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RADIATION DOSE AND RISK ASSESSMENT

Briefing for the St. Louis Hydrology Panel

December 13, 1995

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Radiation Risk Briefing

Objectives

- Define and explain terms and concepts used to describe radioactivity and radiation risk
- Describe the principle types of radiation and their mechanisms of interaction with matter (dose mechanisms)
- Identify principal sources of radiation and discuss radiation dose and its relationship to health effects (risk)
- Summarize relevant radiation regulations and describe FUSRAP regulatory drivers
- Describe the radiological dose/risk assessment process

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Radiation Types

- Alpha (α)
  - Large particle (2 protons, 2 neutrons)
  - Highly ionizing – carries charge of +2
  - Travels only a short distance (1 inch) in air, and will not penetrate skin
  - Primarily an internal (inside the body) exposure hazard
- Beta (β)
  - Small particle (electron)
  - Not as ionizing as an alpha particle – carries charge of -1
  - Travels several feet in air (depending on energy)
  - Stopped (shielded) by wood or plastic

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Radiation Types (cont.)

- Gamma (γ)
  - Electromagnetic energy
  - Can Travel 10s of feet in air
  - Shielded by heavy materials (concrete, steel, soil)
  - Primarily an external (outside the body) exposure hazard

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Radiation Terminology

- Amount of radioactivity
  - Radioactivity concentrations expressed as pCi/g or pCi/l
  - Only indicates how much radioactivity is present – not how much dose or risk
- Dose of radiation = millirem (mrem)
  - Measure of potential biological effect caused by radiation
  - Proportional to energy deposited by radiation in human tissues and organs
  - Related to risk

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How Big is a Picocurie?

Units of Radioactivity	Symbol	Disintergration Rate Per Minute	Examples of Radioactive Materials
1 Curie	Ci	2×10^{12} or 2 Trillion	Nuclear Medicine Generator
1 Millicurie	mCi	2×10^{9} or 2 Billion	Amount Used for a Brain or Liver Scan
1 Microcurie	µCi	2×10^{6} or 2 Million	Amount Used in Thyroid Tests
1 Nanocurie	nCi	2×10^{3} or 2 Thousand	Consumer Products
1 Picocurie	pCi	2	Background Environmental Levels

H1 4-0439.30

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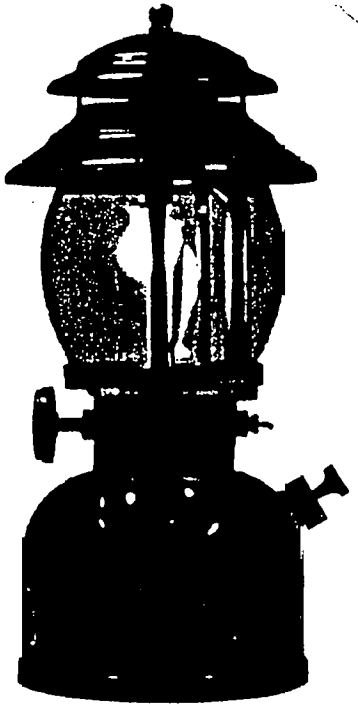
Example of Radioactivity in Consumer Products



- About 20 million gas lantern mantles are used yearly by campers
- Mantle contains approximately 1/3 gram of thorium oxide, or 35,000 picocuries of radioactivity
- If lantern mantle were thrown onto ground at a FUSRAP site, it would be considered low-level radioactive contamination

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Radiation Dose and Dose Effects

- Radiation dose/exposure terms commonly encountered
  - mR - measure of air ionization (exposure)
  - mrad - measure of energy deposition (absorbed dose)
  - mrem - measure of biological effectiveness of radiation dose (dose equivalent)

- The critical term is dose equivalent (mrem). Dose Equivalent provides an organ risk weighted measure of the relative effectiveness of a given dose of radiation for producing cancer.

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Examples of Radiation Doses

1 mrem	Approximate daily dose from background radiation (including radon, medical, and consumer product sources).
4 mrem	Annual dose limit from man-made radioactivity in drinking water (EPA).
10 mrem	Annual dose limit from airborne emissions of radioactivity (EPA).
15 mrem	Proposed annual limit (NRC and EPA) for radiation exposure following clean up of sites containing radioactivity.
100 mrem	Annual dose limit for exposures to a member of the public (from all sources) (ICRP, NCRP, NRC, DOE).
300 mrem	Approximate annual dose from natural radiation sources (U.S.).
5,000 mrem	Annual dose limit for occupational exposures of radiation workers.
25,000 mrem	Possible blood cell count changes - no physical symptoms.
100,000 - 300,000 mrad	Radiation sickness.
500,000 + mrad	Death to 50% of exposed population

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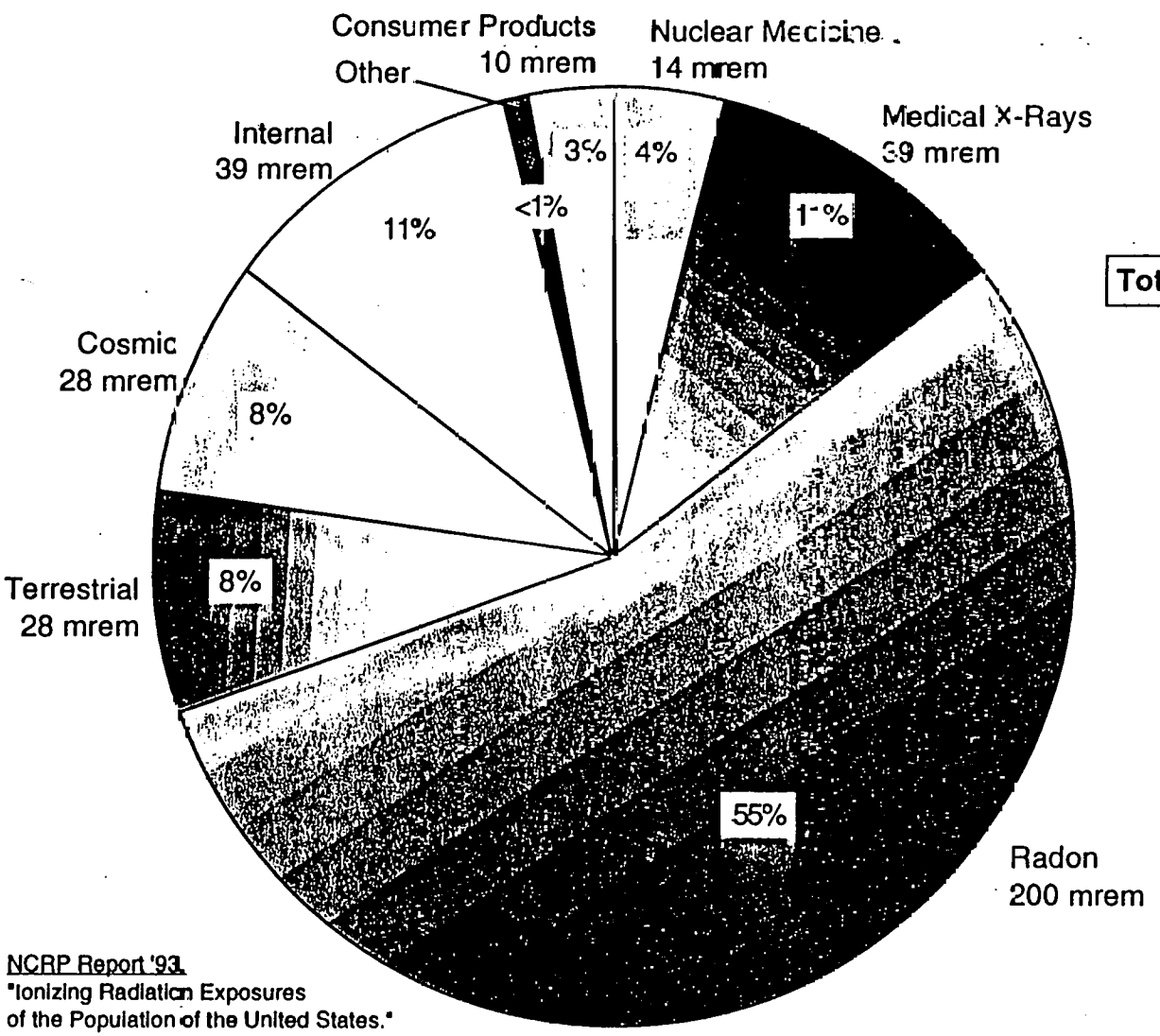
Contribution of Various Sources of Radiation to the Total Background Dose



Source: NCRP Report '93
"Ionizing Radiation Exposures
of the Population of the United States."

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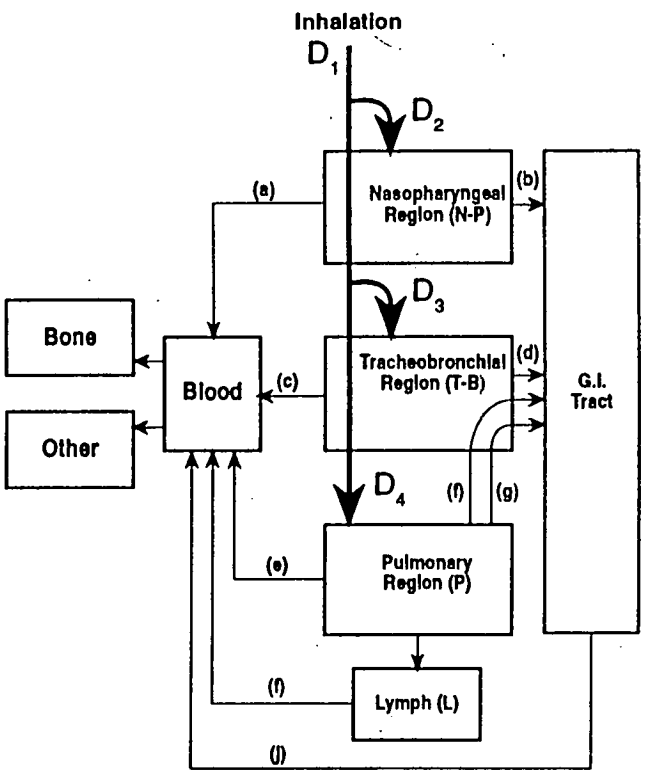
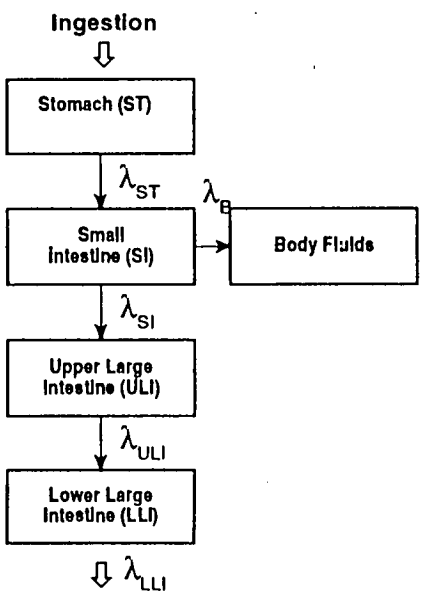
Simplified Dose Calculation Methods

Inhalation Pathway



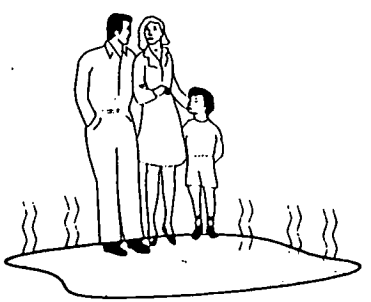
Ingestion DCF
mrem/pCi

Ingestion Pathway



Ingestion DCF
mrem/pCi

External Gamma Pathway



External DCF
$\frac{\text{mrem/1 yr}}{\text{pCi/g}}$

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Radiation Health Effects

- A large body of health effects data is available for high doses (Atomic Bomb survivors, occupational exposures, therapeutic exposures, and animal experiments).
- Primary human health effects from radiation exposure is the increased probability of developing cancer.
- We assume that the effects observed at high doses are linear to zero dose (some increased probability of cancer for any increment of dose).
- Current regulations incorporate this "linear, non-threshold hypothesis," and are designed to reduce the probability of cancer induction to as low as reasonably achievable (ALARA).

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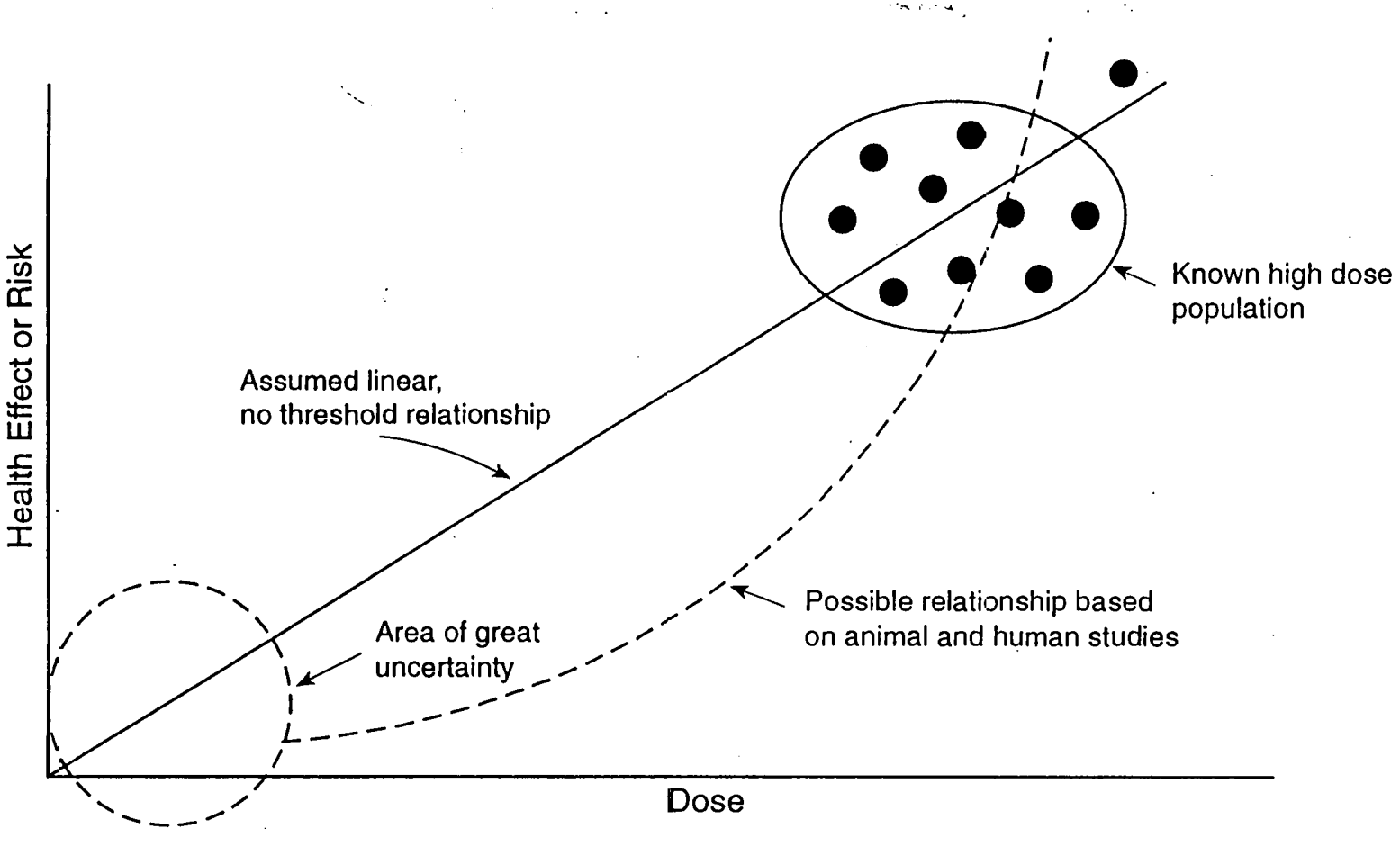
Radiation Dose – Effects Relationship



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Difficulty Measuring Radiation Risk

- One out of four people in the U.S. will develop cancer according to the American Cancer Society. This is 25% or 0.25. Thus 25000 people in a group of 10,000 can be expected to develop cancer.

- If the same group of 10,000 people were each exposed to 1000 mrem of radiation above background (10 x the DOE limit, then an additional 6 people could be expected to develop cancer from the radiation exposure (based on EPA's current radiation risk factors). This would bring the total to 2506 compared to 2500.

- Because of this "background" cancer rate, it is difficult to determine exactly how many additional cancer cases could be due to radiation in an exposed group of people.

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Current Radiation Protection Standards

Standard	Dose Limit	Applicability
10 CFR 20 (NRC) 10 CFR 835 (DOE)	5000 mrem/year	Occupational exposure to workers.
10 CFR 20 (NRC) 10 CFR 834 (DOE, proposed)	100 mrem/year*	Exposures to the public from all sources and pathways
10 CFR 20 (NRC, proposed) 40 CFR 196 (EPA, draft)	15 mrem/year	Exposures to the public from a decontaminated site
40 CFR 61 (EPA)	10 mrem/year	Exposures to the public from atmospheric releases of radioactive particlates
40 CFR 141 (EPA)	4 mrem/year	Exposures to the public from ingestion of drinking water

H1-4-6438.30

* ICRP and NCRP recommendation

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FUSRAP Radioactivity Cleanup Regulations/Guidelines (Primary Soil Cleanup Criteria)

EPA 40 CFR 192 - Environmental Standards for Uranium and Thorium Mill Tailings:

- 5 pCi/g limit in surface soil (0 - 15 cm) for Ra-226 and Ra-228
- 15 pCi/g limit in subsurface soil (>15 cm) for Ra-226 and Ra-228
- Supplemental criteria (in lieu of 5/15 criteria) are allowed for certain circumstances
- ALARA specified for nuclides other than Ra-226 and Ra-228

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FUSRAP Radioactivity Cleanup Regulations/Guidelines (Primary Soil Cleanup Criteria)

DOE — DOE Order 5400.5 - Radiation Protection of the Public and the Environment (Also Proposed 10 CFR 834)

- Defines generic guidelines specifically for Ra-226, Ra-228, Th-230, and Th-232
- Same general criteria (5/15) as 40 CFR 192, but specifically include Th-230 and Th-232
- Supplemental criteria allowed as in 40 CFR 192
- Dose assessment methods specified for development of "derived guidelines" for nuclides other than those listed with generic guidelines

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FUSRAP Radioactivity Cleanup Regulations/Guidelines

- Must meet generic cleanup guidelines for Ra-226, Ra-228, Th-230, and Th-232 (supplemental guidelines may be used in some cases).
- For other radionuclides, must perform dose assessments to derive a cleanup guideline.
- Derived cleanup guideline typically limited so that it could cause only a small fraction of the 100 mrem/yr public dose limit, based on a plausible use exposure scenario.
- EPA cleanup guidance for superfund (10^{-4} – 10^{-6}) also must be considered in deriving cleanup guidelines based on dose.

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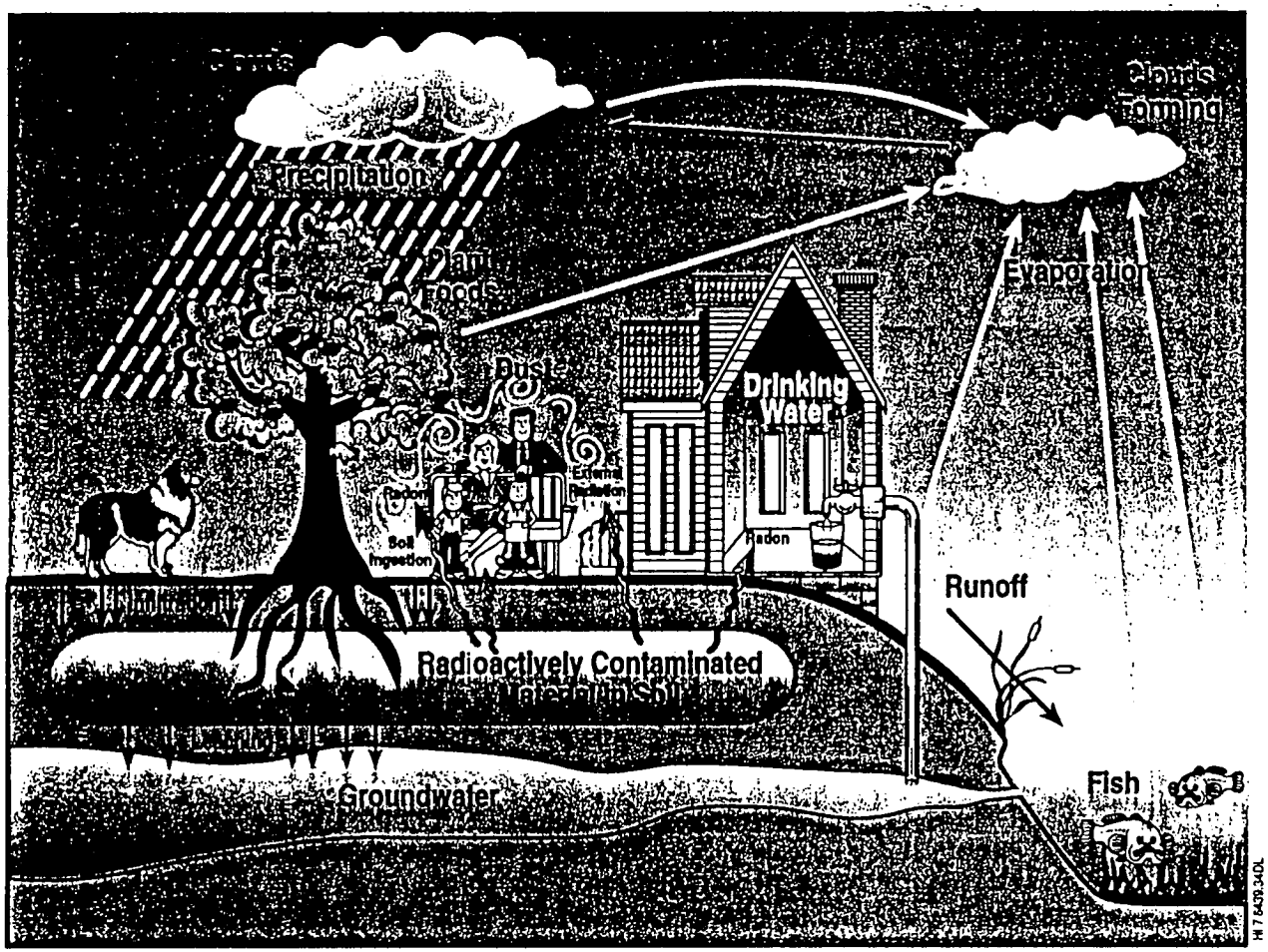
Radiation Dose and Risk Assessment – Pathways Analysis



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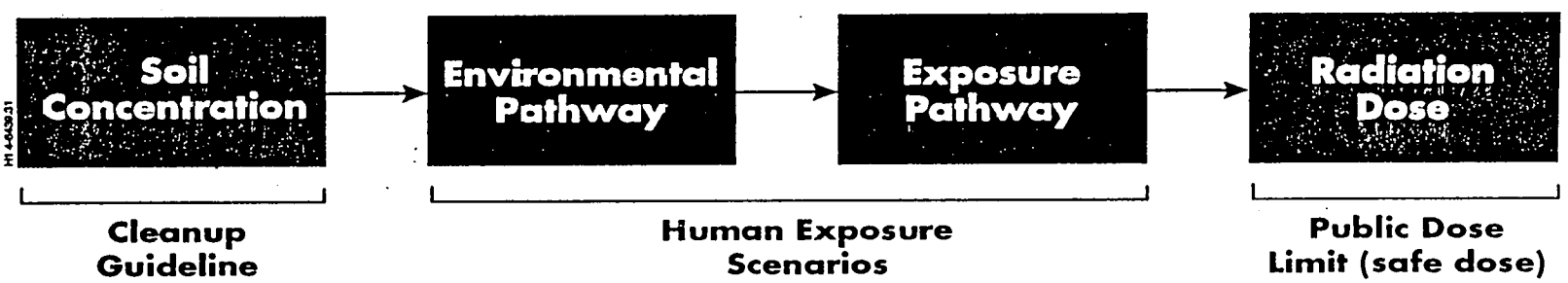
General Process for Assessing Dose or Risk



Hazard	x	Exposure	=	Risk

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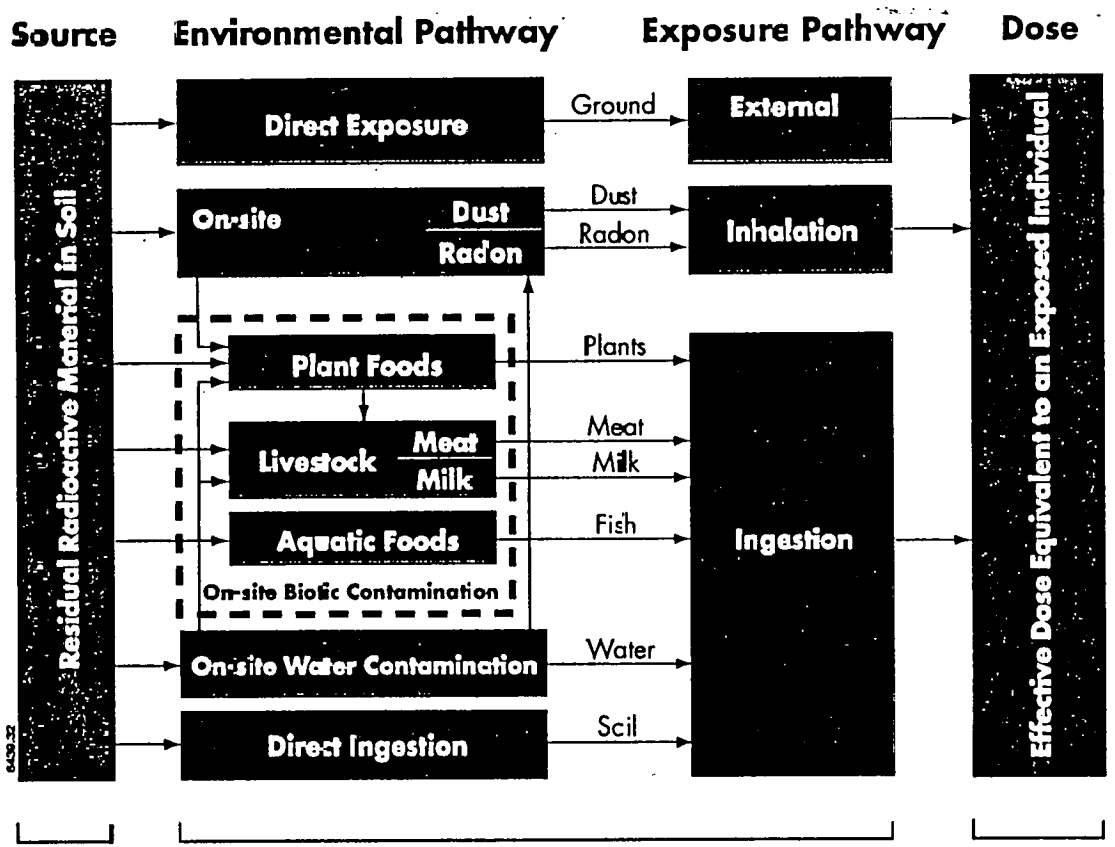
Cleanup Guideline Development – Exposure Pathways



Hazard X Exposure = Risk

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Typical Exposure Scenarios Evaluated

Farmer	Highest exposure potential
Residential	High to intermediate exposure potential
Commercial/ Industrial	Intermediate to low exposure potential
Recreational	Lowest exposure potential

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Exposure Parameters – SLAPS Maintenance Worker

We assume that an employee performs routine maintenance work in the vicinity of the SLAPS ditches with the following exposure conditions:

- 2 hr/day indoors
- 6 hr/day outdoors
- 50 days/yr
- 25 yrs
- 100 mg/day of contaminated soil ingested
- 0.09 mg/day on contaminated soil inhaled

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Exposure Parameters – Future Residential

We assume that a family lives in a home built on a vicinity property with the following exposure conditions:

- 18 hr/day indoors
- 2 hr/day outdoors
- 350 days/yr
- 30 yrs
- 2 L/day drinking water
- 100 mg/day (adult), 200 mg/day (child) of contaminated soil ingested
- 0.09 mg/day of contaminated soil inhaled

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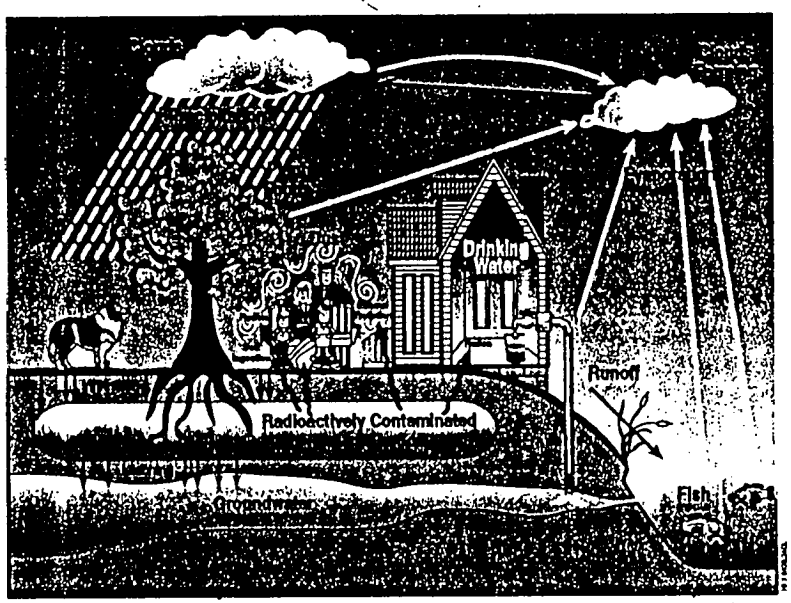
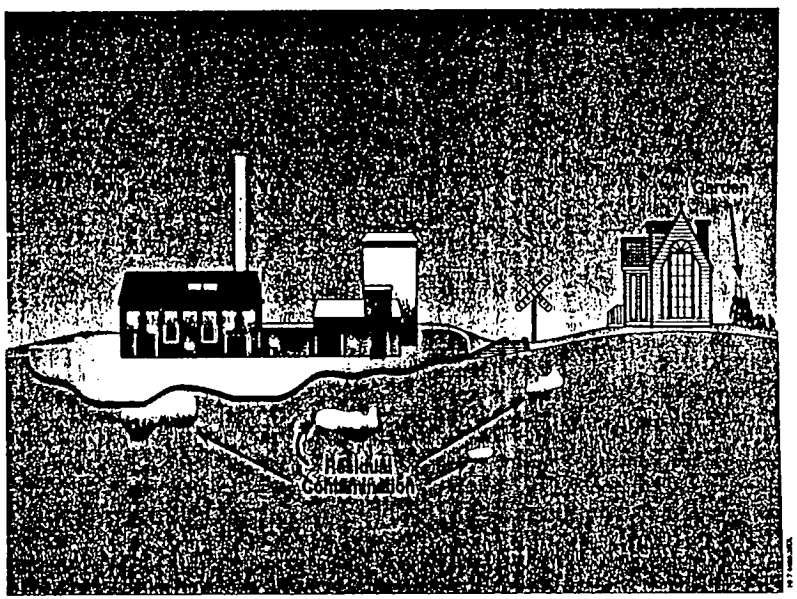
Modeling Assumptions vs. Likely Site Conditions



Projected by Model



Real Life

(likely conditions after remediation)

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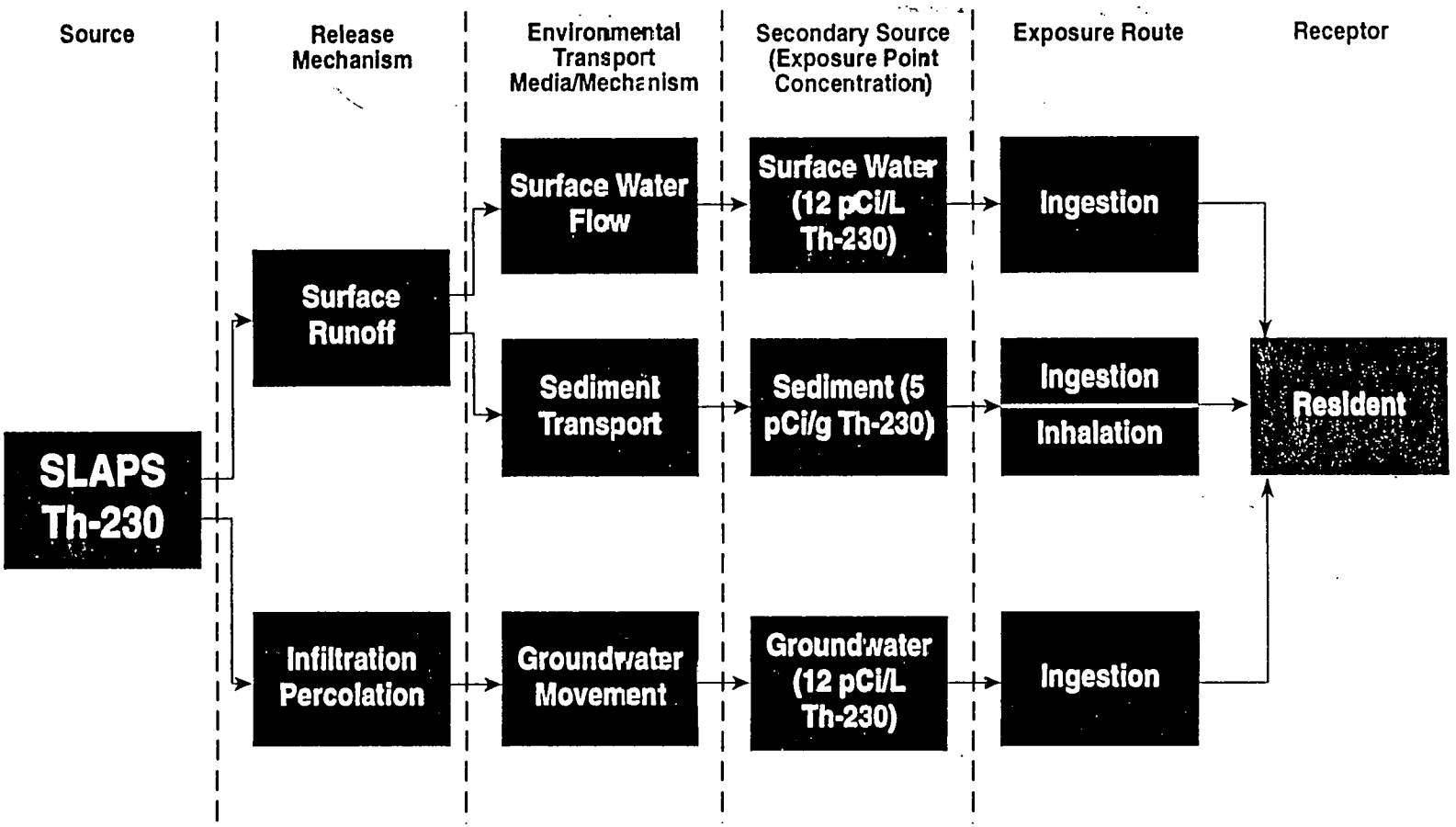
Simplified Conceptual Site Model

(Groundwater and Surface Water Impacts from SLAPS)



Summary of Potential FUSRAP Cleanup Guidelines and modeled and measured concentrations for radionuclides and TCE in water at the St. Louis Site

	Soil/Sediment (pCi/g)	Water (pCi/L)		
		Current[a]	Proposed[b]	DOE (order)
Ra-226	5/15[c]	5[d]	20[e]	5
Th-230	5/15[c]	NA	79[f]	12
Total uranium	100	NA	30[g]	24
TCE	NA	5 µg/L[a]	NA	5 µg/L

Coldwater Creek Surface Water

Location on Coldwater Creek	radium-226 (pCi/L)		thorium-230 (pCi/L)		total uranium (pCi/L)	
	measured	modeled	measured	modeled	measured	modeled
Upstream of SLAPS	0.5		0.5		4.5	
McDonnell Blvd. Bridge	1.9	0.2 pCi/L current	0.6	4.0 pCi/L current	2.9	0.2 pCi/L current
Mouth of Ballfield Ditch	0.8	stormflow load to CWC	0.4	stormflow load to CWC	6.0	stormflow load to CWC
1 mi. from mouth of CWC	2.6		1.0		4.5	

[a] From 40 CFR 141

[b] From the July 1991 Proposed Rule, 40 CFR 141, 142, FR 56 No. 138.

[c] 5 pCi/g in the surface (0 to 15 cm interval) 15 pCi/g in each 15 cm interval below the surface interval. The limit is applicable to the sum of the Ra-226 and Th-232 above background concentrations (or Th-230 and Th-232 if Th-230 is greater than Ra-226).

[d] The current EPA Maximum Contaminant Level (MCL) of 5 pCi/g applies to total radium (Ra-226 and Ra-228).

[e] The proposed EPA MCLs for radium are 20 pCi/L for Ra-226 and 20 pCi/L for Ra-228.

[f] Based on the proposed alpha emitter concentration limits listed in Appendix C of FR 56 No. 138.

[g] The proposed total uranium MCL is 20 µg/L. Based on EPA assumptions in FR 56 No. 138, 20 µg/L is approximately 30 pCi/L.

[h] Modeling indicates that no shallow groundwater transport of radionuclides is currently occurring to Coldwater Creek.

Groundwater

For measured radionuclide concentrations in groundwater see Table 3-21 (provided) from the Remedial Investigation Addendum Report for the St. Louis Site.

The results of the MODFLOW and MT3D models

Modeled total uranium concentrations (pCi/L)				
Stratigraphic unit	100 yr	1,000 yr	10,000 yr	Projected maximum
3M	11	85	210	260
3B	nb	10	100	140
4	nb	2	56	56
Limestone bedrock	nb	nb	10	12
contribution to base flow (2 cfs) concentrations in Coldwater Creek	5.0 E-3	0.4	1	not estimated

nb = No break-through has yet occurred.

For TCE in groundwater, the following measurements were performed:

Well	TCE (µg/L)	year
B	110	1989
M11-9	130	1989
B53W12S	not detected	1992
B53W17S	1400, 1200	1992 & 1993 respectively
B53W18S	not detected	1992
B53W19S	19	1992
B53W20S	not detected	1992

St. Louis Site Expert Geohydrologic Panel

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December 13, 1995

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