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DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING

Structural Standards and Precipitation under a Changing Climate

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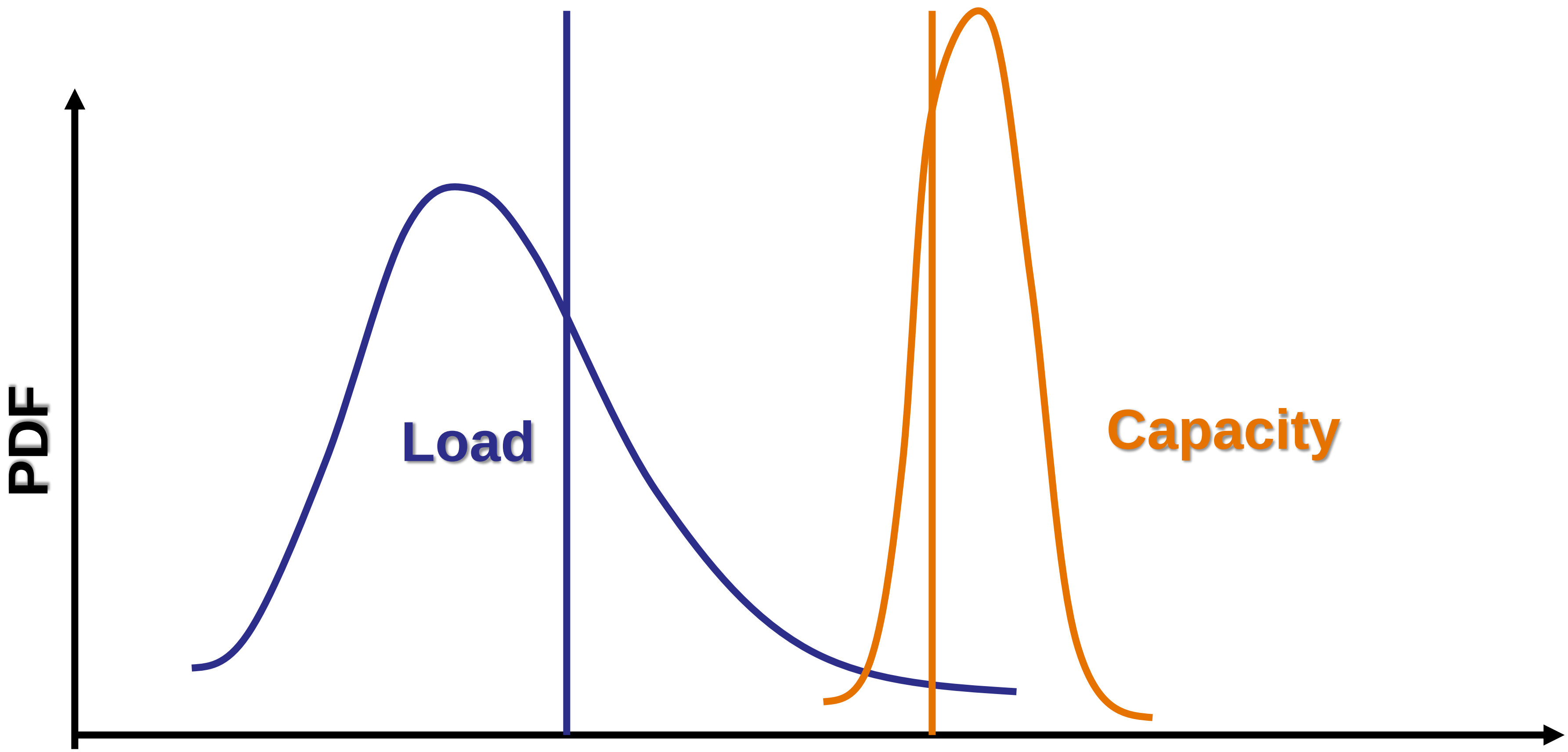
May 30, 2017

Outline of Presentation

- Risk-based design standard
- Current approach
- Potential issues in incorporating non-stationarity in snow load into the design standard

Risk-based Design Standard

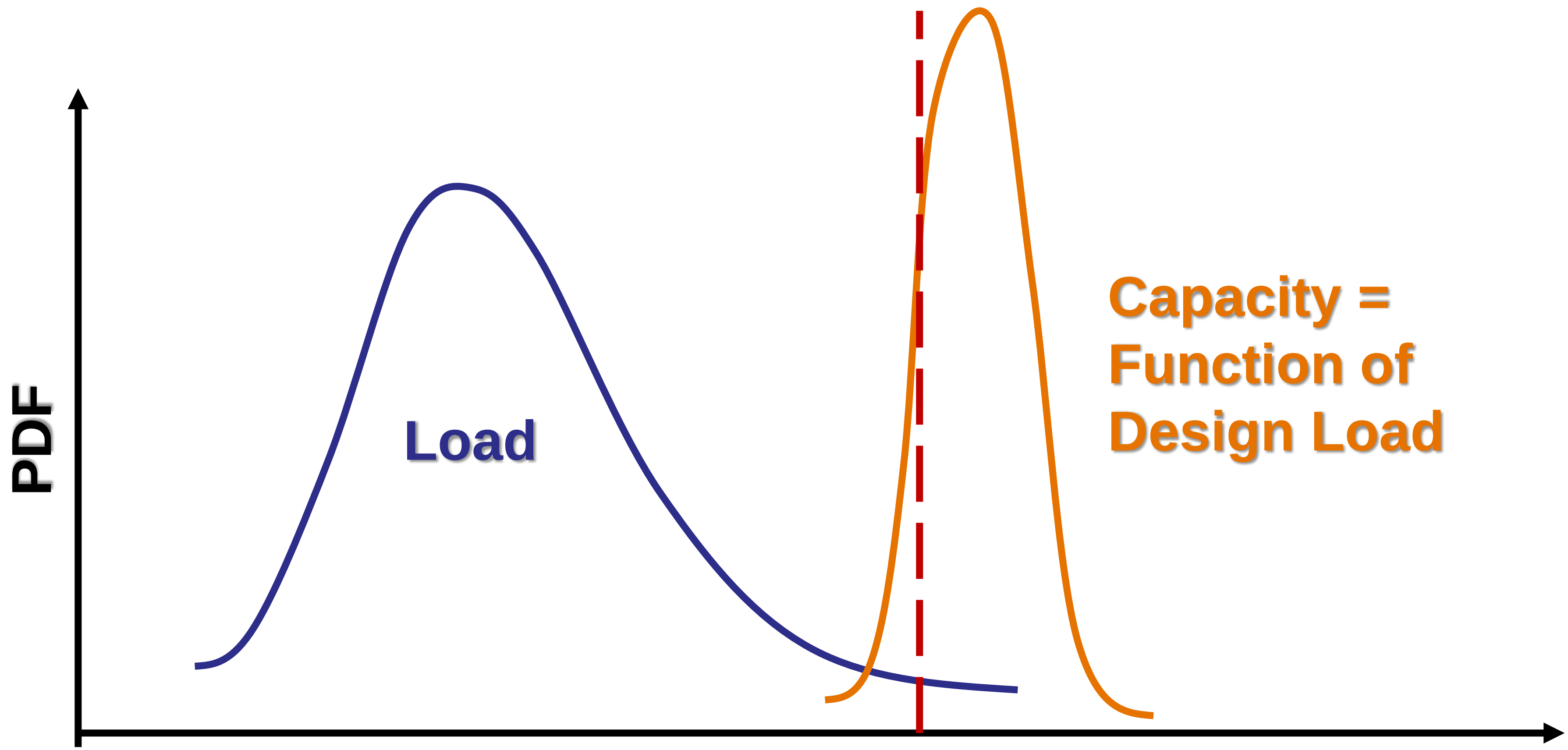
Uncertainties in structural load and the corresponding structural load carrying capacity are considered.



Risk-based Design Standard

Design load is described by

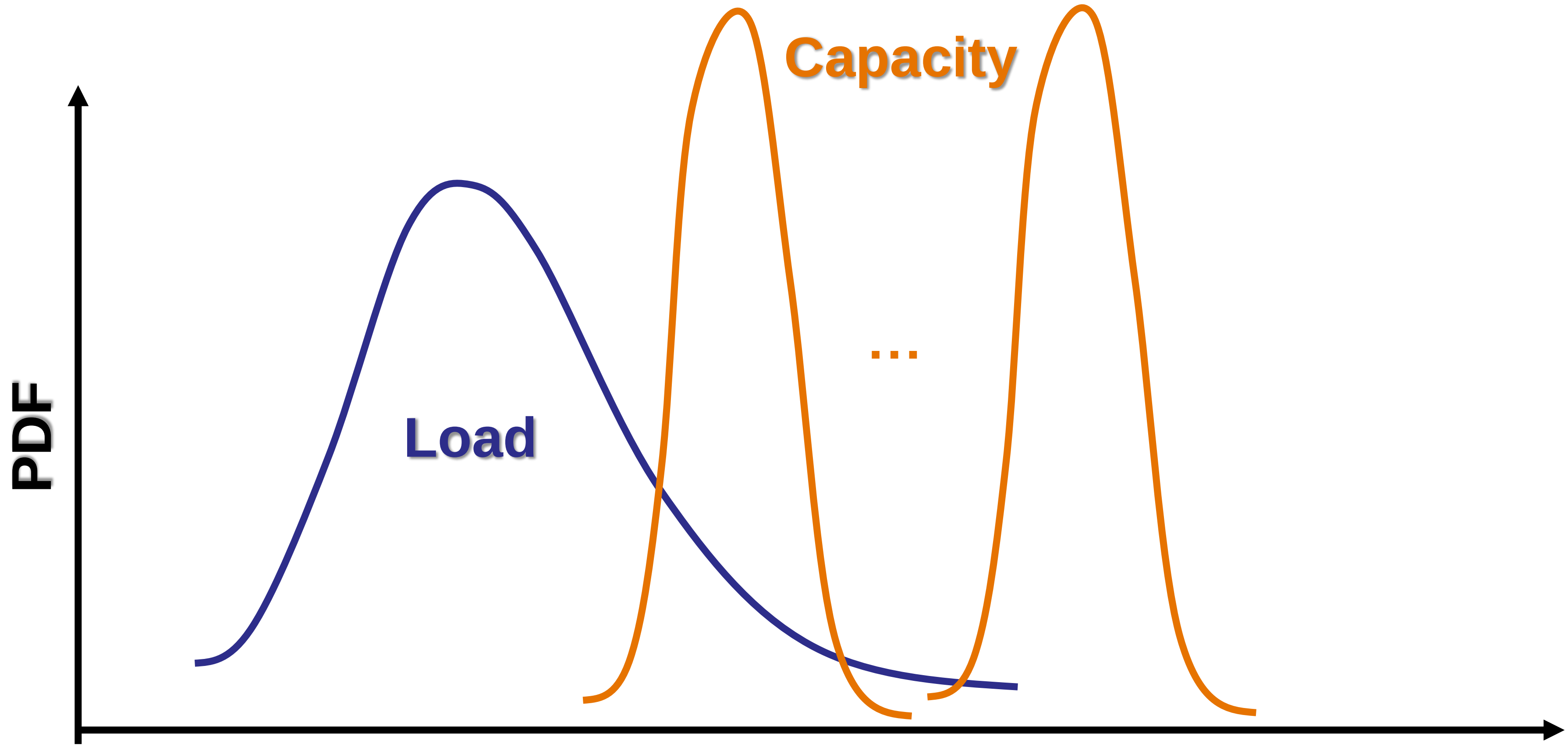
$$P[Load > Design\ Load] = Prescribed\ probability$$



Risk-based Design Standard

Design load changes the probabilistic profile of the structural capacity.

For snow load, $P[.] = 1/50$.

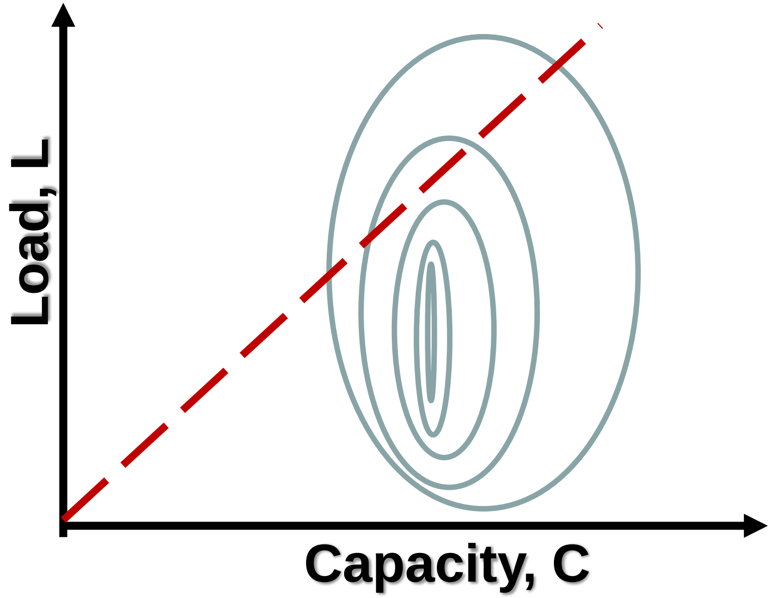


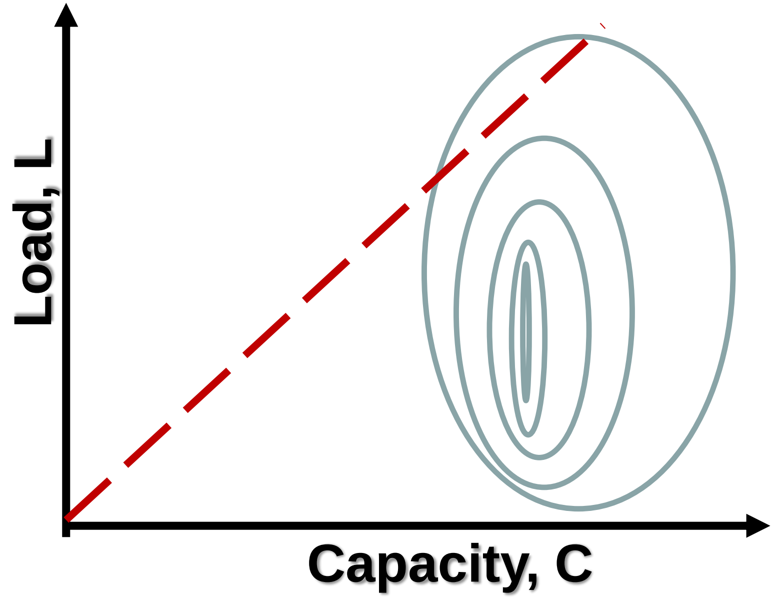
Risk-based Design Standard

Probability of failure is determined as

$$P[Load > Capacity] = \iint_{L>C} f_{L,C}(l,c)\, dl\, dc$$

Target reliability is related to target probability of failure and reflects societally accepted risk level.





Current Approach – Design Snow Load

Conversion from ground to roof snow
- Exposure of the roof to wind and sun, thermal losses from the building, roof geometry, roof cladding, and obstructions on and around the roof.

$$Roof\ Snow\ Load = Ground\ Snow\ Load \times CF$$

Current Approach – Ground Snow Load

Distribution fit for annual extreme (Ellingwood and Redfield, 1983)

- Water equivalent data from 76 first-order weather stations (with at least 10 years' data) in the NE US.
- Lognormal, Log-pearson Type III, Type I, and Type II
- Lognormal was selected in the code.

50-yr MRI value is determined as

$$P[S > s_{design}] = 1/50$$

where S = Annual extreme snow load.

Current Approach – Ground Snow Load

TABLE 1. Annual extreme water-equivalent data through 1980 (cm).

Station	Sample size M (years)	Distribution type[a]	Sample statistics (cm) Mean	Standard Deviation	Maxium	$\hat{x}_{50}$ (cm)	$\hat{x}_{100}$ (cm)
Bridgeport, CT[b]	27	LN	3.3	2.3	9.4	11.4	14.0
Hartford, CT	28	I	5.3	2.5	11.4	12.2	13.7
New Haven, CT	17	I	2.3	1.3	5.3	5.8	6.6
Chicago/O'Hare, IL	20	LP	3.3	2.5	12.2	13.5	18.3
Chicago, IL	26	LP	3.3	3.3	18.0	16.0	22.6
Moline, IL	28	LP	3.0	2.3	10.4	11.4	15.0
Peoria, IL	28	LP	2.5	2.3	13.0	10.2	13.0
Rockford, IL	14	II	3.6	3.6	15.2	34.0[c]	67.3[c]
Ft. Wayne, IN	28	II	2.5	2.0	10.7	11.4	16.5
South Bend, IN	28	II	6.4	5.8	28.2	31.8	45.5

Current Approach – Ground Snow Load

Table 4. Data Summary of result of data-fitting in (Ellingwood and Redfield 1983)

Type of distribution	Number of stations	% of each distribution	γ
Lognormal distribution	23	30%	-
Log-Pearson Type III distribution	16	21%	$\gamma<20$
Type I distribution	18	24%	-
Type II distribution	19	25%	Most $\gamma<10$

Current Approach – Ground Snow Load

Statistical analysis of historic snowfalls (depth and loads) collected from 204 National Weather Service stations with at least 11 years of data during the period of 1952-1992.

Snow depth to snow load relationship (Tobiasson and Greatorex, 1997) to find ground snow loads in 9,200 other locations only with snow depth measurement.

$$L = 0.279D^{1.36}$$

where L = 50-year load in psf
D = 50-year depth in in.

Ground Snow Load Map

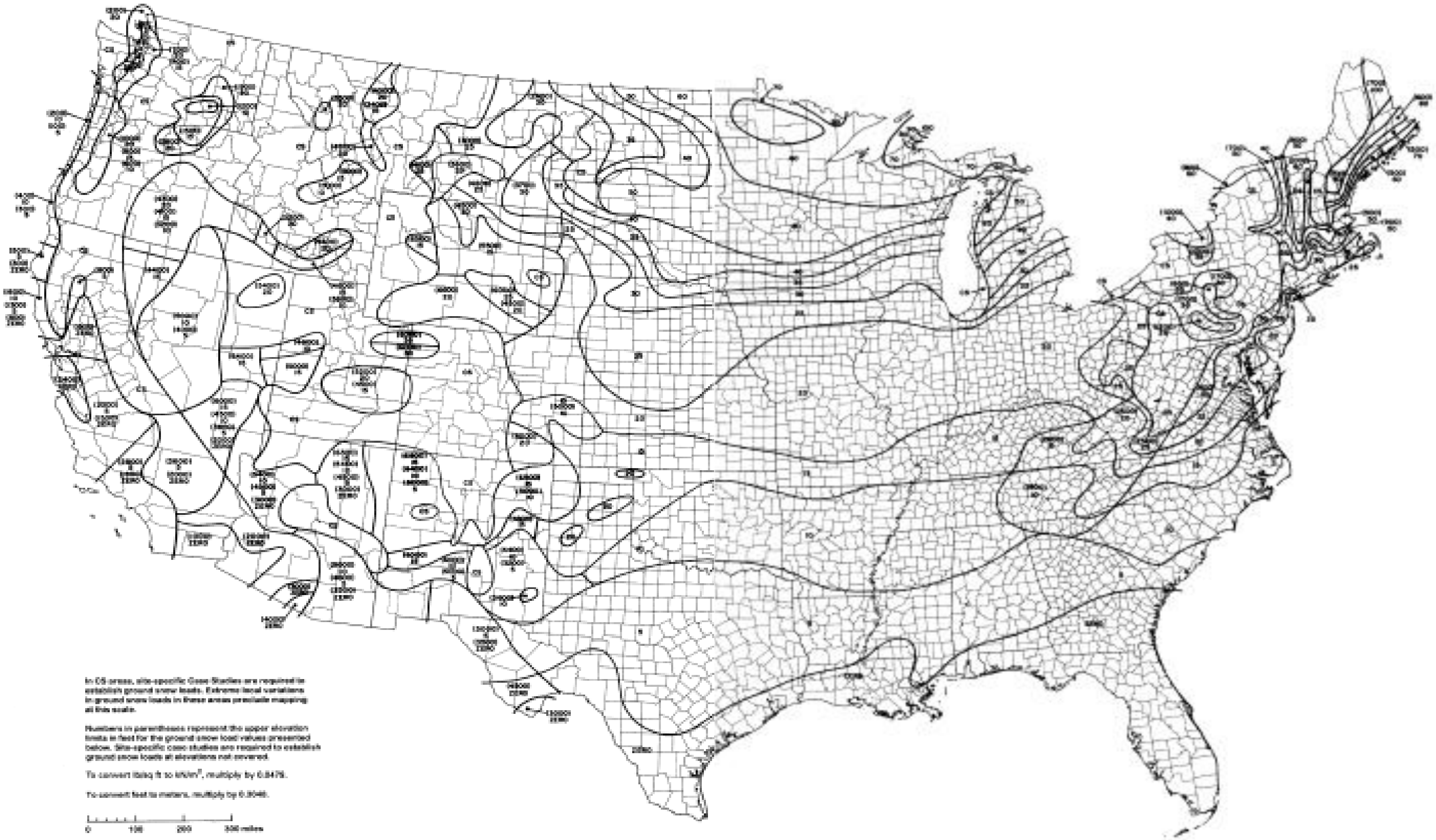


FIGURE 7-1 Ground Snow Loads, p_g, for the United States (Lb/Ft²).

FIGURE 7-1. (Continued)

Issues with Current Approach

The ground snow load map was updated in 1993 and the most recent data was not incorporated.

Lognormal distribution fit works great for NE US but not for some other regions.

Potential Issues with Incorporating Non-stationarity in Snow Load

Issue (1) Probabilistic distribution of annual extreme snow load is expected to change over time.

- Risk level achieved from considering the 50-yr MRI snow load that is calculated based on current climate may not be achieved in future.
- Which year's pdf should be considered to determine 50-yr MRI snow load is questionable.
- New framework is necessary.

Potential Issues with Incorporating Non-stationarity in Snow Load

Issue (2) Uncertainty exists in modeling the non-stationarity.

- Uncertainty is both in the trend of changing climate and in its effect on snow load.
- Epistemic uncertainty is significant and hard to be modeled.

Thank you!

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