# Critical infrastructures and risk assessment for climate change

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***ABSTRACT***
Access to reliable information on technological systems and their vulnerability to weather and climate is crucial for the formulation of realistic climate action plans on critical infrastructures. However, when specialized technical expertise is required, the information necessary for their development among small communities is often not available.

In the case of a risk analysis conducted on water systems of coastal communities, it resulted that weather and climate were responsible for about two third of all the system failures, and that the severity of the damages caused by weather and climate had dependencies in the interactions between water system services and stakeholders.

In order to make such knowledge available to stakeholders and useful for developing informed risk assessments, the risks measured in two sample coastal communities were expressed as use cases, which, in turn, were formalized into an ontology.

From this experience, we realized the need to evolve such a knowledge base to an innovative risk management system suitable not only for guiding users in searching information, but also for enabling sharing of knowledge on infrastructure components, weather, and climate.

It is anticipated that, once implemented, the system will be able to support semantic search of information relevant to the definition of risk parameters and also to suggest sources for related shared experiences. Furthermore, by leveraging artificial intelligence methods, the system will actively propose new sets of vulnerabilities for the stakeholders to investigate and validate.

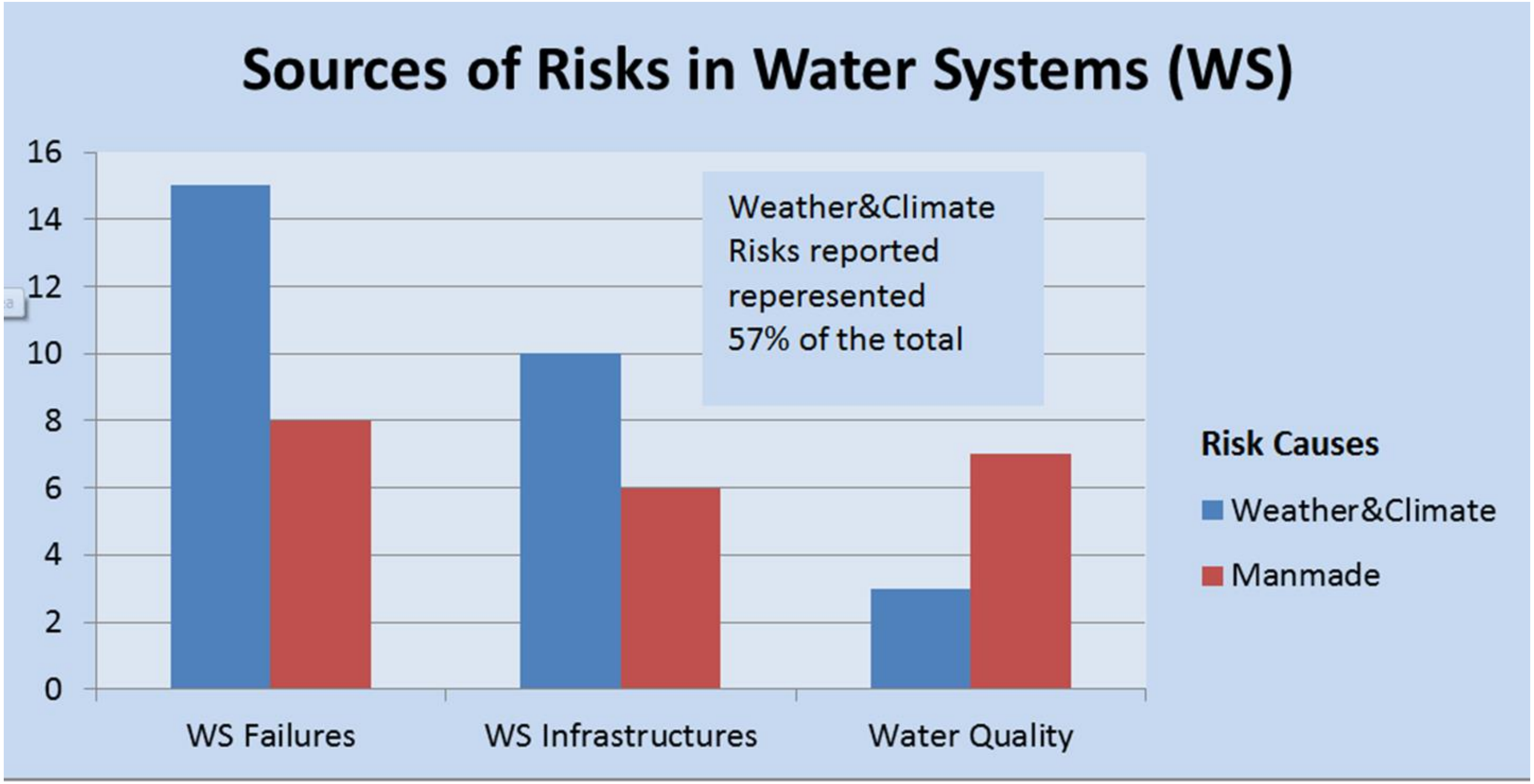
# Background

1) Models indicate that climate change is likely to increase the likelihood of severe droughts, floods, and storm surges.
2) Several floods are threatening Water Systems (WS) causing considerable losses to small systems serving coastal communities.
3) Stakeholders' meetings and focus groups often find it difficult to attract the participation of technical experts with the interdisciplinary knowledge necessary for formulating practical remediation strategies.

# Outline

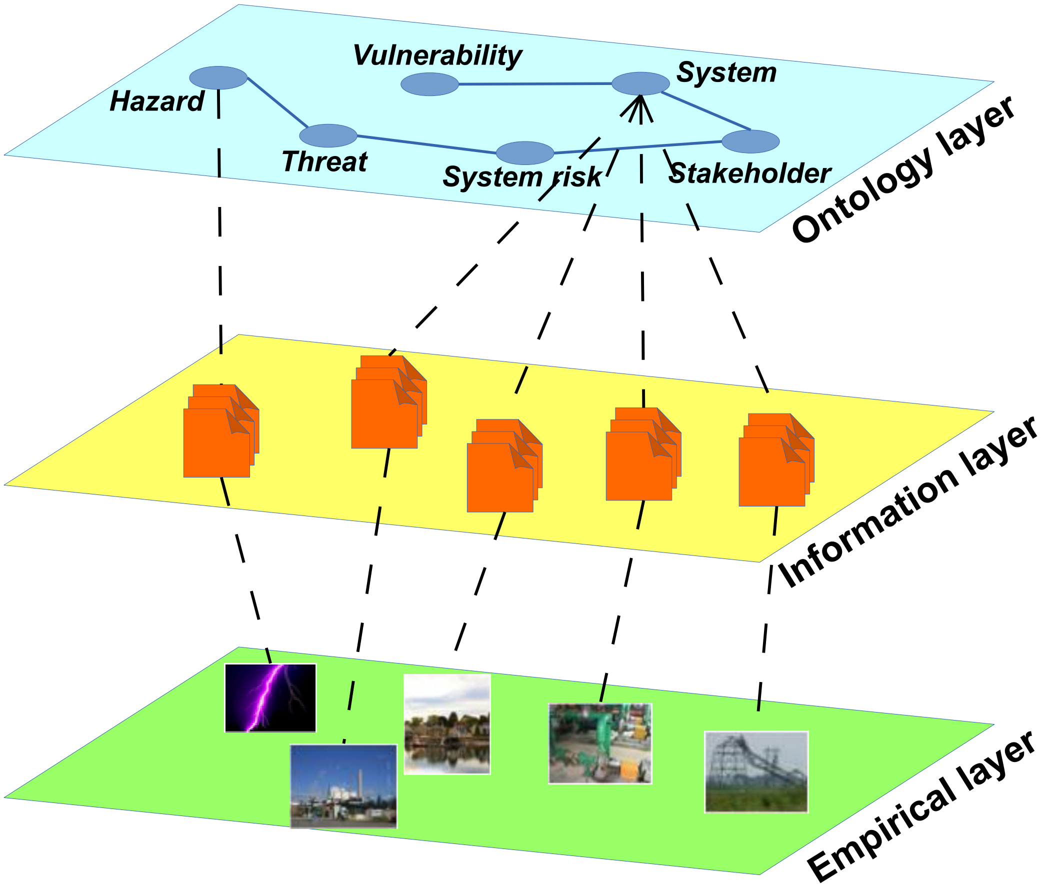
1) Severe weather events and climate change constitute significant threats to Community Water Systems (CWS).
2) Focus group meetings on CWS in two coastal communities found that about one third of the 35 highest level risks are weather and climate change related.
3) This study shows how the CWS vulnerabilities ingrained in the interactions between the environment, the water system, and the stakeholders can be condensed into a semantic model (Vulnerability Upper Model or VUM).
4) The semantic model is therefore proposed as a:
    - Method to entice early involvement of technical experts to participate in focus group meetings.
    - Protocol that links participatory risk assessment focus groups to databases and fact based Decision Support Systems (DSS).

# Climate Effects on WS




Sample size of 35 as per vulnerabilities of Community Water Systems measured by Howe et al. (2012)

# A Framework for a Changing Climate




A Vulnerability Upper Model (VUM) was built on the water systems vulnerabilities

# Vulnerability Model

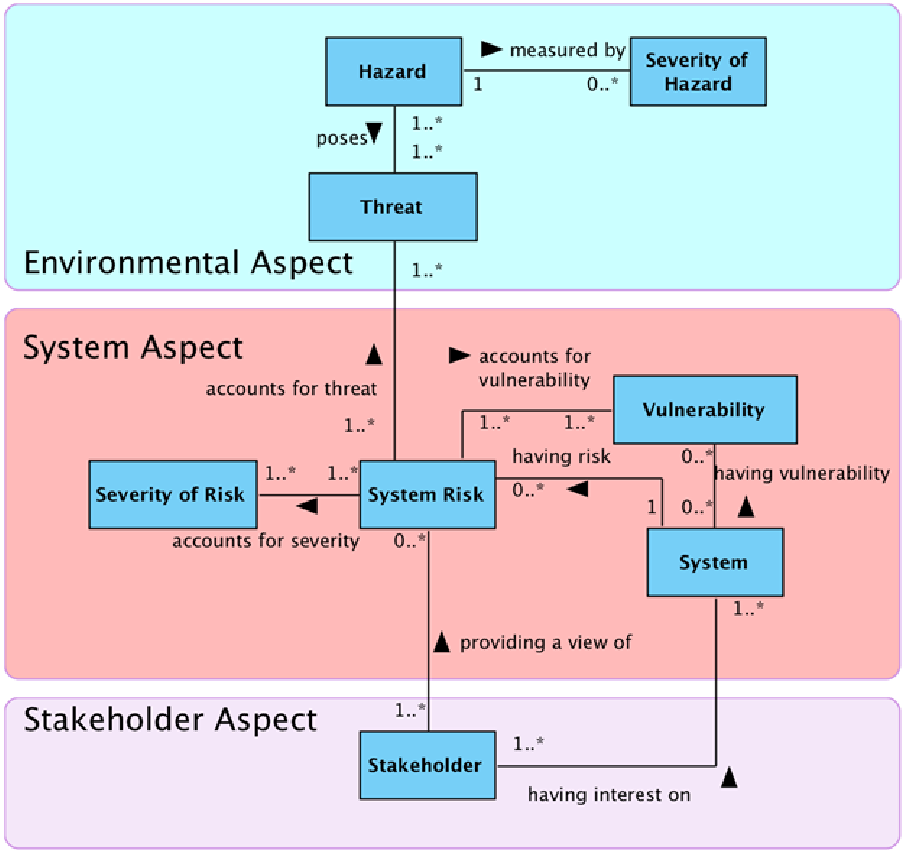
The VUM divides the vulnerability analysis in three aspects:

- *Environmental*
- *System*
- *and Stakeholder.*

System interfaces:

1) Above with Environment through the *threat* a hazards poses on it;
2) Below with stakeholders through
   - ✓ Risk perception;
   - ✓ System properties (Industry standards, fault protection systems, resilience remediation plans, etc.).

*Ref.: Coletti, et al. Natural Hazards, 2016, 84*




The model links hazards with system properties, and system vulnerabilities with societal priorities

# Model Services

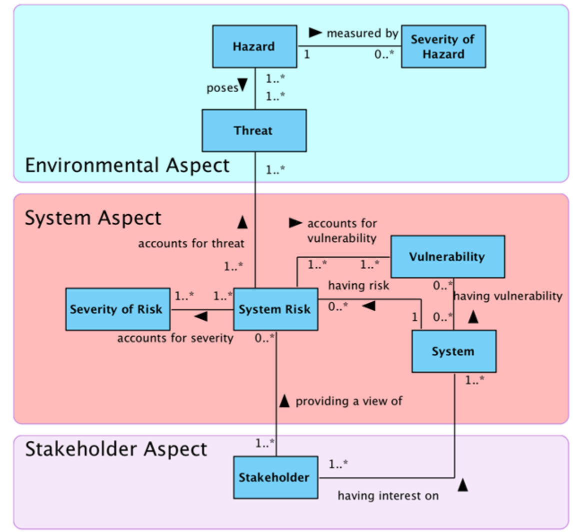
**Input from system:**

1. Level of threat posed by weather and climate on system or component.

**Input from Stakeholders:**

1. Vulnerability of a system or component;
2. Severity of the failure.

V. High
High
Medium
Low
V. Low

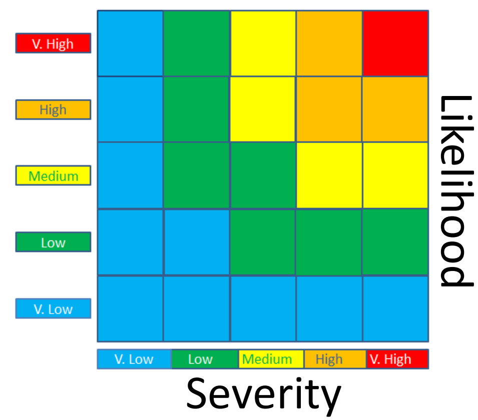



**Outputs:**

a) Traceability of risks from individual and compound events;

b) Measure of *likelihood* and *severity* of risks due to hazards causing multiples failures.

Visually traceable many-to-many dependencies of systems components from threats.

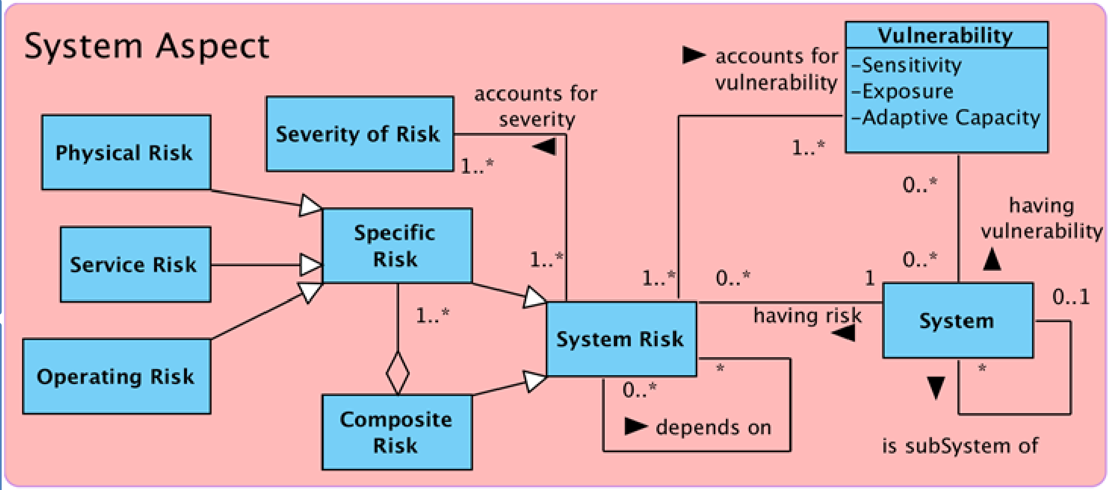


# Vulnerability Model: System Aspect

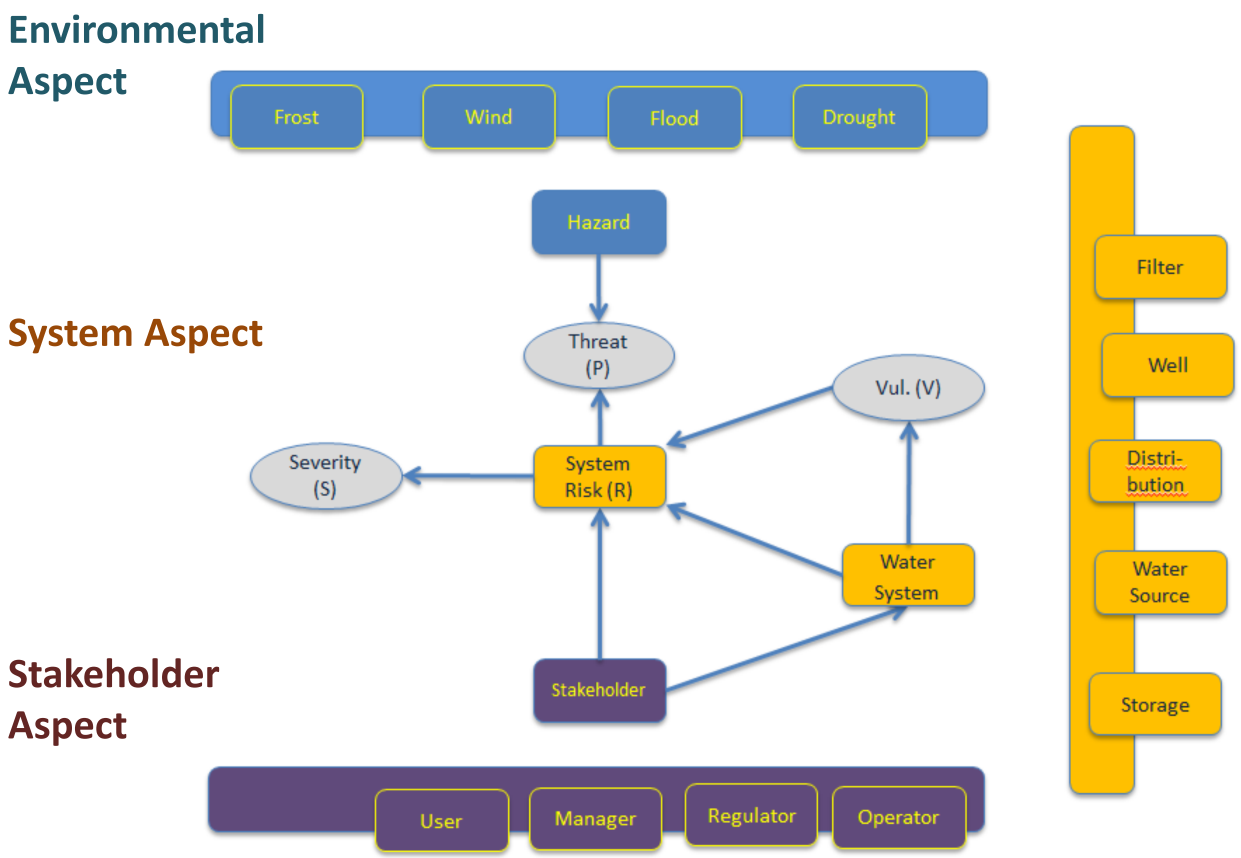
- The model includes the details required by the sample of thirty five vulnerabilities identified of the previous study.
- The same formal method for naming entities and for defining relationships (ontology) can be applied to model other properties of a system.
- Software tools enable efficient mapping of ontologies to SQL and XML lists.

*Specific Risk* can include direct damage on components (***physical***), insufficient maintenance, (***service***), or clients relations (***operating***)

Vulnerability dimensions enable entries for thresholds (***sensitivity***), operating limits (***exposure***), and fault protection (***adaptive capacity***)



# Participatory Vul. Assessment




A set of pre-made sticky notes is moved by the focus group ***coordinator*** over each box in the diagram

**Input Values for P, V, S (*)**

| |
|---|
| V. High |
| High |
| Medium |
| Low |
| V. Low |

**(*) Often severity ranges are not in linear intervals. Combinations of color coded severity ranges is not the same as adding severities (e.g. S = [0-1, 1-10, 10-100, 100-1000, >1000] )**

# Example

In 2011, a team from Penn State University tested a participatory decision support protocol for the development of a Vulnerability Assessment Support System (VASS, Polsky et al. 2007 ).

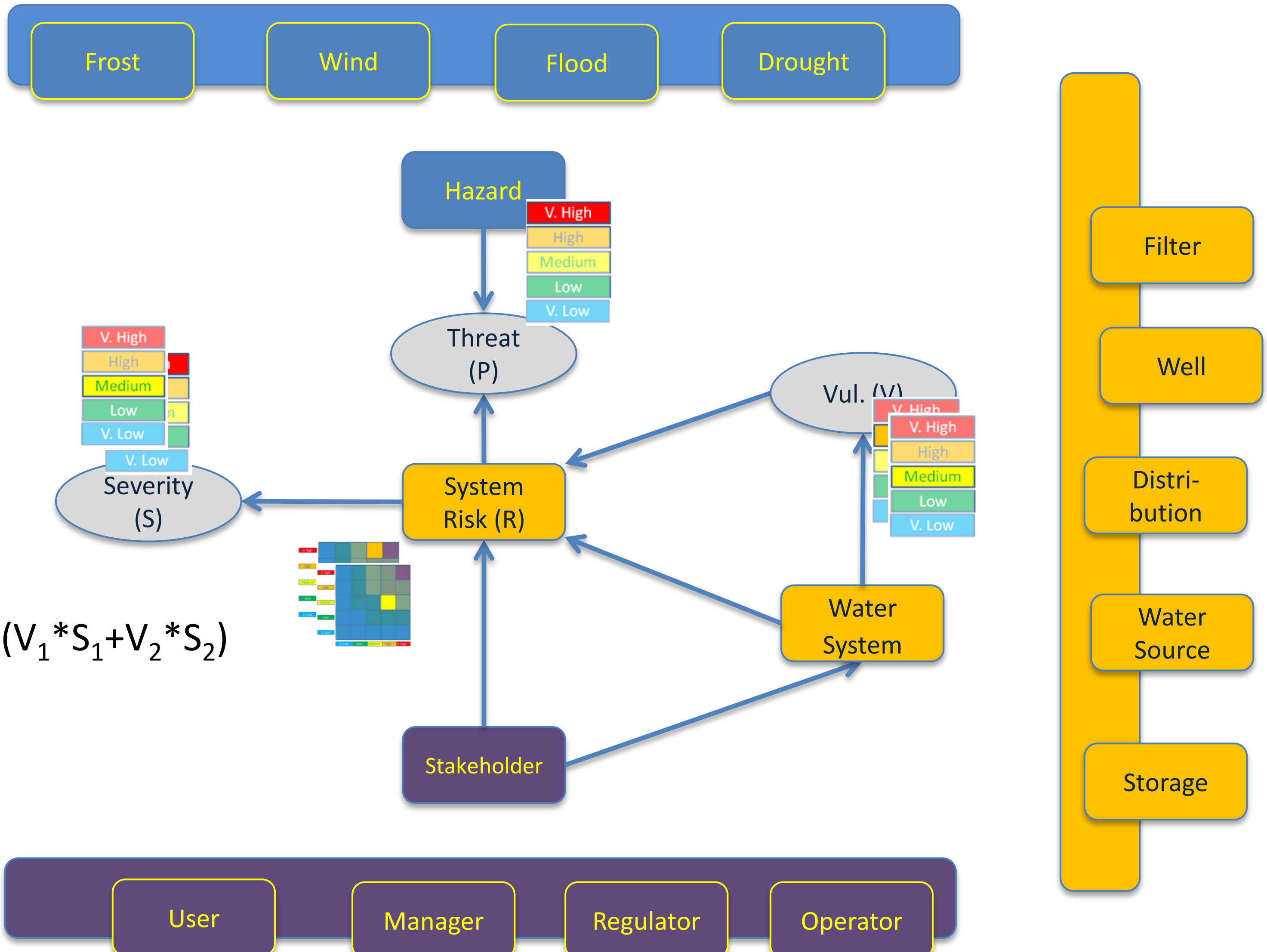
VASS consisted of 6 half-days focus groups during which 18 water systems experts listed 35 major vulnerabilities of Water Systems (WS, Howe et al., 2013).

The demo shows how the vulnerability diagram could facilitate the analysis of three of the vulnerabilities discussed during the VASS:

1) Shortage due to drought
2) Climate change impacts on groundwater system and aquifers
3) Amount of storage capacity of treated water

Polsky, C., R. Neff, and B. Yarnal. 2007. Building comparable global change vulnerability assessments: The vulnerability scoping diagram. *Global Environmental Change* 17 (3-4):472- 485.
Howe, P.D., B. Yarnal, A. Coletti, and N. Wood, 2013*: "The Participatory Vulnerability Scoping Diagram: Deliberative Risk Ranking for Community Water Systems" Annals of the Association of American Geographers, 103, 343-352*

# Proof of Concept, Demo




$$R = P*(V_1*S_1+V_2*S_2)$$

# Takeaway Points

1. The Vulnerability Upper Model uses basic concepts appropriate for wide variety of systems;

2. The model is robust, easy to program with most common computer languages , and apt to visualizations;

3. Modular user friendly Interfaces make the VUM adaptable to any system (including water system);

4. Computer implementation of the model can ease the development of Common Operating Environments (COE) by rescue teams and interest groups.

# Conclusions

- Focus groups and technical experts can use the model as intuitive means that facilitate  exchange of information and common understanding of adaptation plans.
- The model is general and can be used in conjunction of any of the existing vulnerability assessments protocols (e.g. Backcasting, EPA, C-VAT, etc.).
- The semantic based Vulnerability Upper Model (VUM) defines an architecture for analytical risk models,  data bases, and stakeholders' discussions.
- Computer modeling of vulnerability analysis pathways opens the opportunity for the development of a Standard Operating Risk Environment (SORE) where Artificial Intelligence tools can perform searches, retrieve documents and suggest strategies for search and rescue teams, risk reduction strategies, and resilience planning.