

# NRC RAMP Fall 2020 Users Group Meeting RESRAD Session

*Charley Yu, David LePoire, Emmanuel Gnanapragasam*  
*Environmental Science Division*



# RESRAD Family of Codes Update



# RESRAD Family of Codes Can be Used to Conduct Radiological Dose Assessment

## RESRAD Family of Codes

[HOME](#)[CODES](#)[DOWNLOAD](#)[TRAINING](#)[DOCUMENTS](#)[FAQS](#)[E-MAIL LIST](#)[USER CENTER](#)

The RESRAD family of codes is developed at Argonne National Laboratory to analyze potential human and biota radiation exposures from the environmental contamination of RESidual RADioactive materials. The codes use pathway analysis to evaluate radiation exposure and associated risks, and to derive cleanup criteria or authorized limits for radionuclide concentrations in the contaminated source medium. The RESRAD family of codes is widely used by regulatory agencies, the risk assessment community, and universities in more than 100 countries around the world.



### UPCOMING EVENTS

June 8 - June 12, 2020

RESRAD Training: RESRAD-ONSITE, RESRAD-OFFSITE and RESRAD-BUILD

June 15 - June 19, 2020

RESRAD Training: Advanced RESRAD-ONSITE & RESRAD-OFFSITE, RESRAD-BIOTA, and RESRAD-RDD

[Learn More](#)

#### RESRAD-ONSITE

For assessing radiation exposures of a human receptor located on top of soils contaminated with radioactive materials



#### RESRAD-OFFSITE

For assessing radiation exposures of a human receptor located on top of or at some distance from soils contaminated with radioactive materials



#### RESRAD-BUILD

For assessing radiation exposures of a human receptor in a contaminated building or a building housing contaminated furniture or equipment



#### RESRAD-RDD

For evaluating human radiation exposures during the early, intermediate, or late phase of response after a radiological dispersal device (RDD) incident



#### RESRAD-BIOTA

For evaluating radiation exposures of nonhuman biota, including flora and fauna, in a terrestrial or aquatic ecosystem

### DISCLAIMER

Additional User Quality Assurance Requirements

### OTHER RESRAD CODES

[RESRAD-RECYCLE](#)  
[RESRAD-BASELINE](#)  
[RESRAD-CHEM](#)  
[RESRAD-ECORISK](#)

[About Us](#) [Contact Us](#) [Privacy & Security](#)

Argonne National Laboratory | Environmental Science Division

More Info at RESRAD Web Site:

<https://resrad.evs.anl.gov>

Email: [resrad@anl.gov](mailto:resrad@anl.gov)

# Update to RESRAD Family of Codes

- RESRAD-ONSITE Version 7.2
  - New User's Guide (ANL/EVS/TM-18/1)
  - New RESRAD-ONSITE deterministic graphics program (using DevExpress)
  - Improved probabilistic graphics program (using MSChart control)
  - Improved Non-circular Shape Factor for external exposure pathway
  - NUREG/CR on parameter default values and distributions (NUREG/CR-7267, ANL/EVS/TM-20/1)



# Update to RESRAD Family of Codes (Cont'd)

- RESRAD-OFFSITE Version 4.0
  - New RESRAD-OFFSITE deterministic graphics program
  - Updated “Simulate RESRAD-ONSITE Code” option and “Onsite Scenario Template File” option
  - New source term models for waste disposal evaluation
    - Delayed release (waste form, waste in container, institutional control, etc.)
    - Diffusion-controlled release
    - Solubility-limited release
  - New surface water model
  - NUREG/CR on parameter default values and distributions
  - New User’s Manual and User’s Guide (NUREG/CR-7268, ANL/EVS/TM-19/2, Vol. 1 & Vol. 2)



# Update to RESRAD Family of Codes (Cont'd)

- RESRAD-BUILD Version 3.8 beta
  - Updated QA files (included in the installation package)
  - Added 90+ radionuclides to the database to calculate dose coefficients (DCs) for IND scenario
  - Fixed dose contribution allocation to decay progeny
  - Listed external DCs in the text report
  - NUREG/CR on parameter default values and distributions (NUREG/CR-7267, ANL/EVS/TM-20/1)
  - Version 4 will have ability to model more than 3 rooms and other advanced features



# Update to RESRAD Family of Codes (Cont'd)

- RESRAD-RDD Version 1.7 (and 2.0 Beta)
  - Incorporated dose coefficients for 90+ radionuclides calculated with RESRAD-BUILD
  - Rewriting User Interface for RESRAD-RDD&IND
  - Modified the code to correctly retrieve data from previous input file and save file before calculation
  - Added Water PAG as Group H Water Consumption in RESRAD-RDD (and RESRAD-IND)
  - Incorporated new resuspension model
  - Implemented analytical time-integration combining resuspension, weathering, and decay & ingrowth



# Update to RESRAD Family of Codes (Cont'd)

- RESRAD-BIOTA Version 1.8 (and 1.9 Beta)
  - New installation file for RESRAD-BIOTA 1.9.0.6 Beta
  - Compiled sediment Kd data
  - Fixed the code on grid data display for Win 10
  - Improved deterministic and probabilistic graphics program
  - Revised the method of saving allometric input parameters for different organisms
  - Improved the input parameter report
  - Saving input data in memory until user instructing to save in a file
  - New DOE STANDARD--A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota (DOE-STD-1153-2019)





# One Hundred Twenty-One (121) Countries Downloaded

## RESRAD Family of Codes (seven (7) new countries: Burundi, Cuba, Dominican Republic, Jamaica, Lebanon, Nepal, and Uruguay)

|                      |               |                    |           |            |             |              |              |                      |          |
|----------------------|---------------|--------------------|-----------|------------|-------------|--------------|--------------|----------------------|----------|
| Algeria              | Burkina Faso  | Czech Republic     | Ghana     | Kazakhstan | Moldova     | Norway       | Singapore    | Thailand             | Vietnam  |
| Argentina            | Burundi       | D.R. of the Congo  | Greece    | Kenya      | Monaco      | Pakistan     | Slovakia     | Togo                 | Yemen    |
| Armenia              | Cameroon      | Denmark            | Hungary   | Kuwait     | Mongolia    | Peru         | Slovenia     | Tunisia              | Zambia   |
| Australia            | Canada        | Djibouti           | India     | Latvia     | Montenegro  | Philippines  | South Africa | Turkey               | Zimbabwe |
| Austria              | Chad          | Dominican Republic | Indonesia | Lebanon    | Morocco     | Poland       | South Korea  | Uganda               |          |
| Azerbaijan           | Chile         | Egypt              | Iran      | Libya      | Mozambique  | Portugal     | Spain        | Ukraine              |          |
| Bangladesh           | China         | Estonia            | Iraq      | Lithuania  | Namibia     | Puerto Rico  | Sudan        | United Arab Emirates |          |
| Belarus              | Colombia      | Fiji               | Ireland   | Macedonia  | Nepal       | Qatar        | Sweden       | United Kingdom       |          |
| Belgium              | Congo         | Finland            | Israel    | Madagascar | Netherlands | Romania      | Switzerland  | United States        |          |
| Bosnia & Herzegovina | Cote D'Ivoire | France             | Italy     | Malawi     | New Zealand | Russia       | Syria        | Uruguay              |          |
| Botswana             | Croatia       | Gabon              | Jamaica   | Malaysia   | Niger       | Saudi Arabia | Taiwan       | Uzbekistan           |          |
| Brazil               | Cuba          | Georgia            | Japan     | Mauritius  | Nigeria     | Senegal      | Tajikistan   | Vanuatu              |          |
| Bulgaria             | Cyprus        | Germany            | Jordan    | Mexico     | North Korea | Serbia       | Tanzania     | Venezuela            |          |

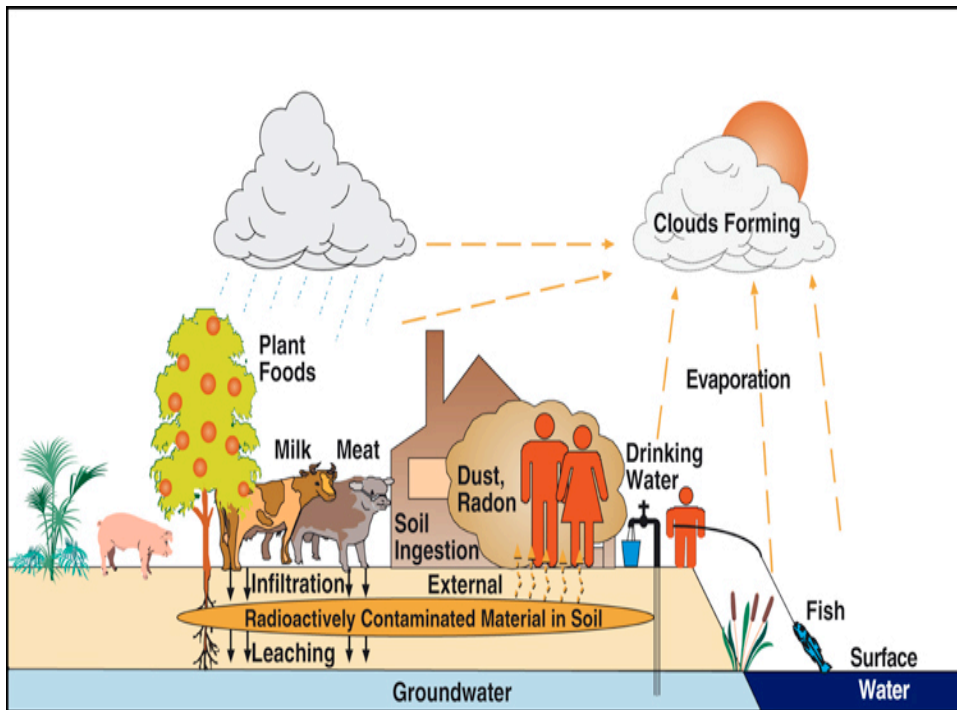


# Overview of RESRAD-ONSITE



# RESRAD-ONSITE - A Regulatory Tool for Determining Allowable RESidual RADioactivity in Site Cleanup

RESRAD, an internationally utilized model, successfully addresses the critical question "How clean is clean?"



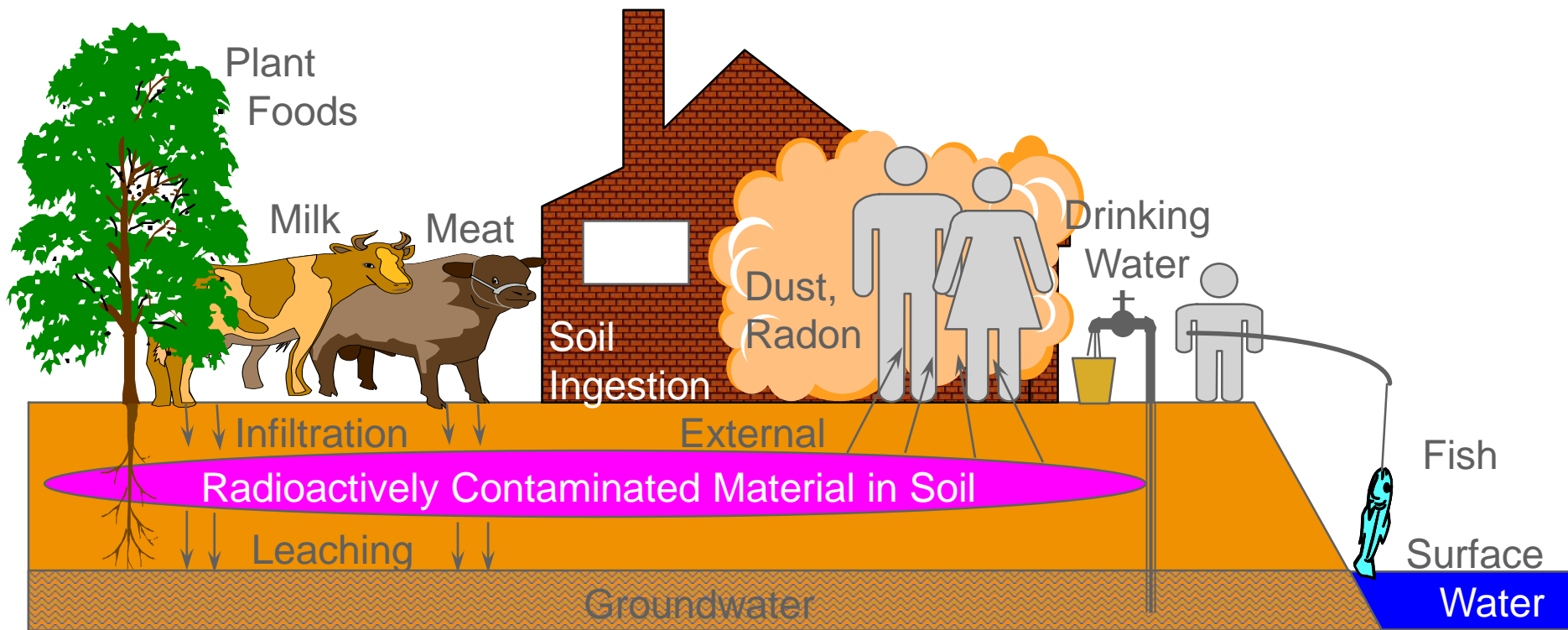
Accepted for use by government regulatory agencies

- DOE (Designated by Order 5400.5 and 458.1)
- NRC (NUREG-1757)
- EPA
- State agencies

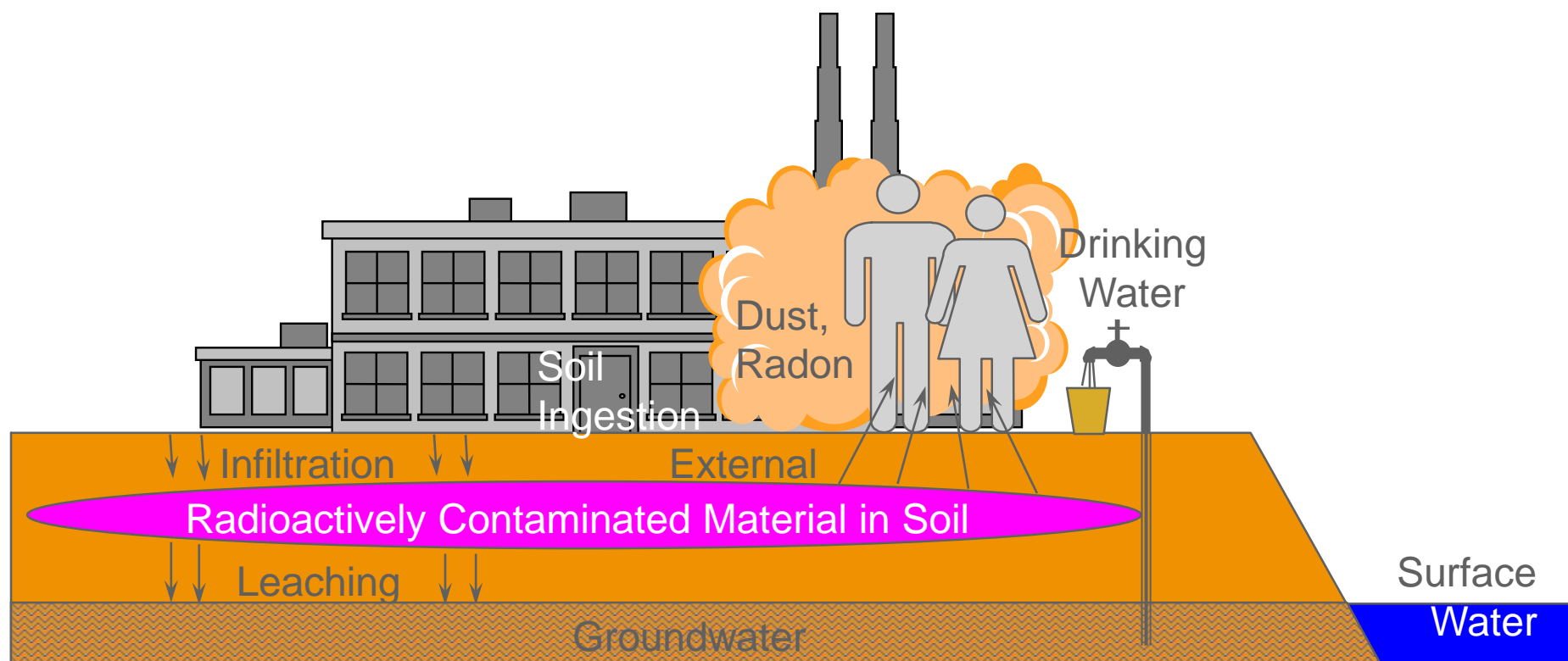
In use for more than 30 years

- Evaluation of over 300 cleanup sites including many DOE/EM sites
- More than 150 training workshops
- International recognition (IAEA multilingual version and training)

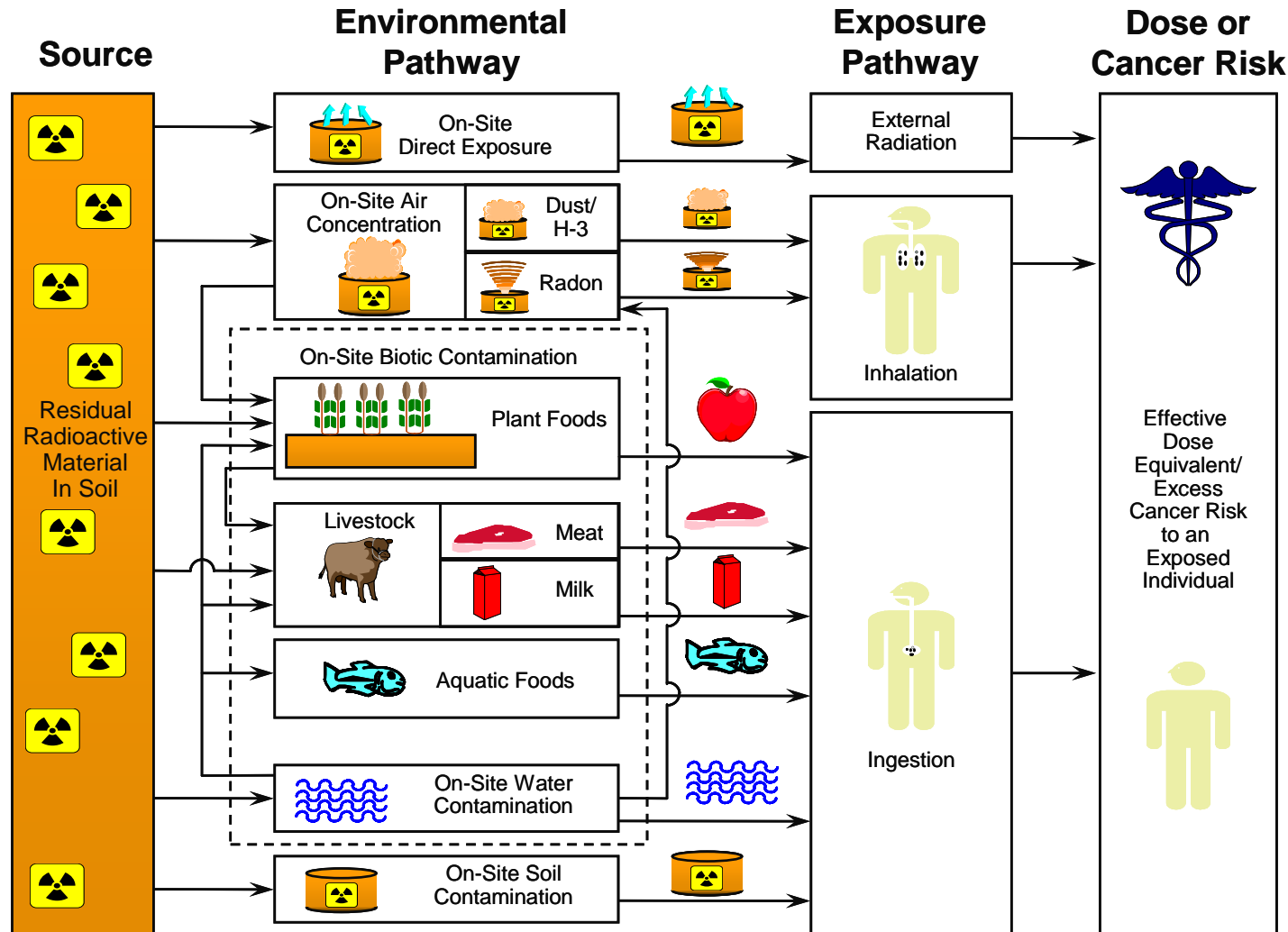
# Exposure Pathways Considered in RESRAD-ONSITE: (Resident Farmer Scenario)



# Exposure Pathways Considered in RESRAD-ONSITE: (Industrial Use Scenario)



# RESRAD Contains An Array of Parameters for Pathway Analysis in Performing Comprehensive Risk Assessment



# Major Categories of Input Parameters for RESRAD

- Contamination
  - Physical size, concentration, nuclides of concern
- Environmental Release and Transport
  - Release: leaching, particulate air release, erosion, root uptake
  - Transport: groundwater, air, radon gas, food chain
- Exposure Pathways (related to land use scenario)
  - External
  - Inhalation (particulates and radon),
  - Ingestion (plant, meat, milk, water, soil, aquatic foods)
- Consideration of Health Impacts
  - Annual dose or lifetime risk
  - Use of different coefficient to convert exposure to impact (dose, risk)



# Use RESRAD-ONSITE for Dose/Risk Estimates or Determining Cleanup Criteria

- **Forward:** Input final/measured residual radioactive material **concentrations**
  - Concentration → Environmental Pathways → Dose or Risk
- **Backward:** Input **dose limit** to estimate residual radioactive material concentrations so that the dose to an individual is below the dose limit (**DCGL = Derived Concentration Guideline Level**)
  - Dose Limit → Environmental Pathways → Concentration
    - Derived separately for each radionuclide based on its maximum dose
    - Requires the use of the “Sum of Fractions” if multiple radionuclides or sources are present



# RESRAD-ONSITE Has Many Conservative Default Assumptions

- All activities occur on the contaminated land
- The well is placed at the contamination edge where the water concentration would be the highest
- Default distribution coefficients and other parameters are often selected to be conservative
- The range of peak annual dose can occur anywhere in the 1,000 years (or the specified time frame)
- The default scenario is subsistence farmer (half of plants, half of meat and milk, all water from contaminated land)
- Internal Dose Coefficients are the largest of the set considering lung clearance class and gastrointestinal fraction
- Food transfer factors are for sensitive organisms
- 1-D transport to the groundwater table and 2-D in groundwater aquifer, no dispersion

**Note that users can overwrite these assumptions by modifying input parameters and by turning pathways on or off.**



# Demonstration of RESRAD-ONSITE Code



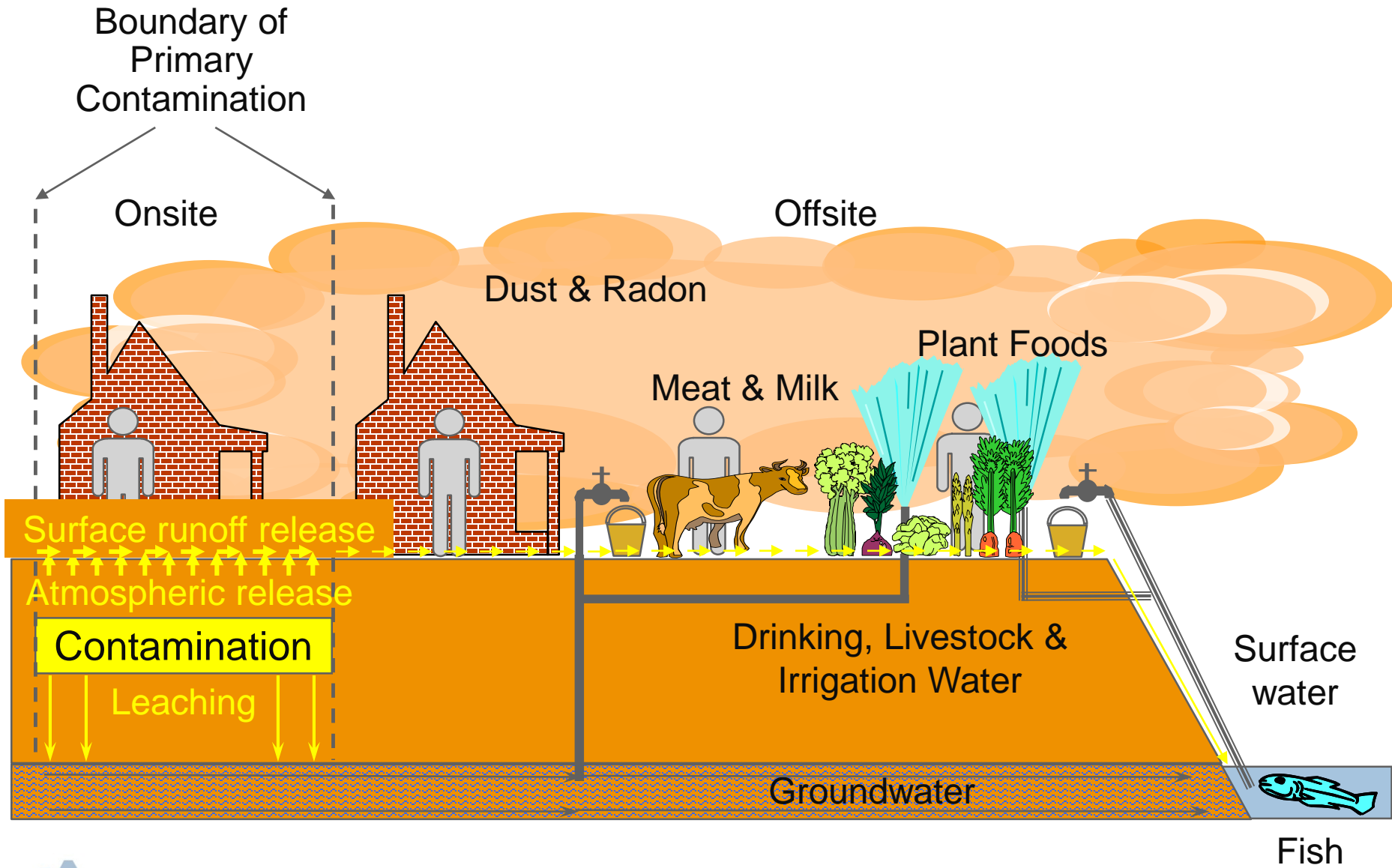
Break / Q&A



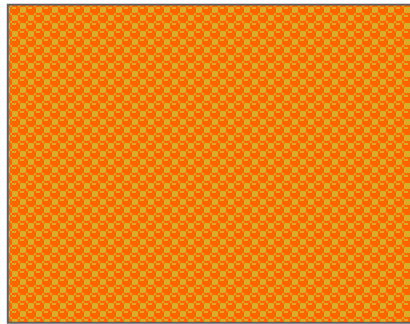
# Overview of RESRAD-OFFSITE



# Environmental Pathways and Exposure Locations

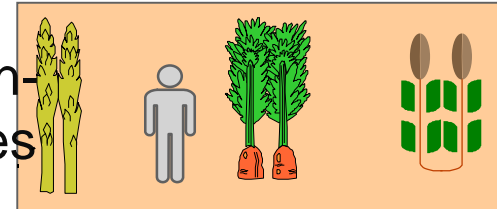


# Areas of Secondary Contamination - RESRAD-OFFSITE

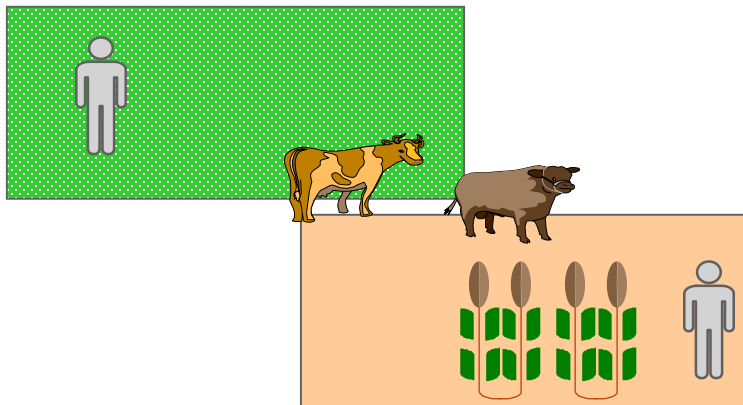


Primary  
contamination

Fruit, grain, non-  
leafy vegetables

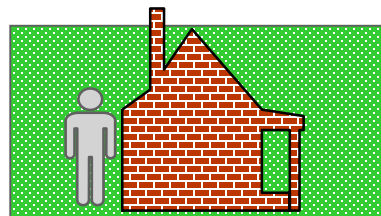


Pasture

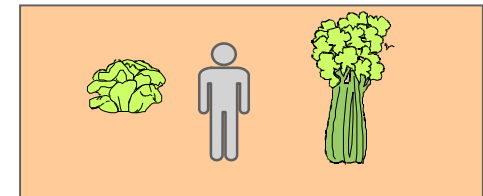


Livestock grain

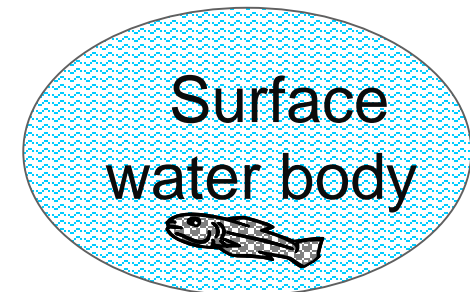
Well



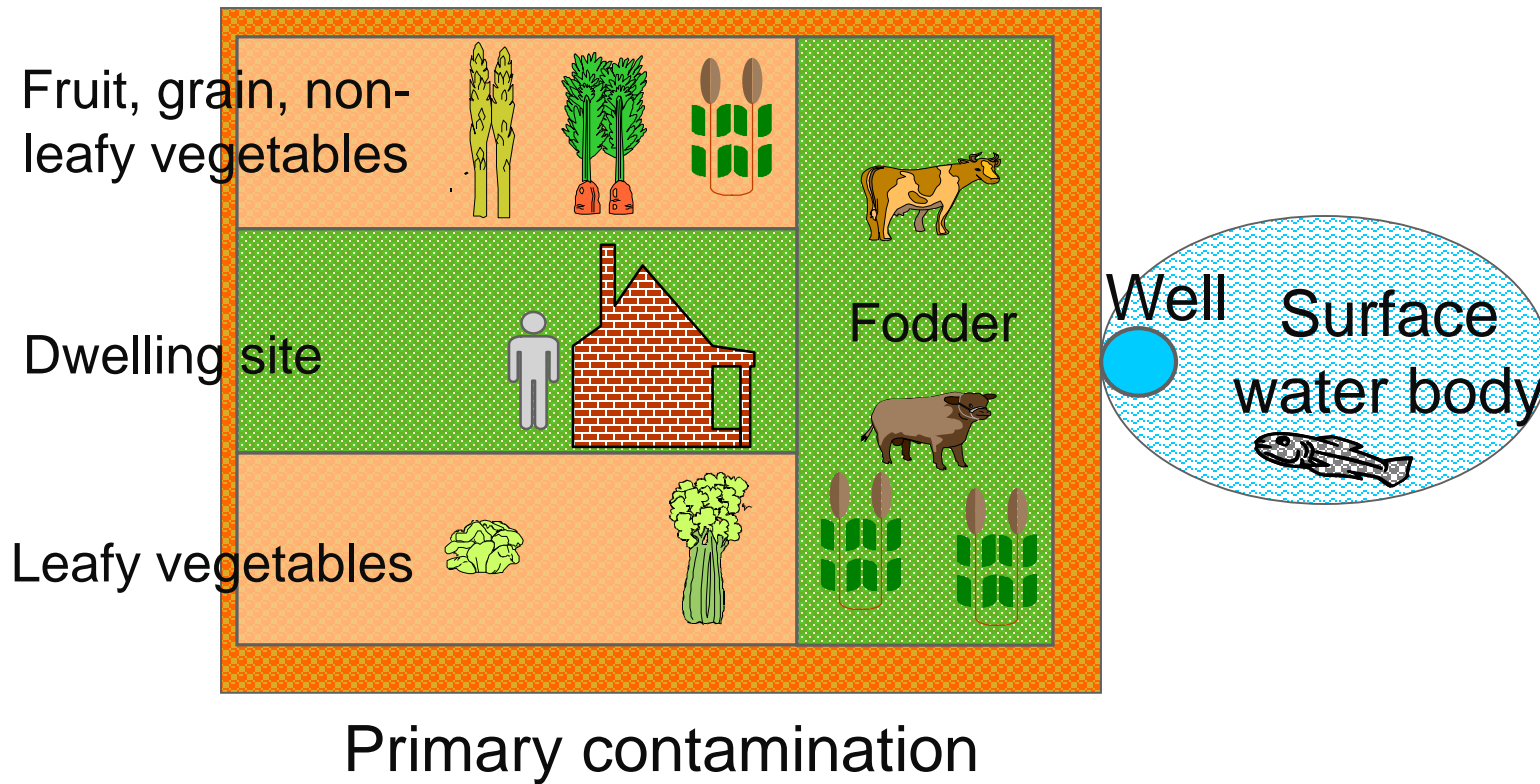
Offsite dwelling



Leafy vegetables



# Areas of Secondary Contamination - RESRAD-ONSITE



Appendices K and L of the manual

# User's Manual accessible from the code

RESRAD - OFFSITE Site1.ROF (Modified)

File Pathways Site Data View Form Options Data Transfer Help

Context Sensitive Help F1  
Users' Guide F3  
Users' Technical Manual F4  
About RESRAD-OFFSITE

RESRAD-OFFSITE  
Version 4.0

File  
Change Title  
Set Pathways  
Modify Data  
Run  
View Output  
Quit

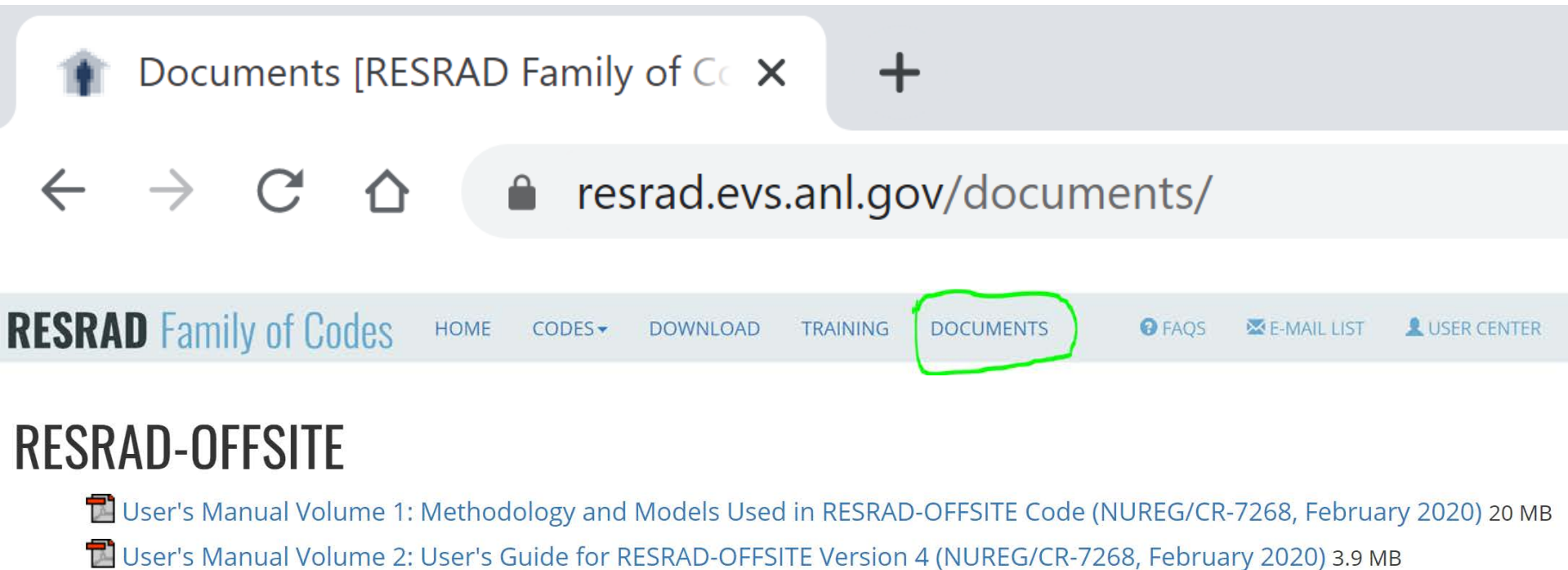
0 Variables

Problem Inputs & Pathways Results Help



The diagram illustrates the environmental pathways of radionuclides. At the top, a cloud represents the source of radionuclides. Arrows show the dispersion of radionuclides (Rn, C-14, H-3) through the environment. The pathways include: 1. Air: Radionuclides are dispersed from the cloud into the air. 2. Water: Radionuclides are dispersed into the water body. 3. Soil: Radionuclides are deposited on the soil. 4. Food: Radionuclides are taken up by plants and animals (e.g., cow, fish). 5. Human: Radionuclides are taken up by humans (e.g., person, house). 6. Exposure: Radionuclides are exposed to humans through inhalation, ingestion, and external exposure. The diagram also shows the resulting exposure pathways (inhalation, ingestion, external) and the resulting dose (clock icon).



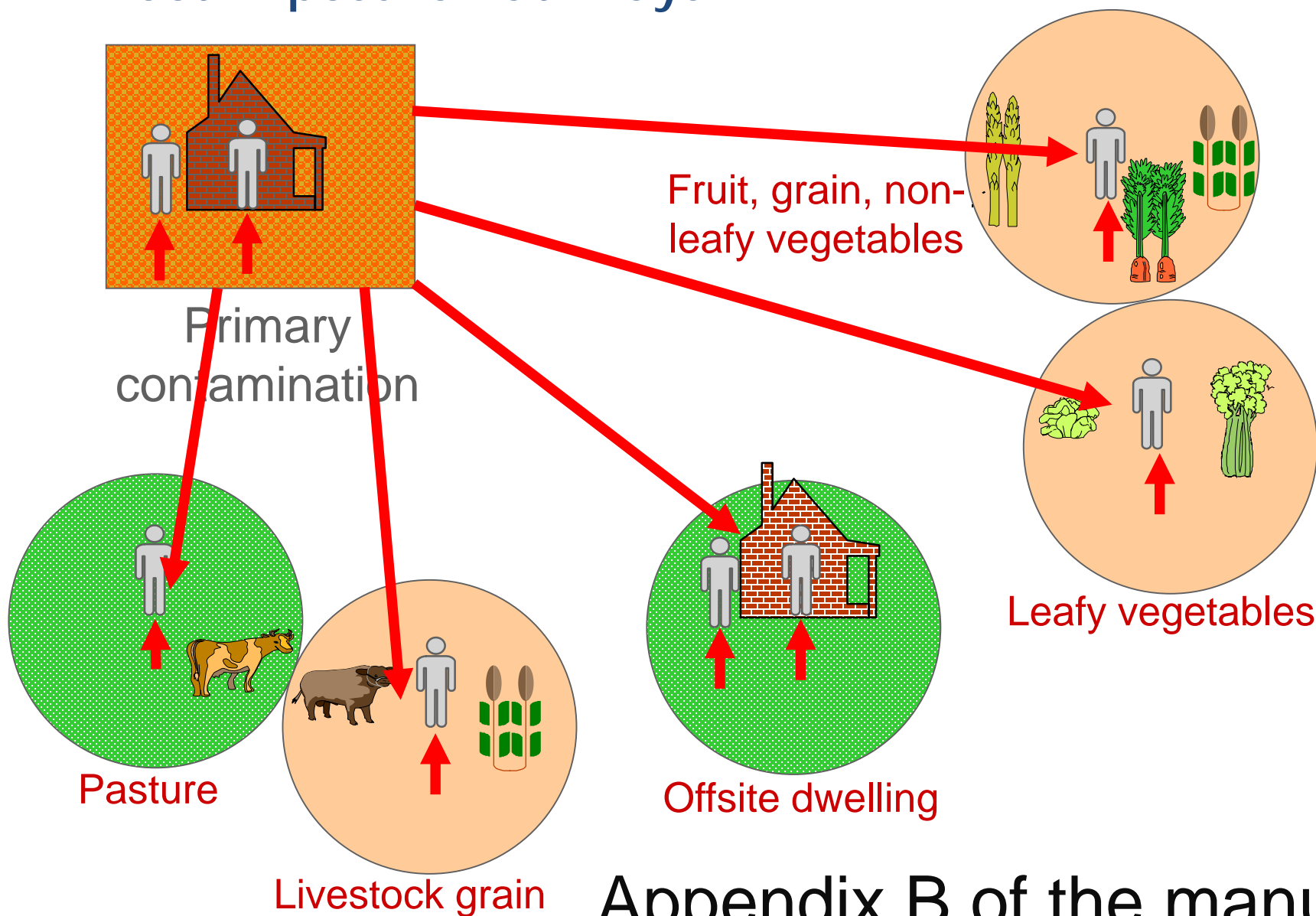
# User's Manual accessible from the web



The screenshot shows a web browser window with a single tab titled "Documents [RESRAD Family of Codes]". The address bar displays the URL "resrad.evs.anl.gov/documents/". The website's navigation bar includes the logo "RESRAD Family of Codes" and several menu items: "HOME", "CODES", "DOWNLOAD", "TRAINING", "DOCUMENTS" (which is highlighted with a green circle), "FAQS", "E-MAIL LIST", and "USER CENTER". Below the navigation bar, the heading "RESRAD-OFFSITE" is displayed. Under this heading, two documents are listed:

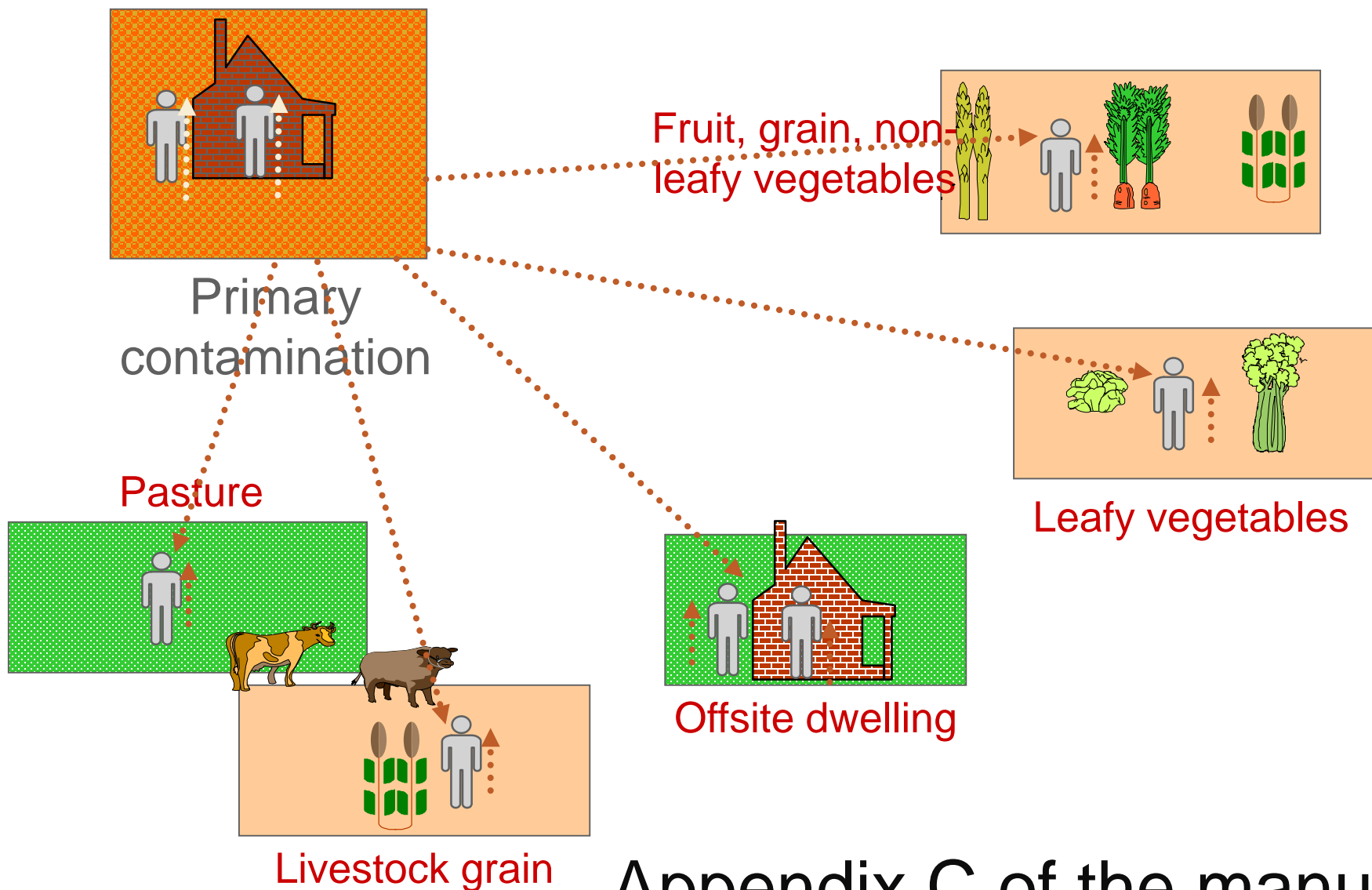
-  User's Manual Volume 1: Methodology and Models Used in RESRAD-OFFSITE Code (NUREG/CR-7268, February 2020) 20 MB
-  User's Manual Volume 2: User's Guide for RESRAD-OFFSITE Version 4 (NUREG/CR-7268, February 2020) 3.9 MB

# Direct Exposure Pathways



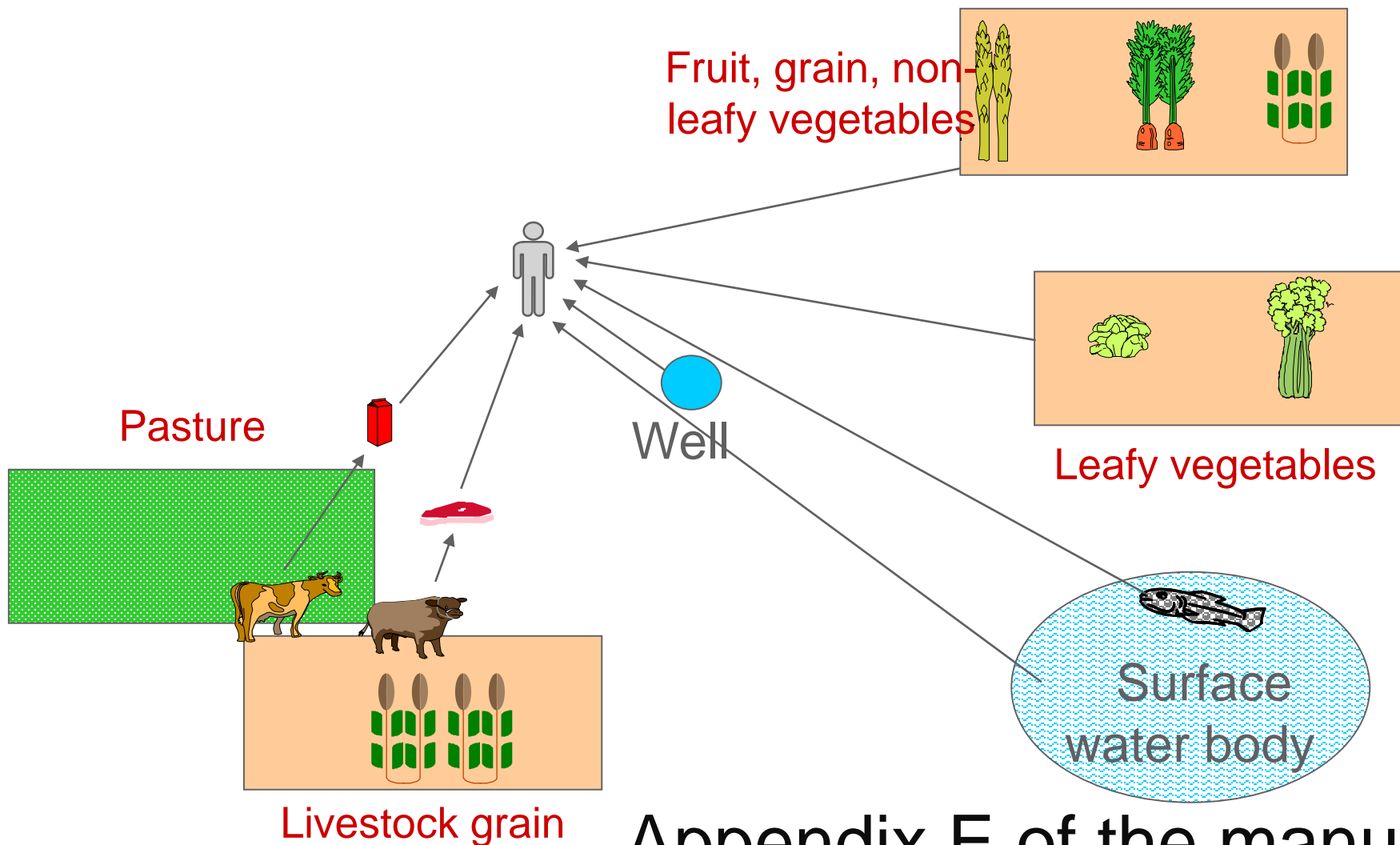
Appendix B of the manual

# Inhalation Exposure Pathway - Particulates



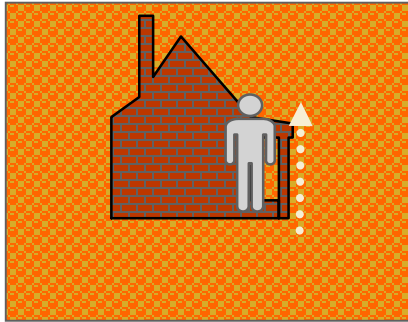
Appendix C of the manual

# Ingestion Exposure Pathway - Food and Water



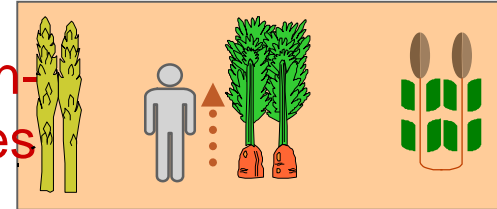
Appendix E of the manual

# Ingestion Exposure Pathway - Soil

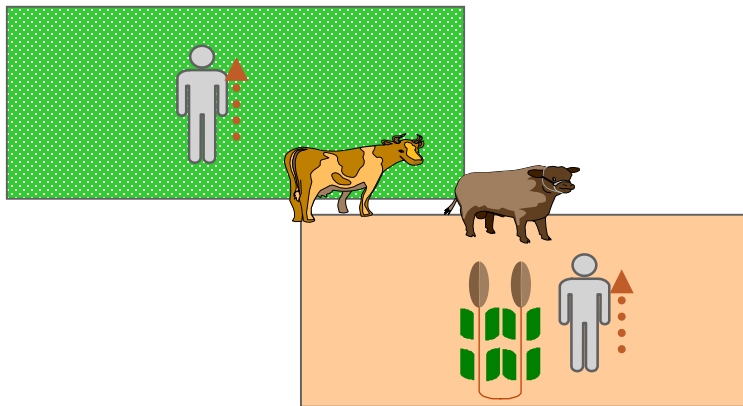


Primary  
contamination

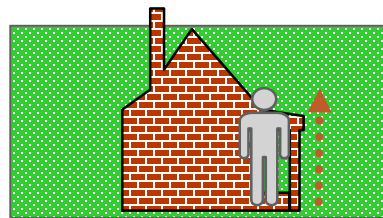
Fruit, grain, non-  
leafy vegetables



Pasture

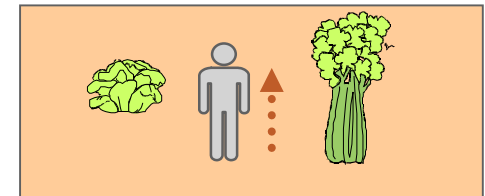


Livestock grain

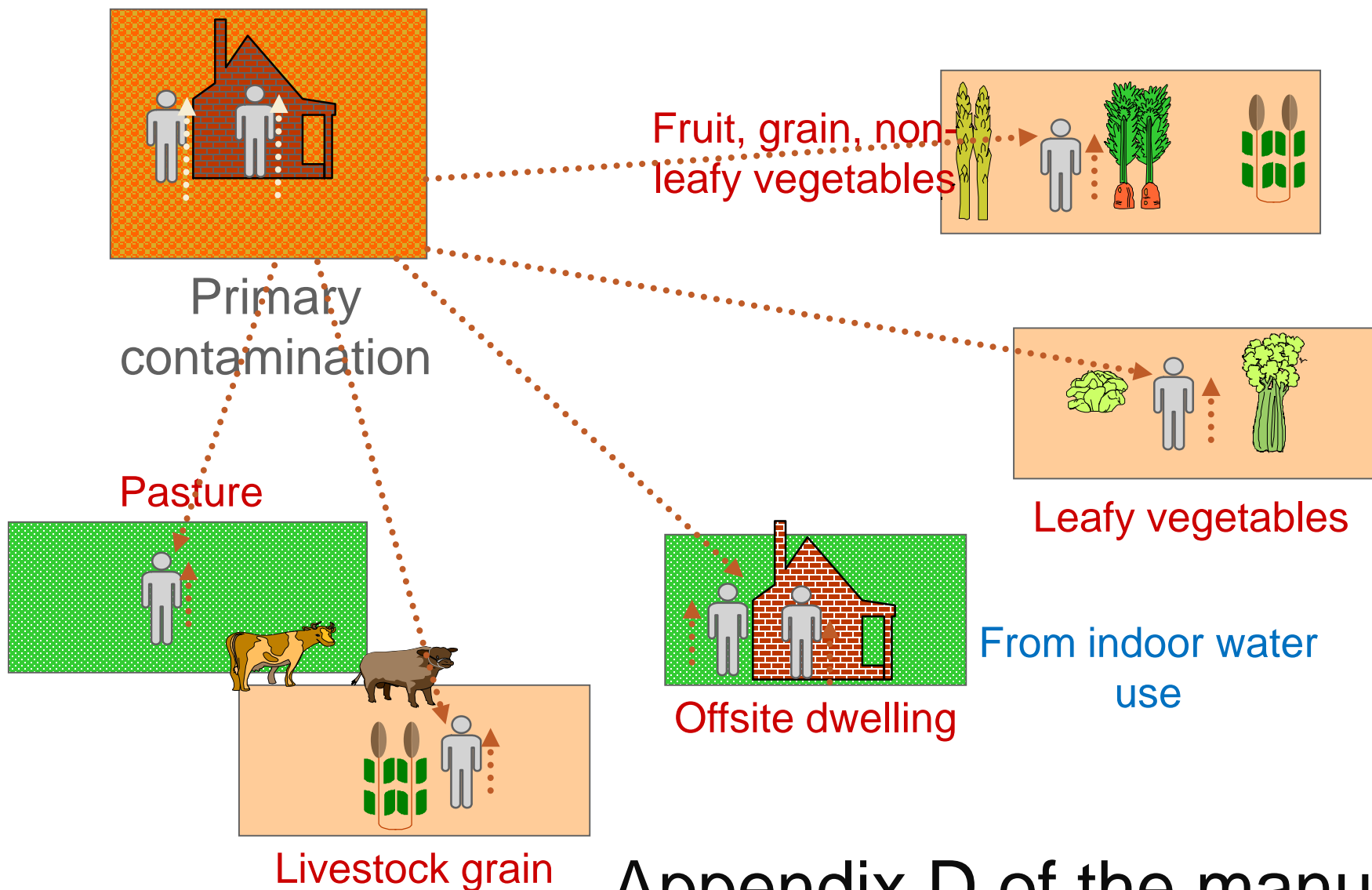


Offsite dwelling

Leafy vegetables

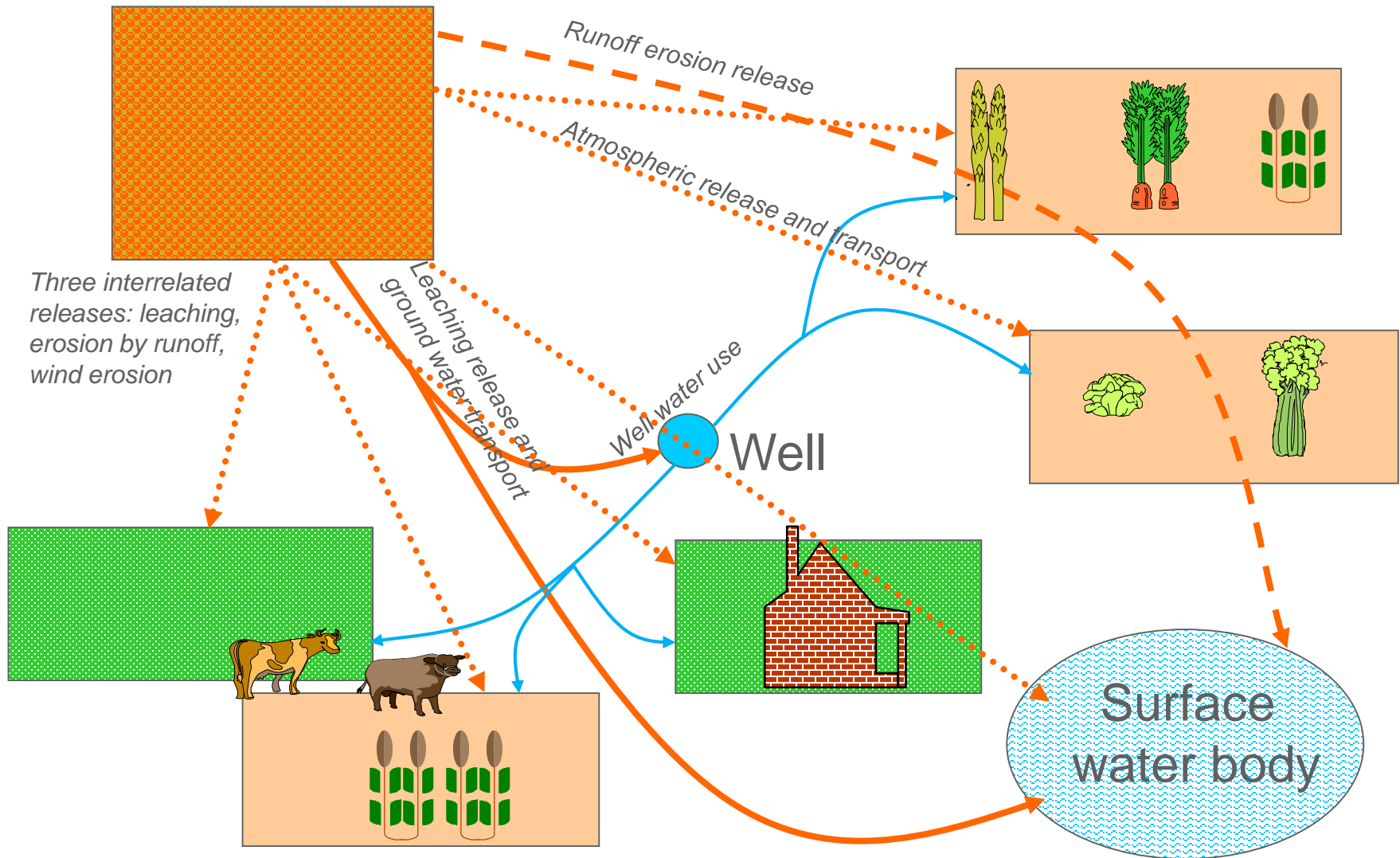


# Inhalation Exposure Pathway - Radon

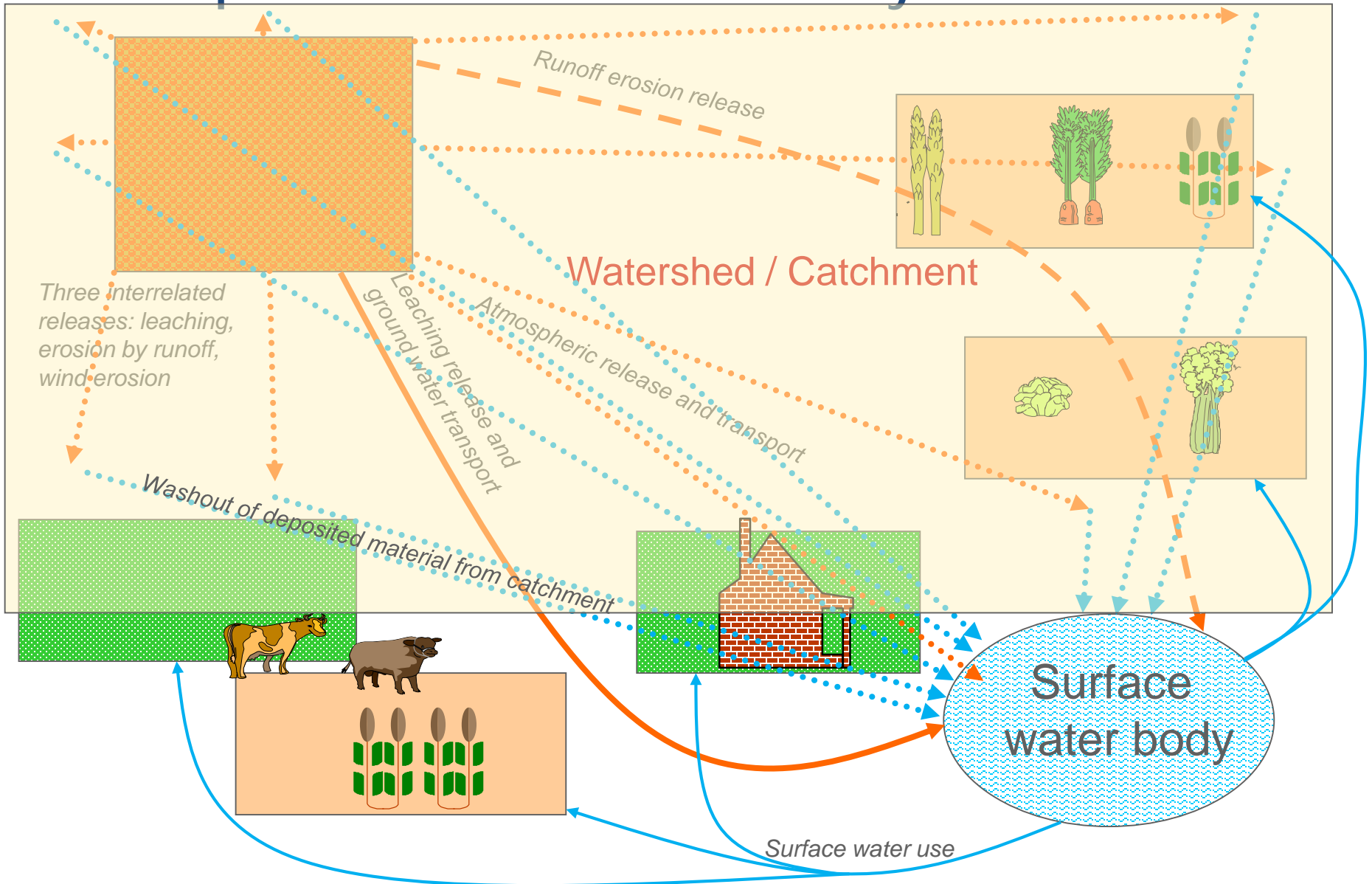


Appendix D of the manual

# Transport to Areas of Secondary Contamination



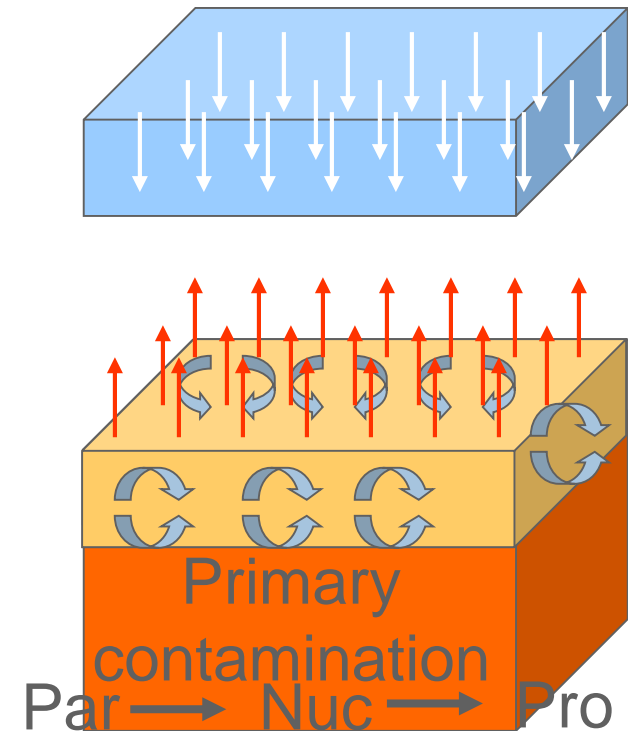
# Transport to Surface Water Body





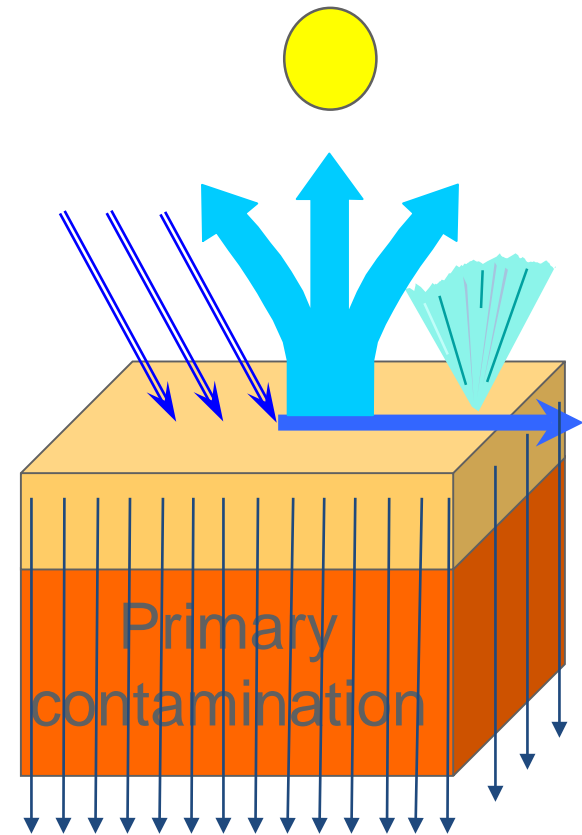
# Processes modeled in the Primary Contamination (1)

- Radiological transformations
- Mixing of the surface layer
- Exchange of particulates between the surface layer and the atmosphere
  - Release of gases for  $^3\text{H}$ ,  $^{14}\text{C}$ ,  $^{220}\text{Rn}$  and  $^{222}\text{Rn}$



## Processes modeled in the Primary Contamination (2)

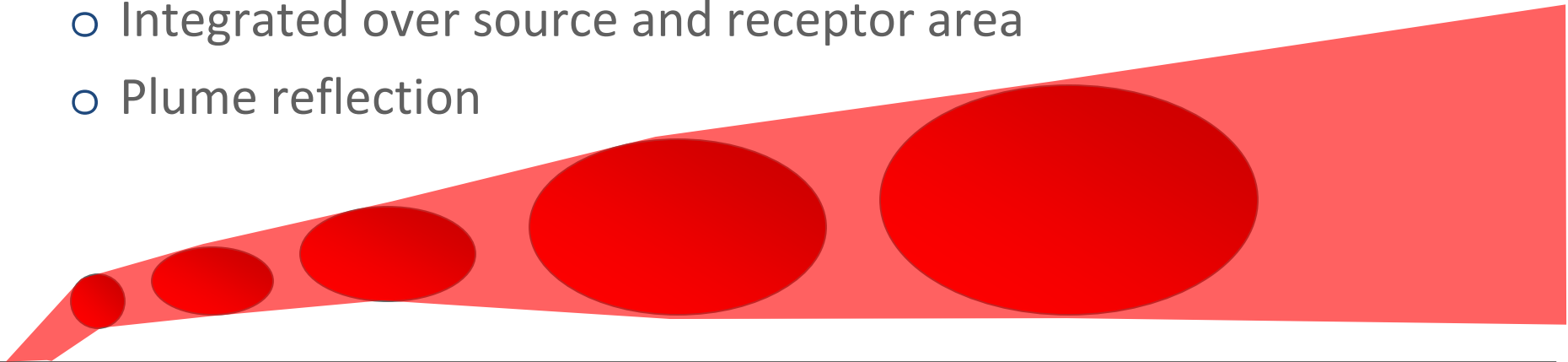
- Removal of particulates by water runoff
- Removal of radionuclides by infiltrating water
- Failure of Engineered Barriers over time



Appendix G of the manual

# Gaussian Puff

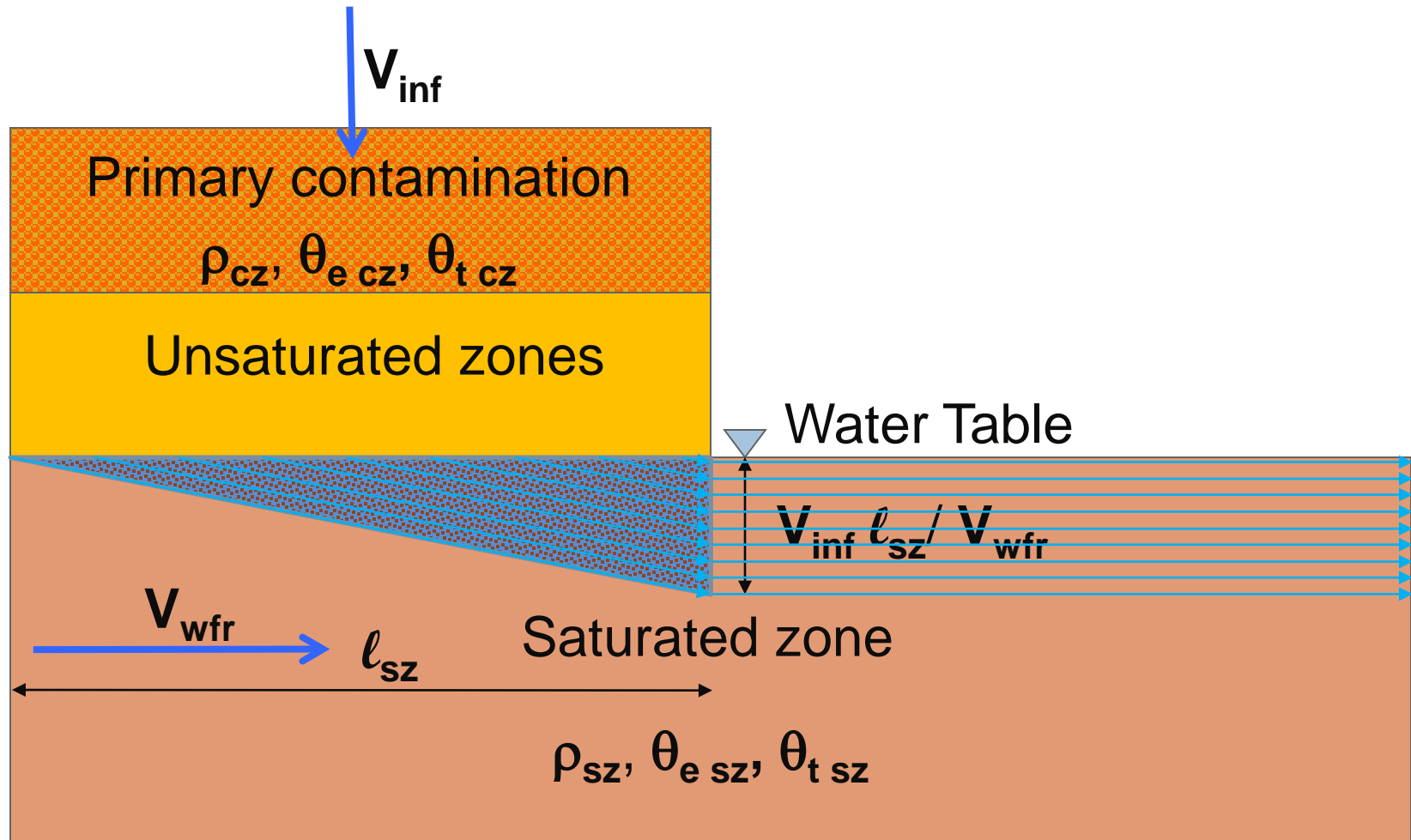
- Chronic Gaussian plume area source
  - Based on discrete puff point source
  - Plume depletion
    - ◇ Dry and wet deposition
    - ◇ Conservation of mass
  - Sector average time-integrated air concentrations
  - Integrated over source and receptor area
  - Plume reflection



Appendix I of the manual

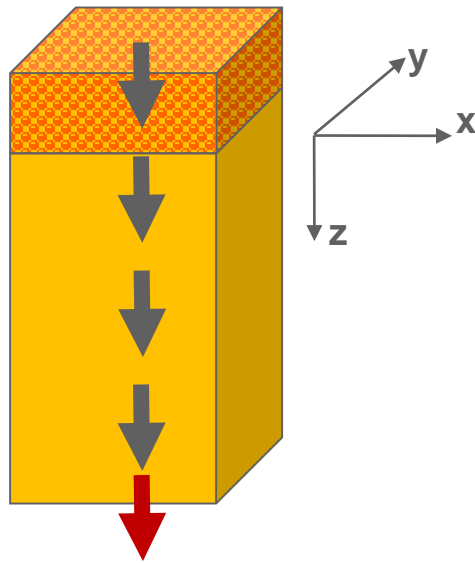
# Conceptualization for Groundwater Transport

## Unsubmerged Primary Contamination



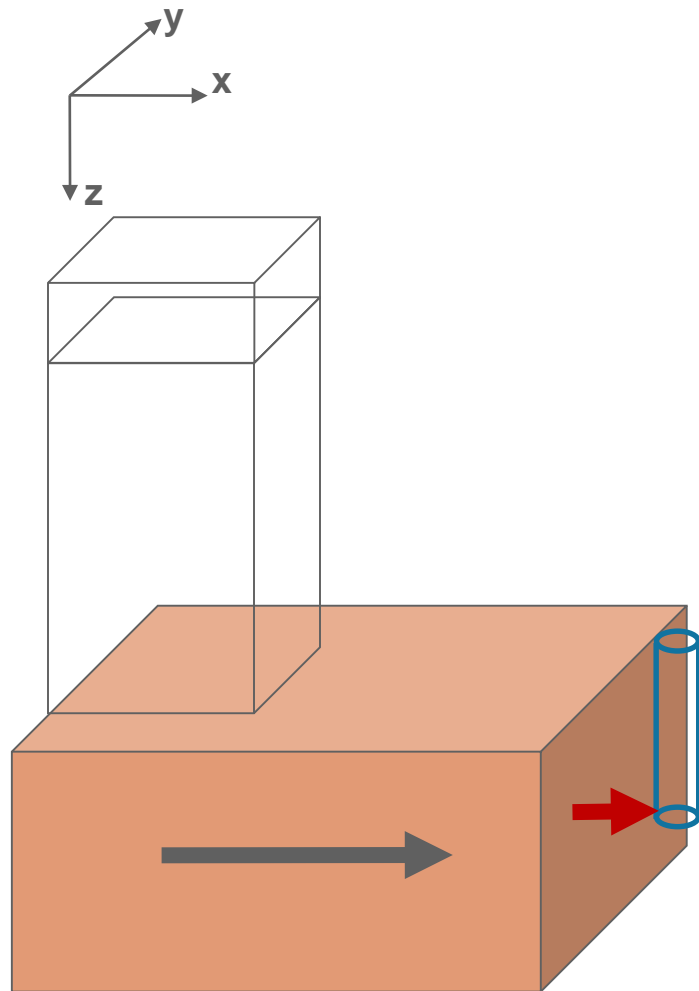
Appendix H of the manual

# Processes Modeled for Vertical Transport in the Unsaturated Zones



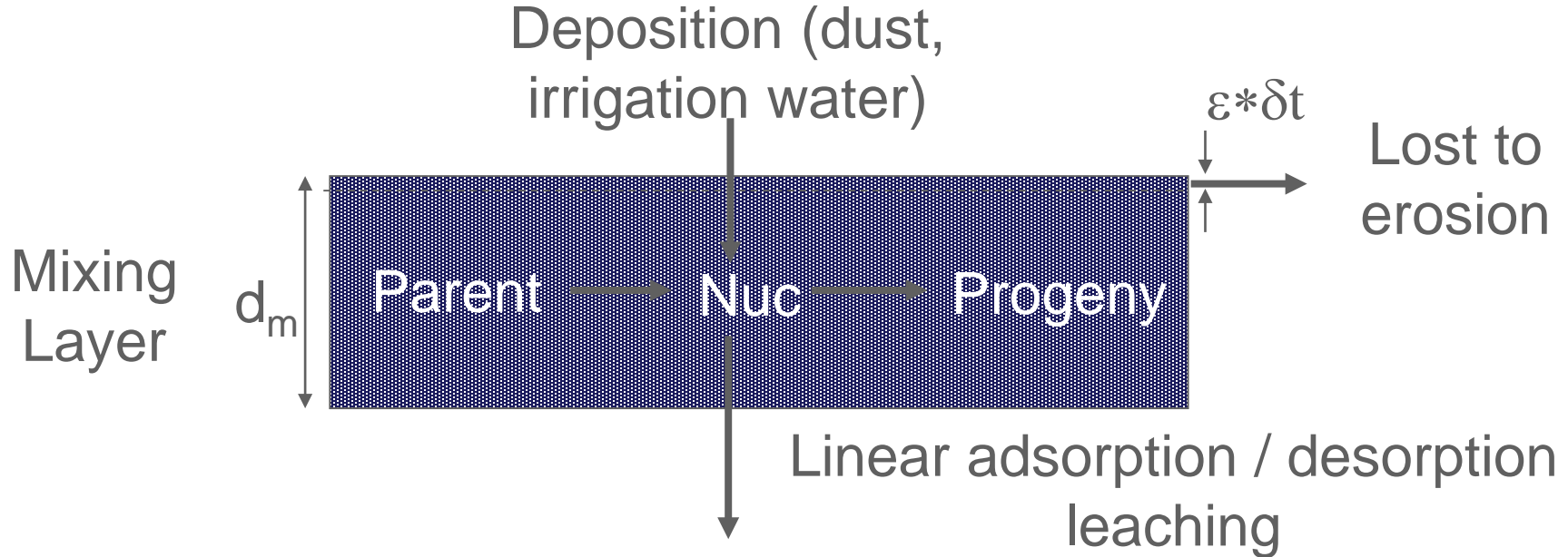
- Vertical transport
  - Longitudinal (z) advection
  - Longitudinal (z) dispersion
  - Transformations during transport
  - Nuclide specific solute-soil interaction
    - ◇ Transport rate
    - ◇ Concentration in water
- Areally integrated flux to water table

# Processes Modeled Saturated Zone Transport



- ☐ Longitudinal (x) advection
- ☐ Longitudinal (x) dispersion
- ☐ Nuclide specific solute-soil interaction
- ☐ Transverse (y, z) dispersion
- ☐ Areally integrated flux to surface water body
- ☐ Concentration in well water
- ☐ Uniformly spaced computation time points require smaller execution time

# Process Modeled for Accumulation in Offsite Soil

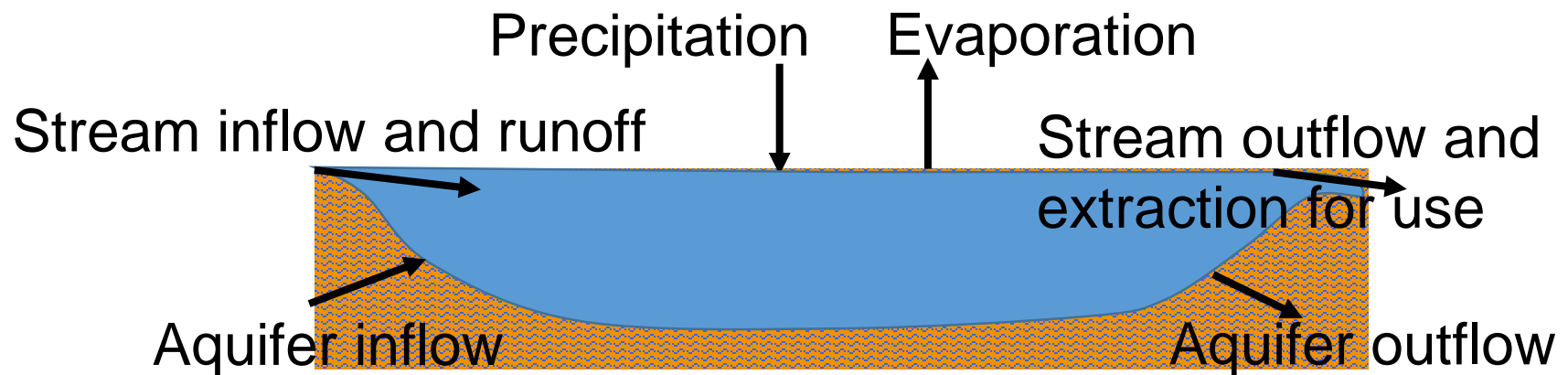


## □ Process modeled

- Uniform mixing within mixing layer
- Loss due to surface erosion
- Linear adsorption desorption
- Radiological transformations
- Time dependent deposition

Appendix J of the manual

# Process Modeled for Surface Water Body - Water Balance

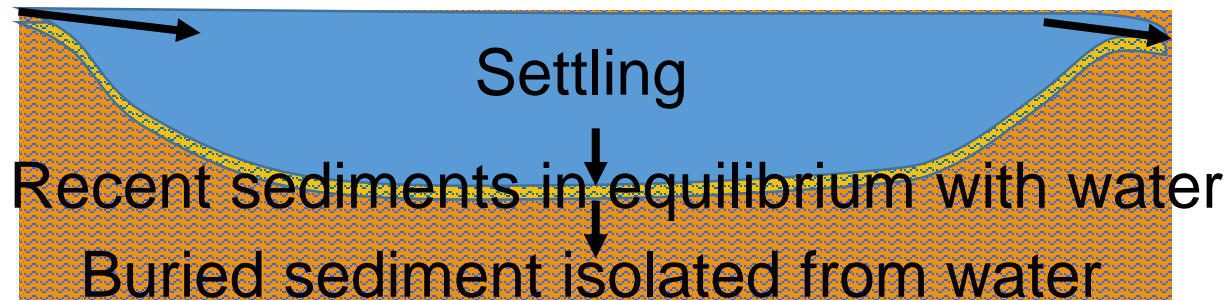




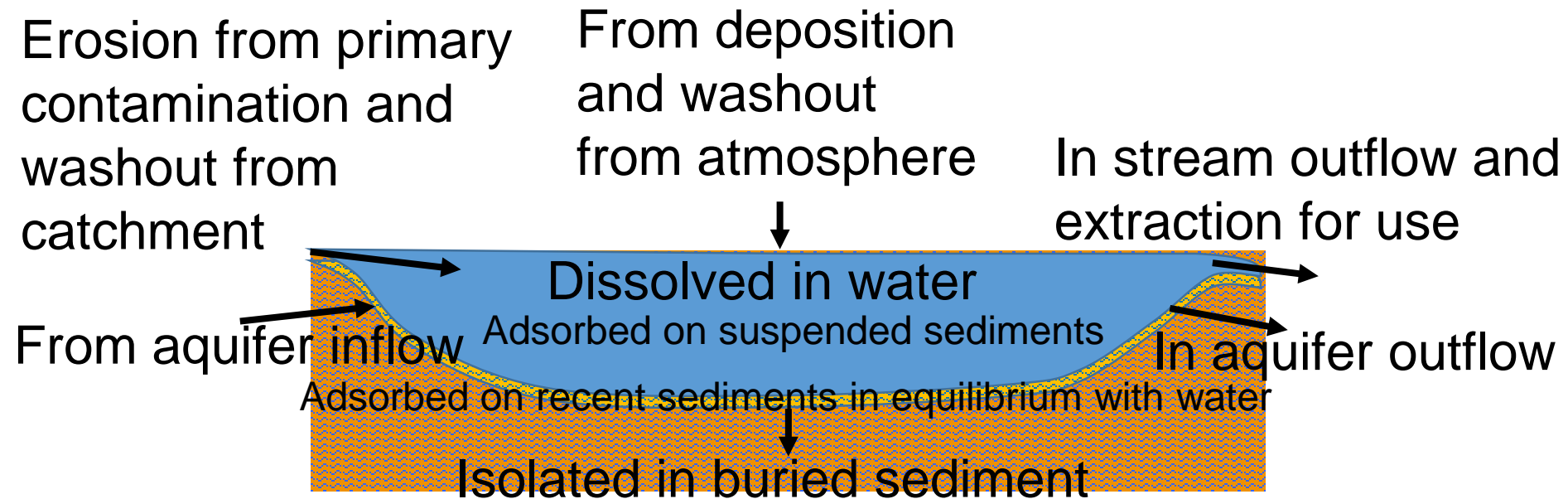
# Process Modeled for Surface Water Body - Sediment/particulate Balance

Erosion from  
catchment

In stream outflow and  
extraction for use

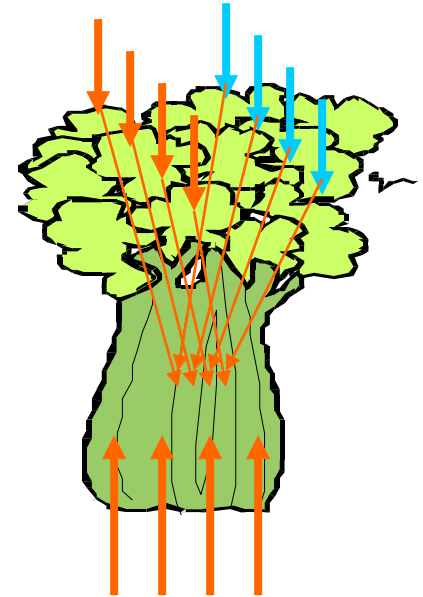


# Process Modeled for Surface Water Body - Nuclide Balance



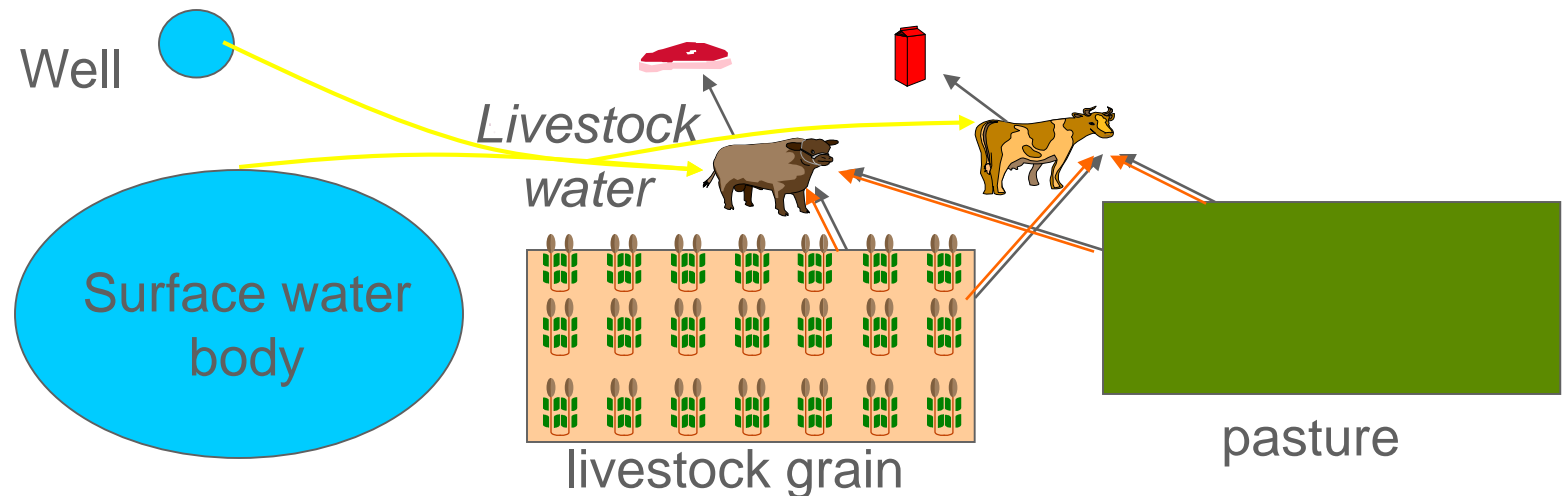
# Process Modeled for Contamination of Plant Food

- Root uptake from soil
- Foliar interception of contaminated dust
- Foliar interception of contaminated irrigation
- Translocation of intercepted contamination to edible part of plant



# Contamination of Meat and Milk

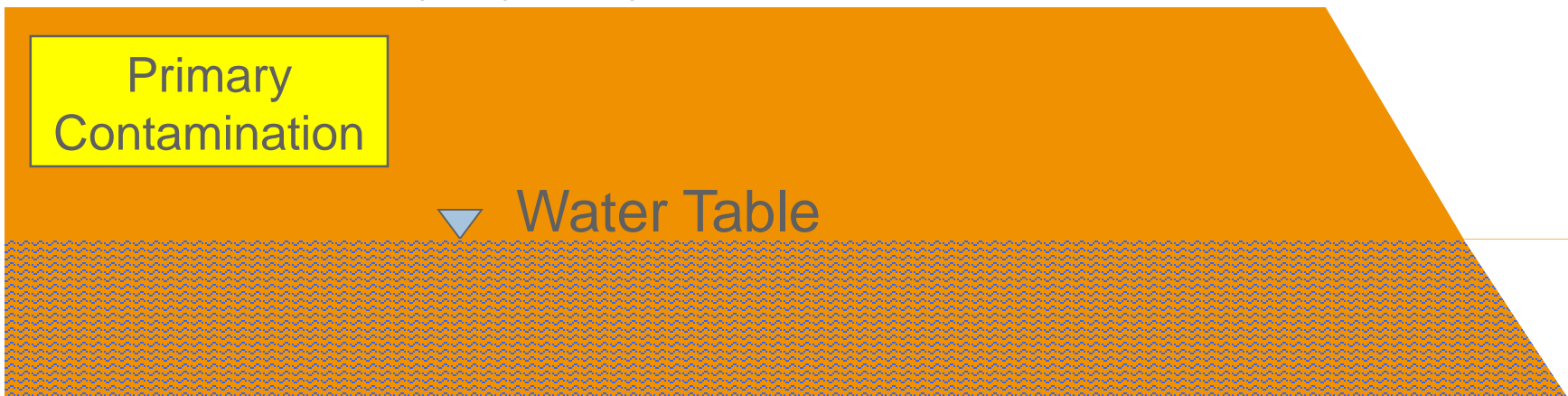
- Ingestion of contaminated feed (grain, grass)
- Ingestion of soil with feed
- Ingestion of contaminated water
- Transfer to milk or accumulation in meat



# Demonstration of RESRAD-OFFSITE Code

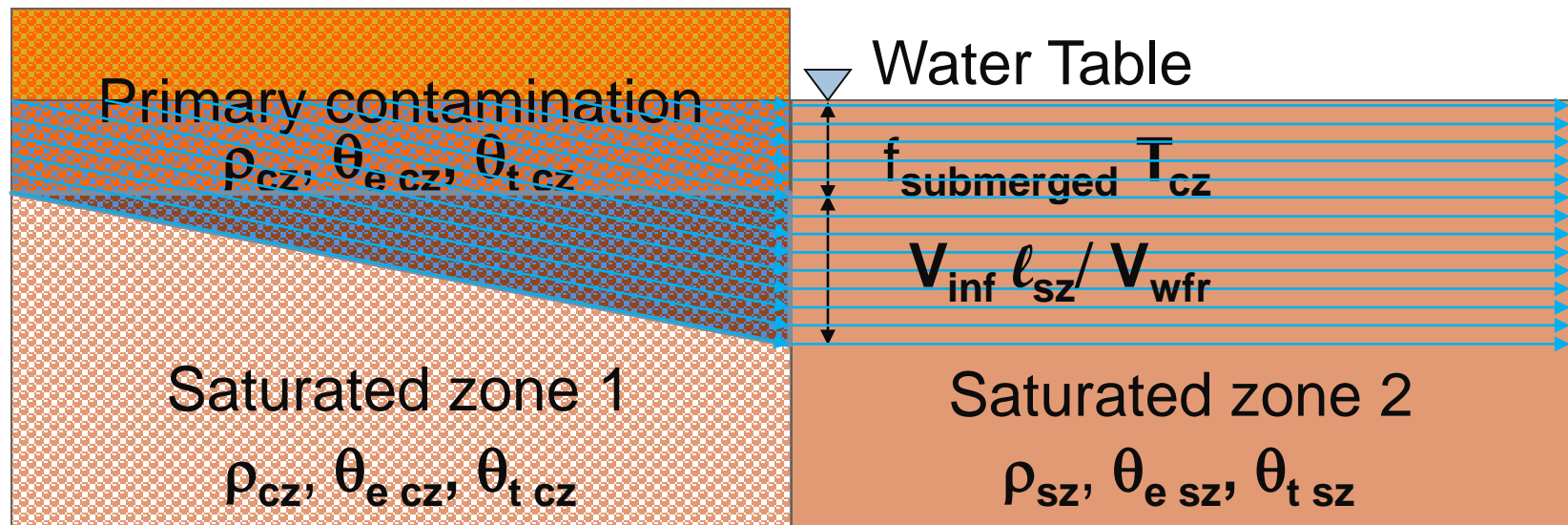
# Conceptualization of Primary Contamination

- Is a layer of “soil”
  - Uniform thickness
  - Homogeneous
    - ◇ Uniformly contaminated
- There may be a layer of clean cover above it
- Can be located
  - above the water table
  - straddling the water table
  - just below the water table
    - ◇ with top of primary contamination at the water table



# Conceptualization for Groundwater Transport

## Partially Submerged Primary Contamination



# Leaching Release to Infiltration

## □ Equilibrium release options

### ○ Adsorption – desorption

◇ Distribution coefficient of **isotope**

◇  $\text{cm}^3 \text{g}^{-1}$  ( $\equiv 0.001 \text{ m}^3 \text{kg}^{-1}$ )

### ○ Precipitation – dissolution

◇ Total soluble concentration of **element**

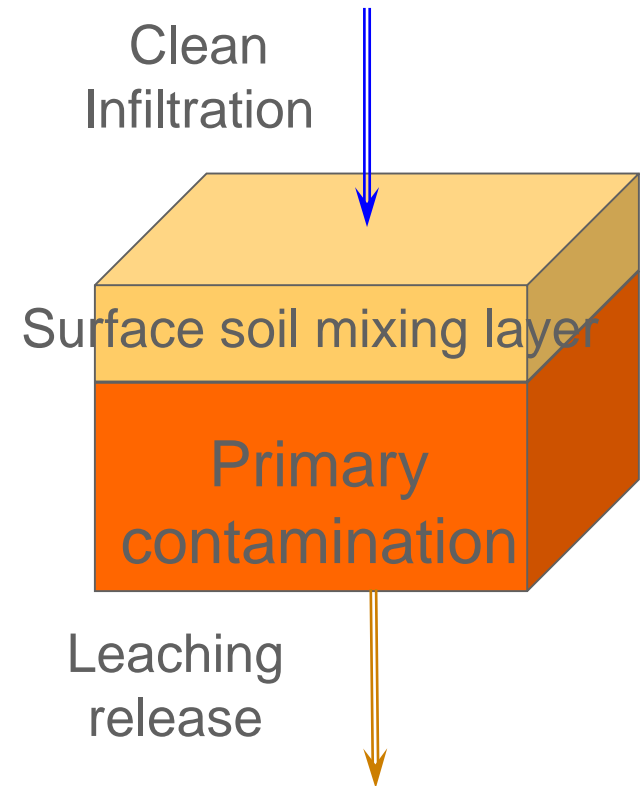
◇ g atomic weights in a liter

◇  $\text{g/L} \div \text{atomic weight (g)}$

## □ Rate controlled release option

### ○ Leach rate of **isotope**

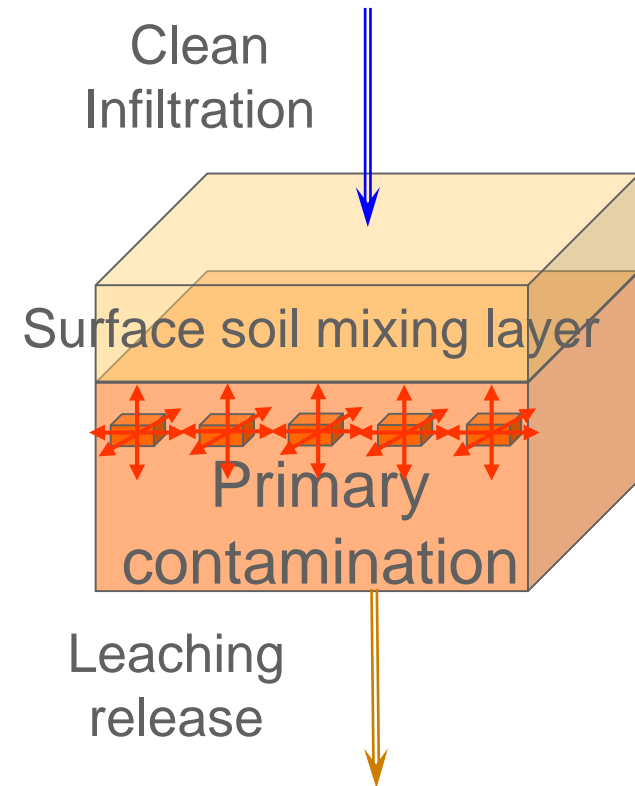
◇ 1/year





# Diffusive Release to Infiltration

- Negligible infiltration through contaminated media
  - Infiltration is through the surrounding soil
- Adsorption – desorption equilibrium of radionuclides between the solid phase and the moisture in the contaminated media
  - Distribution coefficient of **isotope**
- Diffusive transport out of contaminated media into surrounding soil
  - Diffusion coefficient of **isotope**
    - ◇  $\text{m}^2/\text{year}$



# Dispersion Coefficients

- Pasquill-Gifford stability classes (A through F)

- Pasquill coefficients (ground-level release)

$$\sigma_z' = ax^b + c$$

- Briggs coefficients (rural or urban)

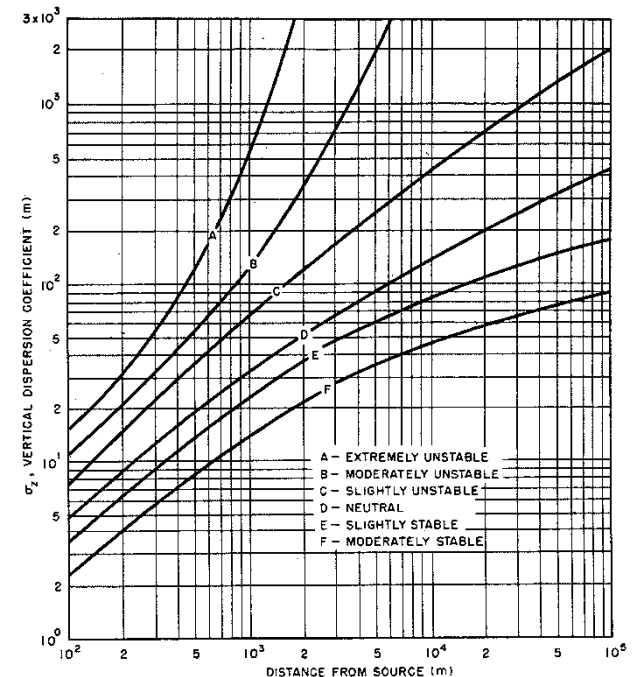
$$\sigma_z' = ax(1 + bx)^c$$

- Buoyancy induced dispersion

$$\sigma_{zb} = \frac{\Delta h}{3.5}$$

- Final form

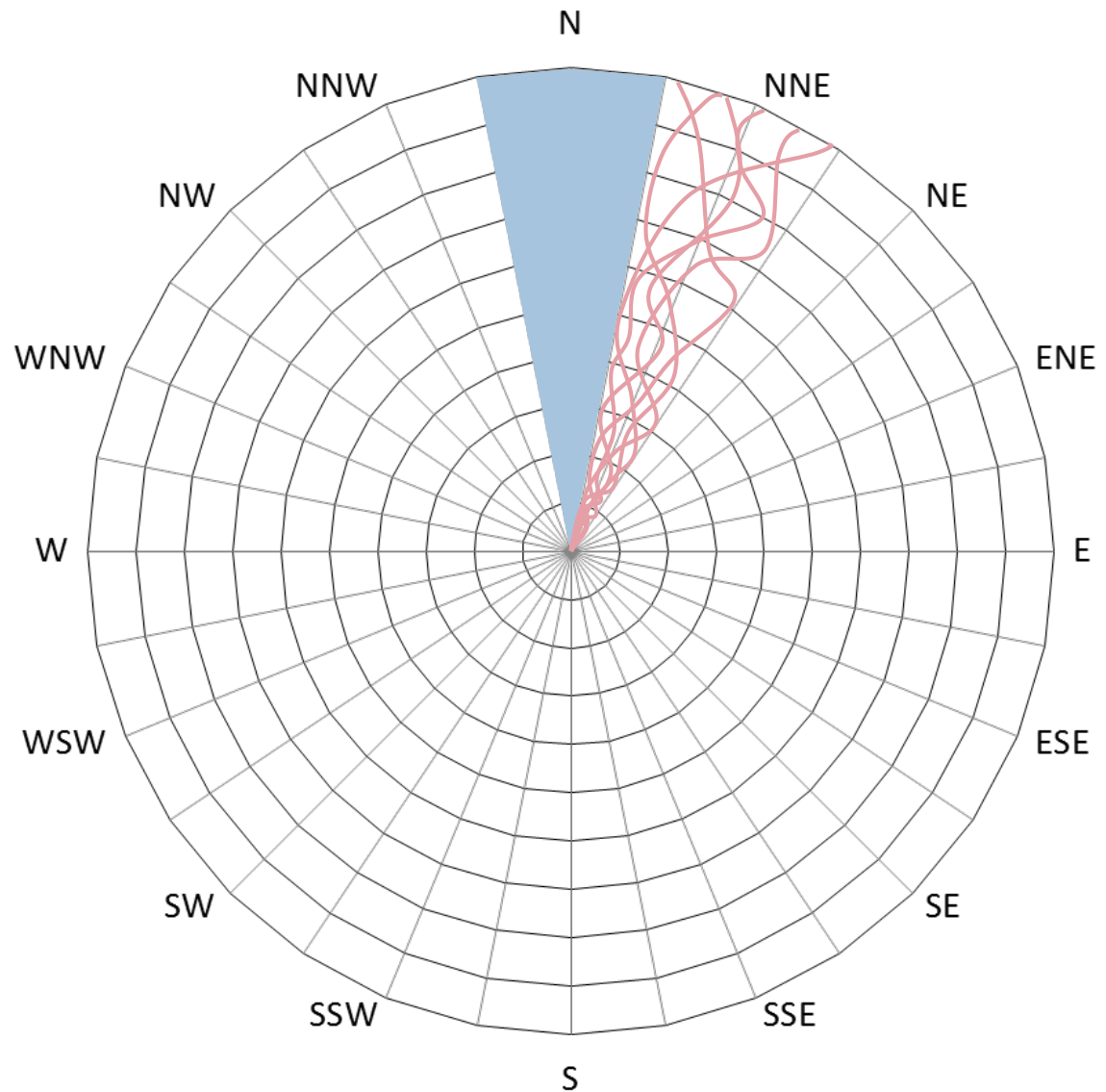
$$\sigma_z = \left( \sigma_{zb}^2 + \sigma_z'^2 \right)^{1/2}$$



*Meteorology and Atomic Energy 1968*  
Air Resources Laboratories  
U.S. Dept. of Commerce, 1968

# Meteorological Data Grid

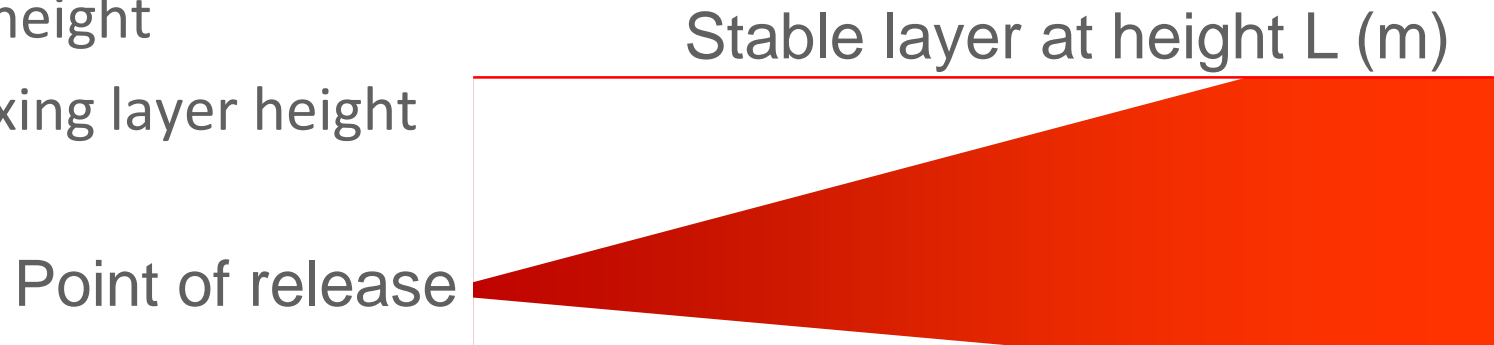
- 16 directions
- 22.5° sectors
- Sector averaged



# Plume Reflection

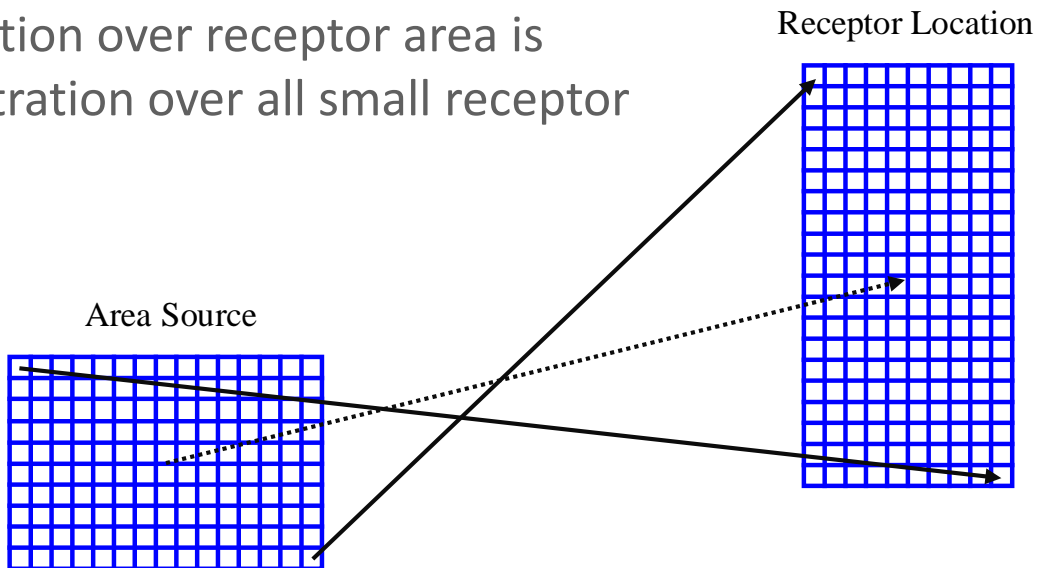
- Plume may become confined by a stable layer

- lid height
- mixing layer height



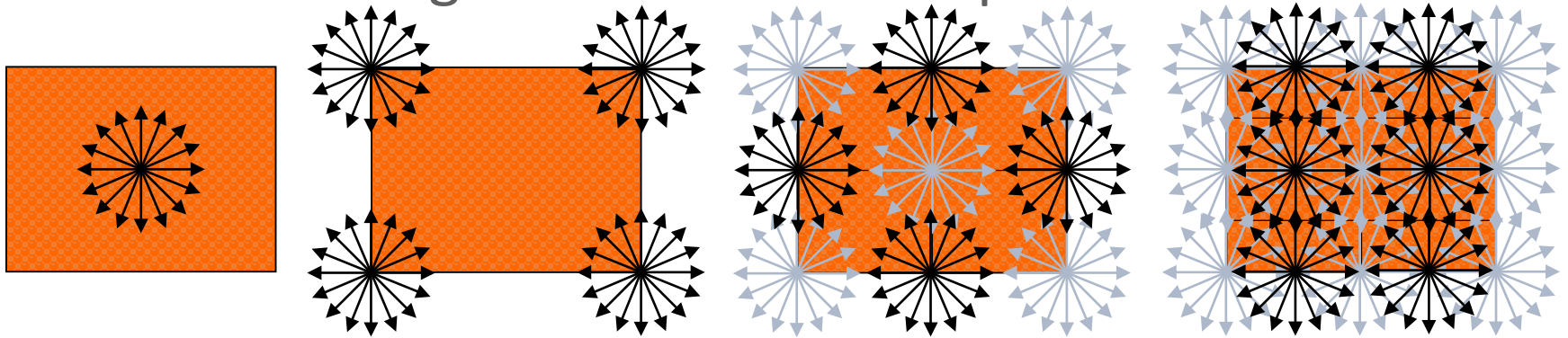
# Area Source Model

- Source and receptor areas segmented by uniform grids into smaller rectangles
- Point-to-point dispersion estimates from center of source rectangles to center of receptor rectangles
- Air concentration over small receptor rectangle point is the sum of contributions from all small source rectangles
- Average air concentration over receptor area is average of air concentration over all small receptor rectangles



# Wet and Dry Deposition over the Catchment

- Use increasing number of source points



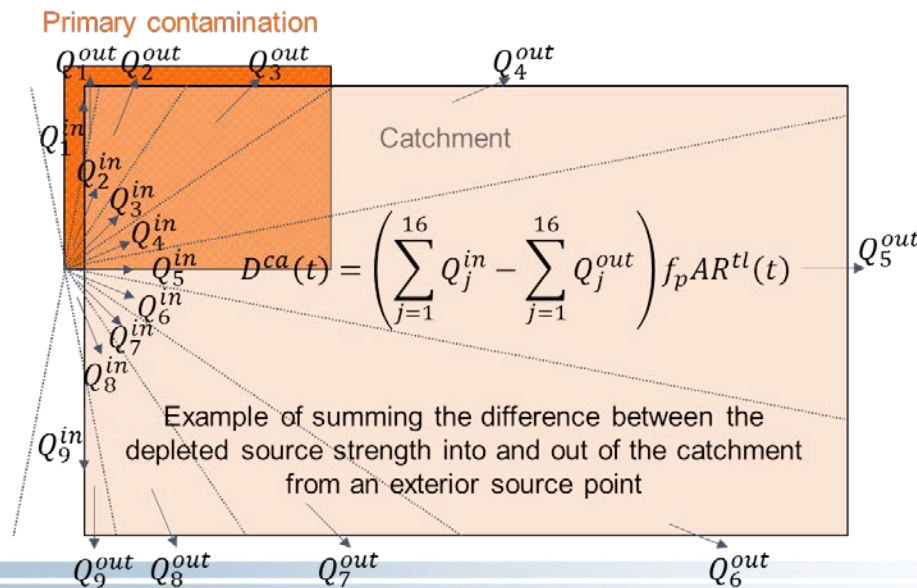
1 point

2 x 2 points

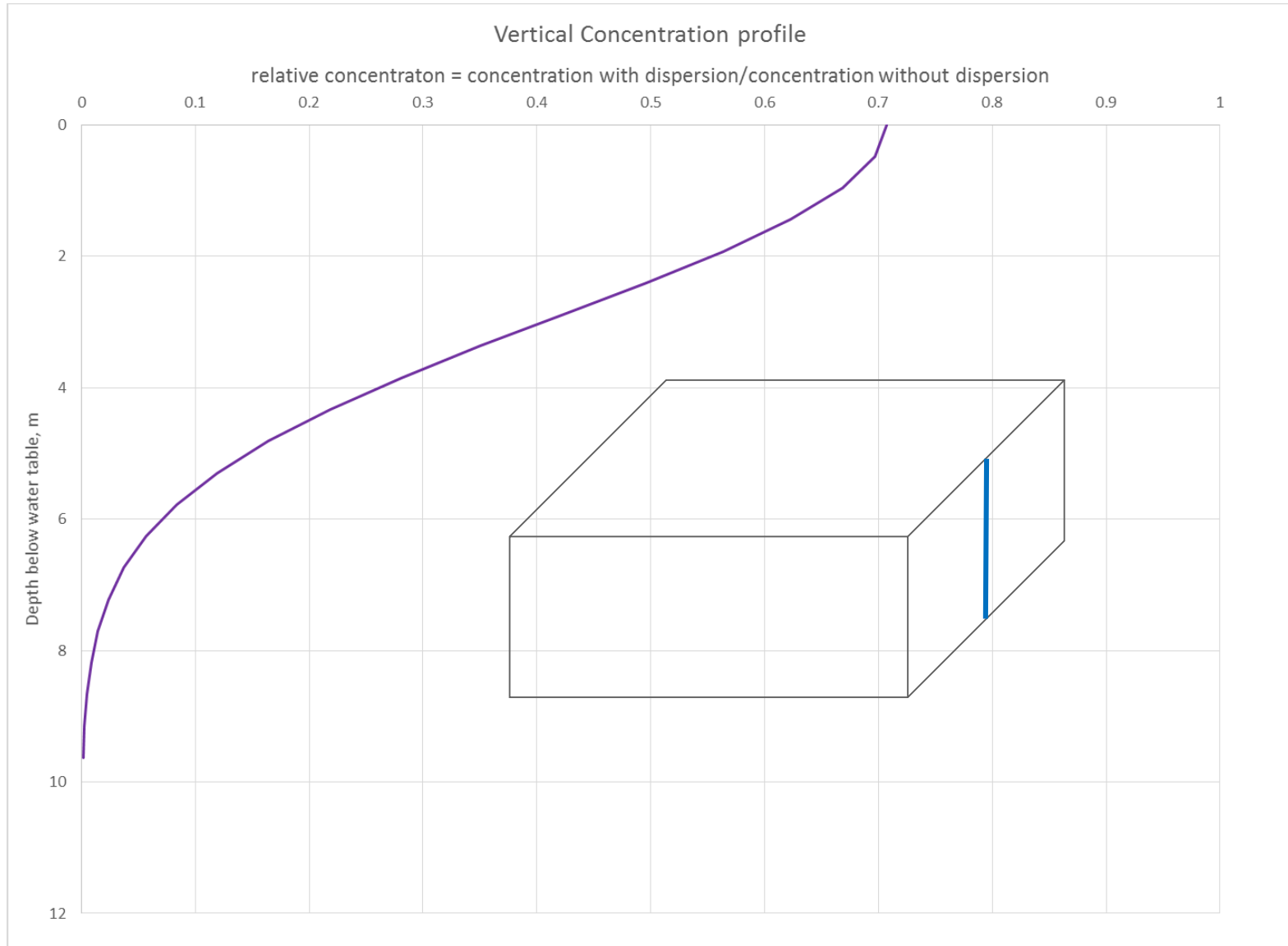
3 x 3 points

5 x 3 points

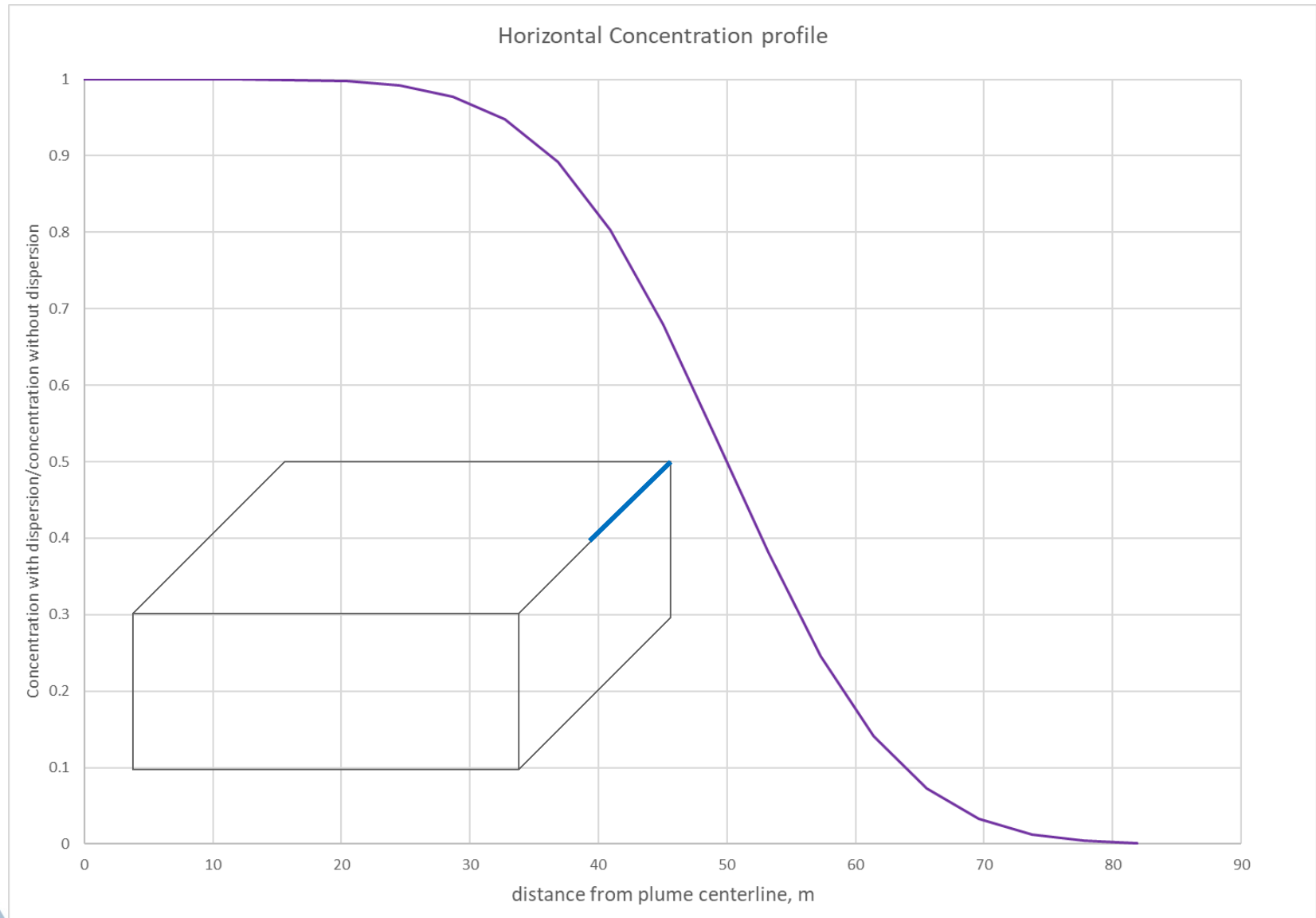
- Calculate deposition over catchment from each source point



# Vertical Concentration Profile in Aquifer



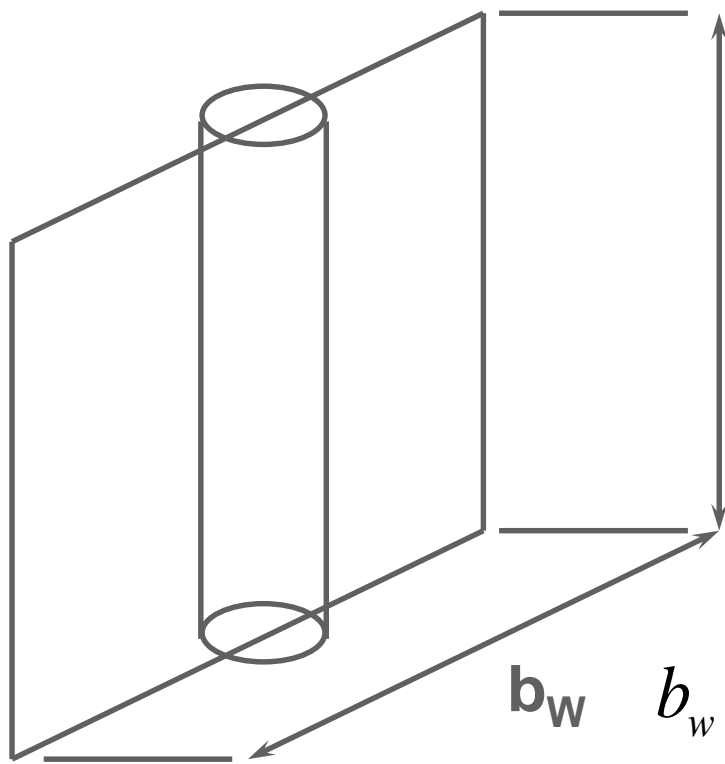
# Horizontal Concentration Profile in Aquifer





# Concentration in Well Water

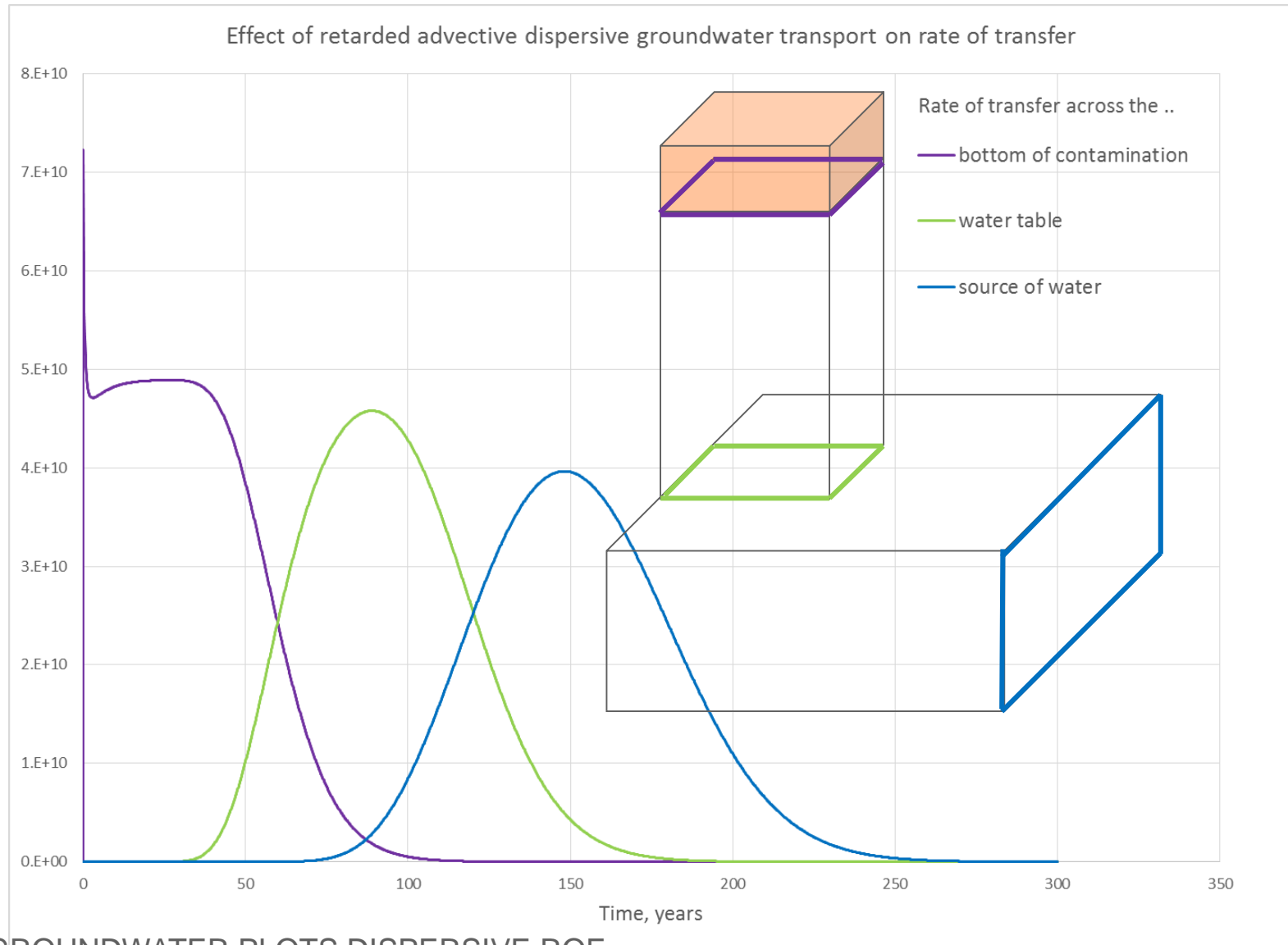
- Average of concentration over the area of the aquifer contributing to the well



The diagram shows a 3D perspective of a well in an aquifer. A vertical cylinder represents the well, with its top and bottom circles indicating its cross-section. The aquifer is represented by a rectangular prism. A vertical double-headed arrow on the right side of the prism is labeled  $d_w$ , representing the thickness of the aquifer. A horizontal double-headed arrow at the bottom of the prism is labeled  $b_w$ , representing the radius of the aquifer contributing to the well.

$$c_w(t) = \frac{\int_0^{d_w} \int_{-r_w}^{r_w} c_{aq}(x, y, z, t) dy dz}{2d_w r_w}$$
$$b_w = \frac{U_w}{V_d d_w}$$
$$r_w = \frac{b_w}{2}$$

# Retarded Advective Dispersive Transport in Groundwater



GROUNDWATER PLOTS DISPERSIVE.ROF

Break / Q&A

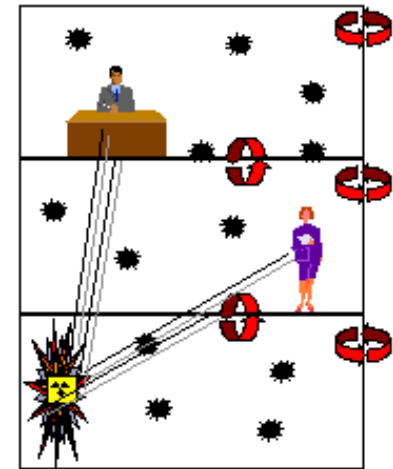
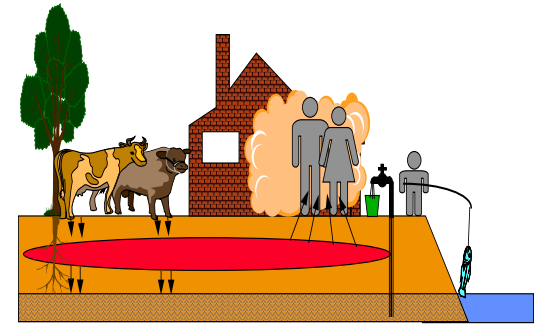


# Overview of RESRAD-BUILD



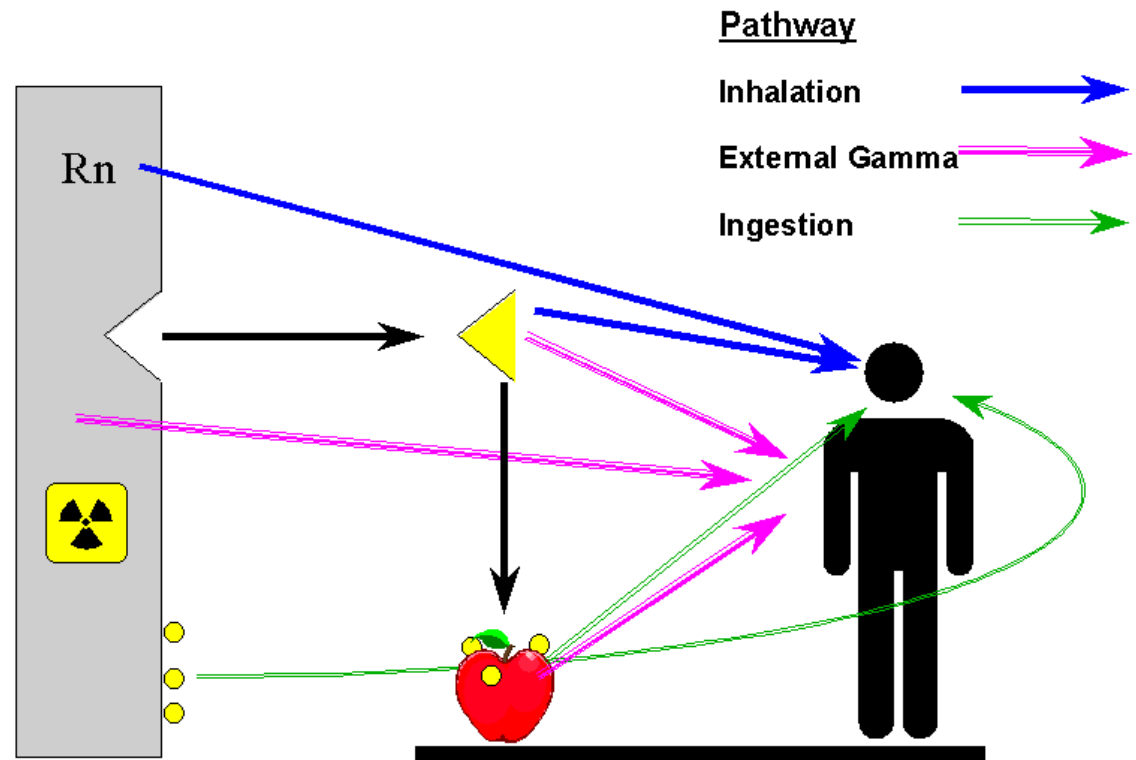
# Comparison of RESRAD-ONSITE and RESRAD-BUILD

- RESRAD-ONSITE (soil) and RESRAD-BUILD (building) codes address different contamination sources and uses:
  - Soil contamination which might lead to foodstuffs and water contamination through movement by natural processes
  - Building contamination in man-made products and air-flows which might lead to exposure during normal building occupancy and/or D&D activities



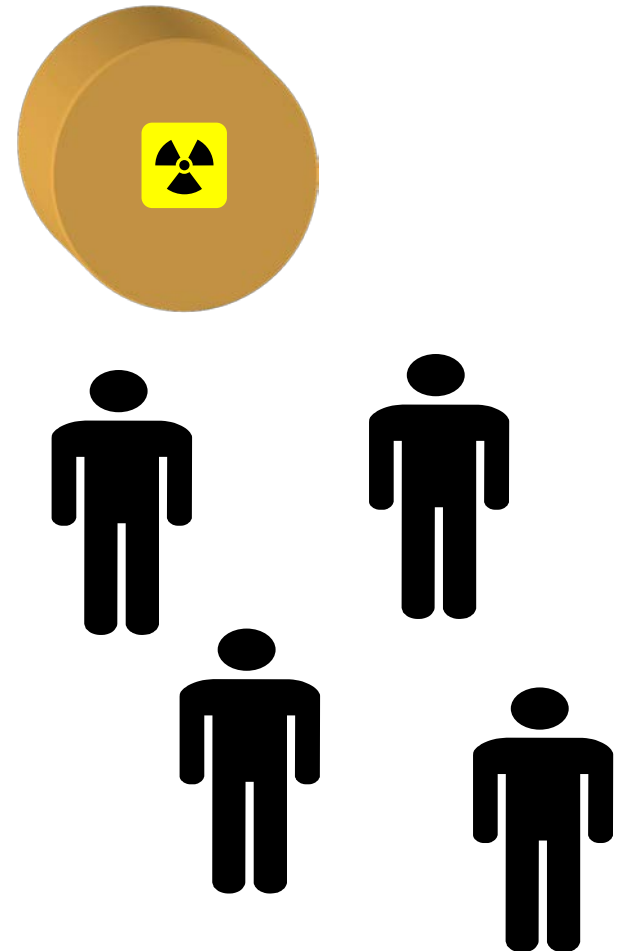
# Pathways Considered in RESRAD-BUILD

- Inhalation
  - Airborne
  - Resuspension
- Ingestion
  - Direct
  - Deposition
- External
  - Direct
  - Deposition
  - Immersion
- Radon



# Sources and Receptors Considered

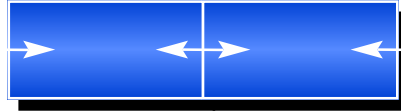
- Four distinct source types
  - Point
  - Line
  - Area
    - Circular
    - Rectangular
  - Volume
    - Circular
    - Rectangular
- Ability to co-locate sources
  - Area source above a volume source
  - Hot-spot in an area source
- Up to 10 sources in a single run
- Up to 10 receptors in a single run



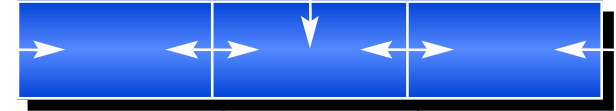
# Building Geometry in RESRAD-BUILD (Version 3)



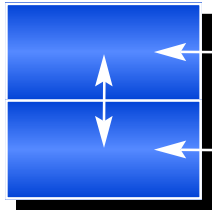
1-Room  
Warehouse



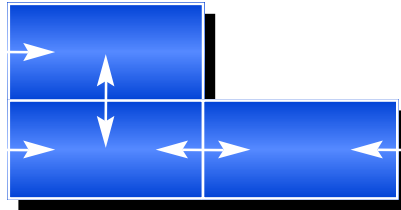
2-Room  
House



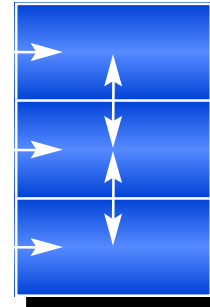
3-Room House



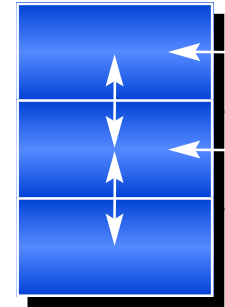
2-Story  
House



2-Story Building with  
2 Rooms on the First Floor



3-Story  
House



2-Story House  
with Basement  
(No air exchange  
between basement  
and outdoors)



# RESRAD-BUILD User Interface

RESRAD-BUILD : site1.bld

File View Modify Help

Case

Title: Default Case for RESRAD-BUILD

Dose/Risk Library: FGR 13 Morbidity

Time Parameters

Exposure Duration (days): 365

Indoor fraction: 0.5

Evaluation Times

Building Parameters

Number of Rooms: 3

Deposition Velocity: 0.01 m/s

Resuspension Rate: 0.0000005 1/s

Air Flow

Radiological Units

Activity: p Ci Dose: m rem

Receptor Parameters

Receptor #: 1

Room: 1

Time Fraction: 1

Breathing Rate: 18 m<sup>3</sup>/d

Ingestion Rate: 0.0001 m<sup>2</sup>/h

Location (m): 3.08 1.15 1.71

Shielding Parameters

Source 1 / Receptor 1

Thickness: 0 cm

Density: 2.4 g/cc

Material: Concrete

View Table Copy Shielding

Source Parameters

Source #: 1

Room: 1

Type/Dir: Volume Z

Location (m): 1.78 1.21 0.08

Display

6 Meters

Reset Scale

Close

# RESRAD-BUILD One Room Air Flow Model

$$V \frac{dC}{dt} = I - QC - \lambda VC + \lambda VC_P - \lambda_D VC + \lambda_R \lambda_D VC / (\lambda_R + \lambda)$$

Change of Activity  
in the room

Exchange  
with outside

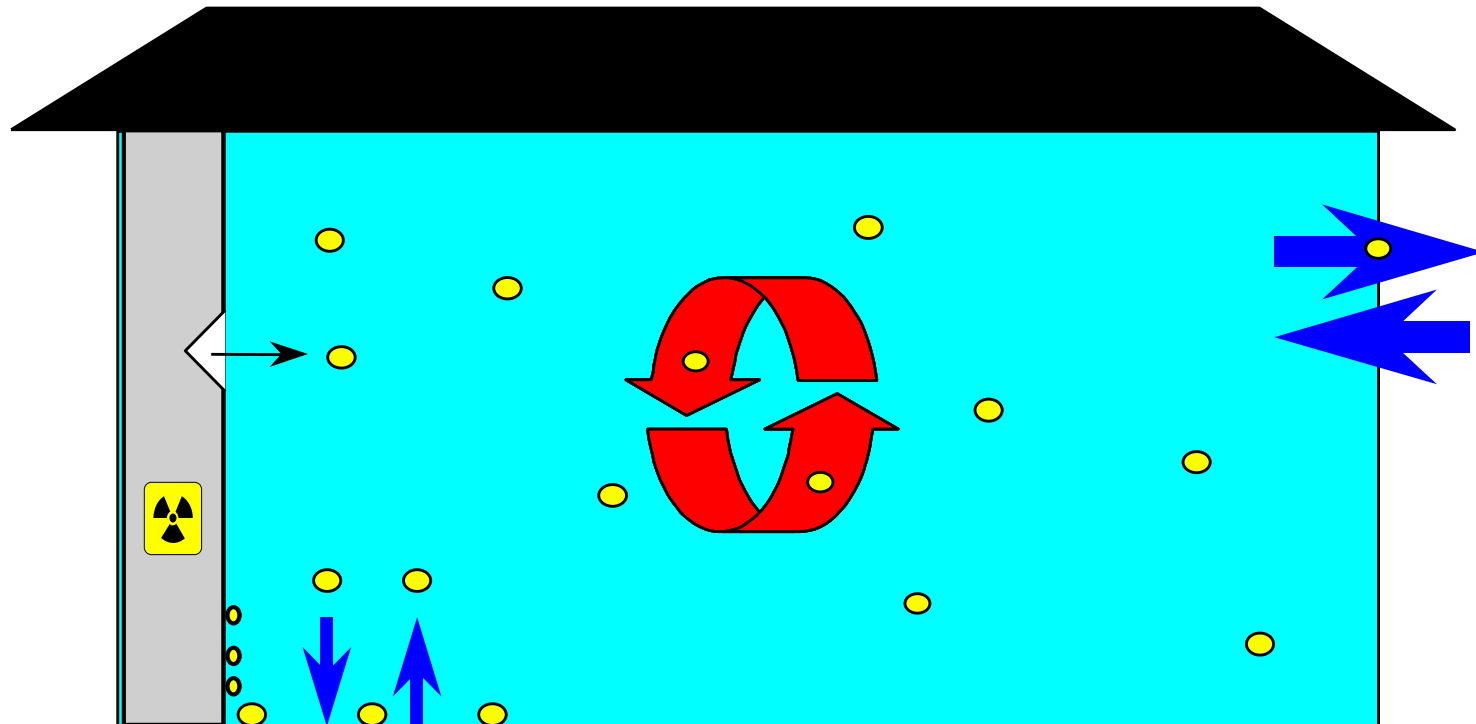
Decay of  
parent in Air

Resuspension

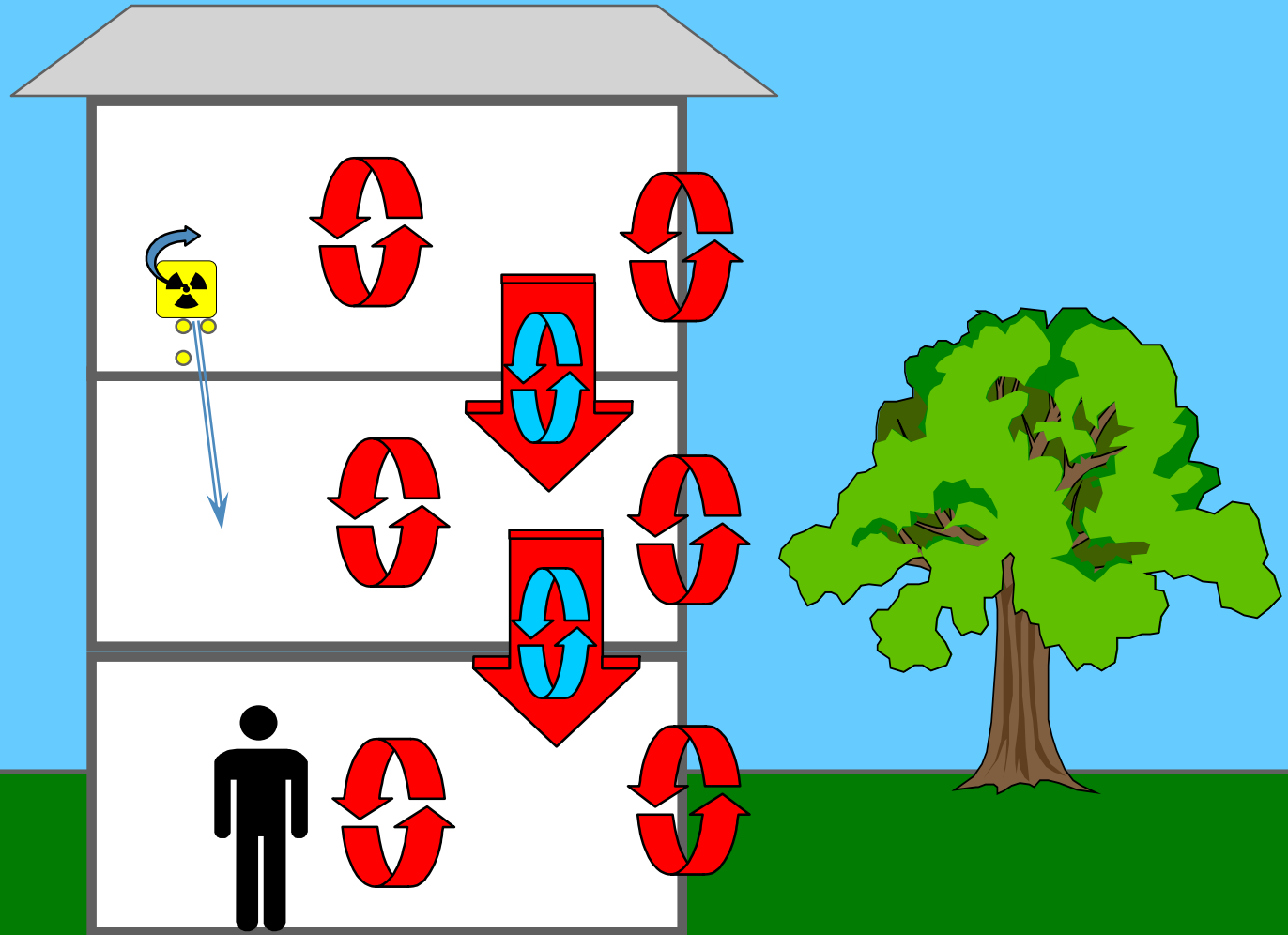
Injection  
Rate

Decay in Air

Deposition



# Three-room Air Flow Model



# Guideline Development

- Users must develop guideline values for each source type
- Guideline values are in units of Concentration over
  - mass (Volume Source)
    - pCi/g or Bq/g
  - area (Area Source)
    - dpm/m<sup>2</sup>
  - length (Line Source)
    - pCi/m or Bq/m
  - pCi or Bq (Point Source)
- Use RESRAD-BUILD to develop DSR<sub>i</sub>(t)

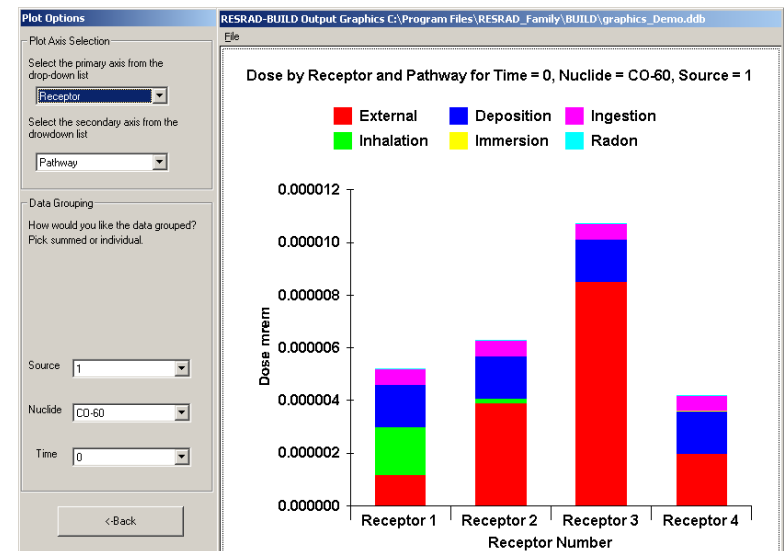
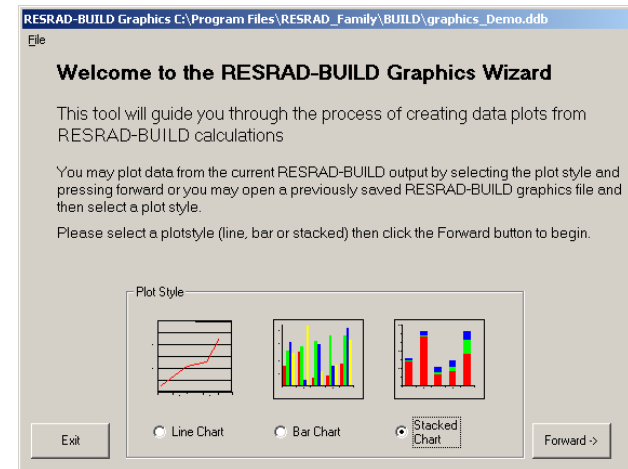
$$G_i(t) = \frac{H_E}{DSR_i(t)}$$

**G<sub>i</sub>(t)**      **Single Radionuclide Guideline**  
**H<sub>E</sub>**        **Dose Limit (0.25 mSv/yr)**  
**DSR<sub>i</sub>(t)** **Dose-to-Source Ratio**  
              **(mrem/yr / Unit Concentration)**



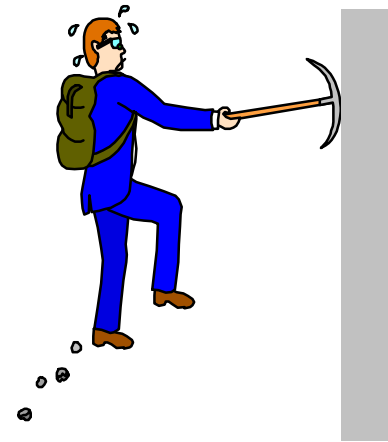
# Output Results

- RESRAD-BUILD provides users with graphical- and text-based results
  - Summary report provides
    - Parameter used
    - Source term
    - Dose
  - Detailed report
    - Intermediate calculations involving airflow
    - Injection rates
    - External dose parameters
  - Graphical results
    - Interactive plotting



# Building Occupancy vs. Building Renovation

- Building Occupancy Scenarios
  - Low release over a long period of time
  - Material that is more likely to become airborne
  - Exposure duration is typically one year
- Building Renovation
  - Large release over a short time
  - Airborne fraction lower than building occupancy
  - Exposure duration usually short (e.g., 30 to 90 days)



# Demonstration of RESRAD-BUILD Code



## Q&A / Poll





Adjourn

