KERR-MCGEE CORPORATION
1001 EAST DEEP ROCK • CUSHING, OKLAHOMA 74023

December 31, 2003

Mr. Derek Widmayer
Low-Level Waste & Decommissioning Projects Branch
Division of Waste Management
Office of Nuclear Materials Safety & Safeguards
US Nuclear Regulatory Commission
Washington, DC 20555

Re: Docket No. 70-3073; License No. SNM-1999
Alternate Concentration Limit for Groundwater

Dear Mr. Widmayer:
Kerr-McGee (KM) submitted "Alternate Concentration Limit (ACL) Derivation for Cushing" in September, 2002. NRC sent KM a request for additional information in a letter dated September 3, 2003. KM herein provides the additional information NRC requested.

NRC Request #1:
Because the physical parameters from the DandD program were developed for the scenario where radionuclide-contaminated soils eventually contaminate the groundwater that is initially uncontaminated, these parameters are frequently not conservative for the ACL scenario where the soils is initially uncontaminated but becomes contaminated later with contaminated groundwater. Therefore, the use of physical parameters from the DandD program in the Cushing Program needs justification. The NRC staff would prefer that the licensee use site-specific parameters for the physical parameters when they are available. When site-specific parameters are not used, the licensee should perform sensitivity analysis on these physical parameters to determine whether they are conservative for the ACL scenario.

KM Response:
Groundwater assessment work performed since the original submittal of the ACL derivation proposal greatly enhanced our ability to use site-specific values for numerous input parameters. KM and NRC agree that the only area in which groundwater is impacted by licensed material is the area under and downgradient from former RMA-11. Since there is a much narrower range of soil types in this area than would be applicable to a site-wide ACL determination, site-specific values can be utilized. The values of input parameters were changed to site-specific when practical. For instance, input values for irrigation rate, root depth, soil type, soil density, soil porosity, distribution coefficient, and hydraulic conductivity were all changed based upon knowledge of soil type in the area of the impacted groundwater plume. Sensitivity analysis was performed not only for parameters for which site-specific values could not be used, but for some parameters for which site-specific parameters were used. The basis for site-specific values and the sensitivity analysis are both addressed in the attached Technical Memorandum 02-04, Revision 1 of Alternate Concentration Limit (ACL) Derivation for Cushing".

NRC Request #2:
The NRC staff recommends that the licensee evaluate the critical physical parameters that impact the concentration levels of radionuclides in the soils within the root zone for the crops at the Cushing site (i.e., deposition rates, leaching rates, retardation factors, precipitation, infiltration rates, runoff, irrigations rates, root zone thickness, irrigation periods, Kds, soil density, and hydraulic conductivity). For example, the licensee should examine its use of Kds from the DandD program, which were selected to provide conservative leaching of radionuclides from the soils into the groundwater. These Kds (e.g., uranium Kd of 14 cm^3/g for loam, thorium Kd of 3200 cm^3/g for sand, and radium Kd of 500 cm^3/g for sand) are not representative of the predominant soil, clay, at the Cushing Site (Lower, 1994) and are not conservative for the ACL scenario.

KM Response:
KM and NRC agreed that the area of concern is the area of and downgradient from former RMA-11, and that uranium is the only nuclide of concern, based on NRC's preliminary review of "Radiological Groundwater Assessment Report" submitted to NRC in April, 2003. Narrowing the scope of concern to uranium in this area enabled KM to determine appropriate values to input for many of these parameters. KM also utilized parameters that are conservative for this scenario. As stated above, these are addressed in the attached Revision 1 of Alternate Concentration Limit (ACL) Derivation for Cushing".

NRC Request #3:
The licensee should justify its assumption that the radionuclides will reach an equilibrium concentration in the soils after the first growing period.

KM Response:
This assumption was an extremely conservative assumption. The concentration used in the original (Revision 0) analysis was the equilibrium concentration that would require 1000 years to achieve given the stated input parameters. In the original analysis, the time to reach the maximum concentration was set at one year to maximize the dose. This eliminated the need to run the model for many years to evaluate the change in dose over time as the soils reach an equilibrium concentration. The revised analysis assumes 50 years as a basis for continuous irrigation, as justified in the attached Technical Memorandum.

NRC Request #4:
The licensee should justify why the root zones for the different crops, including pasture, at this site should be limited to the upper 15 cm of soil.

KM Response:
The revised analysis modified the root zones for the different produce and fruits as described in the attached Technical Memorandum 02-04. The limited yield of the aquifer restricted the credible pathways to the growing and consumption of garden vegetables and fruit as the sole agricultural ingestion pathways.

NRC Request #5:

The licensee should justify that the growing periods, the irrigation periods, and the irrigation rates for each crop at Cushing are reasonable.

KM Response:
In the original analysis, the growing period and irrigation period were selected as the same. The revised analysis utilizes information provided by the Food and Agriculture Organization (FAO) of the United Nations. The FAO data provides detailed information about the various lengths of plant growing stages for individual plant types. The data used in the revised analysis is a statistical summary of the data available. In addition, although the daily application rate is the same for each plant type, the total amount of irrigation water applied to each crop type is related to the crop growing period such that each plant type has a distinct annual irrigation rate.

A Payne County horticulturalist recommended a single irrigation rate for all plants grown in the proposed scenario [Thomas, J. 2003]. This recommendation of a single application rate stems in large part from the small physical area of the garden and the inability to adjust the irrigation rate to the needs of individual plant types. Although the daily application rate of irrigation water is the same, the calculated infiltration rate takes into consideration the total amount of irrigation water used based upon the growing period for each plant type. The growing periods and irrigation rate distributions for each plant type are discussed in Technical Memorandum 02-04.

NRC Request #6:
The licensee should rerun its program based upon the items discussed in RAI 1-5 and calculate new ACLs.

KM Response:
The revised analysis provides the results of the rerun.

KM believes the revised analysis reported in the attached Revision 1 of Alternate Concentration Limit (ACL) Derivation for Cushing" address NRC's comments. This revision is therefore submitted to NRC as a license amendment request. KM requests that condition M of license SNM-1999 be amended to add the statement, "The groundwater concentration limit for total uranium shall be 820 pCi/L." If you have questions or comments, please call me at (918) 223-2522.

Sincerely,

Jeff Lux
Project Manager

Cc: NRC Public Document Room
Cushing Public Repository
Blair Spitzberg, NRC Region IV
Mike Broderick, DEQ Radiation Management Division

NEXTEP Environmental

808 Lyndon Lane Suite 201
Louisville, KY 40222

Phone: (502) 339-9767
Fax: (502) 339-9275

TECHNICAL MEMORANDUM 02-04

December 23, 2003

Originator: A.H. Thatcher, CHP, Senior HP Scientist

Subject: *Alternate Concentration Limit (ACL) Derivation for Cushing*

Revision: 1

ENDORSEMENT: This document contains the results of research and technical analysis which have been reviewed and approved for publication by the Technical Director, NEXTEP Environmental, Inc.	
[signature]	12/24/03
Harry J. Newman, CHP, Technical Director	Date

Introduction:

This memorandum summarizes the methodology of NUREG/CR-5512 [Kennedy and Strenge, 1992] and, to a lesser extent, RESRAD [Yu, et al, 1993], for determining the potential dose to a resident farmer scenario due to uranium contamination in groundwater. The calculations are based upon an initial concentration of 1 pCi/L of uranium in the groundwater. The contamination is carried through the various potential pathways to humans, and the resulting dose per unit concentration (in mrem/y per pCi/L). The Alternate Concentration Limit (ACL) for uranium in groundwater is then derived based upon the regulatory limit of 25 mrem per year to the average member of the critical population. In this case, the exposure pathway scenario assumes that the resident farmer is the average member of the critical population. It is important to emphasize that for this analysis, the only contamination that is assumed to exist in any pathway is as a result of the contaminated

groundwater used for irrigation. Specifically, the soil is assumed to not be contaminated initially but reaches a contaminant concentration in the soil (root zone) as a result of the use of contaminated irrigation water[1].

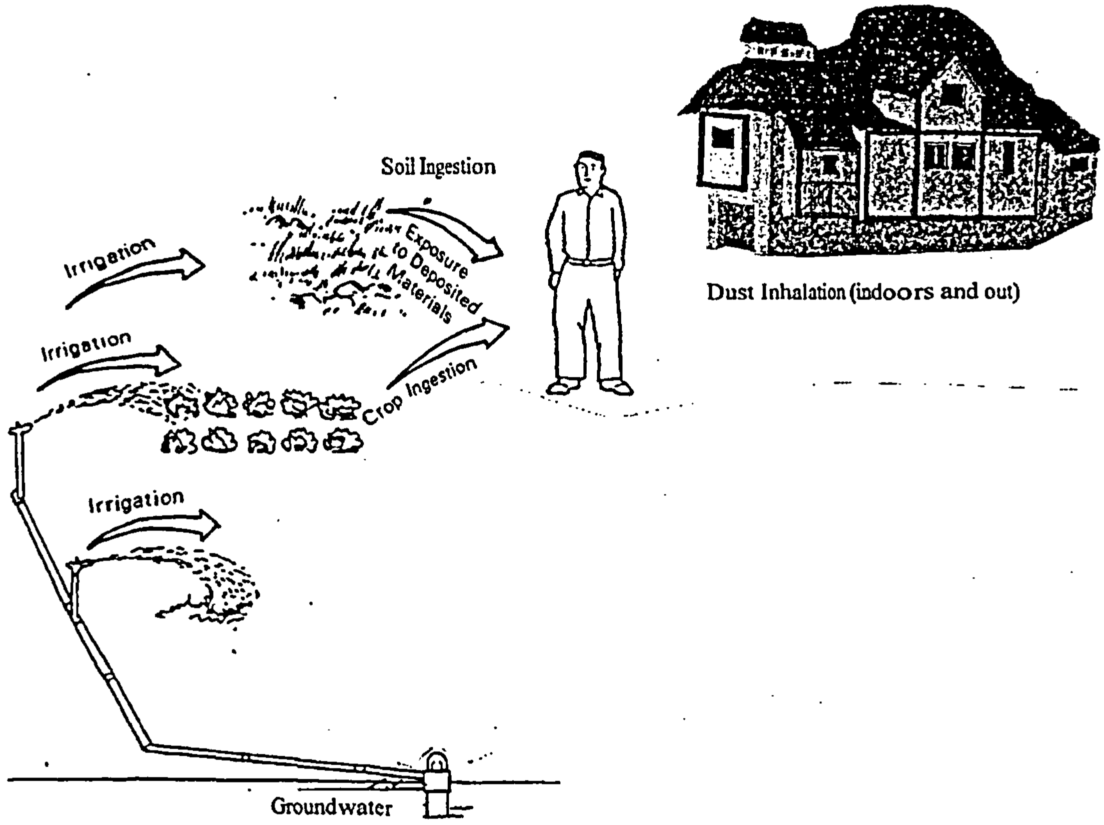

Figure 1
Environmental Pathways

The resident farmer scenario assumes that an individual spends a majority of time on his/her parcel of land. The individual builds a house, drills a well, and raises a typical family garden in order to support the resident farmer lifestyle. Due to the limitations of the quantity and variety of fruits and vegetables produced, only 50% of the total produce consumed is assumed to be grown on the farmer's land. Due to the use of the groundwater well, the individual is exposed to a number of pathways[2]. Figure 1 displays the groundwater related pathways outlined below:

- Ingestion of soil
- External exposure to radiation from contaminated soil while outdoors
- Inhalation exposure of resuspended soil while indoors and outdoors

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[1] Equilibrium cannot be achieved in a realistic framework for this analysis. It was assumed that 50 years of irrigation was performed for a single location resulting in the uranium soil contamination available for uptake.

[2] The assumed contaminated groundwater is used for irrigation and contaminates the soil, which in turn contaminates the plants.

- Ingestion of fruits and vegetables[3]

The drinking water, animal, and fish ingestion pathways are specifically excluded from the analysis. Justification for these exclusions are provided below.

This memorandum first presents the exceptions to the default pathway parameters, then reviews the calculational methodology and concludes by summarizing the ACLs.

General Method for Calculating ACLs:

A sensitivity and uncertainty analysis was performed, relying primarily on the use of default values from NUREG 6697 for the distribution of many of the parameters. Some site specific parameters were used in lieu of the default parameters to take into consideration local climate or conditions data. In several instances, parameters were modified from those recommended in NUREG 6697 due to the intent of the model. For the analysis described in this memorandum, it is the top soil layer (root zone) that is of primary interest. Some modifications were made to infiltration parameters to ensure that a realistically conservative approach was used in the calculation of the resulting leach rate from the root zone. All parameter distributions are defined in Attachment 2. References for parameter distributions are included in Attachment 1.

The following bullets describe key assumptions or parameters and criteria used for this modeling that differ from the recommended default values:

- **Drinking Water Ingestion** – The shallow groundwater for the Cushing Site is described as yielding low quantities of poor quality water with no known drinking water wells screened in the Vanoss Group within a mile radius of the site [Shults, D., 1997]. Both on the Cushing site and in the surrounding vicinity, the productive aquifer used is the Vamoosa-Ada Aquifer. The Vamoosa-Ada on site well is at a depth of approximately 510 feet. The City of Cushing has several municipal water-supply wells in the Vamoosa-Ada Aquifer ranging in depths from 400 feet to as deep as 700 feet [Lower, S.R., 2001]. The shallow Vanoss Group is hydraulically separated from the deeper Vamoosa-Ada Aquifer [Shults, D., 1997].

  The State of Oklahoma Department of Environmental Quality (DEQ) stated the following:
  "Shallow groundwater generally occurs in the Vanoss Group 10 to 15 feet below the site ground surface. This unit yields low quantities of poor quality water. It is highly unlikely that future residential/commercial drinking water will be established from the shallow groundwater at this site. No known drinking water wells are screened in the Vanoss within a one-mile radius of the site" [Shults, D., 1997].

[3] Grain has been eliminated as a viable pathway due to the amount of land and water supply required. Under this scenario, based upon the limited amount of affected water available, the fruit and vegetable pathways would be realistic.

The Oklahoma DEQ letter was transmitted to NRC for docketing by letter dated June 30, 1998 [Lux, J., 1998] which established that the concentration of some inorganic compounds in shallow groundwater sometimes exceeds EPA-established Maximum Contaminant Levels (MCLs) for drinking water even in areas where there is no evidence of impact from site contamination.

As a result, the drinking water pathway has been eliminated from consideration as a dose pathway.

- Animal Pathway – Aquifer yield tests were performed to quantify the supply of groundwater available from the Upper Vanoss Aquifer. That yield test determined that sufficient water supply only exists to supply a 1,000 square meter garden assuming a trickle irrigation method at 1"/week of irrigation [Thomas, J. 2003]. Insufficient volume exists to support the inclusion of farm animals in the model as well. The animal pathway is therefore removed as a possible pathway in favor of the more dominant plant ingestion pathway. The Upper Vanoss Aquifier Yield Paper is provided as Attachment 4.

- Fish Pathway – There is insufficient affected groundwater present to provide a water supply for a pond or other fish bearing resource, for reasons stated above. If the pond were constructed as a surface water holding feature, it would be unreasonable to consider the garden consumption pathway scenarios. Therefore, the fish ingestion pathway was not considered in the pathways analysis.

- Overhead Spray Irrigation versus Trickle Irrigation – The Upper Vanoss Yield test report by Thomas also calculated water requirements for the assumed family farm. Based upon the limited water volume and input from a Payne County horticulturalist [Thomas, J. 2003], trickle irrigation was selected as the only viable means of irrigating the plot size given the available groundwater pumping rate. This selection of trickle irrigation over overhead irrigation is directly related to the increased evapotranspiration and resultant increased water requirements for overhead irrigation. However, this model will remain conservative and assume that an overhead irrigation system is used due to the increased availability of contamination to plants from direct deposition.

- ICRP 72 Ingestion and Inhalation Dose Coefficients – The ingestion and inhalation dose conversion factors (DCFs) from ICRP 56+ documents are summarized in ICRP 72 [ICRP, 1995] and applied in this analysis. The ICRP 72 DCFs were developed specifically for calculation of dose to members of the public. ICRP 72 retains the gastrointestinal tract model used in ICRP 30, but uses the updated tissue weighting factors presented in ICRP 60, and revised biokinetic information to reflect increased knowledge in the uptake and retention of various elements in the body. ICRP 72 inhalation factors represent the application of an updated lung uptake and retention model.

- Soil Classification - The results of three soil samples collected at the site result in a USCS classification of lean clay with sand [Lux, J. 2003]. Lean clays contain less of the clay minerals that absorb more water and contain a correspondingly smaller amount of

ion exchange sites than does a "fat" clay with a higher mineral content. The lean clay with sand USCS classification corresponds to a silty clay classification using the USDA classified soil textures used in NUREG 6697. The silty clay soil affects the distributions of the soil density, total porosity, distribution coefficient for uranium, the hydraulic conductivity, and the soil type b parameter. The distributions used for all of these parameters is the default for silty clay soils recommended by NUREG 6697. Attachment 3 contains the results of the soil analysis performed by the testing laboratory.

- **Distribution Coefficients** – The recommended values for the distribution coefficient cannot differentiate between the various subtypes of clay soils. The uranium mean Kd of 1,600 cm^3/g for clay was selected with an upper bound limit of 100,000 cm^3/g.

- **Translocation factor for non leafy vegetables** – A value of 0.055 is used since a varied crop type would be utilized and the results would tend toward the mean value as opposed to an upper bound value[4].

- **Losses during food preparation** – The removal of contamination is only considered for the resuspended soil fraction and not the contamination initially deposited from irrigation or via root uptake. A removal fraction of 50% is assumed for this particular aspect of soil residue from resuspended material. This assumption is viewed as conservative as it does not consider the added losses due to peeling, cooking or other processes that would result in additional reductions in plant concentrations [Till, J.E. and Meyer, H.R, 1983][Napier, B.A., 2001].

In addition to the parameters discussed above, a number of parameters required specific consideration as the endpoint of this analysis is the root zone and not the infiltration of contamination to the groundwater as is common is most scenarios. The following parameters are discussed in this context:

- Irrigation rate – two factors are at play. First, a smaller irrigation rate results in a lesser amount of leaching from the root zone. Second, a smaller irrigation rate results in less contamination applied to the root zone. The second factor dominates such that a smaller irrigation rate would not be conservative as it would allow for a significantly higher release limit. The conservative value of 1"/week is recommended by a Payne County horticulturalist and is used in this instance.

[4] The translocation factor has a varied meaning, depending upon the reference. NUREG 5512, for example, describes the translocation fraction as the fraction of activity deposited on plant surfaces that reaches the edible parts of the plant. In experiments [Singhal, R.K., et.al, 1994], the translocation factor is defined as the activity fixed in plant parts to the total activity deposited on the surface. Singhal's definition specifically relates to the relationship between the interception fraction and the amount that migrates to the internal parts of the plant. The definition used by the International Atomic Energy Agency is the activity concentration in the edible parts at harvest divided by the activity retained on 1 m^2 of foliage at the time of deposition. The IAEA also uses a ratio that coincides with the definition used in NUREG 5512 and thus retains the dimensionless value used in most calculations. Legumes (peas, soybeans, snap beans, alfalfa, clovers, etc.) exhibit higher radionuclide uptake than non-legumes such as grasses [Till, J.E., and Meyer, H.R., 1983]. Utilizing Table IV from IAEA Technical Series No. 364 [IAEA, 1994] with a harvest yield of 4 kg/m^2 results in estimates of 0.008 for green beans to 0.04 for potatoes and carrots. A uniform distribution is used for non-leafy vegetables with a range of 0.01 to 0.1, making the mean value 0.055.

- Evapotranspiration coefficient (ET) — Modification of this parameter has little impact on the allowable release limit. NUREG/CR-6697 recognizes that small area farmers would tend to over irrigate thereby biasing the ET lower.
- Runoff coefficient – The sensitivity analysis shows that this parameter has little impact on the calculated release level. This minor impact is due to the fact that the soil concentration used in the calculations is the result of 50 years of continuous irrigation and rainfall. The recommended distribution from NUREG 6697 is therefore used.
- Root depth – The recommended values from the USDA National Resources Conservation Service[5] (NRCS) are used in place of NUREG 6697 guidance for several reasons. First, NUREG 6697 guidance is for the entire United States and the range is biased on the high side to arid climates so the distribution is not appropriate for Cushing, OK. Second, according to Chris Stoner (OK NRCS), the plow pan plays a major role in limiting root depth in OK. Breakup of the plow pan occurs periodically at 15-18" breakup depth. The plow pan depth is typically 8-12". The root depth distributions used are conservative without including the increased root depths of arid climates.

Calculations:

The basic equations for dose for each pathway are presented in this section. The spreadsheets containing the parameters and calculations are located in Attachment 1. In Attachment 1, the reference used for a given parameter is cited at the right hand side of each row.

Inadvertent Soil Ingestion

Ingestion of contaminated soil is possible as a result of transfer to vegetables, fruits, and hands [Kennedy and Strenge, 1992]. Although the amount ingested depends upon the activities performed and personal habits, a default value of 18.25 g/y is assumed [U.S.NRC, 1994, Yu et al. 2000]. The equation for calculating the ingestion dose is as follows [Kennedy and Strenge, 1992]:

<u>Equation 1</u>

$$Dose_{soiling} = C_{soil} * IR * ED * DCF * \frac{100,000}{27}$$

Where:

- $Dose_{soiling}$ = Committed effective dose from the ingestion of soil
- C_{soil} = Concentration of soil (Bq/g)
- IR = Ingestion rate of soil (g/day)
- ED = Exposure duration (d/year)
- DCF = Committed effective dose conversion factor for ingestion (Sv/Bq)
- 100,000/27 = Conversion from Sv to mrem and pCi to Bq

The detailed calculations for inadvertent soil ingestion dose are presented in Attachment 1.

[5] NRCS National Engineering Handbook part 652: Irrigation Guide

External Exposure to Soil

The general formula used for calculating the external effective dose equivalent for outdoor exposure is as follows:

Equation 2

$$ExternalDose = C * DCF * ED * 3600$$

Where:

- External dose = Dose in Sieverts (multiply by 100,000 to obtain dose in mrem)
- C = Concentration ($Bq*m^{-3}$)
- DCF = Dose conversion factor, nuclide specific ($Sv*s^{-1}*Bq^{-1}*m^{3}$)
- ED = Exposure duration (hours/year)
- 3600 = Conversion from hours to seconds

The dose conversion factor used in the calculations conservatively assumes an infinite plane source contaminated to an infinite depth [Eckerman, K.F., and J.C. Ryman. 1993]. The detailed calculations for external exposure to soil are presented in Attachment 1.

Soil Resuspension and Inhalation

Contaminated soil may also result in exposure due to resuspension and subsequent inhalation. This exposure may occur from soil contaminated through irrigation water.

The resuspension factor does depend upon the activities that are being performed by the resident farmer. The highest dust loading is related to gardening activities, while the lowest is equated to time spent indoors. The equation for calculating the committed effective dose from inhalation is as follows [Kennedy and Strenge, 1992]:

Equation 3

$$Dose_{Inhalation} = [(V_x * t_x * CDO * C_{soil} * DCF) + (V_r * t_i * (CDI + P_d * RF_r) * C_{soil} * DCF)] * 10^5$$

Where:

- V_x = Breathing rate for time spent outdoors (m^3/h)
- t_x = Time spent outdoors during a year (hours)
- CDO = Dust loading for outdoor activities (g/m^3)
- V_r = Breathing rate for time spent indoors (m^3/h)
- t_i = Time spent indoors during a year (hours)
- CDI = Dust loading for indoor activities (g/m^3)
- P_d = Indoor dust loading on floors (g/m^2)
- RF_r = Indoor resuspension factor (per meter)
- DCF = Inhalation committed effective dose, nuclide and age specific (Sv/Bq)
- 10^5 = Conversion from Sv to mrem

The indoor portion of the above equation differs slightly from the outdoor portion, as it includes contributions from materials blown and soil tracked into the house and resuspended [Kennedy and Strenge, 1992]. Detailed calculations for this pathway are presented in Attachment 5.

Ingestion of Fruit and Vegetable Products

The calculation of the concentration on the plant from overhead irrigation involves two separate stages. The first stage determines the amount retained on plants after being sprayed by irrigation water. The second stage calculates the additional contamination as a result of root uptake and resuspension of contaminated soil onto the plant. The two stages are then added to obtain a combined contaminant concentration on edible plant surfaces. The plant concentration is then calculated according to each plant type, and a dose conversion factor is applied to the total intake to calculate the final dose from ingestion of produce.

In order to calculate the concentration on the plant following the initial deposition, an estimate must first be made of the deposition rate [Kennedy and Strenge, 1992]:

Equation 4

$$R = \{IR * r_v * T_v * C_w\} / Y_v$$

Where:

- R = Average deposition rate to edible parts of plant from application of irrigation water (pCi/kg*d)
- IR = Application rate of irrigation water (L/m²*d)
- r_v = Fraction of initial deposition retained on plant (dimensionless)
- T_v = Translocation factor for transfer of radionuclides from plant surfaces to edible parts (dimensionless)
- C_w = Average concentration in irrigation water (assumed constant) (pCi/L)
- Y_v = Plant yield (kg wet weight/m²)

Following the estimate of the deposition rate, a calculation of the contribution from direct deposition is an ordinary, first order, linear differential equation. The solution to the equation is as follows:

Equation 5

$$C_{plant,deposition} = (R/\lambda)\{1 - e^{-\lambda t}\}$$

Where:

- $C_{plant,deposition}$ = The radionuclide concentration in the plant from deposition onto plant surfaces (pCi/kg)
- λ = Effective weathering and decay constant (d-1)
- t = growth period for plant (d)

For simplicity, losses from radiological decay during the holdup period[6] and consumption period are neglected. This conservative assumption has no significant impact on the dose contribution, as the radionuclides of interest have long half-lives.

The second stage of the calculation is the estimate of the concentration in plants resulting from resuspension and root uptake. In order to estimate this contribution, the average soil concentration must first be calculated. This linear differential equation is similar to equation 5, with the exception of the loss term.

The loss of contaminants from soil is due to leaching by infiltrating water. This infiltration rate applies only to the effective root zone for plants.

Equations 6 through 9 are necessary in order to determine the loss of contaminants due to leaching [Yu, et al, 1993]. Equation 6 utilizes default data to obtain an estimated infiltration rate.

Equation 6

$$I = \{1 - C_e\}\{\{1 - C_r\}P_r + I_{rr}\}$$

Where:

- I = Infiltration rate (m/year)
- C_e = Evapotranspiration coefficient (dimensionless)
- C_r = Runoff coefficient (dimensionless)
- P_r = Precipitation rate (m/year)
- I_{rr} = Irrigation rate (m/year)[7]

In order to determine the retardation factor, it is first necessary to calculate the saturation ratio in equation 7.

Equation 7

$$R_s = \{I / K_{sat}\}^{1/\{2b+3\}}$$

Where:

- R_s = Saturation Ratio
- K_{sat} = Hydraulic conductivity (m/year)
- b = soil specific exponential parameter [Yu, et al, 1993][8] (dimensionless)

The retardation factor in equation 8 [Yu, et al, 1993] is the ratio of the pore water velocity to the radionuclide transport velocity.

Equation 8

$$R_d = 1 + \{\rho_b * K_d\} / \{p_t * R_s\}$$

[6] The holdup period is the time between produce harvest and consumption.
[7] The application rate of irrigation water (L/m²*d) is related to the annual irrigation rate (m/y) by the crop growing period such that each crop type has a distinct annual irrigation rate.
[8] The soil-specific b parameter is an empirical parameter used to evaluate the saturation ratio of the soil.

Where:

- R_d = Retardation factor (dimensionless)
- ρ_b = Soil density (g/cm^3)
- p_t = Soil porosity (dimensionless)
- K_d = Distribution coefficient (cm^3/g)

The volumetric water content in equation 9 [Yu, et al, 1993] is the product of the total soil porosity by the saturation ratio.

Equation 9

$$\theta = R_s * p_t$$

Where:

- θ = Volumetric water content (dimensionless)

Equation 10 [Yu, 1993] is used to obtain a time independent estimate of the leach rate[9] in the root zone as a result of the application of irrigation water and local precipitation.

Equation 10

$$L = I / \{\theta * T * R_d\}$$

Where:

- L = Leach rate (y^{-1})
- T = Thickness of contaminated zone[10] (m)

The area soil density in the root zone thickness is calculated as follows:

Equation 11

$$P_s = p_b * T * 1000$$

Where:

- P_s = Areal soil density[11] (kg/m²)
- 1000 = converts the soil density in g/cm^3 to kg/m^3

Having obtained the information necessary to calculate the loss term in the soil, equation 12 [Kennedy and Strenge, 1992] calculates the radionuclide deposition rate onto the soil.

Equation 12

$$R_{soil} = \{C_w * IR\} / P_s$$

9 The leach rate calculated is a one dimensional uniform depletion of the uranium from the overall root zone.

10 The contaminated zone in this application is the effective root zone where the uptake of contaminants from plants is of concern.

11 The areal soil density is adjusted to reflect the depth of the mass of soil in a given root zone and is plant type specific (i.e. leafy, non leafy, fruit).

Where:

- R_{soil} = Average deposition rate onto soil[12] (pCi/kg*d)
- C_w and IR are as defined in Equation 4.

The final concentration at the end of the growing period is shown in equation 13. The modeling uses a time of 50 years of continuous irrigation as the basis for the estimated soil concentration and the resulting calculated release limit[13].

Equation 13

$$C_{soil} = R_{soil} /(L * 365) * \{1 - e^{-Lt}\}$$

Where:

- C_{soil} = Radionuclide soil concentration at end of growing period (pCi/kg)

Finally, equation 14 calculates the concentration in the plant due to uptake and resuspension [Kennedy and Strenge, 1992].

Equation 14

$$C_{plant,uptake+res} = \{ML * F_r + B\} * C_{soil}$$

Where:

- $C_{plant,uptake+res}$ = Radionuclide concentration in plant due to uptake and resuspension (pCi/kg)
- ML = Mass loading factor for resuspension of soil to edible portions of plant (dry weight)
- F_r = Contamination reduction factor from plant surfaces as a result of rinsing and washing.
- B = Concentration factor for uptake of soil to plant (dry weight basis)

The total contaminant concentration in plants, C_{plants}, is the sum of equations 5 ($C_{plant,deposition}$) and 14 ($C_{plant,uptake+res}$). The resulting formula for dose from ingesting contaminated vegetation is as follows:

Equation 13

$$Dose_{plants} = \frac{C_{plants}}{27} * Q_{plants} * DCF * F * 10^5$$

Where:

- $Dose_{plants}$ = Committed effective dose from ingesting contaminated vegetation (mrem/year)
- C_{plants} = Contaminant concentration in plants from deposition, uptake, and resuspension (pCi/kg)
- Q_{plants} = Intake rate of vegetation (kg/year)
- DCF = 50 year committed effective dose conversion factor for ingestion of contaminants (Sv/Bq)
- F = Fraction of contaminated material that is grown onsite

[12] The deposition rate to the soil per unit area is converted to the deposition rate to the root volume through the use of the areal soil density. Considering a 50 year application of contamination prior to exposure, a uniform contaminant concentration through the root zone is appropriate.

[13] The equilibrium soil concentration for uranium given the input parameters is well over 1,000 years.

- 10^5 = Converts Sieverts (Sv) to mrem
- 27 = Converts pCi to Bq

The fraction of contaminated material that is assumed grown in a particular location is 50% for the resident farmer [U.S.NRC. 1994]. Given the regional information on home grown production provided in the Exposure Factors Handbook [U.S. EPA. 1997], an assumption of 50% is conservative.

Detailed calculations for dose due to consumption of fruit and vegetables are presented in Attachment 1.

Uncertainty Analysis Results

In order to identify significant parameters in the conduct of this modeling effort, a sensitivity and uncertainty analysis was performed. A Monte Carlo analysis [Decisioneering, 2001] was used to determine the uncertainty surrounding the calculated release limit for the resident farmer scenario. The inputs for the Monte Carlo analysis were the probability distributions for the key parameters.

The shape of the probability distributions reflects the depth of information available for a given parameter [NCRP, 1996]. For parameters such as the weathering constant, sufficient data exist to estimate the range and likely value, but insufficient information exists to further define the distribution. The weathering constant is therefore assigned a triangular probability distribution. Greater information exists on the hydraulic conductivity for a given soil type and allows for further definition of the distribution as log-normally distributed, with bounds on the distribution.

A quantitative sensitivity analysis was performed using the data generated during the uncertainty analysis. Using regression techniques, rank correlation coefficients were calculated between each parameter and the uranium release limit. Parameter sensitivities are then established by the degree of correlation between the parameter and the release limit to the resident farmer. The advantage of rank correlation over simple linear correlation is that it is nonparametric. That is, it is not dependent on the underlying distribution of either the input or output variables.

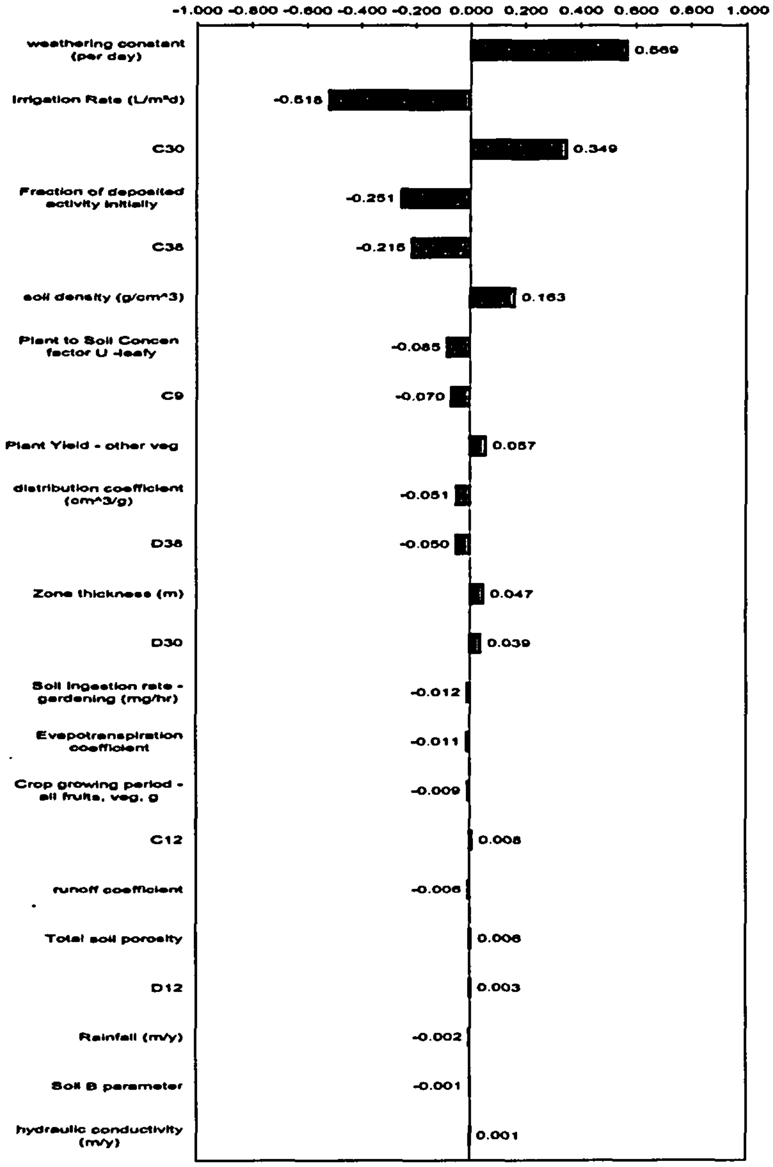
The rank correlation coefficient takes on a value between –1 and +1. If an increase in a given input parameter results in an increase in the allowable release limit, then the correlation is positive, with +1 being a perfect correlation. Similarly, a negative correlation coefficient indicates that a increase in the input parameter results in a decrease in the allowable release limit. A value near zero (0) indicates that the parameter of interest is not correlated with a change in the release limit.

Figure 2 is the output of the Crystal Ball sensitivity analysis for all modeled parameters. The shape and values of the distributions modeled are outlined in Attachment 2. Figure 2 shows that only a handful of parameters significantly impact the final result.

- The most significant parameter is the weathering constant. The implication of this is that a larger weathering constant results in greater contaminant removal and therefore leads to a higher allowable release limit. The possible range for this parameter is adequately modeled as the informational review in Till's Radiological Assessment book support the range provided by NUREG 6997.
- The second most significant parameter is the irrigation rate. Increases in the irrigation rate results in a larger amount of contaminants deposited on the plants and soil leading to a decrease in the allowable release limit. The upper bound on the irrigation rate is estimated as 20% greater than the 1"/week recommended by the Payne County horticulturalist. The lower bound is calculated from actual evapotranspiration data from Stillwater, Oklahoma and matched to the long term precipitation rate for the same area. The resulting lower bound irrigation rate was also adjusted for the type of crop (leafy, non leafy, fruit).
- The root zone thickness for non-leafy vegetables is positively correlated meaning that as the depth of the roots increase the allowable release limit increases as well.
- Fraction of deposited activity initially retained on plant surfaces (leafy vegetables). A weak negative correlation. A greater amount of activity retained on plant surfaces directly results in an increase in the overall contamination on the plant and a lower allowable release limit.
- Consumption rate for non leafy vegetables. A weak negative correlation that indicates that increases in the consumption rate result in a greater uptake of contaminants and a lower allowable release limit.
- The soil density plays a modest role in the predicted release limit. Changes in the soil density has two competing effects. The first, and smaller effect is the impact to the predicted leach rate. Essentially, a greater soil density results in a larger retardation factor which in turn results in a smaller leach rate. The smaller leach rate results in a higher soil concentration and therefore a greater plant concentration and lower overall release limit. The second and greater effect, is that increases in the soil density result in an increase in the overall areal soil density. The increased mass in the root zone as a result of the increase in soil density results in an overall decrease in the contaminant concentration in the soil, the net effect of this is an increase in the allowable release limit. Given a rank correlation coefficient of 0.15, soil density plays a minor role in the allowable release limit.
- All other parameters have less than a ±0.1 correlation coefficient.

Crystal Ball Report
Simulation started on 12/23/03 at 18:17:11
Simulation stopped on 12/23/03 at 18:19:26

Sensitivity Chart
Target Forecast: Release limit for a resident farmer



Notes: C30 is the root zone thickness for non- leafy vegetables.
Fraction of deposited activity initially <u>retained on plant surfaces</u> (leafy vegetables).
C38 is the consumption rate for non- leafy vegetables (kg/y).
C9 is the translocation factor for non- leafy vegetables (unitless).
D30 is the root zone thickness (m) for fruits.
D38 is the consumption rate for fruits (kg/y).
C12 is the growing period in days for non- leafy vegetables.
D12 is the growing period in days for fruits.

Figure 2
Sensitivity Analysis Results

Figure 3 displays the distribution of the allowable release limit to the resident farmer. The distribution is a positively skewed log normal distribution with a kurtosis of 5.5. The median value of the distribution is 765 pCi/L and the mean value is 822 pCi/L. Considering that the endpoint of interest for this analysis is the average member of the critical group, the predicated ACL of 820 pCi/L appears to be the appropriate basis for consideration.

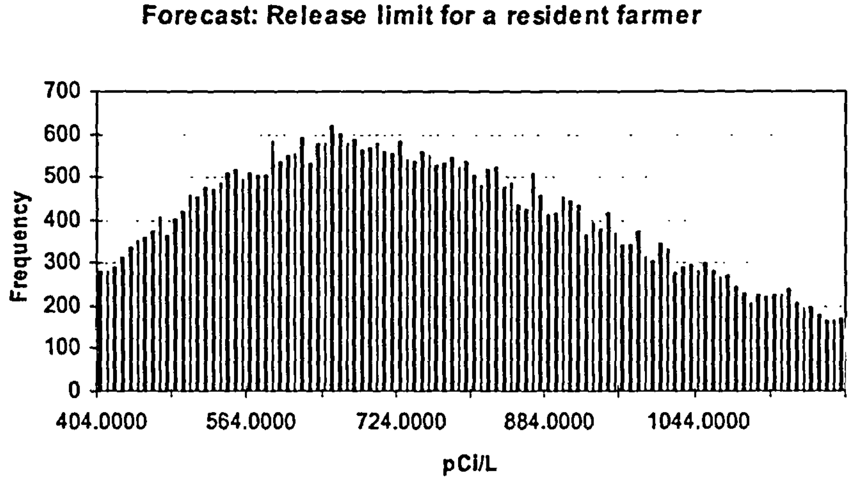


Figure 3
Uncertainty Analysis Results

The derived ACL for total uranium based upon the Cushing Site resident farmer scenario is 820 pCi/L. This proposed ACL was derived from the dose conversion factor of 3.04E-02 mrem/y per pCi/L total uranium, and translates to a dose of 25 mrem/y to the resident farmer from all reasonable exposure pathways.

Conclusion:
The proposed ACL for total uranium in groundwater is 820 pCi/L. These determinations were made with the realistic assumption that the Vanoss Group would not be used as a source for drinking water and could only supply the required volume of water to serve as the water source for the plant pathway. The exposure scenario assumed that the average member of the critically exposed population was the resident farmer.

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ATTACHMENT 1

This Table Supports Calculations for Ingestion of Fruit, Vegetables, Groundwater, and Soil										
Parameters	**Uranium 235**			**Uranium 238**			**Uranium 234**			
Intake of:	**leafy veg**	**Other veg**	**Fruits**	**leafy veg**	**Other veg**	**Fruits**	**leafy veg**	**Other veg**	**Fruits**	Reference
Groundwater Concentration (pCi/l)	2.25E-02	2.25E-02	2.25E-02	4.89E-01	4.89E-01	4.89E-01	4.89E-01	4.89E-01	4.89E-01	
Irrigation Rate (L/m²d)	3.90E+00	3.90E+00	3.90E+00	3.90E+00	3.90E+00	3.90E+00	3.90E+00	3.90E+00	3.90E+00	Lower bound derived based upon Precip @ Stillwater 1951-1978 avg, and model with local ET from http://agweather.mesonet.org/models/evapotranspiration/default.html. Most likely value provided by Payne Co expert (see Thomas paper, 2003), Upper bound is 20% greater than most likely value.
isotope decay constant (per day)	2.70E-12	2.70E-12	2.70E-12	4.24E-13	4.24E-13	4.24E-13	7.71E-09	7.71E-09	7.71E-09	
weathering constant (per day)	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	2.03E-01	[USNRC, 2000] NUREG/CR-6697
Translocation factor (unitless)	1.00E+00	9.28E-02	1.00E-01	1.00E+00	9.28E-02	1.00E-01	1.00E+00	9.28E-02	1.00E-01	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]
Fraction of deposited activity initially retained on plant surfaces (unitless)	3.13E-01	2.50E-01	2.50E-01	3.13E-01	2.50E-01	2.50E-01	3.13E-01	2.50E-01	2.50E-01	[USNRC, 2000] NUREG/CR-6697
Plant Yield - (kg/m²)	2.00E+00	3.50E+00	3.00E+00	2.00E+00	3.50E+00	3.00E+00	2.00E+00	3.50E+00	3.00E+00	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]. And NUREG 6697. Little data was available on yields for OK
Crop growing period (days)	4.23E+01	2.10E+02	1.89E+02	4.23E+01	2.10E+02	1.89E+02	4.23E+01	2.10E+02	1.89E+02	FAO - Food and Agriculture Organization of the United Nations http://www.fao.org/docrep/X0490E/x0490e00.htm#Contents
Avg. deposition onto Plants (pCi/kg-d)	1.37E-02	5.81E-04	7.30E-04	2.98E-01	1.26E-02	1.59E-02	2.98E-01	1.26E-02	1.59E-02	
Concentration at time of harvest - (pCi/kg)	6.76E-02	2.87E-03	3.60E-03	1.47E+00	6.23E-02	7.83E-02	1.47E+00	6.23E-02	7.83E-02	Calculated, See Text
Areal soil density in root zone thickness (kg/m²)	6.34E+02	1.35E+03	2.93E+03	6.34E+02	1.35E+03	2.93E+03	6.34E+02	1.35E+03	2.93E+03	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]
Deposition rate onto soil (pCi/kgd)	1.38E-04	6.48E-05	2.99E-05	3.00E-03	1.41E-03	6.51E-04	3.00E-03	1.41E-03	6.51E-04	Calculated, See Text
Evapotranspiration coefficient (unitless)	5.98E-01	5.98E-01	5.98E-01	5.98E-01	5.98E-01	5.98E-01	5.98E-01	5.98E-01	5.98E-01	[USNRC, 2000] NUREG/CR-6697
runoff coefficient (runoff)	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	3.11E-01	[USNRC, 2000] NUREG/CR-6697
Rainfall (m/y)	8.86E-01	8.86E-01	8.86E-01	8.86E-01	8.86E-01	8.86E-01	8.86E-01	8.86E-01	8.86E-01	Jim Henley, R. Dwaine Gelnar, and Richard E. Mayhugh, Soil Conservation Service United States Department of Agriculture, Soil Conservation Service, in cooperation with the Oklahoma Agricultural Experiment Station. 1987
Irrigation rate (m/y)	1.65E-01	8.17E-01	7.36E-01	1.65E-01	8.17E-01	7.36E-01	1.65E-01	8.17E-01	7.36E-01	[USNRC, 1994]
Infiltration rate (m/y)	3.12E-01	5.74E-01	5.42E-01	3.12E-01	5.74E-01	5.42E-01	3.12E-01	5.74E-01	5.42E-01	Calculated, See Text
Total soil porosity (unitless)	4.60E-01	4.60E-01	4.60E-01	4.60E-01	4.60E-01	4.60E-01	4.60E-01	4.60E-01	4.60E-01	[USNRC, 2000] NUREG/CR-6697
hydraulic conductivity (m/y)	1.26E-01	1.26E-01	1.26E-01	1.26E-01	1.26E-01	1.26E-01	1.26E-01	1.26E-01	1.26E-01	[USNRC, 2000] NUREG/CR-6697
Soil B parameter (unitless)	9.58E+00	9.58E+00	9.58E+00	9.58E+00	9.58E+00	9.58E+00	9.58E+00	9.58E+00	9.58E+00	[USNRC, 2000] NUREG/CR-6697
Saturation ratio	1.04E+00	1.07E+00	1.07E+00	1.04E+00	1.07E+00	1.07E+00	1.04E+00	1.07E+00	1.07E+00	Calculated, See Text
Volumetric water content	4.80E-01	4.93E-01	4.92E-01	4.80E-01	4.93E-01	4.92E-01	4.80E-01	4.93E-01	4.92E-01	Calculated, See Text
soil density (g/cm^3)	1.72E+00	1.72E+00	1.72E+00	1.72E+00	1.72E+00	1.72E+00	1.72E+00	1.72E+00	1.72E+00	[USNRC, 2000] NUREG/CR-6697
distribution coefficient (cm^3/g)	3.64E+04	3.64E+04	3.64E+04	3.64E+04	3.64E+04	3.64E+04	3.64E+04	3.64E+04	3.64E+04	[USNRC, 2000] NUREG/CR-6697
Retardation factor	1.31E+05	1.27E+05	1.27E+05	1.31E+05	1.27E+05	1.27E+05	1.31E+05	1.27E+05	1.27E+05	Calculated, See Text
Zone thickness (m)	3.69E-01	7.87E-01	1.70E+00	3.69E-01	7.87E-01	1.70E+00	3.69E-01	7.87E-01	1.70E+00	NRCS National Engineering Handbook part 652: Irrigation Guide
Leach rate (per day)	3.69E-08	3.19E-08	1.39E-08	3.69E-08	3.19E-08	1.39E-08	3.69E-08	3.19E-08	1.39E-08	Calculated, See Text
Soil Contamination for 50 years of irrigation (pCi/kg)	2.52E+00	1.18E+00	5.46E-01	5.48E+01	2.57E+01	1.19E+01	5.48E+01	2.57E+01	1.19E+01	Calculated, See Text
Plant to soil concentration factor (pCi/g plant/pCi/g soil)	1.18E-03	1.18E-03	1.18E-03	1.18E-03	1.18E-03	1.18E-03	1.18E-03	1.18E-03	1.18E-03	[USNRC, 2000] NUREG/CR-6697
mass loading factor for resuspension to edible portions	1.00E-01	1.00E-01	1.00E-02	1.00E-01	1.00E-01	1.00E-02	1.00E-01	1.00E-01	1.00E-02	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]
Losses during Food Preparation (unitless)	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	Napier, B. 1999.Revised portion of GENII code on terception fraction
Plant concentration as a result of uptake and resuspension (pCi/kg)	1.29E-01	6.05E-02	3.38E-03	2.80E+00	1.31E+00	7.34E-02	2.80E+00	1.31E+00	7.34E-02	Calculated, See Text
total plant concentration (pCi/kg)	1.97E-01	6.34E-02	6.98E-03	4.27E+00	1.38E+00	1.52E-01	4.27E+00	1.38E+00	1.52E-01	Calculated, See Text
Consumption rate of: (kg/y)	1.10E+01	7.43E+01	5.28E+01	1.10E+01	7.43E+01	5.28E+01	1.10E+01	7.43E+01	5.28E+01	[USNRC, 2000] NUREG/CR-6697 and NUREG 5512
fraction of diet from garden -considered in consumption rate	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	5.00E-01	[USNRC, 1994]
Uptake per year (Bq/y)	4.01E-02	8.72E-02	6.82E-03	8.70E-01	1.90E+00	1.48E-01	8.70E-01	1.90E+00	1.48E-01	
Dose conversion factor (Sv/Bq)	5.61E-08	5.61E-08	5.61E-08	4.50E-08	4.50E-08	4.50E-08	4.90E-08	4.90E-08	4.90E-08	ICRP 72
Committed dose (mrem/y)	2.25E-04	4.89E-04	3.83E-05	3.92E-03	8.53E-03	6.67E-04	4.27E-03	9.29E-03	7.26E-04	Calculated, See Text
Total Dose from Plant Ingestion (mrem/y)	**7.52E-04**			**1.31E-02**			**1.43E-02**			
Soil Ingestion Contribution	**U-235**			**U-238**			**U-234**			
Soil ingestion rate - gardening (mg/h)	1.68E+01			1.68E+01			1.68E+01			[USNRC, 2000] NUREG/CR-6697
Dose conversion factor (Sv/Bq)	5.61E-08			4.50E-08			4.90E-08			ICRP 72
Soil concentration at eqlb (pCi/kg)	2.52E+00			5.48E+01			5.48E+01			
Soil Ingestion Dose (mrem/y)	**8.82E-06**			**1.54E-04**			**1.67E-04**			Calculated, See Text
Direct Radiation Contribution	**U-235**			**U-238**			**U-234**			
Dose Coefficient (Sv*m^3/Bq*s)	3.75E-18			5.52E-22			2.14E-21			FRG 12
Exposure time (s)	6.62E+06			6.62E+06			6.62E+06			[USNRC, 1994]
Indoor Soil Shielding factor	3.30E-01			3.30E-01			3.30E-01			[USNRC, 1994]
Exposure time indoors (s)	1.73E+07			1.73E+07			1.73E+07			[USNRC, 1994]
Direct Radiation Dose (mrem/y)	**6.91E-04**			**2.21E-06**			**8.57E-06**			
	U-235			**U-238**			**U-234**			
Total Dose (mrem/y)	**1.48E-03**			**1.38E-02**			**1.51E-02**			
	Total Uranium (without progeny)									
Release limit for a resident farmer (pCi/l)	**8.25E+02**									

NOTE: THE ANALYTICAL RESULTS SHOWN ABOVE ARE A REFLECTION OF THE EXPECTED VALUE. PARAMETERS WHICH ARE OBTAINED FROM DISTRIBUTIONS WILL VARY FROM RUN TO RUN.

REFERENCES

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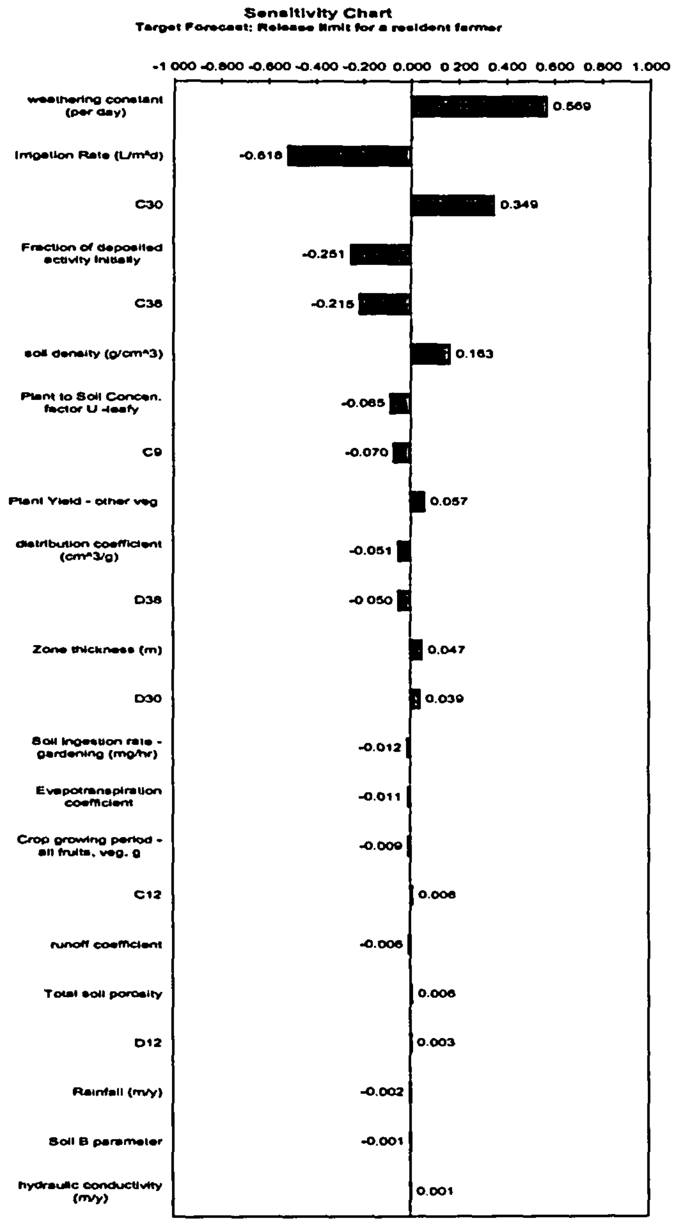
Yu. C. LePoire, D., Gnanapragsasm, E., Arnish, J., Kamboj, S. Biwer, B.M., Cheng, J-J., Zielen, A., and Chen, S.Y. Development of Probabilistic RESRAD 6.0 and RESRAD BUILD 3.0 Computer Codes NUREG/CR- 6697, Argonne National Laboratory, 2000.

ATTACHMENT 2

Crystal Ball Report
Simulation started on 12/23/03 at 18:17:11
Simulation stopped on 12/23/03 at 18:19:26



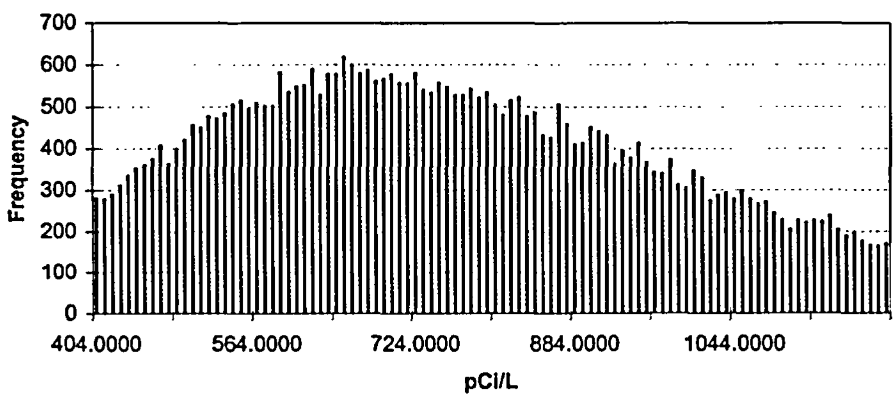
Notes: C30 is the root zone thickness for non- leafy vegetables.
Fraction of deposited activity initially retained on plant surfaces (leafy vegetables).
C38 is the consumption rate for non- leafy vegetables (kg/y).
C9 is the translocation factor for non- leafy vegetables (unitless).
D30 is the root zone thickness (m) for fruits.
D38 is the consumption rate for fruits (kg/y).
C12 is the growing period in days for non- leafy vegetables.
D12 is the growing period in days for fruits.

Forecast: Release limit for a resident farmer **Cell: B62**

Summary:
- Display Range is from 400.0000 to 1200.0000 pCi/L
- Entire Range is from 153.3134 to 3296.4409 pCi/L
- After 50,000 Trials, the Std. Error of the Mean is 1.4846

Statistics:	Value
Trials	50000
Mean	822.4848
Median	764.9035
Mode	---
Standard Deviation	331.9592
Variance	110196.9269
Skewness	1.22
Kurtosis	5.53
Coeff. of Variability	0.40
Range Minimum	153.3134
Range Maximum	3296.4409
Range Width	3143.1275
Mean Std. Error	1.4846

Forecast: Release limit for a resident farmer



Forecast: Release limit for a resident farmer (cont'd) **Cell: B62**

Percentiles:

Percentile	pCi/L
0%	153.3134
10%	460.5542
25%	588.6617
50%	764.9035
75%	988.9020
90%	1253.0094
100%	3296.4409

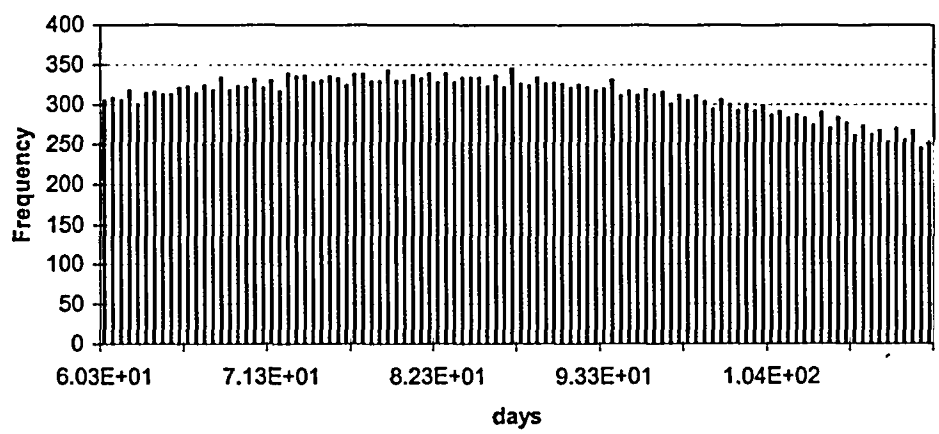
End of Forecast

Forecast: Crop growing period - leafy veg **Cell: B12**

Summary:
Display Range is from 6.00E+1 to 1.15E+2 days
Entire Range is from 4.00E+1 to 1.40E+2 days
After 50,000 Trials, the Std. Error of the Mean is 1.18E-1

Statistics:	Value
Trials	50000
Mean	8.67E+01
Median	8.56E+01
Mode	---
Standard Deviation	2.65E+01
Variance	7.04E+02
Skewness	0.13
Kurtosis	1.99
Coeff. of Variability	0.31
Range Minimum	4.00E+01
Range Maximum	1.40E+02
Range Width	1.00E+02
Mean Std. Error	1.19E-01

Forecast: Crop growing period - leafy veg



Forecast: Crop growing period - leafy veg (cont'd) **Cell: B12**

Percentiles:

Percentile	days
0%	4.00E+01
10%	5.09E+01
25%	6.48E+01
50%	8.56E+01
75%	1.08E+02
90%	1.24E+02
100%	1.40E+02

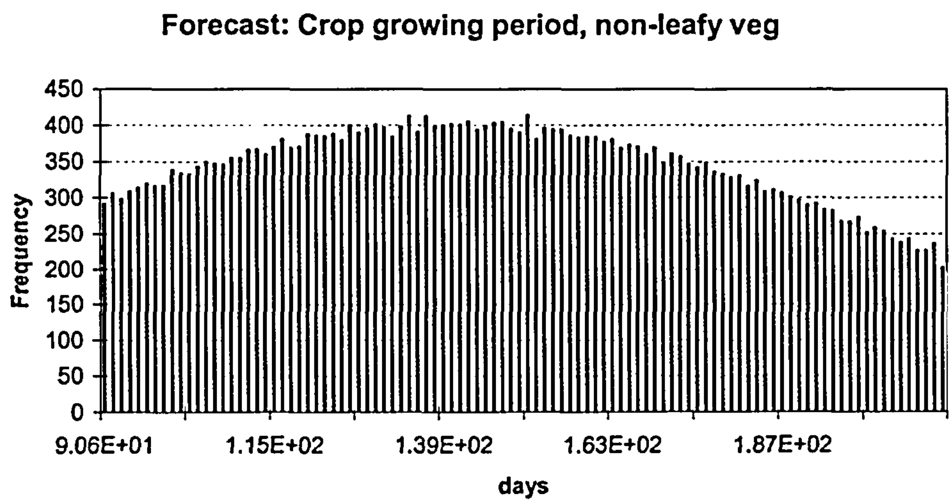
End of Forecast

Forecast: Crop growing period, non-leafy veg **Cell: C12**

Summary:

Display Range is from 9.00E+1 to 2.10E+2 days
Entire Range is from 4.00E+1 to 3.49E+2 days
After 50,000 Trials, the Std. Error of the Mean is 2.50E-1

Statistics:	Value
Trials	50000
Mean	1.47E+02
Median	1.44E+02
Mode	---
Standard Deviation	5.60E+01
Variance	3.14E+03
Skewness	0.34
Kurtosis	2.71
Coeff. of Variability	0.38
Range Minimum	4.00E+01
Range Maximum	3.49E+02
Range Width	3.09E+02
Mean Std. Error	2.50E-01



Forecast: Crop growing period, non-leafy veg (cont'd) **Cell: C12**

Percentiles:

Percentile	days
0%	4.00E+01
10%	7.49E+01
25%	1.06E+02
50%	1.44E+02
75%	1.85E+02
90%	2.23E+02
100%	3.49E+02

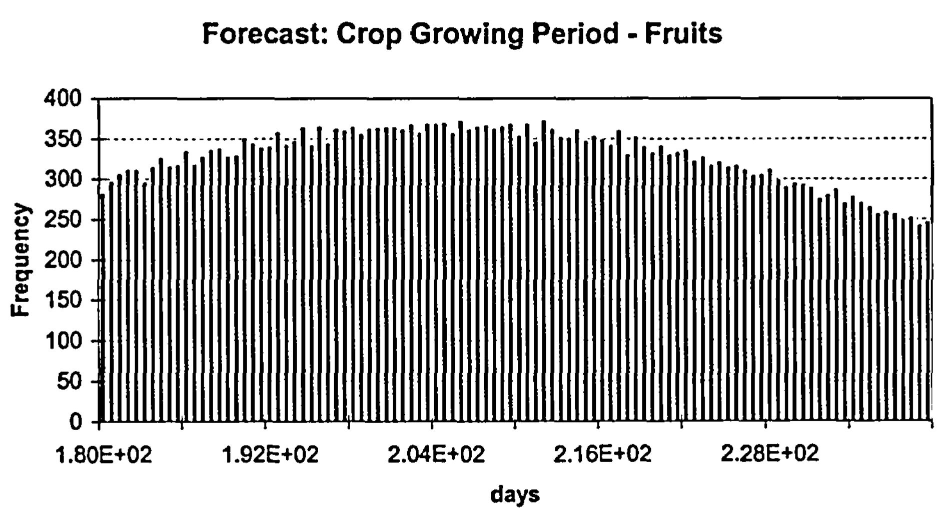
End of Forecast

Forecast: Crop Growing Period - Fruits **Cell: D12**

Summary:

Display Range is from 1.80E+2 to 2.40E+2 days
Entire Range is from 1.55E+2 to 2.70E+2 days
After 50,000 Trials, the Std. Error of the Mean is 1.26E-1

Statistics:	Value
Trials	50000
Mean	2.08E+02
Median	2.07E+02
Mode	---
Standard Deviation	2.83E+01
Variance	7.98E+02
Skewness	0.13
Kurtosis	2.15
Coeff. of Variability	0.14
Range Minimum	1.55E+02
Range Maximum	2.70E+02
Range Width	1.15E+02
Mean Std. Error	1.26E-01



Forecast: Crop Growing Period - Fruits (cont'd) **Cell: D12**

Percentiles:

Percentile	days
0%	1.55E+02
10%	1.70E+02
25%	1.86E+02
50%	2.07E+02
75%	2.30E+02
90%	2.48E+02
100%	2.70E+02

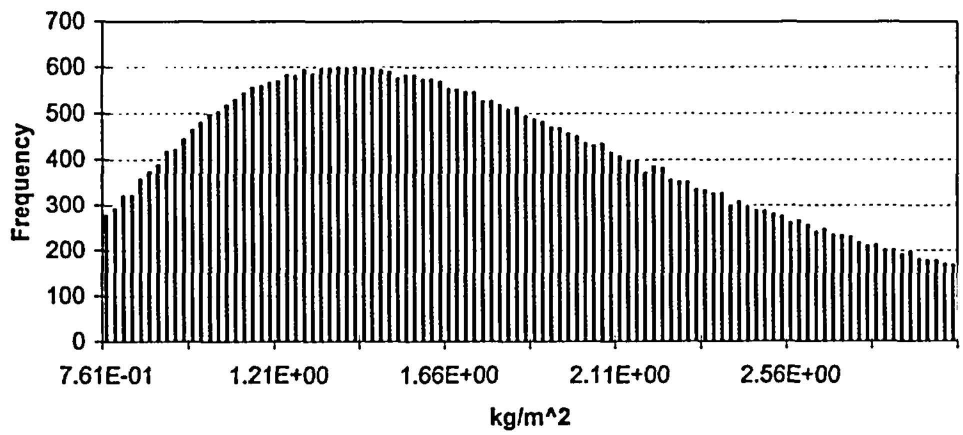
End of Forecast

Forecast: Plant Yield - other veg **Cell: C11**

Summary:
Display Range is from 7.50E-1 to 3.00E+0 kg/m^2
Entire Range is from 2.54E-1 to 1.51E+1 kg/m^2
After 50,000 Trials, the Std. Error of the Mean is 4.47E-3

Statistics:	Value
Trials	50000
Mean	1.96E+00
Median	1.75E+00
Mode	---
Standard Deviation	9.99E-01
Variance	9.98E-01
Skewness	1.66
Kurtosis	8.50
Coeff. of Variability	0.51
Range Minimum	2.54E-01
Range Maximum	1.52E+01
Range Width	1.49E+01
Mean Std. Error	4.47E-03

Forecast: Plant Yield - other veg



Forecast: Plant Yield - other veg (cont'd) **Cell: C11**

Percentiles:

Percentile	kg/m^2
0%	2.54E-01
10%	9.46E-01
25%	1.27E+00
50%	1.75E+00
75%	2.42E+00
90%	3.24E+00
100%	1.52E+01

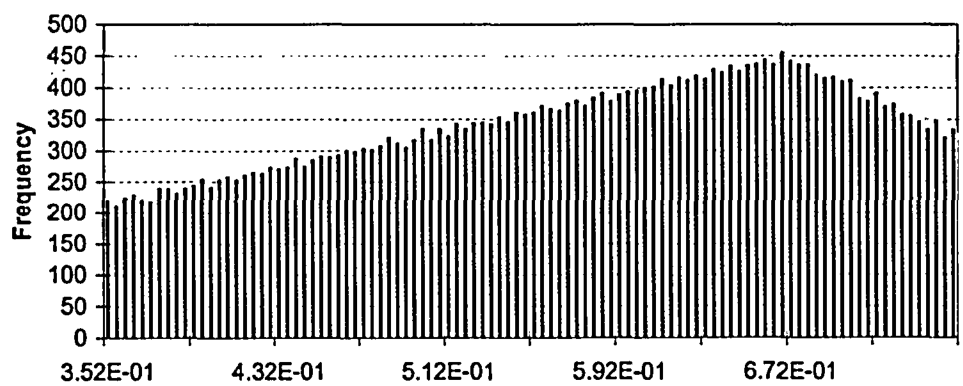
End of Forecast

Forecast: Fraction of deposited activity initially **Cell: B10**

Summary:
Display Range is from 3.50E-1 to 7.50E-1
Entire Range is from 6.25E-2 to 9.47E-1
After 50,000 Trials, the Std. Error of the Mean is 8.31E-4

Statistics:	Value
Trials	50000
Mean	5.60E-01
Median	5.81E-01
Mode	---
Standard Deviation	1.86E-01
Variance	3.45E-02
Skewness	-0.33
Kurtosis	2.40
Coeff. of Variability	0.33
Range Minimum	6.25E-02
Range Maximum	9.47E-01
Range Width	8.85E-01
Mean Std. Error	8.31E-04

Forecast: Fraction of deposited activity initially



Forecast: Fraction of deposited activity initially (cont'd) **Cell: B10**

Percentiles:

Percentile	Value
0%	6.25E-02
10%	2.93E-01
25%	4.28E-01
50%	5.81E-01
75%	7.00E-01
90%	7.92E-01
100%	9.47E-01

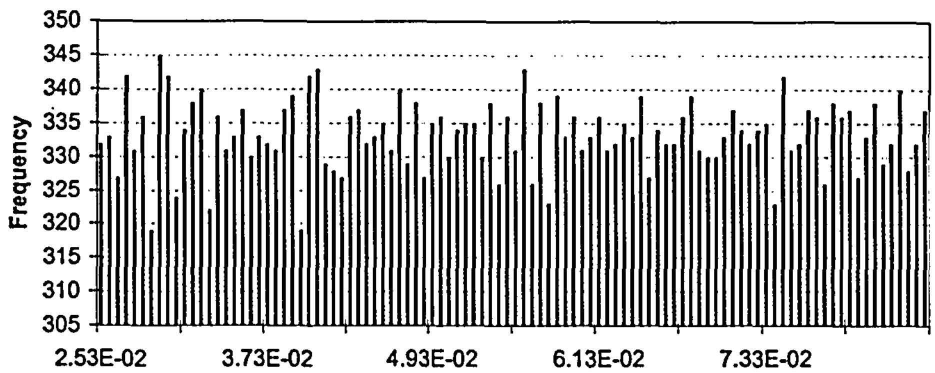
End of Forecast

Forecast: Translocation factor - Other Vegetables **Cell: C9**

Summary:
Display Range is from 2.50E-2 to 8.50E-2
Entire Range is from 1.00E-2 to 1.00E-1
After 50,000 Trials, the Std. Error of the Mean is 1.16E-4

Statistics:	Value
Trials	50000
Mean	5.50E-02
Median	5.50E-02
Mode	---
Standard Deviation	2.60E-02
Variance	6.75E-04
Skewness	0.00
Kurtosis	1.80
Coeff. of Variability	0.47
Range Minimum	1.00E-02
Range Maximum	1.00E-01
Range Width	9.00E-02
Mean Std. Error	1.16E-04

Forecast: Translocation factor - Other Vegetables



Forecast: Translocation factor - Other Vegetables (cont'd) **Cell: C9**

Percentiles:

Percentile	Value
0%	1.00E-02
10%	1.90E-02
25%	3.25E-02
50%	5.50E-02
75%	7.75E-02
90%	9.10E-02
100%	1.00E-01

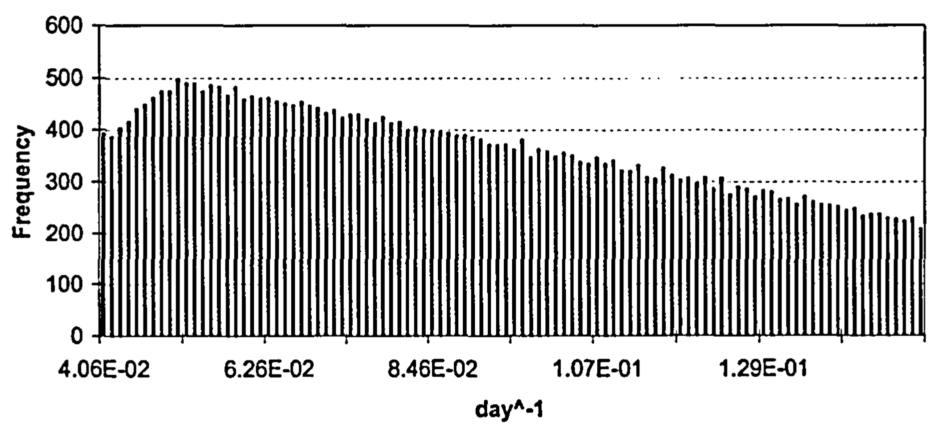
End of Forecast

Forecast: weathering constant **Cell: B8**

Summary:
Display Range is from 4.00E-2 to 1.50E-1 day^-1
Entire Range is from 8.50E-3 to 2.29E-1 day^-1
After 50,000 Trials, the Std. Error of the Mean is 2.15E-4

Statistics:	Value
Trials	50000
Mean	9.61E-02
Median	8.87E-02
Mode	---
Standard Deviation	4.81E-02
Variance	2.32E-03
Skewness	0.49
Kurtosis	2.40
Coeff. of Variability	0.50
Range Minimum	8.50E-03
Range Maximum	2.29E-01
Range Width	2.20E-01
Mean Std. Error	2.15E-04

Forecast: weathering constant



Forecast: weathering constant (cont'd) **Cell: B8**

Percentiles:

Percentile	day^-1
0%	8.50E-03
10%	3.86E-02
25%	5.70E-02
50%	8.87E-02
75%	1.30E-01
90%	1.67E-01
100%	2.29E-01

End of Forecast

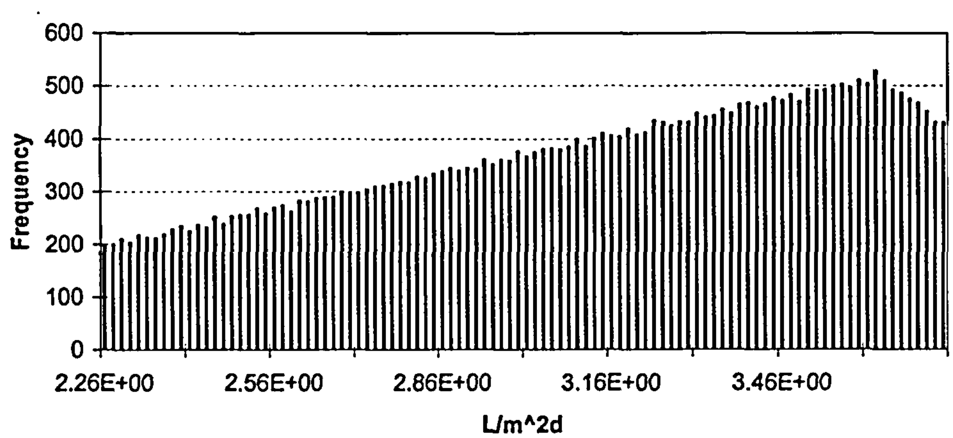
Forecast: Irrigation Rate **Cell: B6**

Summary:

Display Range is from 2.25E+0 to 3.75E+0 L/m^2d
Entire Range is from 1.41E+0 to 4.29E+0 L/m^2d
After 50,000 Trials, the Std. Error of the Mean is 2.77E-3

Statistics:	Value
Trials	50000
Mean	3.11E+00
Median	3.20E+00
Mode	---
Standard Deviation	6.20E-01
Variance	3.84E-01
Skewness	-0.44
Kurtosis	2.40
Coeff. of Variability	0.20
Range Minimum	1.41E+00
Range Maximum	4.29E+00
Range Width	2.88E+00
Mean Std. Error	2.77E-03

Forecast: Irrigation Rate



Forecast: Irrigation Rate (cont'd) **Cell: B6**

Percentiles:

Percentile	L/m^2d
0%	1.41E+00
10%	2.20E+00
25%	2.67E+00
50%	3.20E+00
75%	3.60E+00
90%	3.86E+00
100%	4.29E+00

End of Forecast

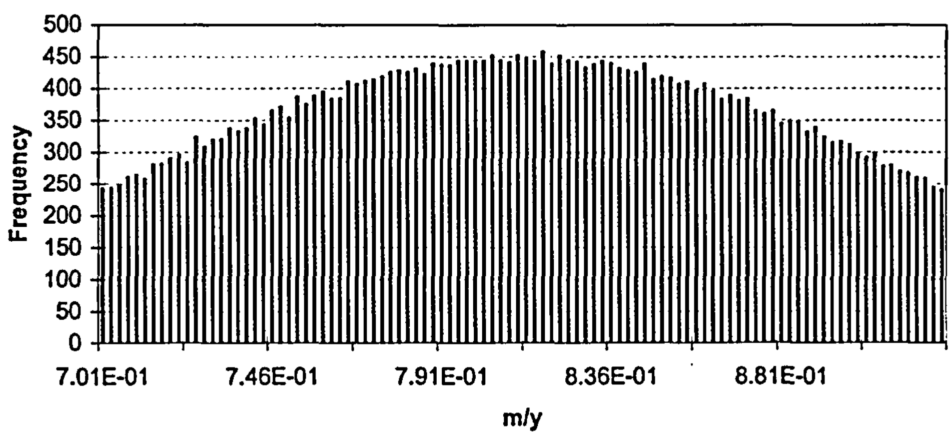
Forecast: Rainfall **Cell: B19**

Summary:

Display Range is from 7.00E-1 to 9.25E-1 m/y
Entire Range is from 4.19E-1 to 1.19E+0 m/y
After 50,000 Trials, the Std. Error of the Mean is 4.47E-4

Statistics:	Value
Trials	50000
Mean	8.13E-01
Median	8.13E-01
Mode	---
Standard Deviation	1.00E-01
Variance	1.00E-02
Skewness	0.00
Kurtosis	2.99
Coeff. of Variability	0.12
Range Minimum	4.19E-01
Range Maximum	1.19E+00
Range Width	7.69E-01
Mean Std. Error	4.47E-04

Forecast: Rainfall



Forecast: Rainfall (cont'd) **Cell: B19**

Percentiles:

Percentile	m/y
0%	4.19E-01
10%	6.85E-01
25%	7.45E-01
50%	8.13E-01
75%	8.80E-01
90%	9.41E-01
100%	1.19E+00

End of Forecast

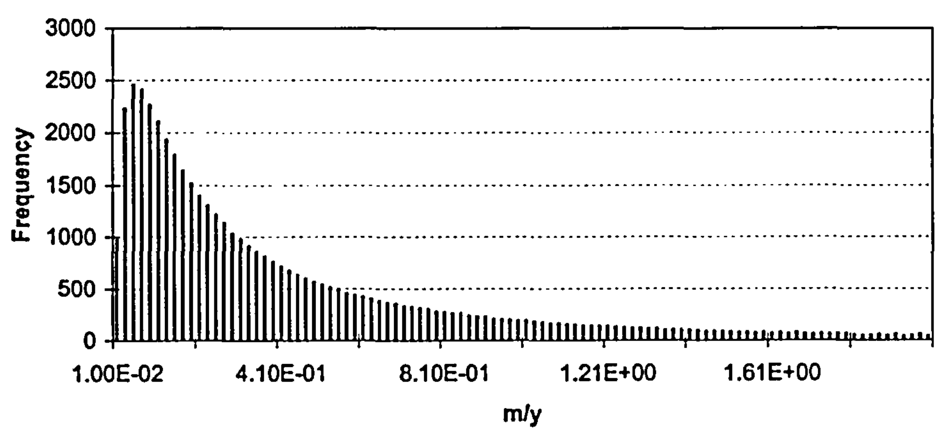
Forecast: hydraulic conductivity **Cell: B23**

Summary:

Display Range is from 0.00E+0 to 2.00E+0 m/y
Entire Range is from 5.07E-3 to 1.65E+1 m/y
After 50,000 Trials, the Std. Error of the Mean is 5.19E-3

Statistics:	Value
Trials	50000
Mean	6.60E-01
Median	2.90E-01
Mode	---
Standard Deviation	1.16E+00
Variance	1.34E+00
Skewness	5.26
Kurtosis	43.39
Coeff. of Variability	1.76
Range Minimum	5.07E-03
Range Maximum	1.65E+01
Range Width	1.65E+01
Mean Std. Error	5.19E-03

Forecast: hydraulic conductivity



Percentiles:

Percentile	m/y
0%	5.07E-03
10%	5.44E-02
25%	1.20E-01
50%	2.90E-01
75%	7.00E-01
90%	1.54E+00
100%	1.65E+01

End of Forecast

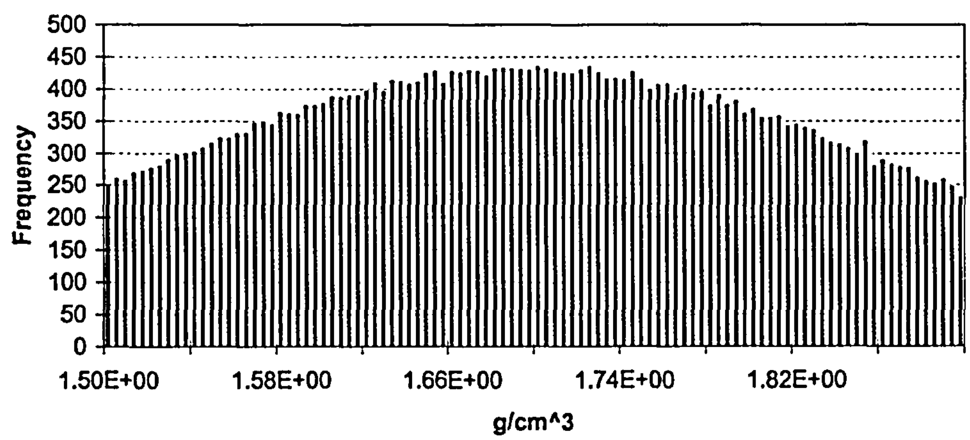
Forecast: soil density **Cell: B27**

Summary:

Display Range is from 1.50E+0 to 1.90E+0 g/cm^3
Entire Range is from 1.12E+0 to 2.27E+0 g/cm^3
After 50,000 Trials, the Std. Error of the Mean is 8.21E-4

Statistics:	Value
Trials	50000
Mean	1.70E+00
Median	1.70E+00
Mode	---
Standard Deviation	1.84E-01
Variance	3.37E-02
Skewness	0.00
Kurtosis	2.86
Coeff. of Variability	0.11
Range Minimum	1.12E+00
Range Maximum	2.27E+00
Range Width	1.14E+00
Mean Std. Error	8.21E-04

Forecast: soil density



Forecast: soil density (cont'd) **Cell: B27**

Percentiles:

Percentile	g/cm^3
0%	1.12E+00
10%	1.46E+00
25%	1.57E+00
50%	1.70E+00
75%	1.82E+00
90%	1.93E+00
100%	2.27E+00

End of Forecast

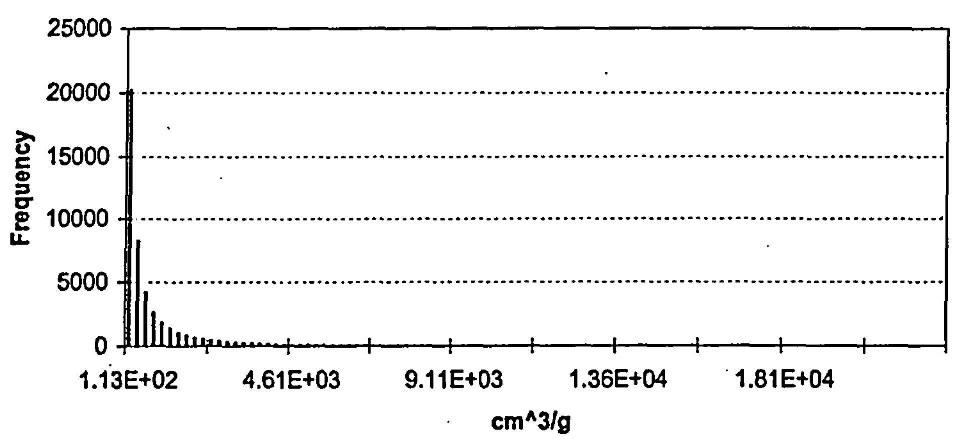
Forecast: distribution coefficient **Cell: B28**

Summary:

Display Range is from 0.00E+0 to 2.25E+4 cm^3/g
Entire Range is from 4.60E+1 to 2.74E+6 cm^3/g
After 50,000 Trials, the Std. Error of the Mean is 8.38E+1

Statistics:	Value
Trials	50000
Mean	2.34E+03
Median	3.28E+02
Mode	---
Standard Deviation	1.87E+04
Variance	3.51E+08
Skewness	77.16
Kurtosis	9,743.85
Coeff. of Variability	8.00
Range Minimum	4.60E+01
Range Maximum	2.74E+06
Range Width	2.74E+06
Mean Std. Error	8.38E+01

Forecast: distribution coefficient



Forecast: distribution coefficient (cont'd) **Cell: B28**

Percentiles:

Percentile	cm^3/g
0%	4.60E+01
10%	6.91E+01
25%	1.23E+02
50%	3.28E+02
75%	1.10E+03
90%	3.68E+03
100%	2.74E+06

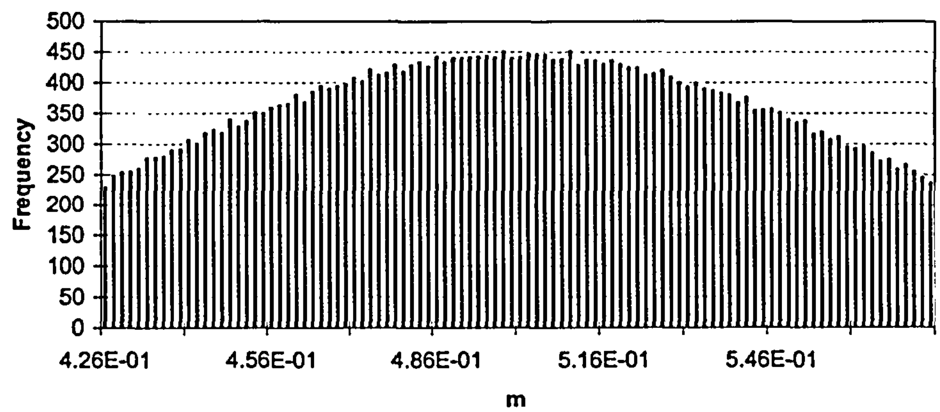
End of Forecast

Forecast: Root Zone Thickness - Leafy Veg **Cell: B30**

Summary:
- Display Range is from 4.25E-1 to 5.75E-1 m
- Entire Range is from 2.28E-1 to 7.73E-1 m
- After 50,000 Trials, the Std. Error of the Mean is 3.00E-4

Statistics:	Value
Trials	50000
Mean	5.00E-01
Median	5.00E-01
Mode	---
Standard Deviation	6.70E-02
Variance	4.49E-03
Skewness	0.00
Kurtosis	2.99
Coeff. of Variability	0.13
Range Minimum	2.28E-01
Range Maximum	7.73E-01
Range Width	5.45E-01
Mean Std. Error	3.00E-04

Forecast: Root Zone Thickness - Leafy Veg



Forecast: Root Zone Thickness - Leafy Veg (cont'd) Cell: B30

Percentiles:

Percentile	m
0%	2.28E-01
10%	4.14E-01
25%	4.55E-01
50%	5.00E-01
75%	5.45E-01
90%	5.86E-01
100%	7.73E-01

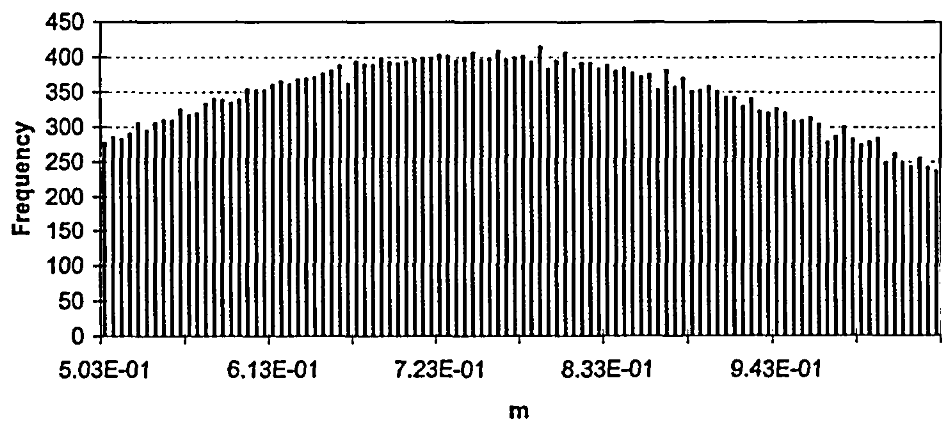
End of Forecast

Forecast: Root Zone Thickness - Other Vegetables **Cell: C30**

Summary:
Display Range is from 5.00E-1 to 1.05E+0 m
Entire Range is from 3.00E-1 to 1.92E+0 m
After 50,000 Trials, the Std. Error of the Mean is 1.15E-3

Statistics:	Value
Trials	50000
Mean	7.87E-01
Median	7.72E-01
Mode	---
Standard Deviation	2.57E-01
Variance	6.61E-02
Skewness	0.37
Kurtosis	2.79
Coeff. of Variability	0.33
Range Minimum	3.00E-01
Range Maximum	1.92E+00
Range Width	1.62E+00
Mean Std. Error	1.15E-03

Forecast: Root Zone Thickness - Other Vegetables



Forecast: Root Zone Thickness - Other Vegetables (cont'd) **Cell: C30**

Percentiles:

Percentile	m
0%	3.00E-01
10%	4.55E-01
25%	5.94E-01
50%	7.72E-01
75%	9.60E-01
90%	1.13E+00
100%	1.92E+00

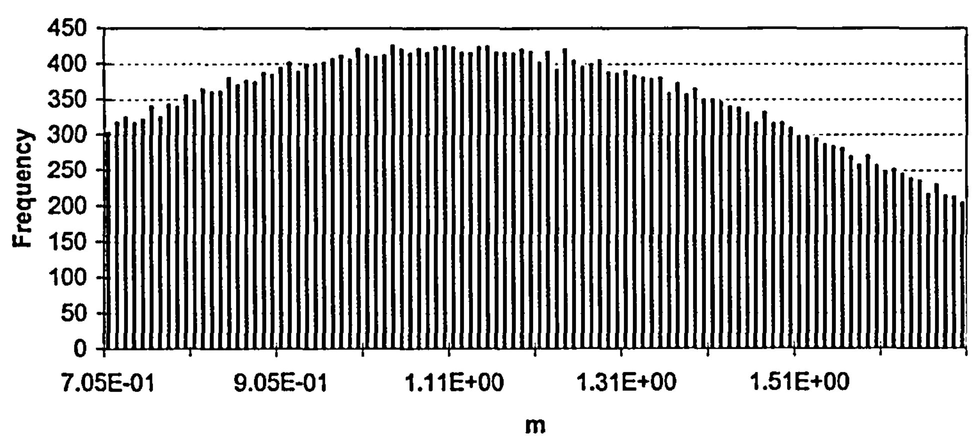
End of Forecast

Forecast: Root Zone Thickness - Fruit **Cell: D30**

Summary:
Display Range is from 7.00E-1 to 1.70E+0 m
Entire Range is from 3.00E-1 to 3.10E+0 m
After 50,000 Trials, the Std. Error of the Mean is 2.00E-3

Statistics:	Value
Trials	50000
Mean	1.16E+00
Median	1.13E+00
Mode	---
Standard Deviation	4.47E-01
Variance	2.00E-01
Skewness	0.35
Kurtosis	2.78
Coeff. of Variability	0.39
Range Minimum	3.00E-01
Range Maximum	3.10E+00
Range Width	2.80E+00
Mean Std. Error	2.00E-03

Forecast: Root Zone Thickness - Fruit



Forecast: Root Zone Thickness - Fruit (cont'd) **Cell: D30**

Percentiles:

Percentile	m
0%	3.00E-01
10%	5.80E-01
25%	8.25E-01
50%	1.13E+00
75%	1.46E+00
90%	1.76E+00
100%	3.10E+00

End of Forecast

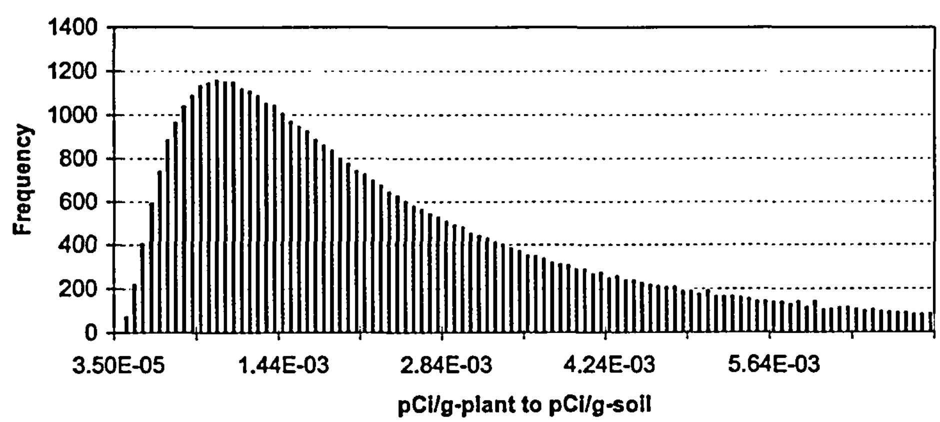
Forecast: Plant to Soil Concen. factor U -leafy **Cell: B33**

Summary:

Display Range is from 0.00E+0 to 7.00E-3 pCi/g-plant to pCi/g-soil
Entire Range is from 4.58E-5 to 8.24E-2 pCi/g-plant to pCi/g-soil
After 50,000 Trials, the Std. Error of the Mean is 1.50E-5

Statistics:	Value
Trials	50000
Mean	3.01E-03
Median	2.01E-03
Mode	---
Standard Deviation	3.37E-03
Variance	1.14E-05
Skewness	4.61
Kurtosis	47.57
Coeff. of Variability	1.12
Range Minimum	4.58E-05
Range Maximum	8.24E-02
Range Width	8.23E-02
Mean Std. Error	1.51E-05

Forecast: Plant to Soil Concen. factor U -leafy



Forecast: Plant to Soil Concen. factor U -leafy (cont'd) **Cell: B33**

Percentiles:

Percentile	pCi/g-plant to pCi/g-soil
0%	4.58E-05
10%	6.34E-04
25%	1.09E-03
50%	2.01E-03
75%	3.69E-03
90%	6.37E-03
100%	8.24E-02

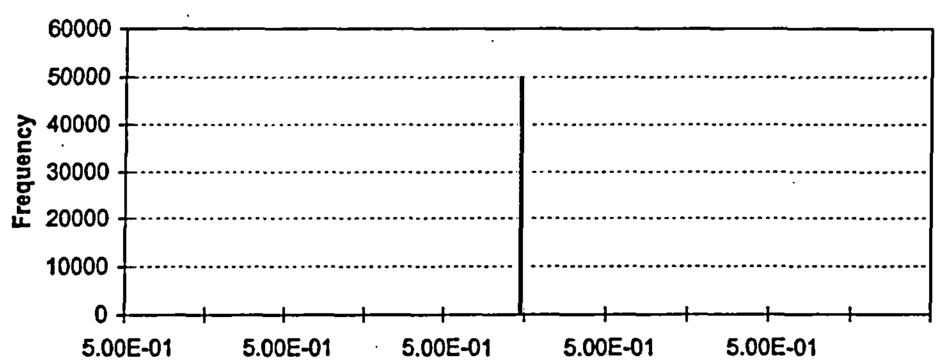
End of Forecast

Forecast: Losses during Food Preparation **Cell: B35**

Summary:
Display Range is from 5.00E-1 to 5.00E-1
Entire Range is from 5.00E-1 to 5.00E-1
After 50,000 Trials, the Std. Error of the Mean is 0.00E+0

Statistics:	Value
Trials	50000
Mean	5.00E-01
Median	5.00E-01
Mode	5.00E-01
Standard Deviation	0.00E+00
Variance	0.00E+00
Skewness	0.00
Kurtosis	+Infinity
Coeff. of Variability	0.00
Range Minimum	5.00E-01
Range Maximum	5.00E-01
Range Width	0.00E+00
Mean Std. Error	0.00E+00

Forecast: Losses during Food Preparation



Forecast: Losses during Food Preparation (cont'd) **Cell: B35**

Percentiles:

Percentile	Value
0%	5.00E-01
10%	5.00E-01
25%	5.00E-01
50%	5.00E-01
75%	5.00E-01
90%	5.00E-01
100%	5.00E-01

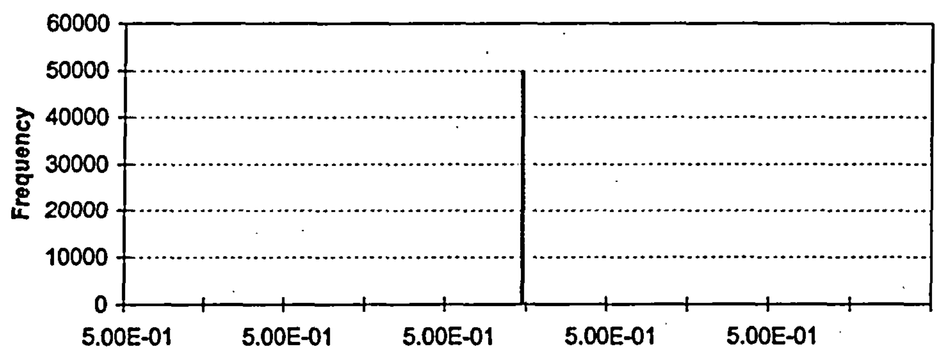
End of Forecast

Forecast: Losses during Food Preparation **Cell: C35**

Summary:
Display Range is from 5.00E-1 to 5.00E-1
Entire Range is from 5.00E-1 to 5.00E-1
After 50,000 Trials, the Std. Error of the Mean is 0.00E+0

Statistics:	Value
Trials	50000
Mean	5.00E-01
Median	5.00E-01
Mode	5.00E-01
Standard Deviation	0.00E+00
Variance	0.00E+00
Skewness	0.00
Kurtosis	+Infinity
Coeff. of Variability	0.00
Range Minimum	5.00E-01
Range Maximum	5.00E-01
Range Width	0.00E+00
Mean Std. Error	0.00E+00

Forecast: Losses during Food Preparation



Forecast: Losses during Food Preparation (cont'd) **Cell: C35**

Percentiles:

Percentile	Value
0%	5.00E-01
10%	5.00E-01
25%	5.00E-01
50%	5.00E-01
75%	5.00E-01
90%	5.00E-01
100%	5.00E-01

End of Forecast

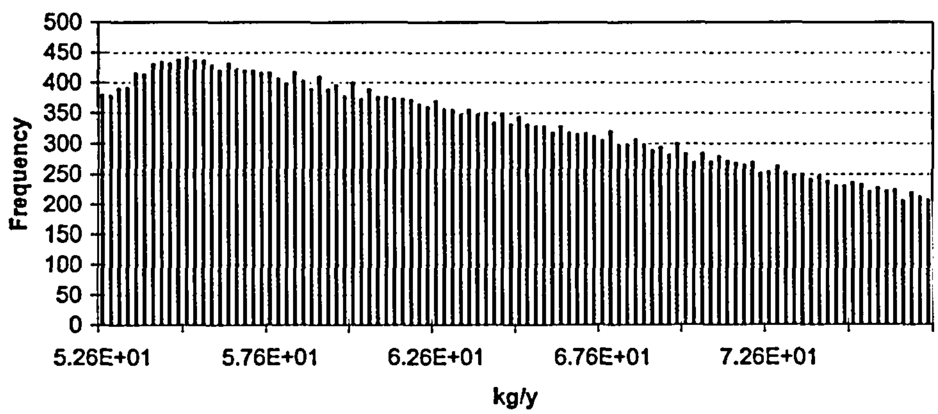
Forecast: Consumption Rate of Non-Leafy Veg **Cell: C38**

Summary:

Display Range is from 5.25E+1 to 7.75E+1 kg/y
Entire Range is from 4.15E+1 to 9.76E+1 kg/y
After 50,000 Trials, the Std. Error of the Mean is 5.37E-2

Statistics:	Value
Trials	50000
Mean	6.46E+01
Median	6.29E+01
Mode	---
Standard Deviation	1.20E+01
Variance	1.44E+02
Skewness	0.44
Kurtosis	2.40
Coeff. of Variability	0.19
Range Minimum	4.15E+01
Range Maximum	9.76E+01
Range Width	5.61E+01
Mean Std. Error	5.37E-02

Forecast: Consumption Rate of Non-Leafy Veg



Forecast: Consumption Rate of Non-Leafy Veg (cont'd) **Cell: C38**

Percentiles:

Percentile	kg/y
0%	4.15E+01
10%	5.01E+01
25%	5.51E+01
50%	6.29E+01
75%	7.31E+01
90%	8.21E+01
100%	9.76E+01

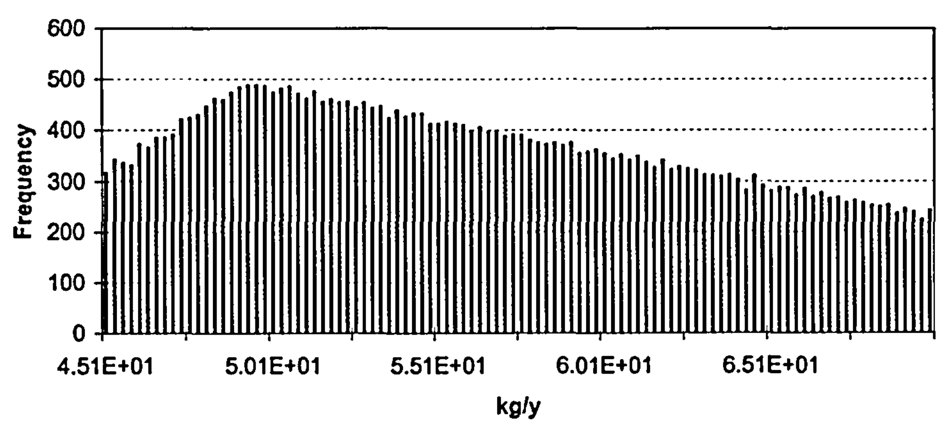
End of Forecast

Forecast: Consumption Rate of Fruit **Cell: D38**

Summary:
Display Range is from 4.50E+1 to 7.00E+1 kg/y
Entire Range is from 3.74E+1 to 8.80E+1 kg/y
After 50,000 Trials, the Std. Error of the Mean is 4.84E-2

Statistics:	Value
Trials	50000
Mean	5.83E+01
Median	5.67E+01
Mode	---
Standard Deviation	1.08E+01
Variance	1.17E+02
Skewness	0.44
Kurtosis	2.40
Coeff. of Variability	0.19
Range Minimum	3.74E+01
Range Maximum	8.80E+01
Range Width	5.05E+01
Mean Std. Error	4.84E-02

Forecast: Consumption Rate of Fruit



Percentiles:

Percentile	kg/y
0%	3.74E+01
10%	4.52E+01
25%	4.97E+01
50%	5.67E+01
75%	6.59E+01
90%	7.41E+01
100%	8.80E+01

End of Forecast

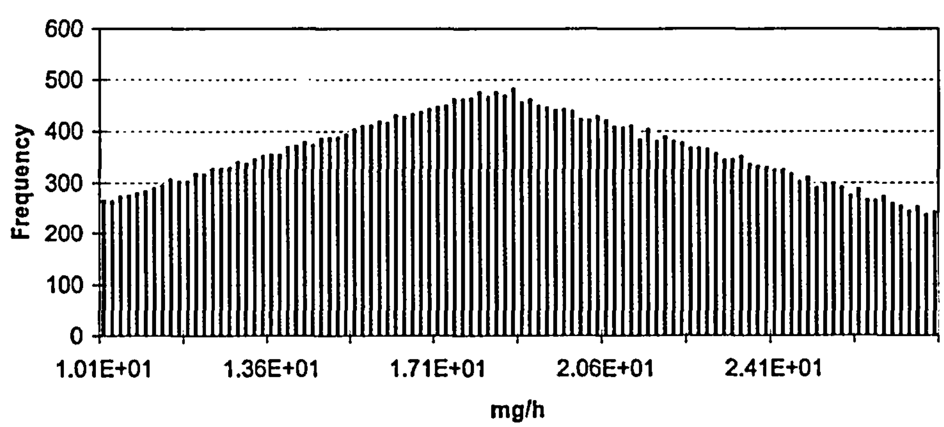
Forecast: Soil ingestion rate - gardening **Cell: B46**

Summary:

Display Range is from 1.00E+1 to 2.75E+1 mg/h
Entire Range is from 2.18E-2 to 3.64E+1 mg/h
After 50,000 Trials, the Std. Error of the Mean is 3.33E-2

Statistics:	Value
Trials	50000
Mean	1.83E+01
Median	1.82E+01
Mode	---
Standard Deviation	7.45E+00
Variance	5.55E+01
Skewness	0.00
Kurtosis	2.40
Coeff. of Variability	0.41
Range Minimum	2.18E-02
Range Maximum	3.64E+01
Range Width	3.64E+01
Mean Std. Error	3.33E-02

Forecast: Soil ingestion rate - gardening



Forecast: Soil ingestion rate - gardening (cont'd) **Cell: B46**

Percentiles:

Percentile	mg/h
0%	2.18E-02
10%	8.16E+00
25%	1.29E+01
50%	1.82E+01
75%	2.36E+01
90%	2.83E+01
100%	3.64E+01

End of Forecast

Crystal Ball Report
Simulation started on 12/24/03 at 12:20:10
Simulation stopped on 12/24/03 at 12:23:42

Assumptions

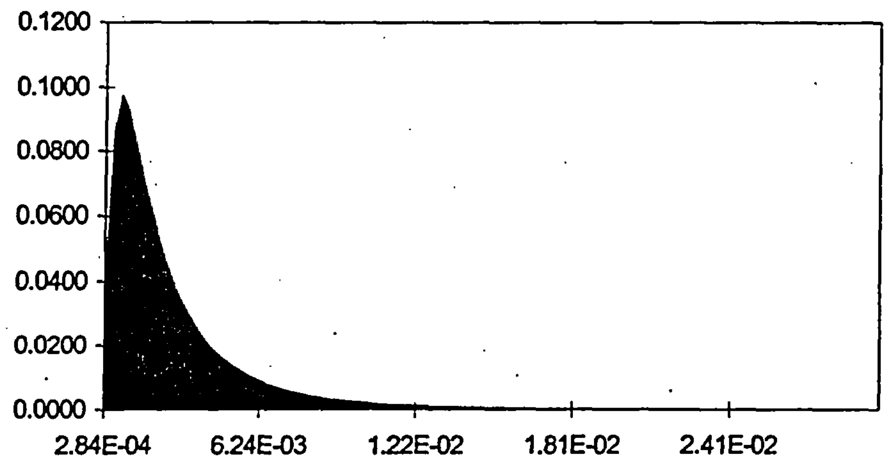
Assumption: Plant to Soil Concen. factor U -leafy **Cell: B33**

Lognormal distribution with parameters:

Log Mean	-6.21E+00
Log Std. Dev.	9.00E-01

Selected range is from 0.00E+0 to +Infinity

Assumption: Plant to Soil Concen. factor U -leafy



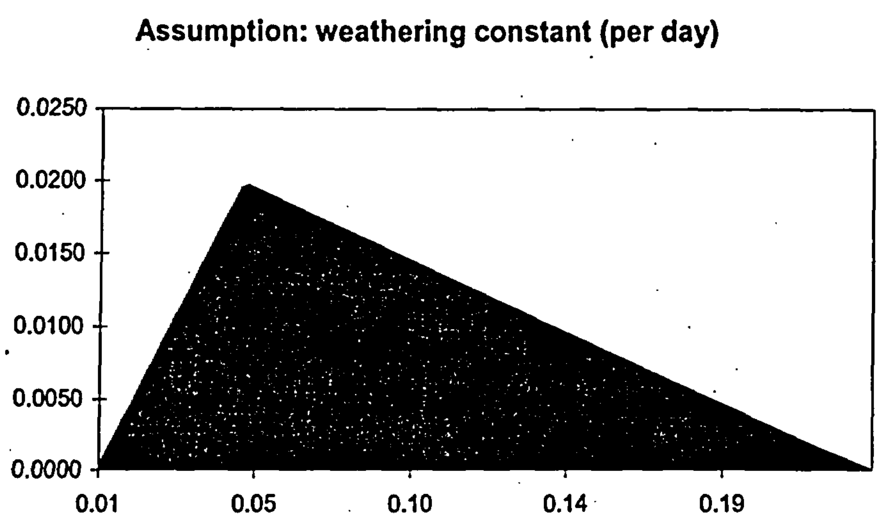
Assumption: weathering constant (per day) **Cell: B8**

Triangular distribution with parameters:

Minimum	0.01
Likeliest	0.05
Maximum	0.23

Selected range is from 0.01 to 0.23

Assumption: weathering constant (per day) (cont'd) **Cell: B8**



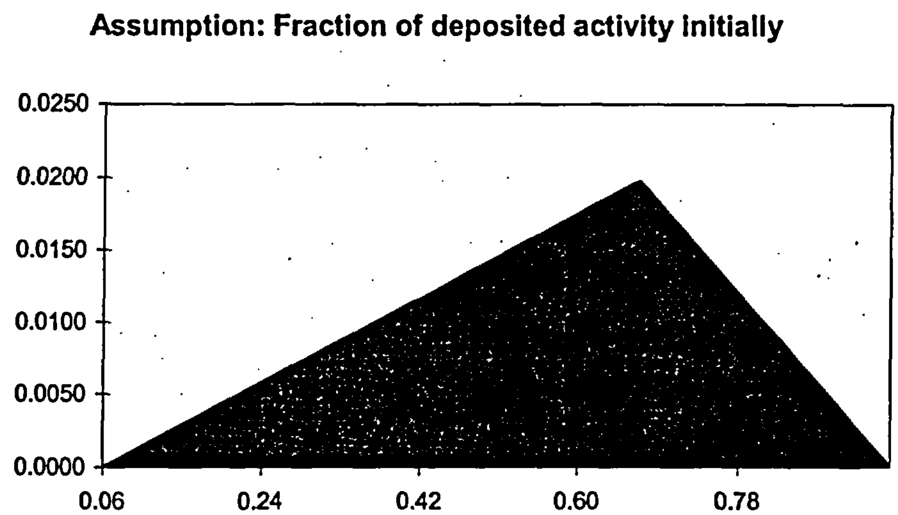
Assumption: Fraction of deposited activity initially **Cell: B10**

Triangular distribution with parameters:

Minimum	0.06
Likeliest	0.67
Maximum	0.95

Selected range is from 0.06 to 0.95

Assumption: Fraction of deposited activity initially (cont'd) **Cell: B10**



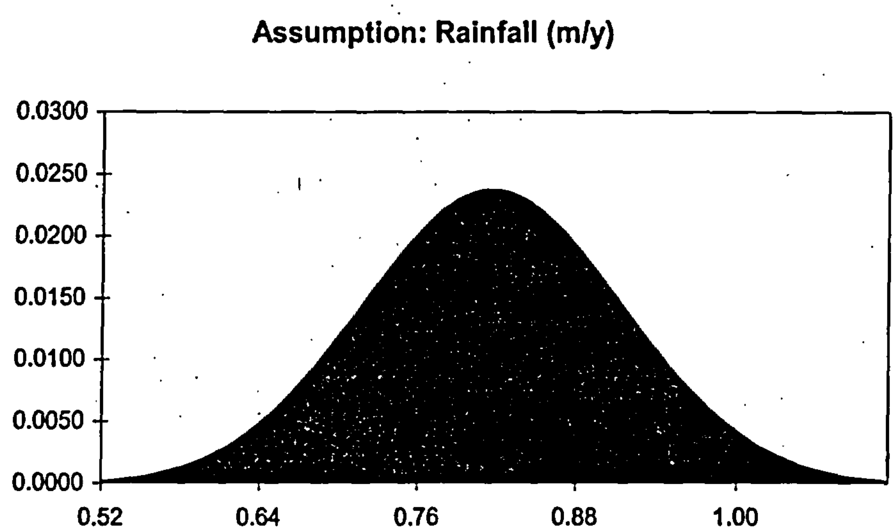
Assumption: Rainfall (m/y) **Cell: B19**

Normal distribution with parameters:

Mean	0.81
Standard Dev.	0.10

Selected range is from -Infinity to +Infinity

Assumption: Rainfall (m/y) (cont'd) **Cell: B19**



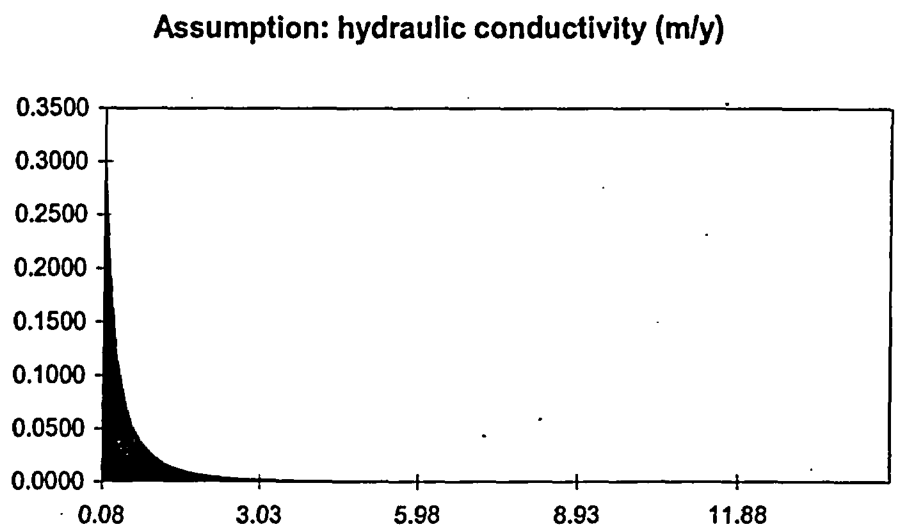
Assumption: hydraulic conductivity (m/y) **Cell: B23**

Lognormal distribution with parameters:

Log Mean	-1.24
Log Std. Dev.	1.31

Selected range is from 0.01 to 16.60

Assumption: hydraulic conductivity (m/y) (cont'd) **Cell: B23**



Assumption: Plant Yield - other veg **Cell: C11**

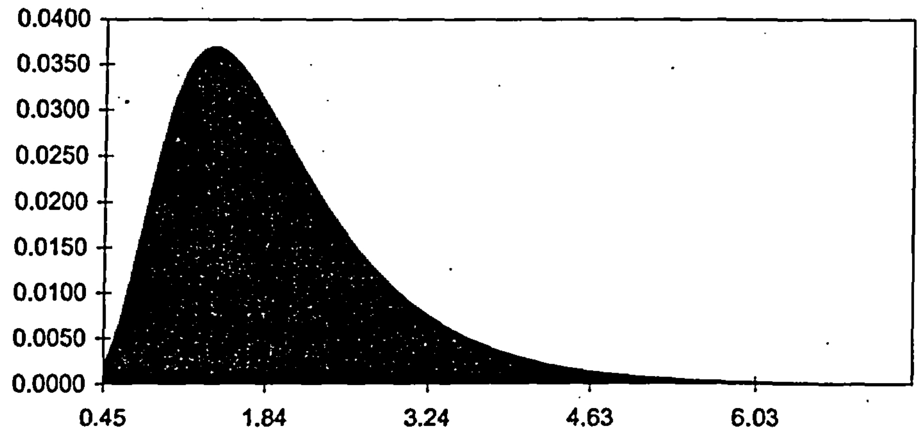
Lognormal distribution with parameters:

Log Mean	0.56
Log Std. Dev.	0.48

Selected range is from 0.00 to +Infinity

Assumption: Plant Yield - other veg (cont'd) **Cell: C11**

Assumption: Plant Yield - other veg



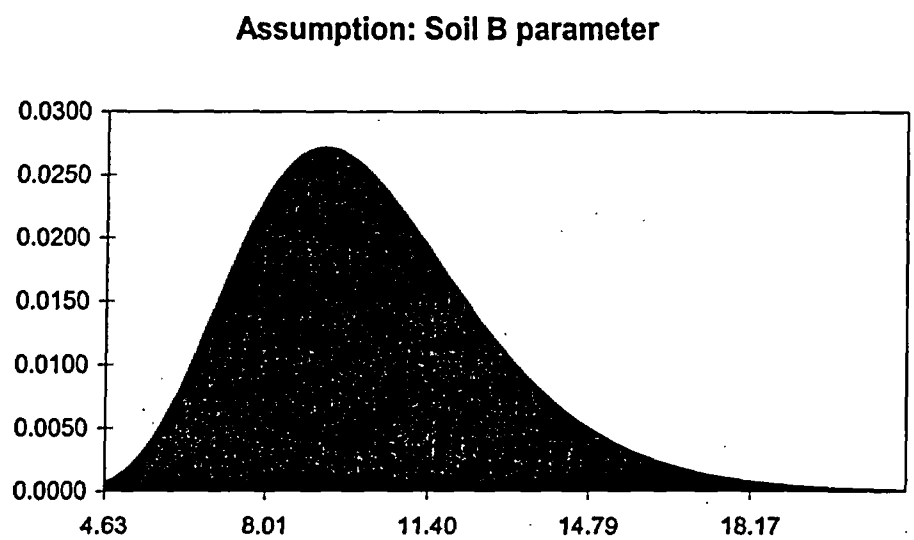
Assumption: Soil B parameter **Cell: B24**

Lognormal distribution with parameters:

Log Mean	2.29
Log Std. Dev.	0.26

Selected range is from 4.43 to 22.00

Assumption: Soil B parameter (cont'd) **Cell: B24**



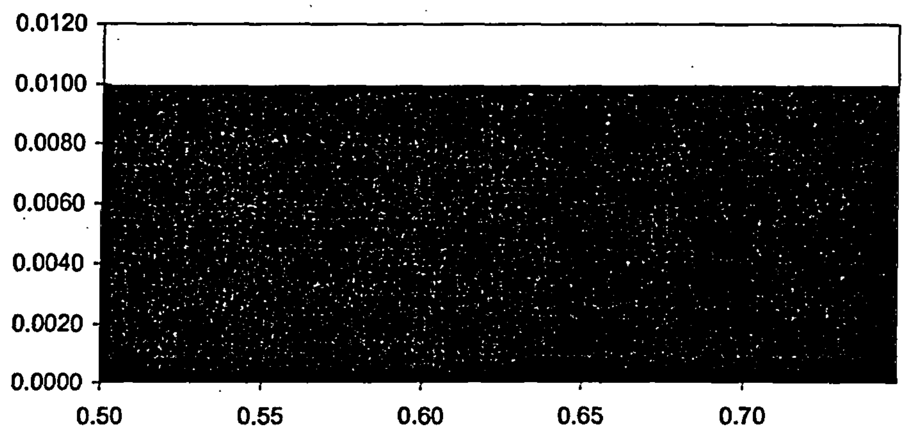
Assumption: Evapotranspiration coefficient **Cell: B17**

Uniform distribution with parameters:

Minimum	0.50
Maximum	0.75

Assumption: Evapotranspiration coefficient (cont'd) **Cell: B17**

Assumption: Evapotranspiration coefficient



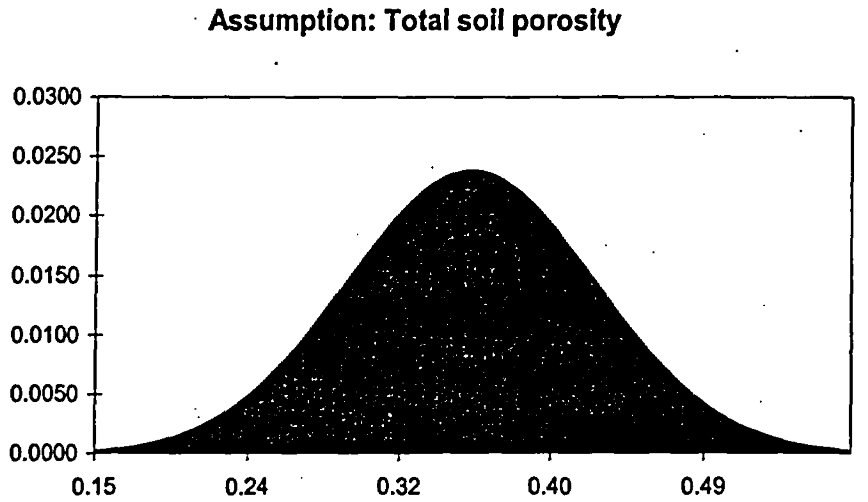
Assumption: Total soil porosity **Cell: B22**

Normal distribution with parameters:

Mean	0.36
Standard Dev.	0.07

Selected range is from 0.14 to 0.58

Assumption: Total soil porosity (cont'd) **Cell: B22**



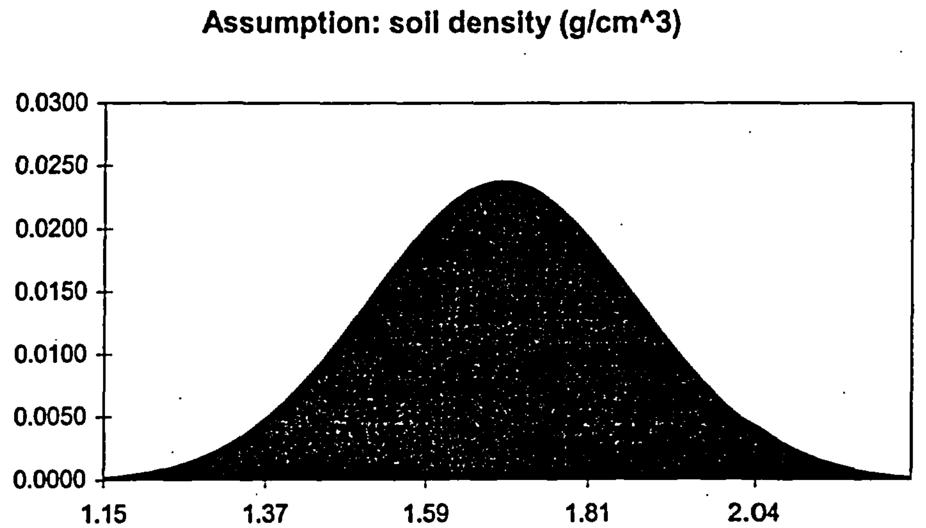
Assumption: soil density (g/cm^3) **Cell: B27**

Normal distribution with parameters:

Mean	1.70
Standard Dev.	0.19

Selected range is from 1.12 to 2.27

Assumption: soil density (g/cm^3) (cont'd) **Cell: B27**



Assumption: C38 **Cell: C38**

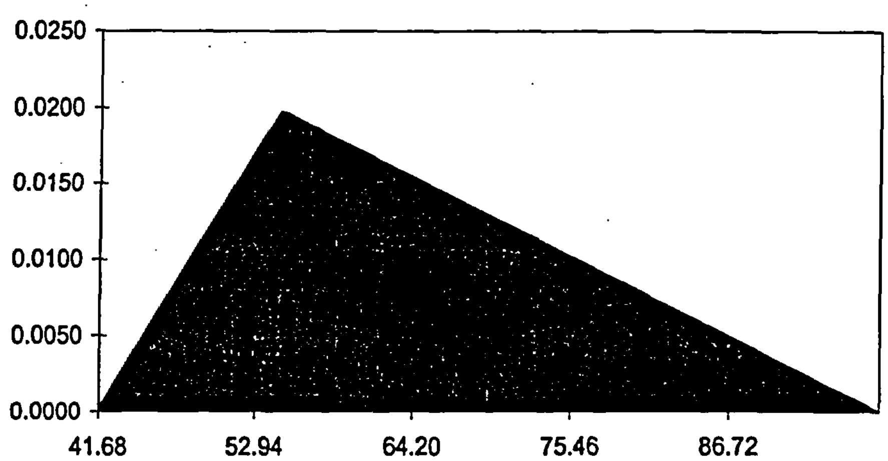
Triangular distribution with parameters:

Minimum	41.40
Likeliest	54.70
Maximum	97.70

Selected range is from 41.40 to 97.70

Assumption: C38 (cont'd) **Cell: C38**

Assumption: C38



Assumption: D38 **Cell: D38**

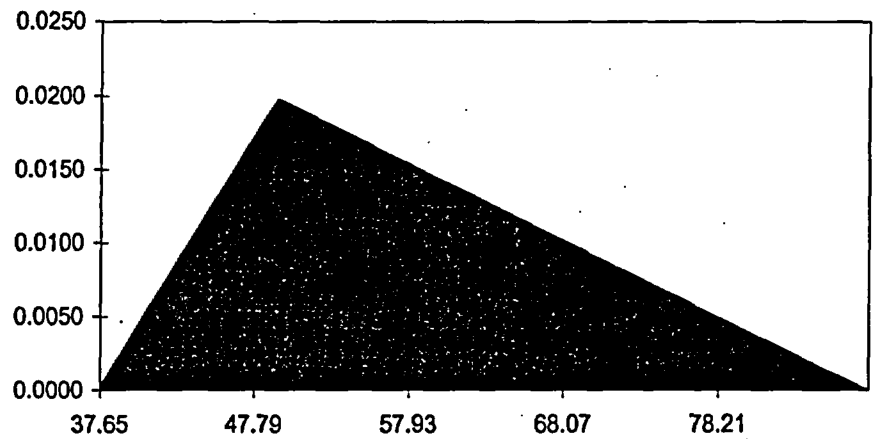
Triangular distribution with parameters:

Minimum	37.40
Likeliest	49.30
Maximum	88.10

Selected range is from 37.40 to 88.10

Assumption: D38 (cont'd) **Cell: D38**

Assumption: D38



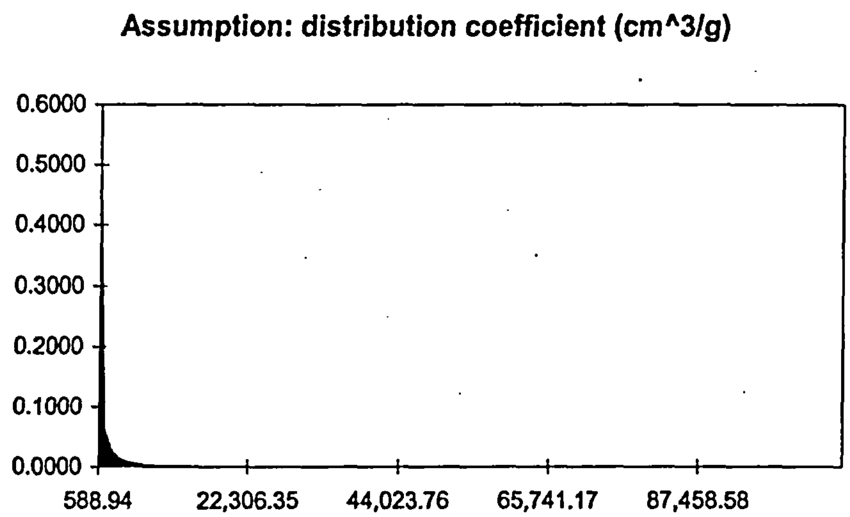
Assumption: distribution coefficient (cm^3/g) **Cell: B28**

Lognormal distribution with parameters:

Mean	1,600.00
Standard Dev.	20,000.00

Selected range is from 46.00 to +Infinity

Assumption: distribution coefficient (cm^3/g) (cont'd) **Cell: B28**

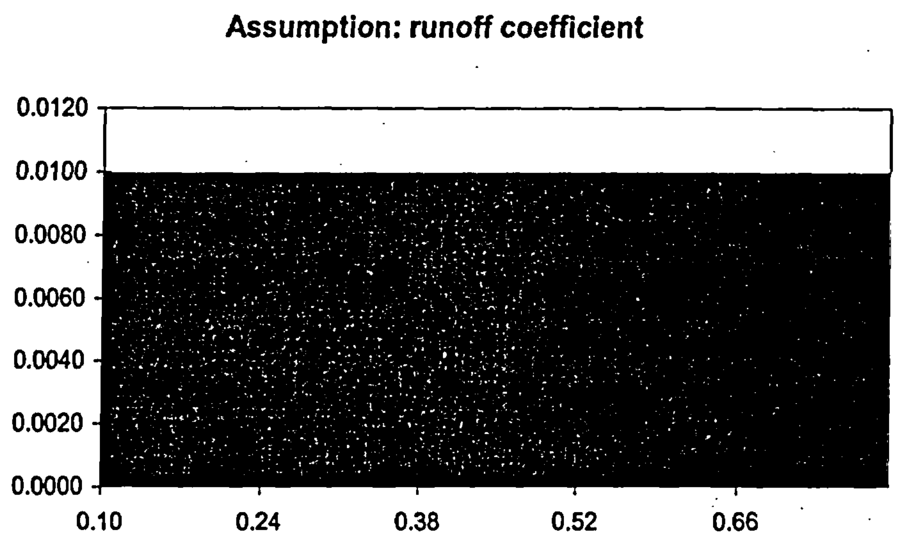


Assumption: runoff coefficient **Cell: B18**

Uniform distribution with parameters:

Minimum	0.10
Maximum	0.80

Assumption: runoff coefficient (cont'd) **Cell: B18**



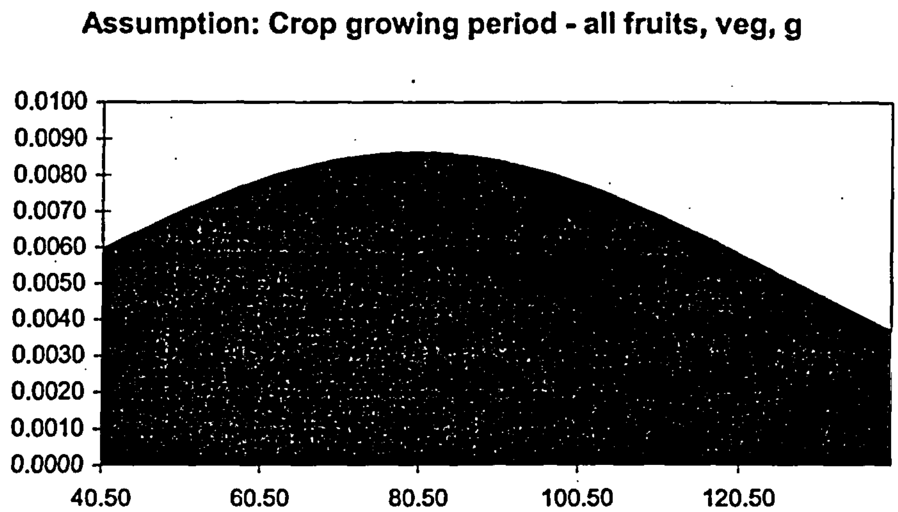
Assumption: Crop growing period - all fruits, veg, g **Cell: B12**

Normal distribution with parameters:

Mean	80.00
Standard Dev.	46.00

Selected range is from 40.00 to 140.00

Assumption: Crop growing period - all fruits, veg, g (cont'd) **Cell: B12**



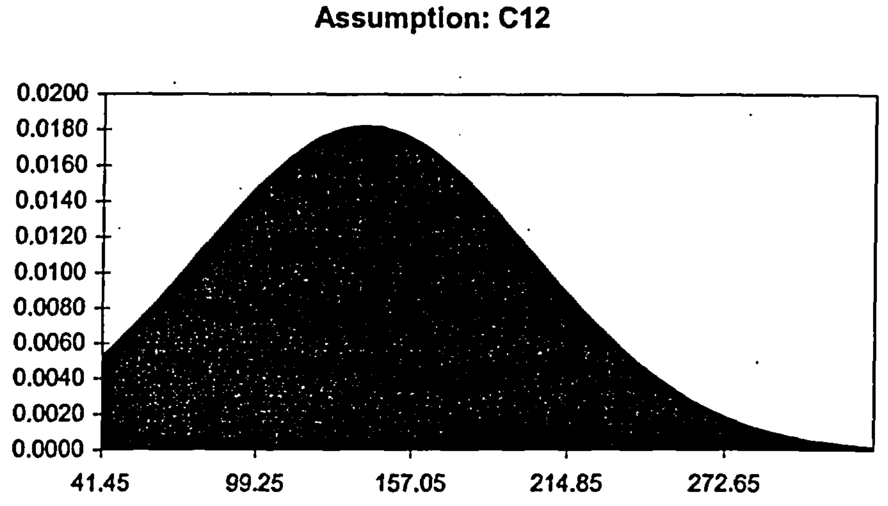
Assumption: C12 **Cell: C12**

Normal distribution with parameters:

Mean	140.00
Standard Dev.	63.00

Selected range is from 40.00 to 350.00

Assumption: C12 (cont'd) **Cell: C12**



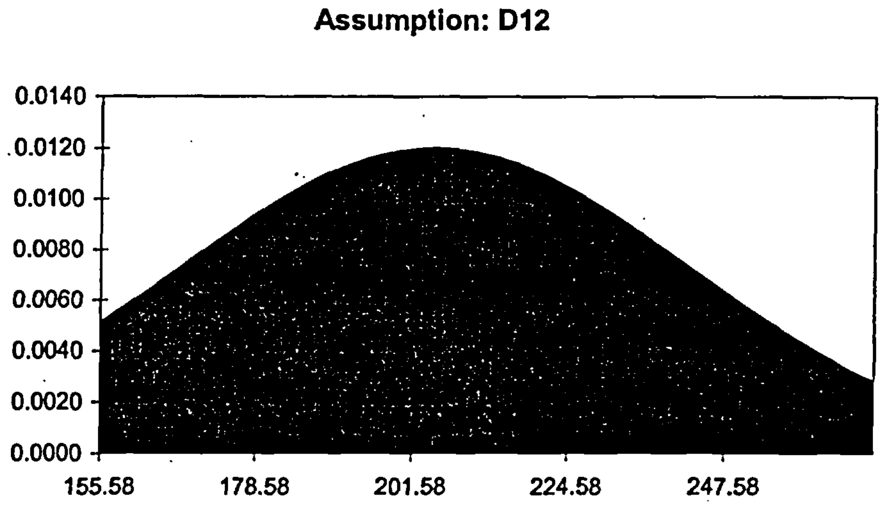
Assumption: D12 **Cell: D12**

Normal distribution with parameters:

Mean	205.00
Standard Dev.	38.00

Selected range is from 155.00 to 270.00

Assumption: D12 (cont'd) **Cell: D12**

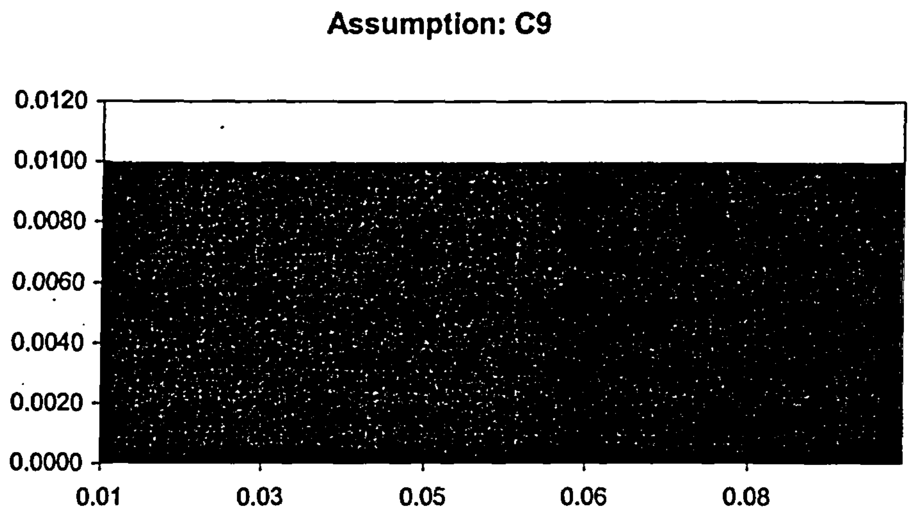


Assumption: C9 **Cell: C9**

Uniform distribution with parameters:

Minimum	0.01
Maximum	0.10

Assumption: C9 (cont'd) **Cell: C9**



Assumption: Soil ingestion rate - gardening (mg/hr) **Cell: B46**

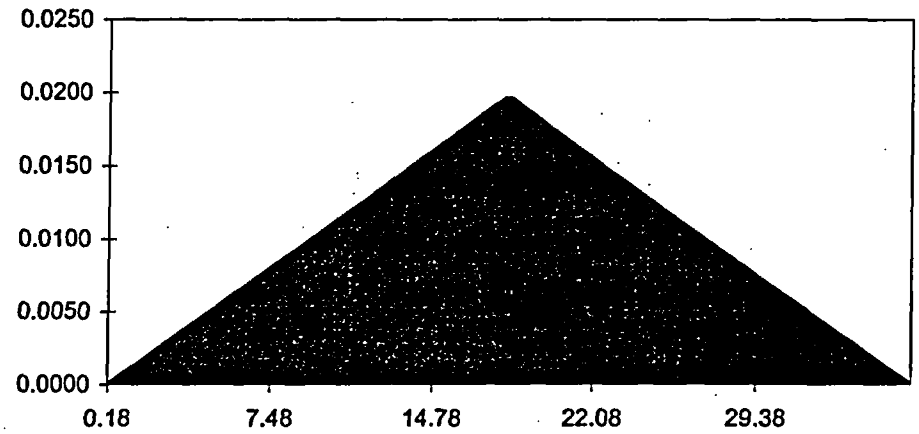
Triangular distribution with parameters:

Minimum	0.00
Likeliest	18.25
Maximum	36.50

Selected range is from 0.00 to 36.50

Assumption: Soil ingestion rate - gardening (mg/hr) (cont'd) **Cell: B46**

Assumption: Soil ingestion rate - gardening (mg/hr)



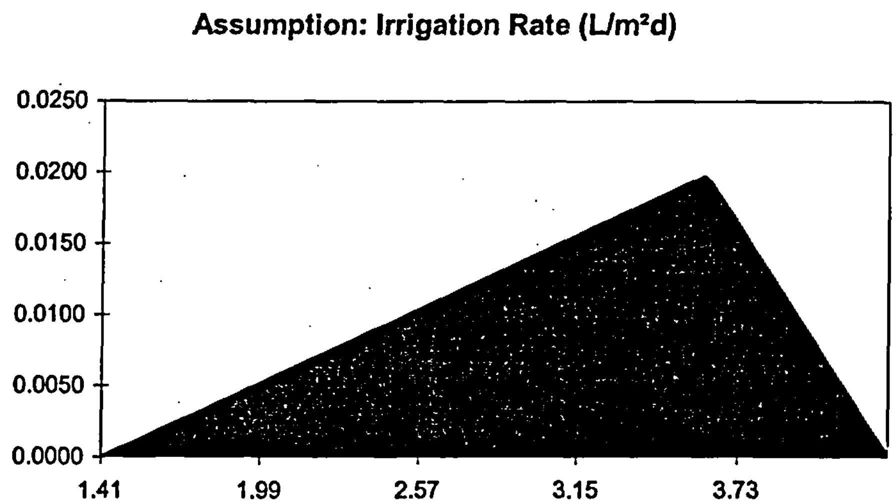
Assumption: Irrigation Rate (L/m²d) **Cell: B6**

Triangular distribution with parameters:

Minimum	1.40
Likeliest	3.63
Maximum	4.30

Selected range is from 1.40 to 4.30

Assumption: Irrigation Rate (L/m²d) (cont'd) **Cell: B6**



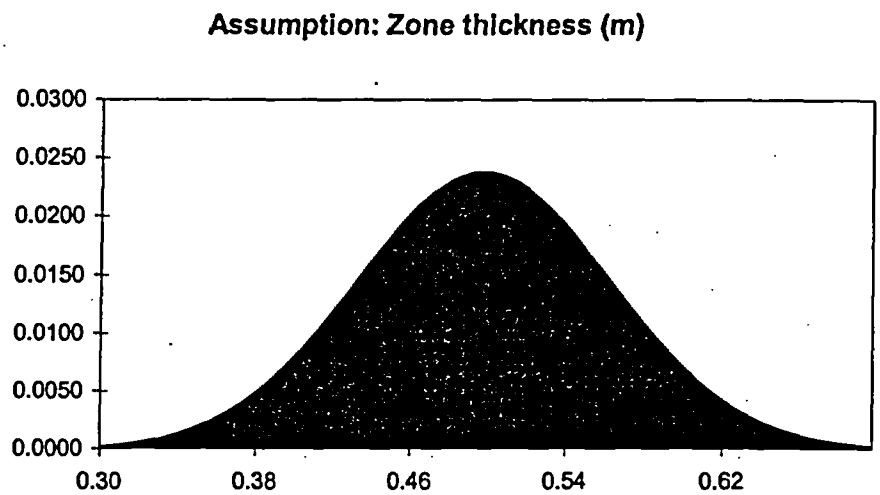
Assumption: Zone thickness (m) **Cell: B30**

Normal distribution with parameters:

Mean	0.50
Standard Dev.	0.07

Selected range is from -Infinity to +Infinity

Assumption: Zone thickness (m) (cont'd) **Cell: B30**



Assumption: C30 **Cell: C30**

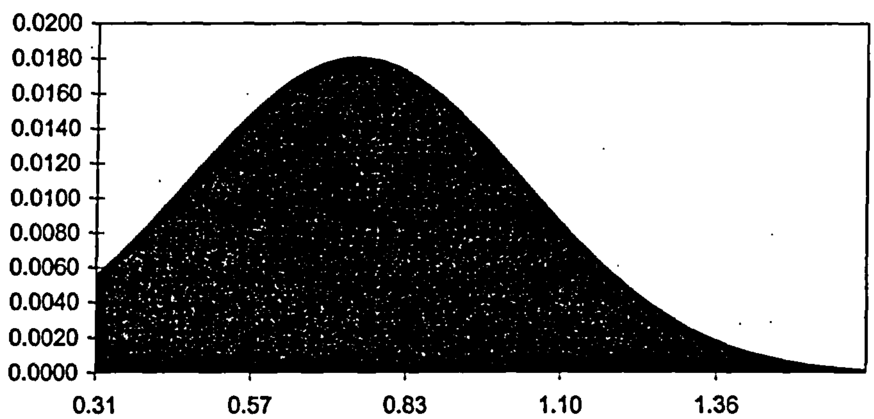
Normal distribution with parameters:

Mean	0.75
Standard Dev.	0.29

Selected range is from 0.30 to +Infinity

Assumption: C30 (cont'd) **Cell: C30**

Assumption: C30



Assumption: D30 **Cell: D30**

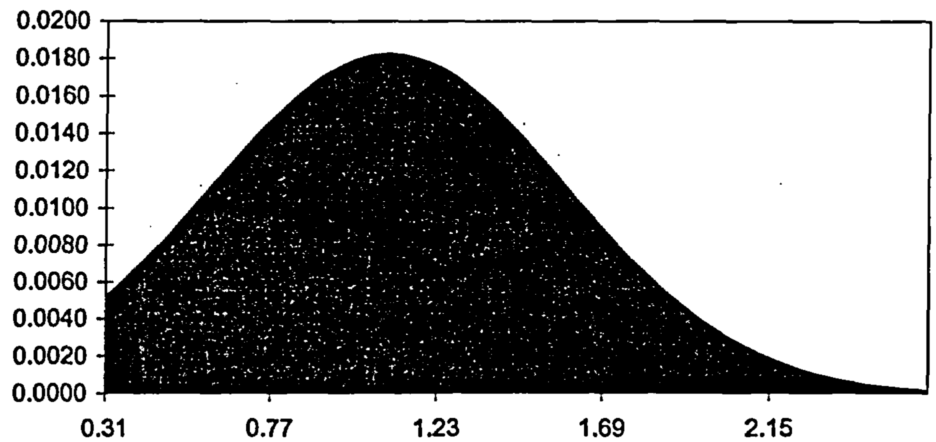
Normal distribution with parameters:

Mean	1.10
Standard Dev.	0.50

Selected range is from 0.30 to +Infinity

Assumption: D30 (cont'd) **Cell: D30**

Assumption: D30



ATTACHMENT 3

STANDARD TESTING AND ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA77 Exp. 06/30/05

Area Offices
902 TRAILS WEST LOOP ENID, OK 73703 (580) 237-3130
900 S.E. SECOND LAWTON, OK 73501 (580) 353-0872
5806 S. 125TH EAST AVE, STE B. TULSA, OK 74134 (918) 459-2700

Project No: 0220KER30 File No: KER30-1
Report Date: 11/3/03 Date Sampled: 10/17/03
Project: Groundwater/ACL Sampled By: Client
Location: CU-23-38-01 By Order Of: T. J. Keane
Arch./Engr: No:
Client: Kerr McGee Corporation Material Represented: Gray Lean Clay w/Sand
REPORT: SOIL CLASSIFICATION & SATURATION RATIO LAB NO: E-8714
Test Method: ASTM D2487

TEST RESULTS

Liquid Limit	29
Plastic Limit	19
Plasticity Index	10
% Passing Sieve No. 10	100
% Passing Sieve No. 40	97
% Passing Sieve No. 100	89
% Passing Sieve No. 200	71.3
Group Symbol	CL
Saturation Ratio	0.945

Charge: Kerr-McGee Corporation
Attn: Terrie Ostmeyer
Cc: Enercon Services Attn: T.J. Keane
Kerr-McGee Laboratory
FAX (918) 225-0567 Attn: T. J. Keane
FAX (918) 225-7749 Attn: T. Lux & T. Ostmeyer

Respectfully submitted,
STANDARD TESTING AND ENGINEERING CO.

Michael W. Morgan, CET
11-03-03

STANDARD TESTING AND ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA77 Exp. 06/30/05

Area Offices

902 TRAILS WEST LOOP	ENID, OK 73703	(580) 237-3130
900 S.E. SECOND	LAWTON, OK 73501	(580) 353-0872
5806 S. 125TH EAST AVE, STE B.	TULSA, OK 74134	(918) 459-2700

Acct. No: 0220KER30 File No: KER30-1
Report Date: 11/3/03 — Date Sampled: 10/17/03
Project: Groundwater/ACL — Sampled By: Client
[illegible] CU-23-38-01 — By Order Of: T. J. Keane
[illegible] — No:
Client: Kerr McGee Corporation — Material Represented: Gray Lean Clay w/Sand
[illegible] GRAIN SIZE ANALYSIS OF SOILS — LAB NO: E-3714A
Test Method: ASTM D422

TEST RESULTS

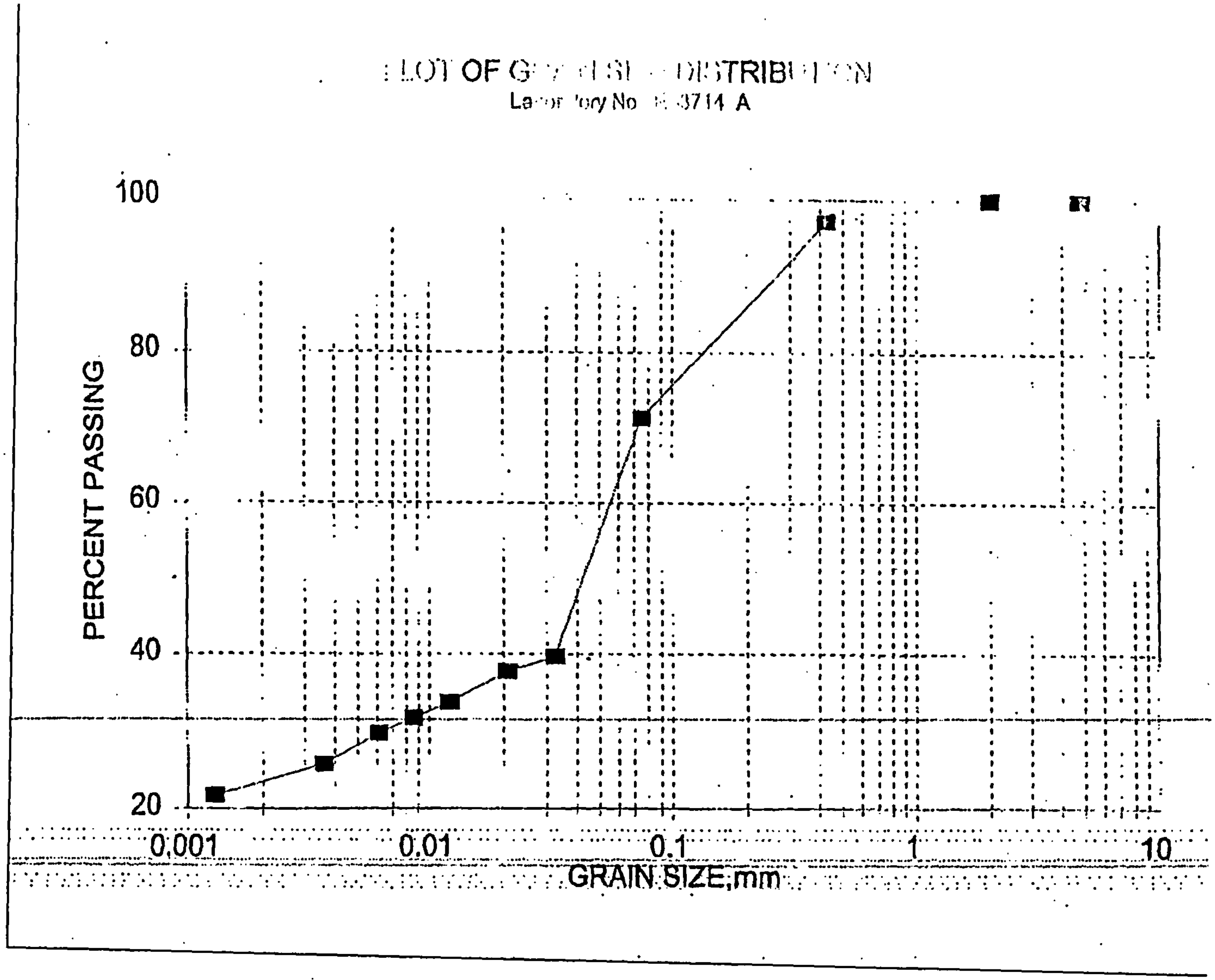
SIEVE ANALYSIS	
SIEVE SIZE	PERCENT PASSING
No. 4	100
No. 10	100
No. 40	97.8
No. 200	71.3
HYDROMETER ANALYSIS	
SMALLER THAN	PERCENT
0.074 mm	70.6
0.005 mm	28.0
0.001 mm	21.2

Charge: Kerr-McGee Corporation
Attn: Terrie Oslmeyer
Orig. Enercon Services Attn: T.J. Keane
[illegible] Laboratory
FAX (918) 225-0567 Attn: T. J. Keane
FAX (918) 225-7749 Attn: T. Lux & T. Oslmeyer

Respectfully submitted,

STANDARD TESTING AND ENGINEERING CO.

Michael W. Morgan, CET
11-3-03



100
80
60
40
20
PERCENT PASSING
0.001
0.01
0.1
1
10
GRAIN SIZE,mm

STANDARD TESTING AND ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA77 Exp. 06/30/05

Area Offices

902 TRAILS WEST LOOP	ENID, OK 73703	(580) 237-3130
900 S.E. SECOND	LAWTON, OK 73501	(580) 353-0872
5806 S. 125TH EAST AVE, STE B.	TULSA, OK 74134	(918) 459-2700

	0220KER30 File No: KER30-1		
Report Date:	11/3/03	Date Sampled:	10/17/03
Project:	Groundwater/ACL	Sampled By:	Client
Location:	CU-23-38-02	By Order Of:	T. J. Keane
Arch./Engr:		No:	
Client:	Kerr McGee Corporation	Material Represented:	Dark Brown Lean Clay w/Sand
REPORT:	SOIL CLASSIFICATION & SATURATION RATIO	LAB NO:	E-3715
		Test Method:	ASTM D2487

TEST RESULTS

Liquid Limit	29
Plastic Limit	19
Plasticity Index	10
% Passing Sieve No. 10	100
% Passing Sieve No. 40	99.
% Passing Sieve No. 100	93
% Passing Sieve No. 200	81.8
Group Symbol	CL
Saturation Ratio	0.951

Kerr-McGee Corporation
Attn: Terrie Ostmeyer
Enercon Services Attn: T.J. Keane
Laboratory
FAX (918) 225-0567 Attn: T. J. Keane
(918) 225-7749 Attn: T. Lux & T. Ostmeyer

Respectfully submitted,

STANDARD TESTING AND ENGINEERING CO.

Michael W. Morgan, CET
11-3-03

STANDARD TESTING AND ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA77 Exp. 06/30/05

Area Offices
902 TRAILS WEST LOOP — ENID, OK 73703 — (580) 237-3130
900 S.E. SECOND — LAWTON, OK 73501 — (580) 353-0872
6806 S. 126[TH] EAST AVE, STE B. — TULSA, OK 74134 — (918) 459-2700

Acct. No: 0220KER30 File No: KER30-1
Report Date: 11/3/03
Project: Groundwater/ACL
Location: CU-23-38-02
Arch/Engr:
Client: Kerr McGee Corporation

Date Sampled: 10/17/03
Sampled By: Client
By Order Of: T. J. Keane
No:
Material Represented: Dark Brown Lean Clay w/Sand

REPORT: GRAIN SIZE ANALYSIS OF SOILS
LAB NO: E-8716A
Test Method: ASTM D422

TEST RESULTS

SIEVE ANALYSIS	
SIEVE SIZE	PERCENT PASSING
No. 4	100
No. 10	100
No. 40	99.1
No. 200	81.8
HYDROMETER ANALYSIS	
SMALLER THAN	PERCENT
0.074 mm	80.9
0.005 mm	28.0
0.001 mm	21.2

Charge: Kerr-McGee Corporation
Attn: Terrie Ostmeyer
Orig. Eneroon Services Attn: T.J. Keane
1-cc Laboratory
FAX (918) 226-0587 Attn: T. J. Keane
FAX (918) 225-7749 Attn: T. Lux & T. Ostmeyer

Respectfully submitted
STANDARD TESTING AND ENGINEERING CO.

Michael W. Morgan, CET
11-3-03

STANDARD TESTING
AND ENGINEERING COMPANY

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3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA77 Exp. 06/30/05

Area Offices

902 TRAILS WEST LOOP	ENID, OK 73703	(580) 237-3130
900 S.E. SECOND	LAWTON, OK 73501	(580) 353-0872
5606 S. 125[TH] EAST AVE, STE B.	TULSA, OK 74134	(918) 459-2700

[illegible] No:	0220KER30 File No: KER30-1		
Report Date:	11/3/03	Date Sampled:	10/17/03
Project:	Groundwater/ACL	Sampled By:	Client
Location:	CU-23-38-03	By Order Of:	T. J. Keane
Arch./Engr:		No:	
Client:	Kerr McGee Corporation	Material Represented:	Yellowish Brown Lean Clay w/Sand

SOIL CLASSIFICATION & SATURATION RATIO — LAB NO: E-3718

Test Method: ASTM D2487

TEST RESULTS

Liquid Limit	44
Plastic Limit	21
Plasticity Index	23
% Passing Sieve No. 4	100
% Passing Sieve No. 10	93
% Passing Sieve No. 40	91
% Passing Sieve No. 100	87
% Passing Sieve No. 200	78.3
Group Symbol	CL
Saturation Ratio	0.84

Charge: Kerr-McGee Corporation
Attn: Terrie Ostmeyer
Orig. Enercon Services Attn: T.J. Keane
[illegible] Laboratory
FAX (918) 226-0567 Attn: T. J. Keane
FAX (918) 225-7749 Attn: T. Lux & T. Ostmeyer

Respectfully submitted,

STANDARD TESTING AND ENGINEERING CO.

[signature]
Michael W. Morgan, CET
11-3-03

TESTING
ENGINEERING COMPANY

CORPORATE OFFICE and CENTRAL LABORATORY
3400 N. LINCOLN, OKLAHOMA CITY, OK 73105 (405) 528-0541
CA77 Exp. 06/30/05

Area Offices
902 TRAILS WEST LOOP — ENID, OK 73703 — (580) 237-3130
900 S.E. SECOND — LAWTON, OK 73501 — (580) 353-0872
6606 S. 125TH EAST AVE, STE B — TULSA, OK 74134 — (918) 459-2700

Acct. No: 0220KER30 File No: KER30-1
Report Date: 11/3/03
Project: Groundwater/ACL
Location: CU-23-38-03
Arch./Engr:
Client: Kerr McGee Corporation

Date Sampled: 10/17/03
Sampled By: Client
By Order Of: T. J. Keane
No:
Material Represented: Yellowish Brown Lean Clay w/Sand

REPORT: GRAIN SIZE ANALYSIS OF SOILS
LAB NO: E-3716A
Test Method: ASTM D422

TEST RESULTS

SIEVE ANALYSIS

SIEVE SIZE	PERCENT PASSING
No. 4	100
No. 10	92.7
No. 40	91.4
No. 200	78.3

HYDROMETER ANALYSIS

SMALLER THAN	PERCENT
0.074 mm	77.9
0.005 mm	46.4
0.001 mm	39.3

Charge: Kerr-McGee Corporation
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Orig. Enercon Services Attn: T.J. Keane
1-cc Laboratory
FAX (918) 225-0567 Attn: T. J. Keane
FAX (918) 225-7749 Attn: T. Lux & T. Ostmeyer

Respectfully submitted,
STANDARD TESTING AND ENGINEERING CO.

Michael W. Morgan, CET
11-3-03

Enercon Services, Inc.
5100 E. Skelly Drive, Suite 450
Tulsa, OK 74135
(918) 665-7693
(918) 665-7232 fax

Upper Vanoss Yield

From: Jim Thomas, Project Manager

Date: 10-21-2003

Subject: Groundwater Yield, Upper Vanoss Unit, RMA-11 Area

Introduction:

Kerr-McGee (KM) has submitted proposed Alternative Concentration Levels (ACLs) for radiological constituents of concern in groundwater for the Cushing Site to the NRC. The NRC comments on the proposed ACLs will require site specific values to be obtained for certain parameters in the model. (Specifically, the yield of wells installed in the Upper Vanoss formation is needed to determine the potential exposure pathways due to irrigation for gardening, grain production, and livestock use.)

The Upper Vanoss is able to supply very limited quantities of groundwater. The Oklahoma Department of Environmental Quality has agreed that it is not a source of drinking water, and alternatives other than EPA's Maximum Contaminant Levels would be appropriate for remediation of the site. Aquifer yield pumping tests were conducted to develop a justifiable estimate of the potential yield should someone install an irrigation or livestock well into the Upper Vanoss. The data from this test was obtained and evaluated in accordance with an Aquifer Yield Test Work Plan that was written to address Kerr-McGee Cushing Remediation Site Sampling and Analysis Plan requirements.

UVMW-116 and UVMW-113 were selected for yield tests because they are down-gradient of the identified source of uranium in the groundwater at the former RMA-11 area. They are also most representative of the Upper Vanoss. These wells were properly installed only in the Upper Vanoss, and properly developed at the time of installation. Past sampling records indicated these wells would be most likely to produce the greatest yield in comparison to other existing monitoring wells in the area.

The objectives of the aquifer yield test were to:

- Determine aquifer yield.
- Develop an estimate of aquifer transmissivity.

Discussion and Analysis:

A pumping rate of one (1) gallon per minute was set as the initial pumping rate. Special attention was taken to establish a constant flow rate immediately upon test initiation. Water level measurements were collected before pumping began. Then, water levels were gauged during pumping to accurately record drawdown. The intent was to establish a steady-state pumping rate in the well where the water level would stabilize during pumping.

UVMW-116 was tested for well yield on October 2, 2003. The test data collection forms are attached in Exhibit A. The initial pumping rate of one (1) gallon per minute was established and monitored for 120 minutes. The total depth of UVMW-116 was measured at 27.84 feet below top of casing, or approximately 25 feet below land surface (bls). The pump was set at 24.84 feet below top of casing. The well was not pumped dry. Pumping well loss was observed during the first four minutes of the test. After the first four minutes, the drawdown proceeded without stopping until test termination. The initial water level in UVMW-116 was 12.79 feet below top of casing (BTOC). The water level after 120 minutes of pumping at 1.0 gpm was 20.29 feet BTOC, and still decreasing.

It was decided the 1.0 gpm pumping rate was too great, as drawdown was continuing without achievement of steady-state conditions. Therefore, the pumping rate was reduced to 0.8 gpm to attempt to obtain a pumping rate close to the yield of the well. The pumping yield test was continued at the rate of 0.8 gpm for an additional 40 minutes. Upon reduction of the flow rate, the water level in UVMW-116 began to rebound even as pumping continued. The water level recovered from 20.25 feet BTOC to 18.30 feet BTOC after 40 minutes pumping at 0.8 gpm. This indicated the yield of UVMW-116 would be between 0.8 and 1.0 gpm.

The yield test of UVMW-116 was terminated and the rate of water level recovery was monitored for 120 minutes. Drawdown and recovery rates were graphically plotted to develop pumping and recovery curves for data evaluation. Only the drawdown for pumping at 1.0 gpm was plotted, since the water level began to recover while pumping at 0.8 gpm. The drawdown and recovery curves are presented for UVMW-116 in Exhibit A.

UVMW-113 was tested for well yield on October 3, 2003. The pumping test data collection forms are attached in Exhibit B. The total depth of UVMW-113 was measured at 34.05 feet below top of casing, or approximately 32 feet below land surface (bls). The pump was set at 31 feet below top of casing. The initial pumping rate of one (1.0) gallon per minute was established and monitored for 70 minutes, after which pumping was terminated upon observation of significant quantities of sand in the discharge. The pumping was terminated to protect the pump impellers. Although the well was not pumped dry, drawdown continued at a relatively constant rate after the initial three minutes, for the duration of the yield test. Pumping well loss was observed in UVMW-113 during the first two to three minutes of the test, but was less distinct than observed in UVMW-116. The initial water level in UVMW-113 was 13.59 feet below top of casing (BTOC). The water level after 70 minutes of pumping at 1.0 gpm was 21.61 feet BTOC.

Since drawdown continued without achievement of steady-state conditions, it indicated the 1.0 gpm pumping rate was greater than the yield of the well. The yield test of UVMW-113 was terminated and the rate of water level recovery was monitored for 70 minutes

following pump shutdown. Drawdown and recovery rates were graphically plotted to develop pumping and recovery curves for data evaluation. The drawdown and recovery curves are presented for UVMW-113 in Exhibit B.

Data Evaluation

Yield tests on both wells indicated the yield of these two-inch monitoring wells completed in the Upper Vanoss Unit at the Cushing Site was less than 1.0 gpm. Yield tests of this nature are commonly employed by water well drillers to determine aquifer yield for domestic use, rather than performance of more time consuming and costly long-term pump tests. Based on local knowledge, it is unlikely that a well would be installed in the Upper Vanoss because of its limited yield. However, should a driller be requested to install a well for watering a garden, lawn, or for livestock usage, it is likely that a well would be installed, and then pumped to define its approximate yield. Therefore, the yield tests conducted on UVMW-116 and UVMW-113 are considered to be valid for approximating yield in the same manner commonly employed in a real world setting.

The non-equilibrium well equation developed by Cooper and Jacob (1946) from the Theis equation (1935) takes into account the effect of pumping time on well yield.[1] The coefficient of transmissivity was calculated from the pumping rate and the slope of the time-drawdown graph by using the equation:

$$T = 264Q/\Delta s$$ (Driscoll, 1986, pg. 221)

Where:
T = coefficient of transmissivity, in gallons per day per foot (gpd/ft)
Q = pumping rate, in gpm
Δs = slope of the time drawdown graph expressed as the change in drawdown between any two times on the log scale whose ratio is 10 (one log cycle).

Using the pumping rate of 1.0 gpm, and $\Delta s = 1.56$ developed from the graph of UVMW-116 drawdown, a coefficient of transmissivity of 169.23 gpd/ft was calculated.
$T = 264(1)/1.56 = 169.23$ gpd/ft for UVMW-116

Using the pumping rate of 1.0 gpm, and $\Delta s = 3.99$ developed from the time-drawdown graph for UVMW-113, a coefficient of transmissivity of 66.17 gpd/ft was calculated.

Comparison of the drawdown graph for UVMW-116 with that developed for UVMW-113 revealed differences in the shape of the time-drawdown curves that account for the variation in T. However, comparison of the well recovery curves showed more similarity between UVMW-116 and UVMW-113. Using the Δs (1.46) from the recovery graph for UVMW-113, a coefficient of transmissivity of 180.82 gpd/ft was obtained. Using the Δs (1.15) from the recovery graph for UVMW-116 resulted in a calculated transmissivity of 229.57 gpd/ft. Part of the discrepancy between UVMW-116 and UVMW-113 may have been due to having to curtail the yield test after only 70 minutes for UVMW-113, due to sand in the pump.

The Upper Vanoss unit in the vicinity of RMA-11 (the former Trash Dump) at the Cushing Remediation Site has been characterized in the "Conceptual Hydrogeologic Model of the Kerr-McGee Corporation Cushing Remediation Site", dated July 2001, as consisting of mudstones, lenticular sandstones, and thin limestones of the Upper Pennsylvanian Vanoss Group. The water bearing thickness of the sand/sandstone lenses in the Upper Vanoss are between 10 to 15 feet in thickness. Assuming a drawdown in a pumping well of no more than 8 to 10 feet below static water level, a daily flow from the Upper Vanoss is estimated at between 1,450 to 2,290 gallons per day total yield from the formation. This is assuming a continuous flow for 24 hours per day, or 1,440 minutes per day. This would result in an estimated yield from the Upper Vanoss at between 1 to 1.5 gpm.

The storage coefficient cannot be determined when only the pumping well is used for water level monitoring. The nearest monitoring wells around UVMW-116 are at least 150 feet away, and were not be suitable as observation wells.

Upper Vanoss Water Supply Capability

Based on the time-drawdown graphs and recovery graphs developed from pumping rate tests on existing site monitoring wells, the coefficient of transmissivity (T) was estimated to be between 170 to 230 gallons per day per foot of drawdown in a pumping well. The saturated thickness of the sand/sandstone in the Upper Vanoss has been recorded to be no more than 10 to 15 feet. Assuming a water supply well were to be installed to withdraw water only from the Upper Vanoss, a reasonable drawdown in a pumping well would not normally exceed eight (8) to ten (10) feet below static water level, and still be able to maintain water over the pump intake. Therefore, the estimated maximum yield of the Upper Vanoss would be near 2,230 gallons per day, assuming a well is pumped 1,440 minutes per day (24 hours). The maximum pumping rate would be approximately 1.5 gallons per minute.

T_{max} = 230 gpd/ft
Yield maximum = Q_{max} = 1.5 gpm

The results of the yield tests conducted near RMA-11 indicated limited availability of groundwater in the Upper Vanoss. A well installed in the Upper Vanoss to water a garden, a lawn, or for livestock would be of limited use. Pumping at a rate greater than 1.5 gpm would quickly deplete the well, and result in pump cavitation.

The yield calculated do not provide assurance that a sustainable yield can be obtained at a rate of 1.5 gpm. Theis' equation for transmissivity assumes the formation is uniform in thickness and infinite in areal extent. Site boring logs reveal the sand/sandstone is of limited extent, especially to the east and the west, and is not uniform in thickness. The actual yield would probably be less than 1.5 gpm, because the formation has limited recharge due to the limited extent.

PG-8-08 uses a reference garden area of 1,000 square meters, minimum, or 10763.9 square feet. A typical garden of this size would require approximately 6,233 gallons of water to apply at a rate of one (1) inch/irrigation event. As can be seen, it would take almost three

(3) days to apply one (1) inch of irrigation water to a typical family garden. Irrigation would be sustainable at no more than 0.36 inches per day for the typical family garden.

10763.9 square feet x 1 inch x 1ft/12 inch = 896.99 cubic feet of water

896.99 cubic feet x 7.48 gallons/cubic foot = 6,709.5 gallons per irrigation event

The Oklahoma State University Cooperative Extension Service was contacted for Payne County irrigation requirements for the typical family garden. The Extension Service recommended trickle irrigation as being most appropriate for minimizing the irrigation requirements. OSU Cooperative Extension Service Fact Sheet F-1511 "*Trickle Irrigation for Lawns, Gardens, and Small Orchards*" (attached) provides guidance on the establishment and implementation of a trickle irrigation system for a garden. This document provides guidance on the required flow rate of a water supply system for trickle irrigation as follows:

GPM = 0.012 (L x W x D x P)/H　　　　Fact Sheet F-1511, pg. 2

Where:

0.012 is a mathematical constant which includes an 85% to 90% application efficiency
"L" is the length of the plot expressed in feet
"W" is the width of the plot expressed in feet
"D" is the depth of water to replace daily expressed as a decimal fraction of an inch
"P" is the percent of the soil covered by foliage if viewed from above expressed as a decimal fraction
"H" is the hours per day the system can or will be operated

Chris Stiegler, Payne County horticulturalist, provided a typical garden moisture requirement of at least 1.0 inch per week for diverse vegetable plantings. Tomatoes, for example, require 1.5 to 2 inches per week during the hotter summer months. When irrigation is required to supply the moisture needs, the daily water replacement requirement would be at least 0.14 inches per day for diverse plantings, assuming the irrigation system operates seven days per week. A 10,763.9 square foot family garden would require a water supply capable of 0.38 gpm, assuming it operated 24 hours per day, seven days per week.

Since pumps are not normally designed to operate continuously, pump operation of 8 hours per day is more realistic. A typical family garden would then require a water supply capable of at least 1.13 gpm, assuming the system is operated eight hours per day, seven days per week.

GPM = 0.012(10,763.9 x 0.14 x 0.5)/8 = 1.13 gallons per minute

The above water supply requirement for a garden is in the approximate range of the yield from a well installed into the Upper Vanoss. If a typical spray irrigation system were to be used, the water supply requirements would be greater, making water supply from the Upper Vanoss marginal to unacceptable, due to greater evaporation loss.

A 500-gallon livestock tank would take almost 5.5 hours to fill at the maximum sustainable yield (1.5 gpm) from a well in the Upper Vanoss.

The data obtained from the yield tests indicates that utilization of the groundwater from the Upper Vanoss might be reasonable if the only use were for gardening, or only for livestock, but unfeasible for both.

This data also indicated it would be impractical to consider groundwater supply from the Upper Vanoss for large water consumption requirements such as grain crop irrigation. Grain crops typically require 0.2 inches or more per day of moisture. The typical evaporation loss causes lower irrigation efficiency. Utilizing the following assumptions:

L x W = 1 acre = 43,560 square feet
D = 0.25 inch per day
P = 0.5
H = 24 hours
GPM = 0.012(43560 x 0.25 x 0.5)/24 = 2.7 gpm (which is greater than the estimated Upper Vanoss yield).

<u>Conclusions:</u>

Yield tests were conducted on two existing groundwater monitoring wells near RMA-11, the former Trash Dump. UVMW-116 was selected as a test well because it is downgradient of RMA-11, and is near the axis of the uranium plume vector toward the southwest. It was also believed that this well was adequately developed, and was fully penetrating the sand/sandstone that comprises the water-bearing unit of the Upper Vanoss. UVMW-113 was selected as a test well because it is also downgradient of RMA-11, and is located near the axis of the uranium plume vector to the southeast. It was also indicated to be fully penetrating the saturated sand/sandstone layer of the Upper Vanoss, and was believed to be well developed at the time of installation.

The yield tests conducted on the 2-inch monitoring wells indicated less than 1.0 gpm could be sustained in the Upper Vanoss. The water level in the well began to rise when the pumping rate in UVMW-116 was reduced to 0.8 gpm. This indicated the formation yield was greater than the 0.8 gpm pumping rate. A yield of approximately 0.9 gpm would be a good estimate for UVMW-116, or approximately 1,300 gallons per day total. The yield obtained from UVMW-113 was also less than 1.0 gpm.

The water bearing thickness of the sand/sandstone lenses in the Upper Vanoss are between 10 to 15 feet in thickness. Assuming a drawdown in a pumping well of no more than 8 to 10 feet below static water level, a daily flow from the Upper Vanoss is estimated at between 1,450 to 2,290 gallons per day total yield from the formation. This would result in an estimated yield from the Upper Vanoss at between 1 to 1.5 gpm.

The yield tests do not necessarily indicate that a sustainable yield can be obtained at a rate of 1.5 gpm. The actual yield would be limited, unless the water bearing sand/sandstone layers were laterally extensive. Site boring logs indicate the sand/sandstone is of limited

extent, especially to the east and west. Estimated yield from the Upper Vanoss is less than 1.5 gpm.

Further, the yield tests indicated utilization of the groundwater in the Upper Vanoss for grain or vegetable crop irrigation on a commercial scale would be unfeasible, due to limited availability.

The Upper Vanoss might provide a marginal groundwater supply for irrigation of a typical family garden, if efficient irrigation techniques such as trickle irrigation is used. A pumping rate of at least 1.1 gpm would be required for garden irrigation.

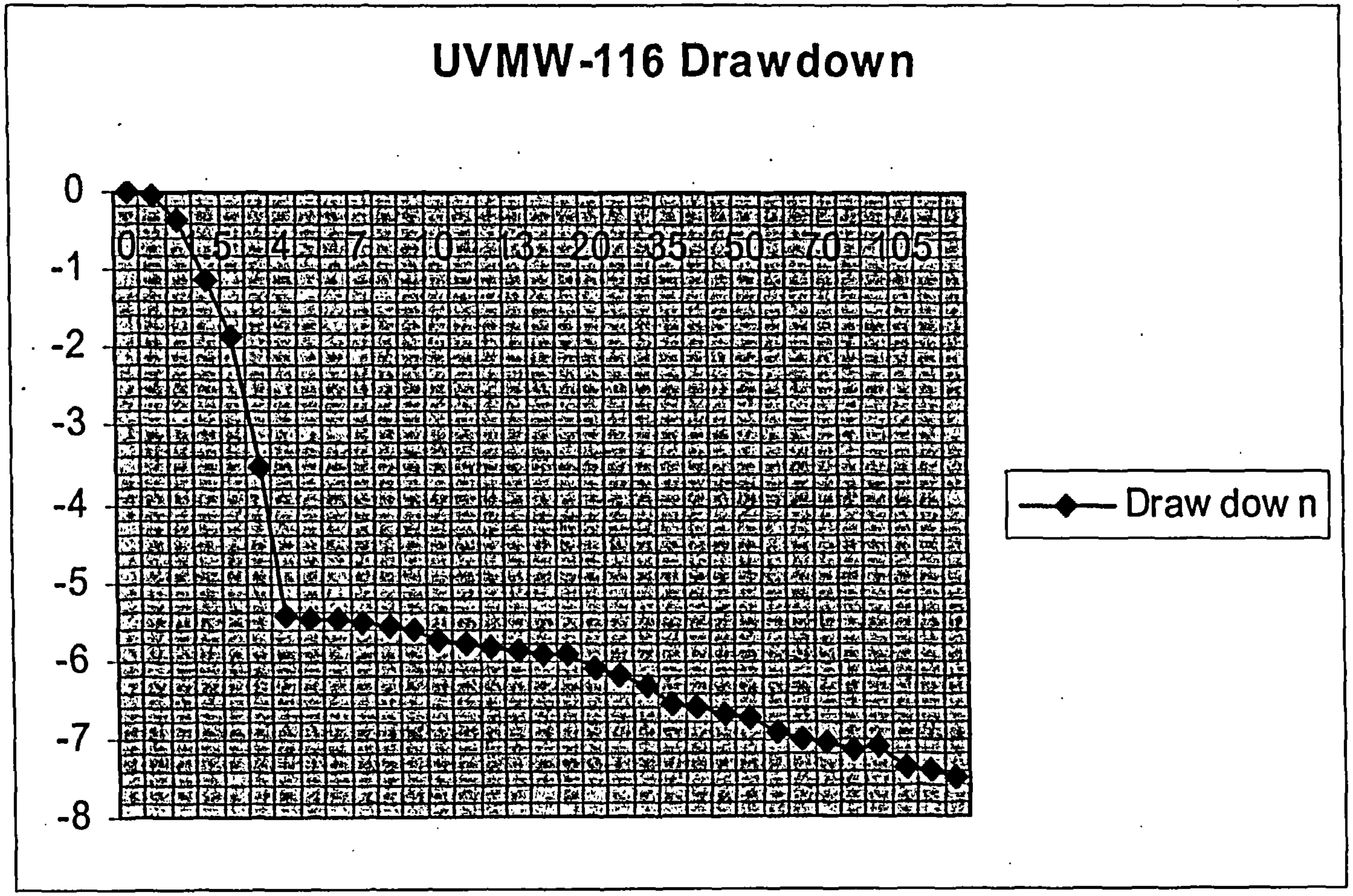
The data obtained from the yield tests indicates that utilization of the groundwater from the Upper Vanoss might be reasonable if the only use were for gardening,. or only for livestock, but unfeasible for both. Trickle irrigation, as considered, provides a mechanism to irrigate utilizing the most effective water conservation method. Traditional spray irrigation would require more groundwater than the Upper Vanoss can supply, even for a family garden.

REFERENCES

1. Driscoll, Fletcher G., Ph.D., 2nd ed., St. Paul, MN, Johnson Filtration Systems, Inc., 1986, pg. 220.

2. Ibid., pg. 221

EXHIBIT A – UVMW-116 YIELD TEST DATA


UVMW-116 Drawdown
0
-1
-2
-3
-4
-5
-6
-7
-8
0
5
4
7
10
13
20
35
50
70
105
Draw dow n

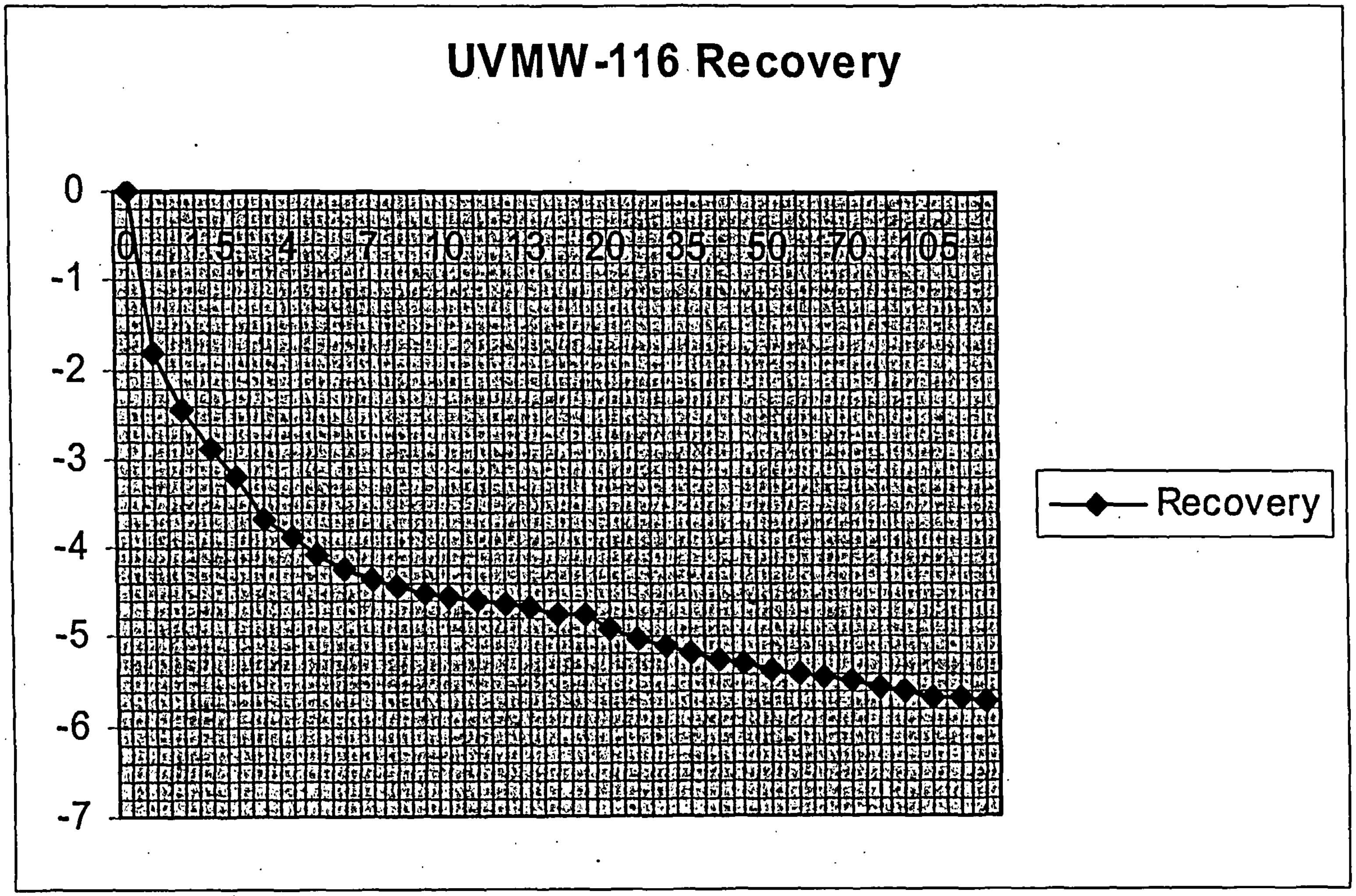
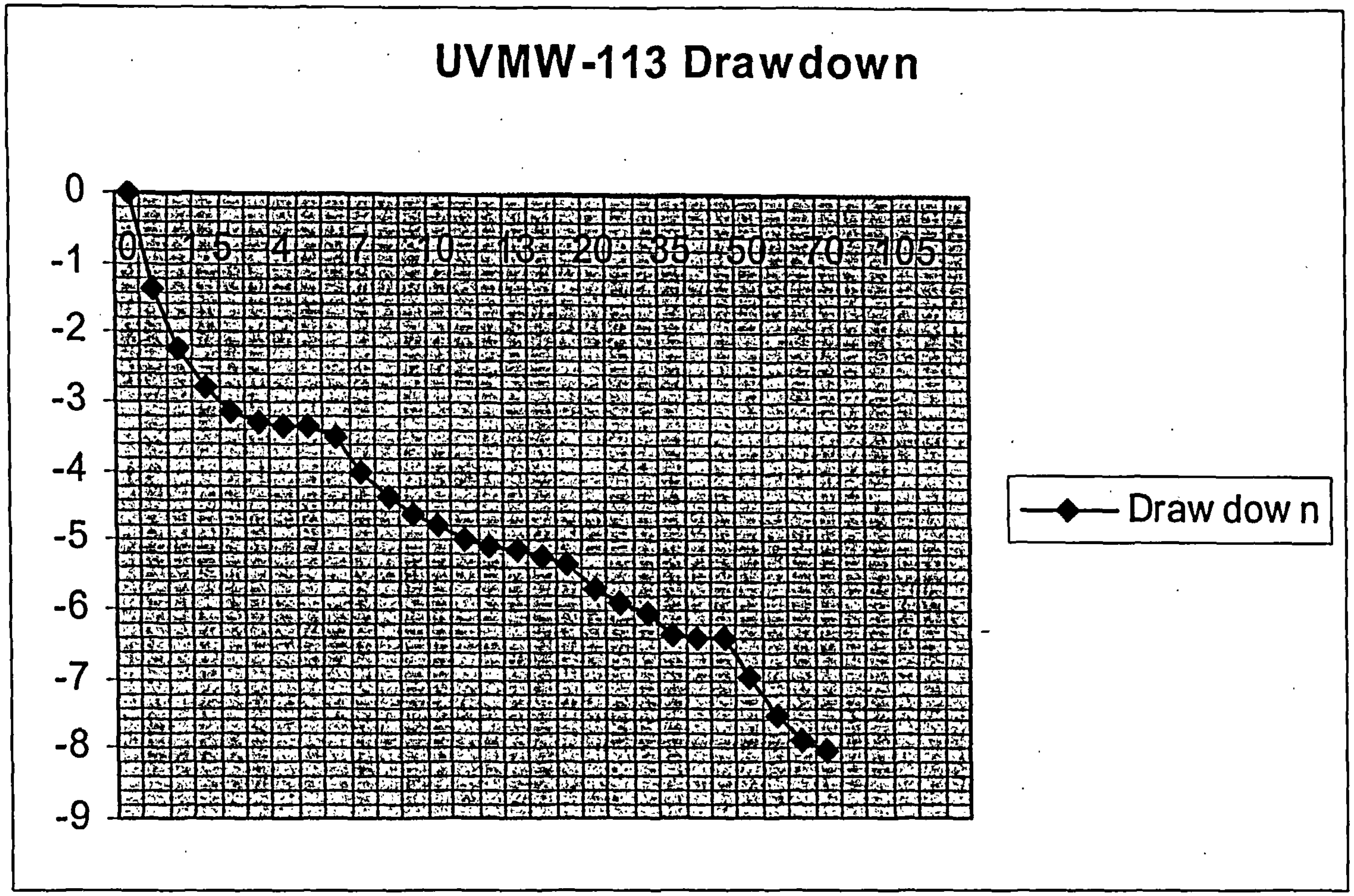
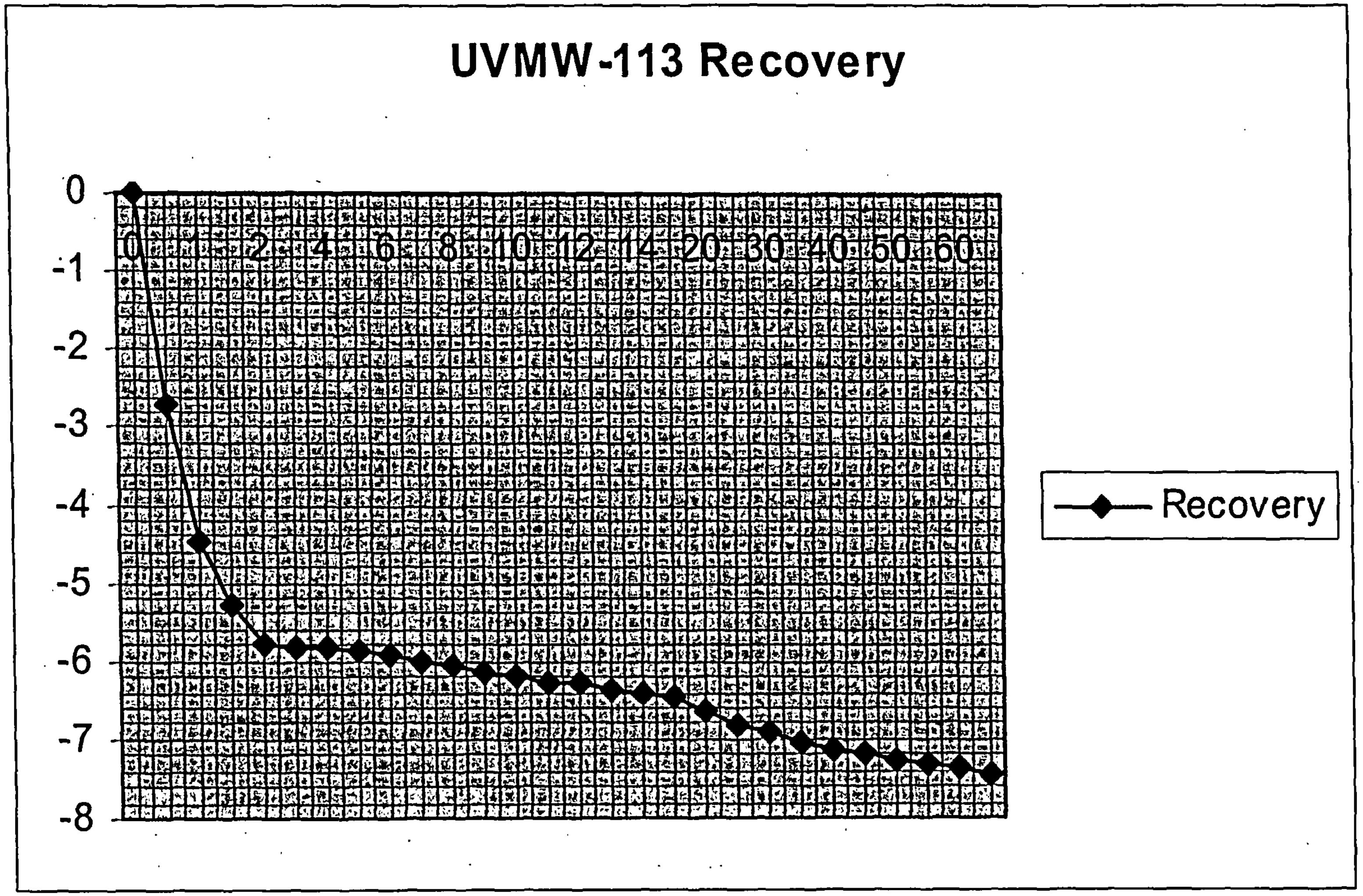

UVMW-116 Recovery
0
-1
-2
-3
-4
-5
-6
-7
0
5
4
7
10
13
20
35
50
70
105
Recovery

EXHIBIT B – UVMW-113 YIELD TEST DATA


UVMW-113 Drawdown
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
0
1.5
4
7
10
13
20
35
50
70
105
Draw dow n


UVMW-113 Recovery
0
-1
-2
-3
-4
-5
-6
-7
-8
0 1 2 4 6 8 10 12 14 20 30 40 50 60
Recovery

ATTACHMENT 5

Inhalation dose estimates as a result of irrigated soil contamination dispersed over an area on site

Isotope	Concentration (pCi/g)	Concentration (Bq/g)	Dose conversion factor (Sv/Bq)	Time spent indoors (d/y)	Time spent outdoors (d/y)	Breathing rate for time indoors or out (m^3/hr)	Dust loading indoors (g/m^3)	Dust Loading Outdoors (g/m^3)	Indoor dust loading on floors (g/m^2)	Indoor resuspension factor (per meter)	Dose Estimate (CED) (Sv/y)	Dose Estimate (CED) (mrem/y)
U-235	2.52E-03	9.33E-05	3.10E-06	200.88	76.7	1.2	0.00005	0.0002	0.4	0.00005	2.45E-10	2.45E-05
U-238	5.48E-02	2.03E-03	2.90E-06	200.88	76.7	1.2	0.00005	0.0002	0.4	0.00005	4.98E-09	4.98E-04
U-234	5.48E-02	2.03E-03	3.50E-06	200.88	76.7	1.2	0.00005	0.0002	0.4	0.00005	6.01E-09	6.01E-04
Reference			[ICRP, 1995]	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]	[USNRC, 1994]	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]	[USNRC, 1994]	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]	[Kennedy, W.E.Jr., and Strenge, D.L., 1992]		1.12E-03
NOTE: THE TIME ESTIMATES ARE FOR THE RESIDENT FARMER												