GEOTECHNICAL RISK: WHAT IS ACCEPTABLE?

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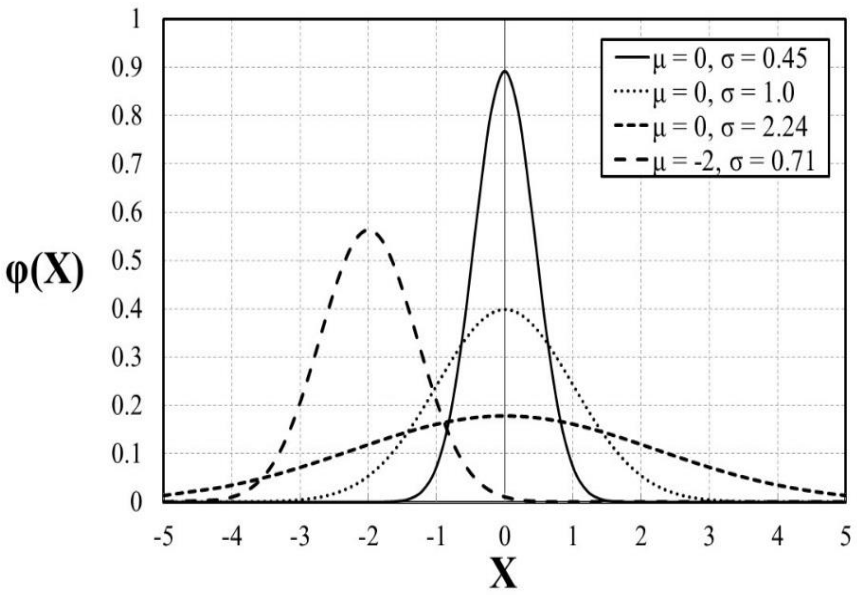
CAUSE OF DEATH IN USA

2.5M people die every year in the USA

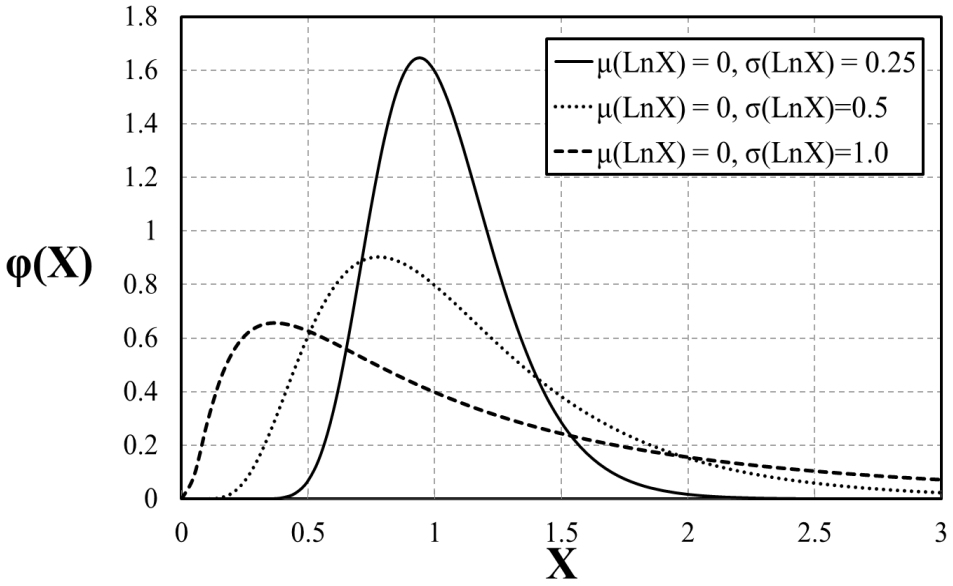
Activity	Probability of death
Heart disease	0.25
Cancer	0.23
Stroke	0.036
Car	0.012
Suicide	0.009
Fire	0.0009
Airplane	0.0002
Bicycle	0.0002
Lightening	0.00001
Earthquake	0.000009
Flood	0.000007

PROBABILITY DISTRIBUTION OF A VARIABLE

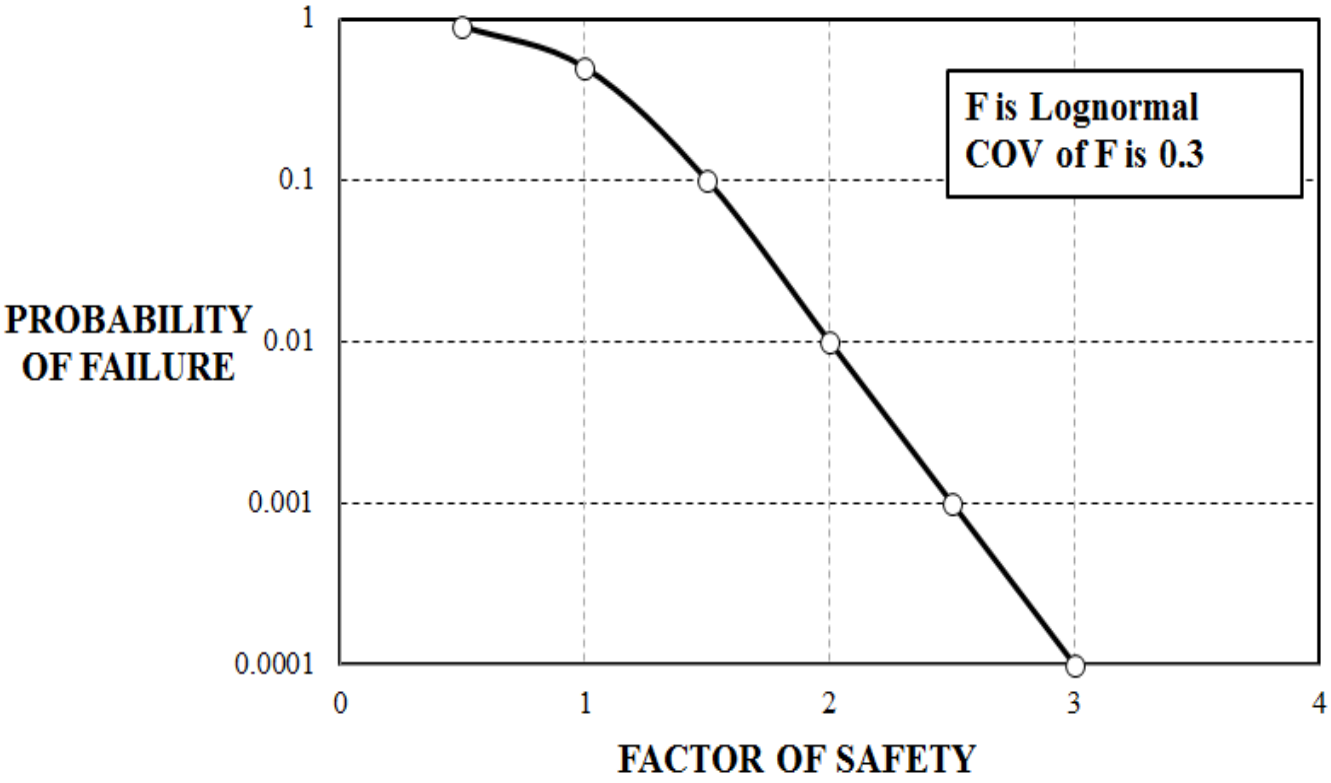
NORMAL DISTRIBUTION



LOGNORMAL DISTRIBUTION (LnX is normal)



PROBABILITY OF FAILURE



DEFINITION OF RISK

$$R = T \times V \times C$$

- R is the risk
- T is the probability that a certain threat will occur
- V is the probability that failure will occur if the threat occurs
- C is the value of consequence

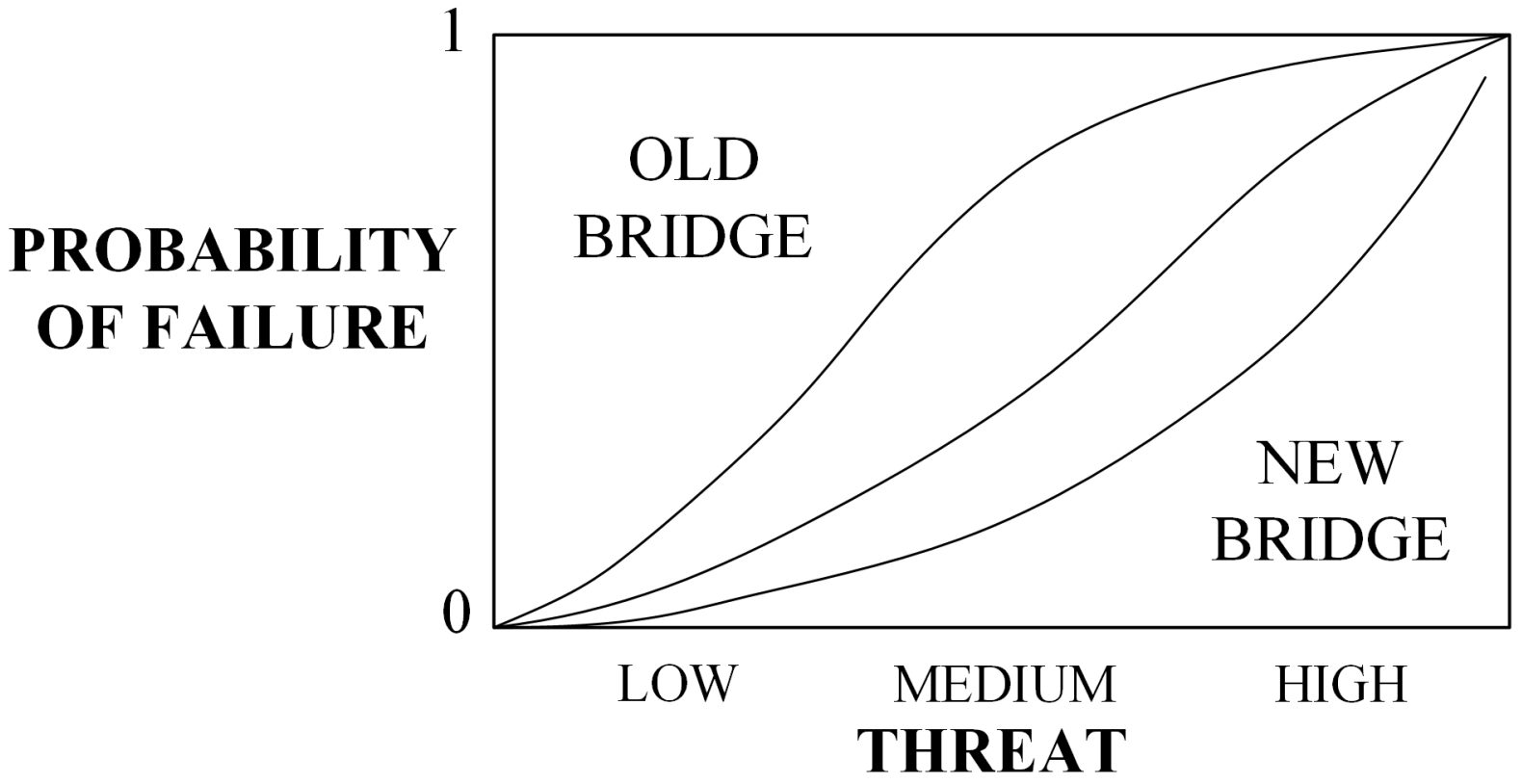
RISK AND VULNERABILITY

R = PoE x PoF/E x C

- R is the risk
- PoE is the probability of occurrence of an event
- PoF/E is the probability of failure if that event occurs
- C is the value of consequence

PoF/E = VULNERABILITY

FRAGILITY CURVES



DEFINITION OF RISK

$$R = PoF \times C$$

R is the risk

PoF is the probability of failure

C is the value of consequence

R = PoF x C

EXAMPLE - KATRINA

PoF =0.01/yr

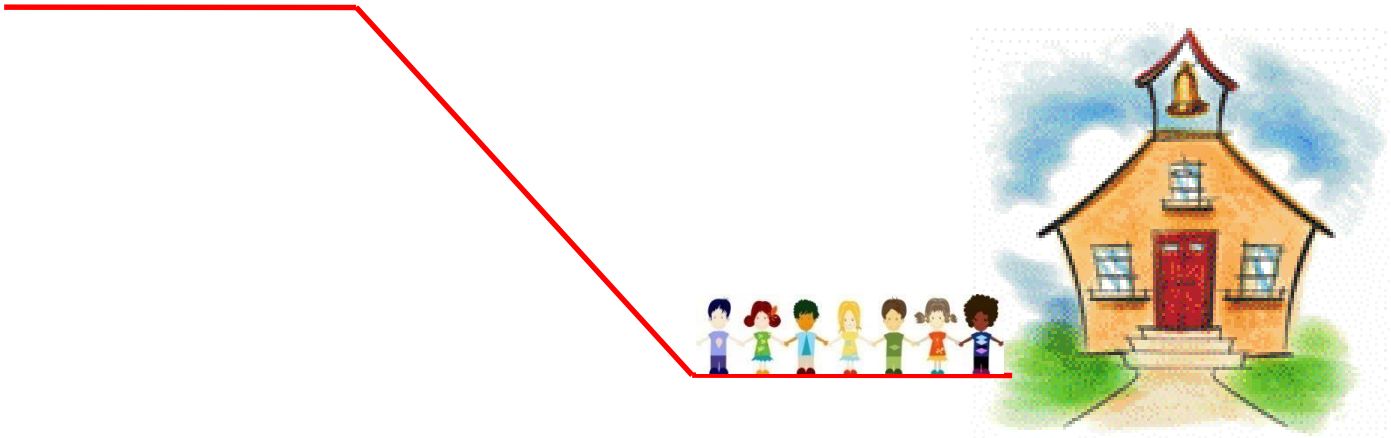
C = 120 billion dollars

C = 1500 fatalities

R = 1.2 billion dollars/yr

R = 15 fatalities/yr

Risk for slope stability



Mean factor of safety, F = 1.5

Standard deviation, S = 0.45

Prob of failure = P(F<1) = 0.088 or 8.8% (large!)

Consequence of failure = 10 fatalities and 5M$

Risk (F=1.5) = 0.088 x 10 = 0.88 fatalities

Risk (F=1.5) = 0.088 x 5 = 0.44 M$

LRFD VS WSD

TRANSITION TO PROBABILISTIC DESIGN

WSD $L < R/F$

LRFD $\gamma L < \phi R$ $\Sigma \gamma_i L_i < \Sigma \phi_i R_i$

$F = \gamma/\phi$

Beware of ~~$\gamma L < R/F$~~

Target Probability of Failure = 0.001

Indiv. components, not entire structure

R = PoF x C

EXAMPLE – BUSINESS DECISION

You sent 5 proposals, each has a probability of success, how do you decide weather you should hire new engineers or not.

	1	2	3	4	5
AMOUNT	50k	250k	1000k	120k	300k
PROBA-BILITY	0.95	0.60	0.25	0.5	0.85
ESTIMATED VALUE	47.5k	150k	250k	60k	255k

Total of proposals values is 1720k

Total of expected values is 762k

DECREASING RISK
THE ROLE OF STATISTICS

TESTING LEADS TO SOIL DATA

THERE IS SCATTER IN THE SOIL DATA

OBTAINING MEAN AND STANDARD DEVIATION OF OUR PARAMETERS MAKES PROBABILITY OF FAILURE CALCULATION MUCH EASIER

THE PROBLEM IS THAT WE RARELY HAVE ENOUGH BORINGS

DECREASING RISK
THE ROLE OF REDUNDANCY

Levees in New Orleans: two solutions costing the same amount

1. **Improve levees significantly**
2. **Fix levees and build a second defense system**

Sol1 decreases PoF by 50%

Sol2 decreases PoF by 99.9% because

PoF(a and b) = PoF(a) x PoF(b) (NOT CORRELATED)

POINTE DU HOC, FRANCE

D-DAY SITE, 6 JUNE 1944

DECREASING RISK
Personal behavior

1. Be curious, inquisitive, and take the time to discover
2. “Cross the street” to find out how people do it in other disciplines
3. Raising the bar, pursuing excellence is not a goal, it is a discipline, a way of life, a mind set.

DECREASING RISK

4 important qualities

1. Smart
2. Nice
3. Hard working
4. Character

One person in this room would score the highest on this scale and one would score the lowest. Do we want to decrease the highest risk, do we want to decrease all risks.

DECREASING RISK

The role of education

1. Professors should have practice experience. Hire professors who have worked for a minimum of 10 years.
2. Professors should know how to teach. Hire professors who have been trained to teach, who know the best communication and education techniques.
3. Dedicate class time to innovation and discuss how practice can be improved while remaining profitable

DECREASING RISK

The responsibility of the practitioner

1. Practitioners should take the time to visit universities and research centers to learn about the latest development
2. Practitioners should attend conferences for the same reason but conferences should be shorter to minimize the interruption
3. Practitioners should have a think tank dedicated to raising the bar (ASFE – GBA - NISSAN)

DECREASING RISK

Practitioner-academician partnership

1. We need to improve that relationship if we want to improve the image of our profession (e.g.: foundation design on shrink swell soils)
2. Most successful geotechnical engineers had one foot in academia and one foot in practice (Kerisel, Schmertmann, Poulos, Jamiolkowski).

DECREASING RISK

Soil testing – how much is enough?

1. Consider a 20x20x40m^3 of heterogeneous soil with a coefficient of variation of 0.3. What percentage of that cube should you test to be able to predict the behavior of the cube within + or – 20% with a 98% level of confidence.
2. Is the answer 10%, 1%, 0.1%, 0.01%?

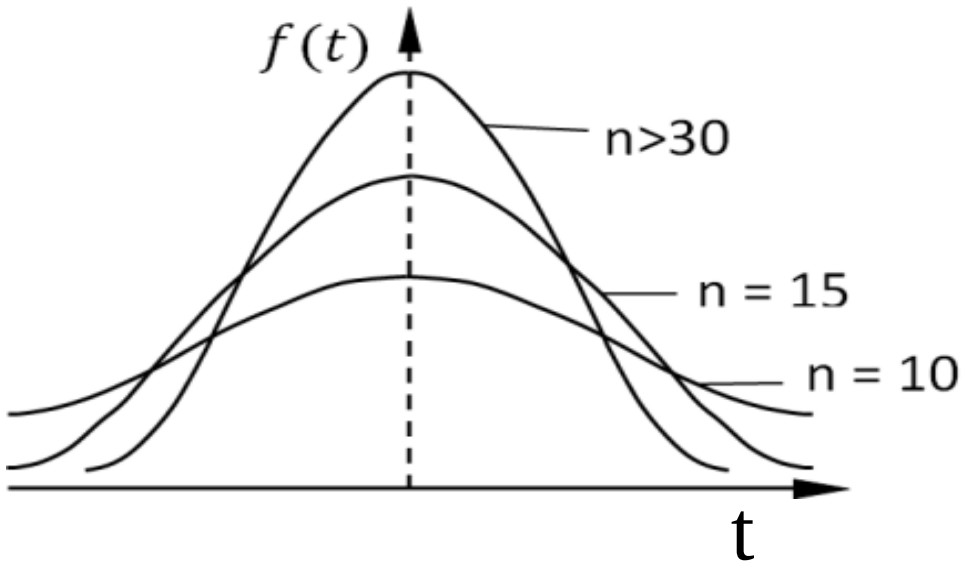
SITE INVESTIGATION MATH

1. Group (E_1, E_2, E_3, …, E_n) of the population.
2. Group mean μ_g and standard deviation σ_g
3. Create many such groups each: μ_g , σ_g
4. Distribution of μ_g has $\mu_{\mu g}=\mu_p$ and $\sigma_{\mu g}=\sigma_p/n^{0.5}$
5. Form the SNV

$$t = \frac{\mu_g - \mu_p}{\sigma_g / \sqrt{n}}$$

The student

t distribution



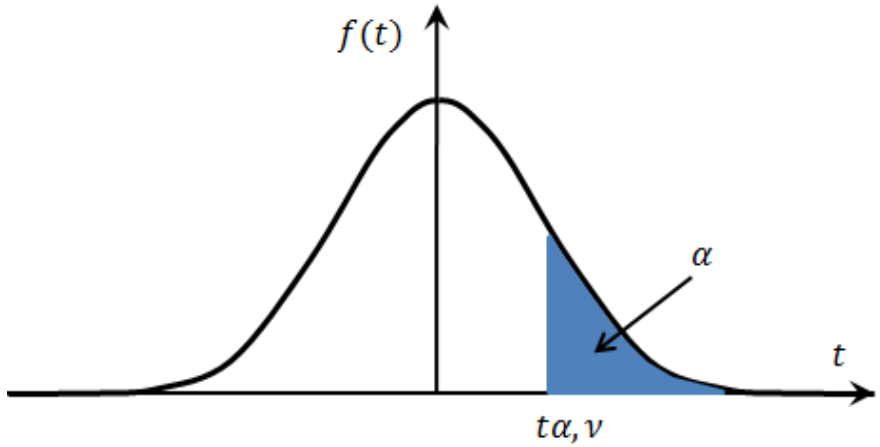
SITE INVESTIGATION MATH

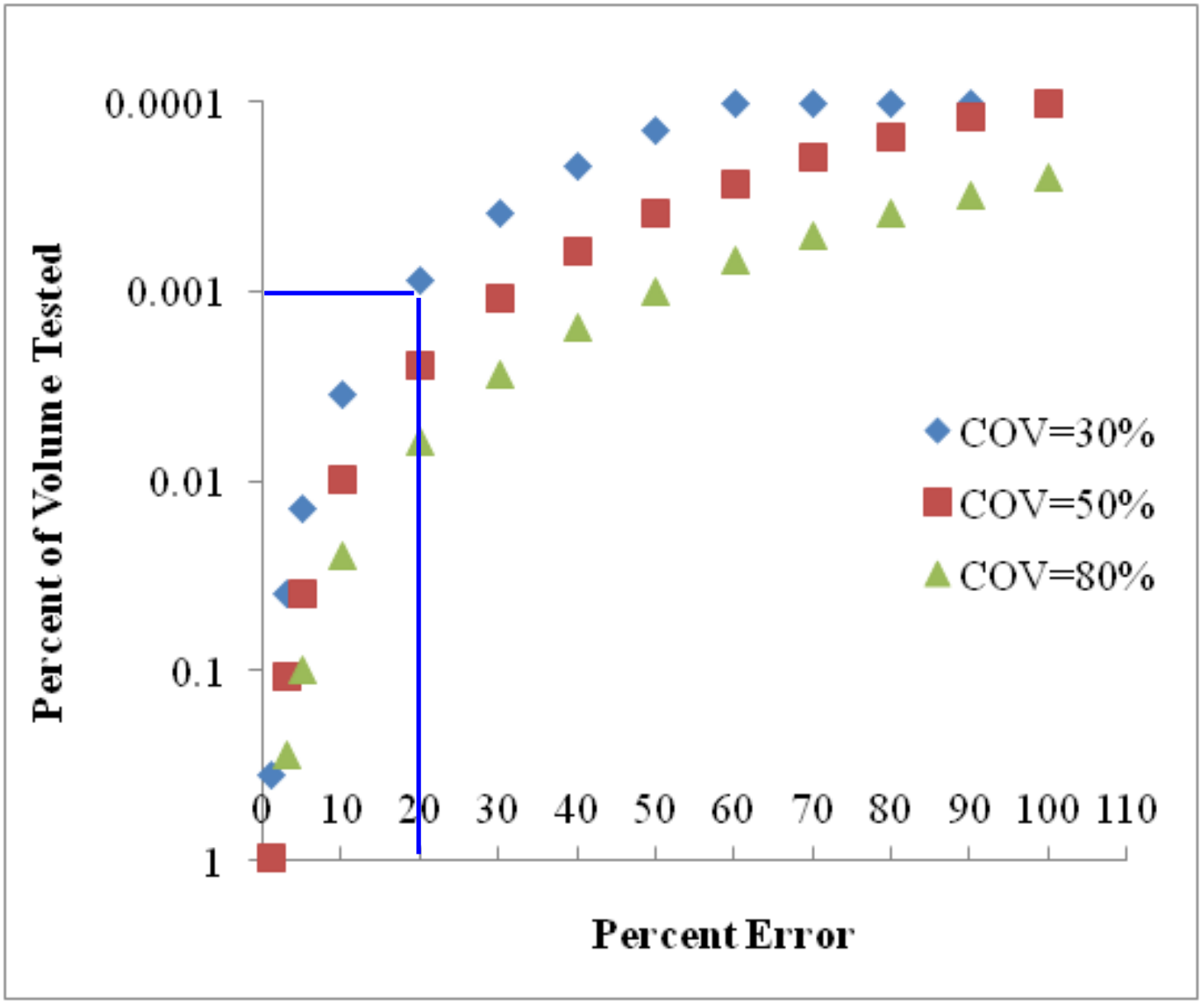
$$P\left(\mu_g(1-\Delta) < \mu_p < \mu_g(1+\Delta)\right) = P_{\text{target}}$$

$$P\left(\left(\mu_g\left(1-t_{\frac{\alpha}{2},n-1}\frac{\sigma_g}{\mu_g\sqrt{n}}\right)\right) < \mu_p < \left(\mu_g\left(1+t_{\frac{\alpha}{2},n-1}\frac{\sigma_g}{\mu_g\sqrt{n}}\right)\right)\right) = 1-\alpha$$

$$\Delta = t_{\frac{\alpha}{2},n-1}\frac{\sigma_g}{\mu_g\sqrt{n}}$$

$$\mathbf{n = \left(\frac{\delta}{\Delta}\right)^2 \left(t_{\frac{\alpha}{2},n-1}\right)^2}$$





For 98% probability, test 0.001% of the volume

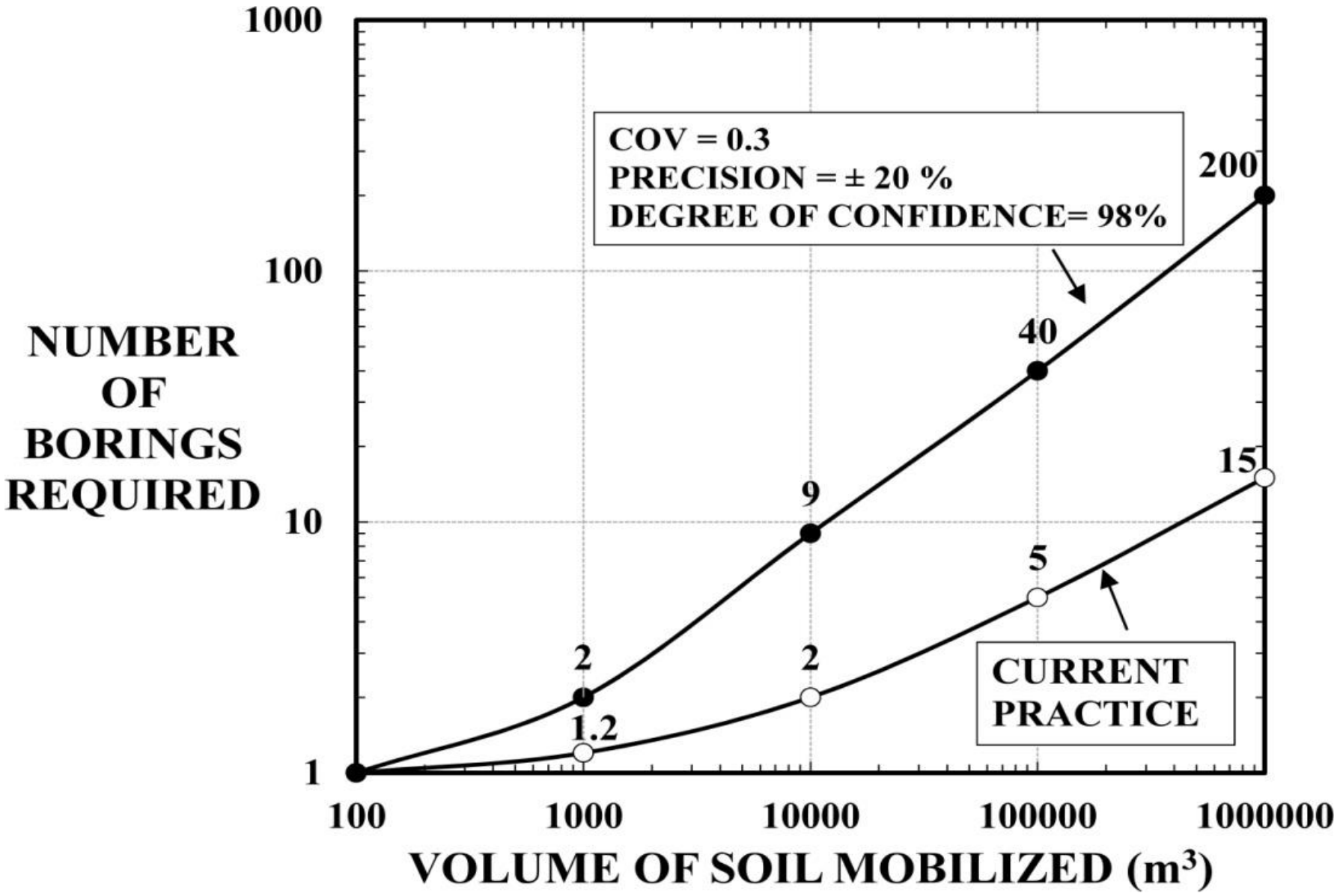
Soil volume: 20x20x40m = 16000 m^3

Required testing volume:
10^{-5} x 16000 m^3 = 0.16 m^3 = 160,000 cm^3

1 triaxial test = 15 x π $7.5^2/4$ = 662 cm^3

Number of triaxial tests required
160,000 / 662 = **240 triaxial tests**

SITE INVESTIGATION RESULTS



DECREASING RISK
EDUCATING THE CLIENT

1. Finding a way to do this can have a significant impact on our practice
2. It needs to be done efficiently
3. Example of the number of borings and factor of safety vs. probability of failure
4. Quality vs. competition
5. Innovation

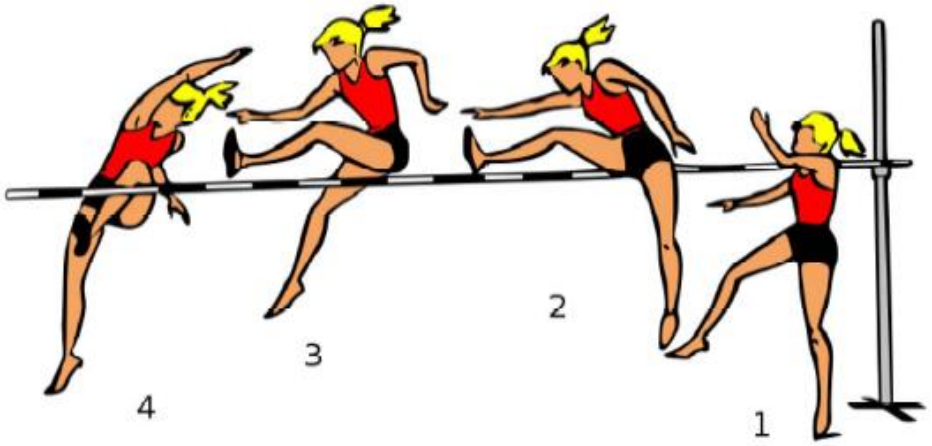
DECREASING RISK

DO INNOVATIONS INCREASE RISK?

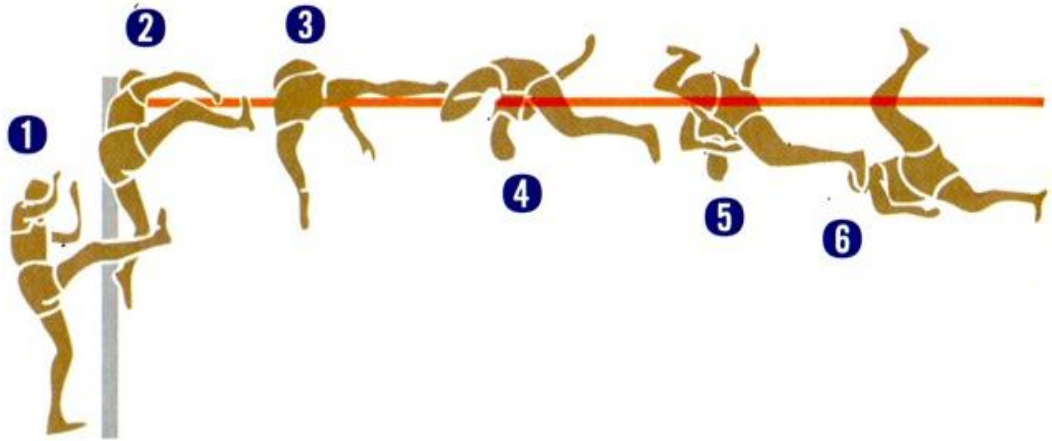
1. They tend to increase the probability of failure PoF because they are new and relatively unproven.
2. The issue is to decide if the risk is worth it
3. Remember

   Risk = PoF x Value of the Consequence.

4. Innovations can decrease the risk if the decision includes such an evaluation.



SCISSORS (1.97m)



STRADDLE (2.33m)

FOSBURY FLOP (2.45m)

http://www.youtube.com/watch?v=Id4W6VA0uLc

REINFORCED EARTH I.D.E.A.

- **I**nnovate (soil reinforcement)
- **D**riven (Henri Vidal was unwavering)
- **E**xecute (Started RECO, convinced the DOTs in France)
- **A**nalyze (developed design rules)

PILE DRIVING ANALYZER IDEA

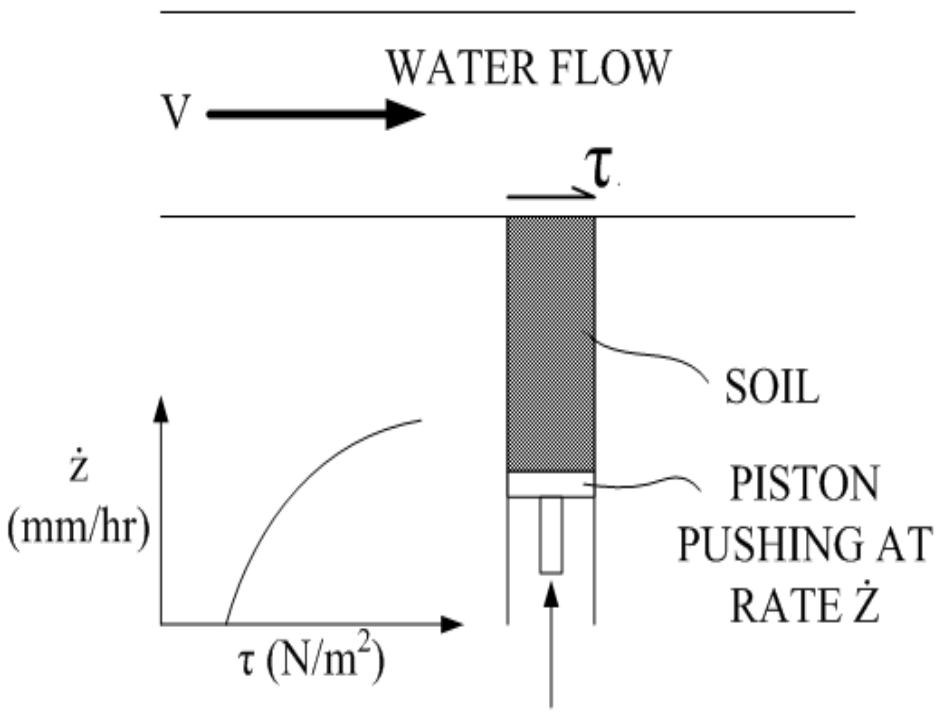
- **I**nnovate (very useful measurements)
- **D**riven (George Goble was relentless in spite of Peck's comment)
- **E**xecute (creation of Goble Rausche Likins)
- **A**nalyze (development of WEAP)

The Pressuremeter I.D.E.A.

- **I**nnovate (in situ stress strain curve)
- **D**riven (Louis Menard was determined and convinced Ponts et Chaussees in France)
- **E**xecute (created Technique Louis Menard)
- **A**nalyze (development of design rules)

The Erosion Function Apparatus

I.D.E.A.



The Erosion Function Apparatus

I.D.E.A.

- **I**nnovate (site specific erosion testing of soils)
- **D**riven (Jean-Louis Briaud had to convince many to accept soil testing in a world dominated by hydraulic engineers)
- **E**xecute (patented the device, provided the service)
- **A**nalyze (developed scour depth methodology to use the results)

DECREASING RISK

Measuring success

1. Any time you set a goal, you have to ask yourself how you will decide that you have achieved that goal.
2. Sometimes the goal is the measurement. Sometimes the goal is diffuse and hard to measure.
3. Set a measurement system with markers along the way. Divide the final goal into a series of smaller “feel good” steps.

THE ROLE OF COMMUNICATIONS

- COMMUNICATE EARLY AND COMMUNICATE OFTEN
- BEST WAY TO DIFUSE PROBLEM AND BUILD A CUSHION OF GOOD-WILL TO ABSORB POTENTIAL PROBLEMS
- NON EXPENSIVE WAY TO LOWER THE RISK

IF YOU WISH TO DECREASE RISK
TAKE THE TIME TO THINK

- We rarely set time aside to think during our work day: take the time to think.
- If you do not have the time to think, organize a group within your company whose job it is to think
- This think tank should innovate and execute or oversee the innovations (e.g.: Google employees are required to spend 20% time on innovations)

DECREASING RISK

Image of the profession

1. Heart surgeon and geotechnical engineer
2. PRC within ISSMGE
3. Movie on YouTube on “What is Geotech?”
4. Web site
5. Time capsule to be open ion 150 years
6. Award for news media people
7. GeoWorld
8. GeoMap

DECREASING RISK

The 10 rules of success

10. Chose the relentless pursuit of excellence as way of life
9. Be curious. The discovery process is a fountain of youth
8. Work hard but balance your interests (fun, family, sport, art, world news)
7. Make lots of friends. Nurture your public relations
6. Look for solutions and not who is to blame. Leave that to the judge.

DECREASING RISK

The 10 rules of success

5. Be firm in your decisions but always fair and polite
4. Treat others as you wish to be treated, you will lead by example
3. Communication is the best way to solve problems. Convince through logic and data
2. Surround yourself with smart people and role models
1. Go after your dreams with vision and perseverance

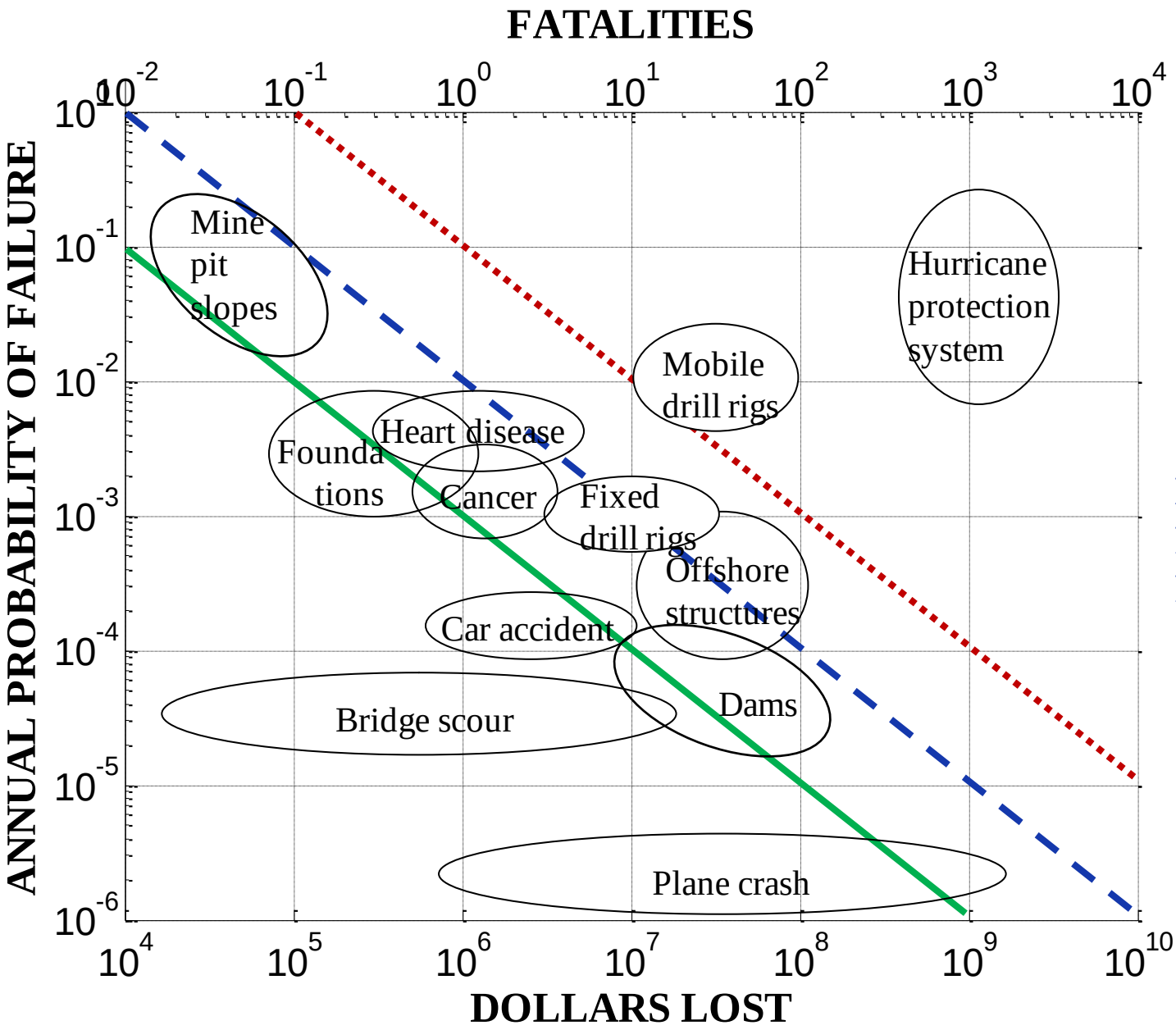
DECREASING RISK

1. Have the courage to change the things that you can change
2. Have the discipline to accept the things that you cannot change
3. And have the wisdom to know the difference

And if all else fails remember that

HAPPINESS IS A CHOICE

ACCEPTABLE RISK



Dotted line
Risk = 0.1 Fat/yr
Risk = 100000 $/yr

Dashed line
Risk = 0.01 Fat/yr
Risk = 10000 $/yr

Solid line
Risk = 0.001 Fat/yr
Risk = 1000 $/yr

ACCEPTABLE RISK

Annual risk level	Fatalities/year in USA	Dollars lost/year in USA
Low	0.001	1000
Medium	0.01	10000
High	0.1	100000