Matrix Approach to Stormwater Management for a Resilient Built Environment

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Engineer Research and Development Center
Environmental Laboratory
Risk and Decision Science Team

“The views, opinions and findings contained in this report are those of the authors(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other official documentation.”
Risk and Decision Science Team

Capabilities

- Over 15 risk/decision analysts, scientists, & engineers developing solutions that support decisions across broad gov’t needs.
- State-of-the-science models and tools for structuring and conducting risk assessment, stakeholder engagement, resource prioritization, planning, and other emerging issues relevant to USACE, DoD, and Nation.

Current Programs

- Cutting edge R&D for DoD as well as for DHS, DOE, DHHS, EPA, CPSC and others.
- Applying Decision-Analytic tools to evaluate alternatives, bridge data-to-decision gaps, integrate stakeholder values into solution development, and prioritize research for a variety of technologies & industries.

Integrating Risk Analysis, Life Cycle Assessment, and Multi-Criteria Decision Analysis models for the assessment of emerging materials & risks.
Innovative solutions for a safer, better world

US Army Engineer Research and Development Center

2500 Employees

Over 1000 engineers and scientists 28% PhDs; 43% MS degrees, $1.3B Budget Annually

Cold Regions Research Engineering Laboratory (Hanover, NH)

Risk and Decision Science Team (Boston, MA)

Topographic Engineering Center (Alexandria, VA)

Construction Engineering Research Laboratory (Champaign, IL)

Environmental Laboratory
Coastal & Hydraulics Laboratory
Geotechnical & Structures Laboratory
Information Technology Laboratory
Headquarters (Vicksburg, MS)

Laboratories
Field Offices

Research Laboratories of the Corps of Engineers

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Laboratories
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Risk and Decision Science Approach
Risk and Decision Science Approach

*Oriented toward a “critical function”
*Emergent property of a system
*Different than risk assessment

Linkov et al., Nature Climate Change 2014
Developing a Framework and Methodology

System Domains
- Physical
- Information
- Cognitive
- Social

Disruptive Event Stages
- PREPARE
- ABSORB
- RECOVER
- ADAPT

Scale
- Home
- Neighborhood
- Town
- County
- Region
- State
- Country
## General Form of Resilience Matrix

<table>
<thead>
<tr>
<th>Time</th>
<th>Physical</th>
<th>Information</th>
<th>Cognitive</th>
<th>Social</th>
</tr>
</thead>
<tbody>
<tr>
<td>Previous Cycle</td>
<td>State and capability of equipment and personnel, network structure</td>
<td>Data preparation, presentation, analysis, and storage</td>
<td>System design and operation decisions, with anticipation of adverse events</td>
<td>Social network, social capital, institutional and cultural norms, and training</td>
</tr>
<tr>
<td>Plan/Prepare</td>
<td>Event recognition and system performance to maintain function</td>
<td>Real-time assessment of functionality, anticipation of cascading losses and event closure</td>
<td>Contingency protocols and proactive event management</td>
<td>Resourceful and accessible personnel and social institutions for event response</td>
</tr>
<tr>
<td>Absorb</td>
<td>System changes to recover previous functionality</td>
<td>Data use to track recovery progress and anticipate recovery scenarios</td>
<td>Recovery decision-making and communication</td>
<td>Teamwork and knowledge sharing to enhance system recovery</td>
</tr>
<tr>
<td>Recover</td>
<td>Changes to improve system resilience</td>
<td>Creation and improvement of data storage and use protocols</td>
<td>Design of new system configurations, objectives, and decision criteria</td>
<td>Addition of or changes to institutions, policies, training programs, and culture</td>
</tr>
<tr>
<td>Adapt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Adverse Event

From: Linkov et al, *Env. Sci. & Tech.*, 2013
RM Applications to Stormwater Management

• Define System and Threats
• Identify Critical Functions of the System
• Develop Performance Indicators (domain-phase)
• Score Performance of System Capabilities
• Identify Gaps to Prioritize Efforts
Stressors & Shocks
Rain!

(Multi-Objective) = Critical Function(s)

- Water Quality
- Infrastructure
RM Applications to Stormwater Management

Some facts for framing the problem:

• SWM systems are inherently multi-objective
• Vary in how active or passive they are
• Experience stressors and shocks
• Multiple responsible parties
• Experience concurrent and cascading failures
How does stormwater management contribute to the resilience of [some] critical function to a storm event?

<table>
<thead>
<tr>
<th>Water Quality</th>
<th>PREPARE</th>
<th>ABSORB</th>
<th>RECOVER</th>
<th>ADAPT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
<td>Grey &amp; Green Infrastructure</td>
<td>Cleanup/Repair</td>
<td>Change Infrastructure</td>
<td></td>
</tr>
<tr>
<td>Information</td>
<td>Monitor &amp; Model</td>
<td>Monitor &amp; Model</td>
<td>Monitor &amp; Model</td>
<td></td>
</tr>
<tr>
<td>Cognitive</td>
<td>Rulemaking</td>
<td>Implement Plans</td>
<td>Mobilize</td>
<td>Lessons-Learned</td>
</tr>
<tr>
<td>Social</td>
<td>Individual Behavior</td>
<td></td>
<td>Place-Based Experience</td>
<td></td>
</tr>
</tbody>
</table>
Metrics and Scoring Performance

Tourism

<table>
<thead>
<tr>
<th>Prep</th>
<th>Abs</th>
<th>Rec</th>
<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phys</td>
<td>Info</td>
<td>Cog</td>
<td>Soc</td>
</tr>
</tbody>
</table>

Housing

<table>
<thead>
<tr>
<th>Prep</th>
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<th>Rec</th>
<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phys</td>
<td>Info</td>
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<td>Soc</td>
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Port

<table>
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<th>Prep</th>
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<th>Adapt</th>
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</thead>
<tbody>
<tr>
<td>Phys</td>
<td>Info</td>
<td>Cog</td>
<td>Soc</td>
</tr>
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</table>

Ecosystem

<table>
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<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phys</td>
<td>Info</td>
<td>Cog</td>
<td>Soc</td>
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</table>
# Mapping Responsibilities and Capabilities

E.g., City DPWs, MWRA, BWSC, USACE, Federal Highway Admin, DEP, EPA, A/E firms, others?

<table>
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<th></th>
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<th>Absorb</th>
<th>Recover</th>
<th>Adapt</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical</strong></td>
<td>USACE</td>
<td>USACE</td>
<td>USACE FEMA</td>
<td>USACE</td>
</tr>
<tr>
<td><strong>Information</strong></td>
<td>NOAA USACE</td>
<td>Mayor’s Office FEMA</td>
<td>FEMA NYC OEM</td>
<td>NYC Planning</td>
</tr>
<tr>
<td><strong>Cognitive</strong></td>
<td>NYC Planning</td>
<td>NYC OEM FEMA</td>
<td>FEMA NYC</td>
<td>USACE NYC</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td>NYC OEM</td>
<td>NYC OEM FEMA</td>
<td>NGO/Non-Profit HUD</td>
<td>NGO/Non-Profit</td>
</tr>
</tbody>
</table>
Resources

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Video Credit

Written by Risk and Decision Science Team
Narrated by Ben Trump
Produced by George Siharulidze
With help from EssenceCartoon and Fernando Suarez