MEAN RECURRENCE INTERVALS AND SEISMIC RISK

[from Robert Reitherman, "Seismic Design Fundamentals" class notes, UC Berkeley Extension, Fall, 1984.]

The average or mean time between instances of a specified severity of ground shaking is estimated by seismologists from several possible sources of data in that given region. Where faults are exposed at the surface, paleoseismicity investigations such as trenching can be used to reveal offsets or traces of liquefaction in the strata, which in turn can be approximately dated, along with the magnitudes of those events. The magnitudes are translated into the expected shaking at the site of interest. Seismological catalogues also provide statistical data on the number, magnitude, and location of earthquakes in the region. Often, several faults may contribute to a given site's risk of experiencing strong ground shaking, and they are all folded into the estimation of the mean recurrence interval. The definition of a ground motion severity that is pegged to this average timespan between events is often phrased in terms of reaching or exceeding a peak ground acceleration or a spectral acceleration.

Given that a seismological estimate of the mean recurrence interval is provided, the mathematics follow from there. The formula for deriving the probability an event will or will not occur, given its mean recurrence interval, is the same whether the mean recurrence interval describes earthquake shaking, flood level, wind velocity, or some other random event. This kind of statistic was used in the field of floods prior to its introduction into earthquake engineering, with the "hundred year flood" being shorthand for the "flood level with a mean recurrence interval of 100 years." Note that the seeming precision of the statistical relationships that follow from a mean recurrence interval, which are discussed below, may belie the fact that the mean recurrence interval itself has been calculated with significant uncertainty. Also note that the phenomenon must obey a Poisson distribution rather than have Markovian traits: The probability at any time is assumed to be the same, regardless of whether any events occur or not. The idea of a mean recurrence interval and its associated statistics do not make sense when strain build-up or other knowledge is available to provide a basis for stating that the risk of an earthquake is different in some time periods as compared to others. If the last earthquake can affect the next one, for example if the last one released enough strain to make another one unlikely until time has allowed strain to build up again, and if this can be accurately forecast, then this would be an example where statistics other than mean recurrence interval are instructive.

ANNUAL PROBABILITY DERIVED FROM MEAN RECURRENCE INTERVAL

Given a mean recurrence interval, the annual chance that the event (the occurrence of the ground motion that at least reaches the minimum specified level of severity), will *not* occur is:

$1 - 1/MRI$, where MRI is the mean recurrence interval in years.

If the event has a mean recurrence interval of 100 years, then the chance it will not occur in any one year is:

$1 - 1/100 = .99$, or there is a 99% chance it will not occur.

Because there are only two alternatives--the event (experiencing the minimum specified level of ground motion) will occur, or it will not--there is a 100% - 99% = 1% chance it will occur.

EXPOSURE PERIOD AND MEAN RECURRENCE INTERVAL
While the annual probability statistic is one useful way to interpret the significance of a mean recurrence interval, it might also be instructive to know the probability the event will occur during some amount of time that a building or structure is expected to exist. This time is called the exposure period, the number of years that the site of interest (and the construction on it) will be exposed to the risk of earthquakes.

The probability that the event will not occur for an exposure time of x years is:

$$(1\text{-}1/MRI)^{x}$$

For a 100-year mean recurrence interval, and if one is interested in the risk over an exposure period of 100 years, the chance the event will not occur in that exposure period is:

$(1 - 1/100)^{100} = .366$, or there is a 37% chance it will not occur and a 67% chance it will.

Building codes often tie the level of seismic hazard used in design to the ground shaking that on average will be reached or exceeded in 475 years, (a mean recurrence interval of 475 years).

This can be expressed as the chance this criterion for earthquake shaking--reaching or exceeding a specified value in units of acceleration--will be met in various exposure periods:

50 years: $(1\text{-}1/475)^{50}$ = 90% chance it will not occur, 10% chance it will occur

75 years: $(1\text{-}1/475)^{75}$ = 85.3% chance it will not occur, 14.7% chance it will occur

100 years: $(1\text{-}1/475)^{100}$ = 19% chance it will not occur, 81% it will occur

325 years: $(1\text{-}1/475)^{325}$ = 50% chance it will not occur, 50% chance it will occur

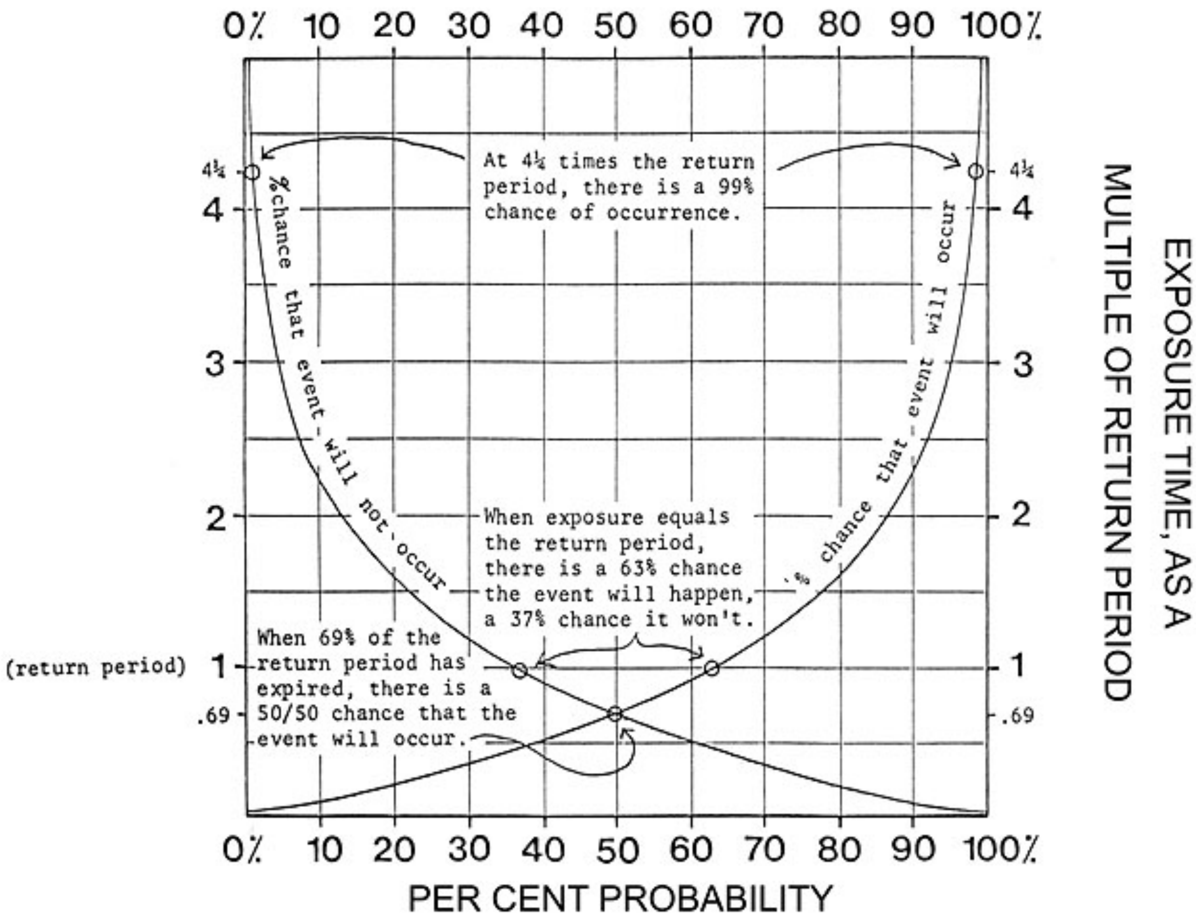
475 years: $(1\text{-}1/475)^{475}$ = 36.7% chance it will not occur, 63.3% chance it will occur.

It is only by chance that the nice round figures, 10% probability of occurrence in 50 years, are associated with the mean recurrence interval of the round figure 475 years (and actually the 10% figure is more precisely associated with a 474.5 year mean recurrence interval). Though it has no absolute validity in and of itself, the 475 mean recurrence interval has tended to become a widely used benchmark for acceptable risk.

Intuitively, one can understand that a structure that will only exist for a short time--a building slated for demolition a year or two in the future for example--faces less seismic risk than a building with a long-term life ahead of it, all other things being equal. A building with a 100-

year lifespan has about a 20% chance of ever experiencing the level of ground motion (475 mean recurrence interval level) for which it was designed. Building lifespans of from 50 to 100 years are often assumed for planning purposes, though historic preservation tends to extend these figures. (To be precise, the "lifespan" would extend up to when a building is significantly remodeled and the seismic aspects of its structure modified, which is likely to occur within a century even if the building continues to exist as recognizably the same building.) A building that is already 150 or 200 years old and has received historic status is likely to be considered even more historic after another 100 years pass, and thus a very long exposure period might be appropriate to consider when figuring the odds that its seismic retrofitting will be called upon to protect it. Another way to "err on the safe side" or take a more conservative approach toward risk is to design for the earthquake that has a longer mean recurrence interval, for example the 2,500-year mean recurrence interval.

The relationship between mean recurrence interval and exposure period is shown in the graph below, (with "return period" meaning "mean recurrence interval" as discussed here).



(accurate to within a fraction of 1% for any return period greater than 50 years)