93 Time: 15:33:23
  *

```

C COMMON STATEMENTS

```

  COMMON /SIMP/ EPS,JMAX,JSTART

```

```

Character ldkeww*72
Data ldkeww /'@(#)simpson.f          1.2 4/7/93 15:33:23\0'/
ldkeww = ldkeww

```

```

IF(T1.EQ.0) THEN
  S=0.0
  RETURN
ENDIF

```

```

C DETERMINE INTEGRATION LIMITS
CALL LIMITS(T1,T2,TI,IFLAG,IMODEL)
IF(IFLAG.GT.0)THEN
  S=0.0
  RETURN
ENDIF

```

```

C INTEGRATION IS NOW PERFORMED BY SIMPSON'S RULE. ROUTINE WAS ADAPTED FROM
C NUMERICAL RECIPES (PRESS ET AL., 1992) PAGE 130 - 133
C INITIALIZE VARIABLES

```

```

OST=-1.0E38
OS=-1.0E-30

```

```

DO 11,J=1,JMAX
  CALL TRAPZD(T1,T2,ST,TI,TSL,J,IMODEL)
  S=(4.0*ST-OST)/3

```

```

C check for convergence
IF(ABS(S-OS).LE.EPS*ABS(OS).AND.J.GT.JSTART)THEN
  RETURN
ELSE
  TOS=OS
  OS=S
  OST=ST
ENDIF

```

```

11 CONTINUE
N1=2*(JMAX-1)
V1=(ABS(S-TOS))/ABS(TOS)
WRITE(*,1000) n1,V1

```

```

1000 FORMAT(2X,'Convergence not Achieved After',I6,' Steps; EPS value
1',1pe11.4)

```

```

999 RETURN
END

```

```

SUBROUTINE TRAPZD(A,B,S,T2,TSL,N,IMODEL)
IMPLICIT REAL*8(A-H,O-Z)

```

```

C .....
C * SUBROUTINE TRAPZD .....
C .....
COMMON /SIMP/ EPS,JMAX,JSTART

```

```

IF(N.EQ.1) THEN
  CALL SRCTERM(A,TSL,Q,IMODEL)
  T4=T2-A
  F1=AREA(T4,Q)

```

```

  CALL SRCTERM(B,TSL,Q,IMODEL)
  T4=T2-B
  F2=AREA(T4,Q)
  S=0.5*(B-A)*(F1+F2)
  ELSE
    IT=2*(N-2)
    TNM=FLOAT(IT)
    DEL=(B-A)/TNM
    X=A+0.5*DEL
    SUM=0
    DO 11, J=1,IT
      T4=T2-X

```



```

        CALL SRCTERM(X,TSL,Q,IMODEL)
        SUM=SUM+AREA(T4,Q)
        X=X+DEL
11      CONTINUE
        S=0.5*(S+(S-A)*SUM/TNM)
      ENDF
      RETURN
      END
C .....
C * SUBROUTINE RDK
C .....
      SUBROUTINE RDK(T,DLR,NN,Q,QDX)
      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: rdkgws.f Version: 1.1
      * Date: 4/6/93 Time: 17:13:05
      *

C FEBRUARY, 1992
C This program is based on an algorithm written by A. Birchall and presented
C in Health Physics Vol 50, No 3 (March 1980, pp 389-397. The program calculates
C the amount of material in n number of first order compartments.

      IMPLICIT REAL*8(A-H,O-Z)
      PARAMETER (ND = 10,NSPEC = 8)

C ND = THE TOTAL NUMBER OF COMPARTMENTS AVAILABLE
C NC = NUMBER OF COMPARTMENTS IN SIMULATION
C IDP=THE PROGENY INDEX
C ND = THE TOTAL NUMBER OF PROGENY AVAILABLE
C NC = NUMBER OF PROGENY IN SIMULATION
C AOUTPUT = OUTPUT MATRIX
C DLR = INPUT RATE CONSTANTS (Y-1)
C R = RATE AND INITIAL ACTIVITY MATRIX (CI AND S-1)
C Q = INITIAL ACTIVITIES (CI)
C QDX = DECAYED ACTIVITIES (CI)
C DT = TIME CONVERTED TO SECONDS
      DIMENSION R(O:ND,O:ND),KPATH(O:ND,O:ND),MAX(O:ND),SUM(O:ND)
      DIMENSION DLR(NSPEC),Q(NSPEC),QDX(NSPEC)

      Character idkeyw*72
      Data idkeyw /'@{#}rdkgws.f 1.1 4/6/93 17:13:05\0'/
      idkeyw = idkeyw

      NC=NN+1

C RESET R,PATH,MAX AND SUM MATRIX
      DO 5, I=1,NC
        DO 6,J=1,NC
          R(I,J)=0
          KPATH(I,J)=0
        6 CONTINUE
        MAX(I)=0
        SUM(I)=0
        QDX(I)=0.0
      5 CONTINUE

C INPUT MATRIX VALUES
      DO 10,I=1,NC
        R(I,I)=Q(I)
      10 CONTINUE

C READ DECAY CONSTANTS AND CONVERTS TO SEC**-1
      DO 20,I=1,NC
        R(I,I+1)=DLR(I)/3.1536E7
      20 CONTINUE
C CONVERSION FROM CI TO DIS PER SECOND

```

```

      CONVERTF = 3.7E+10
C CONVERT ACTIVITY TO NUMBER OF ATOMS AND TIME TO SECONDS

      DO 21,I=1,NC
      IF(I+1.GT.NC)THEN
        GOTO 21
      ENDIF
      R(I,I) = R(I,I)*CONVERTF/R(I,I+1)
21  CONTINUE
      DT=T*3.1536E7
C SET UP KPATH MATRIX

      DO 30,J=2,NC
      DO 40,I=1,J-1
      IF(R(I,J).EQ.0.0)THEN
        GOTO 40
      ENDIF
      MAX(J) = MAX(J) + 1
      KPATH(MAX(J),J) = I
40  CONTINUE
30  CONTINUE

      ZLAM=0.0
C CALCULATE SUM VALUE
      DO 50,I=1,NC
      SUM(I) = ZLAM
      DO 60,J=I+1,NC
      SUM(I) = SUM(I) + R(I,J)

60  CONTINUE
50  CONTINUE

C THE AMOUNT IN THE COMPARTMENT AND THE INTEGRATED NUMBER OF DISINTEGRATIONS
C IS RETURNED IN THE VARIABLES TSUM AND TDIS

      DO 100,I=1,NC

      CALL S1000(I,DT,R,MAX,KPATH,SUM,ZLAM,NC,TSUM,TDIS)
C   CONVERT NUMBER OF ATOMS TO ACTIVITY DO NO CONVERT LAST COMPARTMENT

      QDX(I) = TSUM*R(I,I+1)/CONVERTF

      IF(QDX(I).LT.0.)THEN
        QDX(I) = 0.
      ENDIF

100 CONTINUE
      RETURN
      END

C .....
C *   SUBROUTINE S1000   *
C .....
      SUBROUTINE S1000(KCOM,T,R,MAX,KPATH,ZSUM,ZLAM,NC,TSUM,TDIS)
      IMPLICIT REAL*8(A-H,O-Z)

      PARAMETER (ND = 10)
      DIMENSION R(0:ND,0:ND),KPATH(0:ND,0:ND),MARK(0:ND),MAX(0:ND)
      DIMENSION IPA(0:ND),IP(0:ND)
      DIMENSION ZNO(0:ND),ZK(0:ND),ZKT(0:ND),ZSUM(0:ND),ZI(0:ND)
      TDIS = 0
      TSUM = 0
      NP = 0

      DO 70, I3=1,NC
      MARK(I3) = 1

```



```

PARAMETER (ND = 10)
DIMENSION ZNO(0:ND),ZK(0:ND),ZKT(0:ND)
XSUM = 0
DIS = 0

DO 140, I1 = 1, N
  S1 = 1
  DO 150, I2 = I1, N-1
    S1 = S1 * ZK(I2)
150  CONTINUE
  S2 = 0
  S4 = 0
  DO 160, I2 = I1, N
    S3 = 1
    DO 170, I3 = I1, N
      IF (I3.EQ.I2) THEN
        GOTO 170
      C   LINE 170 IS EQUAL TO LINE 2040 IN BASIC PROGRAM
      ENDF
      S3 = S3 * (ZKT(I3) - ZKT(I2))
      IF (S3.EQ.0) THEN
        RETURN
      ENDF
170  CONTINUE

      S2 = S2 + ZNO(I1) * EXPF(-ZKT(I2)*T)/S3
      IF (ZLAM.EQ.0.) THEN
        GOTO 160
      C   LINE 160 IS EQUAL TO LINE 2070 IN BASIC PROGRAM
      ENDF

      IF (ZKT(I2)*T.GT.0.01) THEN
        S4 = S4 + ZNO(I1) * (1-EXPF(-ZKT(I2)*T))/S3/ZKT(I2)
      ENDF

      IF (ZKT(I2)*T.LE.0.01) THEN
        S4 = S4 + ZNO(I1) * (T-0.5*ZKT(I2)*T)/S3
      ENDF
160  CONTINUE
  XSUM = XSUM + S1 * S2
  DIS = DIS + ZLAM * S1 * S4
140  CONTINUE
  RETURN
END

C .....
C SUBROUTINE SRCPOND
C .....
SUBROUTINE SRCPOND(T,Q)
IMPLICIT REAL*8 (A-H,O-Z)
PARAMETER (A = 6.023E+23, CI = 3.7E+10, SEC = 3.1536E7)

*
* Identification
*
* Program Name: GWSCREEN
* Module Name: srcpond.f Version: 1.2
* Date: 8/21/93 Time: 16:44:16
*
C This subroutine calculates the mass or activity released from a pond
COMMON /POND/ RMI, TOPER, PNDFLX, THETAP, EVAP, PLEACH, WAEFF
COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
I SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD, ZMW, RC2, IMODE

Character Idkeyw*72
Data Idkeyw/'@(#)srcpond.f' 1.2 8/21/93 16:44:16/
Idkeyw = Idkeyw
IF (T.LE.TOPER) THEN
  QMASS = RMI * (1-EXPF(-(EVAP+DLR+PLEACH)*T))/(EVAP+PLEACH
+ DLR) + QI * EXPF(-(EVAP+PLEACH+DLR)*T)

```

```

      Q = PLEACH * QMASS * FRAC
    ELSE
C      calculate flux from sediments already in pond
      QMASS = RMI * (1 - EXP(-(EVAP + DLR + PLEACH) * TOPER)) / (EVAP +
1    PLEACH + DLR) + QI * EXP(-(EVAP + PLEACH + DLR) * TOPER)
      Q = FRAC * SLEACH * QMASS * EXP(-(SLEACH + DLR) * (T - TOPER))
    ENDIF
    RETURN
  END
C .....
C SUBROUTINE SRCTERM
C .....
      SUBROUTINE SRCTERM(T, TSL, Q, IMODEL)
      IMPLICIT REAL*8 (A-H, O-Z)
      PARAMETER (A = 6.023E+23, CI = 3.7E+10, SEC = 3.1536E7)
      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: srcterm.f Version: 1.2
      * Date: 6/8/93 Time: 17:48:12
      *
C      This subroutine calculates the mass or activity released
      COMMON /GW/ AX, AY, VX, THICK, AL, WA, GWLIM, RD, PHI, DLR, QX,
1    SLEACH, FRAC, WFLUX, SL, QSL, QI, XD, YD, ZMW, RC2, IMODEL
      Character idkeyw*72
      Data idkeyw /'@(#)srcterm.f 1.2 6/8/93 17:48:12\0'/
      idkeyw = idkeyw
C      CHECK SOURCE CUTOFF TIME FOR NON TABULATED SOURCE
      ARG = (SLEACH + DLR + RC2) * T
      IF (ARG.GT.500.AND.IMODEL.NE.3) THEN
        Q = 0.0
        RETURN
      ENDIF
C      Call pond model if IMODEL = 2
      IF (IMODEL.EQ.2) THEN
        CALL SRCPOND(T, Q)
        RETURN
      ENDIF
C      Call linear interpolation routine if IMODEL = 3
      IF (IMODEL.EQ.3) THEN
        CALL LINT(T, Q)
        Q = Q * FRAC
        RETURN
      ENDIF
C      IF TSL = 0 THEN DO LEACH EQUATION FOR EITHER ACTIVITY OR MASS
      IF (TSL.EQ.0.0) THEN
        ARG = (-(SLEACH + DLR + RC2) * (T))
        Q = FRAC * SLEACH * QI * EXP(ARG)
        RETURN
      ENDIF
C      IF T IS LESS THAN TSL THEN A SOLUBILITY LIMITED RELEASE IS CALCULATED FOR
C      THE SOURCE TERM. IF A RADIONUCLIDE, THEN MASS IS CONVERTED TO ACTIVITY
      IF (T.GE.TSL) THEN
        ARG = (-(SLEACH + DLR + RC2) * (T - TSL))
        Q = QSL * FRAC * SLEACH * EXP(ARG)
      ELSE
        Q = FRAC * WFLUX * SL
      ENDIF
C      convert mass to activity if a radionuclide
C      CONVERT MG TO CI. USE THE CONVERSIONS 1 CI = 3.7E10 DPS, 3.1536 S/Y
C      6.023E23 ATOMS/MOLE AND 1000 MG/G
      IF (IMODEL.LE.3) THEN
        QA = (Q / (1000 * ZMW)) * A * (DLR / SEC) / CI
        Q = QA
      ENDIF

```

```

      RETURN
      END
C .....
C SUBROUTINE RAD
C .....
      SUBROUTINE RAD(CS,CE,AIC,AIC1,VOL,PKT,ADLR,NN,IMODEL)
      IMPLICIT REAL*8 (A-H,O-Z)

      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: rad.f Version: 1.2
      * Date: 6/21/93 Time: 16:41:31
      *

      COMMON /EXPOSURE/SW,AT,WI,EF,ED,DLIM,CRISK,HQ
      PARAMETER (NSPEC=9)
      COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
      DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
      I,ARD(NSPEC),RCSF(NSPEC)
      COMMON /POND/ RMI,TOPEP,PNOFLX,THETAP,EVAP,PLEACH,WAEFF
      DIMENSION ADLR(NSPEC),Q(NSPEC),QDX(NSPEC),C(NSPEC),D(NSPEC)

C VARIABLES
C DLIM = DOSE LIMIT (4 REM/Y)
C CL = LIMITING GROUNDWATER CONCENTRATION CUM**3
C WI = WATER INTAKE RATE (L/D)
C CDCF = COMPOSITE DOSE CONVERSION FACTOR
C CX = THE CONCENTRATION IN THE POND EFFLUENT
C C(I) = CONCENTRATION OF THE ITH PROGENY MEMBER (C/L)

      Character Idkeyw*72
      Data Idkeyw /'@!$rad.f 1.2 6/21/93 16:41:31\0'/
      Idkeyw = Idkeyw

      WRITE(2,500)
      CDCF = 0.0
C CALCULATE DECAY-INGROWTH FACTORS, CONCENTRATIONS AND COMPOSITE DCF
C CONCENTRATION IN C/L
      IF(NN.GT.1)THEN
        Q(1) = 1.0
        DO 10, I = 2, NN
          Q(I) = 0.0
10      CONTINUE
        CALL RDK(PKT,ADLR,NN,Q,QDX)
        WRITE(2,1000) (QDX(I),I = 1,NN)
        DO 20, I = 1, NN
          C(I) = (AIC1*(QDX(I)/QDX(1)))*(ARD(1)/ARD(I))/1000.
20      CONTINUE
C CALCULATE COMPOSITE DOSE CONVERSION FACTOR
        DO 30, I = 1, NN
          CDCF = CDCF + ADCF(I)*(QDX(I)/QDX(1))*(ARD(1)/ARD(I))
30      CONTINUE
        ELSE
          C(1) = AIC/1000
          CDCF = ADCF(1)
        ENDIF

      CL = DLIM/(CDCF*WI*EF/1000)
      WRITE(2,2000) CDCF,CL/1000
C CALCULATE DOSE
      DT = 0.0
      IF(NN.GT.1)THEN
        WRITE(2,4000)
      ENDIF
      DO 40, I = 1, NN
        D(I) = C(I)*WI*EF*ADCF(I)
        DT = DT + D(I)
        WRITE(2,3000) I,C(I),D(I)
40      CONTINUE

```

```

WRITE(2,4800) DT

C  CALCULATE LIMITING SOIL OF POND EFFLUENT CONCENTRATIONS
  IF(IMODEL.LT.2)THEN
C  1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
    CS = CL/AIC*(1/VOL)
    ELSE
    CU = RMI/PNDFLX
    CE = (CL*CU/AIC)
  ENDF

600 FORMAT(2X,'COMMITTED EFFECTIVE DOSE EQUIVALENT CALCULATION')

1000 FORMAT(2X,'DECAY-INGROWTH FACTORS ',1PE11.4,1X,1PE11.4,1X,1PE11.4,
  11X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4)
2000 FORMAT(2X,'COMPOSITE DOSE CONVERSION FACTOR (rem/CI): ',1PE9.2
  1/2X,'LIMITING GROUNDWATER CONCENTRATION (CI/L): ',1PE9.2)
3000 FORMAT(2X,'MAXIMUM CONCENTRATION FOR MBR #',11,' ',1PE9.2,
  11X,'CI/L',2X,'CEDE = ',1PE9.2,' rem')
4000 FORMAT(2X,'NOTE: PROGENY CONCENTRATIONS ARE REPORTED AT THE TIME 0
  IF THE MAXIMUM PARENT CONCENTRATION')
4800 FORMAT(2X,'MAXIMUM CEDE ',1PE9.2,' rem')

RETURN
END
C .....
C  SUBROUTINE CRAD
C  .....
  SUBROUTINE CRAD(CS,CE,AIC,DAIC,VOL,GWMAXI,PKT,ADLR,NN,IMODEL)
  IMPLICIT REAL*8 (A-H,O-Z)

  *
  *  Identification
  *
  *  Program Name: GWSCREEN
  *  Module Name: crad.f Version: 1.4
  *  Date: 6/21/93 Time: 16:38:21
  *

  COMMON /EXPOSURE/BW,AT,WI,EF,ED,DLIM,CRISK,HQ
  PARAMETER (NSPEC=9)
  COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
  DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
  1,ARD(NSPEC),RCSF(NSPEC)
  COMMON /POND/ RMI,TOPEP,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
  DIMENSION ADLR(NSPEC),Q(NSPEC), QDX(NSPEC),CM(NSPEC),D(NSPEC),
  1 DAIC(NSPEC)
C VARIABLES
C RCSF = RADIOLOGICAL CARCINOGENIC SLOPE FACTOR (1/CI)
C CL = LIMITING GROUNDWATER CONCENTRATION C/M**3
C WI = WATER INTAKE RATE (L/D)
C CSF = COMPOSITE SLOPE COVERION FACTOR
C CX = THE CONCENTRATION IN THE POND EFFLUENT
C DAIC(I) = CONCENTRATION OF THE ITH PROGENY MEMBER (CI/M**3)
  Character idkeyw*72
  Data idkeyw /'@(#)crad.f 1.4 6/21/93 16:38:21\0'/
  idkeyw = idkeyw

  WRITE(2,500)
C  CALCULATE DECAY-INGROWTH FACTORS AND MAX CONC FOR PROGENY
C  CONVERT CONCENTRATIONS TO CI/L
  IF(NN.GT.1)THEN
    Q(1) = 1.0
    DO 10, I = 2,NN
      Q(I) = 0.0
10  CONTINUE
    CALL RDK(PKT,ADLR,NN,Q,QDX)
    WRITE(2,1000) (QDX(I),I = 1,NN)
    DO 20,I = 1,NN
      CM(I) = GWMAXI*(QDX(I)/QDX(1))* (ARD(1)/ARD(I))/1000.

```

```

      DAIC(I) = DAIC(I)/1000
20    CONTINUE
      ELSE
        DAIC(1) = DAIC(1)/1000.
        CM(1) = GWMAXI/1000.
      ENDIF
C    CALCULATE RISK
      RISK = 0.0
      IF (NN.GT.1) THEN
        WRITE(2,4000)
      ENDIF
      DO 40, I = 1, NN
        D(I) = DAIC(I) * W1 * EF * ED * RCSF(I)
        RISK = RISK + D(I)
        WRITE(2,2500) I, CM(I)
        WRITE(2,3000) I, DAIC(I), D(I)
40    CONTINUE
      WRITE(2,4500) RISK
C    CALCULATE LIMITING GROUNDWATER CONCENTRATION
      CL = (DAIC(1) * CRISK) / RISK
      WRITE(2,2000) CL
C    CALCULATE LIMITING SOIL OF POND EFFLENT CONCENTRATIONS
      IF (IMODEL.LT.2) THEN
C      1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
      o convert also to CU/L
        CS = CL / (AIC / 1000) * (1 / VOL)
      ELSE
        CU = RMI / PNDFLX
        CE = (CL * CU / AIC)
      ENDIF

500  FORMAT(2X,'CARCINOGENIC RISK CALCULATION FOR RADIONUCLIDES')
1000 FORMAT(2X,'DECAY-INGROWTH FACTORS:',1PE11.4,1X,1PE11.4,1X,1PE11.4,
11X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4)
2000 FORMAT(2X,'LIMITING PARENT GROUNDWATER CONC. (CU/L): ',1PE9.2)

2500 FORMAT(2X,'MAXIMUM CONCENTRATION FOR MBR #',I1,' ',1PE9.2,
11X,'CU/L')
3000 FORMAT(2X,'AVERAGE CONCENTRATION FOR MBR #',I1,' ',1PE9.2,
11X,'CU/L RISK = ',1PE9.2)
4000 FORMAT(2X,'NOTE: PROGENY CONCENTRATIONS ARE REPORTED AT THE TIME 0
IF THE MAXIMUM PARENT CONCENTRATION')
4500 FORMAT(2X,'MAXIMUM CARCINOGENIC RISK.',1PE9.2)

      RETURN
      END
C .....
C    SUBROUTINE MAXRAD
C .....
      SUBROUTINE MAXRAD(CS,CE,AIC,DAIC,VOL,GWMAXI,PKT,ADLR,NN,IMODEL)
      IMPLICIT REAL*8 (A-H,O-Z)

      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: maxrad.f Version: 1.2
      * Date: 6/21/93 Time: 16:37:45
      *

      COMMON /POND/ RMI,TOPE,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
      PARAMETER (NSPEC=9)
      COMMON /DECAY/ ADCF,AKD,ATHALF,ARD,ARADMAX,RCSF
      DIMENSION ADCF(NSPEC),AKD(NSPEC),ATHALF(NSPEC),ARADMAX(NSPEC)
      I,ARD(NSPEC),RCSF(NSPEC)
      DIMENSION ADLR(NSPEC),C(NSPEC),Q(NSPEC),QDX(NSPEC),DAIC(NSPEC)

      Character Ikeyw*72
      Data Ikeyw/'@(#)maxrad.f'
      Ikeyw = Ikeyw
      1.2 6/21/93 16:37:45/0/

```



```

C VARIABLES
C CL = LIMITING GROUNDWATER CONCENTRATION CI/M**3 FOR PARENT INCLUDING
C   CONTRIBUTIONS FROM PROGENY
C AIC = AVERAGE INTEGRATED CONC FOR UNIT INVENTORY OF PARENT CI/M**3
C AICI = AVERAGE INTEGRATED CONC FOR ACTUAL INVENTORY OF PARENT CI/M**3
C DAIC = THE AVERAGE INTEGRATED CONC FOR PROGENY CI/M**3 (CONVERTED TO CI/L)
C CII = THE MAXIMUM CONCENTRATION FOR PARENT AND PROGENY
C THE FACTOR OF 1000 IN THE BELOW EQUATION CONVERTS FROM L/D TO
C CUBIC METERS PER DAY
C SUMX = TEMP VARIABLE FOR HOLDING INTERMEDIATE VALUES FOR CALCULATION OF THE
C   LIMITING PARENT GROUNDWATER CONCENTRATION ADJUSTED FOR PROGENY
C   CONTRIBUTIONS
      WRITE(2,500)
C   CALCULATE DECAY-INGROWTH FACTORS PRODUCTS AND PEAK CONCENTRATIONS
      IF(NN.GT.1)THEN
        Q(1) = 1.0
        DO 10, I = 2, NN
          Q(I) = 0.0
10      CONTINUE
        SUMX = 0.0
C   UNITS DAIC(I) = CI/L ARADMAX = CI/L
        CALL RDK(PKT,ADLR,NN,Q,QDX)
        WRITE(2,1000) (QDX(I),I = 1,NN)
        DO 20, I = 1, NN
          C(I) = (GWMAXI*(QDX(I)/QDX(1))*(ARD(1)/ARD(I)))/1000.
          DAIC(I) = DAIC(I)/1000.
          SUMX = SUMX + DAIC(I)/ARADMAX(I)
20      CONTINUE
        CL = DAIC(1)/SUMX
        ELSE
          C(1) = GWMAXI/1000.
          DAIC(1) = DAIC(1)/1000
          CL = ARADMAX(1)
        ENDIF
        WRITE(2,1500) CL
C   CONVERT CL TO CI/M3
C   1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
        CL = CL*1000

C   CALCULATE LIMITING SOIL CONC AND POND EFFLENT CONCENTRATIONS
      IF(IMODEL.LT.2)THEN
C   1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
        CS = CL/AIC*(1/VOL)
        ELSE
          CU = RMI/PNDFLX
          CE = (CL*CU/AIC)
        ENDIF
C   PRINT PEAK AND AVERAGE CONCENTRATIONS
      IF(NN.GT.1)THEN
        WRITE(2,4000)
      ENDIF
      DO 30, I = 1, NN
        WRITE(2,2000) I,C(I)
        WRITE(2,3000) I,DAIC(I)
30      CONTINUE

500  FORMAT(2X,'MAXIMUM RADIONUCLIDE CONCENTRATION CALCULATION')
1000  FORMAT(2X,'DECAY-INGROWTH FACTORS ',1PE11.4,1X,1PE11.4,1X,1PE11.4,
1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4,1X,1PE11.4)
1500  FORMAT(2X,'MAXIMUM PARENT CONCENTRATION ADJUSTED FOR PROGENY = ',
1PE9.2,1X,'CI/L')
2000  FORMAT(2X,'MAXIMUM CONCENTRATION FOR MBR #',I1,': ',1PE9.2,
1X,'CI/L')
3000  FORMAT(2X,'AVERAGE CONCENTRATION FOR MBR #',I1,': ',1PE9.2,
1X,'CI/L')
4000  FORMAT(2X,'NOTE: PROGENY CONCENTRATIONS ARE REPORTED AT THE TIME 0
IF THE MAXIMUM PARENT CONCENTRATION')
      RETURN
      EN

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C .....
C SUBROUTINE MAXNRAD
C .....
SUBROUTINE MAXNRAD(CS,CE,AIC,AICI,GWMAXI,VOL,ZRADMAX,IMODEL)
IMPLICIT REAL*8 (A-H,O-Z)
*
* Identification
*
* Program Name: GWSCREEN
* Module Name: %M% Version: %I%
* Date: %G% Time: %U%
*

COMMON /POND/ RMI,TOPE,PNDFLX,THETAP,EVAP,PLEACH,WAEFF

Character idkeyw*72
Data idkeyw /'@(#)%M% %I% %G% %U%\0'/
idkeyw = idkeyw
WRITE(2,500)
C CONVERT ZRADMAX TO mg/M3
C 1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
CL = ZRADMAX*1000
C CALCULATE LIMITING SOIL CONC AND POND EFFLENT CONCENTRATIONS
IF(IMODEL.LT.2) THEN
C 1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
CS = CL/AIC*(1/VOL)
ELSE
CU = RMI/PNDFLX
CE = (CL*CU/AIC)
ENDIF
WRITE(2,1000) GWMAXI/1000,AICI/1000
500 FORMAT(2X,'MAXIMUM NON RADIOLOGICAL CONTAMINANT CALCULATION')
1000 FORMAT(2X,'MAXIMUM CONCENTRATION ',1PE9.2,' mg/L'
//,2X,'AVERAGE CONCENTRATION ',1PE9.2,' mg/L')

RETURN
END
C .....
C SUBROUTINE CARCIN
C .....
SUBROUTINE CARCIN(CS,CE,AIC,VOL,SFACTOR,AICI,GWMAXI,IMODEL)
IMPLICIT REAL*8 (A-H,O-Z)
*
* Identification
*
* Program Name: GWSCREEN
* Module Name: %M% Version: %I%
* Date: %G% Time: %U%
*

COMMON /EXPOSURE/BW,AT,WI,EF,ED,DLIM,CRISK,HQ
COMMON /POND/ RMI,TOPE,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
C VARIABLES
C BW = BODY WEIGHT (kg)
C I = WATER INTAKE RATE (L/d)
C ED = EXPOSURE DURATION (YEARS)
C AT = AVERAGING TIME (days)
C EF = EXPOSURE FREQUENCY (DAYS/YEAR)
C DLIM = DOSE LIMIT (4 REM/Y)
C CRISK = CARCINOGENIC RISK FACTOR (1.0E-6)
C CL = LIMITING GROUNDWATER CONCENTRATION CI/M**3
C WI = WATER INTAKE RATE (L/D)
C THE FACTOR OF 1000 IN THE BELOW EQUATION CONVERTS FROM L/D TO
C CUBIC METERS PER DAY
*
Character idkeyw*72
Data idkeyw /'@(#)%M% %I% %G% %U%\0'/
idkeyw = idkeyw

WRITE(2,500)

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      CL = (CRISK*BW*AT)/(SFACTOR*WI*EF/1000*ED)
      RSK = ((AICI/1000)*SFACTOR*WI*EF*ED)/(BW*AT)
C   1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
      CS = CL/AIC*(1/VOL)
C   CALCULATE LIMITING SOIL CONC AND POND EFFLENT CONCENTRATIONS
      IF(IMODEL.LT.2)THEN
C     1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
        CS = CL/AIC*(1/VOL)
      ELSE
        CU = RMI/PNDFLX
        CE = (CL*CU/AIC)
      ENDIF
      WRITE(2,1000) CL/1000,GWMAXI/1000,AICI/1000,RSK
500  FORMAT(2X,'CARCINOGENIC RISK CALCULATION')
1000 FORMAT(2X,'LIMITING GROUNDWATER CONCENTRATION (mg/L): ',1PE9.2
      //2X,'MAXIMUM GROUNDWATER CONCENTRATION (mg/L): ',1PE9.2
      //2X,'AVERAGE GROUNDWATER CONCENTRATION (mg/L): ',1PE9.2
      //2X,'CARCINOGENIC RISK FOR USER INPUT MASS: ',1PE9.2)

      RETURN
      END
C .....
C   SUBROUTINE NCARCIN
C .....
      SUBROUTINE NCARCIN(CS,CE,AIC,VOL,RFD,AICI,GWMAXI,IMODEL)
      IMPLICIT REAL*8 (A-H,O-Z)
      COMMON /POND/ RMI,TOPE,PNDFLX,THETAP,EVAP,PLEACH,WAEFF
      COMMON /EXPOSURE/BW,AT,WI,EF,ED,DLIM,CRISK,HQ
C  VARIABLES
C  BW = BODY WEIGHT (kg)
C  I = WATER INTAKE RATE (L/d)
C  ED = EXPOSURE DURATION (YEARS)
C  AT = AVERAGING TIME (days)
C  EF = EXPOSURE FREQUENCY (DAYS/YEAR)
C  DLIM = DOSE LIMIT (4 REM/Y)
C  CRISK = CARCINOGENIC RISK FACTOR (1.0E-6)
C  CL = LIMITING GROUNDWATER CONCENTRATION CI/M**3
C  WI = WATER INTAKE RATE (L/D)
C  THE FACTOR OF 1000 IN THE BELOW EQUATION CONVERTS FROM L/D TO
C  CUBIC METERS PER DAY
      *
      * Identification
      *
      * Program Name: GWSCREEN
      * Module Name: %M% Version: %I%
      * Date: %G% Time: %U%
      *
      Character idkeyw*72
      Data idkeyw/'@{#}%M% %I% %G% %U%\'0'/
      idkeyw = idkeyw

      CL = (HQ*BW*AT*RFD)/(WI*EF/1000*ED)
      HQX = ((AICI/1000)*WI*EF*ED)/(BW*AT*RFD)
C  1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY

      CS = CL/AIC*(1/VOL)
C   CALCULATE LIMITING SOIL CONC AND POND EFFLENT CONCENTRATIONS
      IF(IMODEL.LT.2)THEN
C     1/VOL = THE SOIL CONCENTRATION FOR A UNIT INVENTORY
        CS = CL/AIC*(1/VOL)
      ELSE
        CU = RMI/PNDFLX
        CE = (CL*CU/AIC)
      ENDIF
      WRITE(2,1000) CL/1000,GWMAXI/1000,AICI/1000,HQX

500  FORMAT(2X,'NON-CARCINOGENIC RISK CALCULATION')
1000 FORMAT(2X,'LIMITING GROUNDWATER CONCENTRATION (mg/L): ',1PE9.2
      //2X,'MAXIMUM GROUNDWATER CONCENTRATION (mg/L): ',1PE9.2

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I/2X,'AVERAGE GROUNDWATER CONCENTRATION (mg/L): ',1PE9.2
I/2X,'HAZARD QUOTIENT FOR INPUT MASS: ',1PE9.2)
RETURN
END

END

DATE
FILMED
9/24/93