Contaminated Sites Climate Risk Tool:

Incorporating Climate Change Resilience in Conceptual Site Models and Remediation Design

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Agenda

- Background
- Tool Description
- Case Studies
- Results Validation
- Conclusions and Next Steps

WHY A CLIMATE CHANGE ASSESSMENT TOOL FOR CONTAMINATED SITES?

Potential Climate Impact

- Often sensitive site locations
- **Some contaminants' physicochemical properties** can be very sensitive to a changing climate
- **Contaminant transport pathways** can be highly affected by climate parameters
- Climate change stressors on receptors / habitats
- Risk management measures (RMMs) with long-term monitoring
- Remediation with long timespans

Tool Objectives

- More robust and resilient conceptual site models (CSMs), RMMs and remediation
- Minimize reopening sites or significantly changing management strategy
- Responsible decision making
- Strategic planning and risk management

TOOL DEVELOPMENT

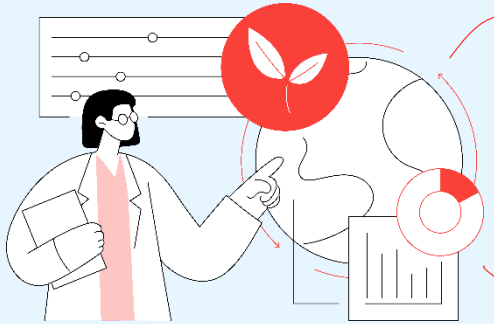
STEP 1

Understanding the Site

- Site-specific assessment of climate hazards
- Climate projections

STEP 2

Risk Scoring



- Climate impacts on CSM
- Climate impacts on remediation

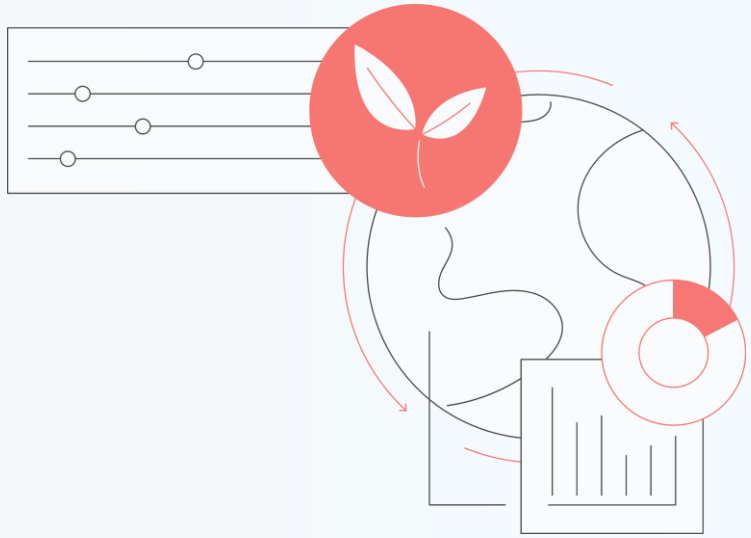
STEP 3

Risk Ranking

- Comparison of sites based on climate risks
- Comparison of remediation options based on climate risks

CONTAMINATED SITE CLIMATE HAZARDS

- TEMPERATURE
- WILDFIRES
- CHANGE IN PERMAFROST
- FLORA SHIFT
- FAUNA SHIFT
- HIGH WINDS
- SNOW COVER
- DROUGHT
- PRECIPITATION / STORM EVENTS
- SEA LEVEL RISE / ARCTIC SEA LEVEL CHANGE
- EROSION



EXAMPLES OF CLIMATE HAZARDS THAT ARE COMMONLY ASSESSED

Use of WSP Climate Change Projection Software ‘TANGO’

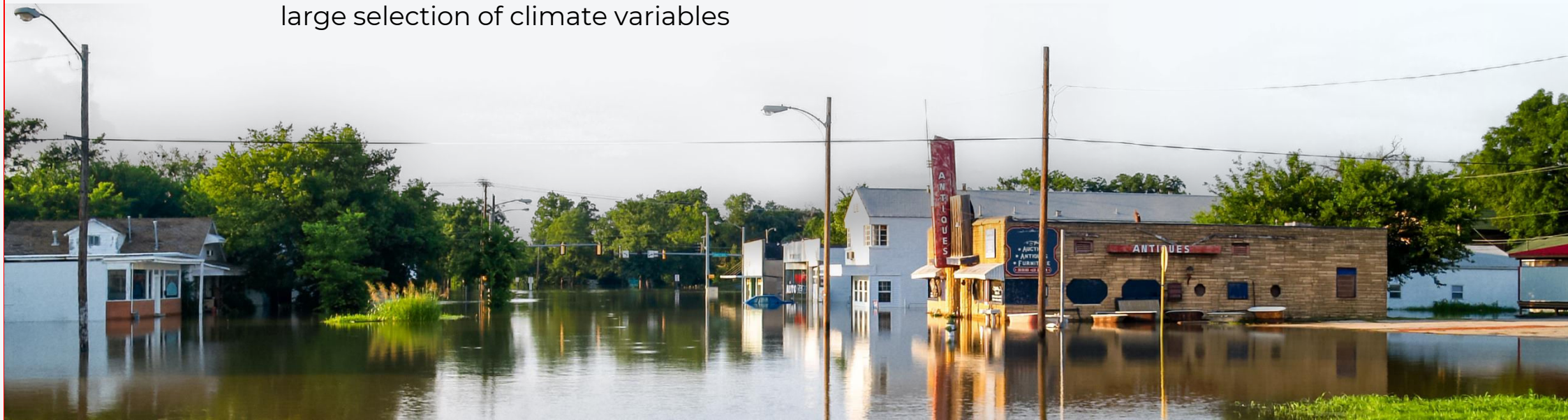
Tango can provide:

Any desired timeframe
(e.g., mid-century, end-of-century)

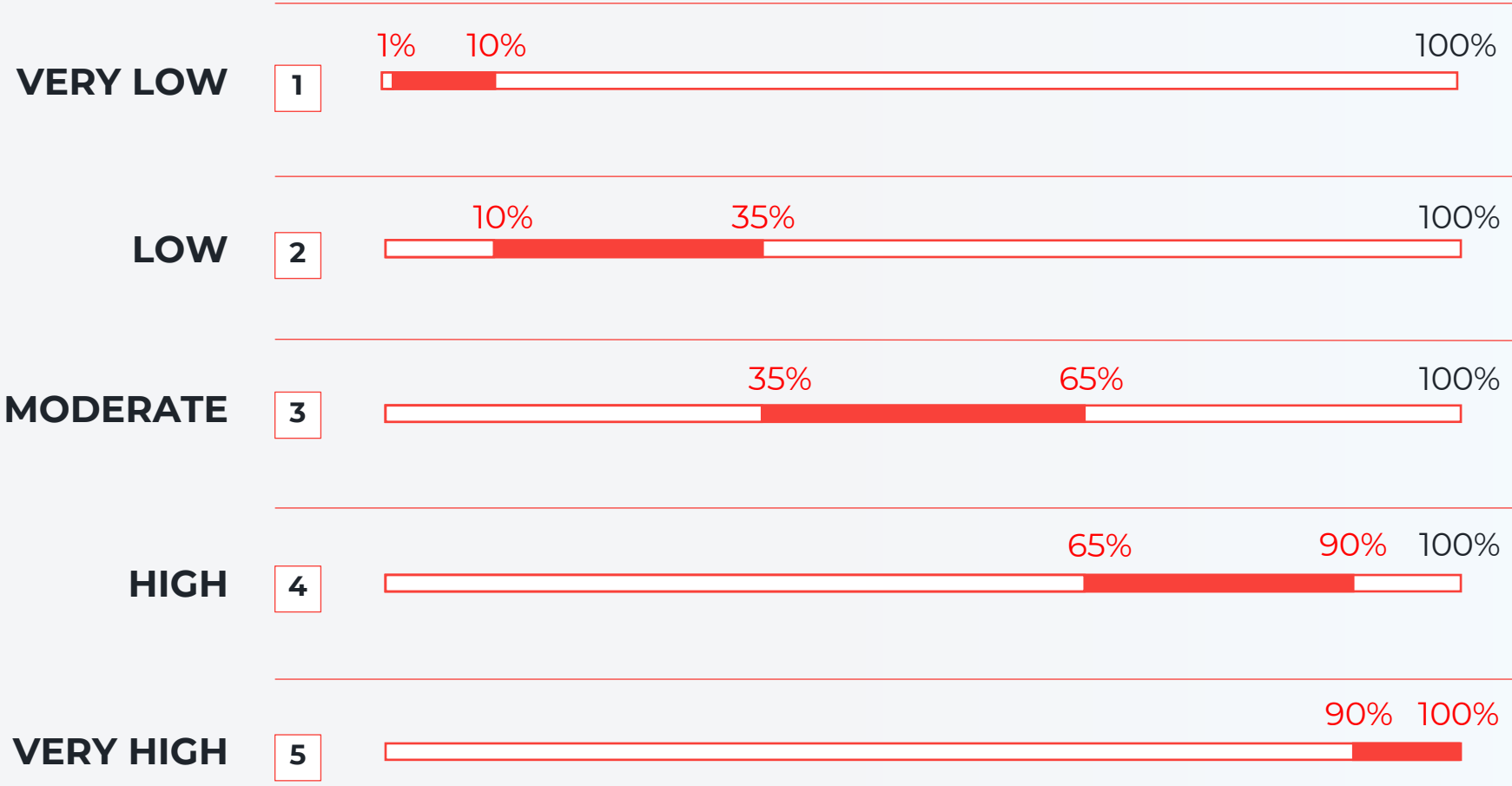
Any desired climate projection scenario
(e.g., SSP2-4.5, SSP5-8.5)

Global coverage

Projection statistics and trend information for a large selection of climate variables



LIKELIHOOD SCORING SCALE



The threshold probability to occur is greater than the lower value, but less than the greater value for any projected ranges in future climate.

RISK SCORING

CSM AND REMEDIATION OPTIONS

Climate impact on CSM

1. Sources
2. Contaminant Transport (groundwater, surface water, air, soil and sediment)
3. Human Receptors
4. Ecological Receptors

Climate impact on existing or future remediation option(s)

- Critical operating or design criteria

EX: Indicators for contaminant transport

Groundwater

- Increased mass flux
- Change in saturated zone thickness
- Increased water level fluctuation
- Change in groundwater/surface water interactions
- Change in partitioning to air/water interfaces
- Increased transformation potential
- Increased compound-specific preferential transport
- Etc.

EX: Criteria for Permeable Reactive Barrier

- PRB residence time too short - higher groundwater velocity
- PRB bypassed - hydraulic gradient change, flooding
- Shorter PRB life span - higher mass flux
- More complex PRB configuration - greater aquifer saturated thickness, groundwater level fluctuations
- Lower PRB efficiency – new preferential pathways, modified groundwater-surface water interactions

CONSEQUENCE SCORING

CSM EXAMPLE

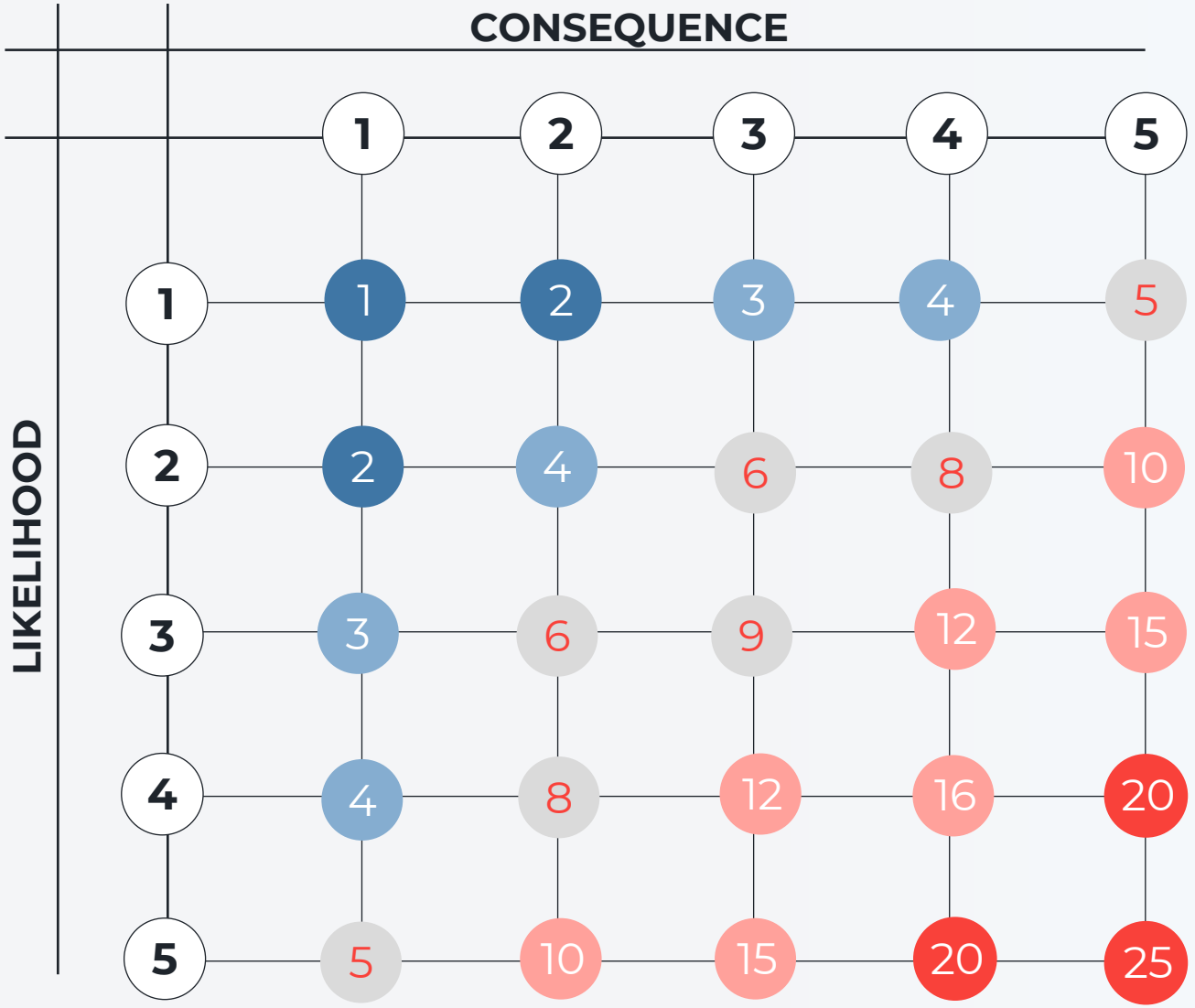
CONTAMINANT TRANSPORT

GROUNDWATER	SURFACE WATER	SOIL AND SEDIMENT
INCREASED MASS FLUX	INCREASED RUN-OFF	ACCELERATED DETERIORATION OF SOIL STRUCTURE/ COMPOSITION
CHANGE IN VERTICAL HYDRAULIC GRADIENT	INCREASED IMPACTED AREA/VOLUME	INCREASED TRANSFORMATION POTENTIAL
CHANGE IN GROUNDWATER FLOW DIRECTION	CHANGE IN GROUNDWATER/ SURFACE INTERACTIONS	

CONSEQUENCE SCORING SCALE

NOT APPLICABLE	0	Site indicator or design criteria does not influence contamination or operations
VERY LOW	1	Likely to cause insignificant or no impacts on the site or site management. Insignificant change site indicators.
LOW	2	Likely to cause minor impacts on the site or site management. Minor change to site indicators.
MODERATE	3	Likely to cause impacts on the site or site management that can be addressed with moderate intervention. Moderate change to site indicators.
HIGH	4	Likely to cause major impacts to the site or effectiveness of site management likely compromised. Major change to site indicators.
VERY HIGH	5	Likely to cause catastrophic impacts to the site or complete failure of site management. Significant change to site indicators.

CLIMATE RISK ASSESSMENT FRAMEWORK



Cumulative Risk Categorization

Cumulative risk across identified climate hazards

Evaluate cumulative climate change risk at:
Site level – impact to site and contamination

RISK RATING	SCORE	ACTIONS REQUIRED
NEGLIGIBLE RISK	< 12	No impact on CSM or site management - no action needed
LOW RISK	13 - 20	No/minimal impact expected on CSM or site management - no action expected
MODERATE RISK	21 - 30	Moderate impact expected on CSM or site management - action may be required
HIGH RISK	31 - 50	High impact expected or CSM or site management - action likely required
EXTREME RISK	> 50	Very high impact expected on CSM or site management - action required

CASE STUDIES
PFAS IMPACTED SITES

Similar site characteristics and **PFAS impacted media**

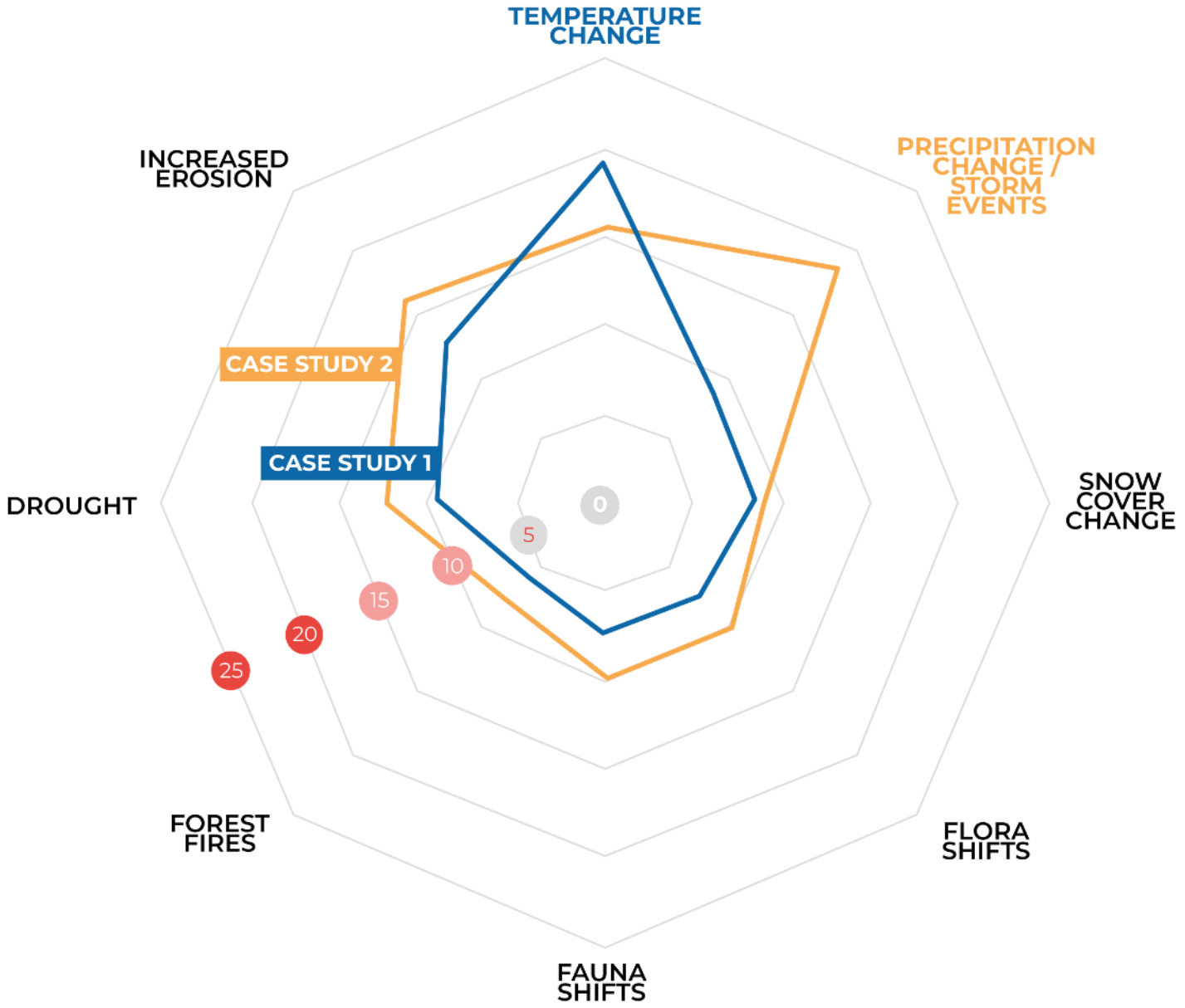
Same remediation options considered

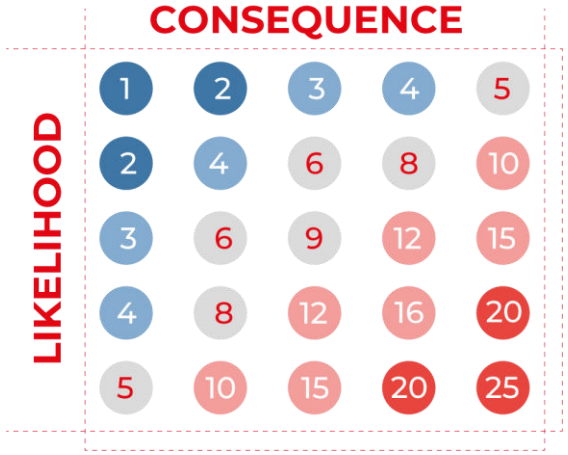
Similar climate hazard impacts

Different geographical locations

Climate projections using **high emission scenario** (SSP5-8.5 shown)

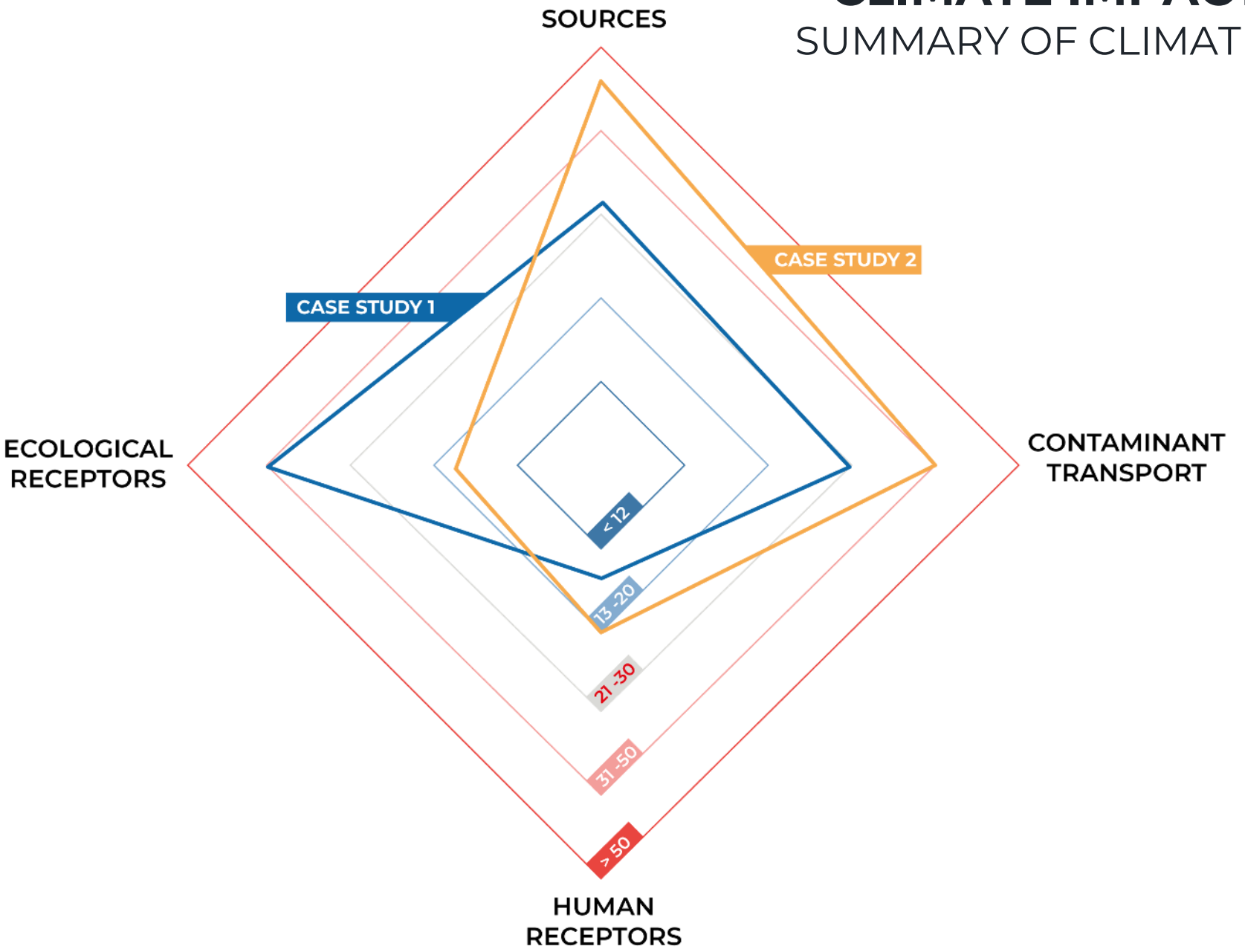
SITE SPECIFIC ASSESSMENT OF CLIMATE HAZARDS





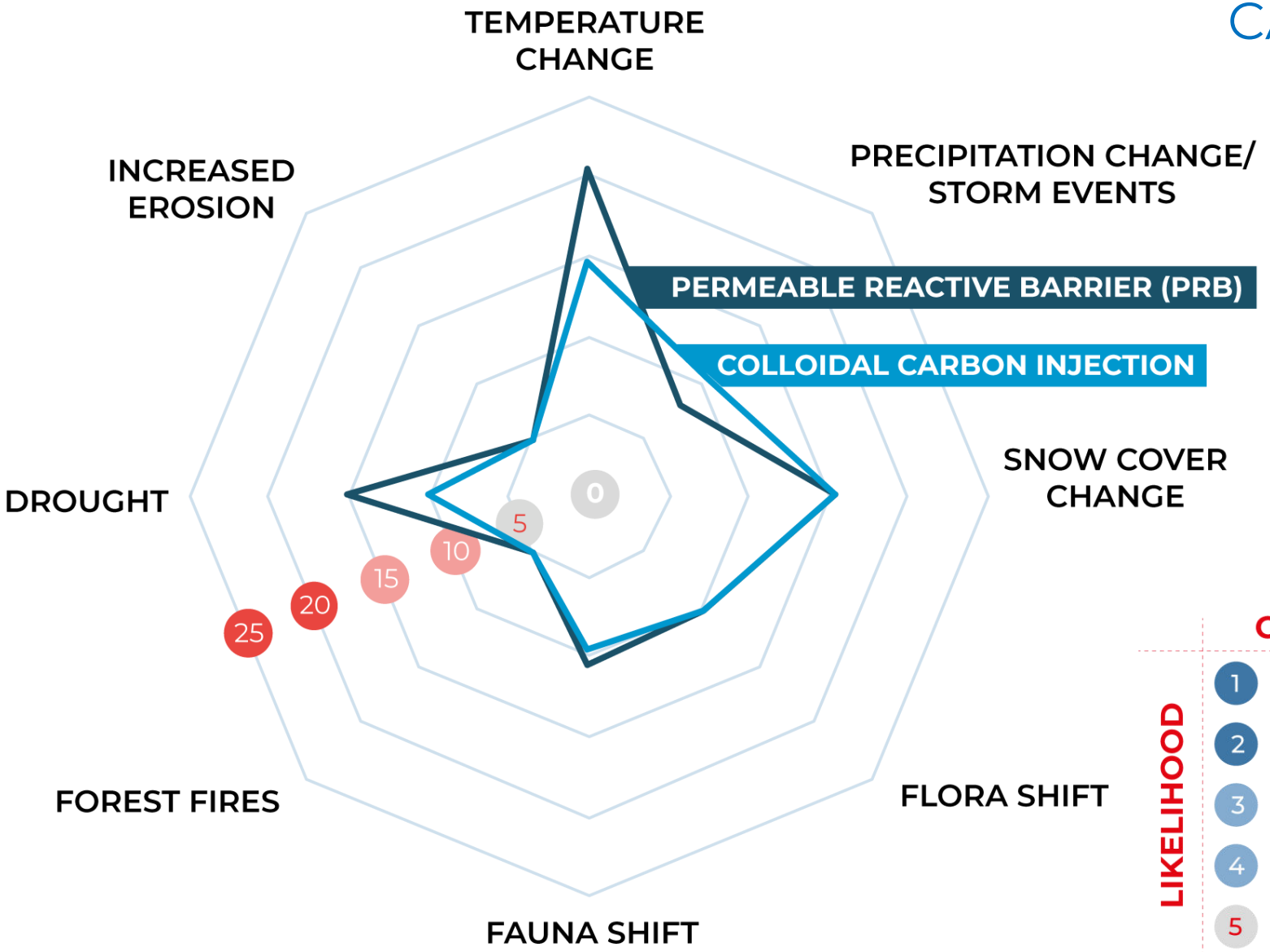
CLIMATE IMPACT ON CSM

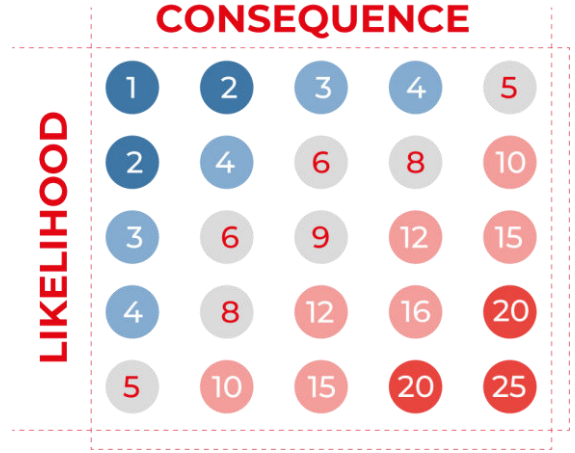
SUMMARY OF CLIMATE HAZARDS



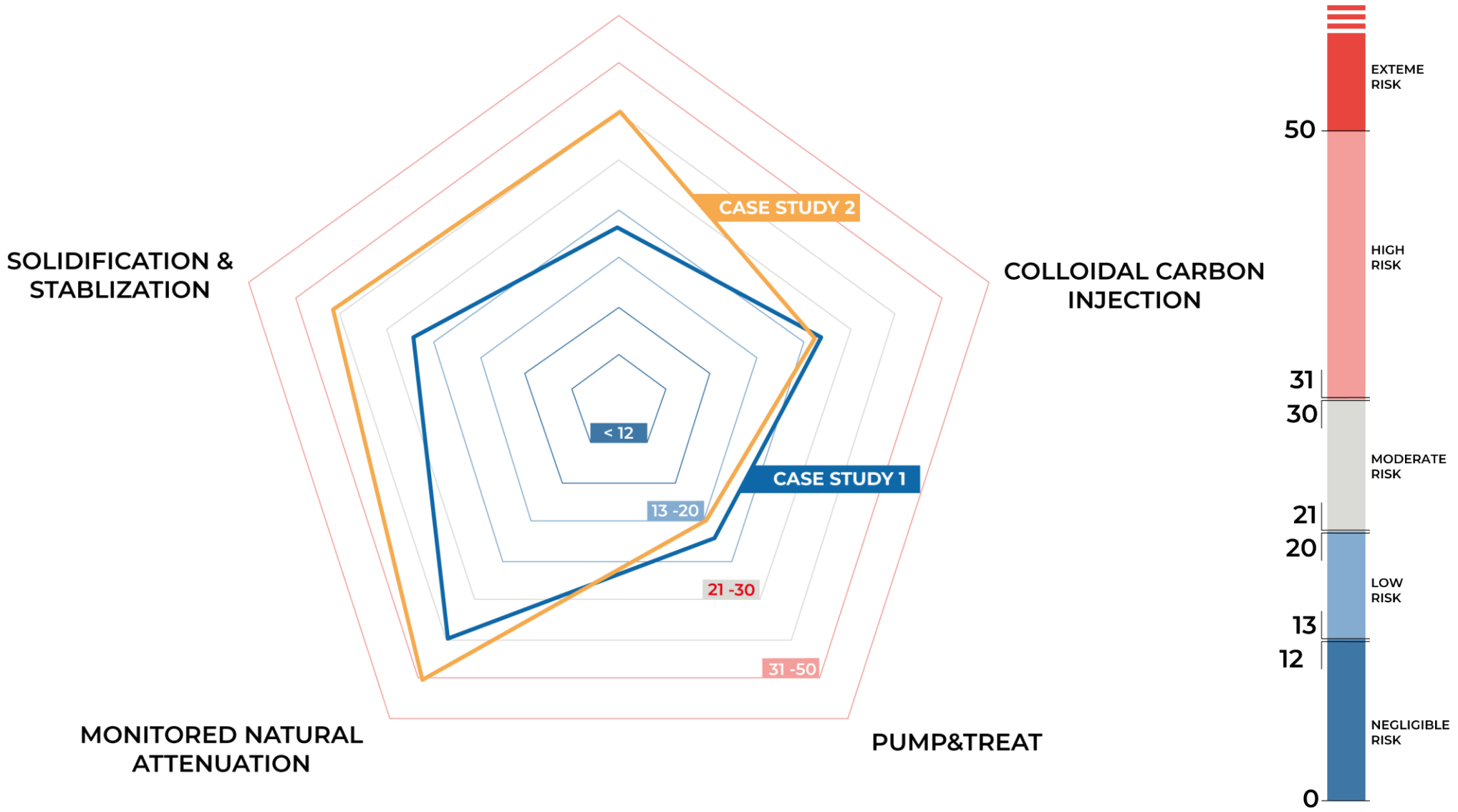
CLIMATE IMPACT ON REMEDIATION

CASE STUDY 1





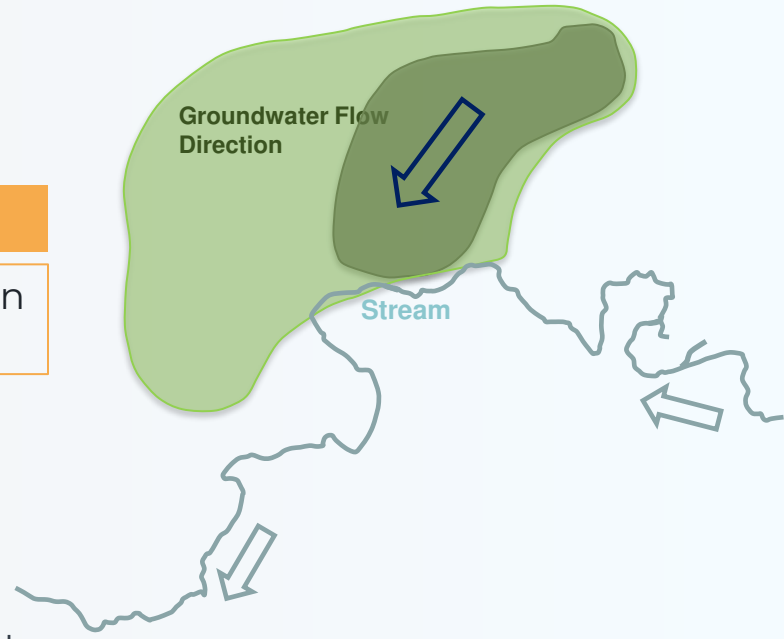
COMPARISON OF REMEDIATION OPTIONS BASED ON CLIMATE RISKS



CLIMATE IMPACT ON CRITICAL CONTAMINATED SITE

CSM ELEMENTS (NO REMEDIATION)

CSM



CASE STUDY 1	CASE STUDY 2
8% increased annual precipitation (676 mm → 730 mm)	85% increased annual precipitation (454 mm → 838 mm)

PRESENT

- PFAS impacted groundwater discharging to a stream
- Surface water body is a gaining stream, limiting plume migration beyond the stream
- Current water level difference between groundwater and surface water is 5-10 cm

FUTURE

- More intense precipitation causing more rapid response in surface water levels followed by groundwater levels
- Expected reversal of vertical hydraulic gradient for longer durations at Site 2
  - Altered PFAS transport
  - Lower PFAS mass discharge to stream
  - Different receptors being affected
  - Potential to significantly affect site risks and site management plan

CLIMATE IMPACT ON REMEDIATION
PRB AND IN-SITU INJECTIONS

CASE STUDY 1	CASE STUDY 2
8% increased annual precipitation (676 mm → 730 mm)	85% increased annual precipitation (454 mm → 838 mm)

FUTURE

- More intense precipitation causing greater fluctuations of groundwater levels at Site 2:
  - Impact on saturated zone thickness, hydraulic gradients, groundwater velocity, PFAS mass flux

PRB

- PRB needs to be designed taller, potentially wider, with more reactive media or with more frequent media change out

INJECTION

- Similar impacts as PRB plus considerations at the time of injections:
  - Can the sorbent media be effectively distributed above the current water table?
  - Should an allowance be included for future injections?
  - Will there be preferential contaminant transport pathways?

WHEN WE ACCOUNT FOR THESE IMPACTS,
IS THE ORIGINAL PREFERRED REMEDIAL OPTION STILL THE RECOMMENDED SOLUTION?

TOOL RESULTS VALIDATION

Validation of the consequence of (some) climate hazards based on past weather events:

Leverage whole plume stability assessment (Plume Analytics)

Site investigation and **remediation data**:

- Lysimeters to measure variations in mass flux
- Seepage meters and mini-piezometers to investigate groundwater-surface water interactions
- Analytical data used for source composition changes (abiotic/biotic transformation) and water quality changes seasonally and in response to weather events
- Monitoring or modelling for hydrogeological / hydraulic changes
- Performance review of existing treatment systems
- ...

Visual observations!

IF IT IS SAFE, VISIT YOUR SITE **DURING OR SOON AFTER WEATHER EVENTS**
OR **INTERVIEW PEOPLE THAT KNOW THE SITE WELL**

THE **CONTAMINATED SITES CLIMATE RISK TOOL** HELPS WITH:

RESPONSIBLE DECISION MAKING	STRATEGIC PLANNING AND RISK MANAGEMENT
More robust and resilient CSMs, RMMs and remediation	Minimization for failure of site management strategy or site reopening

CSM | **Existing or future remediation** | **Single site or portfolio screening**

RELEVANT CONSIDERATIONS

- Key to assess net effects
- Climate projections to be tailored to remedial option lifespan
- Combination of quantitative and qualitative assessment is often the best approach
- Whole plume stability tools, site investigation/remediation data and visual observations should be leveraged

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