The PIEVC Protocol: Toward Resilient Infrastructure

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You've been asked to spec a culvert for a road in Northern Saskatchewan

- The standard is to design for a 24hr – 25yr return period rainfall event

Now, you investigate "recent" precipitation events

- 3 recent rainfall events that exceeded the 185mm in 24hrs
- Two occurred in less than 4 hours

So, what's the risk? It's a gravel road.

Your next project is sizing a city stormwater system...

Edmonton experienced 2, 1:100yr storms in two weeks

Edmonton, White Mud Drive, 2004

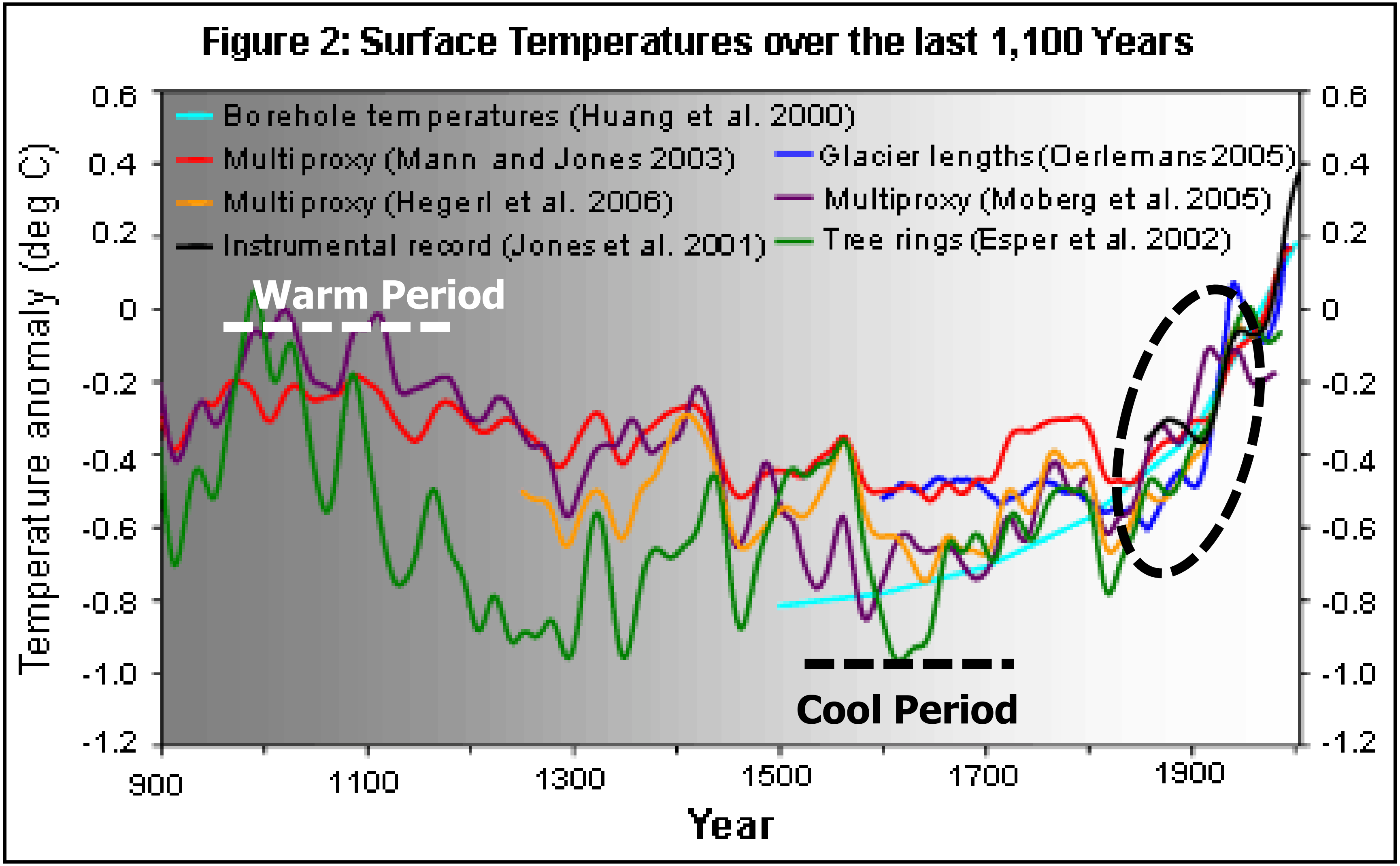
Figure 2: Surface Temperatures over the last 1,100 Years
Borehole temperatures (Huang et al. 2000)
Multiproxy (Mann and Jones 2003)
Multiproxy (Hegerl et al. 2006)
Instrumental record (Jones et al. 2001)
Glacier lengths (Oerlemans 2005)
Multiproxy (Moberg et al. 2005)
Tree rings (Esper et al. 2002)
Warm Period
Cool Period
Temperature anomaly (deg C)
Year
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
900
1100
1300
1500
1700
1900

Regardless of the cause of the change, as engineers and geologists we need to understand that:

Climate change is a significant shift in the variability, average or extremes of climatic conditions for a specific location and over a period of time.

Adapting to a changing climate, Lemay (2006)

Impact?

IBC (2016) reports that payouts for severe weather have doubled every five to 10 years since the 1980's

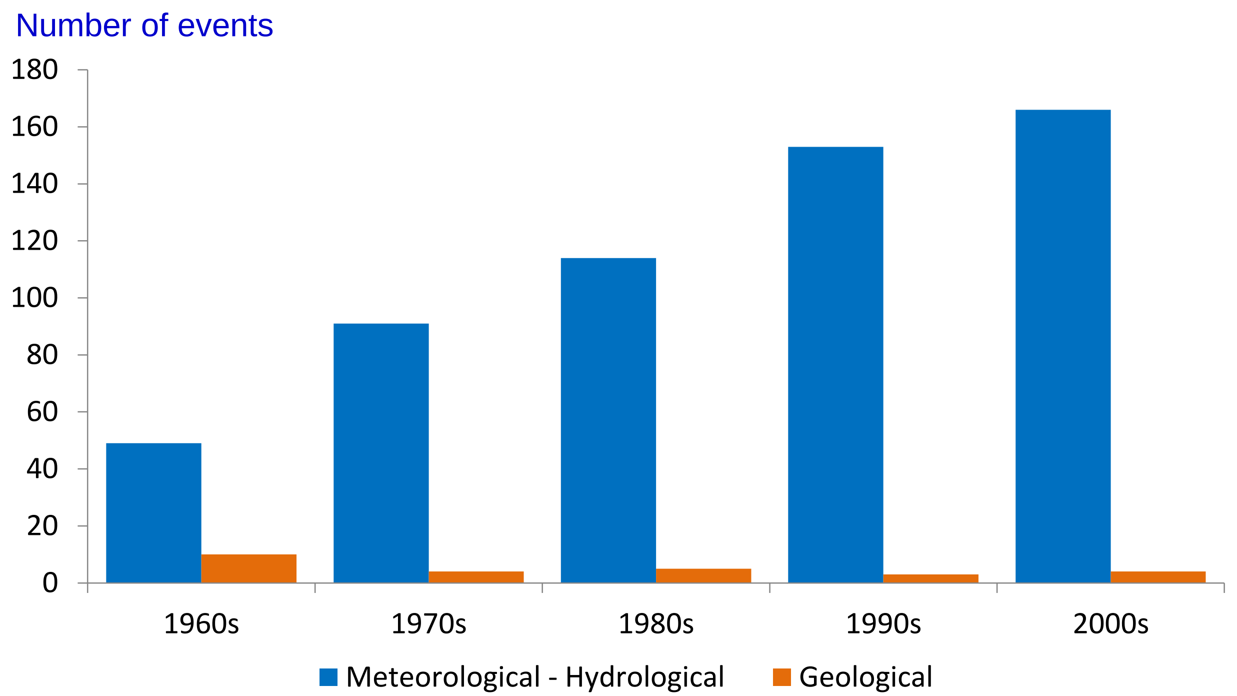

Figure : Trend in natural extreme events in Canada

- March 2007, City of New Orleans v. US Army Corps of Engineers (USACE) - $77 Billion
- October of 2012, six scientists convicted of manslaughter in Italy
- City of Kivalina v. Exxon Mobil
- 2014, Farmers insurance filed nine class actions against nearly 200 municipalities near Chicago, Illinois

- 2010, City of Stratford, $7.7M settlement
- 2012, City of Thunder Bay , $300M suit
- Lead council for Watkins Law, “The recent heavy rains were a predictable event and should have been designed for”.

Principles of Climate Change Adaptation for Engineers (Engineers Canada 2014)

2. Engineers should review design standards used within their professional practice to ensure that these standards reasonably represent the current and anticipated climate that the engineered system will experience over its useful operating life.

Principles of Climate Change Adaptation for Engineers (Engineers Canada 2014)

7. Engineers should ensure that they have reasonably considered of the impact of changing weather and climate conditions over the entire service life of an engineered system.

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Principles of Climate Change Adaptation for Engineers (Engineers Canada 2014)

9. Engineers should ensure that they are aware of the legal liability associated with reliance on historic climatic and weather information within their professional practice.

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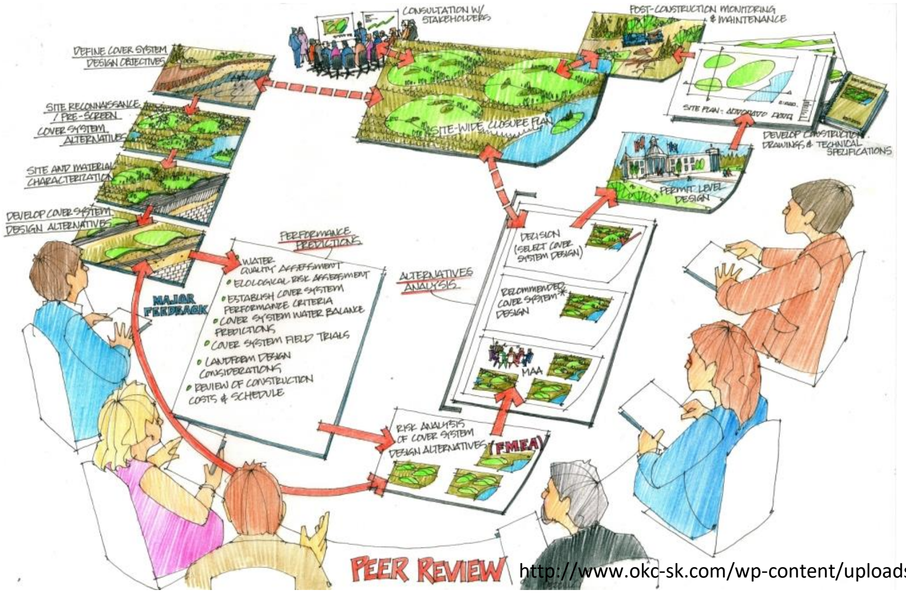
What tools are available to deal with design of infrastructure that must be resilient to climatic stress that we have yet to experience?

How do we fulfill our due diligence?



http://www.okc-sk.com/wp-content/uploads/2013/04/Mine-Closure-Planning-Webpage-Graphic-1.jpg

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The PIEVC Protocol is a tool to allow engineers to assess risk to existing and proposed infrastructure.

"Engineering vulnerability/risk assessment forms the bridge to ensure climate change is considered in engineering design, operations and maintenance of civil infrastructure."

"Identifying the highly vulnerable components of the infrastructure to climate change impacts enables cost-effective engineering/operations solutions to be developed."

Risk Assessment

Climate Change

Adaptation

severity										
	7	catastrophic 0.08	0		14	21	28	35		49
	6	hazardous 0.400	0	6	12	18	24	30	36	42
	5	serious 0.200	0	5	10	15	20	25	30	35
	4	major 0.100	0	4	8	12	16	20	24	28
	3	moderate 0.050	0	3	6	9	12	15		21
	2	minor 0.025	0	2	4	6	8	10		14
	1	measurable 0.0125	0	1	2	3	4	5	6	7
	0	no effect	0	0	0	0	0	0	0	0
			negligible or not applicable	improbable 1:1,000,000	remote 1:100,000	occasional 1:10,000	moderate 1:1,000	probable 1:100	frequent 1:10	continuous 1:1
			0	1	2	3	4	5	6	7
						probability				

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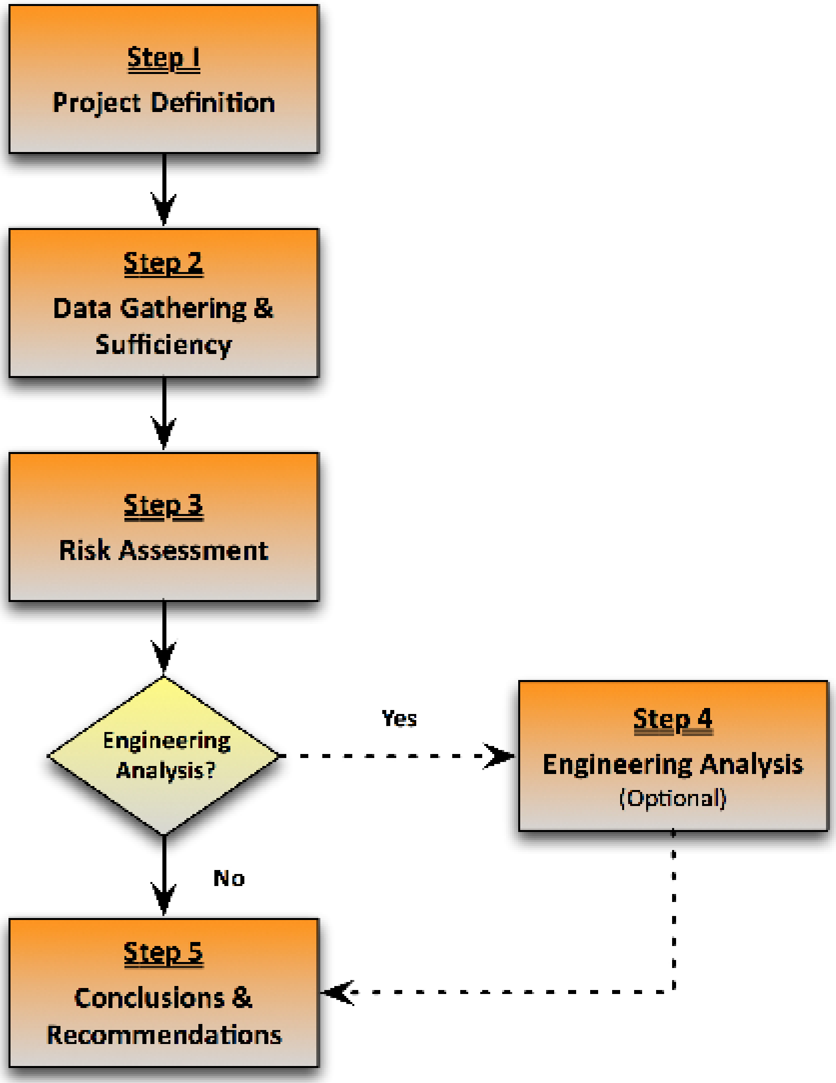
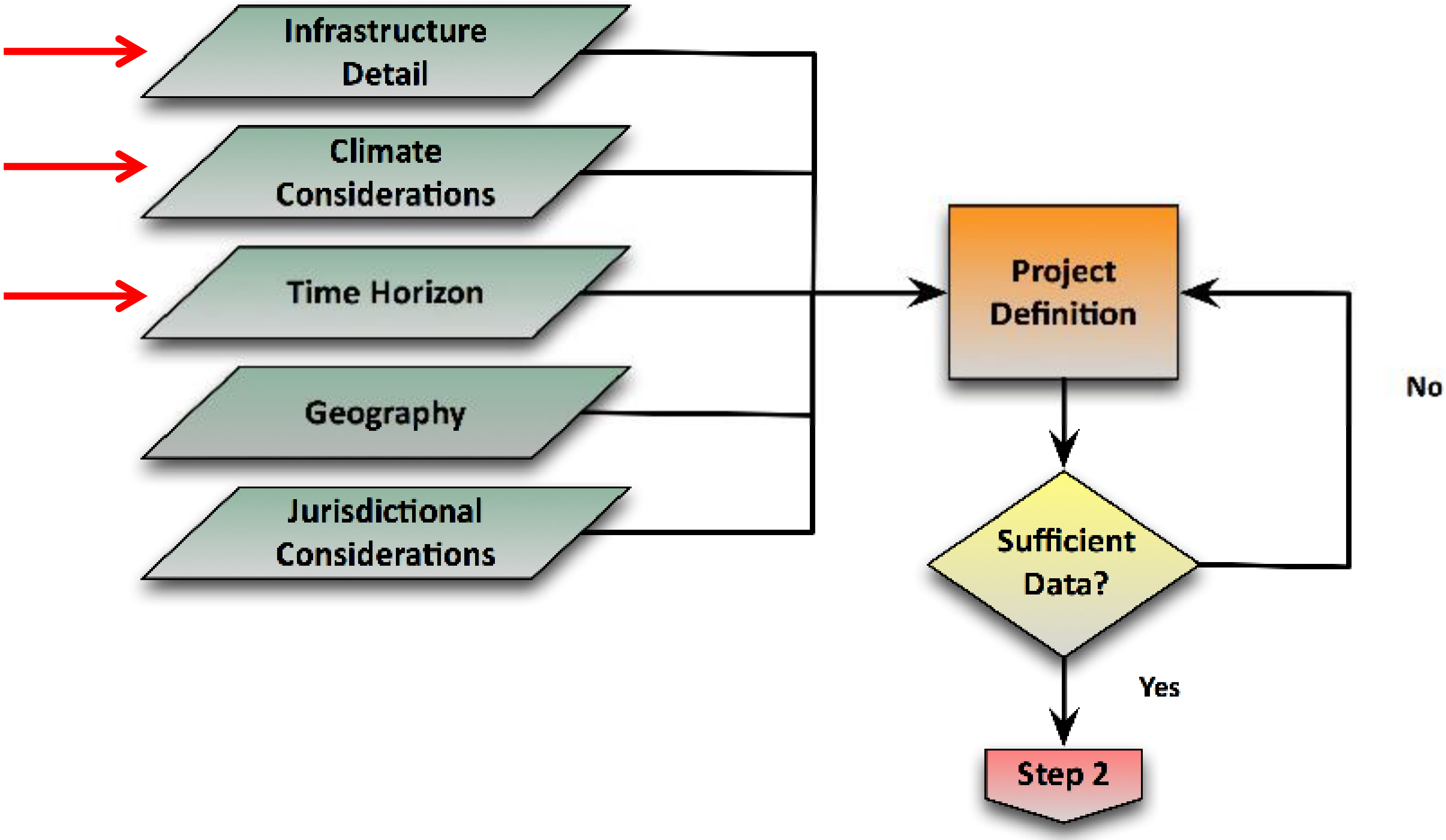
The Protocol is:

"... a structured, formalized and documented process for engineers, planners and decision-makers to recommend measures to address the vulnerabilities and risks to changes in particular climate design parameters and other environmental factors from extreme climatic events. **The assessments help justify design, operations and maintenance recommendations and provide documented results that fulfill due diligence requirements for insurance and liability purposes**."

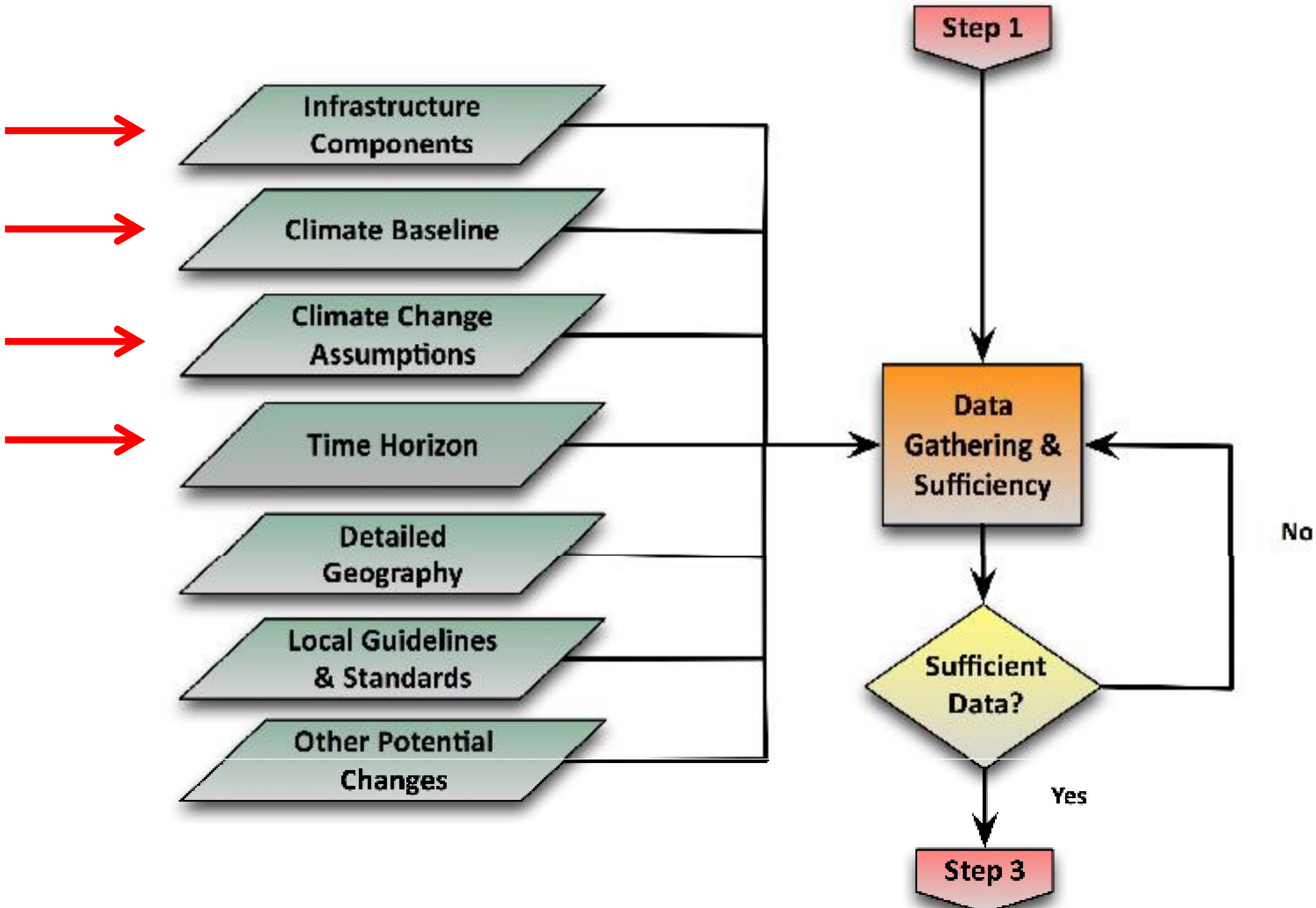
The PIEVC Protocol is a step by step process to assess impacts of climate change on infrastructure



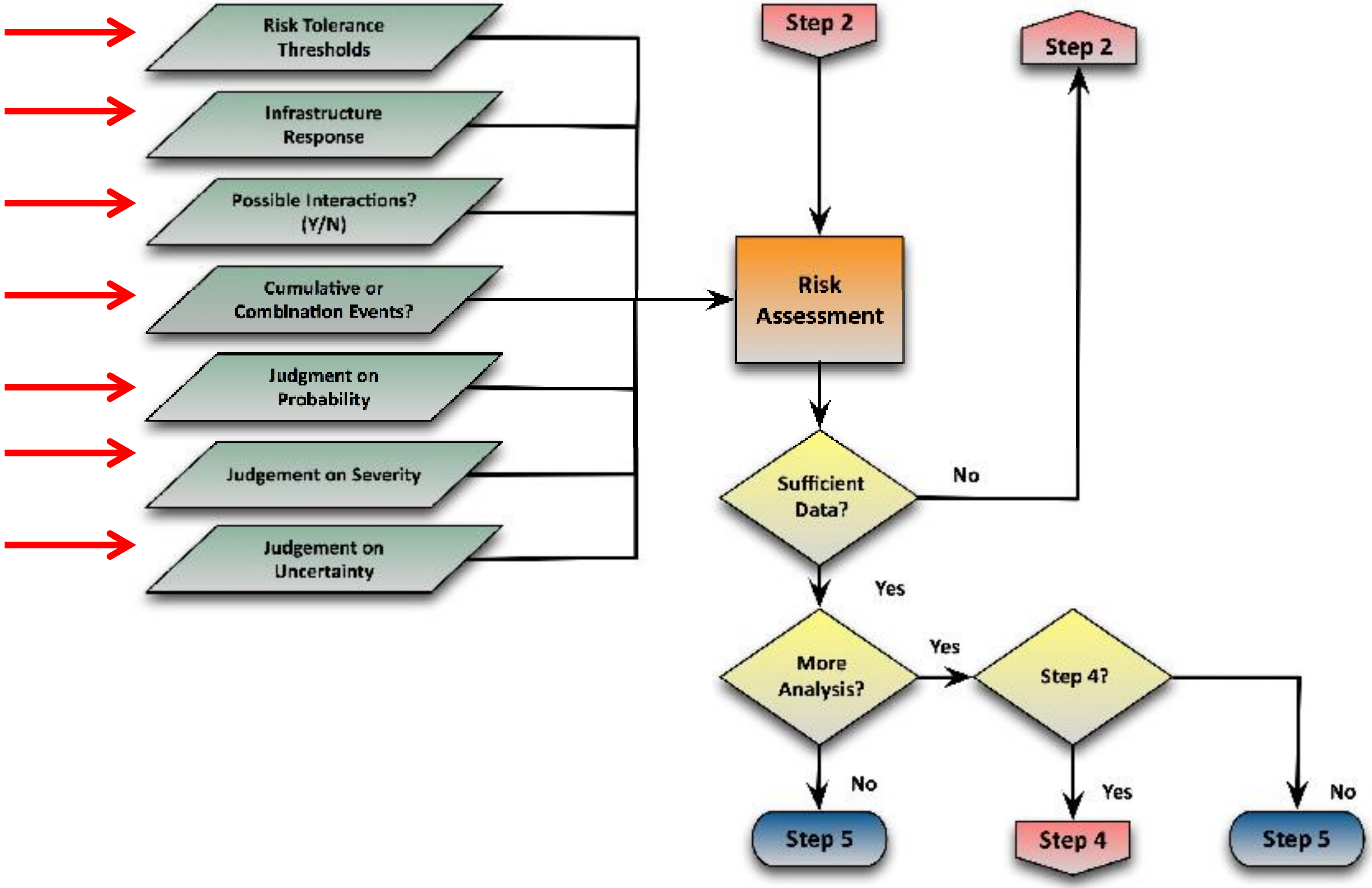
Step 1 – Define Baseline Parameters



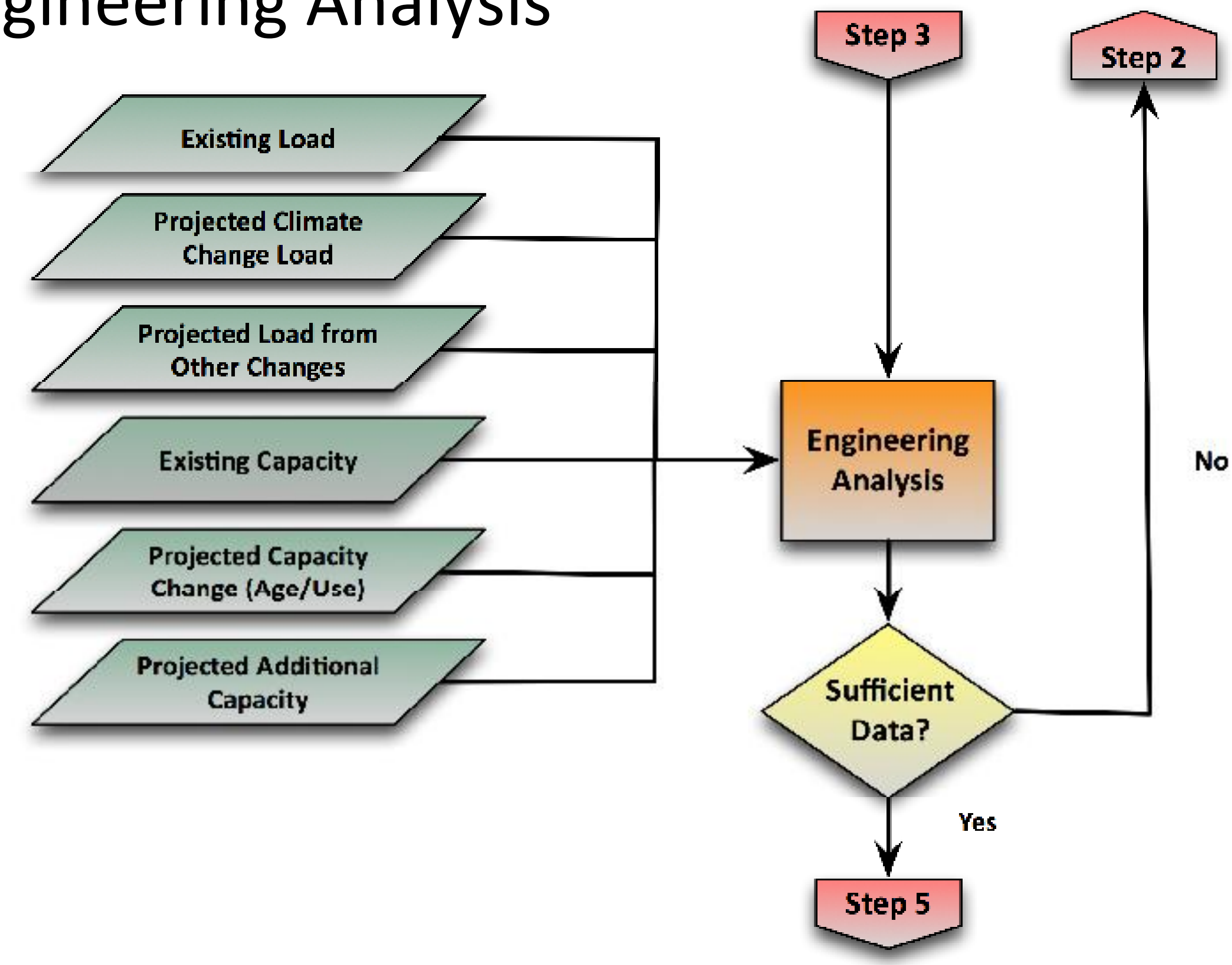
Step 2 – Data Collection



Step 3 – Risk Assessment



Step 4 – Engineering Analysis



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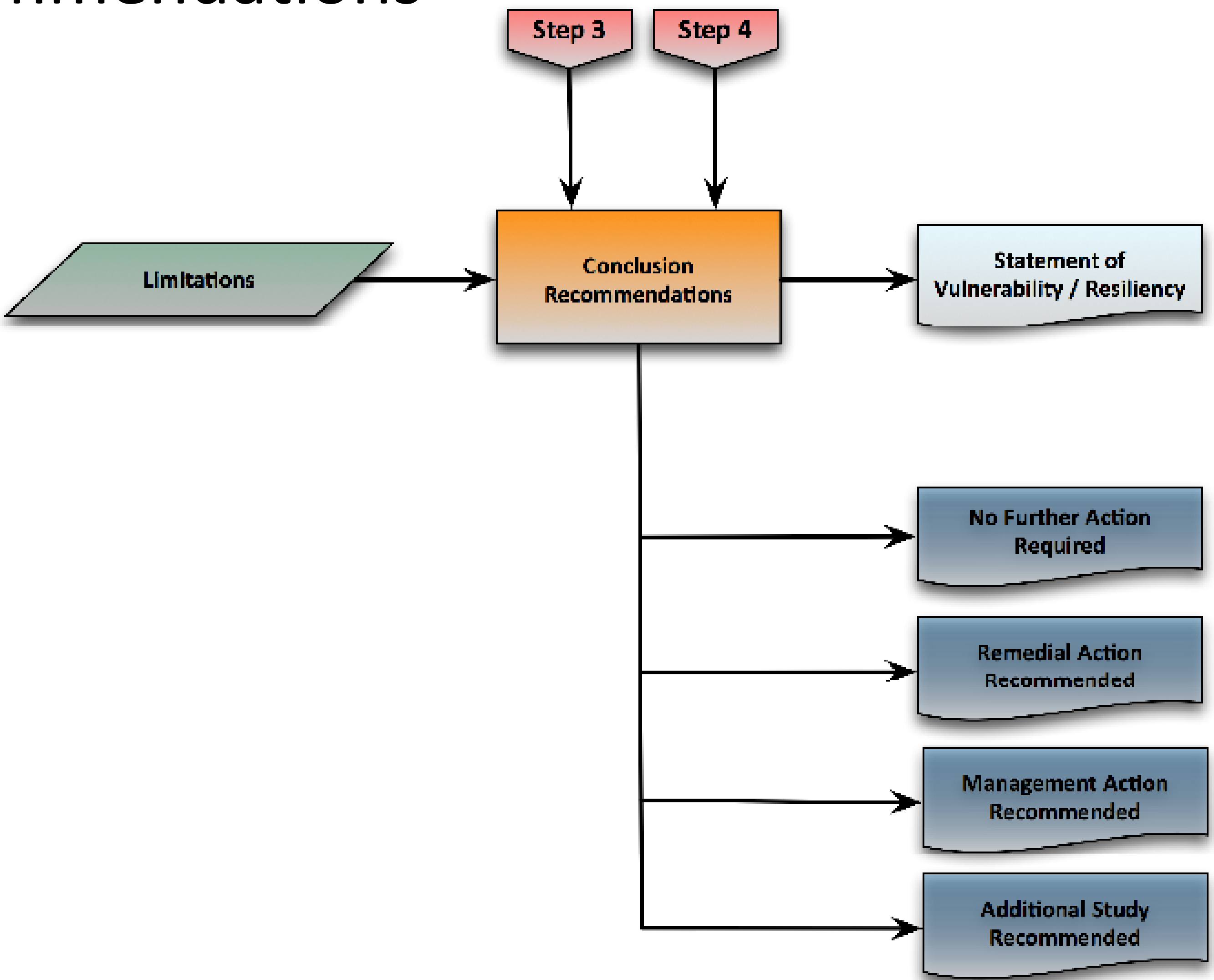
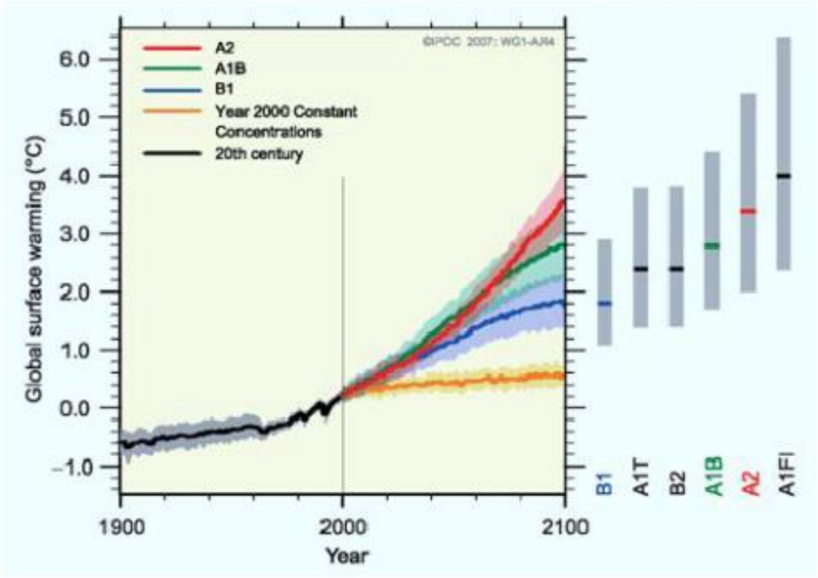
Step 5 – Recommendations



Climate Scientists



– Develop a list of Expected Climate Changes
  - Eg. 2030, 2050 and 2080

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Summary of Expected Changes in Precipitation
(and Precipitation Derived) Parameters by the 2080s

Climate Event		Expected Change by 2080
Precipitation	Total precipitation	Increase: year (11%), winter (31%), spring (22%), summer (1%) and fall (4%)
	Total rain and snow	Increase: rain (12%), snow (3%)
	Very wet days	Increase of 4%
	Frequency of precipitation	Decrease: year (6 days), winter (2 days), spring (1 day) and fall (3 days)
	Frequency of rain	Increase: year (11 days), winter (2 days), spring (5 days) and fall (3 days)
	Frequency of snow	Decrease: year (17 days), winter (5 days), spring (6 days) and fall (6 days)
	Consecutive dry days	Increase: year (2 days)
	Maximum 5-day precipitation total	Increase: year (6mm) or 6%
	Precipitation days >10mm/day	Increase: year (2 days) or 27%
	Simple Daily Intensity Index (SDII)	Increase: year (0.4mm/day) or 7%

Summary of Expected Changes in Other Parameters by the 2080s

Climate Event		Expected Change by 2080
Wind	Mean Wind Speed	-9% to +7%
	North-South Wind Speed	-6% to +5%
	East-West Wind Speed	-10% to +11
	Wind gusts	Frequency of strong gusts increases by 55%
Drought	Palmer drought severity index	Not quantified. Likely droughts become more frequent
Storm Events	Lightning (flash/km^2/year)	Increase
	Freezing rain	Increase in winter frequency of 90%
	Tornados; thunderstorms, hail; fog; rain on snow and ice accretion, blizzards	Not quantified, but frequency is likely to increase

Figure 7: Probability Scale Factors

Scale[5]	Probability* S_C		
	Method A	Method B	Method C
0	negligible or not applicable	<0.1 % <0.1 / 20	negligible or not applicable
1	improbable / highly unlikely	5 % 1 / 20	improbable 1:1 000 000
2	remote	20 % 4 / 20	remote 1:100 000
3	occasional	35 % 7 / 20	occasional 1:10 000
4	moderate / possible	50 % 10 / 20	moderate 1:1 000
5	often	65 % 13 / 20	probable 1:100
6	probable	80 % 16 / 20	frequent 1:10
7	certain / highly probable	>95 % >19 / 20	continuous 1:1

*
a) Choose Method A, Method B or Method C to select the priority.
b) Record in project documentation the Method that was used.
c) Use the same Method for all probability prioritization in the evaluation.

Figure 8: Severity Scale Factors S_R

Scale	Magnitude	Severity of Consequences and Effects
	Method D	Method E
0	no effect	negligible or not applicable
1	measurable 0.0125	very low / unlikely / rare / measurable change
2	minor 0.025	low / seldom / marginal / change in serviceability
3	moderate 0.050	occasional loss of some capability
4	major 0.100	moderate loss of some capacity
5	serious 0.200	likely regular / loss of capacity and loss of some function
6	hazardous 0.400	major / likely / critical / loss of function
7	catastrophic 0.800	extreme/ frequent/ continuous / loss of asset

*
a) Choose Method D or Method E to select the priority.
b) Record in project documentation the Method that was used.
c) Use the same Method for all magnitude prioritization in the evaluation.

$$P_C = S_C \times S_R$$

$P_C < 12$

P_C b/w 12 - 36

$P_C > 36$

Infrastructure Component	Increase in Temperature: Daily Mean				Increase in Number of Frost Free Days				Increase in Temperature Swings: Freeze/Thaw Days				Incr Rai Annua	
	Y/N	P	S	R	Y/N	P	S	R	Y/N	P	S	R	Y/N	P
Infrastructure System														
Physical Infrastructure : Existing Building														
Structural:														
Roofs - coverings	Y	3	3	9	Y	3	1	3	Y	5	5	25	Y	
Doors and windows	Y	5	3	15	Y	2	1	2	Y	2	2	4	Y	
Mechanical:														
Plumbing systems	Y	4	3	12	Y	2	2	4	N				Y	
Building heating	Y	2	2	4	Y	3	2	6	Y	5	5	25	N	
Building ventilation	Y	6	6	36	Y	4	5	20	Y	5	5	25	N	
Air conditioning	Y	7	7	49	Y	3	5	15	Y	5	5	25	N	

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Applying Risk and Vulnerability Assessment to Mining Infrastructure

- The supply of critical inputs
- Employee health and safety
- Obtaining and maintaining a social license

Impacts of Extreme Weather Events and Changing Climate to Mining

1. Disturbance to Mine Infrastructure and Operations:
2. Changing Access to Supply Chains and Distribution Routes:
3. Challenges to Worker Health and Safety Considerations:
4. Challenges to Environmental Management and Mitigation:
5. More Pressure Points with Community Relations:
6. Exploration and Future Growth:

Nelson and Schuchard (2011)

Potential climate change impact areas for the mining and metals sector

1. Inputs
2. Supply Chains
3. Markets
4. Exploration
5. Construction
6. Operation
7. Closure
8. Post-closure

ICMM (2013)

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PIEVC provides a tool to identify highly vulnerable components in the identified areas of (ICMM, 2013);

- risk management policies and procedures,
- emergency response planning,
- asset management,
- capital and long-term planning,
- environmental health and safety,
- biodiversity management,
- etc.

http://wpmedia.business.financialpost.com/2013/11/canadian-natural-resources.jpg?quality=60&strip=all&w=620

Engineers Canada

Infrastructure Resilience Professional (IRP) Certification

Knowledge of the five competency areas required:

- Infrastructure asset management
- Risk management
- Infrastructure vulnerability and risk assessment
- Climate science
- Climate change law in Canada

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Questions or Comments

http://www.syncrudesustainability.com/2012/assets/Uploads/_resampled/resizedimage600400-Tailings-TestPonds-full.png