Uncertainty of Dose Calculations

REEW 2016

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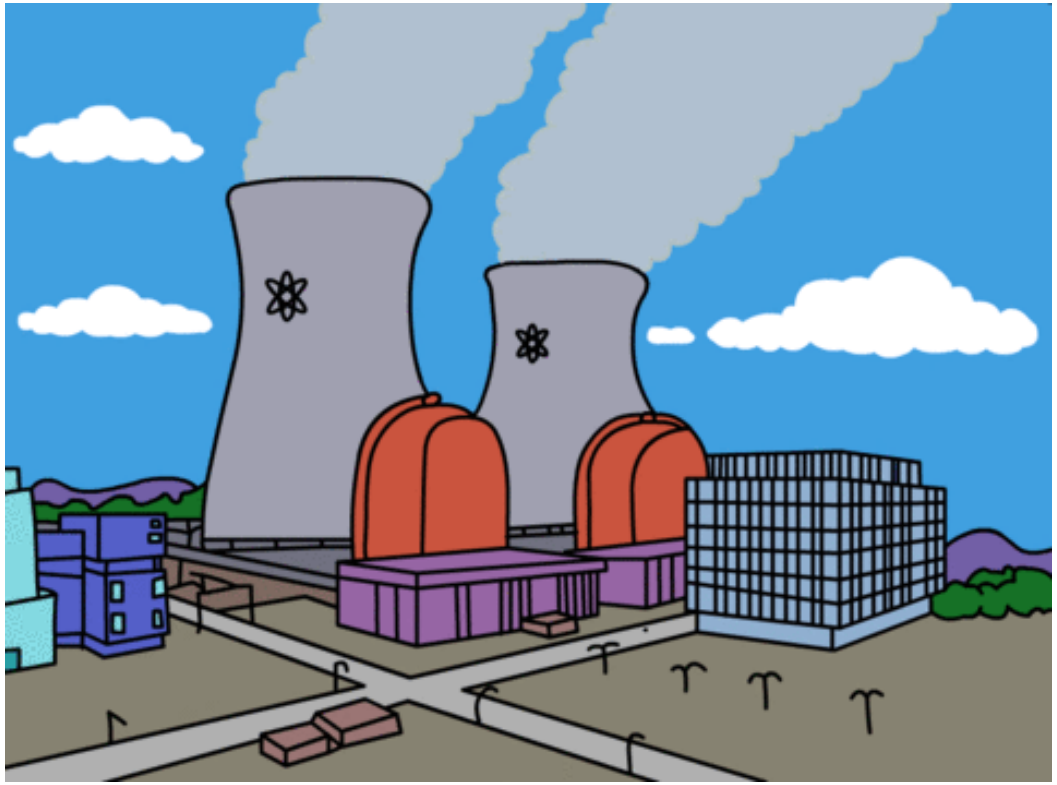
Uncertainty of Dose Calcs

- What Parameters Impact Accuracy?
- To What Degree?
- Uncertainty Associated With the Parameters?
- Ideally
  - Not Overestimate by 100.
  - Not Underestimate by 10.

Dispersion / Deposition



χ/Q

D/Q

Gaussian Plume Model

- Reasonable Results
  - Long Term (Monthly, Quarterly, Annual)
  - Flat or Slowly Varying Terrain
- Limitations
  - Short Term (Hourly, Daily)
    - “Unusual” Atmospheric Events (Inversion, etc.)
  - Ocean / Lake / Valley
  - Complex Terrain / Low Speeds

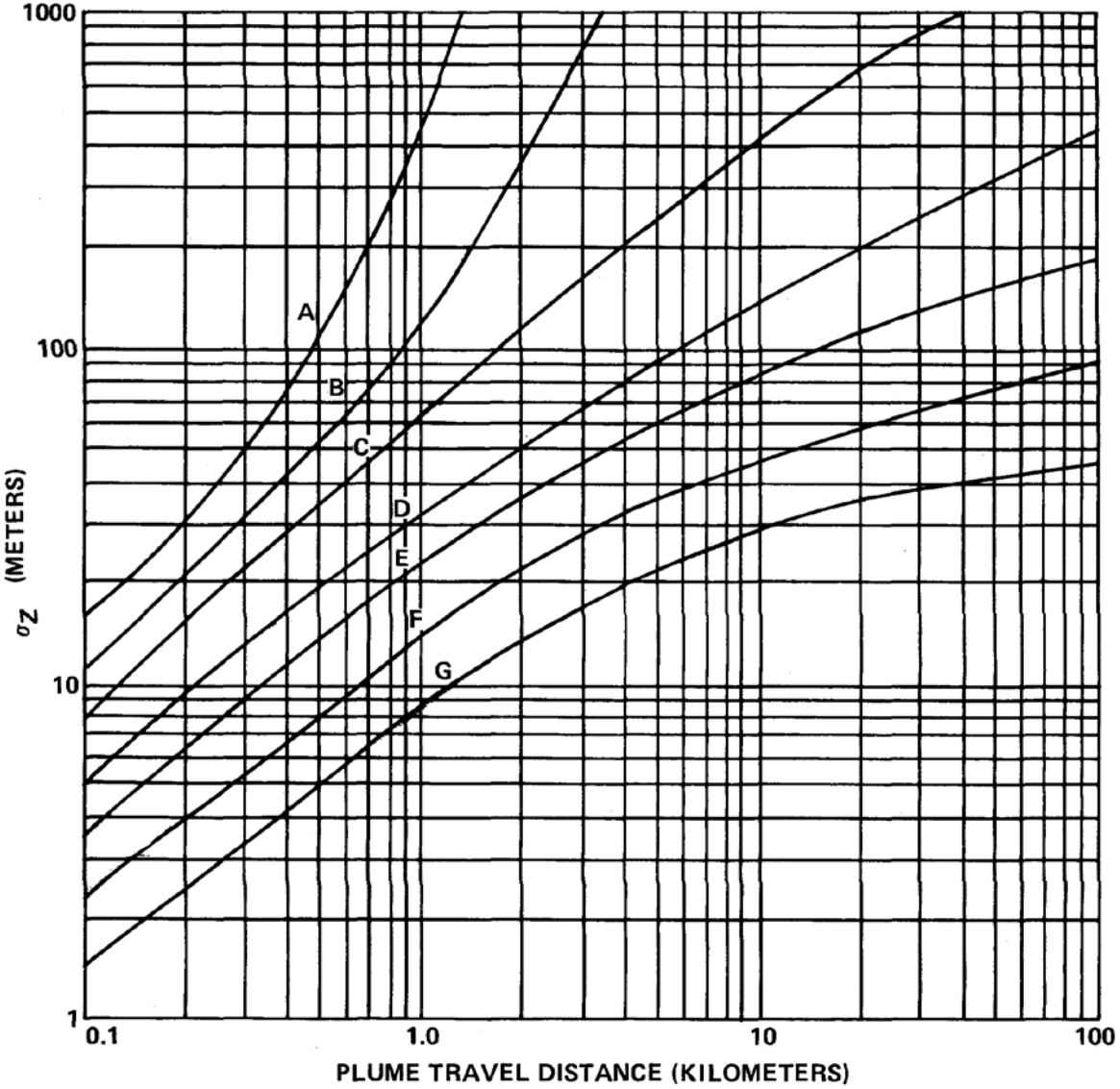
χ/Q

Important Parameters

- Joint Frequency Distribution
- Stability Class
- Dispersion Coefficients
- Terrain Correction
- Effective Plume Height

Reg Guide 1.111 Dispersion Coefficients

Pasquill-Gifford Curves



Dispersion Coefficients

- Based on Stability Class
  - Defined by Pasquill Criteria
  - Dependent on Δ-Temp
- Dispersion Coefficients are Site Specific
- Other Dispersion Coefficients Are Available
  - See NUREG 3332, Table 2.8

Deposition – D/Q

- Dependent Upon
  - χ/Q
  - Particle Size
  - Scavenging
  - Chemical Form
  - Surface Cover

NRC Code XOQDOQ

- Calculates
  - Weekly / Monthly / Quarterly / Annual Averages
  - Renormalized Met Data
    - Daylight Growing Season
    - Grazing Season
  - Decayed and Depleted Source Term

NRC Code XOQDOQ

- Addresses:
  - Dilution (Dispersion and Deposition)
    - Gravitational Plume Depletion
  - Radioactive Decay
- Does Not Address:
  - Plume Scavenging Effects
  - Complex Terrain
  - Falling Terrain

Environmental Transit Pathways

Must Identify Pathway Type

- Transient
  - Inhalation
- Integrating
  - Ground Plane / Vegetation Ingestion
- Compound Integrating
  - Milk / Meat Pathways
- Each Must Be Modeled In a Different Way

Removal Mechanisms

- Radioactive Decay
- Weathering
- Plume Scavenging
- Chemical / Biological / Anthropomorphic Processes

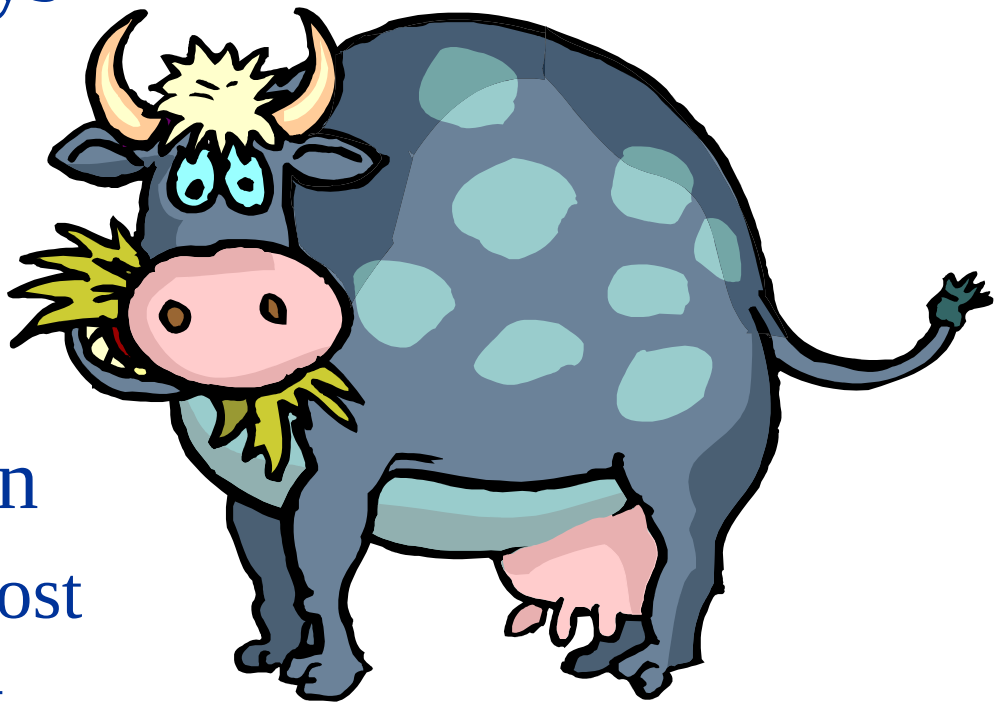
Sinks and Sources

- Environmental Sinks
  - Sink Storage Compartments Not Considered
    - Removes Activity
  - Silt, Detritus, Long Lived Vegetation

- Environmental Sources
  - Source Compartments Not Considered
    - Surprise! Activity Shows When/Where You Did not Expect it
  - Silt, Detritus, Long Lived Vegetation

Is There a Real Pathway?

- Imaginary Pathways
  - Ingestion Of:
    - Vegetation
    - Milk
    - Meat
- Imaginary Location
  - Garden at Fence Post
  - Cow at Fence Post
  - Residence at Fence Post



Parameters

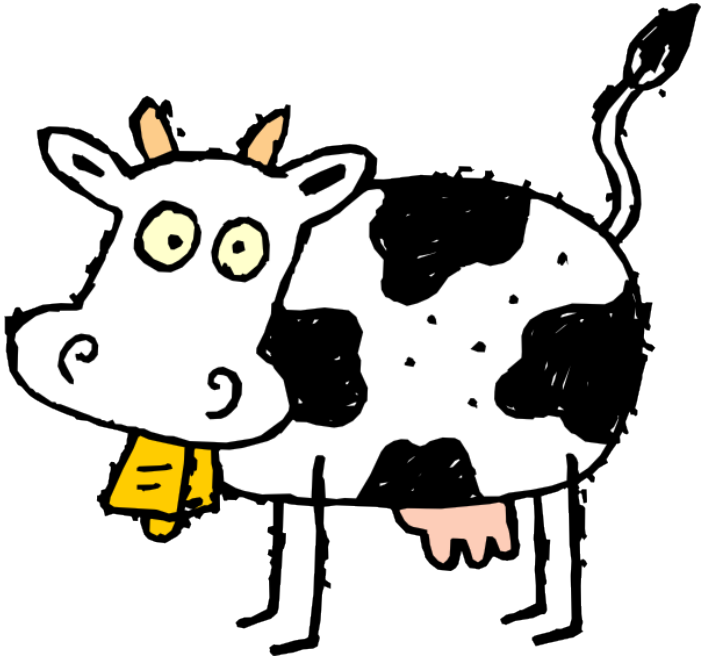
- Consider NUREG 0133 Methodology
  - As many as 15+ Parameters for Single Dose Calculation
- Uncertainty Increases as Number of Parameters Increase
- Which Ones are Important?

Where Did the 1.109 Default Factors Come From?

- Substantial Amount of Information Was Determined at the Hanford Reservation
  - Semi-Arid Conditions
  - Human Data Based on Bomb Workers
- Information is Old
  - Animal Diet →1956
  - Human Diet → 1966
  - SET → 1972

Consider Cow Milk Dose Pathway

- Potentially High Dose Pathway
- NUREG 0133 Methodology
  - 14 Parameters
  - Which Ones Matter?



Cow Milk Consumption Dose

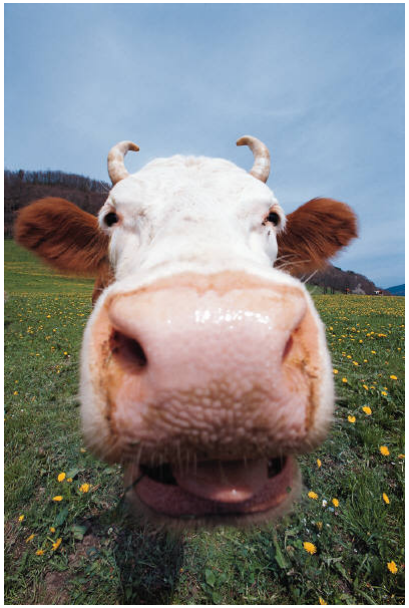
$$D_{aipj}[mrem]$$

$$= K' \frac{D}{Q}\left[\frac{1}{m^2}\right] \frac{Q_F\left[\frac{kg}{da}\right]\left(U_{ap}\left[\frac{l}{yr}\right]\right)}{\lambda_i[sec^{-1}] + \lambda_w[sec^{-1}]} F_m\left[\frac{kg}{l}\right](r)(DFL_i)_a\left[\frac{mrem}{pCi}\right]$$

$$\times \left[\frac{f_P f_S}{Y_P\left[\frac{kg}{m^2}\right]} + \frac{(1 - f_P f_S)e^{-\lambda_i t_h}}{Y_S\left[\frac{kg}{m^2}\right]}\right] e^{-\lambda_i t_f} \tilde{Q}_i[uCi]$$

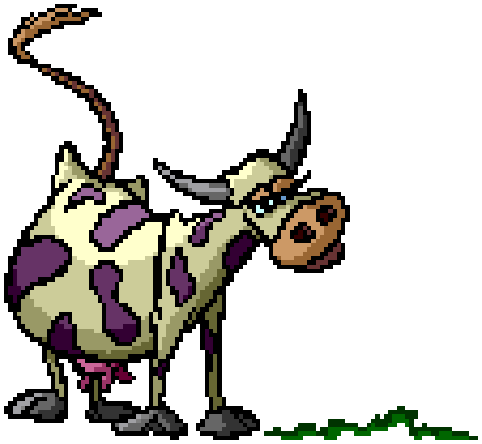
Animal Consumption

- Default Values from RG 1.109, Table E-3
  - Info is 40+ Years Old
- Consumption Rates are for "Professional" Cows or Goats
- Consumption is Lower For Hobby Animals



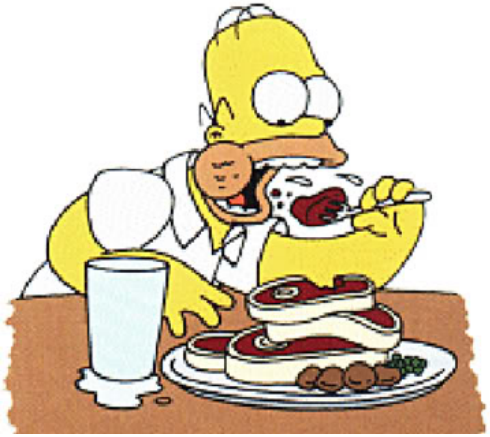
Animal Consumption

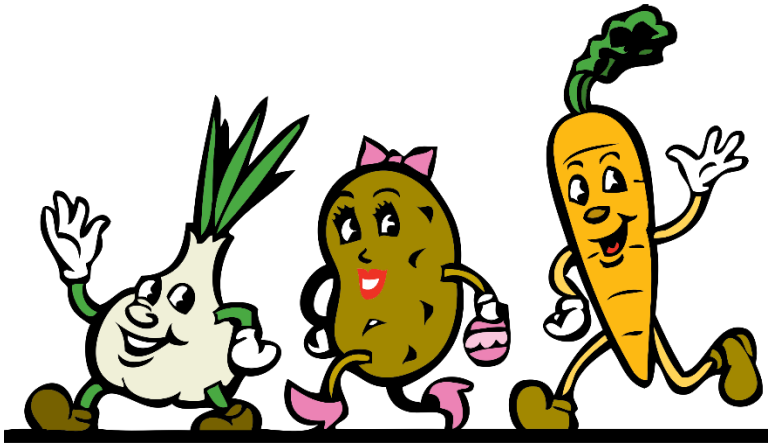
- Actual Local Consumption Can Be Substantially Less Than RG 1.109
  - High Agricultural Productivity
  - Supplemental Feed
- Or Substantially More Than
  - Low Agricultural Productivity (e.g. Drought)



Human Consumption

- RG 1.109, Table E-3
  - Info is From 40+ Years Ago
  - Less Meat/Milk Consumed Now
  - Vegetation Consumption Has Gone Up





Human Consumption

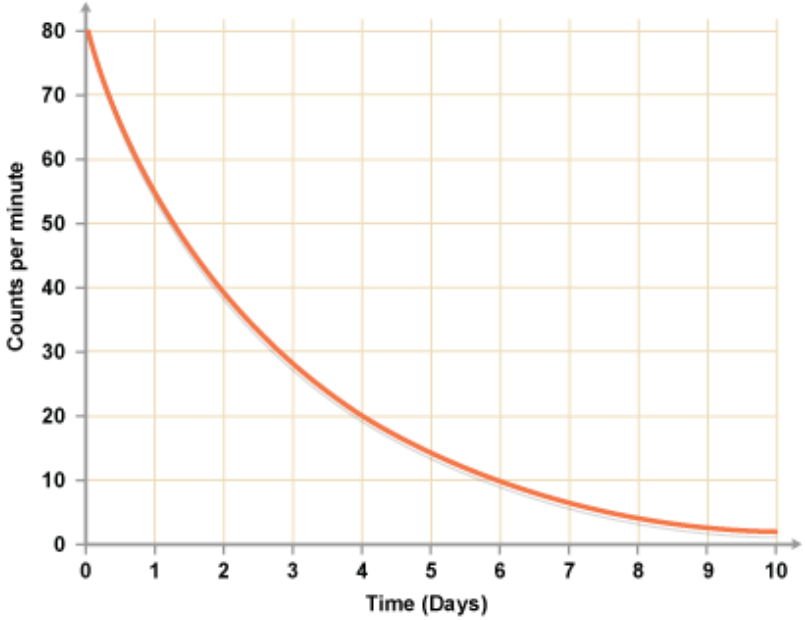
- Substantial Change in Consumption Habits
  - Fast Foods
  - Availability of Cheap Canned Goods, etc. at Stores
  - Cultural / Ethnic
- Actual Local Consumption Can Be Substantially Less

Agricultural Productivity

- Type of Crop
- Growing Conditions
  - Location (quality of soil and amount of precipitation)
  - Length of Growing Season (longer crop or animal exposure time).
  - Weather (long droughts)
- Modern Cultivated Crops and Farming Practices Have a Much Higher Yield

Transport and Hold Up Times

- Can Have Significant Impact on Short Lived I-131 and I-133
- May or May Not be Significant for Other Radionuclides



Reg Guide 1.109 Typo

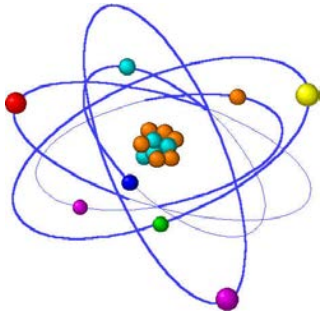
- Reg Guide 1.109 give hold up time for non-leafy vegetation consumed by humans as 60 days (t_h).
  - See RG 1.109, Table E-15 and NUREG 0133 5.3.1.5)
- THIS IS A TYPO!!
  - Correct Value is 6 Days.
  - See ***Uncertainty in Transport Factors Used to Calculate Historical Dose for ^{131}I Releases at the Savannah River Site***, Simpkins, HP Journal, 85(2): 194-203, 2003.

Parameter Sensitivity

Parameter	Relative Sensitivity (%)
Vegetation Productivity	23.4
Consumption Rate of Leafy Vegetation	18.1
Fraction Remaining on Plant Surfaces	17.0
Fraction of Elemental Iodine	16.8
Fraction of Local Leafy Vegetation Consumed	6.6
Weathering Rate	4.0
Holdup Time After Harvest for Non-Leafy Vegetation	3.6
Pasture Grass Productivity	2.4
Milk Animal Consumption Rate	1.4
Feed Transfer Coefficient for Milk	1.4
Human Consumption Rate	1.3
Fraction of Time Milk Animal is on Pasture	1.3

Dose Factors

- Radionuclide
  - Wrong ID
    = Wrong Dose Factor

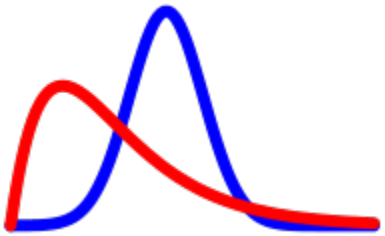


Tennessine-293!
$T_{1/2}$=0.014 sec

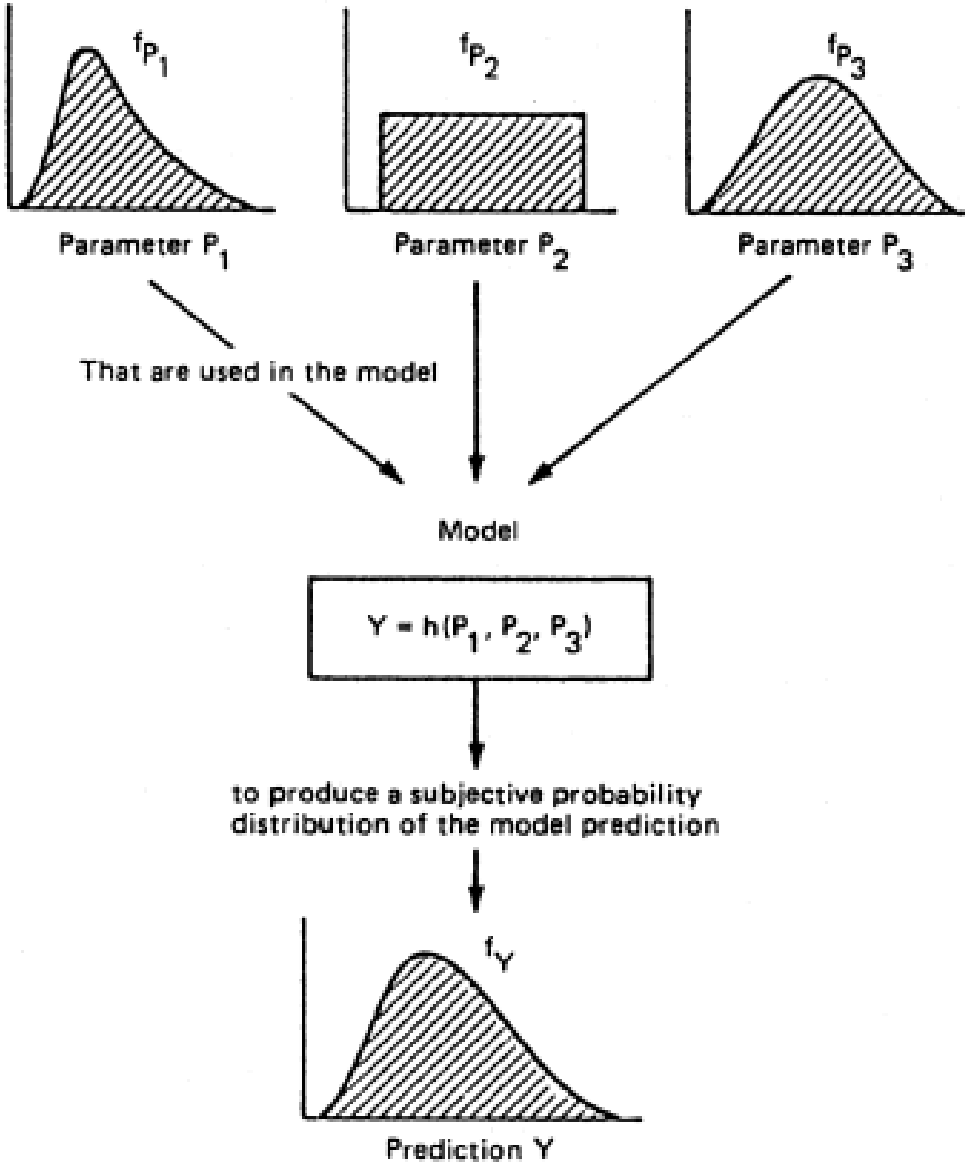
- Age Group
  - ID in LUC!

One Way to Look at Dose Uncertainty

- Use Knowledge of Parameter Statistical Characteristics
- Assign a Distribution to For Each Parameter
- Use This to Derive a Distribution for Dose
- Having Determined Dose Distribution, Then Can Make Statistical Statements About Dose
  - Mean
  - Standard Deviation
  - Confidence Interval

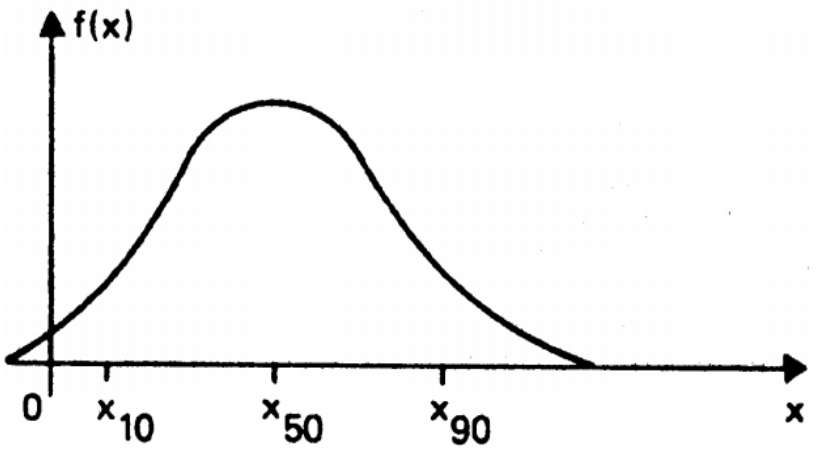


Use of Parameter Distributions

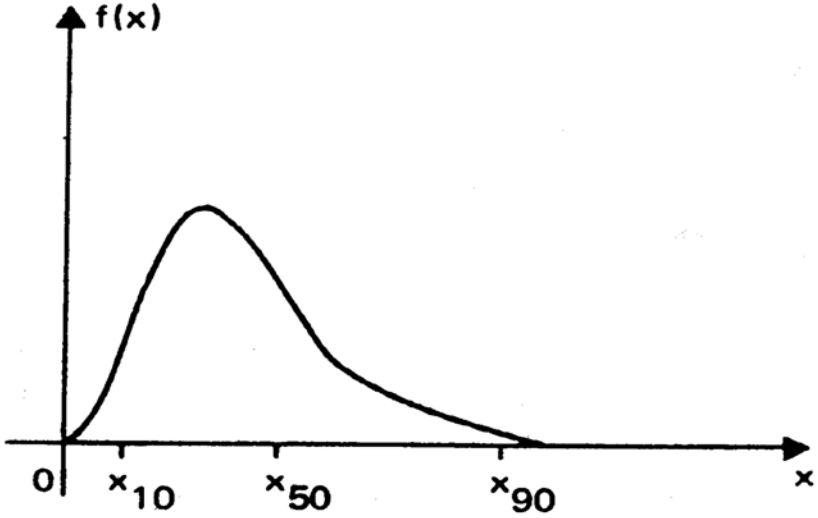


Useful Distributions

Normal

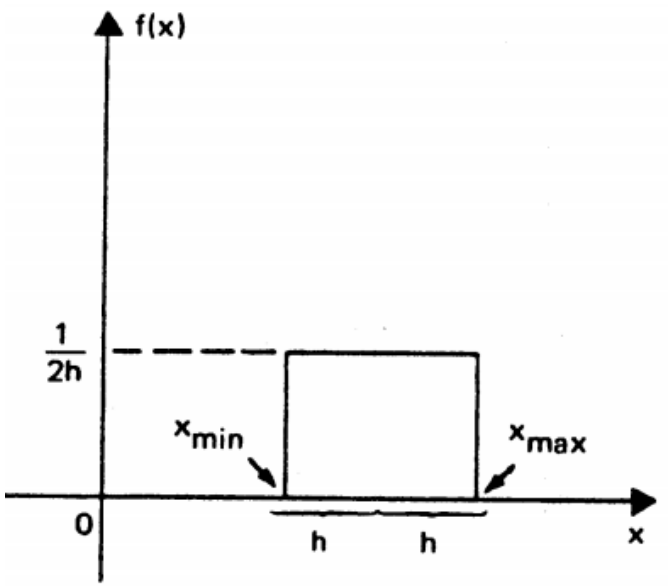


Lognormal

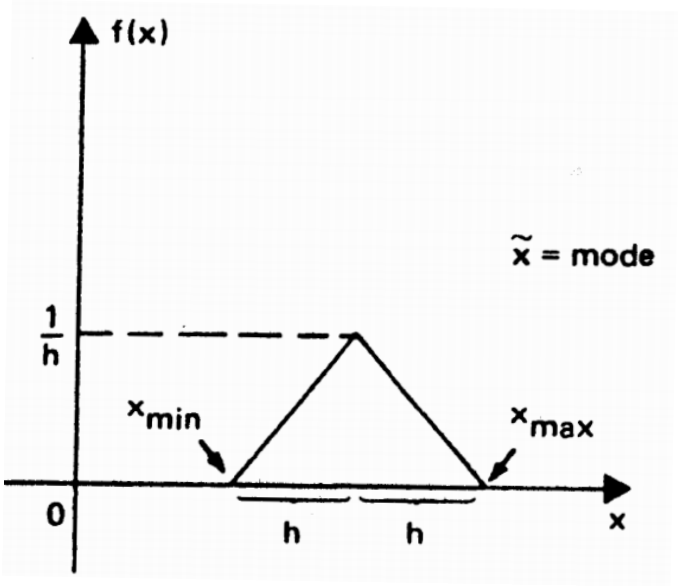


Useful Distributions

- Uniform

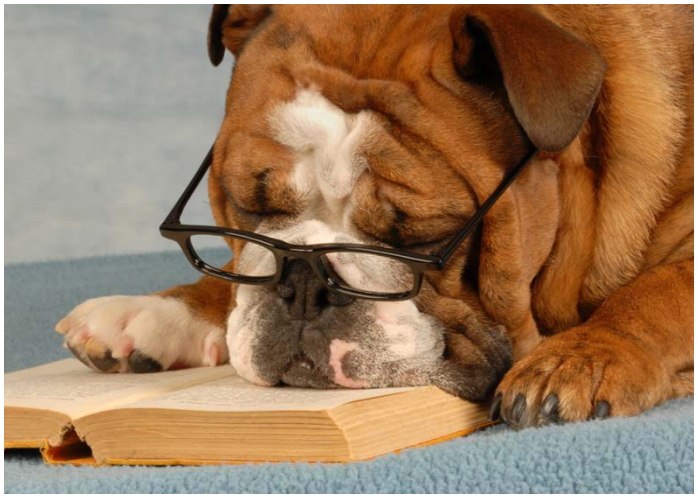


- Triangular



Other Distributions

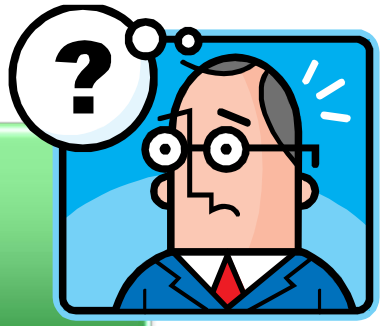
- Piecewise Uniform
- Trapezoidal Distribution
- Empirical Distribution



Information is Available

Symbol	Parameter	Dist Type	Mean	SD or Range
F_I	Fraction of Iodine that is Elemental	U		0-0.6
r_i	Vegetation Retention Fraction	U		0.09-0.9
Y_P	Pasture Grass Productivity (kg/m^2)	LN	0.7	1.8
Y_S	Stored Feed Productivity (kg/m^2)	LN	0.4	1.4
f_{PM}	Fraction of Time Cow on Pasture	U		0.75- 1.0
f_{SM}	Fraction of Grazing on Pasture	U		0.75- 1.0
Q_{MILK}	Consumption of Dairy Cow (kg/da)	N	52	11
F_M	Stable Element Transfer Coefficient (da/L)	LN	0.012	2.0
t_{tm}	Transport Time for Milk (da)	LN	3	1.5
U_L	Human Consumption – Adult – Milk (L/yr)	LN	140	2.2

Need Better Models!!



Uncertainty In

The Perfect Model ($E=MC^2$)

Uncertainty Out

For Casual Bedtime Reading

- ***The Uncertainty Associated with Selected Environmental Models***, ORNL-5528.
- ***Uncertainty in NCRP Screening Models Relating to Atmospheric Transport, Deposition and Uptake by Humans***, NCRP Commentary 8.
- ***A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination***, NCRP Commentary 14.
- ***Meteorology Uncertainty of Atmospheric Dispersion Model Results (MUD)***, Sørensen, et.al., Technical University of Denmark, Report NKS-B-MUD
- ***Radiological Assessment***, NUREG 3332, Chapter 11.

For Casual Bedtime Reading

- ***The Gaussian Atmospheric Transport Model and It's Sensitivity to the Joint Frequency Distribution and Parametric Variability***, Hamby, Oregon State University, Unpublished.
- ***Site-Specific Parameter Values for the Nuclear Regulatory Commission's Food Pathway Dose Model***, Hamby, HP Journal, 62(2):136-143; 1992.
- ***Uncertainty in Transport Factors Used to Calculate Historical Dose for ^{131}I Releases at the Savannah River Site***, Simpkins, HP Journal, 85(2): 194-203, 2003.
- ***Evaluating the Reliability of Predictions Made Using Environmental Transfer Models***, IAEA Safety Series 100.
- **And Much More!!!**

That’s It!