VULNERABILITY ANALYSIS AND RESILIENT DESIGN CONSIDERATIONS FOR STORMWATER BEST MANAGEMENT PRACTICES

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Urban Stormwater Workgroup

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Overview

1. Quick Recap of Preceding Memos
2. Risk in the Urban BMP Landscape
3. LID Practices
4. Conveyance Network
5. Ponds and Wetlands
6. Stream Corridors and Shorelines
7. Other Urban Practices
8. Resilient Design and Next Steps

Past Work:

Links to CSN Reports:

- Memo 1: Summary of Stakeholder Concerns, Current Management and Future Needs for Addressing Climate Change Impacts on Stormwater Management
    - Link:https://chesapeakestormwater.net/wp-content/uploads/dlm_uploads/2020/02/FINAL-Climate-Change-and-Stormwater-Survey-Memo.pdf

- Memo 2:Review of Current Stormwater Engineering Standards and Criteria for Rainfall and Runoff Modeling in the Chesapeake Bay Watershed
    - Link: https://chesapeakestormwater.net/download/10023/

- Memo 3:Review of Recent Research on Climate Projections for the Chesapeake Bay Watershed
    - Link: https://chesapeakestormwater.net/download/10027/

- Memo 4: Vulnerability Analysis and Resilient Design Considerations for Stormwater Best Management Practices
    - Link: Will Be Posted When Final

RECAP OF PREVIOUS WORK

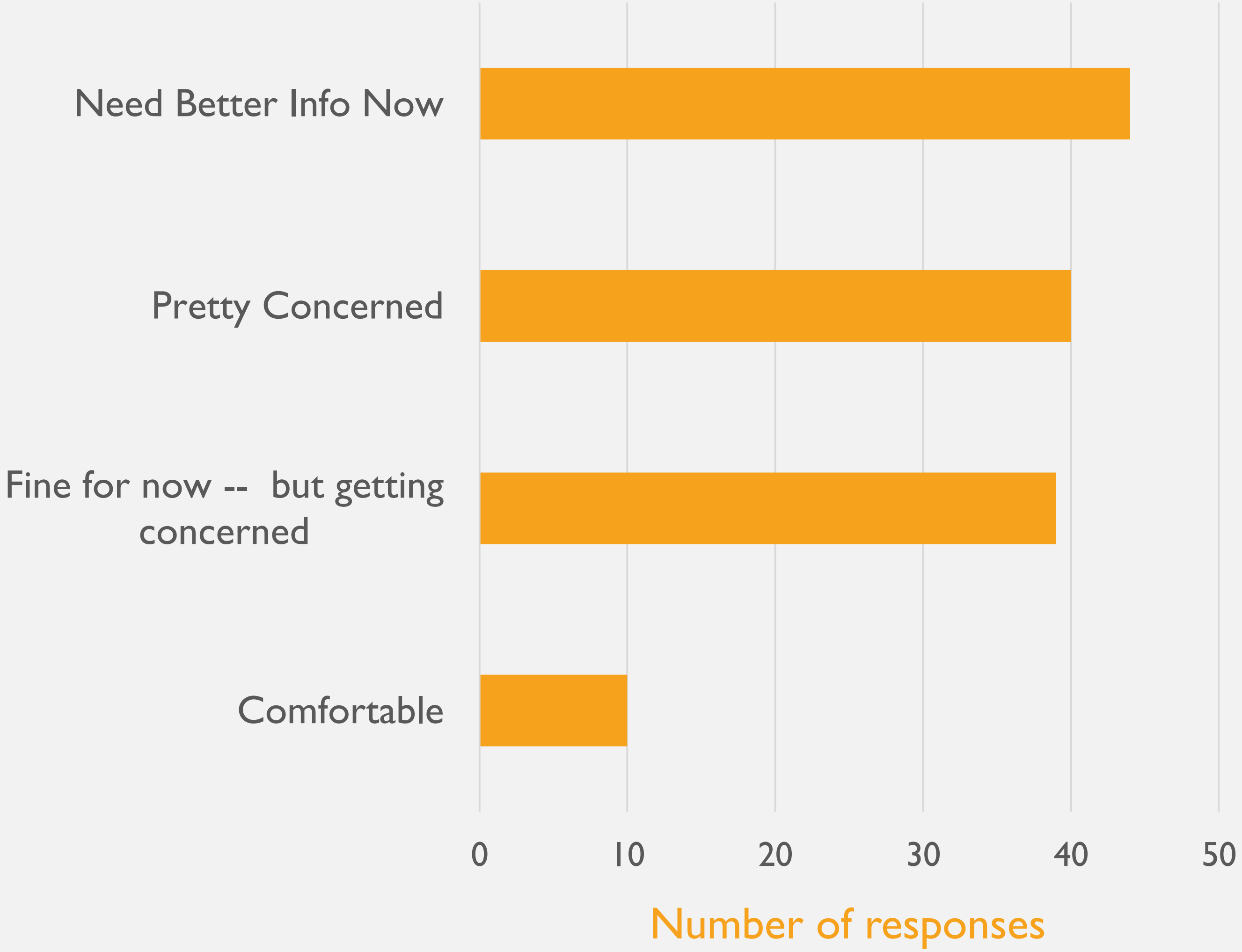
MEMO 1

Key Takeaways

- Everyone is worried about damage to critical infrastructure during large storm events
- Particularly how to pay for both routine and non-routine maintenance
- The current stormwater design criteria aren’t cutting it
- All tools are useful but they really want new design specs.

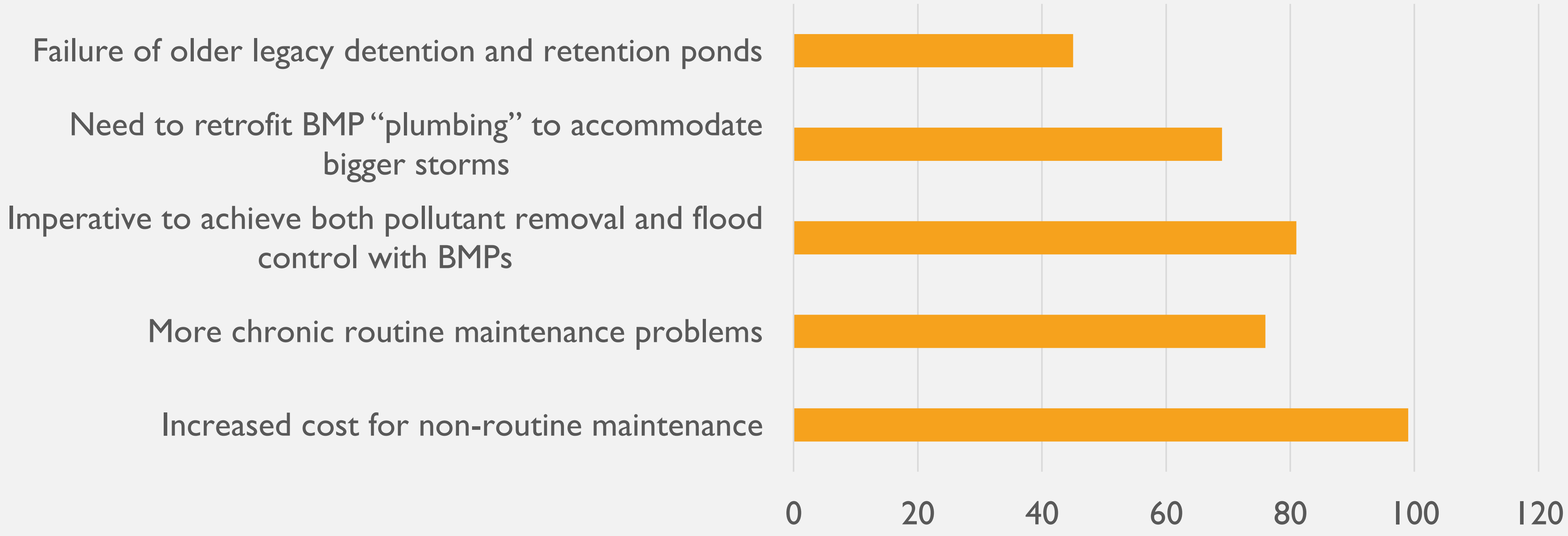
TAKEAWAY 1

- Respondents are not comfortable with the current quality and utility of engineering design criteria on future rainfall intensity



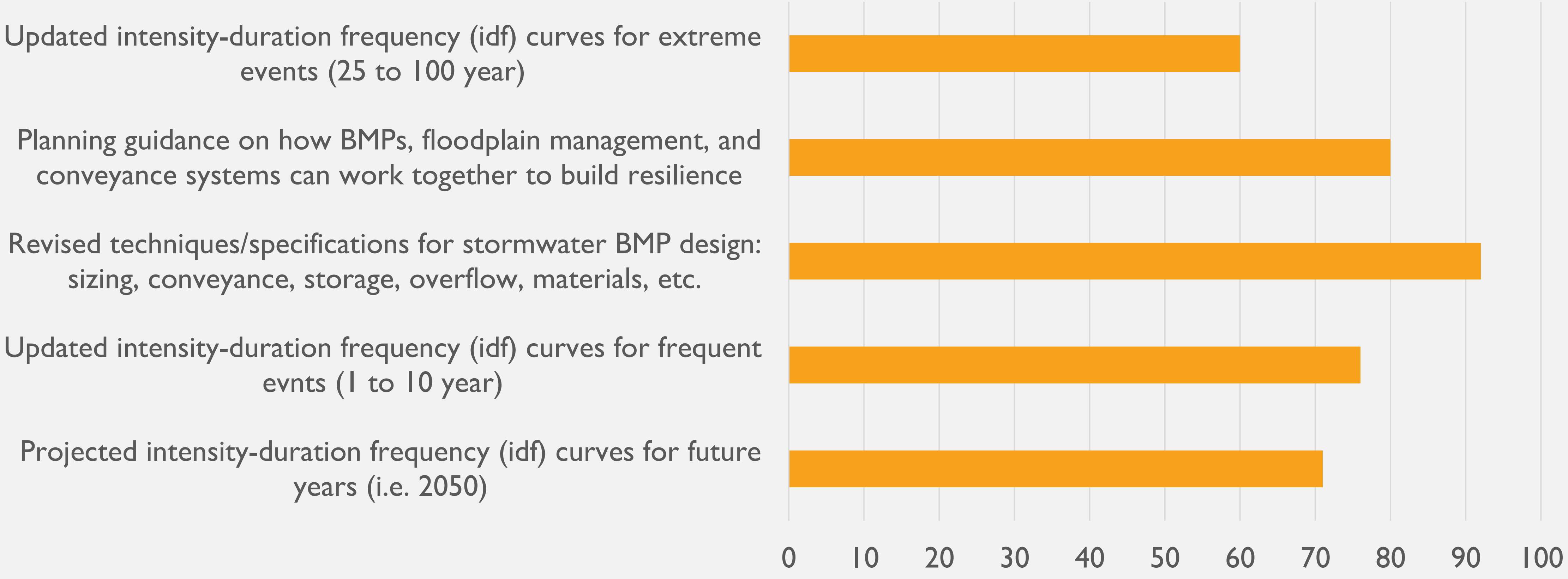
TAKEAWAY 2

Everyone is concerned with how to pay for the necessary maintenance and upgrades, as well as to plan for future resilience.



TAKEAWAY 3

All tools are useful, but if we need new designs, give us new design specs



MEMO 2

Key Takeaways

- Each state and the District of Columbia uses different design criteria.
- Further, within states, there are often differences
- With one or two exceptions, the most recent wave of state stormwater manual updates occurred between 2006-2013.
- Engineering design criteria and stormwater runoff models generally rely on historic precipitation data that is unlikely to reflect future conditions.

MEMO 3

Key Takeaways

- Global and regional climate models are in general agreement about expected changes in temperature and sea level rise.
- Global and regional climate models agree that precipitation volume is increasing and so is the intensity of storm events.
- Downscaled models are needed but methods and results can vary
- There are few examples of downscaled climate projections being used to inform stormwater management

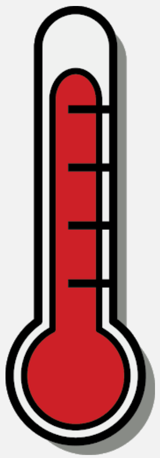
Precipitation Downscaling Studies

Models

Reality

- 6 Chesapeake Bay Downscaling Studies
- Different methods, similar results: 5-35% increase in storm intensity
- More on the way…

Changing Conditions



2-3°F of warming

5-35% increase in precip intensity

1-2 feet of sea level rise

<u>In 30 years, Bioretentions will see:</u>

- Shifting vegetation palettes
- More sediment mobilization in CDA
- Additional rainfall volume in similar # of events
- Rising water tables in coastal areas
- Unknown impacts on pollutant removal efficiency

RISK IN THE URBAN BMP LANDSCAPE

Urban BMP Risk and Vulnerability

Catastrophic Failure	Complete failure of the practice to perform its design function, resulting in risk to human health and public safety
Structural Failure	Complete failure of the practice to operate as designed, but with no immediate risk to public safety
Water Quality Performance Failure / Water Quantity Performance Failure	Practice still exists and may perform some intended functions, but either no longer provides any pollutant removal or leads to impacts on downstream floodplain boundaries
Diminishing Performance	Practice still exists provides some pollutant removal function, at a diminished rate
Anticipated Failure	Some degree of failure or loss of performance was anticipated due to causes unrelated to climate change

Key Factors:

Location in the Watershed

Age

Maintenance/Design Condition

"TYPICAL" TIMELINE FOR THE PROGRESSION OF STORMWATER INFRASTRUCTURE

- 1960's and before: Conveyance only (no detention storage)
- 1980's and before: Detention pond era (quantity control, no quality control)
- 1990's -2010: Quality and quantity control
- 2010 to present: LID era (and in recent years, the stream restoration era)

Upland "LID" Practices

- ➢ Maintenance "needy",
- ➢ Primarily designed for water quality

- ➢ Vulnerabilities:
  - Erosion (in and out)
  - Bypass/Overflow
  - Clogged Filter Media
  - Distressed Vegetation

Vulnerabilities are often the result of flawed design or maintenance – climate change just makes it worse:

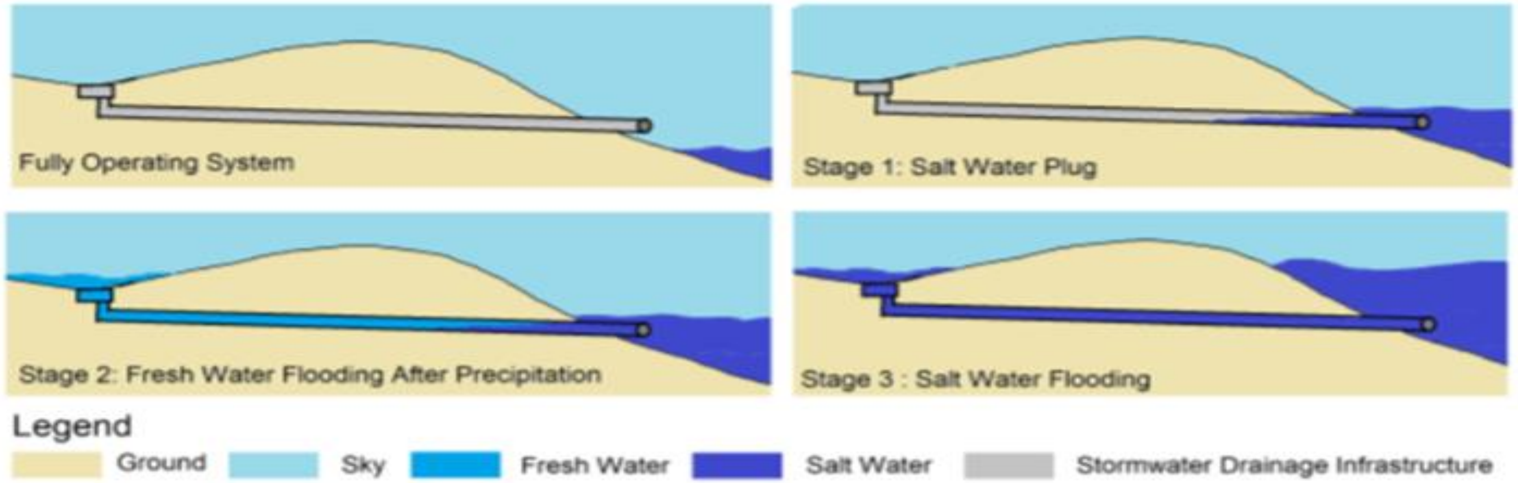
- Improper design elevations
- Preferential flow paths through the facility
- An undersized curb cut
- Insufficient pre-treatment
- Insufficient bypass measures for storms larger than the design storm

Figure 4. Examples of vulnerable design elements in upland LID practices.

Tidal Flooding Impacts

- Reduced infiltration capacity
- Submerged outlet structures resulting in back-up and loss of capacity
- Saltwater intrusion – vegetation and pollutant removal impacts

Figure 2.5: Stages of stormwater drainage failure due to sea-level rise. Graphic by Emily Niederman, Stetson University.



Water Quality Performance Impacts

The 90th percentile storm event hasn't changed much – and may not.

- The 90th percentile storm increased by ~ 6% from 1.14" to 1.21" in the last 15 years at Reagan National
- The predicted intensity of the 90th percentile, 24-hour event does not show a consistent increase at most Maryland stations under future conditions (Butcher, 2020)

But this doesn't mean there won't be water quality performance impacts on BMPs

Water Quality Performance Impacts

Table 1. Summary of Select Climate Change Pollutant Removal Impact Studies

Citation	Type of Study	BMP	Performance Metric	Change in Performance
Hathaway et al., 2014	Modeled	Bioretention (online)	Overflow volume	70-136% increase in overflow volume by 2055
Catalano de Souza et al., 2016	Field (extreme weather as proxy for climate change)	Bioretention (offline)	Bypass volume	40% bypass during extreme events vs 23% bypass during non-extreme events
Butcher, 2020	Modeled	Bioretention	Overflow volume	11% increase in overflow volume by 2055
Alamdari et al., 2020	Modeled	Mixed	BMP removal efficiency	6-11% decline (TSS) 7-12% decline (TN) 11-17% decline (TP)
U.S. EPA, 2018	Modeled	Mixed	BMP removal efficiency	0-10% decline (TSS) 0-6% decline (TN) 0-5% decline (TP)

Conveyance Practices

- Serves as choke point that can elevate risk elsewhere
- Impacts on transportation infrastructure
- Vulnerabilities:
  - Erosion (in and out)
  - Loss of Capacity
  - Damage at the Outfall

Pond Practices

- Potentially high impact on public safety
- Older practices
- Vulnerabilities:
  - Erosion
  - Sedimentation
  - Emergency Spillway
  - Leaching and Resuspension

Figure 6. Examples of vulnerable design elements for stormwater ponds.

Erosion at the Inlet

Loss of Capacity – Full Pilot Channel

Embankment Failure

Damage to Emergency Spillway

Pond Water Quality Vulnerabilities

- High flows may disrupt the settling process and shorten the HRT of stormwater retention ponds during extreme conditions
- High flows also mean more inlet loads and less pond performance
- Overall, higher storm intensity is a bigger problem for ponds than more volume

Stream Corridor and Shoreline Practices

- Most "online", w/ large CDA
- Designed to withstand floods, not reduce them

- Vulnerabilities:
  - Structural elements of restorations
  - Increased erosion

Stream Restoration Vulnerabilities

- Inaccurate predictions regarding design parameters (width, depth, meander radii, etc.)
- Poor reference site selection

- Design principles have shifted – impacts of climate change are still not well understood

Figure 7. Examples of vulnerable design elements for stream restoration practices.

		
Structural Flanking	**Bank Erosion**	**Headcuts**

Stream Restoration Water Quality Performance

- Little to no research on pollutant removal changes
- Theoretically there is potential for increased load reductions from prevented sediment and floodplain restoration practices
- Gains could be offset by a single extreme storm event.

Other Urban Practices

- Data is lacking for programmatic BMPs (Street sweeping, UNM, NDGI)
- Tree BMPs are somewhat better understood, but again lack data
- Vulnerabilities:
  - Shifting tree ranges
  - Tree mortality
  - Build-up wash off dynamics

Resilient Design and Next Steps

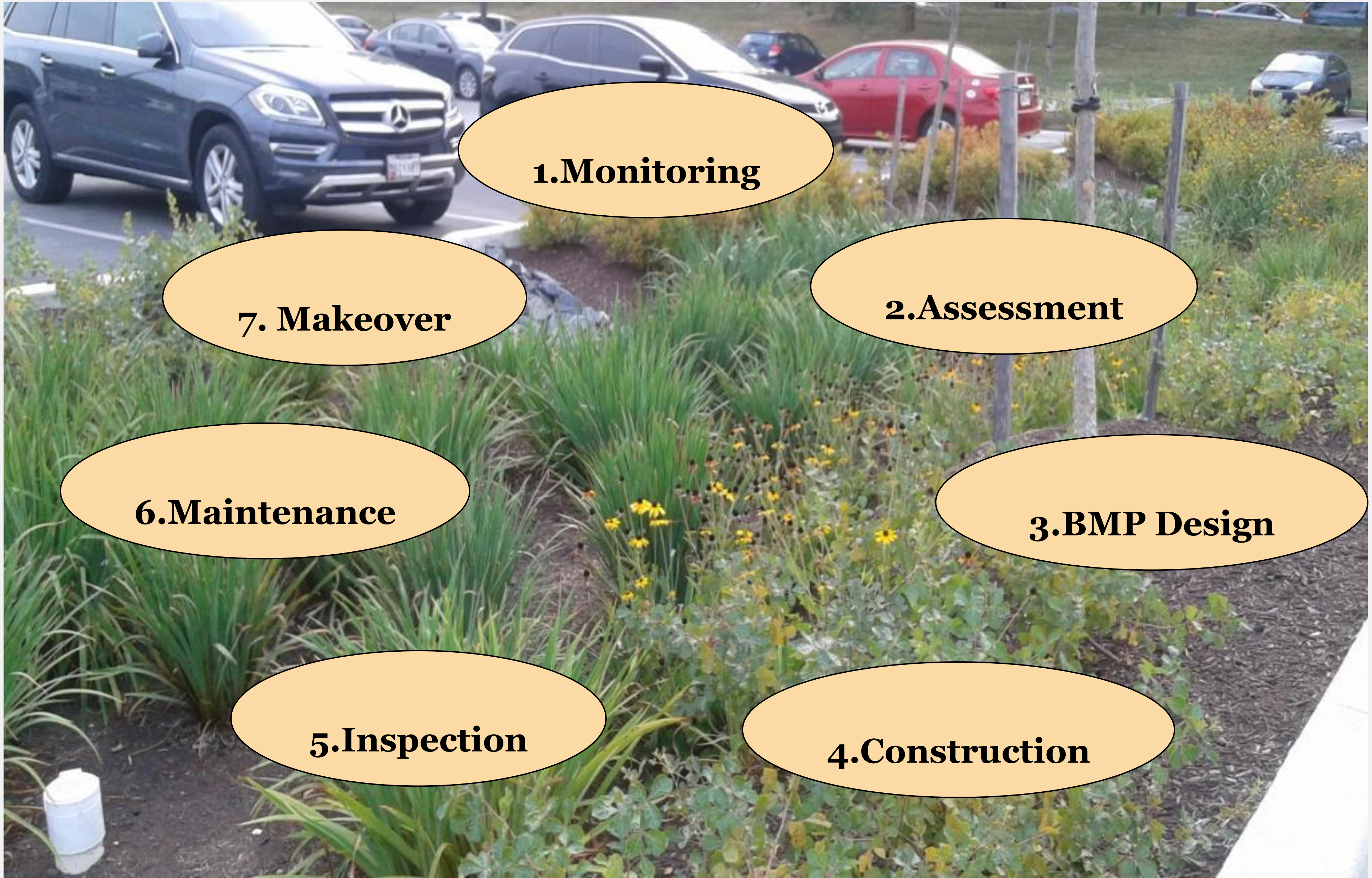
Resilient Stormwater Design Principles

- Comprehensive Watershed Management
- Sizing for acceptable level of risk under future climate
- Flow-Plains
- Full Cycle Implementation
- Redundancies
- Performance Enhancers

Some Sizing Options

- Replace existing IDF curves with projected IDF curves
  - Still lack temporal resolution needed for most design applications
- Factor of Safety – Add % to existing IDF curves based on projections
- Increase the design storm criteria (ex. design for the 15 year, 24 hr instead of the 10 year, 24 hr)
- Over-management criteria – (ex. release the 150-year post-development storm at the 100-year pre-development level)

RESILIENCE IS A FULL CYCLE



BETTER SPECS

- Standard inflow method that works and can be easily cleaned
- Provide a range sustainable landscaping templates that are easy to maintain and require less mulch
- Incorporate maintenance benchmarks and indicators into design specifications
- Use performance enhancers like media amendments and Smart BMPs to offset performance losses
- Coastal design adaptations

Where do we go from here?

- Develop effective new state stormwater design standards and specifications

- Consider revisiting the Stormwater Performance Standards EPR to reflect new designs

- Individual state stormwater/floodplain/dam safety agencies should work together to develop stream-lined design criteria for pond retrofits

Where do we go from here?

- Design charette with stream restoration practitioners and researchers to establish recommended best practices for stream, floodplain, and riparian corridor design
- Convene small group of shoreline management practitioners and climate experts to recommend whether the existing BMP crediting protocols (or qualifying conditions) need to be adjusted
- The Forestry Workgroup may wish to provide guidance on which tree planting species and techniques will work best in the warmer and wetter climate of the future.
- The FWG may also outline research on both the risk of riparian tree mortality during extreme floods, as well as impacts on canopy interception and pollutant removal capabilities of tree BMPs.

QUESTIONS?