7 February 2024

**TO: Rep Dacia Grayber, Chair, House Committee on Emergency Management. General Government, and Veterans**
**Vice Chairs Rep Rick Lewis and Rep Thuy Tran**
**Committee Members**

**Subject: Math Research Supporting Early Correction to Risk Assessment Math for HB 4044 Reporting**

## Summary

Five ways of computing likelihood of near-term Subduction Zone Emergency Event are discussed, as guidance to be considered for supporting proposed HB 4044 reports this year

**Introduction.**
STEM folks are going to like this report. You already know that a sensible way to compute aggregated risks has not been established, leaving risk managers with no standard method for quantifying a single math expression for multiple risks. If you can't measure it, you can't manage it. Emergency managers can't get out ahead of the hazards they are responsible for responding to, you know, to reduce the worst-case hazards. For example: with airport fire crews, their best friends are the aircraft design teams spending extra money on highly reliable, multiple-redundant instruments and controls like the Boeing 777 (my assignment in 1990), supported by massive ground navigation infrastructure networks all over the known world. Full disclosure: weather sensing and reporting technology helps a lot. They don't like responding to crashes.

At a time when made-up stories are accepted as truthy theory, this factual guidance deals only in fully verifiable numbers and sound math.

The best seismic risk computational standard we have found is the USGS Circular from 1990 (USGS 1990 Circular). USGS chose a 30-year look-ahead for their earthquake risk metrics. At this link they report that the four separate San Francisco (SF) fault risks add up to a probability of recurrence of 67% in the next 30 years, for the local Metro area. This single, mathematically sound number provides a credible basis for the $20B in infrastructure investments committed after the Loma Prieta M6.9 catastrophe in 1989, a homeless multiplier for up to 12,000 residents.

The USGS 1990 Circular is steeped in Bayesian probability calcs but such considerations don't explain the math for summing the known risks. We sussed it out and present it here, as a way of quantifying the total risk facing not only the totally unprepared Portland but also Puget Sound civic infrastructure. Moreover, aggregated risks threaten the industrial infrastructure of the carbon-fuel dependent economies of Oregon and Washington.

**Summary of findings**
Multiple methods of computing risk are presented.

1. SF present-day risk of M6.7 forecasted a standard 30 years ahead: 22%, 28%, 23%, 23%
   Aggregated SF seismic risk forecasted 30 years = 67%.
2. Percent of known Cascadia M8/M9 recurrence intervals exceeded since 1700 = 93%.
3. Cascadia risk since 1700 = 0.86, computed from log normal model.

4. Cascadia megathrust risk from present forecasted 50 years …
   for each Pacific offshore segment: seg A, 7-12%; B 11 – 17%, C 15 – 21%. D 37 – 43 %
   conventional policy wisdom = 37% / 50 years (OR, WA, US Army Core of Engineers)
   yielding aggregated risk from all 4 segments = 67% max.
5. Ten-year risk forecasting.

Looking at the different math methods, you should concur we need more than seatbelts.

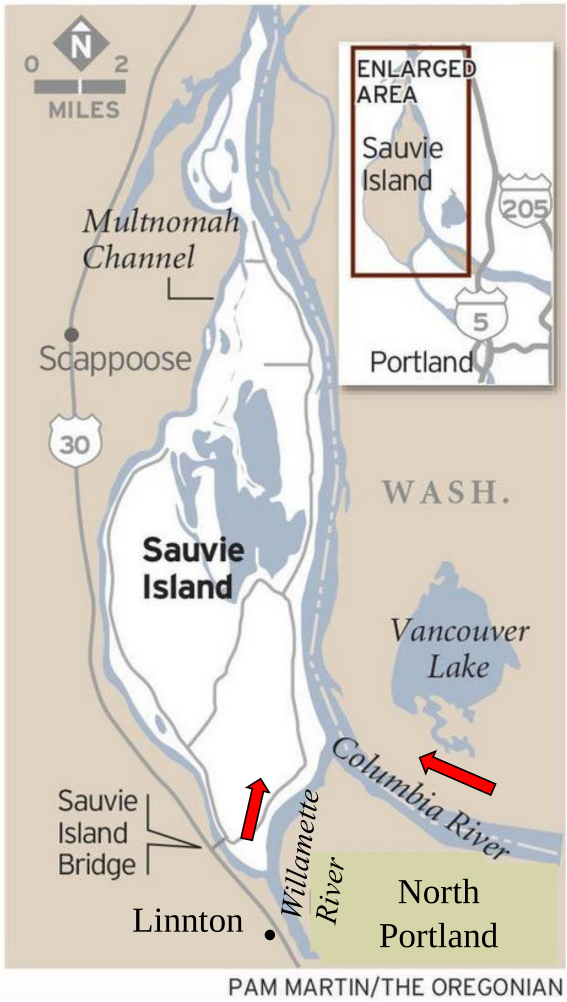
**What don't we know about compound risk? Too much.**
The mathematical combination of statistical risk is not done by adding probabilities.

When we want to know the probability of two independent events happening at the same time, such as a lightning strike and a car accident simultaneously, the valid math is multiplication.
P (crash) x P (strike) = 1% x 0.2% = 0.01 x 0.002 = 0.00002 = 0.002%

If the crash causes a heart attack, it is not valid to multiply P (crash) x P (coronary). Because the crash and the coronary are not independent.

One thing we can do is compute the probability of a crash without a lightning strike.
P (crash) x (P no strike) = P (crash) x (1 – P strike) = 1% x 99.8% = 0.998%
This aligns with intuition about the likelihood of such a coincidence.

**Sauvie Island Safety Risk**
When risk accrues from exposure to natural hazards, it is tempting to mathematically add the risk numbers. For example, in Portland Oregon, flooding from an atmospheric river inundating the Willamette Valley watershed is possible (given by experts as 1% per year). The same for the massive Columbia River watershed. Both flood risks could arrive at the confluence of the two rivers at Sauvie Island.




Thus, the impact of two storms in close succession or one massive one could add to catastrophe (though mitigated by the intervention of flood control dams).

| | | | |
|---|---|---|---|
| Columbia River Basin | 258,000 sq mi | 400 dams | < 1% per year |
| Willamette River Basin | 11,500 sq mi | 25 dams | 1% per year |

And outflow from both rivers would be seriously impeded by occurrence of an exceptionally high tide on the Pacific Coast, which compounds total flood risk.

Sauvie Island


Sauvie Island Confluence, Columbia and Willamette Basin Outflow

So, there is a real need to quantify the risk to the public for realistically additive conditions, employing valid math to quantify public safety risk.

Here are the root causes of Sauvie Island multiple risk scenarios:

Willamette flood
Columbia flood
High Pacific tide
Upriver CEI Hub tank farm collapse from Cascadia Subduction Zone M8/M9 event
Wapato Bridge failure – the only traffic bridge serving Sauvie Island since 2007

The question is, which hazard poses the most risk? What is the total risk from known causes?

**Trouble at Sauvie Island**
Standing on the beach at Sauvie Island you can also see some of over 500 Critical Energy Infrastructure (CEI) Hub fuel storage tanks upriver to the South, built on wet sandy dredge tailings decades before the

Cascadia megathrust history was discovered and then extensively reported in 2012. The probability of the tanks collapsing and sending a wall of flaming fuel to your picnic on the beach has not been computed, nor can it be excluded from midday tomorrow. So how does anyone who really cares about public safety know what to do?

Portland's precarious Linnton fuel storage tanks located upriver 2 mi from Sauvie Island

**1. San Francisco Present-day Fault Risk Forecasted 30 Years Forward**

The USGS standard seems to be set by the referenced USGS 1990 Circular that invokes a 30-year forward looking time window, applied to the 4 known faults in the San Francisco region. Forecasts for the next 30 years are reported as "conditional" probabilities – "the condition being that no event has occurred between the previous event and the day of the forecast" (see 1990 Circular p37). Aggregated probabilities are discussed for fault segments local to the San Francisco Bay, suggesting a compound probability of 0.67.

We believe the method used for this derivation is straight forward. The authors of USGS Circular from 1990 may not have presented the math behind the 67% number, but it is easy to see where it came from. The cover of their Circular shows 30-year probabilities attributed to each of 4 independent faults as 22%, 28%, and two at 23%. The 67% figure is the total probability that a major earthquake will happen from at least one of the faults within the next 30 years. It is determined by first calculating the probability that no big earthquake will occur on any of the 4 faults within 30 years.

P(no earthquake) = (1 - 0.22) x (1 - 0.28) x (1 - 0.23) x (1 - 0.23) = 0.33

P(at least one earthquake) = 1 - P(no earthquake) = 1 - 0.33 = 0.67

This would justify serious investment in more robust infrastructure … while we are waiting for the 67% chance of recurrence.

In San Francisco this is math basis, provided by best science has not been dismissed by civic leadership. It helps provide justification the post- Loma Prieta infrastructure rebuild investment of $20B.

**USGS has updated research identifying the mathematical risk for the San Francisco region**
Not only the San Francisco region but the whole state of California is modeled now, with 30-year likelihoods for future events. UCERF3: A New Earthquake Forecast 2015 (CA Forecast 2015). The USGS has published this remarkable update to what was known in 1990, employing a new seismic model. In this report they state (bold font for emphasis here)…

> For example, compared to the previous forecast (UCERF2), the likelihood of moderate-sized earthquakes (magnitude 6.5 to 7.5) is lower, whereas **that of larger events is higher.** This is because of the inclusion of multi-fault ruptures, where earthquakes are no longer confined to separate, individual faults, but can occasionally rupture multiple faults simultaneously.
> The **public-safety implications** of this and other model improvements depend on several factors, including site location and type of structure (for example, family dwelling compared to a long-span bridge).
> Building codes, earthquake insurance products, emergency plans, and other risk-mitigation efforts will be updated accordingly.

| USGS regards public safety to be a proper goal of seismic research in CA |
|---|

**2. Percent of known Cascadia intervals exceeded since 1700**
Geologists predict the chance of various fault segments off the Northwest coast to produce a catastrophic M8/M9 megathrust event. In Holocene Paleoseismicity, 2012 (USGS Holocene 2012), the USGS theorizes many probabilities for various events that have been analyzed by many researchers for distinct fault segments. This USGS report seems to be a multi-decade research effort with a lot of time taking soil samples drilled from the sea floor and inland lakes. Call each sample a turbidite. There are thousands that were examined. The Holocene report characterizes geologic probabilities for the next 50 years in all cases. This seems a little unusual, given that the USGS standard forecast seems to be 30 years.

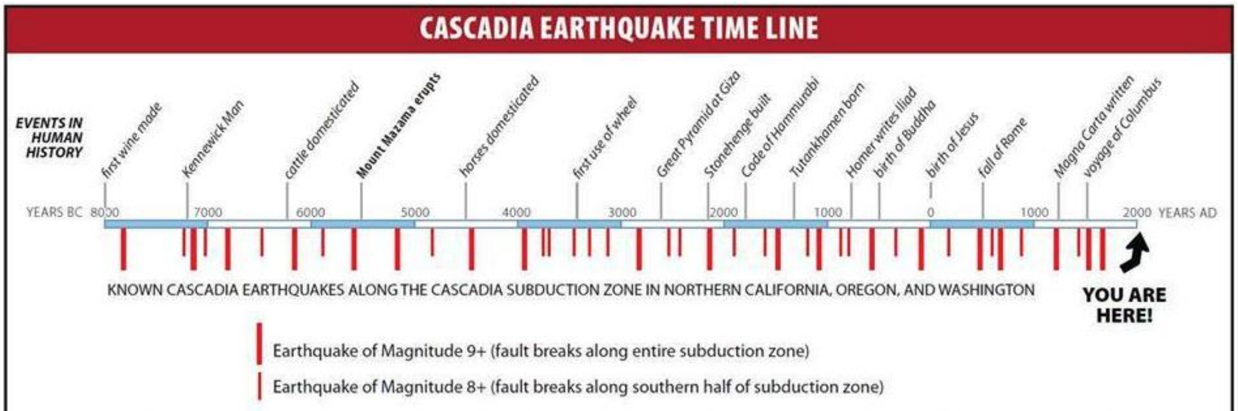
USGS Holocene 2012 scientists reported the last Cascadia disaster in year 1700. They also list all the previous intervals between such events going back 10,000 years. Like the San Francisco USGS team the Cascadia team reports the conditional probability of various segments letting go, using a 50-year look-ahead, not the standard 30 years. **But they do not report even an intuitive aggregated potential risk probability** of threatening events posed by ALL of the reported Cascadia segments.

Here is a summary of all known Holocene Cascadia event intervals discovered from the last 10,000 years of event data. All we know from best science is shown in green, with computed intervals on the right side of the spreadsheet. This could be the best forecast data for any seismic threat anywhere.

| Prior Event Sequence, from 1700CE looking back in time | Age, years before 1700CE | Interval in years |
|---|---|---|
| 1 (1700) | 0 | |
| 2 | 265 | 265 |
| 3 | 481 | 216 |
| 4 | 548 | 67 |
| 5 | 796 | 248 |
| 6 | 1066 | 270 |
| 7 | 1243 | 177 |
| 8 | 1422 | 179 |
| 9 | 1554 | 132 |
| 10 | 1820 | 266 |
| 11 | 2040 | 220 |
| 12 | 2317 | 277 |
| 13 | 2536 | 219 |
| 14 | 2730 | 194 |
| 15 | 2822 | 92 |
| 16 | 3028 | 206 |
| 17 | 3157 | 129 |
| 18 | 3443 | 286 |
| 19 | 3599 | 156 |
| 20 | 3890 | 291 |
| 21 | 4108 | 218 |
| 22 | 4438 | 330 |
| 23 | 4535 | 97 |
| 24 | 4770 | 235 |
| 25 | 5062 | 292 |
| 26 | 5260 | 198 |
| 27 | 5390 | 130 |
| 28 | 5735 | 345 |
| 29 | 5772 | 37 |
| 30 | 5959 | 187 |
| 31 | 6466 | 507 |
| 32 | 6903 | 437 |
| 33 | 7182 | 279 |
| 34 | 7625 | 443 |
| 35 | 7943 | 318 |
| 36 | 8173 | 230 |
| 37 | 8459 | 286 |
| 38 | 8906 | 447 |
| 39 | 9074 | 168 |
| 40 | 9101 | 27 |
| 41 | 9218 | 117 |
| 42 | 9795 | 577 |
| | | 9795 |

If we need to become armchair quarterbacks, we can start here with conventional off-the-shelf computational tools like MSExcel, to report the aggregated risk as known from these intervals that encompass all the known segments.  The result is a not a “conditional” probability but a conventional risk probability, and it can be formally verified independently by the reader, using the same Holocene interval data and any other algorithm or tool of choice.

From the Oregon Department of Geology graphic depicting these intervals, we recognize a decrease in intervals in the last 6,000 years, meaning events recur more frequently.




**Comparison of the history of subduction zone earthquakes along the Cascadia Subduction Zone in northern California, Oregon, and Washington, with events from human history. Ages of earthquakes are derived from study and dating of submarine landslides triggered by the earthquakes. Earthquake data provided by Chris Goldfinger, Oregon State University; time line by Ian P. Madin, DOGAMI.**

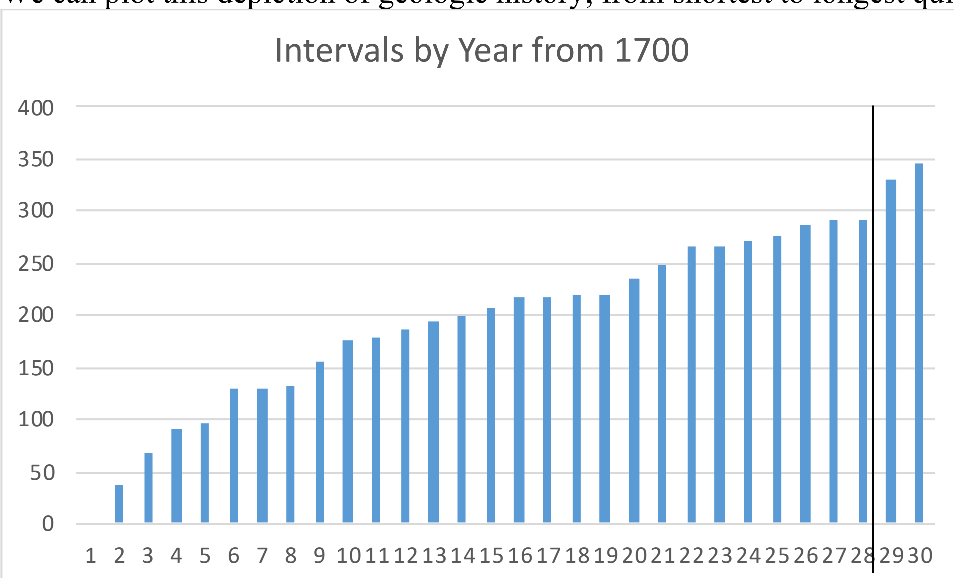
The fundamental geologic root cause of these events is attributed to the accumulation of tectonic plate stress, with no particular meaning from considering a median of all event intervals, because we want to know the evident trends driven by the buildup of tectonic forces. Noting that it has been over 300 years from the last catastrophic event, we can gain perspective from seeing how many historic event intervals have already been exceeded in our 300+ years of quiet time.

Here is the same set of intervals ordered from shortest to longest, encompassing the historical aggregated risk from any root cause. We can see all the historic intervals exceeded, added to the last real event starting in 1700CE. In 1992 we see 93% of intervals were exceeded with only a few remaining before all know intervals from the last 6,000 years are exceeded – NOT GOOD. This is not a probability number, and it is also not very reassuring. And it characterizes the aggregated results from all reported Cascadia fault segments.

| Prior Event Sequence, from 1700CE | Years before 1700CE | Interval in years | | Sorted | Year interval was exceeded | Percent |
|---|---|---|---|---|---|---|
| 1 (1700) | 0 | | | | 1700 | 0% |
| 2 | 265 | 265 | | 37 | 1737 | 3 |
| 3 | 481 | 216 | | 67 | 1767 | 7 |
| 4 | 548 | 67 | | 92 | 1792 | 10 |
| 5 | 796 | 248 | | 97 | 1797 | 14 |
| 6 | 1066 | 270 | | 129 | 1829 | 17 |
| 7 | 1243 | 177 | | 130 | 1830 | 21 |
| 8 | 1422 | 179 | | 132 | 1832 | 24 |
| 9 | 1554 | 132 | | 156 | 1856 | 28 |
| 10 | 1820 | 266 | | 177 | 1877 | 31 |
| 11 | 2040 | 220 | | 179 | 1879 | 34 |
| 12 | 2317 | 277 | | 187 | 1887 | 38 |
| 13 | 2536 | 219 | | 194 | 1894 | 41 |
| 14 | 2730 | 194 | | 198 | 1898 | 45 |
| 15 | 2822 | 92 | | 206 | 1906 | 48 |
| 16 | 3028 | 206 | | 216 | 1916 | 52 |
| 17 | 3157 | 129 | | 218 | 2097 | 55 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 18 | 3443 | 286 | | 219 | 1919 | 59 |
| 19 | 3599 | 156 | | 220 | 1920 | 62 |
| 20 | 3890 | 291 | | 235 | 1935 | 66 |
| 21 | 4108 | 218 | | 248 | 1948 | 69 |
| 22 | 4438 | 330 | | 265 | 1965 | 72 |
| 23 | 4535 | 97 | | 266 | 1966 | 76 |
| 24 | 4770 | 235 | | 270 | 1970 | 79 |
| 25 | 5062 | 292 | | 277 | 1977 | 83 |
| 26 | 5260 | 198 | | 286 | 1986 | 86 |
| 27 | 5390 | 130 | | 291 | 1991 | 90 |
| 28 | 5735 | 345 | | 292 | 1992 | 93 |
| 29 | 5772 | 37 | | 330 | 2030 | 97 |
| 30 | 5959 | 187 | | 345 | 2045 | 100 |

We can plot this depiction of geologic history, from shortest to longest quiet times.

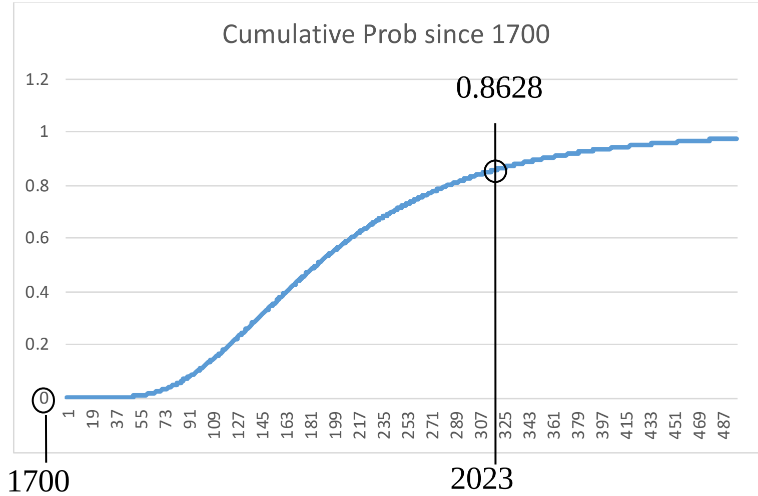



In 1992 we see 93% of intervals were exceeded with only a few remaining before all known intervals from the last 6,000 years are exceeded.

**3. Log-Normal Cascadia Probability Since 1700**

In our application of lognormal distribution to the 28 most recent Cascadia intervals, we depict the increasing probability of a Cascadia event as the years go by, when no event has occurred. The use of the lognormal probability model is so common that MSExcel includes lognormal math functions. Our MSExcel model is given here: [Lognormal Model Recent 28 Events Plus Odds]

If we were standing on the Sauvie Island beach after the last Cascadia event in 1700, and if we knew all the previous M8/M9 intervals, we could compute the increasing probability profile of the next event. It increases for each interval exceeded without a release of accumulated seismic energy. Using the lognormal statistical model, we get at least 86% in the next 323 years, i.e. in 2023.




In year 323, the probability that this event will have occurred by now is 86% and increases every year in the future. This is of course consistent with the unrelieved accumulation of tectonic stress. Odds at 86% are 6 to 1 for a Cascadia M8/M9 by now. This should be more than enough math to call for action. Would you want to bet your West Coast civic infrastructure against a 6-to-1 coin?

> By 323 years after 1700, the lognormal probability of the next Cascadia catastrophe is shown to be 0.86.

The question comes up, after the simplistic 93% of known intervals, plus the lognormal odds of 0.86, **is any additional math modeling needed to justify immediate emergency intervention?** The USGS probability of 0.72 for the San Francisco region has already come to pass in the Loma Prieta event. Just for a little emphasis, note 0.86 > 0.72.

**4. Present-day Cascadia Catastrophic Risk Forecasted 50 Years in Future**

USGS Holocene 2012 reported conditional risk with a lookahead of 50 years from 2010, assessed various fault segments with various conditional risk models, with no total aggregated risk cited. The aggregated risk is what the public safety community can't live without. From the 2012 report we find this summary on p129:

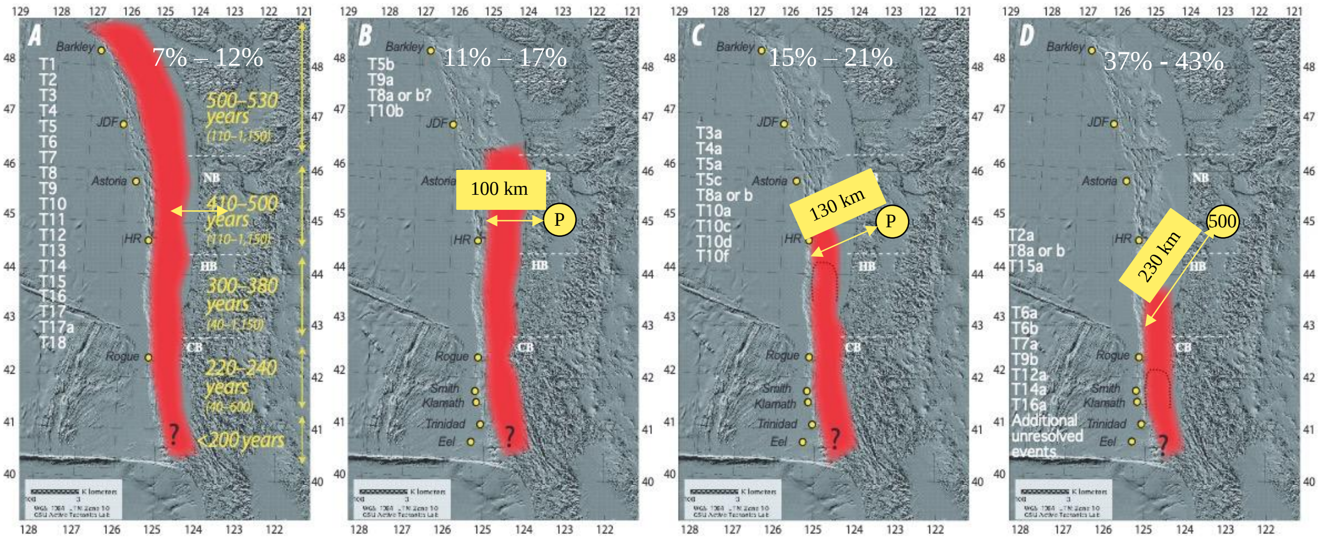
> Using the same recurrence estimates, time-dependent probabilities for the next 50 years, ending in 2060, are ~7–12 percent for Segment A, 11–17 percent for Segment B, 15–21 percent for Segment C, and 37–43 percent for Segment D.

From Figure 55 we depict ranges from Portland Oregon to the Holocene segments.

## Cascadia Rupture Segments

Aggregated risk is accrued from all 4 segments

No carbon fuels for OR:
Most of 500 precarious PDX tanks
breached and many burning




Liquefaction occurs anywhere the water table is 1 m or less, coastal or inland.
https://www.youtube.com/watch?v=v24vLY6Wqc4

Since the aggregated risk was not cited, we offer this computation, which assumes each segment is geologically independent per USGS definitions:

Probability of no Cascadia Subduction Zone Event in 50 years = "P(no CSZE)50."

P(no CSZE)50 = (1 – Seg A%) x (1- Seg B%) x (1 – Seg C%) x (1 – Seg D%)

Taking the lower end percentages,

P(no CSZE)50 lo = (1 – 0.07) x (1 – 0.11) x (1 – 0.15) x (1 – 0.37)
P(no CSZE)50 lo = (0.93) x (0.89) x (0.85) x (0.63)
P(no CSZE)50 lo = 0.37

P(CSZE)50 lo = (1 – 0.37) = 0.63. This is not the widely quoted likelihood of 37%.

For the high-end percentages,

P(no CSZE)50 hi = (1 – 0.12) x (1 – 0.17) x (1 – 0.21) x (1 – 0.43)
P(no CSZE)50 hi = (0.88) x (0.83) x (0.79) x (0.57)
P(no CSZE)50 hi = 0.33

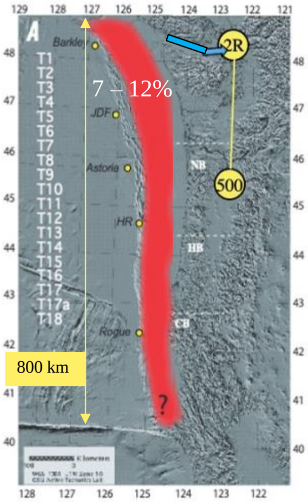
P(CSZE)50 hi = (1 – 0.33) = 0.67. This is not the widely quoted likelihood of 37%.

Taken from Holocene 2012 Figure 55, this next depiction of the precarious NW carbon fuel infrastructure justifies aggregation of segment risks.

Journalists reporting a Cascadia risk of 37% in 50 years do not realize …..

1) 37% applies to only one reported segment
2) Total Cascadia risk results from all 4 reported segments
3) Employing USGS data and USGS math, the total aggregated Cascadia risk is 67% in 50 years
4) USGS has discarded the 50-year forecast in favor of a more conclusive 30 years




Full rip risk

No carbon fuels for OR or WA:

2 WA refineries collapsed and
later inundated by tsunami
Fragile WA pipeline inoperative
Most of 500 precarious PDX tanks
breached and many burning

All 4 segments threaten Sauvie Island, Oregon carbon fuel infrastructure, and the Oregon economy

Cascadia risk exceeds all others
No physical investment to date

It seems 37% is not the right answer. It seems 50 years is not the right forecast.

The 400-mile Olympic pipeline from Seattle is vulnerable to being unearthed by liquefaction buoyancy effects. Oregon State University field trip video studying liquefaction evidence Every one of the Cascadia segments can result in a rebounded petroleum pipeline with successive breaks along its full length, preventing fuel delivery. The aggregated risk of 67% certainly stems from pervasive liquefaction.

 https://better-energy-llc.com/ 

**Few know Washington state is deciding Oregon's fate.**

Nearly all (90%) of transport fuel consumed in Oregon is delivered to Portland's rickety tank farms from a single marginal pipeline. If Washington State's Olympic Pipeline were anything like the seismically sound North Slope pipeline to Valdez, it would look something like this.

The Olympic Pipeline does not look like this, is 60 years old, and has never seen a current seismic construction standard.

Washington's petroleum infrastructure, unlike Oregon's, is exposed to Fukushima scale tsunami inundation a couple hours after their refinery towers, pipelines, docks, pumpstations, pressure vessels, manifolds and holding tanks sink into the liquified sands at March Point, starting a one square mile campfire. The chain link security barriers are no match for 10-foot surge of Puget Sound washing the flaming refinery rubble into Padilla Bay. Please see Attachment A.

**Washington, Oregon and Military emergency management policies all state a Cascadia 50-year forecast.**

| Policy Document | Date | Ref | Probability Citation |
|---|---|---|---|
| Resilient Washington State | November 2012 | P11 | 50-year goal set by (obsolescent) 2008 USGS Seismic Hazard Map |
| Oregon Resilience Plan from OSSPAC | February 2013 | P31 | Ranges from 7-12% to 37% in next 50 years |
| US Army Core of Engineers – Worst Case | January 2020 | - - - | 40% chance in next 50 years |

There is no sense of urgency with baselining a 50-year goal. This regrettably justifies years of delayed physical intervention and fails to serve the interests of Oregon and Washington public safety.

USGS likely never published "USGS Holocene 2012" as a public safety guidance document.

The 30-year forecast is the USGS standard set by the USGS 1990 Circular and is way more actionable than the 50-year USGS Holocene 2012 paleoseismicity professional paper.

**What do we need from the USGS Public Safety Department right away?**
As noted above in CA Forecast 2015, USGS acknowledges the “public safety implications” of risk math models. Washington and Oregon Governors, elected officials, agency officials, emergency management authorities, Public Safety officials, educators and taxpayers all need the 30-year lookahead for the Cascadia region just like the work done for San Francisco following Loma Prieta devastation that produced the 0.72 aggregated risk. Our approach that relies on the USGS 1990 Circular risk aggregation to totalize the USGS Holocene 2012 interval data yielded a 67% risk in the next 50 years. There are better USGS models that determine standard risk forecasts for the next 30 years.

**How to motivate prudent and timely action**
This concern is highly relevant because the USGS response to the post- Loma Prieta infrastructure rebuild investment of $20B has not been replicated on behalf of Oregon, or Washington. Except for the Bonneville Power Administration (BPA investments) and the PDX Airport North Runway Project, the $20B resilience investments have not been matched. Politically this means that the generous first responder funding and emergency management agencies and training in Oregon and Washington do absolutely nothing to blunt the known risk of the pending massive coastal and inland M8/M9 destruction.

Unmitigated exposure to seismic hazards is an economic inflation multiplier. According to the National Institute of Building Sciences, after-the-fact earthquake rebuilds cost 13x that of prudent retrofits in advance.

| National Institute of BUILDING SCIENCES | ADOPT CODE | ABOVE CODE | BUILDING RETROFIT | LIFELINE RETROFIT | FEDERAL GRANTS |
|---|---|---|---|---|---|
| Overall Benefit-Cost Ratio | 11:1 | 4:1 | 4:1 | 4:1 | 6:1 |
| Cost ($ billion) | $1/year | $4/year | $520 | $0.6 | $27 |
| Benefit ($ billion) | $13/year | $16/year | $2200 | $2.5 | $160 |
| Riverine Flood | 6:1 | 5:1 | 6:1 | 8:1 | 7:1 |
| Hurricane Surge | not applicable | 7:1 | not applicable | not applicable | not applicable |
| Wind | 10:1 | 5:1 | 6:1 | 7:1 | 5:1 |
| Earthquake | 12:1 | 4:1 | 13:1 | 3:1 | 3:1 |

https://www.nibs.org/files/pdfs/ms_v3_adopts_earthquake.pdf

M8 and M9 are x30 and x900 the energy released during the M7 Loma Prieta, and still we see no full-scale action on state infrastructure vulnerabilities. How can this happen? Best answer is that Oregon has lower GDP and a lower tax revenue base, our electeds dismiss science and math (Oregon geology department is not looking forward to another governor proposing that they get defunded, again), and even worse, OR and WA hazard response planners plus FEMA and US COE believe our USGS has reported aggregated public safety risk: a 37% chance in next 50 years. No, USGS has not. The 37% is only one coastal fault segment - of at least 4 that pose combined immanent risk.

Cascadia researchers with Portland State University (PSU) have focused on the risk prospects in the next 10 years, not the standard USGS 50-year and 30-year characterizations that so far has dissipated any motivation for near term action in the Northwest. We regard a 10-year lookahead as a prudent ground rule for our analysis.

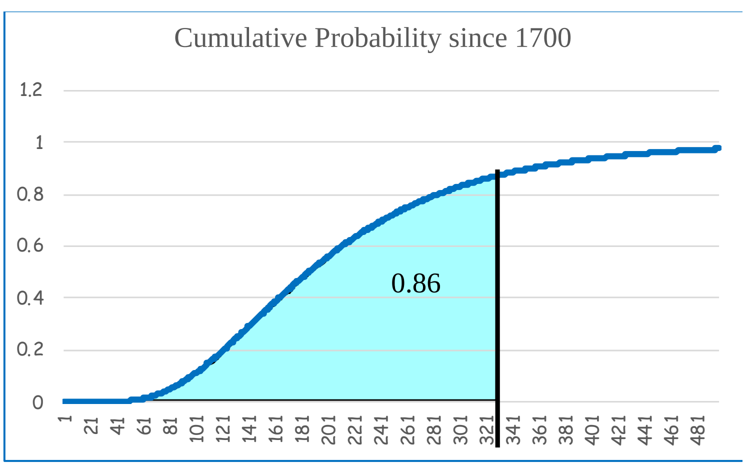
**5. Ten-year Risk Forecasting**

Both Oregon DEQ and Portland State University are interested in 10-year seismic risk forecasting. If credible probabilities support near term action to rectify precarious carbon fuel infrastructure, the interests of public safety in Oregon and Washington can be defended against ignorance, neglect, and active lobbying to preclude those terrible "proscriptive" policy mandates. Known infrastructure deficiencies disclosed in the public record in 2012 have not been corrected since disclosure by due diligence STEM researchers. Please see Attachment B.

Insurer and reinsurers have studied the statistics of housefires. We can compute the risk of a housefire starting with their numbers. In the next ten years the risk of a house fire can be shown to be 1.2%. Please see Attachment C.

This can be compared to the aggregated risk of a Cascadia seismic event that is shown to be 8.3% in the next ten years, relying on the Cascadia 1700 log normal risk profile.

Employing the off the shelf math tool MSExcel, intervals between seismic events as taken from the USGS Holocene 2012 report are used to generate a log normal graphic depicting the increasing risk trends characterizing the Cascadia subduction stress from locked tectonic plates. The area under the curve represents an approximate likelihood of the next event at 0.86%, an aggregated probability from all causes, known or unknown.

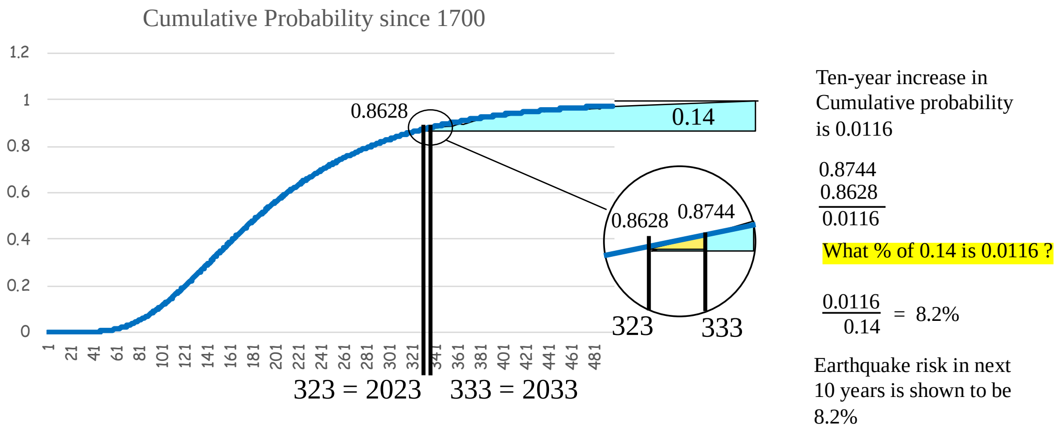



323 = 2023

From 2023 on, the remaining area under the curve is (1 – 0.86) = 0.14.

We are interested in the area from 2023 to 2033, where the probability is increasing. This graphic depicts the area under the curve that increases for 10 years.




Cascadia seismic risk in next 10 years:
Shown to be about 7x that of a housefire (7x1.2% = 8.4%)

Allstate Insurance and State Farm Insurance companies have suspended underwriting household fire insurance in California, citing high risk threats that we know exist in other west coast states. The seismic risk in the next ten years is 7 times worse than the housefire risk.

8.2%/1.2% = about 7x

**How to get help**
Both the Biden Bipartisan Infrastructure Act and the Biden IRA resources can fund infrastructure investments on time for the Cascadia catastrophe unless we try to sleep through it. Among requirements for states to access the relief is a State Energy Security Plan. Here is the status of these efforts.

| Cascadia State | Action Required | Lead Agency |
|---|---|---|
| Oregon | 2022 SB 1567, Sec 12, State Energy Security Plan<br>2023 HB 3630, Sec 2, State Energy Strategy<br>2023 HB 3426, First responder mental health | Oregon Dept. of Energy<br>ODEQ<br>OHA |
| Washington | WA State 2021 Energy Strategy | Washington Department of Commerce |

**Conclusions**

Aggregated risk from the pending M8/M9 Cascadia Megathrust Event can be shown from revisiting the recent 6,000 years of USGS discovered Holocene seismic intervals. Employing the math taken from the USGS 1990 Circular, the Cascadia risk is shown to range from 63% to 67% in the next 50 years. USGS has not published any 30-year percentages for the Northwest as done for San Francisco.

Computed another way, this 10-year Oregon risk is 7x worse than nation's housefire exposure, recently found uninsurable in CA. Unlike San Francisco post-Loma Prieta investment of $20B to shore up civic infrastructure, such investment in Washington State is still pending, apparently with no federal funds awarded. Same for Oregon.

Without due diligence in Washington State, in a post-Cascadia megathrust scenario, any diligent Oregon seismic infrastructure investment in seismic-tolerant commodity fuel infrastructure would just await intolerable delays to then rebuild Washington State refineries, pipelines, bridges, overpasses, underpasses, interchanges, rail lines with **limited fuel for construction equipment** trucked like a wartime WWII (Patton) Red Ball express to Pasco from the east. Economically, the WA/OR paralysis is an inflation multiplier, because the excessive cost is … literally inevitable and catastrophic.

Is it possible for politicians to notice this infrastructure spending is inescapable, and that continued negligence just drives the ultimate and unaffordable totals? **Does math offered here even help?**

Is it possible that BPA Transmission Planning already initiates an intelligent response to the tragic gap in transport fuel resilience against the inescapable Cascadia Megathrust hazard? The recent Transportation Electrification Strategy - Washington State Department of Commerce could offer relief from neglected carbon fuel infrastructure if executed near term. Substantial electrified transportation is possible by 2035. Since mass repair of electricity infrastructure is logistically far easier than rebuilding carbon fuel infrastructure, Washington already has sound planning for Cascadia risk tolerance. Oregon seems to be at much higher risk, from buying into a 50-year USGS lookahead instead of standard 30-year modeling, underestimated risk math, and reliance on overdue Washington infrastructure public safety investment. Regrettably there is no math to the effect this seismic catastrophe could not happen tomorrow.

Continuing the seatbelt analogy, its not just about airplanes. Would a licensed pilot leave the gate knowing there are no seatbelts on the plane? Very doubtful. Would you buy a car with no seatbelts? They are required for a reason. Considering Cascadia M8/M9 null investments in precautionary infrastructure, unless we missed something, there are no seatbelt equivalents. Worse than that, we never voted to get rid of them, leaving government holding the bag for predictable, inescapable but avoidable grief.

Please see Attachments.

ATTACHMENT A

**Why the Oregon Economy Depends on Washington's March Point Infrastructure - Totally Exposed to Massive Tsunami Inundation**

Petroleum pipeline infrastructure is a witness to industry investment in robust energy distribution with redundant delivery paths. Not so, with the single 60-year old Olympic Pipeline, vulnerable to innumerable single-point failures.

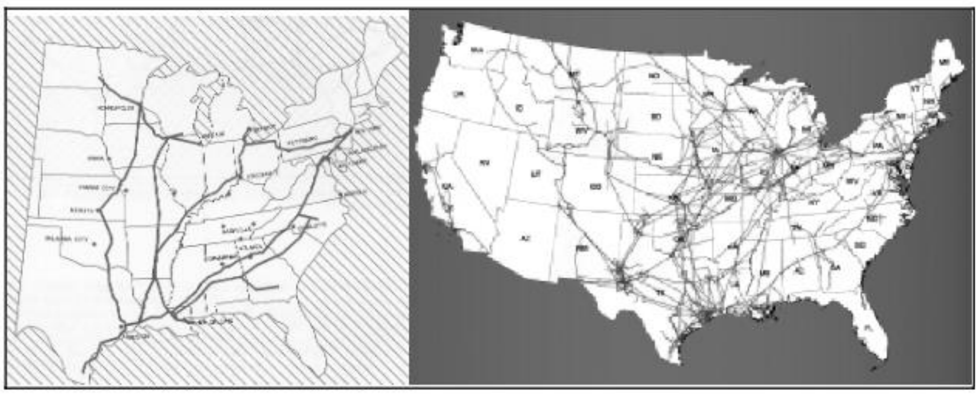
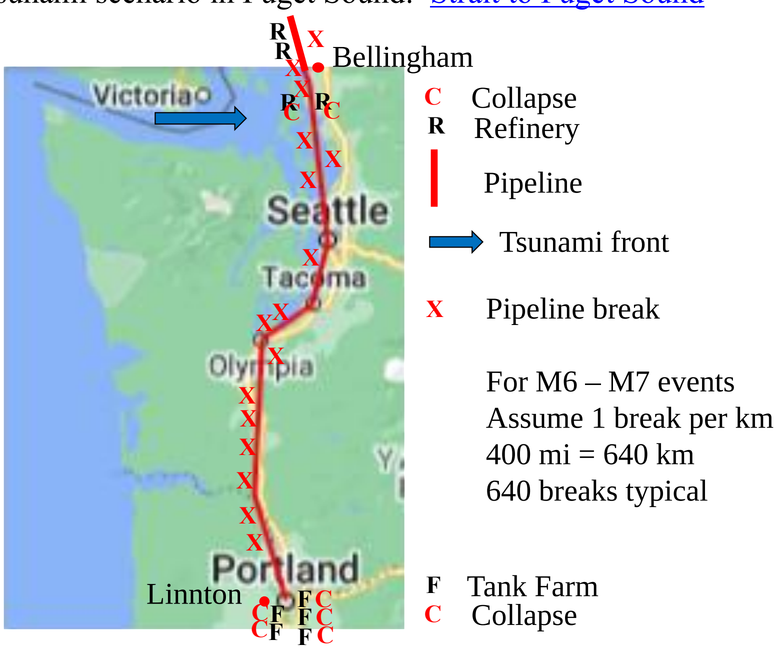


**Figure 4.** Major Petroleum and Crude Products (2002) Pipelines (after AAES and NEPDG Reports)

[Vulnerability of Energy Distribution Systems to an Earthquake in the Central and Eastern United States]

The tsunami scenario in Puget Sound: [Strait to Puget Sound]




"Tanks in the CEI hub [600] are unlikely to be anchored and would need to be retrofitted."

[Liquid Storage Tanks at the Critical Energy Infrastructure (CEI) Hub]

For a high-resolution depiction of the Olympic Pipeline, try to follow the disappearing yellow dotted line symbology here. https://pubs.usgs.gov/sim/3027/sim3027_front.pdf

ATTACHMENT B

**Shabby Portland Carbon Fuel Infrastructure List Disclosed in 2012 With None Corrected Since.**
Earthquake Risk Study for Oregon's Critical Energy Infrastructure Hub, 2012
Deficiencies cited, assumed to be neglected:

Photos P9
Fig 28 on p58
Photos pp 76, 77, 78, 79, 80, 89, 97, 107

An audit of the findings of this report, if conducted, is not known to have been published.

ATTACHMENT C

**Risk of a Housefire in Next 10 Years**

Probability of housefire = 0.12% /yr
Equivalent to 1 in 850 homes
"Expert advice"

P (No housefire) = (1 – 0.12%)
= 1 - 0.0012 = 0.9988/yr

After 2 years, $P_2$ = 0.9988 x 0.9988
P2 = $(0.9988)^2$ = 0.9976 = 99.76%

After 10 years, $P_{10} = (0.9988)^{10}$
$P_{10}$ = 0.9881 = 98.81%

P (Housefire) = (1 – 98.81%)
= 1 – 0.9881 = 0.0119
= 1.19% in 10 years
Call it 1.2% in 10 years