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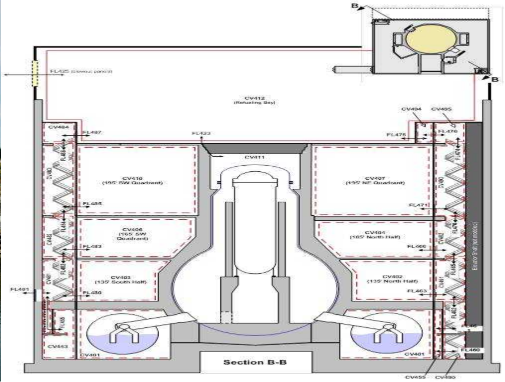

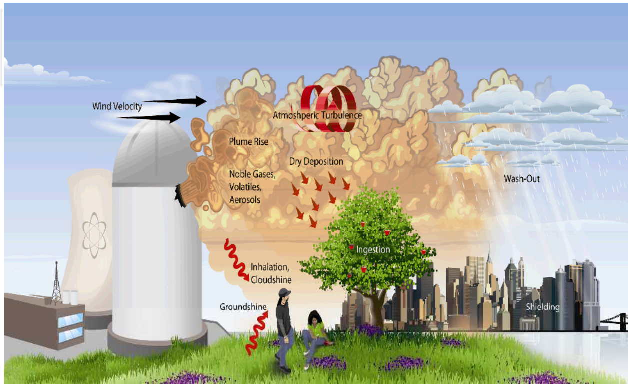

MELCOR/MACCS2 Analysis for BWR Mark-I Filtered Containment Venting

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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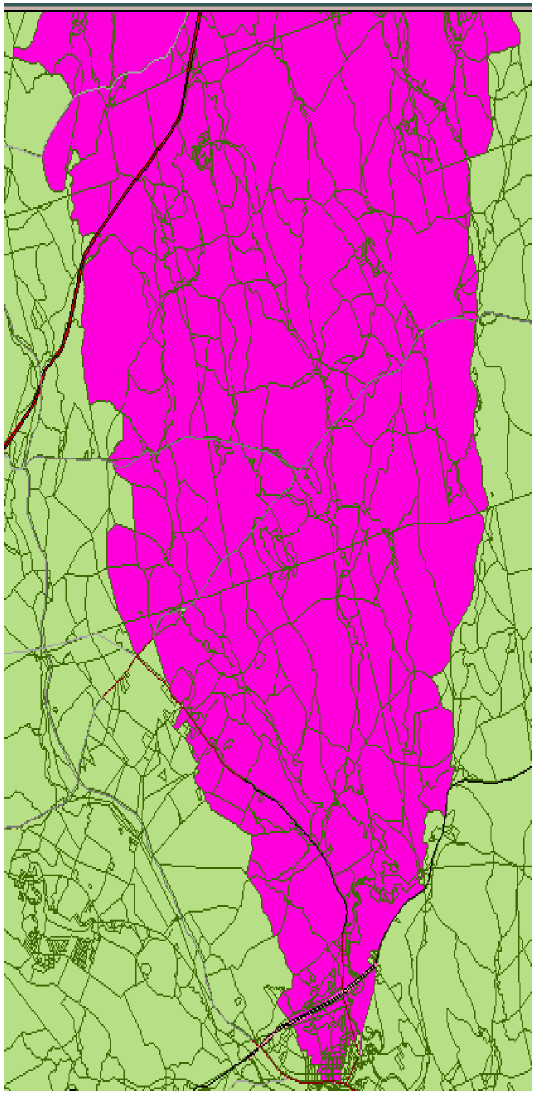
Overview

- Background
- MELCOR Analysis
- MACCS2 Analysis
- Conclusions



Background

MELCOR

MELCOR is a fully integrated, engineering-level computer code that models the progression of severe accidents in light-water reactor nuclear power plants.

MELCOR is being developed at SNL for the NRC as a second-generation plant risk assessment tool and the successor to the Source Term Code package.

A broad spectrum of severe accident phenomena in both boiling and pressurized water reactors is treated in MELCOR in a unified framework.

These include thermal-hydraulic response in the reactor coolant system, reactor cavity, containment, and confinement buildings; core heatup, degradation, and relocation; core-concrete attack; hydrogen production, transport, and combustion; fission product release and transport behavior.

MELCOR applications include estimation of severe accident source terms, and their sensitivities and uncertainties in a variety of applications.

MELCOR is also used to analyze design basis accidents for advanced plant applications (ESBWR, EPR, APWR).

MELCOR Accident Consequence Code System MACCS2

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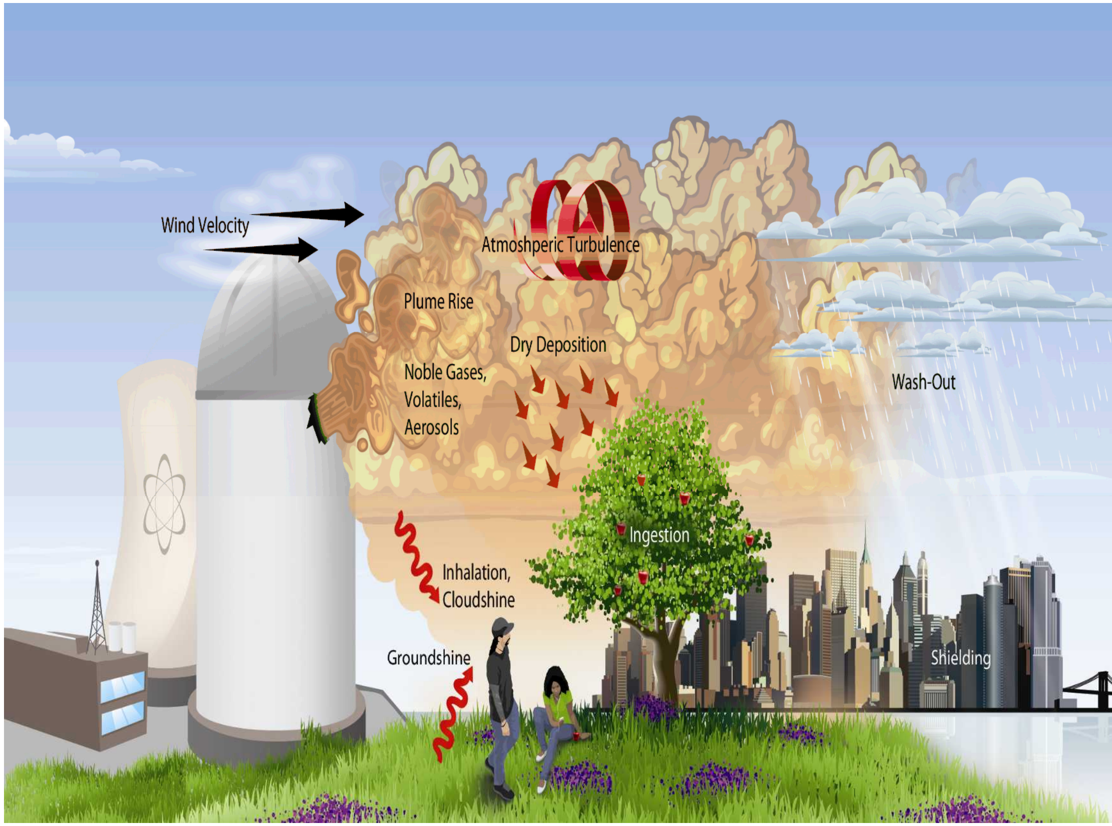
MACCS2 was developed at SNL for the NRC.

Its primary use is in performing PRAs for commercial nuclear reactors to evaluate the impact of accidental atmospheric releases of radiological materials on humans and on the surrounding environment.

MACCS2 has been widely distributed and used by the NRC and its subcontractors, private industry, and throughout the U.S. Department of Energy complex.

It has also been distributed to Cooperative Severe Accident Research Program members and other international organizations.



MELCOR Analysis

- Peach Bottom Atomic Power Station
  - BWR Mark-I Containment
- SOARCA MELCOR Deck
- Long-Term SBO
- 16 hour DC Station Battery Life

MELCOR scenarios used in the consequence analyses

Case	Drywell spray at 24 hours	Wetwell venting at 60 psig
A		
B		X
C	X	
D	X	X

Case A & B

For Case A and Case B at 36.5 hours, the containment fails due to core melt through of the drywell liner. The drywell liner failure provides a lower resistance pathway to the environment than through the wetwell vent. Unlike drywell head flange leakage, the flow path opened by melt-through of the drywell liner can never be reclosed. The drywell liner failure is a permanent leak path out of the containment to the environment that bypasses wetwell pool scrubbing and any external filter on the wetwell vent.

Scenario	Integral Release Fractions by Chemical Group									Atmospheric Release Timing	
	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La	Start (hr)	End (hr)
Case A	0.77	0.013	0.0014	0.019	0.016	0	0.003	0	0	25.7	48
Case B	1.00	0.0046	0.0081	0.028	0.033	0	0.0004	0.0002	0	23.9	48
Case B DF=2	1.00	0.0029	0.0047	0.017	0.022	0	0.0003	0.0001	0	23.9	48
Case B DF=10	1.00	0.0015	0.0020	0.0077	0.013	0	0.0002	0.00002	0	23.9	48
Case B DF=100	1.00	0.0011	0.0014	0.0057	0.011	0	0.0002	0.000002	0	23.9	48

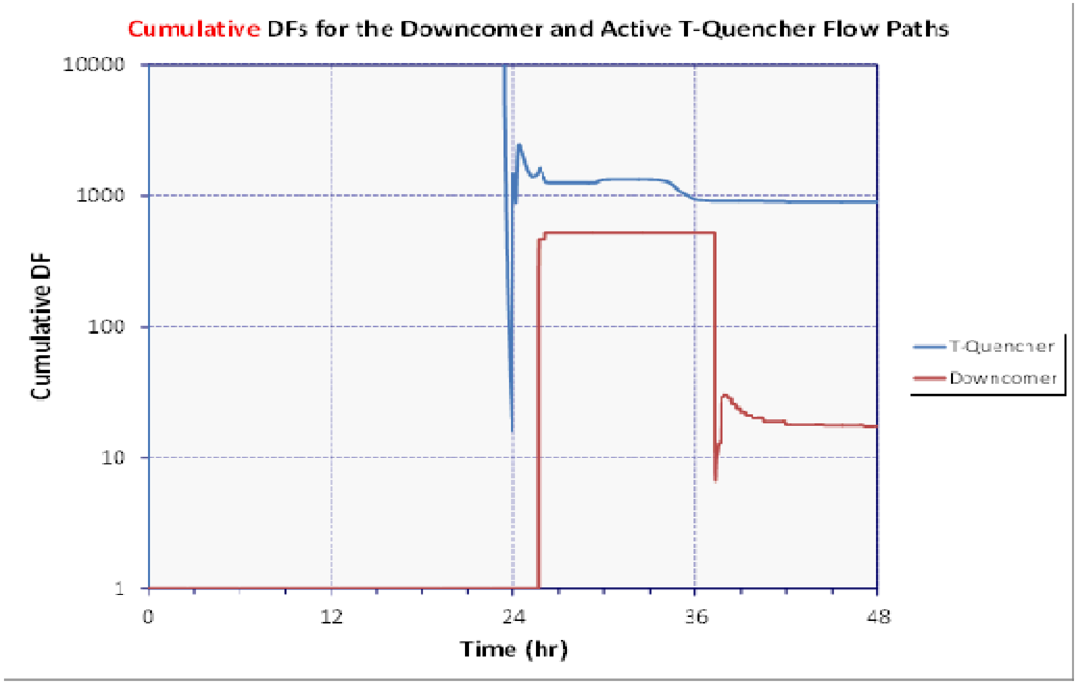
Case C & D

The increased revaporization of cesium and iodine from RPV internals combined with the larger vent flows and imperfect wetwell scrubbing for Case D, the elastic drywell head flange model in MELCOR, and the effectiveness of the drywell containment sprays lead to the non-intuitive larger environmental release for Case D relative to Case C.

Scenario	Integral Release Fractions by Chemical Group									Atmospheric Release Timing	
	Xe	Cs	Ba	I	Te	Ru	Mo	Ce	La	Start (hr)	End (hr)
Case C	**0.68**	**0.001**	**0**	**0.004**	**0.005**	0	0	0	0	28.2	48
Case D	**1.00**	**0.003**	**0.002**	**0.019**	**0.021**	0	0	0	0	23.9	48
Case D DF=2	1.00	0.002	0.001	0.010	0.011	0	0	0	0	23.9	48
Case D DF=10	1.00	0.0003	0.0002	0.002	0.002	0	0	0	0	23.9	48
Case D DF=100	1.00	0.00003	0.00002	0.0002	0.0002	0	0	0	0	23.9	48

T-quencher vs. Downcomer

In Case D, part of the source term is from aerosols carried from the drywell through the containment downcomers and into the wetwell. This path bypasses the T-quenchers during wetwell venting. When the T-quenchers are bypassed, a lower DF occurs for the wetwell than might be expected. The wetwell DF is typically observed to be an order of magnitude higher when the T-quenchers are not bypassed. The reduced DF in the wetwell causes more of the radionuclides to be scrubbed in the external filters and thus increase the DF for the external filters.



Example of MELCOR modeling of cumulative DF for the downcomer versus the T-quenchers

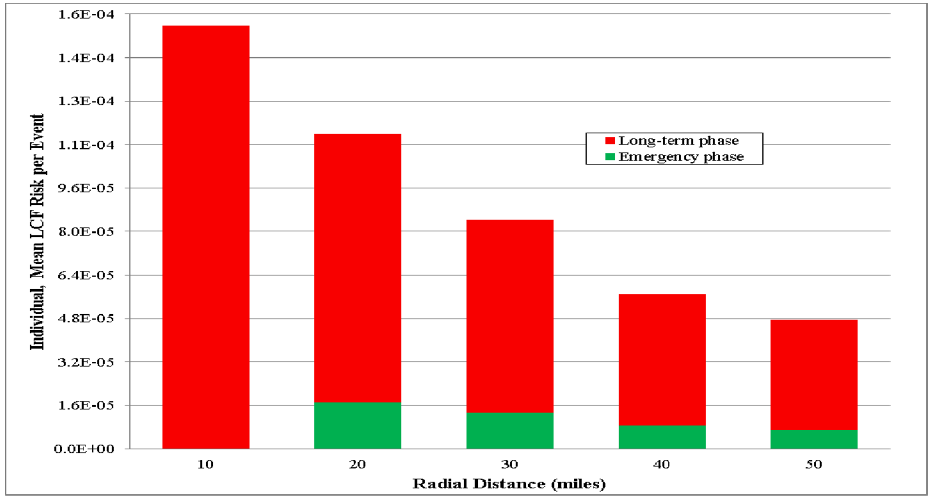
MACCS2 Analysis

- Latent Cancer Fatality Risk
- Prompt Fatality Risk
- Land Contamination
- Population Dose
- Economic Impact

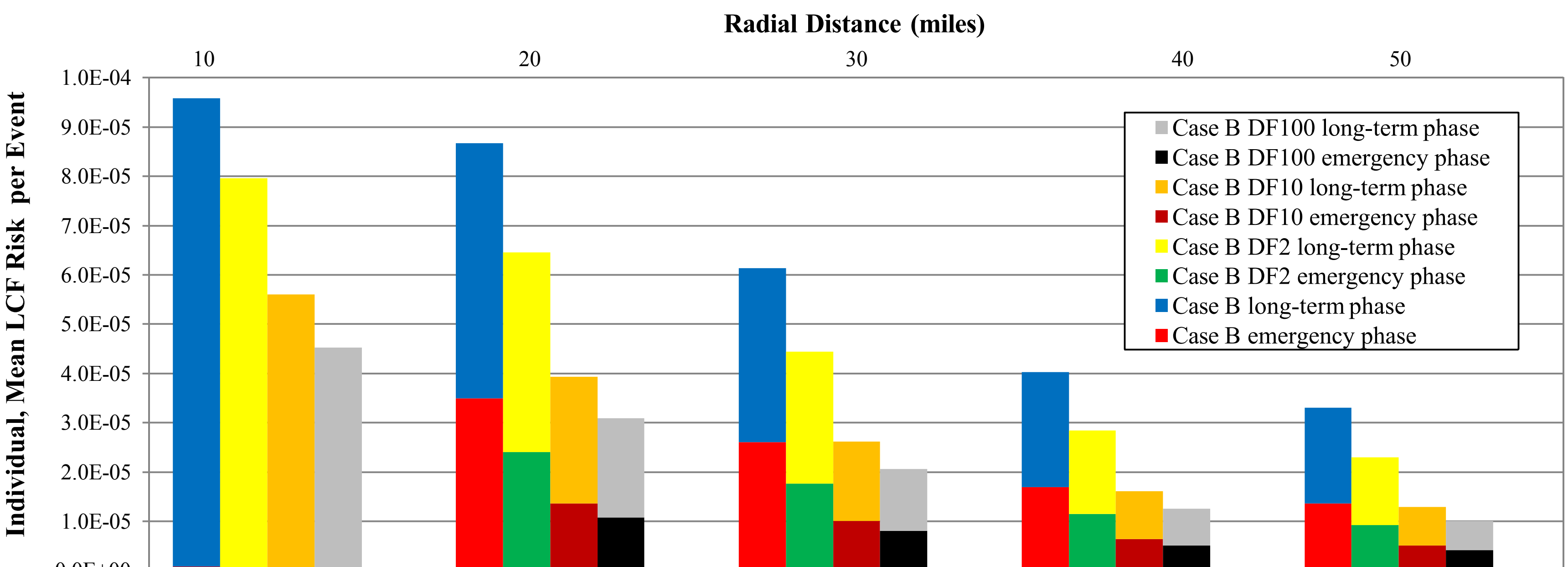
LCF Risk

Case A

Case B



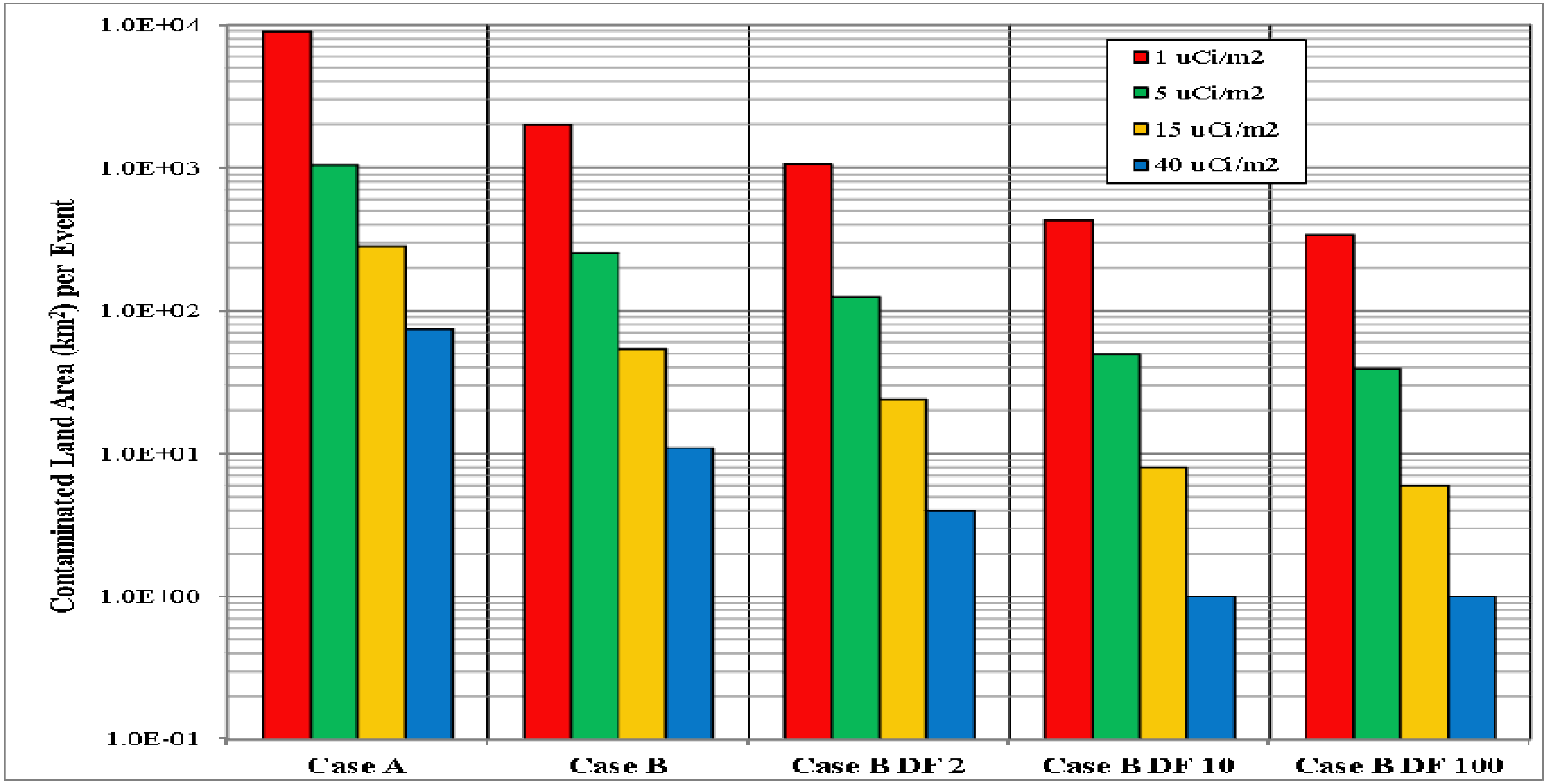
No Prompt Fatality Risk for any cases



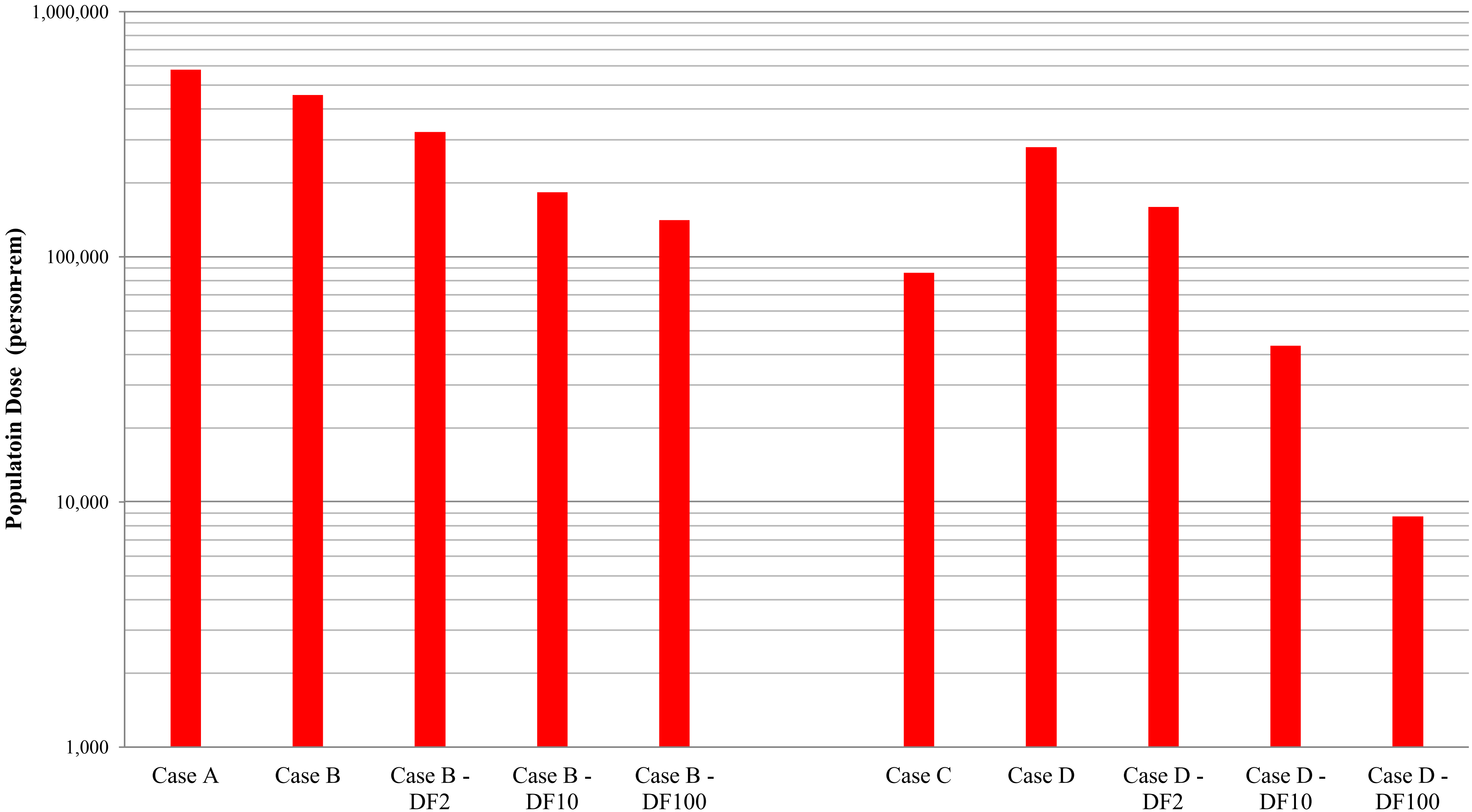
Land Contamination

Chernobyl annual effective external dose estimates for 1986 to 1995

Soil Deposition ($\mu Ci/m^2$ of ^{137}Cs)	Annual Effective External Dose (rem)									
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
15	0.79	0.20	0.19	0.18	0.18	0.18	0.17	0.15	0.14	0.13
5	0.25	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04
1	0.06	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01



Population Dose

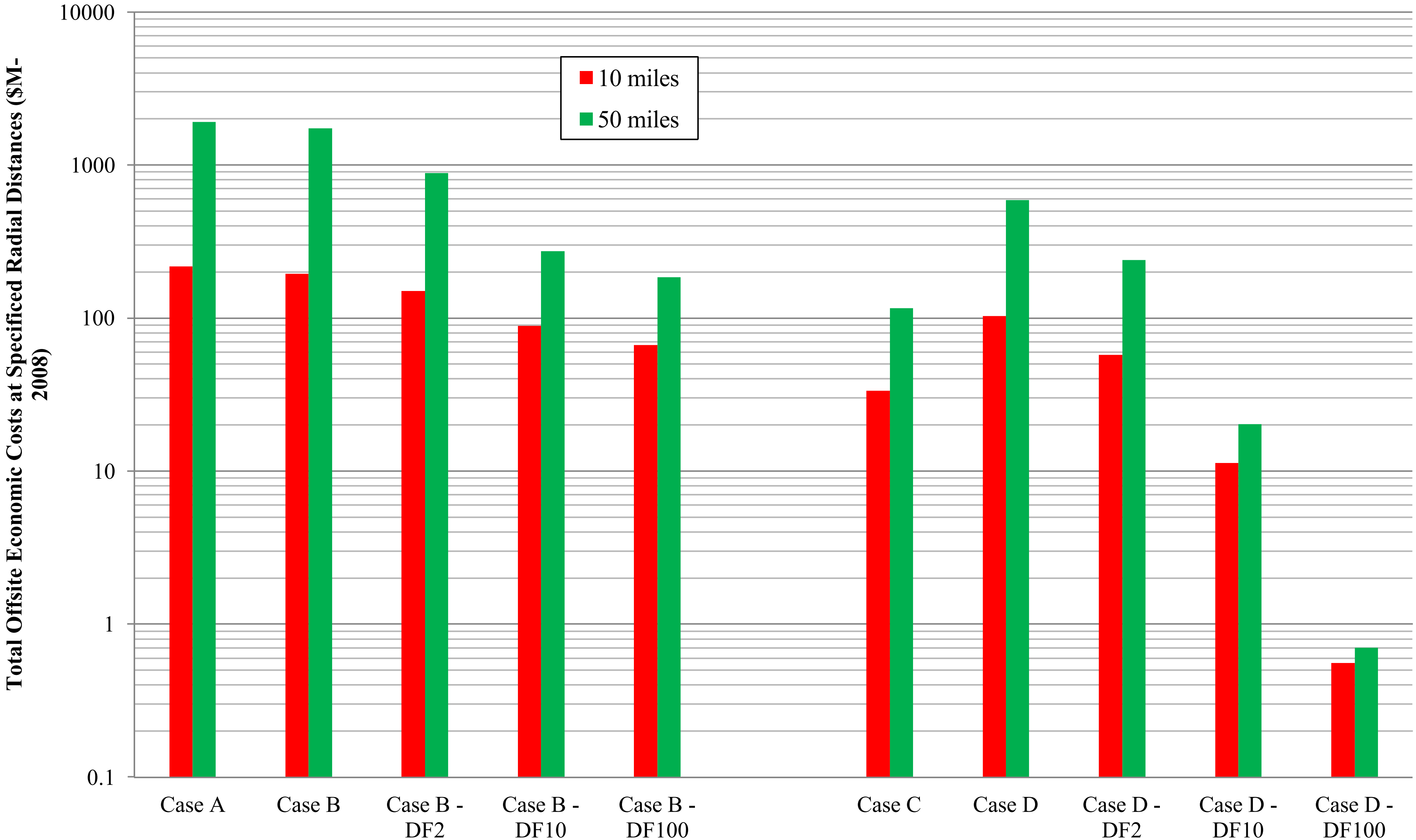


Note: Case D and Case D – DF2 are greater than Case C

Economic Impacts

Case A, Mean, Total Offsite Economic Cost Measures per Event for the 0-50 mile radial distance	($M - 2005)
Population Dependent Nonfarm Decontamination Cost	440
Population Dependent Nonfarm Interdiction Cost	1200
Population Dependent Nonfarm Condemnation Cost	0.26
Farm Dependent Decontamination Cost	23
Farm Dependent Interdiction Cost	55
Farm Dependent Condemnation Cost	0.040
Emergency Phase Cost	83
Milk Disposal Cost	7.0
Crop Disposal Cost	70
Total Offsite Economic Costs	**1910**

Economic Impacts (continued)



Conclusions

- When a DF is applied to the external filtered vent path, the LCF risk, land contamination area, population dose, and economic results are nonlinear. A decision on the use of external filters on either a wetwell vent path should not be solely based on health effect risk, land contamination, population dose, or economic costs.

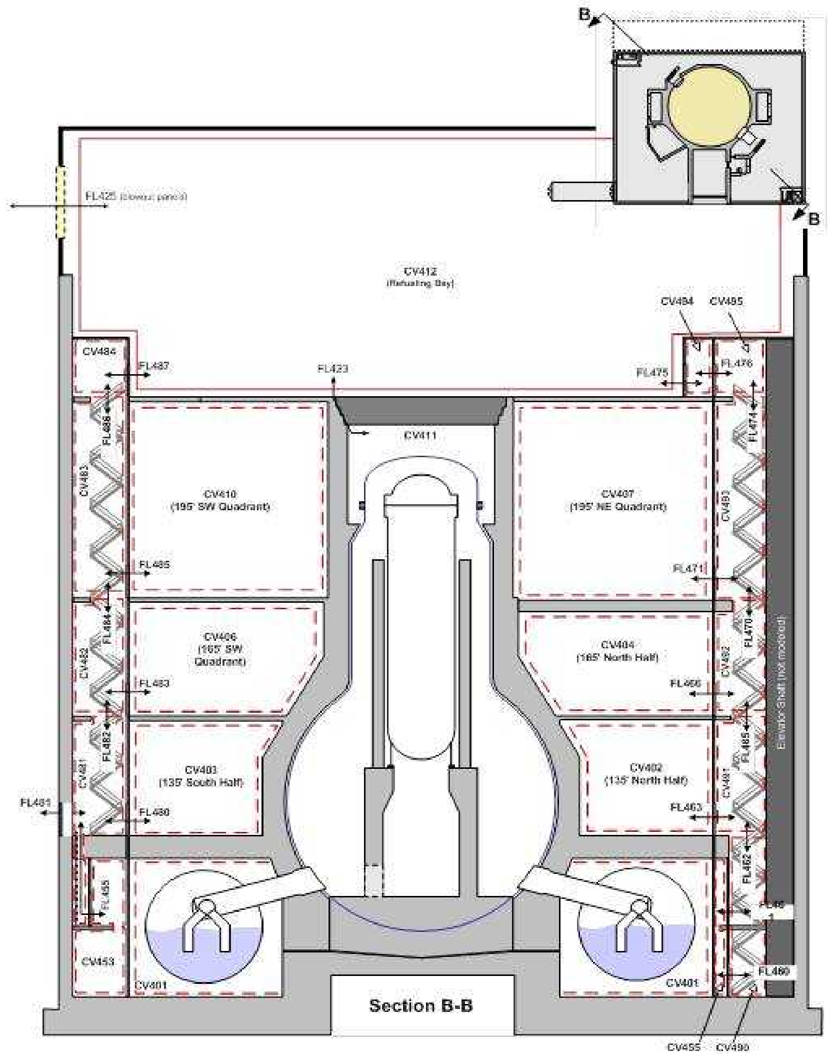
- Based on these consequence analyses, the filtered cases with an external filter on the wetwell and a DF ≥10 for wetwell venting results in a lower conditional LCF risk when compared to the unfiltered cases. When the previously specified DFs are applied to the pathway that flows through the filtered vent, the relationship is sublinear between the inverse of DF and LCF risk. Also, the consequence analyses show that for all cases considered, the conditional prompt fatality risk is either zero or essentially zero.

- Additionally, when an external filtered vent path DF is used to estimate Cs-137 land contamination, a several order-of-magnitude reduction is observed for all cases. The relationship between the inverse of DF and land contamination area is observed to be superlinear.

- The relationship between population dose and inverse DF is sublinear because less remedial action is taken at lower contamination levels. In some cases, it is also sublinear because a portion of the release bypasses the filter vent path. For the cases considered, a DF ≥10 for all wetwell venting filtered cases results in lower population doses than their respective unfiltered cases. The population dose results include societal doses from the ingestion pathway or doses to decontamination workers working in the contaminated area; LCF risks do not include either of these doses. Ingestion is considered during the long-term phase from contaminated food and water. The ingestion pathway accounts for 10% to 30% of the population dose for the cases considered.

- Lastly, the implementation of decontamination, which along with the associated interdiction of land, is the dominant contributor to the overall economic costs, and depends on whether or not the habitability criterion is exceeded. Habitability and farmability criteria are based on contamination thresholds, which lead to inherently nonlinear relationships between source term magnitude and economic costs. Thus applying a DF to represent an external filter does not result in a linear relationship between release (i.e., reciprocal of DF) and economic costs. For the cases considered, a DF ≥10 for all wetwell venting filtered cases results in lower economic costs than their respective unfiltered cases.

Questions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B
CV412
CV411
CV410
(195' SW Quadrant)
CV407
(195' NE Quadrant)
CV406
(165' SW
Quadrant)
CV404
(165' North Half)
CV403
(135' South Half)
CV402
(135' North Half)
CV401
CV401
CV455
CV490
CV494
CV495
Section B-B