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by

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A MODEL FOR PREDICTING THE REDISTRIBUTION OF PARTICULATE CONTAMINANTS FROM SOIL SURFACES

by

John R. Travis

ABSTRACT

A computerized model was developed to describe the redistribution of wind eroding soil-contaminant mixtures. Potentially mobile particulate contaminants can, in the first approximation, be assumed to be indistinguishable from the wind eroding soil in which they are distributed. A grid network characterizes important soil and surface conditions, and mass conserving control volumes are constructed on each cell. Material is transported through the vertical and top surfaces of a control volume by a modified Bagnold-Chepil horizontal flux formulation and modified Gillette vertical flux formulation, respectively. The vertical emissions, considered as puffs from area sources, create at regular time intervals a contaminant cloud which is proportional to the suspendable ground concentration. These puffs diffuse downwind under time-dependent wind velocity and atmospheric stability conditions, maintaining during the time interval a three-dimensional Gaussian distribution of concentration with cloud volume. Material from each puff is deposited in downwind cells, leading to the possibility of many different flights from these new sources. The usefulness of this predictive tool is demonstrated by calculations involving mixtures of particulate $^{238}\text{PuO}_2$ in highly erodible soils under dust storm conditions. Time-dependent surface concentration and breathing zone exposure isopleths, evolving from a small contaminated area, show the potential hazard from wind eroding toxic materials.

I. INTRODUCTION

A. Purpose of the Present Study

On a worldwide basis, it has been estimated¹ that wind erosion of the earth's surface contaminates the atmosphere in the amount of 2×10^4 - 10^6 tons of soil and dust per day. Using this estimate in an assessment of global sources of tropospheric aerosols, Hidy and Brock² report that dust rise by wind constitutes 9.3% of the total mass of atmospheric aerosols. A comprehensive understanding of the wind pickup or resuspension processes of particulate materials from the earth's surface is,

therefore, of great practical importance and interest.

In particular, safety analyses involving risk and consequence evaluations of nuclear systems in accident conditions require extensive data to accurately describe the wind erosion modification of radioactive sources in the environment. That is, in order to accurately predict the time-dependent downwind toxic concentrations and exposures from accidental radioactive releases, we must describe resuspension mechanisms and particulate transport modes.

In the past, analyses involving the suspension of environmental contaminants from surfaces have been performed³⁻⁸ by characterizing the wind pickup processes in a resuspension factor K , which is defined as the ratio of the air concentration (activity units/ m^3) to the deposited ground concentration (activity units/ m^2). The resuspension factor physically represents an inverse length (m^{-1}) and can be thought of as the fraction of material suspended from a surface divided by the vertical height through which the suspended material is dispersed. The resuspension factor concept is very simple, yet by its very definition, serious shortcomings are encountered which prohibit any real general formulation of the wind pickup problem. For example, in using the resuspension factor, the suspended activity is computed as being directly dependent upon the surface activity; however, it has been observed⁹ that the suspended activity levels are more dependent upon surface concentrations directly below the point in question. Furthermore, such important influences as soil characteristics, surface characteristics, and meteorological conditions are neglected in the resuspension factor analyses. This becomes very evident when one examines the compilation of plutonium resuspension factors tabulated by Mishima¹⁰ in which values range from 10^{-2} for active conditions to 10^{-13} for aged deposits. There is evidence^{5,9} that the suspended air activity decreases in time with a half-life of 30-80 days. This "weathering" or material aging process occurs as the contamination deposit diffuses and mixes into the uppermost soil layer.

It is clear that with resuspension factor data spanning eleven orders of magnitude, any effort to accurately describe resuspension processes must incorporate the effects of the neglected, but nevertheless very important soil, surface, and meteorological conditions. It is the objective of this work to develop a computational model, or tool, for predicting the redistribution of particle contaminants from soil surfaces.

B. Particle Movement by the Wind

It is well documented¹¹⁻¹⁵ that soil particles resting on the earth's surface are set in motion by either or both of two mechanisms: (1) the aerodynamic forces of the atmospheric wind in the surface layer, and (2) the mechanical disturbance of an impinging particle. As for the first mechanism, particle motion is due to aerodynamic pressures and shearing stresses caused by the wind at the atmospheric-soil interface; while for the second mechanism, particle motion is due to the transfer of momentum at impact from the impinging particle. Once soil motion is initiated, movement continues in three modes of transport: surface creep, particle saltation, and airborne suspension. Surface creep describes the rolling or sliding motion of a particle on the surface in which the external forces (aerodynamic and/or mechanical) fail to exceed the gravitational force and the adhesive force between the particle and substrate. Particle saltation describes the motion of a dislodged particle which is injected into the air stream almost vertically, and then while gaining horizontal momentum from the wind descends, due to its relatively large mass, with a rather flat trajectory to impact the substrate. Particles moving in saltation do not generally travel in a single flight more than ten meters. Chepil^{12,13} has shown, however, that over 90% of the total eroding soil mass is carried in the first 30 cm above the surface, and by far the largest fraction of this soil movement is transported in saltation. A very abrasive process called soil avalanching¹⁴ is set up by saltating soil. In this process, the rate of soil flow increases from zero at the upwind edge of an eroding surface to a maximum or critical mass loading for a particular wind velocity. This results in a sandblasting effect of the surface by the saltating soil particles. Airborne suspension describes the movement of a dislodged particle with relatively little mass, i.e., its settling velocity is less than the average vertical fluctuations of the surface wind. Particles moving in suspension may be transported distances up to many thousands of

meters.^{16,17} One quantitative correlation between soil moving in suspension and saltation has definitely been observed^{11-13,18-21}; without saltation movement, suspended dust clouds would not arise.

Broad general limits^{3,12,17,22} for soil particle size (average diameter) motion in the three transport modes are:

Surface creep	> 1000 μm
Saltation	50-1000 μm
Suspension	< 50 μm

Certainly these limits are not definitive, because such effects as variations in the soil and surface conditions can cause shifting and overlapping of these general bands. Nevertheless, a qualitative feeling for the particle size spectrum of the various transport modes is reflected in the above classification. In addition, it has been shown by Chepil²³ that the density of the erodible particles has little or no effect on the rate of erosion for sizes up to 200 μm in diameter under a 8.9 meter/sec (20 mile/hour) wind, up to 350 μm under a 11.2 meter/sec (25 mile/hour) wind, and up to 450 μm under a 13.4 meter/sec (30 mile/hour) wind. These wind velocities were reported at 15.24 cm (6 inches) above the soil surface. One can conclude that particle contaminants which potentially are the most mobile, e.g., particle sizes moving in saltation and suspension, are generally indistinguishable on a density basis from the eroding soil in which they are distributed.

The rate of soil flow, i.e., the mass of soil material moving through a vertical plane perpendicular to the direction of movement per unit width per unit time, was found experimentally by Bagnold¹¹ for desert sand surfaces and Chepil²⁴ for dry soils to obey

$$F_h = C_h u_*^3, \quad (1)$$

where the horizontal soil flux F_h (gm/cm-sec) is seen to vary directly as the cube of the surface friction or drag velocity u_* (cm/sec). The coefficient of proportionality C_h varies greatly with factors involving soil and surface conditions. The Wind Erosion Laboratory at Manhattan, Kansas, has

been actively engaged for some thirty years in the determination of the primary factors that cause soil wind erosion. Eleven primary wind erosion variables were identified;^{14,25} however, because of the nature of the relationship between soil erodibility and some of these variables, it has been found convenient to neglect some variables, collect others, and convert some to equivalents. The reduced set of variables which influence the coefficient C_h in equation (1) include a soil erodibility index I , a soil surface roughness K , a surface vegetative cover R , and a field length L . Drawing from three publications²⁶⁻²⁸ of the Wind Erosion Laboratory, Gillette, et al.¹⁸ formulated an empirical formula for the horizontal soil flux,

$$F_h = \frac{2IX}{16,500} \left(\frac{\tau_e}{\tau_r} \right)^{3/2}, \quad (2)$$

where F_h is the rate of soil flow in tons per rod width per hour, L is the field length in feet, τ_e is the effective surface shear stress, τ_r is the reference surface shear stress, and X is the erodibility function given by

$$X = 400 \frac{I}{(RK)^{1.26}}. \quad (3)$$

In this relationship, I denotes the dimensionless soil-erodibility index for the percentage of surface soil material greater than 840 μm in diameter, R denotes the weight of surface residue in pounds per acre, and K denotes the surface ridge roughness equivalent in inches. Since the surface shear τ is related to the surface drag velocity u_* by

$$\tau = \rho u_*^2, \quad (4)$$

where ρ is the density of the surface atmosphere, it is noted that the term $(\tau_e/\tau_r)^{3/2}$ in equation (2) reflects the u_*^3 dependency found in equation (1). The effective surface shear stress τ_e is the actual or observed surface shear stress τ corrected for the surface soil moisture content α ,

$$\tau_e = \tau - \alpha, \quad (5)$$

where α can be thought of as the resistance due to cohesion of the absorbed water films exerted against the wind drag. Therefore, the resistance α may be

visualized as a force acting on the same level but in the opposite direction from the surface wind shear stress. The value of this resistance was found²⁶ to be equal to $6(\omega/\omega')^2$, where (ω/ω') is defined as the equivalent moisture, or the ratio of the amount of water held in the soil and the amount of water held by the same soil at a 15-atmosphere percentage. The 15-atmosphere percentage is the upper limit of hygroscopic water and corresponds approximately to the percentage of water at the permanent wilting points of plants.

The empirical equation (2) and a modified formulation²⁹

$$F_h = X(\tau_e/\tau_r)^{3/2} \quad (6)$$

where the field length dependence is discarded, have predicted horizontal soil fluxes within a factor of 2 of the observed experimental values.²¹

The production of soil wind erosion aerosols, expressed as a vertical soil flux, is recently receiving more attention.¹⁸⁻²⁰ This vertical flux component of soil movement constitutes the smaller soil particle contribution (diameter $< 50 \mu\text{m}$)* which have the potential for long distance transport. Gillette¹⁹ found for similar erosion conditions, i.e., soil moisture, soil cloddiness, surface roughness, and vegetative cover, two distinct soil types produced vertical soil fluxes F_v (soil mass per unit area per unit time), which obeyed the empirical function

$$F_v = C_v(u^*/u_t^*)^\gamma, \quad (7)$$

where u_t^* is the surface threshold drag velocity when soil begins to move, and the exponent γ is greater than 3 and highly dependent upon the mass fraction of suspendible soil. The coefficient of proportionality for this particular erosion condition is approximately 2×10^{-10} . In addition, good agreement with a modified relationship proposed by Lettau and reported by Gillette¹⁹ for the horizontal

soil flux was observed for the various soil types and similar erosion conditions. This modification of equation (1) is given by

$$F_h = C u^{*2} (u^* - u_t^*), \quad (8)$$

where the drag velocity u^* and u_t^* have units of cm per sec, the horizontal flux F_h has units of gm per cm per sec, and C equals 10^{-6} for these particular erosion conditions. In both equations (7) and (8) the fluxes are interpreted as being identically zero for the condition $u^* < u_t^*$.

In the following section, we will make use of the above ideas and empirical formulations to develop a model for predicting the redistribution of particulate contaminants in soil surfaces.

II. MODEL DEVELOPMENT

A. The Physical Interpretation of the Problem

The wind pickup of particulate material from soil surfaces, typically characterized by resuspension factors, is not well understood. While there appears to be a good deal of knowledge about the qualitative behavior of the resuspension phenomenon, few quantitative results are deducible. For example, the influence of meteorological, surface, and soil conditions on the resuspension factor have not been thoroughly investigated. This lack of basic knowledge coupled with the uncertainties of currently used resuspension factor values suggests the need for a different modeling approach to describe the redistribution of toxic materials as influenced by the atmospheric winds.

We consider a grid network overlay of the contaminant-containing soil, typically presented by Figure 1. Each of the grid cells, e.g., cell $(n+2, m+1)$: $I = n+2$ and $J = m+1$ with area equalling $\Delta x \Delta y$, is characterized by soil and surface conditions while the overall grid structure is subjected to specified meteorological conditions. A control volume with the base coinciding with the soil-atmosphere interface (Figure 2) can be constructed on each of the grid cells, and a conservation of mass equation for the control volume³⁰ can be written

*Gillette and coworkers¹⁸⁻²⁰ found from vertical soil flux size distribution measurements that nearly all the particles are less than $20\text{-}\mu\text{m}$ diameter.

$$\frac{\partial}{\partial t} \iiint_{C.V.} \rho \, dv + \iint_{C.S.} \rho \bar{V} \cdot d\bar{A} = 0. \quad (9)$$

This equation states that the rate of change of contaminant inside the control volume plus the net efflux rate of contaminant through the control surface equals zero. In other words, the time rate of change of material inside the control volume equals the addition of material from upwind cells minus the depletion of material to downwind cells. Material flowing through the side and top surfaces can be thought of as the horizontal and vertical flux components, respectively. In terms of an eroding contaminated soil surface, this generally means that the larger nonsuspendible particles are transported through the sides while the smaller suspendible particles exit and enter through the top surface.

B. Erosion Model

The horizontal and vertical mass fluxes which develop from expanding equation (9) (shown in a top and side view of the control volume in Figure 3) can be represented by the empirical formulas presented in the previous section.

1. Horizontal Soil and Contaminant Flux.

The horizontal soil flux in mass per unit width per unit time[†] is given by equation (6)

$$F_h = X(\tau_e / \tau_r)^{3/2}, \quad (6)$$

or, upon introducing equation (4) for the surface friction velocity u^*_r , F_h is

$$F_h = X(u^*_e / u^*_r)^3. \quad (10)$$

An alternate formulation for the horizontal soil flux having considerable physical appeal is presented by equation (8) as

$$F_h = Cu^{*2}(u^*_e - u^*_t), \quad (8)$$

which provides the mathematical property: as the surface friction velocity approaches the threshold value from above, the horizontal flux tends to zero.

[†]Note that since this formulation considers flux on a per unit width rather than on a per unit area basis, the increment height Δz in the horizontal mass flow rates in Figure 3 is considered equal to 1.

With this modification, equation (10) for the horizontal soil flux becomes

$$F_h = X(u^*_e / u^*_r)^3(u^*_e / u^*_r - u^*_t / u^*_r), \quad (11)$$

where u^*_e , u^*_r , and u^*_t denote respectively the effective, reference,[‡] and threshold surface friction velocities. The erodibility function X is represented by

$$X = a \frac{I}{(RK)^b}, \quad (12)$$

where

- X = erodibility function in tons per rod per hour
- I = soil erodibility index based on percent of soil fraction greater than 840- μ m in diameter
- R = amount of vegetative residue in pounds per acre
- K = surface roughness equivalent in inches
- a and b = constants whose values depend on past erosional history, type of residue and roughness, and condition of the surface crust.

Methods for determining the above quantities are discussed in the appendices.

The mass fraction which constitutes the contaminant portion of the horizontal flux is

$$\frac{\Omega_s + \Omega}{\rho_s \Delta x \Delta y \delta + \Omega_s + \Omega} \quad (13)$$

where ρ_s is the soil density (gm/cm³), δ is the thickness (cm) of the soil-contaminant surface layer, and Ω_s and Ω are respectively the suspendible and nonsuspendible contaminant masses (grams) in the surface layer. This surface layer thickness δ can be a function of time describing a uniform distribution or mixing of soil and contaminant as the contaminant diffuses or ages into the soil. Another method for describing the weathering-in process is to define a constant mixing layer thickness, which for freshly contaminated soil is probably no more than a few millimeters, and

[‡]Gillett²⁹ uses a value of 33.1 dynes/cm² for the reference shear stress τ_r . The reference surface friction velocity u^*_r is calculated from $(\tau_r / \rho)^{1/2}$ where ρ denotes the atmospheric density in gm/cm³.

simply decreases the amount of contaminant in the mixing layer by some prescribed weathering-in function.⁹ In an analogous fashion, if there is evidence of small-to-large particle agglomeration, then certain amounts of suspendible contaminant Ω_s can be transferred into the nonsuspendible category Ω according to available agglomeration observations.

The horizontal material flow formulation of equation (9) applied to Figure 1 does not allow mass to directly enter a diagonal cell in a given time step. For example, if the wind is at 30° counter-clockwise from the + x-axis, material from cell (n+2, m+1) does not directly enter cell (n+3, m+2) for forward time finite differencing. A simple model that allows material to directly enter the three adjacent cells is one of considering a receiver area, equal to the donor cell area $\Delta x \Delta y$, which is swept out by rays parallel to the wind direction but connected to the corners of the donor cell and extending into the three receiver cells distances which yield the prescribed area. This method is diagrammed in Figure 4, where $A_1 + A_2 + A_3 = \Delta x \Delta y$. Note that for the limiting cases, $\theta \rightarrow 0^\circ$ and $\theta \rightarrow 90^\circ$, this model and that of applying equation (9) with forward time differencing are identical.

2. Vertical Soil and Contaminant Flux. The vertical soil flux in mass per unit area per unit is given by equation (7) as

$$F_v = C_v (u^*/u_t^*)^\gamma. \quad (7)$$

Since vertical fluxes are never observed without horizontal fluxes, we assume that for wind eroding surfaces F_v is directly proportional to F_h . Upon substituting equation (1)

$$F_h = C_h u^{*3} \quad (1)$$

into equation (7), we obtain

$$F_v = F_h \left(\frac{C_v}{u_t^{*3} C_h} \right) \left(\frac{u^*}{u_t^*} \right)^{\gamma-3}, \quad (14)$$

where γ is greater than 3 and is larger for soils

having more suspendible particles per unit mass. A linear curve fitting Gillette's data¹⁹ for γ as a function of the particle mass percentage less than 20- μ m diameter P yields the expression

$$\gamma = P/3 + 3, \quad (15)$$

and upon substituting this relationship into equation (14), we obtain

$$F_v = F_h \left(\frac{C_v}{u_t^{*3} C_h} \right) \left(\frac{u^*}{u_t^*} \right)^{P/3}. \quad (16)$$

There are two limiting cases: (1) the vertical flux must tend to zero as the surface friction velocity approaches the threshold value from above, and (2) the vertical flux must tend to zero as the suspendible particle mass percentage P approaches zero. The first case is satisfied by equation (11) with $F_h \rightarrow 0$ as $u^* \rightarrow u_t^*$, and by modifying equation (16)

$$F_v = F_h \left(\frac{C_v}{u_t^{*3} C_h} \right) \left[\left(\frac{u^*}{u_t^*} \right)^{P/3} - 1 \right], \quad (17)$$

the second case is satisfied. The constants C_v and C_h are given by Gillette¹⁹ to be approximately 2×10^{-10} and 10^{-6} , respectively.

In determining the mass percentage of suspendible particles P for use in equation (17), we calculate

$$P = 100 \frac{\rho_s \Delta x \Delta y \delta f + \Omega_s}{\rho_s \Delta x \Delta y \delta f + \Omega_s + \Omega}, \quad (18)$$

where f denotes the mass fraction of suspendible soil particles in the mixing layer. The mass fraction which constitutes the contaminant portion of the total vertical flux is simply calculated by the ratio

$$\frac{\Omega_s}{\rho_s \Delta x \Delta y \delta f + \Omega_s}. \quad (19)$$

C. Atmospheric Dispersion Model

A quantity of contaminant material Q grams, centered at position vector x_c and at time t , is generated by the vertical flux exiting the control volume top (area = $\Delta x \Delta y$) in time Δt , and then is

allowed to disperse under the influence of the atmospheric wind and stability conditions. An equation describing this process is the "Gaussian Puff" model^{6,8} for an instantaneous point source of material diffusing in three dimensions

$$\chi(\bar{x}, t) = \frac{Q(t) (2\pi)^{-3/2}}{\sigma_x \sigma_y \sigma_z} \exp \left[-\frac{(x-x_c)^2}{2\sigma_x^2} - \frac{(y-y_c)^2}{2\sigma_y^2} - \frac{(z-z_c)^2}{2\sigma_z^2} \right] \quad (20)$$

where $\chi(\bar{x}, t)$ is the position and time-dependent material concentration (gm/m³) and σ_x , σ_y , and σ_z represent the "along wind," "cross-wind," and "vertical" atmospheric dispersion coefficients (in meters),[†] respectively.

The amount of cloud material is a function of time when the puff is allowed to deposit material on the soil surface as it drifts downwind. The puff center (x_c , y_c , z_c) moves away from the origin in a time increment Δt to a new position

$$x_c(t + \Delta t) = x_c(t) + |\bar{V}(t)| \cos[\theta(t)] \Delta t \quad (21)$$

and

$$y_c(t + \Delta t) = y_c(t) + |\bar{V}(t)| \sin[\theta(t)] \Delta t \quad (22)$$

where $\theta(t)$ is the time-dependent angle in radians that the wind magnitude $|\bar{V}(t)|$ makes with the +x-axis. If the puff leaves the control volume with a significant amount of momentum and/or buoyancy, due respectively to a rapid exit velocity and excess temperature relative to the ambient air, a correction for the cloud's height $z_c(t)$ must be made.

The dispersion coefficients³¹ presented in Figures 5 and 6* show a dependency on the puff's travel distance. In changing stability classes it is necessary that the dispersion coefficient be kept

[†]We assume that $\sigma_x = \sigma_y$. This is consistent with most atmospheric dispersion models; however, if adequate data for the along-wind dispersion coefficient σ_x is available, this restriction can easily be removed.

*The curves on these two figures are represented by least square variable knot cubic spline functions. These functions provide a means for easily calculating σ_x and σ_z as a function of travel distance, or for solving the inverse problem of calculating the travel distance knowing σ_y and σ_z . Appendix A contains a brief discussion on splines and presents tables for evaluating the functions.

continuous. This is accomplished by changing the travel distance on the new stability curve such that the dispersion coefficient remains constant. For example, in Figure 7 the puff is traveling under the

influence of an E atmospheric stability class, and at point 1 there is a change in class D stability. The cloud effectively loses travel distance but retains a continuous dispersion coefficient at point 2. The cloud travels through points 3-8 while the stability evolves from D $\rightarrow$ C $\rightarrow$ B and back to C. The travel distance of any given puff is merely an artifice, but when coupled with a particular stability class it defines the dispersion coefficient.

Vertical emissions from the control volume are not point sources but rather area sources from projected area = $\Delta x \Delta y$. The initial dispersion coefficient σ_{y0} for a square area ($\Delta x = \Delta y$) can be approximated³¹ by

$$\sigma_{y0} \approx \Delta x / 4.3 \quad (23)$$

A fictitious travel distance or virtual origin corresponding to this initial value is found for a specified atmospheric stability class. In a similar manner, σ_{z0} is calculated and the corresponding virtual origin is determined.

Turner³¹ points out that estimates for the dispersion coefficient σ_z are subject to errors for the longer travel distances. In fact, σ_z can only be expected to be within a factor of 2 for travel distances less than the intersecting line drawn in Figure 6. Uncertainties in the estimates of σ_y are less than those of σ_z . Accounting for these errors in σ_y and σ_z , i.e., in the region where σ_z can be expected to be within a factor 2, the ground level concentrations from the Gaussian Puff model should be correct within a factor of 3.

D. Particle Deposition Model

As the puff drifts downwind, the quantity of material $Q(t)$ is depleted as material deposits on the soil surface. Chamberlain³² introduced the concept of a "velocity of deposition" of the puff particulate to the surface as

$$V_d = \frac{\text{Amount deposited per cm}^2 \text{ of surface per second}}{\text{Volumetric concentration per cm}^3 \text{ above surface}}$$

Thus, the total amount of material deposited on the surface area A in the time interval Δt is

$$\omega(x, y, t) = \iint_A V_d \bar{\chi}(x, y, z = 0, t) dx dy, \quad (24)$$

where $\bar{\chi}$ is the average surface concentration over A during the time interval. Considering all puffs p , the amount of contaminant deposited on the surface area $[x_1 \leq x \leq x_2, y_1 \leq y \leq y_2]$ in the same time interval is given by

$$\omega(x_1 \leq x \leq x_2, y_1 \leq y \leq y_2, t) = \sum_{i=1}^P \int_{x_1}^{x_2} dx \int_{y_1}^{y_2} V_d \bar{\chi}_i(x, y, z = 0, t) dy. \quad (25)$$

For the purpose of this presentation, we assume that the deposition velocity V_d equals the gravitational settling or terminal velocity V_g of the suspended particles. While this is true for particles having relatively large terminal velocities it is in error for smaller particles where the surface and wind characteristics began to influence the deposition process. Nevertheless, the errors introduced by this assumption are within the uncertainties existing in other sections of the overall model. The terminal velocity V_g for a small spherical particle³³ is

$$V_g = \frac{D^2 g}{18\mu} (\rho_p - \rho), \quad (26)$$

provided the particle Reynolds number $V_g D \rho / \mu < 1$. In the above relationship D , ρ_p , g , ρ , and μ denote the particle diameter, particle density, gravitational constant, air density, and air viscosity, respectively.

E. The Friction Velocity for an Unobstructed Surface

The functional form of the wind velocity profile near the ground has been carefully examined by E. L. Deacon.³⁴ He proposed the general law

$$\frac{du(z)}{dz} = az^{-\beta} \quad (27)$$

for heights z of up to 13 meters. The effect of atmospheric stability is introduced in equation (27) when

$$\begin{aligned} \beta &> 1 & \text{for} & \quad Ri < 0 \\ \beta &= 1 & \text{for} & \quad Ri = 0 \\ \beta &< 1 & \text{for} & \quad Ri > 0 \end{aligned}$$

where the Richardson number Ri is a dimensionless quantity defining the atmospheric temperature gradient, e.g., $Ri < 0$ designates a super-adiabatic lapse rate (unstable atmosphere), $Ri = 0$ designates a small or adiabatic temperature gradient (neutrally stable atmosphere) and $Ri > 0$ designates an inversion (stable atmosphere). Integrating equation (27) for $u(z = z_0) = 0$, Deacon found

$$\frac{u(z)}{u^*} = \frac{2.5}{(1 - \beta)} \left[\left(\frac{z}{z_0} \right)^{1-\beta} - 1 \right], \quad (28)$$

where the constant a in equation (27) was set equal to $u^* \beta^{-1} / 2.5$ which allowed matching the classic logarithmic profile³⁵

$$u(z)/u^* = 2.5 \ln(z/z_0) \quad (29)$$

as $\beta \rightarrow 1$. The integration limit z_0 is known as the roughness length which is related to the roughness of the surface. In reporting Nikuradse's rough surface measurements, Schlichting³⁵ shows that

$$z_0 = \phi k_s$$

where k_s denotes the average surface roughness height and ϕ is a constant approximately equal to 1/30.

Given the atmospheric stability, average wind speed at height z , and surface roughness characteristics, the surface friction velocity can be found by direct evaluation of equation (28) or (29). Equation (29) is valid only for a neutrally stable atmosphere, i.e., $\beta = 1$.

F. The Friction Velocity in the Presence of Large Roughness Elements

The total force F imparted to a surface covered with large roughness elements, such as sagebrush or trees, can be partitioned into the force exerted on the roughness elements F_r and the force exerted on the soil surface F_s in the following manner:

$$F = F_r + F_s \quad (30)$$

Rewriting this equation in terms of the shear stresses, it becomes

$$\tau = \frac{F_r}{A} + \tau_s \left(\frac{A'}{A} \right) \quad (31)$$

where A and A' represent the total surface area and projected uncovered soil area, respectively. Rearranging equation (31) to solve for the surface shear stress τ_s , we obtain

$$\tau_s = \tau \left(\frac{A}{A'} \right) \left(1 - \frac{F_r}{\tau A} \right) \quad (32)$$

The force exerted on the roughness elements can be expressed in terms of the roughness element drag coefficient C_f as

$$F_r/A = C_f \rho u_\infty^2 L_c/2 \quad (33)$$

where u_∞ denotes the free stream wind speed and L_c denotes the lateral cover. The lateral cover is defined as the sum of all frontal or silhouette roughness element areas L_a divided by the surface area A :

$$L_c = L_a/A \quad (34)$$

Marshall³⁶ performed a fundamental study in a wind tunnel to determine the partitioning effect for various roughness element sizes and density distributions. The results of Marshall's study are shown in Figs. 8 and 9. Figure 8 presents data on a $1 - (F_r/\tau A)^{1/2}$ versus $\log_{10}(1/L_c)$ plot for various roughness element diameter to height ratios. Note that for $\log_{10}(1/L_c)$ approximately 1.5, the entire force of the atmospheric wind is exerted on the roughness elements, while for $\log_{10}(1/L_c) > 4$, the shear stress at the soil surface becomes maximum. In this transition region, $1.5 < \log_{10}(1/L_c) < 4$, the function

$$1 - (F_r/\tau A)^{1/2} = 0.38 \log_{10}(1/L_c) - 0.55 \quad (35)$$

provides a good fit of the data. The roughness element drag coefficient C_f is plotted against the square root of the reciprocal lateral cover in Figure 9. For sparsely distributed roughness elements, e.g., $1/\sqrt{L_c} > 10$, the drag coefficient for any one element shape is shown to remain practically constant. This is true because the elements tend to react relatively independent of each other in the air flow. However, as the element density distribution increases and the roughness elements begin to interact with each other due to their influence on air movement, the roughness element drag coefficient rapidly decreases on a curve

$$C_f = 0.0985 / \sqrt{L_c} - 0.134 \quad (36)$$

The point at which the roughness element spacing becomes critical is at the intersection of equation (36) and the various constant unobstructed drag coefficient lines. For the purpose of this model, we have selected the $d/H = 1$ and $d/H = 5$ unobstructed drag coefficient lines as a basis, thus providing a relationship

$$C_f = 0.6525 - 0.0525 (d/H) \quad (37)$$

for the unobstructed roughness element drag coefficient as a function of the diameter to height ratio.

The results reported in Figures 8 and 9 have been normalized to a free stream velocity $u_\infty = 20.3$

m/sec. We are able to calculate the surface shear τ for any free stream velocity u by

$$\tau = \tau_s (u/u_\infty)^{1/2} \quad (38)$$

where τ_s is the partitioned surface shear stress calculated from equation (32).

G. Summary

The essence of this model is to describe the relocation of wind eroding soil-contaminant mixtures. This is accomplished by first characterizing soil and surface conditions within a square mesh structure overlayed on the surface. Then, according to certain meteorological conditions, a horizontal flux component transports material into adjacent mass conserving cells, and a vertical flux component generates puffs of suspendible particles. These puffs are emitted at regular time intervals. They diffuse downwind under time-dependent wind velocity and atmospheric stability conditions, maintaining during the time interval a three-dimensional Gaussian distribution of concentration with the cloud volume. The center of each Gaussian Puff configuration is determined by the trajectory since release, and its distribution is determined by the three dispersion coefficients σ_x , σ_y , and σ_z , which are increasing functions of travel distance. During the time interval, each cloud depletes material according to the area integral of the product of the deposition velocity and the average ground level concentration. Thus each puff has a center, volume, and material mass which are determined by the wind velocity, atmospheric stability, travel distance, and deposition velocity. After material is deposited on the soil, the contaminant redistribution processes, depending upon local conditions, may recycle to provide additional contaminant movement from these new sources.

III. INPUT DESCRIPTION

A computer code, incorporating the above models is listed in Appendix E. The input can be considered in two parts: The first part is supplied in whole each time a problem is started or restarted, while the

second part varies in card numbers depending on problem startup, restart, or restart with rezoning.

A. Part 1 of the Input Stream

Card 1 (FORMAT: 6F10.5)

(ABETA (I), I = 1, 6)

The ABETA array contains the values of β for evaluating the velocity profile or surface friction velocity given by equations (28) and (29). The sequential values in ABETA correspond respectively to atmospheric stability classes A through F. Note that ABETA (4) = 1.0 implies neutral stability class D and the classic logarithmic velocity profile of equation (29).

Card 2 through 19 (FORMAT: 4E20.10)

DQ 1 J = 1, 6

KNQTY (I, J), I = 1, 3

C1Y (I, J), I = 1, 4

1 C2Y (I, J), I = 1, 4

The above 18 cards are read in groups of 3. KNQTY (I, J) is a declared floating point two dimensional array of knots for the cubic spline representation of the σ_y dispersion coefficients. J running from 1 to 6 corresponds respectively to the six stability classes A through F. I running from 1 to 3 on KNQTY contains the three knots for two spline intervals. I running from 1 to 4 on C1Y and C2Y defines the four spline coefficients for each stability class J in respectively the first and second intervals. See Appendix A for a spline description and tabulation of the coefficients.

Cards 20 through 37 (FORMAT: 4E20.10)

DQ 2 J = 1, 6

KNQTYZ (I, J), I = 1, 3

C1Z (I, J), I = 1, 4

2 C2Z (I, J), I = 1, 4

Analogous to cards 2 through 19, the above 18 cards are read in groups of 3 to define the knots and coefficients for the cubic spline representation of the σ_z dispersion coefficient.

Cards 38 through 55 (FORMAT: 10F8.3)

((EROS (I), PER(I)), I = 1, 90)

The above 18 cards contain parred values of the soil erodibility index table discussed in

Appendix B.

B. Part 2 of the Input Stream

Card 56 (FORMAT: I5, F10.5, 3I5)

- IFGREST - Restart flag
 IFGREST = 0 Problem startup
 IFGREST $\neq$ 0 Problem restart.
 Code reads a restart file from
 FSET1 in SUBROUTINE READP
 ROUTINE READP
- STIME - Problem stop time in minutes.
 Code writes a restart file on
 FSET2 in SUBROUTINE WRITEP.
- IREZONE - Rezone flag
 IREZONE = 0 No rezoning.
 IREZONE $\neq$ 0 Mesh structure
 is rezoned.
- NIP - Number of I or X-direction cells
 in the rezoned mesh. Must be
 defined if IREZONE $\neq$ 0.
- NJP - Number of J or y-direction cells
 in the rezoned mesh. Must be
 defined in IREZONE $\neq$ 0.

Note on rezoning: If IREZONE $\neq$ 0, then square mesh cells will double on each side of a new NIP by NJP active mesh. There is a single row of inactive periphery cells which serves as a boundary to conserve mass on the total mesh. Material is transported into but never out of these boundary cells. Therefore, for this version of the code $(NIP + 2) \times (NJP + 2) \leq 1800$. An additional restriction on the mesh size is $(NIP + 2) + (NJP + 2) \leq 200$. This comes from a plotting limitation, i.e., array XY is dimensioned 200.

Card 57 (FORMAT: 2F10.5)

- SGN - Number of standard deviations defining the deposition area for each puff in equation (25), i.e., the deposition area for evaluating equation (25) is defined by a circle centered at the puff's center with radius $SGN \cdot \sigma_x$. For example with $SGN = 1.5$, 75% of the total amount of material available for deposition is accounted for; while with $SGN = 3.0$, 99% is accounted for.
- ORDMAGL - Puffs generated with less material than ORDMAGL $\cdot Q_{max}$ where Q_{max} is the maximum

material in a puff from the previous time step, are not allowed. For example, if ORDMGL = 10^{-3} , only puffs within three orders of magnitude of the maximum puff are created.

Note on SGN and ORDMGL: Since the code running time is directly proportional to the number of puffs in the system, these input quantities give the user the option of trading accuracy for less execution time.

Card 58 (FORMAT: 2I5, 3F10.5)

- IPRINT - Print option.
 IPRINT = 0 No major and minor printouts.
 IPRINT $\neq$ 0 Major and minor printouts.
- IPL0T - Plot option.
 IPL0T = 0 No plotting output.
 IPL0T $\neq$ 0 Plotting output.
- PMIN0RT - Minor printout time increment in minutes. If IPRINT $\neq$ 0, the code will print a minor printout every PMIN0RT time increment.
- PRTIME - Major printout time increment in minutes. If IPRINT $\neq$ 0, code will print a major printout every PRTIME time increments.
- PLTIME - Plotting time increment in minutes. If IPL0T $\neq$ 0, the code will plot surface concentration and exposure contours every PLTIME time increments.

Card 59 (FORMAT: 2I5, 2F10.5)

- N1 - Number of surface concentration contours ≤ 10 . Needed for plotting.
- N2 - Number of exposure contours ≤ 10 . Needed for plotting.
- ACT1 - Conversion factor for converting grams/m² to desired surface concentration activity/m². For example, for ²³⁸PuO₂ systems, 1 gm/m² = 12.1×10^6 μ Ci/m². Needed for plotting.
- ACT2 - Conversion factor for converting activity-sec/m³. For ²³⁸PuO₂ systems, 1 gm-sec/m³ = 12.1 Ci-sec/m³. Needed for plotting.

Card 59 is required whether or not plotting is requested.

Card 60 (FORMAT: 10F8.4)

(Z1(I), I = 1, N1)

N1 ≤ 10 values of the surface concentration contours. Card 60 is required whether or not plotting is requested.

Card 61 (FORMAT: 10F8.4)

(Z2(I), I = 1, N2)

N2 ≤ 10 values of the exposure contours. Card 61 is required whether or not plotting is requested.

Card 62 (FORMAT: 2I5, F10.5)

NI - Start up number of I or X-direction active cells.
 NJ - Start up number of J or Y-direction active cells.
 DELTA - Side length of the square cell in meters.

Note: (NI+2) × (NJ+2) ≤ 1800 and (NI+2) + (NJ+2) ≤ 200. See card 56 for explanation.

Card 63 (FORMAT: 2F10.5)

DIA - Average diameter of suspendible contaminant in microns.
 DEN - Density of suspendible contaminant in gm/cm³.

Card 64 (FORMAT: 2F10.5)

ZINF - Height in meters where the wind speed is specified by SUBROUTINE VELVECT. U(Z=ZINF) is considered to be essentially a free stream value.
 ZTOP - Height in meters where the suspended puffs are created.
 ZEXP - Height in meters where the exposure contours are plotted.

Card 65 (FORMAT: 2F10.5)

RHØ - Atmospheric density in gm/cm³.
 RHØSOIL - Average soil density in gm/cm³.

Cards 66 through 76 define soil and surface conditions on the mesh structure. Each of these cards is actually a card packet defined by the following example:

Suppose an active mesh structure (NI = 8 and NJ = 10) consists of the four distinct surface conditions α, β, γ, and δ as diagrammed in Figure 10.

A packet of 12 cards, each card in a format (IB, JB, ε) defining a sub-rectangular grid of surface condition ε and positioned at (IB ≤ I ≤ NI, JB ≤ J ≤ NJ), will describe the surface quantity ε by the following:

Card	IB	JB	Quantity
1	1	1	α
2	5	1	β
3	4	2	β
4	3	3	β
5	2	4	γ
6	1	5	γ
7	1	6	δ
8	3	6	γ
9	3	8	α
10	3	10	δ
11	7	7	δ
12	-1		

The last card (card 12) sets ε flag to stop reading cards for this particular packet and continue with the next card packet in the input stream.

Card Packet 66 (FORMAT: 2I5, F10.5)

IB, JB, TEMP1

(IB, JB) - Integer coordinate.

TEMP1 - Temporary mesh array of vegetative residue in grams/m² for evaluating equation (12). See Appendix B for details.

Card Packet 67 (FORMAT: 2I5, F10.5)

IB, JB, RIDGE

(IB, JB) - Integer coordinate.

RIDGE - Mesh array of surface roughness equivalence in cm for evaluating equations (12), (28) and (29). See Appendix B for details.

Card Packet 68 (FORMAT: 2I5, F10.5)

IB, JB, TEMP2

(IB, JB) - Integer coordinate.

TEMP2 - Temporary mesh array of the constant b in evaluating equation (12). See Appendix B for details.

Card Packet 69 (FORMAT: 2I5, F10.5)

IB, JB, TEMP3

- (IB, JB) - Integer coordinate.
- TEMP3 - Temporary mesh array for the soil fraction greater than 840 μ m in diameter. See Appendix B for details.

Card Packet 70 (FORMAT: 2I5, F10.5)

IB, JB, TEMP4

- (IB, JB) - Integer coordinate.
- TEMP4 - Temporary mesh array for the constant a in equation (12). See Appendix B for details.

Note: The above 5 card packets define the erosion function X

$$X = a I / (RK)^b,$$

by $X = TEMP4 * F(TEMP3) / (RIDGE * TEMP1)$, where $F(TEMP3)$ equals the soil erodibility index presented in Appendix B.

Card Packet 71 (FORMAT: 2I5, F10.5)

IB, JB, TEMP5

- (IB, JB) - Integer coordinate.
- TEMP5 - Temporary mesh array for the amount of water held by soil at 15-atmosphere percentage. See Appendix C for details.

Card Packet 72 (FORMAT: 2I5, F10.5)

IB, JB, TEMP6

- (IB, JB) - Integer coordinate.
- TEMP6 - Temporary mesh array for the amount of water held by the soil. See Appendix C for details.

Note: The above 2 card packets define the equivalent moisture mesh array ALPHA for equation (5) by $ALPHA = 6(TEMP6/TEMP5)^2$.

Card Packet 73 (FORMAT: 2I5, F10.5)

IB, JB, TEMP7

- (IB, JB) - Integer coordinate.
- TEMP7 - Temporary mesh array for the threshold friction velocity U_t^* in cm/sec. See Appendix D for details. The threshold surface shear stress mesh array TAUCRIT is calculated by $TAUCRIT = RH0 * TEMP7^2$.

Card Packet 74 (FORMAT: 2I5, 3F10.5)

IB, JB, ELEMENT, TEMP8, TEMP9

- (IB, JB) - Integer coordinate.
- ELEMENT - Mesh array for the number of major roughness elements.
- TEMP8 - Temporary mesh array for the average height in meters of the major roughness elements.
- TEMP9 - Temporary mesh array for the average diameter in meters of the major roughness elements.

Note: Mesh arrays for the diameter to height ratio (DDH) and the uncovered area (UNCAREA) are calculated from the above card packet.

Card Packet 75 (FORMAT: 2I5, F10.5)

IB, JB, SCDEPTH

- (IB, JB) - Integer coordinate
- SCDEPTH - Mesh array for the depth in cm of the soil-contaminant mixing layer.

Card Packet 76 (FORMAT: 2I5, F10.5)

IB, JB, PERSS

- (IB, JB) - Integer coordinate.
- PERSS - Mesh array for the fraction of the soil mass in the mixing layer which is suspendible. See Appendix B for details.

Card Packet 77 (FORMAT: 4I5, 3F10.5)

IB, IE, JB, JE, TEMP10, FRACT1, FRACT2

- (IB, IE) - Range of I cells $IB \leq I \leq IE$.
- (JB, JE) - Range of J cells $JB \leq J \leq JE$.
- TEMP10 - Temporary mesh array containing the total amount of suspendible plus nonsuspendible contaminant (grams) in the soil mixing layer.
- FRACT1 - Fraction of the total amount of contaminant which is suspendible.

FRACT2 - Fraction of the total amount of suspendible contaminant which is suspended above the surface in an initial cloud.

Note: The initial contaminant surface concentration is:

For nonsuspendible particles

$\text{OMEGA1} = \text{TEMP10} * (1.0 - \text{FRACT1})$, and

for suspendible particles

$\text{OMEGA1} = \text{TEMP10} * \text{FRACT1} * (1.0 - \text{FRACT2})$.

If $\text{FRACT2} \neq 0.0$ on the next to last card in this packet (the card before the -1 card), then a single initially suspended spherical puff of strength $\text{TEMP10} * \text{FRACT1} * \text{FRACT2}$ is positioned at (XO, YO, ZO). FRACT2 must be zero on all other cards. See card 78 below.

Card 78 (FORMAT: 3F10.5)

XO, YO, ZO - Position in meters of an initially suspended puff. If $\text{FRACT2} \neq 0$ in the above card packet (#77), this card must be included in the input stream.

For the problem startup the entire input stream as presented above is required. For a problem restart without rezoning, all of Part 1 and cards 56, 57, and 58 are required; while for a problem restart with rezoning, Part 1, cards 56, 57, 58 and card packets 66 through 76 are required.

IV. SAMPLE CALCULATIONS

A. Introduction

The most probable accident involving a SNAP (space nuclear auxiliary power) radioisotopic fuel system that would lead to a particulate $^{238}\text{PuO}_2$ release into the environment is the heat source package impacting a hard surface at terminal velocity. It has been estimated³⁷ that up to 59.3 Ci (4.9 gm) could be released in the unlikely event that a typical MHW (Multi-hundred Watt) heat source did impact an extremely hard surface. The particulate fines would be distributed as follows:

Total non-respirable fines
($4 \mu\text{m} < \text{diameter} \leq 1500 \mu\text{m}$) 58 Ci or
4.8 gm.

Total respirable fines

(diameter $\leq 4 \mu\text{m}$) 1.3 Ci or 0.1 gm.

At impact, it is assumed that the $^{238}\text{PuO}_2$ fines are initially distributed over a small area (the order of 100 m^2) directly on the impact site.

Of the amount of material in the respirable range, ten percent is assumed³⁸ to form a small promptly suspended cloud directly over the impact. This cloud will settle on the contaminated impact site in a calm atmosphere or disperse downwind in an active atmosphere. Under certain soil, surface, and atmospheric conditions, the particulate $^{238}\text{PuO}_2$ on the surface may be redistributed and develop a potential hazard downwind.

In the two sample calculations presented below, we examine a $^{238}\text{PuO}_2$ fueled heat source failing at impact and releasing particulate fines. In the first case a typical dust storm is in progress, while in the second, soon after the initial cloud settles in a calm atmosphere a dust storm of equal intensity begins.

B. Characterization of the Sample Calculations

An upper bound on the potential redistribution of particulate $^{238}\text{PuO}_2$ can be assessed by intentionally selecting conservative meteorological, surface, and soil conditions. Data characteristic of a major dust storm of the southern great plains¹⁹ will serve this purpose.

1. Meteorological Conditions

Wind Speed = steady 10 meters/sec at 1 meter above surface

Wind Direction = constant direction parallel to +x-axis

Atmospheric Stability = class D or number 4 - neutrally stable

Atmospheric Density = $1.22 \times 10^{-3} \text{ gm/cm}^3$

2. Surface Conditions

Vegetative Cover = 10 gm/m^2

Surface Roughness Equivalent = 2.5 cm

Major Roughness Elements - NONE

Threshold Friction Velocity = 18 cm/sec

3. Soil-Contaminant Conditions

Percentage of soil greater than $840 \mu\text{m}$ diameter = 10%

Amount of water held by soil at 15-atmosphere percentage = 2.1

Amount of water held by soil = 1.0

Depth of soil-contaminant mixing layer = 0.2 cm

Fraction of soil mass that is suspendable = 0.2

Soil density = 2.5 gm/cm³

Contaminant density = 10 gm/cm³

Average diameter of respirable contaminant = 2 μ m.

A complete listing of the input stream is presented in Figure 11.

C. Results

The results of the two sample calculations which describe the redistribution of particulate ²³⁸PuO₂ over eight hours of dust storm conditions are presented in Figures 12a through 12k. Surface concentration and exposure isopleths are contoured on an initial active 25 x 15 grid structure with each square cell 20 meters on a side. The lower left hand corner of the active mesh centered at position (10., 10.) meters. After sixty minutes, the mesh is rezoned to 23 x 7 with each cell 40 meters on a side and the lower left-hand corner of the active mesh centered at (30., 30.) meters. The relocation of the combined respirable and nonrespirable particulate ²³⁸PuO₂ is represented by the 62 μ Ci/m² surface concentration isopleth, while exposure in the breathing zone (2 meters above the surface) for the general population (0.0005 μ Ci or 7.1×10^{-6} Ci-sec/m³) and the occupational worker (0.016 μ Ci or 2.3×10^{-4} Ci-sec/m³) is depicted respectively as isopleths A and B. In each of the figures, the two plots side by side at the top correspond to the example with the initial cloud dispersing downwind, and the two plots at the bottom correspond to the example with all material initially on the surface near the impact site.

In rezoning the grid, as shown in Figure 12c and Figure 12d, the shape of the exposure contours is not maintained, although the areas are roughly the same. This is due to the fact that the exposure is a time integrated point function; and therefore, only information at every other cell center is re-

tained in this effective 4 to 1 cell rezoning operation. On the other hand, the surface concentration isopleth, because of the mass conservation property, is observed to preserve its shape.

It is noted that after eight hours, there is little disagreement between the two calculation sequences. This indicates that for dust storm conditions of highly erodible soil-contaminant surfaces, it makes little difference whether or not one considers an initially suspended ²³⁸PuO₂ cloud. In fact, since the calculation without the initial cloud contains roughly 10% more respirable ²³⁸PuO₂ on the active grid, the exposure area for this case is likely to be larger at long times. Evidence of this is given by the slightly longer exposure isopleth length depicted in Figure 12k. It is interesting that the occupational exposure limit (contour B = 2.3×10^{-4} Ci-sec/m³), due to the initial cloud dispersing downwind, is restricted to a rather small area near the impact site. As the respirable particles redistribute on the surface, and actually translate downwind as shown in the surface concentration sequence, the local concentrations for the stated meteorological conditions are not sufficient to produce vertical fluxes with the necessary intensity to develop occupational standard levels. After eight hours of dust storm conditions, it is noted that the general population exposure isopleth (contour A = 7.1×10^{-6} Ci-sec/m³) encloses an area less than one tenth of a square kilometer.

The above examples demonstrate the usefulness of this redistribution model for predicting the relocation of surface contaminants. No attempt have been made to perform a parametric study involving various soils, surface conditions, and meteorological effects. It is important that these parameters be adequately characterized in order that a meaningful calculation be the outcome. To help define certain parameters, a compilation of useful material is tabulated in the appendices.

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41. L. A. Richards and L. R. Weaver, "Fifteen-Atmosphere Percentage as Related to the Permanent Wilting Percentage," *Soil Science* 56, 331-339 (1943).
42. W. S. Chepil, "Soil Conditions that Influence Wind Erosion," *United State Department of Agriculture Technical Bulletin No. 1185* (June 1958).

Fig. 1. Two-dimensional mesh cell structure.

Fig. 2. Example of a control volume located on each mesh cell.

Fig. 3. Control volume top and side view showing the contaminant mass flow.

Fig. 4. Diagram of model describing the contaminant mass entering the three adjacent receiver cells.

Fig. 5. Horizontal dispersion coefficient as a function of downwind travel distance (after Turner³¹).

Fig. 6. Vertical dispersion coefficient as a function of downwind travel distance (after Turner³¹).

Fig. 7. Example of keeping the dispersion coefficient constant while changing atmospheric stability classes.

Fig. 8. Variation of stress partition with lateral cover (after Marshall³⁶).

Fig. 9. Variation of the mean roughness element drag coefficient with lateral cover (after Marshall³⁶).

Fig. 10. Example of various surface conditions on the active mesh structure.

7.8		19.		
1.8		1.8	2.8	
8.88122		2.5		
1	1	18.8		
-1				
1	1	2.5		
-1				
1	1	1.24		
-1				
1	1	18.		
-1				
1	1	888.		
-1				
1	1	2.1		
-1				
1	1	1.8		
-1				
1	1	18.		
-1				
1	1	8.8	8.8	8.8
-1				
1	1	2.2		
-1				
1	1	8.2		
-1				
2	2	8	8 8.9	8.8219
31				8.1
18.8		158.8	1.8

Fig. 12 (a-k). Surface concentration (A equals $62 \mu\text{Ci}/\text{m}^2$) and exposure (A equals $7.1 \times 10^{-6} \text{ Ci-sec}/\text{m}^3$ and B equals $2.3 \times 10^{-4} \text{ Ci-sec}/\text{m}^3$) isopleths for various times: (a) 0.0 minutes, (b) 1.0 minute, (c) 60.0 minutes--before rezoning, (d) 60.0 minutes--after rezoning, (e) 120.0 minutes, (f) 180.0 minutes, (g) 240.0 minutes, (h) 300.0 minutes, (i) 360.0 minutes, (j) 420.0 minutes, and (k) 480.0 minutes. The top pair of plots refers to the initial cloud dispersing downwind, while the bottom pair refers to all material initially on the surface.

Fig. 12b. Surface concentration and exposure isopleths at 1.0 minutes.

Fig. 12c. Surface concentration and exposure isopleths at 60.0 minutes (before rezoning).

Fig. 12d. Surface concentration and exposure isopleths at 60 minutes (after rezoning).

Fig. 12e. Surface concentration and exposure isopleths at 120.0 minutes.

Fig. 12f. Surface concentration and exposure isopleths at 180.0 minutes.

Fig. 12g. Surface concentration and exposure isopleths at 240.0 minutes.

Fig. 12h. Surface concentration and exposure isopleths at 300.0 minutes.

Fig. 12i. Surface concentration and exposure isopleths at 360.0 minutes.

Fig. 12j. Surface concentration and exposure isopleths at 420.0 minutes.

Fig. 12k. Surface concentration and exposure isopleths at 480.0 minutes.

APPENDIX A

Turner's³¹ atmospheric dispersion coefficients have been extrapolated to range in travel distance over the five orders of magnitude 1 meter to 10⁵ meters. The curves for different stability classes are approximated by a least squares variable knot cubic spline function.^{39,40} These functions combine ease of handling in a computer with great flexibility. The cubic spline function used in this work can be defined

$$\log(\sigma) = \sum_{i=1}^4 C_i (\log d - \alpha)^{i-1},$$

where d is the travel distance and the spline coefficient C_i is valid in the range $\alpha \leq \log d \leq \beta$. Table A-1 presents the spline knots and coefficients for the atmospheric dispersion coefficients σ_y and σ_z in the six stability classes A through F.

TABLE A-1

CUBIC SPLINES DESCRIBING THE ATMOSPHERIC DISPERSION COEFFICIENTS σ_y AND σ_z

LOG(d)	NOTES	C1	C2	C3	C4
LOG(SIGMA Y) STABILITY CLASS A					
0.000000 2.071000	0.071000 5.000000	-1.000000 5.700000	0.211000 0.000000	-0.000000 -2.110000	-1.170000 0.130000
LOG(SIGMA Y) STABILITY CLASS B					
0.000000 2.000000	0.000000 5.000000	-0.000000 1.000000	0.110000 0.100000	-0.000000 -0.500000	-1.170000 -0.500000
LOG(SIGMA Y) STABILITY CLASS C					
0.000000 1.770000	1.770000 5.000000	-1.000000 0.000000	0.000000 0.000000	1.000000 0.000000	-2.110000 0.000000
LOG(SIGMA Y) STABILITY CLASS D					
0.000000 2.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	0.000000 -0.000000	-1.170000 -0.500000
LOG(SIGMA Y) STABILITY CLASS E					
0.000000 0.000000	0.000000 5.000000	-1.000000 -0.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.000000
LOG(SIGMA Y) STABILITY CLASS F					
0.000000 1.000000	1.000000 5.000000	-1.000000 0.000000	0.000000 0.000000	0.000000 0.000000	-1.170000 -0.000000
LOG(SIGMA Z) STABILITY CLASS A					
0.000000 2.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.500000
LOG(SIGMA Z) STABILITY CLASS B					
0.000000 2.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.500000
LOG(SIGMA Z) STABILITY CLASS C					
0.000000 0.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.000000
LOG(SIGMA Z) STABILITY CLASS D					
0.000000 0.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.000000
LOG(SIGMA Z) STABILITY CLASS E					
0.000000 0.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.000000
LOG(SIGMA Z) STABILITY CLASS F					
0.000000 0.000000	0.000000 5.000000	-0.000000 1.000000	0.000000 0.000000	-0.000000 -0.000000	-1.170000 -0.000000

APPENDIX B*

The horizontal soil flux described by equation (11) is directly proportional to the erodibility function X (tons/rod-hour),

$$X = a \frac{I}{(RK)^b}$$

where

a and b = constants whose values depend upon past erosional history, type of residue and roughness, and condition of the surface crust

K = surface roughness equivalent in inches

R = amount of vegetative residue in pounds per acre

I = soil erodibility index based on percentage of soil greater than 840 μ m in diameter

The constants a and b are reported to vary considerably for soils having various erosional

histories and on soils that were previously subjected to a series of uniform erosive winds that had a variable influence on the surface crust. Based upon certain average values and on crusted surface soil, the constants a and b equal 400 and 1.26, respectively. Gillette²⁹ found good agreement with his west Texas dust storm data and the predicted horizontal flux using these values.

The degree of surface roughness depends on height, length, density, orientation, and quality of vegetative cover and on size, shape, and lateral frequency of clods, ripples, and ridges. It is extremely difficult to determine surface roughness by measuring these surface obstructions. For this reason, a "ridge roughness equivalent" was devised, and with the aid of a wind tunnel, ridge roughness equivalent values were compiled for various field surfaces. Estimates of K can be made with reasonable accuracy from photographs of different field roughness for which the ridge roughness equivalent

*Much of the material in this appendix, including the standard photographs, has been taken directly from reference (28).

TABLE B-1

SOIL ERODIBILITY INDEX I BASED ON PERCENTAGE OF
SOIL FRACTIONS GREATER THAN 840 μ m IN DIAMETER
AND DETERMINED BY DRY SIEVING (AFTER CHEPIL
AND WOODRUFF²⁸)

Percentage of soil fractions greater than 84 μ m UNITS TENS	9	8	7	6	5	4	3	2	1	0
9										0.02
8	0.02	0.03	0.03	0.04	0.05	0.06	0.07	0.08	0.09	.10
7	.12	.14	.16	.20	.25	.30	.35	.40	.45	.5
6	.55	.60	.65	.70	.75	.80	.85	.90	.95	1.0
5	1.1	1.2	1.3	1.4	1.6	1.8	2.0	2.2	2.5	2.8
4	3.1	3.4	3.7	4.0	4.3	4.6	4.9	5.2	5.6	6.0
3	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.5	11.0	12.0
2	13	14	15	16	17	18	19	20	21	23
1	25	27	30	33	36	39	43	47	51	55
0	70	80	100	120	150	175	280	450	1,000	

is known. Photographs have served as a standard guide for visual estimation of the ridge roughness equivalent. These standard photographs (numbers 1 to 18) are given in this appendix.

Visual estimates of the vegetative residue, designated as R, can also be found from these standard photographs. Otherwise, a random sampling of the vegetative residue from the area of interest must be analyzed. Briefly, the procedure is to cut and rake off level with the ground three 1-square-yard samples. The residue is thoroughly shaken and washed to remove soil before the cleaned residue is dried in an oven and weighed. The three samples in ounces, multiplied by 100, equals the quantity of residue in pounds per acre.

The soil erodibility index I is found from Table B-1 which is based on the percentage of soil fraction greater than 840 μ m in diameter as determined by dry sieving. A hand-rotating sieve, such as that shown in Figure B-1, may be used to obtain the desired result. The following procedure is important when using the hand-rotating sieve:

1. Take at least 4 soil samples to 1-inch depth. Each sample should weigh 1,812 grams (4 pounds).
2. Sieve the soil only when it is air dry.
3. Turn the sieve 2 turns per 5 seconds.
4. If the soil is sand, loamy sand, or sandy

loam, turn sieve 5 times; if it is loam, silt loam, clay loam, or silty clay loam, turn 10 times; if it is silty clay or clay, turn 15 times. The soil remaining in the sieve is weighed and expressed in percentage of total weight of soil.

Table B-2¹⁴ may serve as a qualitative guide for various soil classes and the percentage of soil fraction greater than 840 μ m in diameter. In addition, the water-stable particles, less than 20 μ m in diameter, which are the fundamental building blocks of soil structure, are also tabulated for the various soil classes. For our purposes, these small particles can be thought of as the suspendible or respirable fraction of the soil.

TABLE B-2

RELATION OF WATER-STABLE STRUCTURE TO DRY SOIL STRUCTURE AND ERODIBILITY BY WIND (AFTER CHEPIL AND WOODRUFF¹⁴)

<u>Soil Class</u>	<u>> 840 μm (%)</u>	<u>< 20 μm (%)</u>
Sand	3.3	1.7
Loamy sand	6.9	3.0
Sandy loam	36.6	10.0
Loam	44.4	13.8
Silt loam	48.6	17.8
Clay loam	43.6	14.0
Silty clay loam	49.4	14.4
Silty clay	19.2	10.8
Clay	20.2	10.8

Fig. B-1. Rotary hand sieve for determining percentage of soil greater than 840 μm in diameter (after Chepil and Woodruff²⁸).

Guide for Visual Estimation of Field Surfaces

PHOTOGRAPH 1.—Loose, blowing sand, surface practically bare and smooth.

$K=1.0$ inch

$R=312$ pounds per acre

PHOTOGRAPH 2.—Smooth, fallow surface beaten down by rain, practically bare.

$K=1.5$ inches

$R=224$ pounds per acre

PHOTOGRAPH 3.—Good wheat residue cover, flattened down with one-way disk.

$K=1.6$ inches $R=425$ pounds per acre

PHOTOGRAPH 4.—Loose surface of loamy sand with some grass.

$K=2.0$ inches $R=311$ pounds per acre

PHOTOGRAPH 5.- Smooth surface with very sparse sorghum stubble.
 $K = 2.0$ inches $R = 400$ pounds per acre

PHOTOGRAPH 6.- Smooth surface with very short, thin sorghum
 stubble.
 $K = 2.5$ inches $R = 245$ pounds per acre

PHOTOGRAPH 7.—Semideep furrow drill ridges with some wheat stubble.

K=2.6 inches

R=790 pounds per acre

PHOTOGRAPH 8.—Good stand of growing wheat, about 3.5 inches high, slightly ridged by drill.

K=3.2 inches

R=779 pounds per acre

PHOTOGRAPH 9.—Heavy wheat stubble that was combined, partly flattened by one-way disk.

$K=4.0$ inches $R=3,980$ pounds per acre

PHOTOGRAPH 19. Recently plowed land with cloddy and moderately rough surface.

$K=4.0$ inches $R=100$ pounds per acre

PHOTOGRAPH 11.—Cotton, machine-stripped.
K=4.3 inches *R*=1,090 pounds per acre

PHOTOGRAPH 12.—Sorghum stubble, cut with binder 5 to 7 inches
 high, 40-inch rows.
K=4.35 inches *R*=575 pounds per acre

PHOTOGRAPH 13.—Wheat stubble, combined 8 to 10 inches high.
 $K=4.4$ inches $R=1,090$ pounds per acre

PHOTOGRAPH 14.—Sorghum stubble, chiseled, with some large clods;
 considerable drifting.
 $K=4.6$ inches $R=640$ pounds per acre

PHOTOGRAPH 15.—Sorghum, combined 10 to 12 inches high, 40-inch rows.

$K=6.3$ inches

$R=1,220$ pounds per acre

PHOTOGRAPH 16.—Heavy sorghum stubble on irrigated land, thick and leafy, cut 8 to 10 inches high, 40-inch rows.

$K=8.5$ inches

$R=1,890$ pounds per acre

PHOTOGRAPH 17.—Listed, with little or no residue on top.
K = 10.1 inches *R* = 155 pounds per acre

PHOTOGRAPH 18.—Milo on irrigated land, combined for grain, leaving
 16- to 18-inch stubble.
K = 12.5 inches *R* = 2,275 pounds per acre

APPENDIX C

The resistance against the wind drag due to the cohesion of absorbed water films may be characterized²⁶ by the equivalent moisture (w/w') where w is the amount of water held by the soil at a 15-atmosphere-percentage. * Determination of the 15-atmospheric percentage for a given soil type requires a rather complex and time-consuming laboratory

*The 15-atmosphere percentage corresponds approximately to the percentage of water at the permanent wilting point of plants.

procedure.⁴¹ A limited amount of data** is available from reference (26):

Soil	15-atmosphere percentage (%)
Dune sand	1.28
Pratt sandy loam	3.89
Baca silt loam	11.21
Sutphen silty clay	20.71

and qualitative values of equivalent moisture for these soil types may be found in Table C-1.

**A more complete compilation of 15-atmosphere percentages of various soil types is tabulated in reference (41).

TABLE C-1

SOIL PROPERTIES AT DIFFERENT LEVELS OF EQUIVALENT MOISTURE (AFTER CHEPIL²⁶)

Degree dryness or wetness	Cohesion between discrete soil particles	Equivalent moisture after exposure to wind			
		Dune quartz sand	Pratt sandy loam	Baca silt loam	Sutphen silty clay
Oven-dried at 105°C	None, except between minute dust particles	0.03	0.01	0.01	0.01
Air-dried in hot sun	None, except between minute dust particles	0.23	0.15	0.25	0.29
Air-dried in cool shade .	None, except between minute dust particles	0.31	0.26	0.29	0.32
Barely damp	Dust clings strongly to larger particles	0.39	0.36	0.42	0.43
Moderately damp	Barely stick together when pressed in hand	0.55	0.54	0.71	0.64
Extremely damp	Form a fragile ball when pressed in hand	0.78	1.03	1.04	0.87
Moist.....	Plasticity noticeable, but not in sand	1.17	1.54	1.34	1.06

APPENDIX D

In order to initiate soil movement, the atmospheric wind must exert some minimal force on a given soil type. Generally this minimum force is expressed as the threshold friction or drag velocity U_{*t} , which is defined as the square root of the ratio of the surface shear stress at incipient motion and the atmospheric density. Chepil⁴² obtained, by plotting the threshold drag velocity versus the maximum equivalent diameter for soils of various ratios

of minimum to maximum diameter and mixtures of erodible and nonerodible fractions, the threshold friction velocity curves in Figure D-1. The minimum is shown to be approximately 15 cm/sec for the most erodible soils (equivalent diameters of 100 μ m). Equivalent soil diameter is defined as $\rho_s d / 2.65$, in which ρ_s is the bulk density of the soil in gm/cm³ and d is the diameter of the soil determined by sieving.

Fig. D-1. Relation of the threshold drag velocity of the wind to the maximum equivalent diameter of the transported soil particles: (a) Sieved fractions in which the ratio of minimum to maximum diameter varies as $1/\sqrt{2}$; (b) sieved fractions in which the size of particles ranges from fine dust to the indicated maximum size; (c) soil containing 15 percent of nonerodible clods ranging up to 25 mm in diameter (after Chepil⁴²).

APPENDIX E

In order to help the reader understand the model implementation, a FORTRAN-IV listing is provided in this appendix.

There are several routines, the function of which the user should be aware. SUBROUTINE VELVECT (TB, VBAR, THETA, ISTAB) is a user supplied subroutine that furnishes time-dependent (current time TB) wind velocity magnitude VBAR in m/sec at ZINF (input stream) meters above the surface, wind velocity angle THETA in radians counterclockwise from the +X-axis, and atmospheric stability class ISTAB (1 through 6) to the calculational section of the code. Given the wind velocity magnitude and the size of a mesh cell DELTA (input stream), a time step is automatically calculated

which allows contaminant puffs to travel the length of the cell side.

System called routines include an error function evaluator ERF(X) for calculating the deposition integral in equation (25), a contour plotting routine CONTRJB for plotting surface concentration and exposure isopleths, a JOB CARD interrogation routine GETQ for finding the job time limit, and a time monitoring routine SECOND for determining the amount of central processor time used. When the JOB CARD time minus the used central processor time is less than 10 seconds, a restart file is written on file set number 2 (FSET2) and the job terminates. The same sequence occurs when the simulation time is greater than or equal to the problem time STIME (input stream).

```

PROGRAM REDIST (INP,OUT,FSET5=INP,FSET6=OUT,FILM,FSET1,FSET2)      RED      1
C PROGRAM REDIST SERVES AS THE DRIVER FOR THIS REDISTRIBUTION OF    RED      2
C CONTAMINATES FROM SOIL SURFACES COMPUTER CODE                     RED      3
COMMON /ERO/ NERO,EROS(99),PER(99) $ COMMON /FIXP/ PJ,OV,RHO,XO,YMRED 4
1,ZO,QO,ZTOP,ZEXP,DELTA,TAREA,DEFN,ZINF,RHOSOL,SGN,ORDMAGL,SHIFT RED 5
COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIM,JENDM1,IENDM1,NT,NJ,MAXMESHRED 6
COMMON /LCM1/ ALPHA(1800),TAUWUOH(1800),RIDGE(1800),FLEMENT(1800),RED 7
1UNCAREA(1800),EROSCOF(1800),SCDEPTH(1800),PERSS(1800),DJH(1800),TARED 8
2UCRIT(1800) $ COMMON /LCM2/ QPUFF(800),VOIST(800),ZDIST(800),XPUFFRED 9
3(800),YPUFF(800),ZPUFF(800) $ COMMON /PRTINFO/ TC,IPRINT,PRTIME,IPRED 10
4LOT,PLTIME,PMINORT,XV(200),ITITLE(5),XLABEL(2),YLABEL(2),Z1(10),Z2RED 11
5(10),JTITLE(7),NXLBL,NYLBL,MTITLE,NTITLE,N1,N2,ACT1,ACT2 $ COMMON RED 12
6/RESTART/ STIME,TIMEJC,XC,YC,ZC,Q,VCFLOW2,VBAR,ISTAH,YDISTQ,ZDISTRED 13
7,NUMPUFF,IFGREST,QOUT,QPUFFOT,PRTIMEC,PLTIMEC,PMINORC $ COMMON /SCREN 14
8M1/ OMEGA1(1800),OMEGA2(1800),OMEGAS1(1800),OMEGAS2(1800),EXPOSUR(RED 15
91800) $ COMMON /SCM2/ VIRORIG(12),ARETA(6) $ COMMON /YSIGMA/ KNOTYRED 16
$(3,6),C1Y(4,6),C2Y(4,6) $ COMMON /ZSIGMA/ KNOTY(3,6),C1Z(4,6),C2Z(RED 17
$(4,6) $ REAL KNOTY,KNOTZ $ MAXMESH=1800 $ MAXPUFF=800 $ CALL INPOITRED 18
$1 $ CALL GFTQ (4LKTLM,JCTL) $ TIMEJC=FLOAT(JCTL)*27.5E-09/60,V RED 19
READ (5,5)IFGREST,STIME,IREZONE,NIP,NJP $ WRITE (6,6)IFGREST,STIMERED 20
1,TIMEJC $ STIME=60.0*STIME $ TIMEJC=60.0*TIMEJC $ READ (5,7)SGN,ORDRED 21
2DMAGL $ WRITE (6,8)SGN,ORDMAGL RED 22
C IS THIS A PROBLEM RESTART RED 23
IF (IFGREST.EQ.0) GO TO 3 $ CALL READF $ READ (5,9)IPRINT,IPLOT,PMKRED 24
1INORT,PRTIME,PLTIME $ WRITE (6,10)IPRINT,IPLOT,PMINORT,PRTIME,PLTIPRED 25
2ME $ PRTIME=60.0*PRTIME $ PLTIME=60.0*PLTIME $ PMINORT=60.0*PMINORRED 26
3T RED 27
C SHOULD THE MESH BE REZONED RED 28
IF (IREZONE.EQ.0) GO TO 2 $ WRITE (6,11)NIP,NJP $ ITFMP=(NIP+2)*(NRED 29
1JP+2) $ JTEMP=(NIP+2)+(NJP+2) $ IF (JTEMP.LE.MAXMESH.AND,JTEMP.LE.RED 30
2200) GO TO 1 $ WRITE (6,12) RED 31
1 CONTINUE $ CALL REZONE1 (IEND,NIP+2,NIP,NJP,OMEGA2,OMEGA1) $ CALL RED 32
1REZONE1 (IEND,NIP+2,NIP,NJP,OMEGA2,OMEGAS1) $ CALL REZONE2 (IEND,NRED 33
2IP+2,NIP,NJP,OMEGA2,EXPOSUR) $ REWIND 2 $ WRITE (2)OMEGA1,OMEGAS1,RED 34
3EXPOSUR $ NI=NIP $ NJ=NJP $ DELTA=2.0*DELTA $ SHIFT=SHIFT+DELTA/4,RED 35
40 $ CALL INPOUT2 (IREZONE) $ REWIND 2 $ READ (2)OMEGA1,OMEGAS1,EXPRE 36
5OSUR $ WRITE (6,13) $ CALL PRINT (OMEGA1,IEND,JEND,DELTA,SHIFT) RED 37
WRITE (6,14) $ CALL PRINT (OMEGAS1,IEND,JEND,DELTA,SHIFT) $ WRITE RED 38
1(6,15)ZEXP $ CALL PRINT (EXPOSUR,IEND,JEND,DELTA,SHIFT) $ WRITE (6RED 39
2,16) $ IF (IPLOT.NE.0) CALL PLOTCHT RED 40
2 CONTINUE $ WRITE (6,17) $ GO TO 4 RED 41
3 CONTINUE $ CALL INPOUT2 (IREZONE) RED 42
4 CONTINUE $ CALL ERODE $ STOP RED 43
C RED 44
5 FORMAT (15,F10.5,315) RED 45
6 FORMAT (* RESTART **15* PROBLEM STOP TIME **F10.1* MINUTES. JOB CRED 46
1ARD TIME **F10.2* MINUTES*) RED 47
7 FORMAT (2F10.5) RED 48
9 FORMAT (* DEPOSITION WITHIN*F8.2* SIGMA AND SUSPENSION CLOUDS GREARE 49
1TER THAN*E10.3* TIMES THE MAXIMUM CLOUD*) RED 50
9 FORMAT (2I5,6F10.5) RED 51
10 FORMAT (* IPRINT **15* IPLOT **15* MINOR TIME STEP PRINT**F10.2* MRED 52
1AJOR TIME STEP PRINT **F10.2* PLOT TIME STEP **F10.2) RED 53
11 FORMAT (* REZONE WITH NEW ACTIVE MESH SIZE*15* BY*15* CELLS*) RED 54
12 FORMAT (* PROGRAM STOPPED BECAUSE MESH STRUCTURE IS TOO LARGE FOR RED 55
1THIS VERSION OF THE CODE*) RED 56
13 FORMAT (1H1,* REZONED SURFACE DISTRIBUTION OF NON-RESPIRABLE CONTARE 57
1MINATE IN GRAMS PER MESH CELL*) RED 58
14 FORMAT (1H1,* REZONED SURFACE DISTRIBUTION OF RESPIRABLE CONTAMINARE 59
1TE IN GRAMS PER MESH CELL*) RED 60
15 FORMAT (1H1,* REZONED EXPOSURE AT *F10.3* METERS ABOVE THE SURFACERED 61
1 *) RED 62

```

16	FORMAT (1H1,* TIME WIND MAGNITUDE WIND DIRECTION STRENGTH AND VED	63
	1ABILITY MATERIAL OUTSIDE MESH NUMBER OF H. AND VED	64
	2, SOIL FLOW*,/* (MINUTES) (METERS/SEC) (DEGREES) RED	65
	3 (CLASS) (GRAMS) SUSPENDED PUFFS (GM/M-SPED	66
	4EC) (GM/M**2=SEC)** RED	67
17	FORMAT (1H1)	68
	END RED	69
	SUBROUTINE INPOUT1 IN1	1
C	THIS SUBROUTINE READS PART 1 OF THE INPUT STREAM IN1	2
	COMMON /ERO/ NERO,EROS(99),PER(99) \$ COMMON /SCM2/ VIRORIG(12),ABETA(12)	3
	1TA(6) \$ COMMON /YSIGMA/ KNOTY(3,6),C1Y(4,6),C2Y(4,6) \$ COMMON /ZSIIN1	4
	2GMA/ KNOTZ(3,6),C1Z(4,6),C2Z(4,6) \$ REAL KNOTY,KNOTZ IN1	5
C	READ DEACON BETA VALUES FOR VFLOCITY PROFILES IN1	6
	READ (5,3)(ABETA(I),I=1,6) IN1	7
C	READ SPLINE KNOTS AND COEFFICIENTS FOR APPROXIMATING SIGMA AND IN1	8
C	SIGMAZ AS A FUNCTION OF THE ATMOSPHERIC STABILITY CONDITION IN1	9
	DO 1 J=1,6 \$ READ (5,4)(KNOTY(I,J),I=1,3) \$ READ (5,4)(C1Y(I,J),I=1,3)	10
	11,4) \$ READ (5,4)(C2Y(I,J),I=1,4) IN1	11
1	CONTINUE \$ DO 2 J=1,6 \$ READ (5,4)(KNOTZ(I,J),I=1,3) \$ READ (5,4)(C1Z(I,J),I=1,4)	12
	1C1Z(I,J),I=1,4) \$ READ (5,4)(C2Z(I,J),I=1,4) IN1	13
2	CONTINUE IN1	14
C	READ SOIL FRODIBILITY INDEX DATA IN1	15
	NERO=90 \$ READ (5,5)(EROS(I),PER(I),I=1,NERO) \$ RETURN IN1	16
C	FORMAT (8F10.5) IN1	17
3	FORMAT (4E20.10) IN1	18
4	FORMAT (10F8.3) IN1	19
5	END IN1	20
	SUBROUTINE INPOUT2(IREZONE) IN2	21
C	THIS SUBROUTINE READS PART 2 OF THE INPUT STREAM IN2	2
	COMMON /ERO/ NERO,EROS(99),PER(99) \$ COMMON /FIXP/ PI,DV,RHO,X0,Y0,IN2	3
	1,Z0,Q0,ZTOP,ZEXP,DELTA,TAREA,DEN,ZINF,RHOSOIL,SGN,ORDMAGL,SHIFT IN2	4
	COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIM,JENDM1,IENDM1,N1,NJ,MAXMESHIN2	5
	COMMON /LCM1/ ALPHA(1000),TAUWUOR(1000),RIDGE(1000),ELEMENT(1000),IN2	6
	1UNCAREA(1000),EROSCOF(1000),SCDEPTH(1000),PERSS(1000),DDH(1000),TAIN2	7
	2UCRIT(1000) \$ COMMON /PRTINFO/ TC,IPRINT,PRTIME,IPLT,PLTIME,PMINOIN2	8
	3RT,XY(200),ITITLE(5),XLABEL(2),YLABEL(2),Z1(10),Z2(10),JTITLE(7),NIN2	9
	4XLBL,NYLBL,MTITLE,NTITLE,N1,N2,ACT1,ACT2 \$ COMMON /SCM1/ OMEGA1(10IN2	10
	500),OMEGA2(1000),OMEGAS1(1000),OMEGAS2(1000),EXPOSUR(1000) \$ COMMONIN2	11
	6N /SCM2/ VIRORIG(12),ABETA(6) \$ IF (IREZONE.NE.0) GO TO 2 \$ PI=4.0IN2	12
	7*ATAN(1.0) \$ SHIFT=0.0 \$ TAREA=1.0 IN2	13
C	READ PRINT AND PLOT DATA IN2	14
	READ (5,99)IPRINT,IPLT,PMINORT,PRTIME,PLTIME \$ WRITE (6,76)IPRINTIN2	15
	1,IPLT,PMINORT,PRTIME,PLTIME \$ PRTIME=60.0*PRTIME \$ PLTIME=60.0*PLIN2	16
	2TIME \$ PMINORT=60.0*PMINORT \$ READ (5,99)N1,N2,ACT1,ACT2 \$ WRITE (IN2	17
	36,77)N1,ACT1,N2,ACT2 \$ READ (5,79)(Z1(I),I=1,N1) \$ WRITE (6,78)(Z1IN2	18
	4(I),I=1,N1) \$ READ (5,79)(Z2(I),I=1,N2) \$ WRITE (6,80)(Z2(I),I=1,NIN2	19
	52) IN2	20
C	READ MESH STRUCTURE DATA IN2	21
	READ (5,99)N1,NJ,DELTA \$ WRITE (6,81)N1,NJ,DELTA \$ ITEMP=(N1+2)*(NJIN2	22
	1J+2) \$ JTEMP=(N1+2)*(NJ+2) \$ IF (ITEMP.LE.MAXMESH.AND.JTEMP.LE.200IN2	23
	2) GO TO 1 \$ WRITE (6,82) IN2	24
1	CONTINUE IN2	25
C	SET UP PLOT DATA IN2	26
	N1=-N1 \$ N2=-N2 IN2	27
2	CONTINUE \$ IEND=N1+2 \$ JEND=NJ+2 \$ MAXDIM=IEND*JEND \$ IENDM1=IEND-IN2	28
	11 \$ JE=JENDM1 \$ JENDM1=JEND-1 \$ JE=JENDM1 \$ ACT1=TARFA*ACT1 \$ TARETN2	29
	2A=DELTA*DELTA \$ ACT1=ACT1/TAREA \$ DO 3 I=1,IEND IN2	30
3	XY(I)=DELTA*(FLOAT(I-1)-0.5)+SHIFT \$ DO 4 J=1,JEND IN2	31
4	XY(IEND+J)=DELTA*(FLOAT(J-1)-0.5)+SHIFT \$ IF (IREZONE.NE.0) GO TO IN2	32
	15 \$ XLABEL(1)=10H METERS \$ YLABEL(1)=10H METERS \$ NXLBL=10 IN2	33
	NYLBL=10 \$ ITITLE(1)=10H SURFACE CO \$ ITITLE(2)=10H CONCENTRATIO \$ ITIIN2	34

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1 1TLE(3)=10HM (TIME = $ ITITLE(5)=10M MINUTES) $ JTITLE(1)=10M EXIN2 35
2 POSURE $ JTITLE(3)=10M METERS AB $ JTITLE(4)=10HVE SURFAC $ JTITLIN2 36
3 F(5)=10ME (TIME = $ JTITLE(7)=10M MINUTES) $ NTITLE=70 IN2 37
C READ SUSPENDABLE PARTICLE DIAMETER AND DENSITY IN2 38
READ (5,102)DIA,DEN $ WRITE (6,83)DIA,DEN IN2 39
C READ FREE STREAM VELOCITY HEIGHT, TOP OF CONTROL VOLUME HEIGHT, ANDIN2 40
C EXPOSURE CONTOUR HEIGHT - ALL IN METERS IN2 41
READ (5,102)ZINF,ZTOP,ZEXP $ WRITE (6,84)ZINF,ZTOP,ZEXP IN2 42
C READ ATMOSPHERIC DENSITY AND SOIL DENSITY BOTH IN GM/CC IN2 43
READ (5,102)RHO,RHOSOIL $ WRITE (6,85)RHO,RHOSOIL IN2 44
C CALCULATE TERMINAL VELOCITY (M/SEC) IN2 45
DV=DIA*DIA*(DEN-RHO)*980./(18.*0.15*RHO)*1.0E-10 IN2 46
S CONTINUE IN2 47
C CALCULATE VIRTUAL ORIGINS IN2 48
SY0=DELTA/4.3 $ SZ0=2.0*ZTOP/4.3 $ DO 6 ISTAB=1,6 $ XIP1=DELTA IN2 49
CALL ROOT (XIP1,SY0,ISTAB,1) $ VIRORIG(ISTAB)=XIP1 $ XIP1=2.0*ZTOPIN2 50
CALL ROOT (XIP1,SZ0,ISTAB,2) $ VIRORIG(6+ISTAB)=XIP1 IN2 51
6 CONTINUE IN2 52
C READ R(AMOUNT OF VEGETATIVE RESIDUE IN GRAMS PFR SQUARE METER) ANDIN2 53
C CONVERT TO POUNDS PER ACRE IN2 54
CONVCST=4.046856E+03/4.535924E+02 $ WRITE (6,86) $ DO 7 I=1,MAXDIMIN2 55
7 OMEGA1(I)=0.0 IN2 56
8 READ (5,99)IB,JB,ADXY $ IF (IB.LE.0) GO TO 10 $ WRITE (6,87)IB,JB,IN2 57
1ADXY $ IB=IB+1 $ JB=JB+1 $ ADXY=CONVCST*ADXY $ DO 9 J=JB,JE $ JINDIN2 58
2EX=(J-1)*IEND $ DO 9 I=IB,IE $ INDEX=JINDEX+I $ OMEGA1(INDEX)=ADXYIN2 59
9 CONTINUE $ GO TO 8 IN2 60
10 CONTINUE IN2 61
C READ K(RIDGE ROUGHNESS EQUIVALENT IN CM) AND CONVERT TO INCHES IN2 62
CONVCST=1.0/2.54 $ WRITE (6,88) $ DO 11 I=1,MAXDIM $ OMEGA1(I)=0.0IN2 63
10 $ OMEGA2(I)=0.0 IN2 64
11 OMEGA2(I)=0.0 IN2 65
12 READ (5,99)IB,JB,ADXY $ IF (IB.LE.0) GO TO 14 $ IF (ADXY.LE.0.0) AIN2 66
1DXY=0.001 $ WRITE (6,87)IB,JB,ADXY $ IB=IB+1 $ JB=JB+1 $ ADXYC=CONIN2 67
2VCST*ADXY $ DO 13 J=JB,JE $ JINDEX=(J-1)*IEND $ DO 13 I=IB,IF IN2 68
INDEX=JINDEX+I $ OMEGA2(INDEX)=ADXYC $ OMEGA2(INDEX)=ADXY IN2 69
13 CONTINUE $ GO TO 12 IN2 70
14 CONTINUE IN2 71
C IN2 72
C TRANSFER RIDGE ROUGHNESS (IN CM) TO RIDGE ARRAY IN2 73
C IN2 74
DO 15 I=1,MAXDIM IN2 75
15 RIDGE(I)=OMEGAS2(I) IN2 76
C CALCULATE THE SURFACE SHEAR STRESS FOR AN UNOBSTRUCTED SURFACE IN2 77
CALL VELVECT (0.0,VBAR,THETA,ISTAB) $ BETA=ABETA(ISTAB) $ DO 17 J=JIN2 78
12,JENDM1 $ JINDEX=(J-1)*IEND $ DO 17 I=2,IENDM1 $ INDEX=JINDEX+I IN2 79
ZDZ0=3000.*ZINF/OMEGAS2(INDEX) $ IF (ISTAB.FQ.4) GO TO 16 $ UBDUS=IN2 80
12.5/(1.-BETA)*(ZDZ0**((1.-BETA)-1.)) $ US=100.*VBAR/UBDUS $ OMEGAS1(IN2 81
2INDEX)=RHO*US*US $ GO TO 17 IN2 82
16 CONTINUE $ UBDUS=2.5*ALOG(ZDZ0) $ US=100.*VBAR/UBDUS $ OMEGAS1(IN2 83
1EX)=RHO*US*US IN2 84
17 CONTINUE IN2 85
C IN2 86
C TRANSFER SURFACE SHEAR STRESS TO TAUWUOR ARRAY IN2 87
C IN2 88
DO 18 I=1,MAXDIM IN2 89
18 TAUWUOR(I)=OMEGAS1(I) IN2 90
C CALCULATE THE PRODUCT OF R AND K IN2 91
DO 19 J=2,JENDM1 $ JINDEX=(J-1)*IEND $ DO 19 I=2,IENDM1 $ INDEX=JIN2 92
INDEX+I $ OMEGA1(INDEX)=OMEGA1(INDEX)*OMEGA2(INDEX) IN2 93
19 CONTINUE IN2 94
C READ THE EROSION FUNCTION EXPONENT H IN2 95
WRITE (6,89) $ DO 20 I=1,MAXDIM IN2 96

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20 OMEGA2(I)=0.0 IN2 97
21 READ (5,99)IB,JH,ADXY $ IF (IB,LE,0) GO TO 23 $ WRITE (6,87)IB,JH,IN2 98
1ADXY $ IB=IB+1 $ JH=JH+1 $ DO 22 J=JH,JF $ JINDEX=(J-1)*IEND $ DO IN2 99
22 I=IB,IE $ INDEX=JINDEX+I $ OMEGA2(INDEX)=ADXY IN2 100
22 CONTINUE $ GO TO 21 IN2 101
23 CONTINUE IN2 102
C CALCULATE (RK)**8 IN2 103
DO 24 J=2,JENDM1 $ JINDEX=(J-1)*IEND $ DO 24 I=2,IFNDM1 $ INDEX=JIN2 104
INDEX+I $ OMEGA1(INDEX)=OMEGA1(INDEX)**OMEGA2(INDEX) IN2 105
24 CONTINUE IN2 106
C READ PERCENTAGE OF SOIL FRACTION GREATER THAN 840 MICRONS IN2 107
WRITE (6,90) $ DO 25 I=1,MAXDIM IN2 108
25 OMEGA2(I)=0.0 IN2 109
26 READ (5,99)IB,JH,ADXY $ IF (IB,LE,0) GO TO 32 IN2 110
C CALCULATE THE SOIL ERODIBILITY INDEX FROM THE PERCENTAGE OF SOIL IN2 111
C FRACTION GREATER THAN 840 MICRONS IN2 112
DO 27 I=1,NEND $ IF (PER(I)-ADXY) 29,28,27 IN2 113
27 CONTINUE IN2 114
28 EROSI=EROS(I) $ GO TO 30 IN2 115
29 IF (I,EG,1) GO TO 28 $ EROSI=EROS(I-1)+(EROS(I)-EROS(I-1))/(PER(I)IN2 116
1-PER(I-1))*(ADXY-PER(I-1)) IN2 117
30 CONTINUE $ WRITE (6,87)IB,JH,ADXY,EROSI $ IB=IB+1 $ JH=JH+1 $ DO 31IN2 118
11 J=JH,JF $ JINDEX=(J-1)*IEND $ DO 31 I=IB,IE $ INDEX=JINDEX+I IN2 119
OMEGA2(INDEX)=EROSI IN2 120
31 CONTINUE $ GO TO 26 IN2 121
32 CONTINUE IN2 122
C COMPUTE I/(RK)**8 IN2 123
DO 33 J=2,JENDM1 $ JINDEX=(J-1)*IEND $ DO 33 I=2,IFNDM1 $ INDEX=JIN2 124
INDEX+I $ OMEGA1(INDEX)=OMEGA2(INDEX)/OMEGA1(INDEX) IN2 125
33 CONTINUE IN2 126
C READ EROSION FUNCTION COEFFICIENT AND CONVERT FROM TONS/ROD-HR IN2 127
C TO GM/M-SFC IN2 128
CONVCST=907.1847/(5.0292*3.6) $ WRITE (6,91) $ DO 34 I=1,MAXDIM IN2 129
34 OMEGA2(I)=0.0 IN2 130
35 READ (5,99)IB,JH,ADXY $ IF (IB,LE,0) GO TO 37 $ WRITE (6,87)IB,JH,IN2 131
1ADXY $ IB=IB+1 $ JH=JH+1 $ ADXY=CONVCST*ADXY $ DO 36 J=JH,JF $ JIN2 132
2DEX=(J-1)*IEND $ DO 36 I=IB,IE $ INDEX=JINDEX+I $ OMEGA2(INDEX)=ADIN2 133
3XY IN2 134
36 CONTINUE $ GO TO 35 IN2 135
37 CONTINUE IN2 136
C COMPUTE A*I/(RK)**8 IN2 137
DO 38 J=2,JENDM1 $ JINDEX=(J-1)*IEND $ DO 38 I=2,IFNDM1 $ INDEX=JIN2 138
INDEX+I $ OMEGA1(INDEX)=OMEGA2(INDEX)*OMEGA1(INDEX) IN2 139
38 CONTINUE IN2 140
C IN2 141
C TRANSFER RESULTS TO EROSCOF ARRAY IN2 142
C IN2 143
DO 39 I=1,MAXDIM IN2 144
39 EROSCOF(I)=OMEGA1(I) IN2 145
C READ SOIL MOISTURE CORRECTION PARAMETERS AND CALCULATE EQUIVALENT IN2 146
C MOISTURE IN2 147
WRITE (6,92) $ DO 40 I=1,MAXDIM $ OMEGA1(I)=0.0 IN2 148
40 OMEGA2(I)=0.0 IN2 149
41 READ (5,99)IB,JH,ADXY $ IF (IB,LE,0) GO TO 43 $ WRITE (6,87)IB,JH,IN2 150
1ADXY $ IB=IB+1 $ JH=JH+1 $ DO 42 J=JH,JF $ JINDEX=(J-1)*IEND $ DO IN2 151
242 I=IB,IE $ INDEX=JINDEX+I $ OMEGA2(INDEX)=ADXY IN2 152
42 CONTINUE $ GO TO 41 IN2 153
43 CONTINUE $ WRITE (6,93) IN2 154
44 READ (5,99)IB,JH,ADXY $ IF (IB,LE,0) GO TO 46 $ WRITE (6,87)IB,JH,IN2 155
1ADXY $ IB=IB+1 $ JH=JH+1 $ DO 45 J=JH,JF $ JINDEX=(J-1)*IEND $ DO IN2 156
245 I=IB,IE $ INDEX=JINDEX+I $ IF (OMEGA2(INDEX),EQ,0.0) GO TO 45 IN2 157
OMEGA1(INDEX)=6.0*(ADXY/OMEGA2(INDEX))**2 IN2 158

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45	CONTINUE \$ GO TO 44	IN2	159
46	CONTINUE	IN2	160
C		IN2	161
C	TRANSFER RESULTS TO ALPHA ARRAY	IN2	162
C		IN2	163
	DO 47 I=1,MAXDIM	IN2	164
47	ALPHA(I)=OMEGA1(I)	IN2	165
C	READ THE THRESHOLD FRICTION VELOCITY IN CM/SEC	IN2	166
	WRITE (6,94) \$ DO 48 I=1,MAXDIM	IN2	167
48	OMEGA1(I)=0.0	IN2	168
49	READ (5,99)IB,JB,ADXY \$ IF (IB,LE,0) GO TO 51 \$ WRITE (6,87)IB,JB,IN2	169	
	1ADXY \$ IB=IB+1 \$ JB=JB+1 \$ DO 50 J=JB,JE \$ JINDEX=(J-1)*IEND \$ DO IN2	170	
	250 I=IB,IE \$ INDEX=JINDEX+1 \$ OMEGA1(INDEX)=RHO*ADXY*ADXY IN2	171	
50	CONTINUE \$ GO TO 49	IN2	172
51	CONTINUE	IN2	173
C		IN2	174
C	TRANSFER RESULTS TO TAUCRIT ARRAY	IN2	175
C		IN2	176
	DO 52 I=1,MAXDIM	IN2	177
52	TAUCRIT(I)=OMEGA1(I)	IN2	178
C	READ NUMBER OF ELEMENTS, AVERAGE HEIGHT, AND AVERAGE DIAMETER	IN2	179
	WRITE (6,95) \$ DO 53 I=1,MAXDIM \$ OMEGA1(I)=0.0 \$ OMEGA2(I)=0.0 IN2	180	
53	OMEGA2(I)=0.0	IN2	181
54	READ (5,99)IB,JB,ADXY,AVFH,AVED \$ IF (IB,LE,0) GO TO 56 \$ WRITE (6,IN2	182	
	1,87)IB,JB,ADXY,AVFH,AVED \$ IB=IB+1 \$ JB=JB+1 \$ DO 55 J=JB,JE \$ JINDEX IN2	183	
	2DEX=(J-1)*IEND \$ DO 55 I=IB,IE \$ INDEX=JINDEX+1 \$ OMEGA2(INDEX)=AD IN2	184	
	3XY*AVFH*AVED/TAREA \$ OMEGA2(INDEX)=TAREA-ADXY*PI*AVED*AVED*0.25 IN2	185	
	IF (AVFH,LE,0.0) GO TO 55 \$ OMEGA1(INDEX)=AVED/AVFH IN2	186	
55	CONTINUE \$ GO TO 54	IN2	187
56	CONTINUE	IN2	188
C		IN2	189
C	TRANSFER RESULTS TO ELEMENT, UNCAREA, AND DDH ARRAYS	IN2	190
C		IN2	191
	DO 57 I=1,MAXDIM \$ DDH(I)=OMEGA1(I) \$ UNCAREA(I)=OMEGA2(I)	IN2	192
57	ELEMENT(I)=OMEGA2(I)	IN2	193
C	READ THE DEPTH OF THE SOIL-CONTAMINATE MIXING LAYER IN CM	IN2	194
	WRITE (6,96) \$ DO 58 I=1,MAXDIM	IN2	195
58	OMEGA2(I)=0.0	IN2	196
59	READ (5,99)IB,JB,ADXY \$ IF (IB,LE,0) GO TO 61 \$ WRITE (6,87)IB,JB,IN2	197	
	1ADXY \$ IB=IB+1 \$ JB=JB+1 \$ ADXY=ADXY*0.01 \$ DO 60 J=JB,JE \$ JINDEX IN2	198	
	2=(J-1)*IEND \$ DO 60 I=IB,IE \$ INDEX=JINDEX+1 \$ OMEGA2(INDEX)=ADXY IN2	199	
60	CONTINUE \$ GO TO 59	IN2	200
61	CONTINUE	IN2	201
C		IN2	202
C	TRANSFER RESULTS TO SCDEPTH ARRAY	IN2	203
C		IN2	204
	DO 62 I=1,MAXDIM	IN2	205
62	SCDEPTH(I)=OMEGA2(I)	IN2	206
C	READ FRACTION OF SOIL MASS THAT IS SUSPENDABLE	IN2	207
	WRITE (6,97) \$ DO 63 I=1,MAXDIM	IN2	208
63	OMEGA2(I)=0.0	IN2	209
64	READ (5,99)IB,JB,ADXY \$ IF (IB,LE,0) GO TO 66 \$ WRITE (6,87)IB,JB,IN2	210	
	1ADXY \$ IB=IB+1 \$ JB=JB+1 \$ DO 65 J=JB,JE \$ JINDEX=(J-1)*IEND \$ DO IN2	211	
	265 I=IB,IE \$ INDEX=JINDEX+1 \$ OMEGA2(INDEX)=ADXY IN2	212	
65	CONTINUE \$ GO TO 64	IN2	213
66	CONTINUE	IN2	214
C		IN2	215
C	TRANSFER RESULTS TO PERSS ARRAY	IN2	216
C		IN2	217
	DO 67 I=1,MAXDIM	IN2	218
67	PERSS(I)=OMEGA2(I) \$ IF (IREZONE,NE,0) GO TO 75	IN2	219
C	READ INITIAL SURFACE CONCENTRATIONS	IN2	220

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WRITE (6,9A) $ DO 68 I=1,MAXDIM $ OMEGA1(I)=0.0 IN2 221
68 OMEGA1(I)=0.0 IN2 222
69 READ (5,100)IR,IE,JB,JE,ADXY,FRACT1,FRACT2 $ IF (IR.GT.0) ADXYT=ADIN2 223
1XY $ IF (IR.GT.0) FRACT1T=FRACT1 $ IF (IR.GT.0) FRACT2T=FRACT2 IN2 224
IF (IR.LE.0) GO TO 71 $ WRITE (6,101)IR,IE,JB,JE,ADXY,FRACT1,FRACTIN2 225
12 $ IB=IB+1 $ IE=IE+1 $ JB=JB+1 $ JE=JE+1 $ DO 70 J=JB,JE $ JINDEXIN2 226
2=(J-1)*IEND $ DO 70 I=IR,IE $ INDEX=JINDEX+I $ OMEGA1(INDEX)=ADXY*IN2 227
3(1.0-FRACT1) $ OMEGA1(INDEX)=ADXY*FRACT1*(1.0-FRACT2) IN2 228
70 CONTINUE $ GO TO 69 IN2 229
71 CONTINUE $ ADXY=ADXYT $ FRACT1=FRACT1T $ FRACT2=FRACT2T $ IF (FRACTIN2 230
172.EQ.0.0) GO TO 72 $ QR=ADXY*FRACT1*FRACT2 IN2 231
C READ INITIAL PUFF DATA IN2 232
READ (5,102)X0,Y0,Z0 $ WRITE (6,103)Q0,X0,Y0,Z0 $ GO TO 73 IN2 233
72 CONTINUE $ WRITE (6,104) $ Q0=X0=Y0=Z0=0.0 IN2 234
73 CONTINUE $ IF (IPRINT.EQ.0) GO TO 74 $ WRITE (6,105) $ CALL PRINT IN2 235
1(OMEGA1,IEND,JEND,DFLTA,SHIFT) $ WRITE (6,106) $ CALL PRINT (OMEGA1IN2 236
2S1,IEND,JEND,DFLTA,SHIFT) IN2 237
74 CONTINUE $ WRITE (6,107) IN2 238
75 CONTINUE $ RETURN IN2 239
C IN2 240
76 FORMAT (* IPRINT ==15* IPLOT ==15* MINOR TIME STEP PRINT==F10.2* MIN2 241
1AJOR TIME STEP PRINT ==F10.2* PLOT TIME STEP ==F10.2) IN2 242
77 FORMAT (* NUMBER OF SURFACE CONCENTRATION CONTOURS ==15,/,* THE COIN2 243
1VERSION FACTOR FROM GRAMS/SQUARE METER TO SURFACE CONCENTRATION AIN2 244
2CTIVITY/SQUARE METER IS*F16.8,/,* NUMBER OF EXPOSURE CONTOURS ==15IN2 245
3,/,* THE CONVERSION FACTOR FROM GRAMS-SEC/CUBIC METER TO EXPOSURE IN2 246
4ACTIVITY-SEC/CUBIC METER IS*E16.8) IN2 247
78 FORMAT (* THE VALUES OF THE SURFACE CONCENTRATION CONTOURS ARE*,/,IN2 248
110E13.5) IN2 249
79 FORMAT (10F8.4) IN2 250
80 FORMAT (* THE VALUES OF THE EXPOSURE CONTOURS ARE*,/,10E13.5) IN2 251
81 FORMAT (* NUMBER OF MESH CELLS IN X-DIRECTION ==15* NUMBER OF MESHIN2 252
1 CELLS IN Y-DIRECTION ==15* SIDE OF SQUARE MESH IN METERS ==F10.3)IN2 253
82 FORMAT (* PROGRAM STOPPED BECAUSE MESH STRUCTURE IS TOO LARGE FOR IN2 254
1THIS VERSION OF THE CODE*) IN2 255
83 FORMAT (* AVERAGE DIAMETER OF RESPIRABLE CONTAMINATE IN MICRONS ISIN2 256
1*F7.2* AND THE DENSITY OF THE CONTAMINATE IS*F7.3* GM/CC*) IN2 257
84 FORMAT (* WIND VELOCITY IS SPECIFIED AT*F6.1* METERS ABOVE SURFACEIN2 258
1*/* TOP OF CONTROL VOLUME WHERE PUFFS ARE GENERATED ==*F6.1* METERSIN2 259
2*/* EXPOSURE CONTOURS ARE*F6.1* METERS ABOVE SURFACE*) IN2 260
85 FORMAT (* ATMOSPHERIC DENSITY EQUALS*F10.3* GM/CC AND SOIL DENSITYIN2 261
1 EQUALS*F10.3* GM/CC*) IN2 262
86 FORMAT (* AMOUNT OF VEGETATIVE RESIDUE IN GRAMS PER SQUARE METER*)IN2 263
87 FORMAT (2I5,3E20.10) IN2 264
88 FORMAT (* RIDGE ROUGHNESS EQUIVALENT IN CM*) IN2 265
89 FORMAT (* EROSION FUNCTION EXPONENT R*) IN2 266
90 FORMAT (* PERCENTAGE OF SOIL FRACTION GREATER THAN 840 MICRONS ANDIN2 267
1 CALCULATED SOIL EROSION INDEX*) IN2 268
91 FORMAT (* EROSION FUNCTION COEFFICIENT A*) IN2 269
92 FORMAT (* AMOUNT OF WATER HELD BY SOIL AT 15 - ATMOSPHERE PERCENTAIN2 270
1GE*) IN2 271
93 FORMAT (* AMOUNT OF WATER HELD BY SOIL*) IN2 272
94 FORMAT (* THRESHOLD FRICTION VELOCITY IN CM/SEC*) IN2 273
95 FORMAT (* NUMBER OF ROUGHNESS ELEMENTS, AVERAGE HEIGHT (METERS) ANIN2 274
1D AVERAGE DIAMETER (METERS)*) IN2 275
96 FORMAT (* DEPTH OF THE SOIL-CONTAMINATE MIXING LAYER IN CM*) IN2 276
97 FORMAT (* FRACTION OF SOIL MASS THAT IS SUSPENDABLE*) IN2 277
98 FORMAT (* INITIAL SURFACE CONCENTRATIONS IN GRAMS*) IN2 278
99 FORMAT (2I5,6F10.5) IN2 279
100 FORMAT (4I5,6F10.5) IN2 280
101 FORMAT (4I5,3E20.10) IN2 281
102 FORMAT (8F10.5) IN2 282

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103  FORMAT (* INITIALLY SUSPENDED PUFF IS*F11.5* GRAMS STRENGTH LOCATE IN2 283
1D AT COORDINATE (*F6.1*,*F6.1*,*F6.1* ) IN METERS*) IN2 284
104  FORMAT (* NO INITIALLY SUSPENDED PUFF*) IN2 285
105  FORMAT (1H1,* INITIAL SURFACE DISTRIBUTION OF NON-RESPIRABLE CONTAIN2 286
1MINUTE IN GRAMS PER MESH CELL*) IN2 287
106  FORMAT (1H1,* INITIAL SURFACE DISTRIBUTION OF RESPIRABLE CONTAMINATIN2 288
1TE IN GRAMS PER MESH CELL*) IN2 289
107  FORMAT (1H1,* TIME WIND MAGNITUDE WIND DIRECTION STIN2 290
1ABILITY MATERIAL OUTSIDE MESH NUMBER OF H. AND VIN2 291
2. SOIL FLOW*,/,* (MINUTES) (METERS/SFC) (DEGRFES) IN2 292
3 (CLASS) (GRAMS) SUSPENDED PUFFS (GM/M-SEC) IN2 293
4EC) (GM/M**2=SEC)* IN2 294
END IN2 295
SUBROUTINE ERODE ERO 1
C THIS SUBROUTINE CALCULATES THE REDISTRIBUTION OF CONTAMINATES FROM ERO 2
C SOIL SURFACES ERO 3
COMMON /FIXP/ P1,DV,RHO,X0,Y0,Z0,Q0,ZTOP,ZFXP,DELTA,TAREA,DEN,ZINFERO 4
1,RHOSOIL,SGN,ORDMAGL,SHIFT $ COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIERO 5
2M,JENDM1,IENDM1,NI,NJ,MAXMESH $ COMMON /LCM1/ ALPHA(1800),TAUWJOB(FRO 6
31800),RIDGF(1800),ELEMENT(1800),UNCAREA(1800),EROSCOF(1800),SCDEPTERO 7
4H(1800),PERSS(1800),DUH(1800),TAUCRIT(1800) $ COMMON /LCM2/ QPUFF(ERO 8
5800),YDIST(800),ZDIST(800),XPUFF(800),YPUFF(800),ZPUFF(800) $ COMME 9
6ON /PRTINFO/ TC,IPRINT,PRTIME,IPL0T,PLTIME,PMINORT,XY(200),ITITLE(ERO 10
75),XLABEL(2),YLABEL(2),Z1(10),ZP(10),JTITLE(7),NXLBL,NYLBL,MTITLE,FRO 11
8NTITLE,N1,N2,ACT1,ACT2 $ COMMON /RESTART/ STIME,TIMEJC,XC,YC,ZC,Q,FRO 12
9VCFLOW2,VBAR,ISTAB,YDISTQ,ZDISTQ,NUMPUFF,IFGREST,QOUT,QPUFFOT,PRTIERO 13
$MEC,PLTIMEC,PMINORC $ COMMON /SCM1/ OMEGA1(1800),OMEGA2(1800),OMEGERO 14
$AS1(1800),OMEGAS2(1800),EXPOSUR(1800) $ COMMON /SCM2/ VIRORIG(12),ERO 15
$ABETA(6) $ PID2=PI/2. $ PIT3D2=PI*3./2. $ PIT2=PI*2. $ TAUREF=33.1FRO 16
XRANGE=FLOAT(IEND-2)*DELTA+SHIFT $ YRANGE=FLOAT(JEND-2)*DELTA+SHIFERO 17
1T $ C1=2.0*PI $ C2=C1*C1 $ C1=SQRT(C2) $ C3=SQRT(PI/2.) $ IHESIFERO 18
2AR=0 $ IF (IFGREST.NE.0) GO TO 4 $ XC=X0 $ YC=Y0 $ ZC=Z0 $ J=J0 FRO 19
TC=0.0 $ VCFLOW2=0.0 $ CALL VELVECT (TC,VBAR,THETA,ISTAB) $ IF (Q,FRO 20
1EQ.0.0) GO TO 1 ERO 21
C CALCULATE THE VIRTUAL ORIGIN OF THE INITIALLY SUSPENDED PUFF ERO 22
SY0=2.0*ZC/4.3 $ XIP1=2.0*ZC $ CALL ROOT (XIP1,SY0,ISTAB,1) $ YDISERO 23
1TQ=XIP1 $ SZ0=2.0*ZC/4.3 $ XIP1=2.0*ZC $ CALL ROOT (XIP1,SZ0,ISTABERO 24
2,2) $ ZDISTQ=XIP1 FRO 25
1 CONTINUE $ NUMPUFF=0 $ QOUT=0.0 $ QPUFFOT=0.0 $ DO 2 I=1,MAXDIM FRO 26
EXPOSUR(I)=0.0 $ OMEGAS2(I)=0.0 ERO 27
2 OMEGA2(I)=0.0 $ IF (IPL0T.EQ.0) GO TO 3 $ CALL PLOTINT ERO 28
3 CONTINUE $ PRTIMEC=PRTIME $ PLTIMEC=PLTIME $ PMINORC=PMINORT FRO 29
4 TB=TC $ VCFLOW1=VCFLOW2 $ VCFLOW2=0.0 $ IF (TB.GE.STIME) IRESTAR=1ERO 30
CALL VELVECT (TB,VBARC,THETA,ISTABC) $ IF ((ISTABC.EQ.ISTAB).AND.(ERO 31
1VBARC.EQ.VBAR)) GO TO 10 $ IF (ISTABC.EQ.ISTAB) GO TO 7 ERO 32
C CHANGE THE TRAVEL DISTANCES FOR STABILITY CHANGE FRO 33
IF (Q.EQ.0) GO TO 5 $ CSIGMA=SIGY(YDISTQ,ISTAB) $ XIP1=CSIGMA FRO 34
CALL ROOT (XIP1,CSIGMA,ISTABC,1) $ YDISTQ=XIP1 $ CSIGMA=SIGZ(ZDISTERO 35
1Q,ISTAB) $ XIP1=CSIGMA $ CALL ROOT (XIP1,CSIGMA,ISTABC,2) $ ZDISTERO 36
2=XIP1 FRO 37
5 CONTINUE $ IF (NUMPUFF.EQ.0) GO TO 7 $ DO 6 I=1,NUMPUFF $ CSIGMA=SERO 38
1IGY(YDIST(I),ISTAB) $ XIP1=CSIGMA $ CALL ROOT (XIP1,CSIGMA,ISTABC,ERO 39
21) $ YDIST(I)=XIP1 $ CSIGMA=SIGZ(ZDIST(I),ISTAB) $ XIP1=CSIGMA FRO 40
CALL ROOT (XIP1,CSIGMA,ISTABC,2) $ ZDIST(I)=XIP1 FRO 41
6 CONTINUE ERO 42
7 CONTINUE ERO 43
C CHANGE SURFACE SHEAR STRESS FOR VELOCITY CHANGE ERO 44
BETA=ABETA(ISTABC) $ DO 9 J=2,JENDM1 $ JINDEX=(J-1)*IEND $ DO 9 I=ERO 45
12,IENDM1 $ INDEX=JINDEX+1 $ ZDZ0=3000.0*ZINF/RIDGE(INDEX) $ IF (ISTERO 46
2ABC.EQ.4) GO TO 8 $ UBDUS=2.5/(1.-BETA)*(ZDZ0**((1.-BETA)-1.)) $ US=FRO 47
3100.0*VBAR/UBDUS $ TAUWJOB(INDEX)=RHO*US*US $ GO TO 9 ERO 48
8 CONTINUE $ UBDUS=2.5*ALOG(ZDZ0) $ US=100.0*VBAR/UBDUS $ TAUWJOB(INDERO 49

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1FX)=RHO*US*US                                FRQ 50
9  CONTINUE                                     FR 51
10 ISTAR=ISTAHC $ VBAR=VHARC                     F J 52
C  CALCULATE NEW TIME STEP                        0 53
DT=DELTA/VBAR $ TC=YB+DT $ XT=VBAR*COS(THETA)*DT $ YT=VBAR*SIN(THETA) 54
1TA)*DT $ DD=SQRT(XT*XT+YT*YT) $ IF (Q.EQ.0) GO TO 14 $ YDIST=YDISER 55
2TQ+DD $ ZDIST=ZDISTQ+DD $ XC=XC+XT $ YC=YC+YT $ IF ((XC.LT.SHIFT-EN 56
3DELTA).OR.(XC.GT.XRANGE+DELTA)) GO TO 13 $ IF ((YC.LT.SHIFT-DELTA)ER 57
4.OR.(YC.GT.YRANGE+DELTA)) GO TO 13 $ SIGMAZ=SIGZ(ZDISTQ,ISTAR)  FRO 58
SIGMA=SIGY(YDISTQ,ISTAR) $ SIGMA=SIGMA $ IJD=INT(.49999+SGN*SIGER 59
1MAX/DELTA) $ IC=INT(1.99999+(YC-SHIFT)/DELTA) $ JC=INT(1.99999+(YCER 60
2-SHIFT)/DELTA) $ ILOW=IC-IJD $ IHIGH=IC+IJD $ JLOW=JC-IJD $ JHIGH=FR 61
3JC+IJD $ IF (ILOW.LT.1) ILOW=1 $ IF (IHIGH.GT.IEND) IHIGH=IEND  ERO 62
IF (JLOW.LT.1) JLOW=1 $ IF (JHIGH.GT.JEND) JHIGH=JEND $ C2=3/(C1*SGFR 63
1IGMAX*SIGMA*SIGMAZ) $ C2EXP=C2*EXP(-(ZEXP-ZC)**2/(2.0*SIGMAZ*SIGMA 64
2AZ))*DT $ C2DV=C2*EXP(-(ZC-ZC)/(2.0*SIGMAZ*SIGMAZ))*DT $ C4=SQRT(2.ER 65
30)*SIGMA $ C5=SQRT(2.0)*SIGMA $ TAD=0.0  FRO 66
C  DEPOSITION FROM INITIAL SUSPENDED PUFF ON SURFACE  ERO 67
DO 12 J=JLOW,JHIGH $ JINDEX=(J-1)*IEND $ YRC=DELTA*(FLOAT(J-2)+0.5)FR 68
1)+SHIFT $ Y1=(YRC-DELTA*0.5-YC)/C5 $ Y2=(YRC+DELTA*0.5-YC)/C5  ERO 69
IF (J.EQ.1) Y1=-100. $ IF (J.EQ.JEND) Y2=100. $ YINT=C3*SIGMA*(ERFR 70
1F(Y2)-ERF(Y1)) $ YEXP=EXP(-(YRC-YC)**2/(2.0*SIGMA*SIGMA)) $ DO 10 I 71
21 I=ILOW,IHIGH $ INDEX=JINDEX+1 $ XRC=DELTA*(FLOAT(I-1)-0.5)+SHIFTFR 72
X1=(XRC-DELTA*0.5-XC)/C4 $ X2=(XRC+DELTA*0.5-XC)/C4 $ IF (I.EQ.1) FR 73
1X1=-100.0 $ IF (I.EQ.IEND) X2=100. $ XINT=C3*SIGMA*(ERF(X2)-ERF(XER 74
21)) $ XEXP=EXP(-(XRC-XC)**2/(2.0*SIGMA*SIGMA)) $ ADXY=C2*XINT*YIER 75
3NT $ OMEGAS2(INDEX)=OMEGAS2(INDEX)+ADXY $ TAD=TAD+ADXY $ ADXY=C2EXER 76
4P*YEXP*XEXP $ EXPOSUR(INDEX)=EXPOSUR(INDEX)+ADXY  ERO 77
11 CONTINUE                                     FRO 78
12 CONTINUE $ Q=Q-TAD $ GO TO 14  ERO 79
13 CONTINUE                                     ERO 80
C  INITIALLY SUSPENDED PUFF HAS LEFT MESH  ERO 81
QOUT=0 $ WRITE (6,39)QOUT,XC,YC $ Q=0.0  ERO 82
14 CONTINUE $ IF (NUMPUFF.EQ.0) GO TO 22 $ ICPUFF=0  ERO 83
C  DEPOSITION FROM SUSPENDED PUFFS  ERO 84
DO 21 IPUFF=1,NUMPUFF  ERO 85
15 CONTINUE $ ICPUFF=ICPUFF+1 $ YD=YDIST(IPUFF)+DD $ YDIST(IPUFF)=YD  ERO 86
ZD=ZDIST(IPUFF)+DD $ ZDIST(IPUFF)=ZD $ XPUFF(IPUFF)=XPUFF(IPUFF)+XER 87
1T $ YPUFF(IPUFF)=YPUFF(IPUFF)+YT $ IF ((XPUFF(IPUFF).LT.SHIFT-DELTER 88
2A).OR.(XPUFF(IPUFF).GT.XRANGE+DELTA)) GO TO 18 $ IF ((YPUFF(IPUFF)ER 89
3.LT.SHIFT-DELTA).OR.(YPUFF(IPUFF).GT.YRANGE+DELTA)) GO TO 18 $ SIGFR 90
4MAZ=SIGZ(ZD,ISTAR) $ SIGMA=SIGY(YD,ISTAR) $ SIGMA=SIGMA $ IJD=IER 91
5NT(.49999+SGN*SIGMAX/DELTA) $ IC=INT(1.99999+(XPUFF(IPUFF)-SHIFT)/ER 92
6DELTA) $ JC=INT(1.99999+(YPUFF(IPUFF)-SHIFT)/DELTA) $ ILOW=IC-IJD  ERO 93
IHIGH=IC+IJD $ JLOW=JC-IJD $ JHIGH=JC+IJD $ IF (ILOW.LT.1) ILOW=1  ERO 94
IF (IHIGH.GT.IEND) IHIGH=IEND $ IF (JLOW.LT.1) JLOW=1 $ IF (JHIGH.ER 95
1GT.JEND) JHIGH=JEND $ C2=QPUFF(IPUFF)/(C1*SIGMA*SIGMA*SIGMAZ)  ERO 96
C2EXP=C2*EXP(-(ZEXP-ZPUFF(IPUFF))**2/(2.0*SIGMAZ*SIGMAZ))*DT $ C2=FR 97
1DV*C2*EXP(-(ZPUFF(IPUFF)-ZPUFF(IPUFF))/(2.0*SIGMAZ*SIGMAZ))*DT $ C4=FR 98
2SQRT(2.0)*SIGMA $ C5=SQRT(2.0)*SIGMA $ TAD=0.0 $ DO 17 J=JLOW,JH 99
3IGH $ JINDEX=(J-1)*IEND $ YRC=DELTA*(FLOAT(J-2)+0.5)+SHIFT $ Y1=(YFR 100
4RC-DELTA*0.5-YPUFF(IPUFF))/C5 $ Y2=(YRC+DELTA*0.5-YPUFF(IPUFF))/C5ER 101
IF (J.EQ.1) Y1=-100. $ IF (J.EQ.JEND) Y2=100. $ YINT=C3*SIGMA*(ERFR 102
1F(Y2)-ERF(Y1)) $ YEXP=EXP(-(YRC-YPUFF(IPUFF))**2/(2.0*SIGMA*SIGMA 103
2Y)) $ DO 16 I=ILOW,IHIGH $ INDEX=JINDEX+1 $ XRC=DELTA*(FLUAT(I-1)-FR 104
3Y.5)+SHIFT $ X1=(XRC-DELTA*0.5-XPUFF(IPUFF))/C4 $ X2=(XRC+DELTA*0.ER 105
45=XPUFF(IPUFF))/C4 $ IF (I.EQ.1) X1=-100.0 $ IF (I.EQ.IEND) X2=100FR 106
5. $ XINT=C3*SIGMA*(ERF(X2)-ERF(X1)) $ XEXP=EXP(-(XRC-XPUFF(IPUFF)ER 107
6)**2/(2.0*SIGMA*SIGMA)) $ ADXY=C2*XINT*YINT $ OMEGAS2(INDEX)=OMEG 108
7AS2(INDEX)+ADXY $ TAD=TAD+ADXY $ ADXY=C2EXP*YEXP*XEXP $ EXPOSUR(IER 109
8INDEX)=EXPOSUR(INDEX)+ADXY  ERO 110
16 CONTINUE                                     FRO 111

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17 CONTINUE $ QPUFF(IPUFF)=QPUFF(IPUFF)-TAD $ GO TO 21 FRO 112
18 CONTINUE ERO 113
C IPUFF PUFF IS OUT OF RANGE FRO 114
  QPUFFOT=QPUFFOT+QPUFF(IPUFF) $ IF (IPUFF.EQ.NUMPUFF) GO TO 20 FRO 115
  IPUFFP1=IPUFF+1 $ DO 19 I=IPUFFP1,NUMPUFF $ QPUFF(I)=QPUFF(I) ERO 116
  YDIST(I-1)=YDIST(I) $ ZDIST(I-1)=ZDIST(I) $ XPUFF(I-1)=XPUFF(I) ERO 117
  YPUFF(I-1)=YPUFF(I) $ ZPUFF(I-1)=ZPUFF(I) ERO 118
19 CONTINUE ERO 119
C REDUCE THE NUMBER OF PUFFS BY ONE FRO 120
  NUMPUFF=NUMPUFF-1 $ GO TO 15 FRO 121
20 NUMPUFF=NUMPUFF-1 $ GO TO 22 FRO 122
21 CONTINUE ERO 123
22 CONTINUE $ IF (THETA.LE.PID2.AND.THETA.GE.0.0) GO TO 23 $ IF (THETA.FRO 124
  1A.LE.PI.AND.THETA.GT.PID2) GO TO 24 $ IF (THETA.LE.PIT3D2.AND.THETA.FRO 125
  2A.GT.PI) GO TO 25 $ IF (THETA.LE.PIT2.AND.THETA.GT.PIT3D2) GO TO 2ERO 126
  36 $ WRITE (6,40) $ STOP FRO 127
23 CONTINUE $ THETAP=THETA $ IS1=1 $ IS2=1 $ IS3=0 $ JS1=0 $ JS2=1 ERO 128
  JS3=1 $ GO TO 27 ERO 129
24 CONTINUE $ THETAP=THETA-PID2 $ IS1=0 $ IS2=-1 $ IS3=-1 $ JS1=1 ERO 130
  JS2=1 $ JS3=0 $ GO TO 27 ERO 131
25 CONTINUE $ THETAP=THETA-PI $ IS1=-1 $ IS2=-1 $ IS3=0 $ JS1=0 $ JS2ERO 132
  1=-1 $ JS3=-1 $ GO TO 27 ERO 133
26 CONTINUE $ THETAP=THETA-PIT3D2 $ IS1=0 $ IS2=1 $ IS3=1 $ JS1=-1 ERO 134
  JS2=-1 $ JS3=0 FRO 135
27 CONTINUE $ CALL AREA (THETAP,DELTA,T1,T2,T3) $ A1=T1/TAREA $ A2=T2FRO 136
  1/TAREA $ A3=T3/TAREA $ HSFLOW=0.0 $ VSFLOW=0.0 $ DO 31 J=2,JENDHRO 137
  21 $ JINDEX=(J-1)*IEND $ JINDEX1=(J+JS1-1)*IEND $ JINDEX2=(J+JS2-1)ERO 138
  3*IEND $ JINDEX3=(J+JS3-1)*IEND $ YRC=DELTA*(FLOAT(J-2)+0.5)+SHIFT ERO 139
  DO 30 I=2,IENDM1 $ INDEX=JINDEX+I $ IF ((OMEGA1(INDEX).EQ.0.0).ANDERO 140
  1.(OMEGA1(INDEX).EQ.0.0)) GO TO 30 $ TAUOB=TAUWUOB(INDEX) $ IF ((TERO 141
  2AUOB=ALPHA(INDEX)).LE.TAUCRIT(INDEX)) GO TO 30 $ IF (ELEMENT(INDEX)ERO 142
  3).LE.0.0) GO TO 28 ERO 143
C EXAMINE THE PARTITIONING OF THE SHEAR STRESS ERO 144
  AA1=-0.55 $ BB1=0.38 $ FLC=BB1*ALOG10(1.0/ELEMENT(INDEX))+AA1 ERO 145
  IF (FLC.GE.1.0) GO TO 28 $ IF (FLC.LE.0.0) GO TO 30 $ ETDIT=(1.0-FERO 146
  1LC)**2.0 $ CF1=0.6525-0.0525*DDH(INDEX) $ CF2=0.0985/SQRT(ELEMENT(FRO 147
  2INDEX))-0.134 $ AEDRAG=AMIN1(CF1,CF2) $ ET=5000.*AEDRAG*RHO*VBAR*VERO 148
  3BAR*ELEMENT(INDEX) $ TT=ET/ETDIT $ TW=TT*TAREA/UNCAREA(INDEX)*(1.0FRO 149
  4-ETDIT) ERO 150
C ADJUST FOR DIFFERENT VELOCITIES ERO 151
  TAUW=TW*(VBAR/20.3)**2.0 $ IF (TAUW.GT.TAUOB) TAUW=TAUOB $ TAUOB=TERO 152
  1AUW $ IF ((TAUOB=ALPHA(INDEX)).LE.TAUCRIT(INDEX)) GO TO 30 ERO 153
28 CONTINUE $ INDEX1=JINDEX1+IS1+I $ INDEX2=JINDEX2+IS2+I $ INDEX3=JIFRO 154
  1INDEX3+IS3+I $ XRC=DELTA*(FLOAT(I-1)-0.5)+SHIFT ERO 155
C CALCULATE HORIZONTAL SOIL FLOW FOR CELL (I,J) IN GM/M-SEC ERO 156
  TAUOFF=TAUOB-ALPHA(INDEX) $ HSFLOW=EROSCOF(INDEX)*(TAUEFF*(SQRT(TAERO 157
  1UEFF)-SQRT(TAUCRIT(INDEX)))/TAUREF**1.5) $ IF (HSFLOW.GT.HSFLOWM) ERO 158
  2HSFLOWM=HSFLOW $ IF (HSFLOW.LE.0.0) GO TO 30 $ TAS=RHOSDIL*DELTA*DERO 159
  3ELTA*SCDEPTH(INDEX)*1.0E+06 $ TASAC=TAS+OMEGAS1(INDEX)+OMEGA1(INDEERO 160
  4X) $ HCFLOWT=HSFLOW/TASAC*DELTA*DT $ HCFLOW=OMEGA1(INDEX)*HCFLOWT ERO 161
  HCFLOWS=OMEGAS1(INDEX)*HCFLOWT ERO 162
C CALCULATE THE AMOUNT OF HORIZONTAL CONTAMINATE FLOW INTO THE ERO 163
C ADJACENT THREE CELLS ERO 164
  OMEGA2(INDEX1)=HCFLOW*AA1+OMEGA2(INDEX1) $ OMEGAS2(INDEX1)=HCFLOWS*ERO 165
  1AA1+OMEGAS2(INDEX1) $ OMEGA2(INDEX2)=HCFLOW*AA2+OMEGA2(INDEX2) $ OMEERO 166
  2GAS2(INDEX2)=HCFLOWS*AA2+OMEGAS2(INDEX2) $ OMEGA2(INDEX3)=HCFLOW*A3FRO 167
  3+OMEGA2(INDEX3) $ OMEGAS2(INDEX3)=HCFLOWS*AA3+OMEGAS2(INDEX3) $ OMEERO 168
  4GA1(INDEX)=OMEGA1(INDEX)-HCFLOW $ OMEGAS1(INDEX)=OMEGAS1(INDEX)-HCFRO 169
  5FLOWS $ IF (OMEGAS1(INDEX).EQ.0.0) GO TO 30 ERO 170
C CALCULATE VERTICAL SOIL FLUX IN GM/M**2-SEC AND SET UP A NEW PUFF ERO 171
  TASACAS=TAS*PERSS(INDEX)+OMEGAS1(INDEX) $ FASAPAS=TASACAS/TASAC ERO 172
  EXPON=16.7*FASAPAS $ FVFC=OMEGAS1(INDEX)/TASACAS $ VSFLOW=7.0E-03*FRO 173

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1HSFLOW*((TAUEFF/TAUCRIT(INDEX))*EXPON-1.0)*(RHO/TAUCRIT(INDEX))*ERO 174
21.5 $ IF (VSFLOW.GT.VSFLOWM) VSFLOWM=VSFLOW $ VCFLOW=VSFLOW*FVFC*TERO 175
3AREA=DT $ IF (VCFLOW.GT.VCFLOW2) VCFLOW2=VCFLOW $ IF (VCFLOW.LT.09FRO 176
4DMAGL*VCFLOW1) GO TO 30 $ OMEGAS1(INDEX)=OMEGAS1(INDEX)-VCFLOW FRO 177
NUMPUFF=NUMPUFF+1 $ IF (NUMPUFF.LE.MAXPUFF) GO TO 29 $ WRITE (6,41FRO 178
1) $ STOP ERO 179
29 CONTINUE $ QPUFF(NUMPUFF)=VCFLOW $ XPUFF(NUMPUFF)=XRC $ YPUFF(NUMPUFF)= 180
1UFF)=YRC $ ZPUFF(NUMPUFF)=ZTOP $ YDIST(NUMPUFF)=VIRORIG(ISTAB) ERO 181
ZDIST(NUMPUFF)=VIRORIG(6+ISTAB) ERO 182
30 CONTINUE ERO 183
31 CONTINUE ERO 184
C ADVANCE IN TIME ALL EXISTING PUFFS FRO 185
DO 32 I=1,MAXDIM $ OMEGA1(I)=OMEGA1(I)+OMEGA2(I) $ OMEGA2(I)=0.0 ERO 186
OMEGAS1(I)=OMEGAS1(I)+OMEGAS2(I) $ OMEGAS2(I)=0.0 ERO 187
32 CONTINUE ERO 188
C CALCULATE TOTAL MASS OUTSIDE MESH FRO 189
TAD=0.0 $ INDEX=IEND*JENDM1 $ DO 33 I=1,IEND ERO 190
TAD=TAD+OMEGA1(I)+OMEGAS1(I)+OMEGA1(INDEX+I)+OMEGAS1(INDEX+I) FRO 191
DO 34 J=2,JENDM1 $ INDEX=(J-1)*IEND ERO 192
34 TAD=TAD+OMEGA1(INDEX+1)+OMEGAS1(INDEX+1)+OMEGA1(INDEX+IEND)+OMEGAS1(I 193
11(INDEX+IEND) $ TAD=TAD+QOUT+QPUFFOT $ THETAD=THETA*360.0/PI*2 ERO 194
TM=TC/60. $ IF (TC.LT.PMINORC) GO TO 35 $ WRITE (6,42)TM,VVAR,THETERO 195
1AD,ISTAB,TAD,NUMPUFF,HSFLOWM,VSFLOWM $ PMINORC=PMINORC+PMINORI ERO 196
35 CONTINUE $ IF (IPRINT.EQ.0) GO TO 36 $ IF (TC.LT.PRTIMEC) GO TO 36ERO 197
WRITE (6,43)TM $ CALL PRINT (OMEGA1,IEND,JEND,DELTA,SHIFT) $ WRITEERO 198
1 (6,44)TM $ CALL PRINT (OMEGAS1,IEND,JEND,DELTA,SHIFT) $ WRITE (6,ERO 199
245)ZEXP,TH $ CALL PRINT (EXPOSUR,IEND,JEND,DELTA,SHIFT) $ CALL WRITEERO 200
3TEF $ PRTIMEC=PRTIMEC+PRTIME $ WRITE (6,46) ERO 201
36 CONTINUE $ IF (IPLOT.EQ.0) GO TO 37 $ IF (TC.LT.PLTIMEC) GO TO 37 ERO 202
CALL PLOTCT $ PLTIMEC=PLTIMEC+PLTIME ERO 203
37 CONTINUE $ CALL SECOND (TIMES) $ IF ((TIMEJC-TIMES).LT.10.0) IRESTERO 204
1AR=1 $ IF (IRESTAR.EQ.0) GO TO 4 $ IF (IPRINT.EQ.0) GO TO 38 $ WRITEERO 205
2TE (6,43)TM $ CALL PRINT (OMEGA1,IEND,JEND,DELTA,SHIFT) $ WRITE (6FRO 206
3,44)TM $ CALL PRINT (OMEGAS1,IEND,JEND,DELTA,SHIFT) $ WRITE (6,45)ERO 207
4ZEXP,TH $ CALL PRINT (EXPOSUR,IEND,JEND,DELTA,SHIFT) ERO 208
38 CONTINUE $ IF (IPLOT.NE.0) CALL PLOTCT $ CALL WRITEF $ RETURN ERO 209
C FRO 210
39 FORMAT (* INITIALLY SUSPENDED PUFF HAS LEFT MESH - STRENGTH =*E16.FRO 211
18* GRAMS AT X =*F10.2* AND Y =*F10.2* METERS*) ERO 212
40 FORMAT (* THETA IS NOT IN THE RANGE OF 0.0 TO 2.PI*) ERO 213
41 FORMAT (* PROGRAM STOP - NUMBER OF PUFFS EXCEEDS THE NUMBER THAT CERO 214
1AN BE HANDLED BY THIS VERSION OF THE CODE*) ERO 215
42 FORMAT (1X,F10.3,6X,F10.2,6X,F10.2,12X,I1,15X,E9.3,14X,I5,11X,E9.3ERO 216
1,4X,E9.3) ERO 217
43 FORMAT (1H1,* SURFACE DISTRIBUTION OF NON-RESPIRABLE CONTAMINATE IFRO 218
1N GRAMS PER MESH CELL AT TIME = *F10.3* MINUTES*) ERO 219
44 FORMAT (1H1,* SURFACE DISTRIBUTION OF RESPIRABLE CONTAMINATE IN G-ERO 220
1AMS PER MESH CELL AT TIME = *F10.3* MINUTES*) ERO 221
45 FORMAT (1H1,* EXPOSURE AT *F10.3* METERS ABOVE THE SURFACE AT TIMEERO 222
1 = *F10.3* MINUTES*) ERO 223
46 FOR. AT (1H1,* TIME WIND MAGNITUDE WIND DIRECTION STERO 224
1ABILITY MATERIAL OUTSIDE MESH NUMBER OF M. AND VERO 225
2. SOIL FLOW*,/,* (MINUTES) (METERS/SEC) (DEGREES) FRO 226
3 (CLASS) (GRAMS) SUSPENDED PUFFS (GM/M-SFRO 227
4EC) (GM/M**2-SEC***) FRO 228
END ERO 229
SUBROUTINE AREA(THETA,DELTA,A1,A2,A3) ARE 1
C THIS SUBROUTINE CALCULATES THE FRACTIONS OF MATERIAL THAT ARE ARE 2
C TRANSPORTED INTO THE ADJACENT THREE CELLS ARE 3
THETA1=0.5987667053 $ THETA2=0.9720296215 $ SINE=SIN(THETA) $ COSIARF 4
1NE=COS(THETA) $ S=DELTA*(1.0-COSINE*SINE)/(COSINE+SINE) $ IF (THETAARE 5
2A.GT.THETA1) GO TO 1 $ TANGENT=TAN(THETA) $ A1=0.5*DELTA*DELTA*SINARF 6

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3E*COSINE+S*DELTA*COSINE=0.5*S*S*TANGENT $ A2=0.5*DELTA*DELTA*TANGENT ARE 7
4NT*TANGENT*TANGENT+0.5*TANGENT*(S=DELTA*TANGENT*SINE)**2+DELTA*TANGENT ARE 8
5GENT/COSINE*(S=DELTA*TANGENT*SINE) $ A3=0.5*DELTA*DELTA*TANGENT ARE 9
GO TO 3 ARE 10
1 CONTINUE $ IF (THETA.GT.THETA2) GO TO 2 $ TANGENT=TAN(THETA) $ A1=ARE 11
10.5*DELTA*DELTA*SINE*COSINE+S*DELTA*COSINE=0.5*S*S*TANGENT $ A2=0. ARE 12
25*S*S/(COSINE*SINE) $ A3=0.5*DELTA*DELTA*COSINE*SINE+S*DELTA*SINE=ARE 13
30.5*S*S/TANGENT $ GO TO 3 ARE 14
2 CONTINUE $ COTAN=COSINE/SINE $ A1=0.5*DELTA*DELTA*COTAN $ A2=0.5* ARE 15
1ELTA*DELTA*COTAN*COTAN*COTAN+DELTA*COTAN/SINE*(S=DELTA*COTAN*COTAN ARE 16
2*SINE)+0.5*COTAN*(S=DELTA*COTAN*COTAN*SINE)**2 $ A3=0.5*DELTA*DELTA ARE 17
3A*SINE*COSINE+S*DELTA*SINE=0.5*S*S*COTAN ARE 18
3 CONTINUE $ RETURN ARE 19
END ARE 20
SUBROUTINE ROOT(XIP1,CSIGMA,ISTAB,IYORZ) R00 1
C GIVEN A VALUE OF THE DISPERSION COEFFICIENT, THIS SUBROUTINE USES R00 2
C NEWTON'S METHOD TO FIND THE TRAVEL DISTANCE ON A PARTICULAR R00 3
C ATMOSPHERIC STABILITY CURVE. ROUTINE USED TO FIND VIRTUAL R00 4
C ORIGINS AND TRAVEL DISTANCES FOR CONTINUOUS DISPERSION R00 5
C COEFFICIENTS AS STABILITY CLASS CHANGES R00 6
COMMON /YSIGMA/ KNOTY(3,6),C1Y(4,6),C2Y(4,6) $ COMMON /ZSIGMA/ KNOR00 7
1TZ(3,6),C1Z(4,6),C2Z(4,6) $ REAL KNOTY,KNOTZ $ CS=CSIGMA $ IS=ISTAB R00 8
2B $ I=IYORZ $ XI=XIP1 $ GO TO (1,2), I R00 9
1 CONTINUE $ XI=10.**KNOTY(1,IS) $ X3=10.**KNOTY(3,IS) $ GO TO 3 R00 10
2 CONTINUE $ XI=10.**KNOTZ(1,IS) $ X3=10.**KNOTZ(3,IS) R00 11
3 CONTINUE $ GO TO (4,5), I R00 12
4 CONTINUE $ FXI=SIGY(XI,IS) $ FPIX=DSIGY(XI,IS) $ GO TO 6 R00 13
5 CONTINUE $ FXI=SIGZ(XI,IS) $ FPIX=DSIGZ(XI,IS) R00 14
6 CONTINUE $ XIP1=XI-(FXI-CS)/FPIX $ IF (ABS(XIP1-XI)/ABS(XIP1).LT.1R00 15
1.0E-06) RETURN $ XI=XIP1 $ IF (XI.LT.X1) XI=X1 $ IF (XI.GT.X3) XIR00 16
2=X3 $ GO TO 3 R00 17
END R00 18
FUNCTION SIGY (X,ISTAB) SIY 1
C THIS FUNCTION FINDS THE SIGMA Y DISPERSION COEFFICIENT AS A SIY 2
C FUNCTION OF TRAVEL DISTANCE AND ATMOSPHERIC STABILITY CLASS. SIY 3
C ENTRY DSIGY EVALUATES THE DERIVATIVE. SIY 4
COMMON /YSIGMA/ KNOT(3,6),C1(4,6),C2(4,6) $ REAL KNOT $ I=ISTAB SIY 5
IF (X.EQ.0.0) GO TO 1 $ ALGX=ALOG10(X) $ IF (ALGX.GT.KNOT(2,I)) GOSIY 6
1 TO 3 $ IF (ALGX.GE.KNOT(1,I)) GO TO 2 SIY 7
1 CONTINUE $ WRITE (6,8)X,ALGX $ STOP SIY 8
2 CONTINUE $ ALGX=ALGX-KNOT(1,I) $ SIGY=10.0**((C1(1,I)+ALGX*(C1(2,I)SIY 9
1+ALGX*(C1(3,I)+C1(4,I)*ALGX))) $ RETURN SIY 10
3 CONTINUE $ IF (ALGX.LE.KNOT(3,I)) GO TO 4 $ WRITE (6,9)X,ALGX SIY 11
STOP SIY 12
4 CONTINUE $ ALGX=ALGX-KNOT(2,I) $ SIGY=10.0**((C2(1,I)+ALGX*(C2(2,I)SIY 13
1+ALGX*(C2(3,I)+C2(4,I)*ALGX))) $ RETURN $ ENTRY DSIGY $ I=ISTAB SIY 14
E=EXP(1.) $ ALGX=ALOG10(X) $ IF (ALGX.GT.KNOT(2,I)) GO TO 6 $ IF (SIY 15
1ALGX.GE.KNOT(1,I)) GO TO 5 $ WRITE (6,10)X,ALGX $ STOP SIY 16
5 CONTINUE $ ALGX=ALGX-KNOT(1,I) $ DSIGY=10.0**((C1(1,I)+ALGX*(C1(2,I)SIY 17
1)+ALGX*(C1(3,I)+C1(4,I)*ALGX)))*ALOG(10.)*ALOG10(E)*(C1(2,I)+ALGX*SIY 18
2(2.)*C1(3,I)+3.*C1(4,I)*ALGX))/X $ RETURN SIY 19
6 CONTINUE $ IF (ALGX.LE.KNOT(3,I)) GO TO 7 $ WRITE (6,11)X,ALGX SIY 20
STOP SIY 21
7 CONTINUE $ ALGX=ALGX-KNOT(2,I) $ DSIGY=10.0**((C2(1,I)+ALGX*(C2(2,I)SIY 22
1)+ALGX*(C2(3,I)+C2(4,I)*ALGX)))*ALOG(10.)*ALOG10(E)*(C2(2,I)+ALGX*SIY 23
2(2.)*C2(3,I)+3.*C2(4,I)*ALGX))/X $ RETURN SIY 24
C SIY 25
8 FORMAT (* X VALUE LESS THAN FIRST KNOT IN SIGY*,2E16.8) SIY 26
9 FORMAT (* X VALUE LARGER THAN LAST KNOT IN SIGY*,2E16.8) SIY 27
10 FORMAT (* X VALUE SMALLER THAN FIRST KNOT IN DSIGY*,2E16.8) SIY 28
11 FORMAT (* X VALUE LARGER THAN LAST KNOT IN DSIGY*,2E16.8) SIY 29
END SIY 30

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FUNCTION SIGZ (X,ISTAR)                                SI/ 1
C THIS FUNCTION FINDS THE SIGMA Z DISPERSION COEFFICIENT AS A SI/ 2
C FUNCTION OF TRAVEL DISTANCE AND ATMOSPHERIC STABILITY CLASS. SI/ 3
C ENTRY DSIGZ EVALUATES THE DERIVATIVE. SI/ 4
COMMON /ZSIGMA/ KNOT(3,6),C1(4,6),C2(4,6) $ REAL KNOT $ I=ISTAR SI/ 5
IF (X.EQ.0.0) GO TO 1 $ ALGX=ALOG10(X) $ IF (ALGX.GT.KNOT(2,1)) GOSI/ 6
1 TO 3 $ IF (ALGX.GE.KNOT(1,1)) GO TO 2 SI/ 7
1 CONTINUE $ WRITE (6,8)X,ALGX $ STOP SI/ 8
2 CONTINUE $ ALGX=ALGX-KNOT(1,1) $ SIGZ=10.0*(C1(1,1)+ALGX*(C1(2,1)SI/ 9
1+ALGX*(C1(3,1)+C1(4,1)*ALGX))) $ RETURN SI/ 10
3 CONTINUE $ IF (ALGX.LE.KNOT(3,1)) GO TO 4 $ WRITE (6,9)X,ALGX SI/ 11
STOP SI/ 12
4 CONTINUE $ ALGX=ALGX-KNOT(2,1) $ SIGZ=10.0*(C2(1,1)+ALGX*(C2(2,1)SI/ 13
1+ALGX*(C2(3,1)+C2(4,1)*ALGX))) $ RETURN $ ENTRY DSIGZ $ I=ISTAR SI/ 14
E=EXP(1.) $ ALGX=ALOG10(X) $ IF (ALGX.GT.KNOT(2,1)) GO TO 6 $ IF (SI/ 15
1ALGX.GE.KNOT(1,1)) GO TO 5 $ WRITE (6,10)X,ALGX $ STOP SI/ 16
5 CONTINUE $ ALGX=ALGX-KNOT(1,1) $ DSIGZ=10.0*(C1(1,1)+ALGX*(C1(2,1)SI/ 17
1+ALGX*(C1(3,1)+C1(4,1)*ALGX))*ALOG(10.)*ALOG10(E)*(C1(2,1)+ALGX*SI/ 18
2(C2(3,1)+3.*C1(4,1)*ALGX))/X $ RETURN SI/ 19
6 CONTINUE $ IF (ALGX.LE.KNOT(3,1)) GO TO 7 $ WRITE (6,11)X,ALGX SI/ 20
STOP SI/ 21
7 CONTINUE $ ALGX=ALGX-KNOT(2,1) $ DSIGZ=10.0*(C2(1,1)+ALGX*(C2(2,1)SI/ 22
1+ALGX*(C2(3,1)+C2(4,1)*ALGX))*ALOG(10.)*ALOG10(E)*(C2(2,1)+ALGX*SI/ 23
2(C2(3,1)+3.*C2(4,1)*ALGX))/X $ RETURN SI/ 24
C SI/ 25
8 FORMAT (* X VALUE LESS THAN FIRST KNOT IN SIGZ*2E16.8) SI/ 26
9 FORMAT (* X VALUE LARGER THAN LAST KNOT IN SIGZ*2E16.8) SI/ 27
10 FORMAT (* X VALUE SMALLER THAN FIRST KNOT IN DSIGZ*2E16.8) SI/ 28
11 FORMAT (* X VALUE LARGER THAN LAST KNOT IN DSIGZ*2E16.8) SI/ 29
END SI/ 30
SUBROUTINE PRINT(OMEGA,IEND,JEND,DELTA,SHIFT) PRI 1
C THIS SUBROUTINE PRINTS THE TWO DIMENSIONAL SURFACE CONCENTRATION PRI 2
C OR EXPOSURE ARRAYS IN A MAJOR PRINT PRI 3
DIMENSION OMEGA(IEND,1) $ DIMENSION XPRTARY(10), IPRTARY(10) $ DO PRI 4
13 IS=1,IEND,10 $ WRITE (6,4) $ IE=IS+9 $ IF (IE.GT.IEND) IE=IEND PRI 5
DO 1 JJ=1,JEND $ J=JEND+1-JJ $ YPRINT=DELTA*(FLOAT(JEND-JJ)-0.5)+SPRI 6
1HIFT $ WRITE (6,5)YPRINT,(OMEGA(I,J),I=IS,IE) $ JP=J-1 $ WRITE (6,PRI 7
26)JP PRI 8
1 CONTINUE $ IC=0 $ DO 2 I=IS,IE $ XPRINT=DELTA*(FLOAT(I-1)-0.5)+SHIPRI 9
1FT $ IC=IC+1 $ IPRTARY(IC)=I-1 PRI 10
2 XPRTARY(IC)=XPRINT $ WRITE (6,7)(XPRTARY(I),I=1,IC) $ WRITE (6,8)(PRI 11
1IPRTARY(I),I=1,IC) PRI 12
3 CONTINUE $ RETURN PRI 13
C PRI 14
4 FORMAT (//) PRI 15
5 FORMAT (//,F10.2,6X,10E12.4) PRI 16
6 FORMAT (IR) PRI 17
7 FORMAT (//,10X,10F12.2) PRI 18
8 FORMAT (8X,10I12) PRI 19
END PRI 20
SUBROUTINE REZONE1(IDIM1,IDIM2,NIP,NJP,OMEGA2,OMEGA1) RE1 1
C THIS SUBROUTINE REZONES THE SURFACE CONCENTRATION MESH. EXISTING RE1 2
C MESH VALUES ARE COMBINED AND NEW CELLS TO THE RIGHT AND ABOVE THE RE1 3
C EXISTING MESH ARE ASSIGNED EXPONENTIALLY DECREASING EXTRAPOLATED RE1 4
C VALUES RE1 5
COMMON /FIXP/ PI,DV,RHO,X0,Y0,Z0,Q0,ZTOP,ZEXP,DELTA,TAREA,DEN,ZINFRE1 6
1,RHOSOIL,SGN,ORDMAGL,SHIFT $ COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIRE1 7
2M,JENDM1,IENDM1,NI,NJ,MAXMESH $ DIMENSION OMEGA1(IDIM2,1), OMEGA2(RE1 8
3IDIM1,1) $ IENDP=NIP+2 $ IENDMIP=IENDP-1 $ JENDP=NJP+2 $ JENDMIP=JRE1 9
4ENDP-1 $ MAXDIMP=IENDP*JENDP $ NID2=NI/2+1 $ NJD2=NJ/2+1 $ IH=MINORF1 10
5(NID2,IENDMIP) $ JH=MIN0(NJD2,JENDMIP) $ DO 1 I=1,MAXDIM RE1 11
1 OMEGA2(I)=OMEGA1(I) $ DO 2 I=1,MAXDIMP RE1 12

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2      OMEGA1(I)=0.0 $ DO 11 J=2,JH $ JP=(J-1)*2+1 $ DO 3 I=2,IH $ IP=(I-1)*2+1 13
C      COMPRESS ORIGINAL MESH 14
3      OMEGA1(I,J)=OMEGA2(IP,JP)+0.5*(OMEGA2(IP+1,JP)+OMEGA2(IP,JP+1)+OMEGA2(IP+1,JP+1)+OMEGA2(IP,JP-1))+0.25*(OMEGA2(IP+1,JP-1)+OMEGA2(IP+1,JP+1)+OMEGA2(IP-1,JP+1)+OMEGA2(IP-1,JP-1)) $ IF (IH+1.GT.IENDM1P) RE1 16
C      CHECK LAST TWO VALUES FOR EXTRAPOLATION ON THE RIGHT 17
      IF ((OMEGA2(NI,JP-1).EQ.0.0).OR.(OMEGA2(IENDM1,JP-1).EQ.0.0).OR.(OMEGA2(NI,JP-1).LE.OMEGA2(IENDM1,JP-1))) GO TO 4 $ B1=ALOG(OMEGA2(NI,JP-1)/OMEGA2(IENDM1,JP-1))/DELTA $ A1=OMEGA2(IENDM1,JP-1)*EXP(B1*DELTA*(FLOAT(NI)-0.5)) $ GO TO 5 18
4      A1=B1=0. 19
5      CONTINUE $ IF ((OMEGA2(NI,JP).EQ.0.0).OR.(OMEGA2(IENDM1,JP).EQ.0.0).OR.(OMEGA2(NI,JP).LE.OMEGA2(IENDM1,JP))) GO TO 6 $ B2=ALOG(OMEGA2(NI,JP)/OMEGA2(IENDM1,JP))/DELTA $ A2=OMEGA2(IENDM1,JP)*EXP(B2*DELTA*(FLOAT(NI)-0.5)) $ GO TO 7 20
6      A2=B2=0. 21
7      CONTINUE $ IF ((OMEGA2(NI,JP+1).EQ.0.0).OR.(OMEGA2(IENDM1,JP+1).EQ.0.0).OR.(OMEGA2(NI,JP+1).LE.OMEGA2(IENDM1,JP+1))) GO TO 8 $ B3=ALOG(OMEGA2(NI,JP+1)/OMEGA2(IENDM1,JP+1))/DELTA $ A3=OMEGA2(IENDM1,JP+1)*EXP(B3*DELTA*(FLOAT(NI)-0.5)) $ GO TO 9 22
8      A3=B3=0. 23
9      CONTINUE 24
C      COMPRESS LAST VALUES PLUS FIRST EXTRAPOLATED VALUES ON THE RIGHT 25
      OMEGA1(IH+1,J)=A2*EXP(-B2*DELTA*(FLOAT(NI)+0.5))+0.5*(A2*EXP(-B2*DELTA*(FLOAT(NI)+1.5))+A3*EXP(-B3*DELTA*(FLOAT(NI)+0.5))+OMEGA2(IENDM1,JP)+A1*EXP(-B1*DELTA*(FLOAT(NI)+0.5))+0.25*(A1*EXP(-B1*DELTA*(FLOAT(NI)+1.5))+A3*EXP(-B3*DELTA*(FLOAT(NI)+1.5))+OMEGA2(IENDM1,JP+1)) $ ILOW=IH+2 $ IF (ILOW.GT.IENDM1P) GO TO 10 26
5 11 27
C      COMPRESS EXTRAPOLATED VALUES ON THE RIGHT 28
      DO 10 I=ILOW,IENDM1P $ IP=(I-1)*2+1 $ X2=DELTA*(FLOAT(IP)-0.5) 29
      X1=X2-DELTA $ X3=X2+DELTA 30
10     OMEGA1(I,J)=A2*EXP(-B2*X2)+0.5*(A2*EXP(-B2*X3)+A3*EXP(-B3*X2)+A2*EXP(-B2*X1)+A1*EXP(-B1*X2))+0.25*(A1*EXP(-B1*X3)+A3*EXP(-B3*X3)+A3*EXP(-B3*X1)+A1*EXP(-B1*X1)) 31
11     CONTINUE $ IF (JH+1.GT.JENDM1P) RETURN $ DO 19 I=2,IH $ IP=(I-1)*2+1 32
12+1 33
C      CHECK LAST TWO VALUES FOR EXTRAPOLATION ON THE TOP 34
      IF ((OMEGA2(IP-1,NJ).EQ.0.0).OR.(OMEGA2(IP-1,JENDM1).EQ.0.0).OR.(OMEGA2(IP-1,NJ).LE.OMEGA2(IP-1,JENDM1))) GO TO 12 $ B1=ALOG(OMEGA2(IP-1,NJ)/OMEGA2(IP-1,JENDM1))/DELTA $ A1=OMEGA2(IP-1,JENDM1)*EXP(B1*DELTA*(FLOAT(NJ)-0.5)*DELTA) $ GO TO 13 35
12     A1=B1=0. 36
13     CONTINUE $ IF ((OMEGA2(IP,NJ).EQ.0.0).OR.(OMEGA2(IP,JENDM1).EQ.0.0).OR.(OMEGA2(IP,NJ).LE.OMEGA2(IP,JENDM1))) GO TO 14 $ B2=ALOG(OMEGA2(IP,NJ)/OMEGA2(IP,JENDM1))/DELTA $ A2=OMEGA2(IP,JENDM1)*EXP(B2*DELTA*(FLOAT(NJ)-0.5)*DELTA) $ GO TO 15 37
14     A2=B2=0. 38
15     CONTINUE $ IF ((OMEGA2(IP+1,NJ).EQ.0.0).OR.(OMEGA2(IP+1,JENDM1).EQ.0.0).OR.(OMEGA2(IP+1,NJ).LE.OMEGA2(IP+1,JENDM1))) GO TO 16 $ B3=ALOG(OMEGA2(IP+1,NJ)/OMEGA2(IP+1,JENDM1))/DELTA $ A3=OMEGA2(IP+1,JENDM1)*EXP(B3*DELTA*(FLOAT(NJ)-0.5)*DELTA) $ GO TO 17 39
16     A3=B3=0.0 40
17     CONTINUE 41
C      COMPRESS LAST VALUES PLUS FIRST EXTRAPOLATED VALUES ON THE TOP 42
      OMEGA1(I,JH+1)=A2*EXP(-B2*DELTA*(FLOAT(NJ)+0.5))+0.5*(A3*EXP(-B3*DELTA*(FLOAT(NJ)+1.5))+A1*EXP(-B1*DELTA*(FLOAT(NJ)+0.5))+OMEGA2(IP,JENDM1)+0.25*(OMEGA2(IP+1,JENDM1)+A3*EXP(-B3*DELTA*(FLOAT(NJ)+1.5))+A1*EXP(-B1*DELTA*(FLOAT(NJ)+1.5))+OMEGA2(IP-1,JENDM1)) $ JLOW=JH+2 $ IF (JLOW.GT.JFNDM1P) GO TO 18 43
4     44

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	5 19		RF1	75
C	COMPRESS EXTRAPOLATED VALUES ON THE TOP		RE1	76
	DO 10 J=JLOW,JENDM1P \$ JP=(J-1)*2+1 \$ Y2=DELTA*(FLOAT(JP-1)-0.5)		RE1	77
	Y1=Y2-DELTA \$ Y3=Y2+DELTA		RE1	78
18	OMEGA1(I,J)=A2*EXP(-B2*Y2)+0.5*(A3*EXP(-H3*Y2)+A2*EXP(-H2*Y3)+A1*ERE1		RE1	79
	1XP(-B1*Y2)+A2*EXP(-B2*Y1))+0.25*(A3*EXP(-B3*Y1)+A3*EXP(-B3*Y3)+A1*RE1		RE1	80
	2EXP(-B1*Y3)+A1*EXP(-B1*Y1))		RE1	81
19	CONTINUE \$ RETURN		RF1	82
	END		RE1	83
	SUBROUTINE REZONE2(IDIM1,IDIM2,NIP,NJP,OMEGA2,OMEGA1)		RE2	1
C	THIS SUBROUTINE REZONES THE EXPOSURE MESH. EXISTING MESH VALUES		RE2	2
C	ARE SELECTED AND NEW CELL VALUES TO THE RIGHT AND ABOVE THE		RE2	3
C	EXISTING MESH ARE EXTRAPOLATED IN A EXPONENTIALLY DECREASING CURVERE2		RE2	4
	COMMON /FIXP/ PI,DV,RHO,X0,Y0,Z0,G0,ZTOP,ZFXP,DELTA,TAREA,DEN,ZINFRF2		RE2	5
	1,RHOSOIL,SGN,ORDMAGL,SHIFT \$ COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIR2		RE2	6
	2M,JENDM1,IENDM1,N1,NJ,MAXMESH \$ DIMENSION OMEGA1(IDIM2,1), OMEGA2(RE2		RE2	7
	3IDIM1,1) \$ IENDP=NIP+2 \$ IENDM1P=IENDP-1 \$ JENDP=NJP+2 \$ JENDM1P=JRF2		RE2	8
	4ENDP=1 \$ MAXDIMP=IENDP*JENDP \$ NID2=N1/2+1 \$ NJD2=NJ/2+1 \$ IH=MINVRE2		RE2	9
	5(NID2,JENDM1P) \$ JH=MIN0(NJD2,JENDM1P) \$ DO 1 I=1,MAXDIM		RF2	10
1	OMEGA2(I)=OMEGA1(I) \$ DO 2 I=1,MAXDIMP		RE2	11
2	OMEGA1(I)=0.0 \$ DO 7 J=2,JH \$ JP=(J-1)*2+1 \$ DO 3 I=2,IH \$ IP=(I-1)RF2		RF2	12
	1)*2+1		RF2	13
C	SAMPLE ORIGINAL MESH		RE2	14
3	OMEGA1(I,J)=OMEGA2(IP,JP) \$ IF (IH+1.GT.IENDM1P) GO TO 7		RE2	15
C	CHECK LAST TWO VALUES FOR EXTRAPOLATION ON THE RIGHT		RF2	16
	IF ((OMEGA2(NI,JP).EQ.0.0).OR.(OMEGA2(IENDM1,JP).EQ.0.0).OR.(OMEGARE2		RE2	17
	12(NI,JP).LE.OMEGA2(IENDM1,JP))) GO TO 4 \$ B2=ALOG(OMEGA2(NI,JP)/OMRE2		RE2	18
	2EGA2(IENDM1,JP))/DELTA \$ A2=OMEGA2(IENDM1,JP)*FXP(H2*DELTA*(FLOAT(RE2		RE2	19
	3NI)-0.5)) \$ GO TO 5		RE2	20
4	A2=B2=0.		RE2	21
5	CONTINUE \$ ILOW=IH+1 \$ IF (ILOW.GT.IENDM1P) GO TO 7		RE2	22
C	CALCULATE EXTRAPOLATED VALUES ON THE RIGHT		RE2	23
	DO 6 I=ILOW,IENDM1P \$ IP=(I-1)*2+1 \$ X2=DELTA*(FLOAT(IP-1)-0.5)		RE2	24
6	OMEGA1(I,J)=A2*EXP(-B2*X2)		RE2	25
7	CONTINUE \$ JLOW=JH+1 \$ IF (JLOW.GT.JENDM1P) RETURN \$ DO 11 I=2,IHRF2		RF2	26
	IP=(I-1)*2+1		RF2	27
C	CHECK LAST TWO VALUES FOR EXTRAPOLATION ON THE TOP		RF2	28
	IF ((OMEGA2(IP,NJ).EQ.0.0).OR.(OMEGA2(IP,JENDM1).EQ.0.0).OR.(OMEGARE2		RE2	29
	12(IP,NJ).LE.OMEGA2(IP,JENDM1))) GO TO 8 \$ B2=ALOG(OMEGA2(IP,NJ)/OMRF2		RE2	30
	2EGA2(IP,JENDM1))/DELTA \$ A2=OMEGA2(IP,JENDM1)*EXP(B2*(FLOAT(NJ)-0.REF2		RE2	31
	35)*DELTA) \$ GO TO 9		RE2	32
8	A2=B2=0.		RE2	33
9	CONTINUE		RE2	34
C	CALCULATE EXTRAPOLATED VALUES ON THE TOP		RE2	35
	DO 10 J=JLOW,JENDM1P \$ JP=(J-1)*2+1 \$ Y2=DELTA*(FLOAT(JP-1)-0.5)		RE2	36
10	OMEGA1(I,J)=A2*EXP(-B2*Y2)		RF2	37
11	CONTINUE \$ RETURN		RF2	38
	END		RE2	39
	SUBROUTINE PLOTCT		PLO	1
C	THIS SUBROUTINE PLOTS SPECIFIED CONTOURS OF THE TWO DIMENSIONAL		PLO	2
C	SURFACE CONCENTRATION AND EXPOSURE ARRAYS		PLO	3
	COMMON /FIXP/ PI,DV,RHO,X0,Y0,Z0,G0,ZTOP,ZEXP,DELTA,TAREA,DEN,ZINFPLO		PLO	4
	1,RHOSOIL,SGN,ORDMAGL,SHIFT \$ COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIPLO		PLO	5
	2M,JENDM1,IENDM1,N1,NJ,MAXMESH \$ COMMON /PRTINFO/ TC,IPRINT,PRTIME,PLO		PLO	6
	3IPLOT,PLTIME,PMINDRY,XY(200),ITITLE(5),XLABEL(2),YLABEL(2),Z1(10),PLO		PLO	7
	4Z2(10),JTITLE(7),NXL6L,NYLB1,MTITLE,NTITLE,N1,N2,ACT1,ACT2 \$ COMMDPLO		PLO	8
	5N /SCH1/ OMEGA1(1800),OMEGA2(1800),OMEGAS1(1800),OMEGAS2(1800),EXPLO		PLO	9
	60SUR(1800) \$ DO 1 I=1,MAXDIM \$ OMEGA2(I)=0.0		PLO	10
1	OMEGAS2(I)=0.0		PLO	11
C	COMBINE SUSPENDABLE AND NON-SUSPENDABLE PORTIONS		PLO	12
	DO 2 J=2,JENDM1 \$ JINDEX=(J-1)*IEND \$ DO 2 I=2,IENDM1 \$ INDEX2=JINPLO		PLO	13
	1DEX+I \$ OMEGA2(INDEX2)=(OMEGA1(INDEX2)+OMEGAS1(INDEX2))*ACT1 \$ OMFPLO		PLO	14

	2GAS2(INDEX2)=EXPOSUR(INDEX2)*ACT2	PLO	15
2	CONTINUE \$ IGRD=0 \$ TIME=TC/60. \$ ENCODE (10,4,ITITLE(4))TIME	PLO	16
	MTITLE=50 \$ DMPX=XY(IEND)-XY(1) \$ DMPY=XY(IEND+JEND)-XY(IEND+1)	PLO	17
C	PLOT SURFACE CONCENTRATION CONTOURS	PLO	18
	CALL CONTRJB (XY(1),IEND,XY(IEND+1),JEND,OMEGA2,IEND,JEND,N1,ZMN,ZPLN	PLO	19
	1MX,DLZ,Z1,DMPX,DMPY,IGRD,ITITLE,MTITLE,XLABFL,NXLBL,YLABFL,NYLBL)	PLO	20
	ENCODE (10,4,ITITLE(2))ZEXP \$ ENCODE (10,4,ITITLE(6))TIME	PLO	21
C	PLOT EXPOSURE CONTOURS	PLO	22
	CALL CONTRJB (XY(1),IEND,XY(IEND+1),JEND,OMEGA2,IEND,JEND,N2,7MN,PLO	PLO	23
	1ZMX,DLZ,Z2,DMPX,DMPY,IGRD,ITITLE,MTITLE,XLABFL,NXLBL,YLABFL,NYLBL)	PLO	24
	DO 3 I=1,MAXDIM \$ OMEGA2(I)=0.0	PLO	25
3	OMEGA2(I)=0.0 \$ RETURN	PLO	26
C		PLO	27
4	FORMAT (F10,3)	PLO	28
	END	PLO	29
	SUBROUTINE READF	RFA	1
C	THIS SUBROUTINE READS THE RESTART FILE FROM FSET1	RFA	2
	COMMON /FIXP/ PI,DV,RHO,X0,Y0,Z0,Q0,ZTOP,ZEXP,DELTA,TAREA,DEN,ZINFREA		3
	1,RHOSOIL,SGN,ORDMAGL,SHIFT \$ COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIM		4
	2M,JENDM1,IENDM1,N1,NJ,MAXMESH \$ COMMON /LCM1/ ALPHA(1000),TAUWUOB(RFA		5
	31000),RIDGE(1000),ELEMENT(1000),UNCAREA(1000),EROSCOF(1000),SCDEPTREA		6
	4H(1000),PERSS(1000),DDH(1000),TAUCRIT(1000) \$ COMMON /LCM2/ QPUFF(RFA		7
	5800),YDIST(800),ZDIST(800),XPUFF(800),YPUFF(800),ZPUFF(800) \$ COMMON		8
	60N /RESTART/ STIME,TIMEJC,XC,YC,ZC,Q,VCFLOW2,VBAR,ISTAB,YDISTQ,ZDIREA		9
	7STQ,NUMPUFF,IFGREST,QOUT,QPUFFOT,PRTIMEC,PLTIMEC,PMINORC \$ COMMON		10
	8/PRINTINFO/ TC,IPRINT,PRTIME,IPLDT,PLTIME,PMINORT,XY(200),ITITLE(5),REA		11
	9XLABEL(2),YLABEL(2),Z1(10),Z2(10),JTITLF(7),NXLBL,NYLBL,MTITLE,NTIRFA		12
	\$TLE,N1,N2,ACT1,ACT2 \$ COMMON /SCH1/ OMEGA1(1000),OMEGA2(1000),OMEGREA		13
	\$AS1(1000),OMEGAS2(1000),EXPOSUR(1000) \$ COMMON /SCH2/ VIRORIG(12),REA		14
	SABETA(6) \$ REWIND 1 \$ READ (1)TC,XY,ITITLE,XLABFL,YLABEL,Z1,Z2,JTIREA		15
	\$TLE,NXLBL,NYLBL,MTITLE,NTITLE,N1,N2,ACT1,ACT2 \$ READ (1)OMEGA1,OMEGA		16
	\$GA2,OMEGAS1,OMEGAS2,EXPOSUR \$ READ (1)VIRORIG \$ READ (1)IEND,JFND,RFA		17
	\$MAXDIM,JENDM1,IENDM1,N1,NJ \$ READ (1)PI,DV,RHO,X0,Y0,Z0,Q0,ZTOP,ZREA		18
	\$XP,DELTA,TAREA,DEN,SHIFT,ZINF,RHOSOIL \$ READ (1)ALPHA,TAUWUOB,RIDGREA		19
	\$E,ELEMENT,UNCAREA,EROSCOF,SCDEPTH,PERSS,DDH,TAUCRIT \$ READ (1)QPUFFREA		20
	\$F,YDIST,ZDIST,XPUFF,YPUFF,ZPUFF \$ READ (1)XC,YC,ZC,Q,VCFLOW2,VBAR,REA		21
	\$ISTAB,YDISTQ,ZDISTQ,NUMPUFF,QOUT,QPUFFOT,PRTIMEC,PLTIMEC,PMINORC		22
	RETURN	REA	23
	END	REA	24
	SUBROUTINE WRITEF	WRI	1
C	THIS SUBROUTINE WRITES THE RESTART FILE ON FSET2	WRI	2
	COMMON /INTG/ MAXPUFF,IEND,JEND,MAXDIM,JENDM1,IFNDM1,N1,NJ,MAXMESH		3
	COMMON /FIXP/ PI,DV,RHO,X0,Y0,Z0,Q0,ZTOP,ZEXP,DELTA,TAREA,DEN,ZINF		4
	WRI 1,RHOSOIL,SGN,ORDMAGL,SHIFT \$ COMMON /LCM1/ ALPHA(1000),TAUWUOB(1000		5
	WRI 20),RIDGE(1000),ELEMENT(1000),UNCAREA(1000),EROSCOF(1000),SCDEPTH(1000		6
	WRI 3000),PERSS(1000),DDH(1000),TAUCRIT(1000) \$ COMMON /LCM2/ QPUFF(1000		7
	WRI 4),YDIST(800),ZDIST(800),XPUFF(800),YPUFF(800),ZPUFF(800) \$ COMMON		8
	WRI 5/PRINTINFO/ TC,IPRINT,PRTIME,IPLDT,PLTIME,PMINORT,XY(200),ITITLE(5),		9
	WRI 6XLABEL(2),YLABEL(2),Z1(10),Z2(10),JTITLF(7),NXLBL,NYLBL,MTITLE,NTI		10
	WRI 7TLE,N1,N2,ACT1,ACT2 \$ COMMON /RESTART/ STIME,TIMEJC,XC,YC,ZC,Q,VCF		11
	WRI 8LOW2,VBAR,ISTAB,YDISTQ,ZDISTQ,NUMPUFF,IFGREST,QOUT,QPUFFOT,PRTIMEC		12
	WRI 9,PLTIMEC,PMINORC \$ COMMON /SCH1/ OMEGA1(1000),OMEGA2(1000),OMEGAS1		13
	WRI \$S(1000),OMEGAS2(1000),EXPOSUR(1000) \$ COMMON /SCH2/ VIRORIG(12),ABE		14
	WRI \$TA(6) \$ REWIND 2 \$ WRITE (2)TC,XY,ITITLE,XLABFL,YLABEL,Z1,Z2,JTITL		15
	WRI \$E,NXLBL,NYLBL,MTITLE,NTITLE,N1,N2,ACT1,ACT2 \$ WRITE (2)OMEGA1,OMEG		16
	WRI \$A2,OMEGAS1,OMEGAS2,EXPOSUR \$ WRITE (2)VIRORIG \$ WRITE (2)IEND,JEND		17
	WRI \$S,MAXDIM,JENDM1,IENDM1,N1,NJ \$ WRITE (2)PI,DV,RHO,X0,Y0,Z0,Q0,ZTOP,		18
	WRI \$ZEXP,DELTA,TAREA,DEN,SHIFT,ZINF,RHOSOIL \$ WRITE (2)ALPHA,TAUWUOB,		19
	WRI \$RIDGE,ELEMENT,UNCAREA,EROSCOF,SCDEPTH,PERSS,DDH,TAUCRIT \$ WRITE (2)		20
	WRI \$QPUFF,YDIST,ZDIST,XPUFF,YPUFF,ZPUFF \$ WRITE (2)XC,YC,ZC,Q,VCFLOW2,		21
	WRI \$VBAR,ISTAB,YDISTQ,ZDISTQ,NUMPUFF,QOUT,QPUFFOT,PRTIMEC,PLTIMEC,PMIN		22
	WRI \$SORC \$ RETURN	WRI	23

END	NRJ	24
SUBROUTINE VELVECT(TB,VBAR,THETA,ISTAB)	VEL	1
C THIS SUBROUTINE SUPPLIES ATMOSPHERIC CONDITIONS AS A FUNCTION OF	VEL	2
C TIME TO THE CODE	VEL	3
C TB = TIME AT BEGINNING OF TIME STEP	VEL	4
C VBAR = WIND VELOCITY MAGNITUDE AT HEIGHT ZINF	VEL	5
C THETA = WIND DIRECTION IN RADIAN (0.0,LE,THETA,LT,2PI) MEASURED	VEL	6
C COUNTER CLOCKWISE FROM THE +X-AXIS	VEL	7
C ISTAB = ATMOSPHERIC STABILITY CLASS, E.G., 1=A, 2=B, ETC.	VEL	8
C VBAR=10. \$ ISTAB=4 \$ THETA=0.0 \$ RETURN	VEL	9
END	VEL	10