




The Threat of Climate Change to Urban Stormwater Infrastructure



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Professor Emeritus
St. Anthony Falls Lab, University of Minnesota
July 16, 2025

<https://www.noaa.gov/stories/ask-scientist-extreme-rainfall-why-it-happens-and-how-we-predict-it>

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<http://stormwater.safl.umn.edu/>



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Acknowledgements

- Thesis work of Noah Gallagher
- Co-advised by Dr. Andy Erickson
- With help from Dr. Bill Herb and Dr. Bruce Wilson



Why Care About Extreme Rainfall Events?

- Dangerous
 - “Flash floods”
 - Damaging outside of FEMA flood zones
- Expensive
 - 2012 Duluth storm >\$100 Million
- Risks to Urbanized Areas
 - Concentration of people and property
 - Greater impervious cover -> More runoff



Extreme Weather in the News

 The Guardian

[More than 150 'unprecedented' climate disasters struck world in 2024, says UN](#)

Floods, heatwaves and supercharged hurricanes occurred in hottest climate human society has ever experienced.

2 days ago




 The New York Times

[Your Home Is Vulnerable to Extreme Weather. Here's How to Protect It.](#)

Wildfires in Los Angeles. Tornadoes in the South and Midwest. Flooding in North Carolina. From coast to coast, a wave of extreme weather...

2 days ago



 FOX Weather

[Tornadoes spotted in Illinois as powerful storm system blasts through Midwest](#)

Communities from the Midwest to the Great Lakes region are picking up the pieces after severe weather barreled across the region on...



 The Bali Sun

[Extreme Weather And An Earthquake Hits Bali: Tourists Advised To Be Cautious](#)

It's wild out there folks! Tourists in Bali are being urged to stay safe as more intense weather is forecast.

1 day ago



 World Meteorological Organization WMO

[WMO report documents spiralling weather and climate impacts](#)

The clear signs of human-induced climate change reached new heights in 2024, with some of the consequences being irreversible over hundreds...

2 days ago



 DW

[Using Tech and AI to cope with extreme weather – Shift](#)

Innovative technologies such as AI are to make weather forecasting more precise. Networked sensors and devices record data in real time for...

4 hours ago



Google search for extreme weather news, March 21, 2025

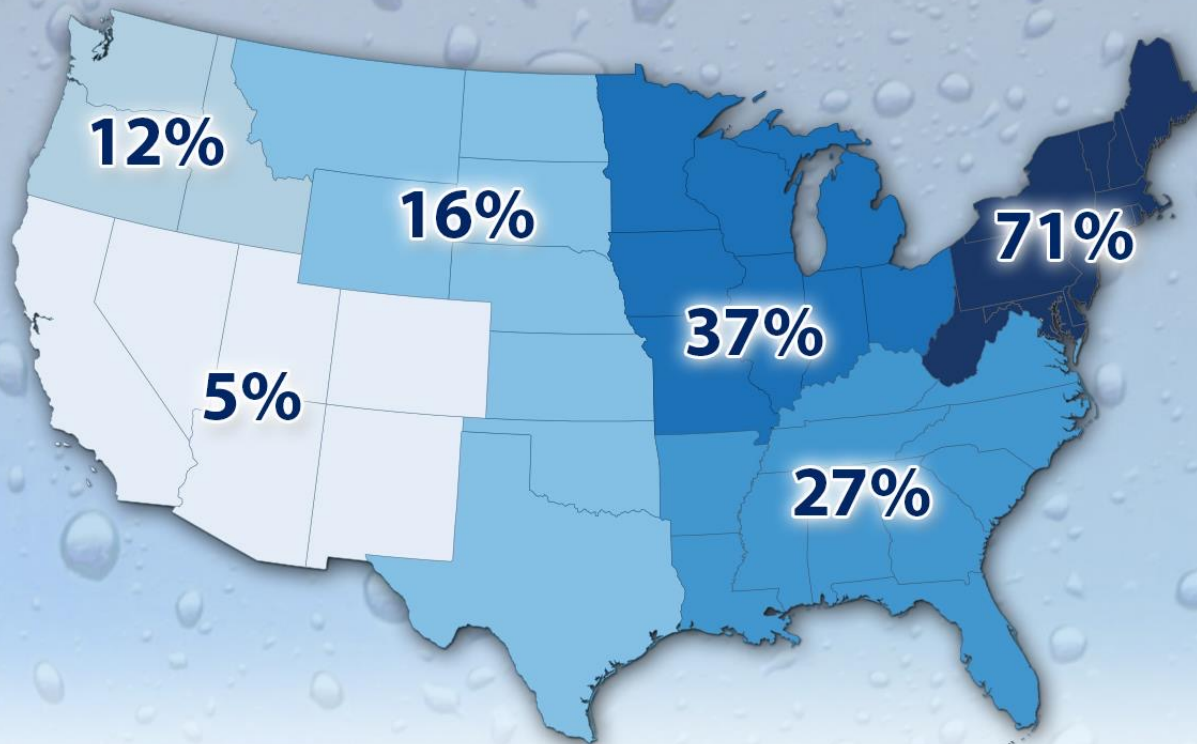
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Heavy Downpours Increasing



Percent increase from 1958 to 2012 in the amount of precipitation falling in very heavy events.
Very Heavy Precipitation is defined as the heaviest 1% of all daily events from 1958-2012.

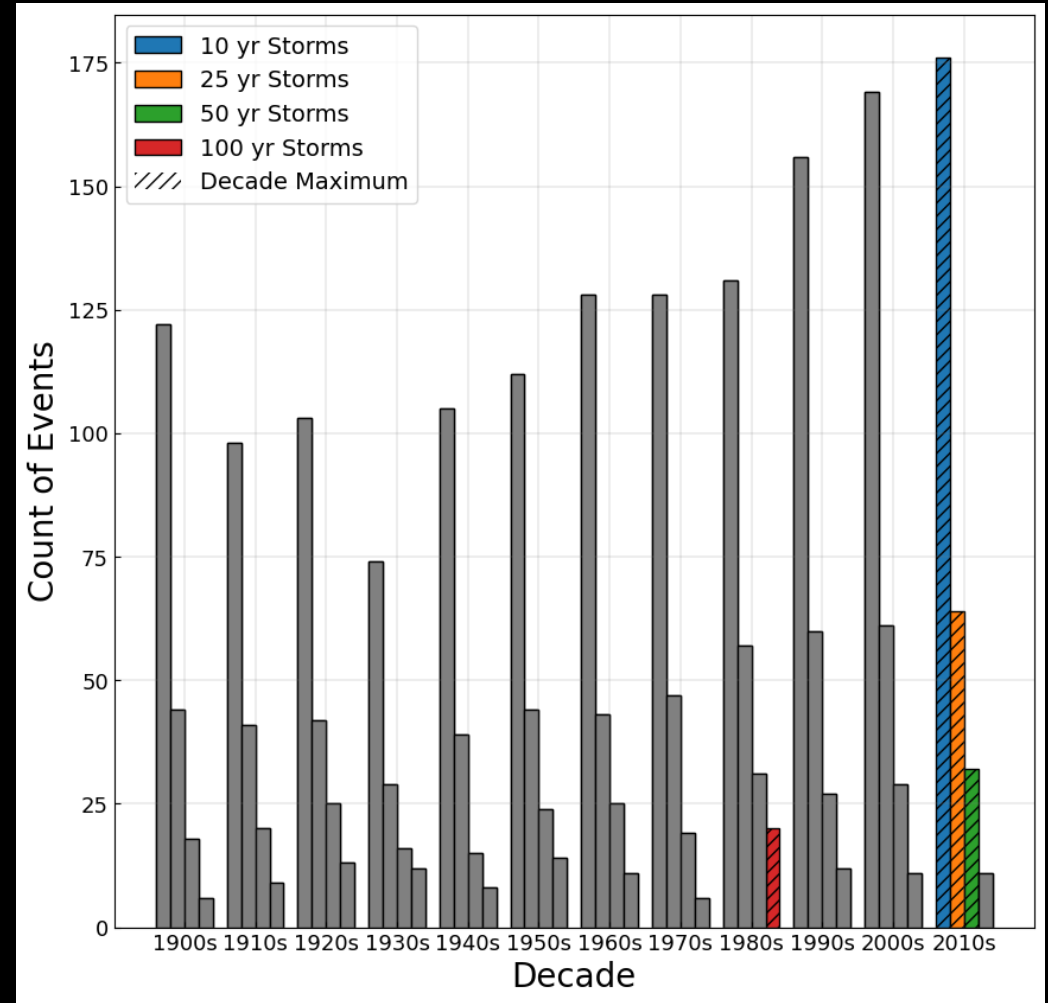
Source: Kenneth Kunkel, Cooperative Institute for Climate and Satellites, North Carolina State University and NOAA NCDC

CLIMATE  CENTRAL

Climate Central: <http://104.130.239.126:8080/gallery/maps/extreme-precipitation-events-are-on-the-rise>

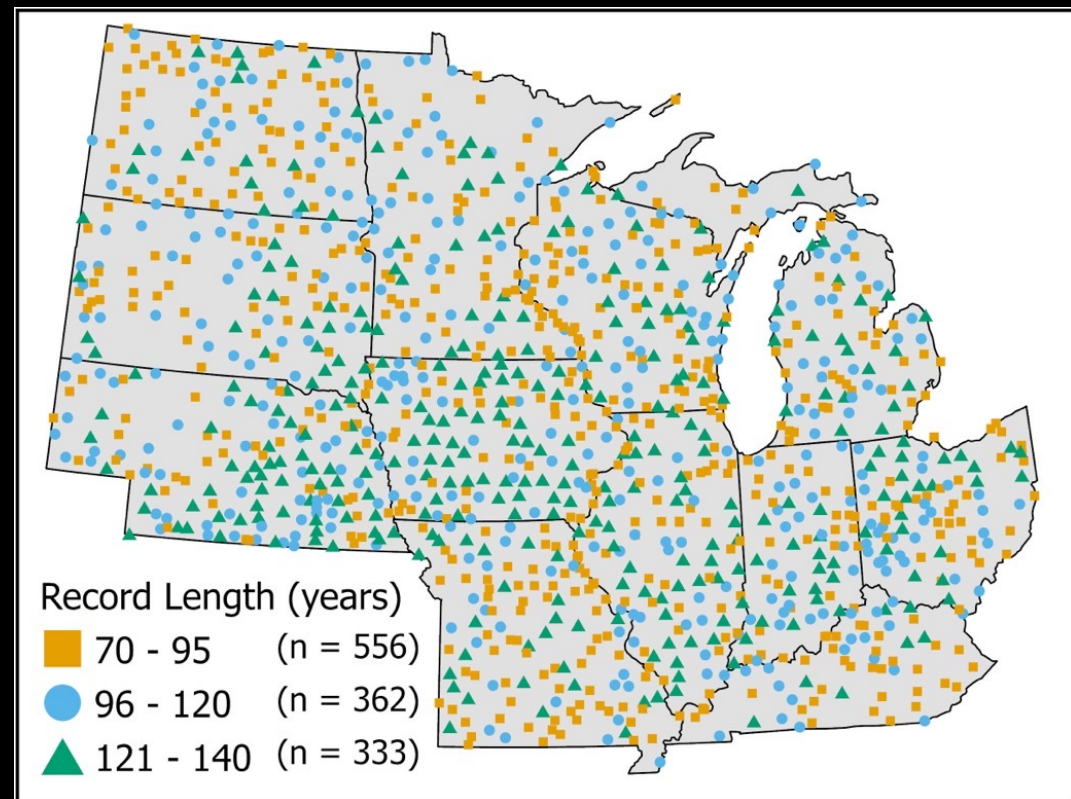
Background

- Large Storms pose Flood Risks for Urban Areas
 - Impervious Cover
 - Concentrated Population
- More Frequent Large Storm Events



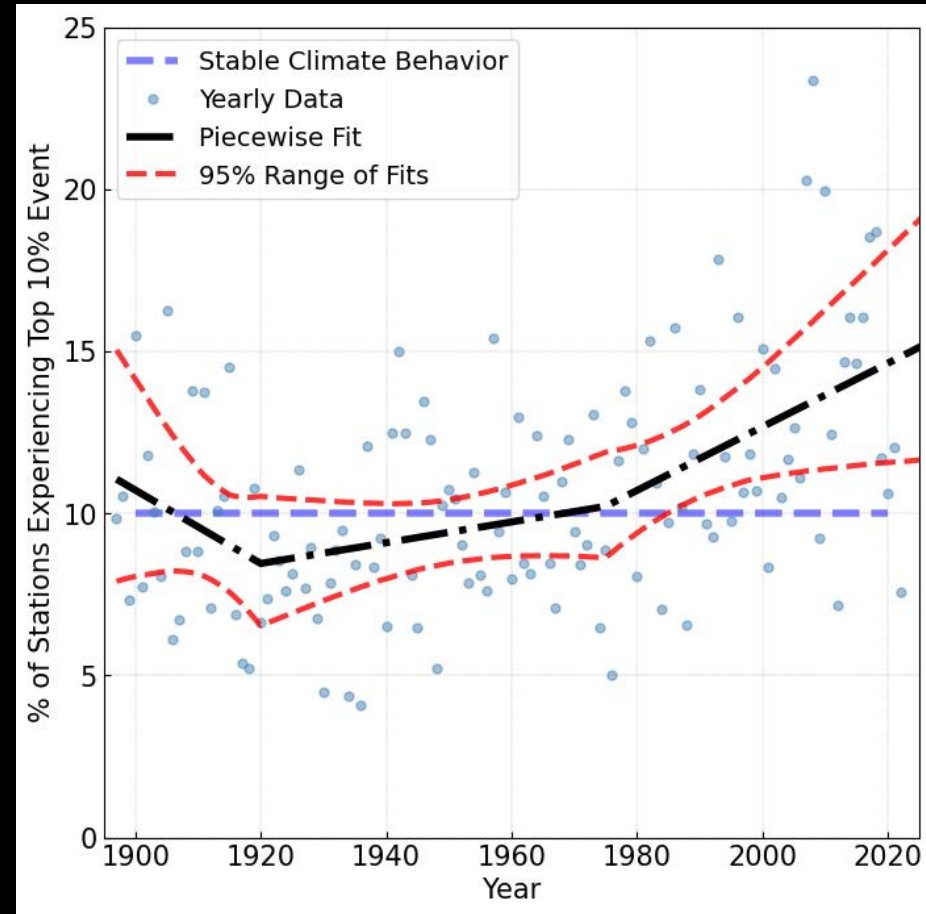
Data

- NCEI Global Historical Climatology Network
 - Daily Records
- 1,251 Stations
 - Minimum 70yr Record
 - Avg. 102yr Record



Plot 10-year events Interpret the Results

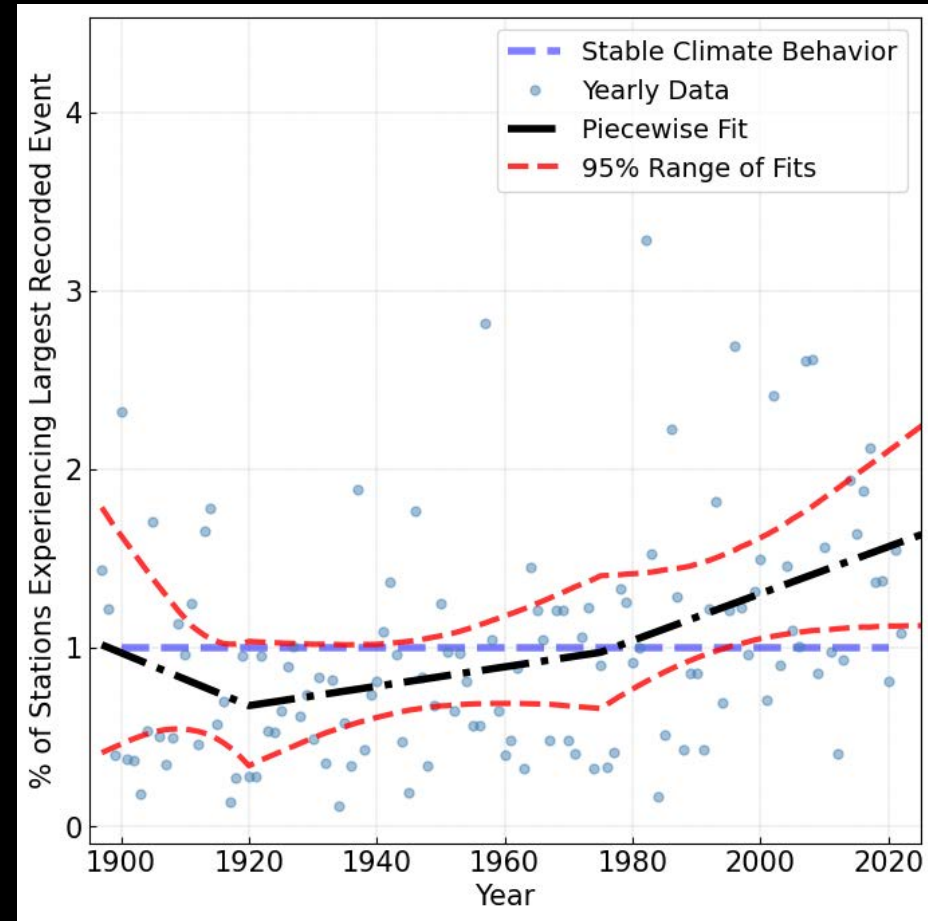
- 10th Percentile Events
Approximates the 10yr Storm
- '10yr depth' occurring ~15%
of stations in 2024 → 7yr
Storm



Plot 100 yr events

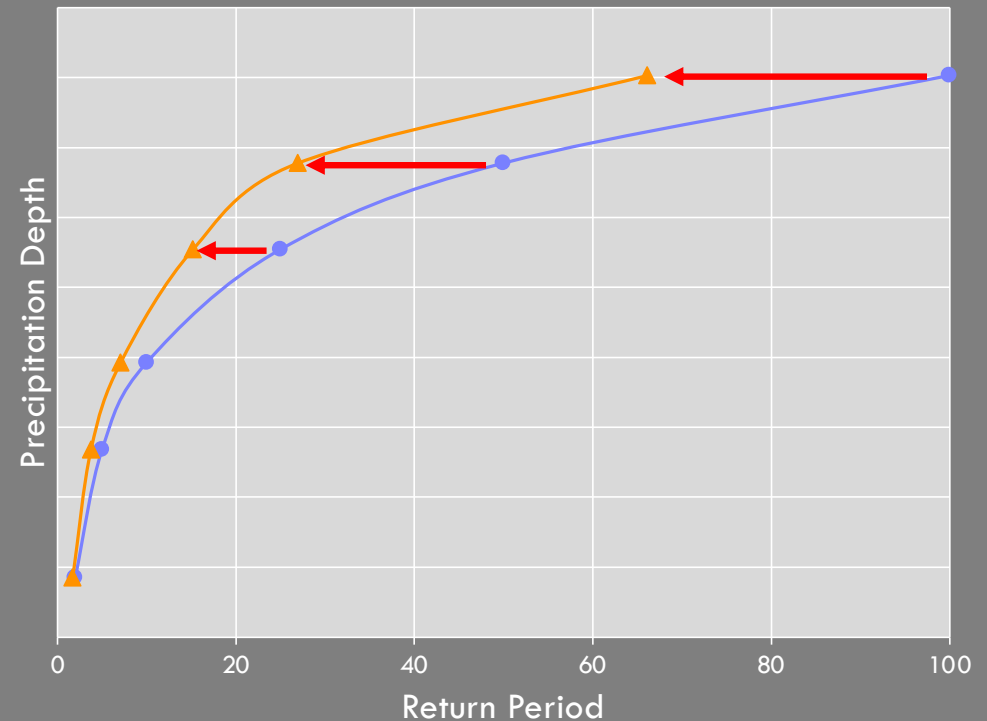
Interpret the Results

- Largest Events Approximates the 102yr Storm
- Largest Event on Record occurring $\sim 1.6\%$ of stations in 2024
- 102yr \rightarrow 62.5yr Storm



Interpreting the Results

- Intensity – Duration – Frequency Curves
- **Greater Frequency** results in **Greater Depths** for smaller return period storms



Stormwater Adaptation Strategies

We ran:

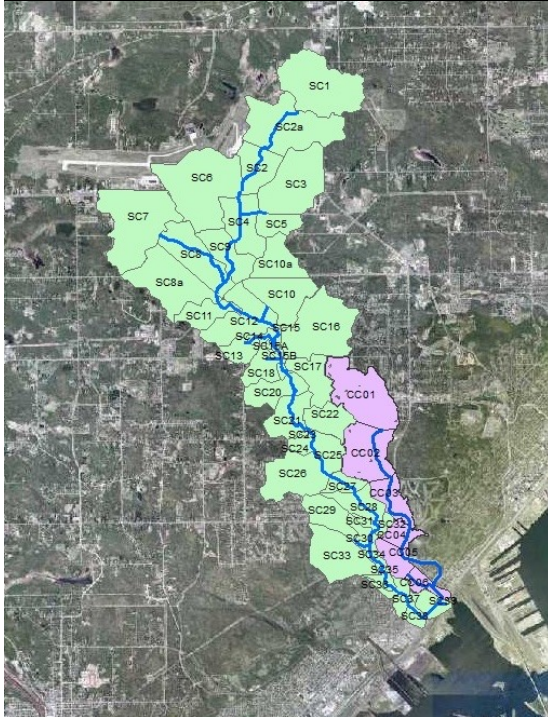
- Current MSE3 Design Storm (similar to Type 2) in SWMM through three watersheds

We considered:

- Existing Infrastructure
- More Ponds (a.k.a. Storage)
- Smart Ponds (Storage)
- Green Infrastructure
- Bigger Pipes

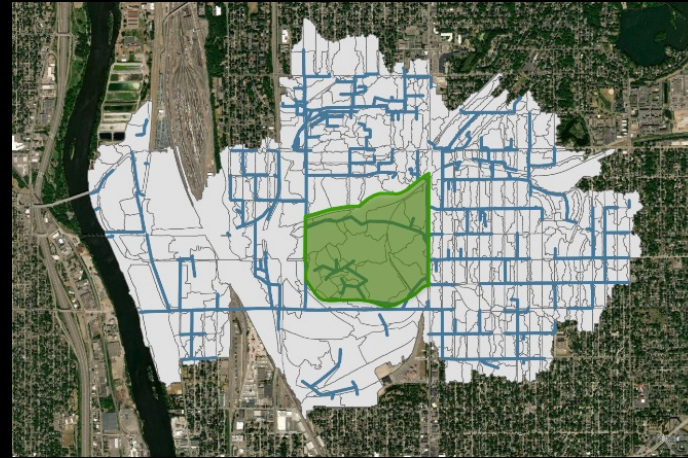
Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

Modeled Watersheds



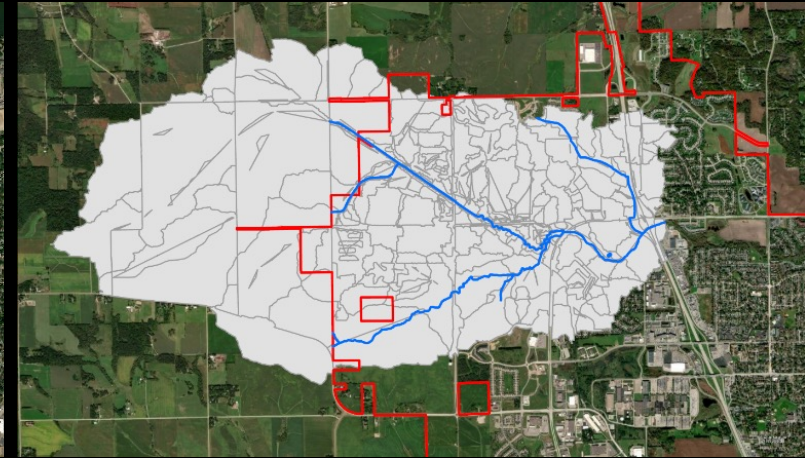
Duluth's Miller Creek

~10 square miles (6,400 acres)
23% impervious



Minneapolis's 1NE

~3.25 square miles (2,100 Acres)
47% impervious



Rochester's Kings Run

~8.75 square miles (5,600 Acres)
17% impervious

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

Stormwater Adaptation Strategies

1. Baseline: Existing stormwater infrastructure: Ponds treating

1. ~50% connected impervious surface (Duluth),
2. ~11% connected impervious surface (Minneapolis),
3. ~40% connected impervious surface (Rochester)

2. Extra Ponds: new stormwater ponds were installed for untreated connected impervious (i.e., 100% connected impervious treated by ponds)

3. Infiltration: infiltration basins (aka **green infrastructure**) were installed for untreated connected impervious

4. Smart Ponds: existing stormwater ponds retrofit to be 'smart'

5. More Smart Ponds: combination of extra ponds (#2) and smart ponds (#4)

6. Pipe Upsizing: increase existing conduits' cross-sectional area by 30%

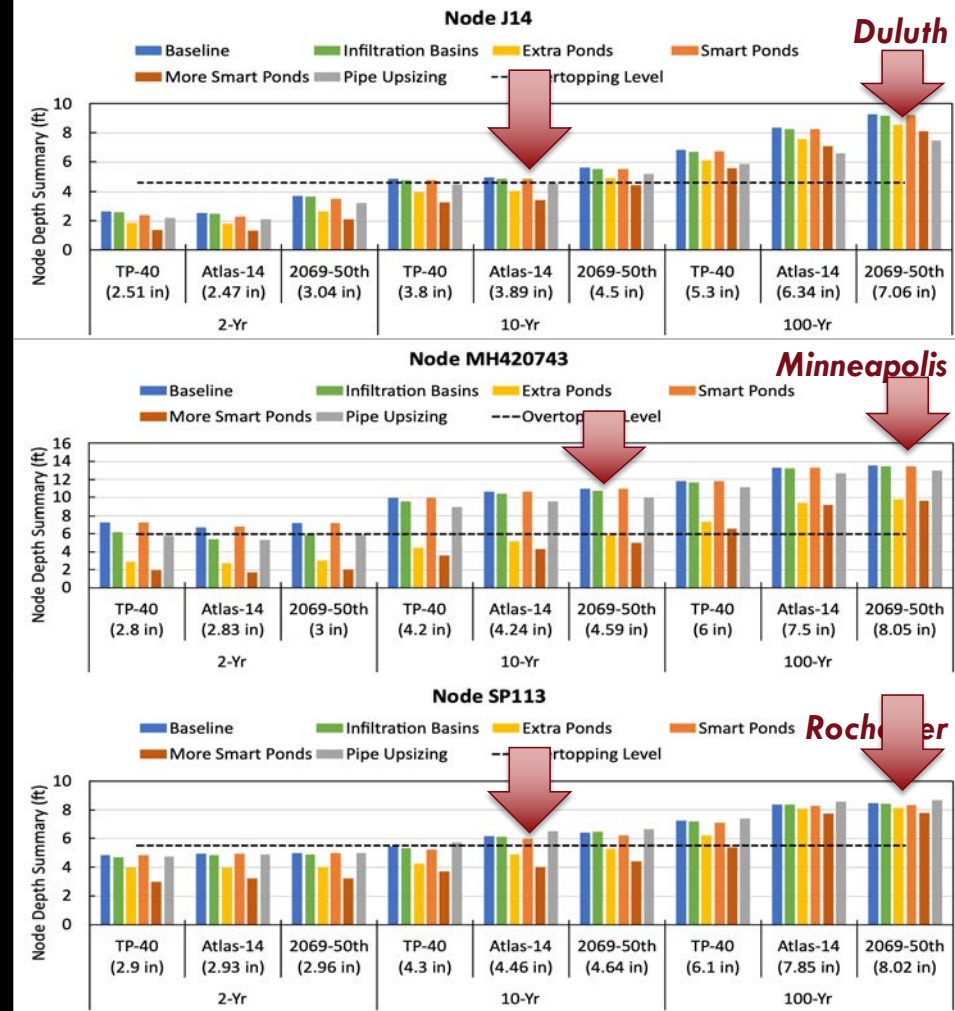
Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

Adaptation Strategies Results

Node Depth (aka flood depth)

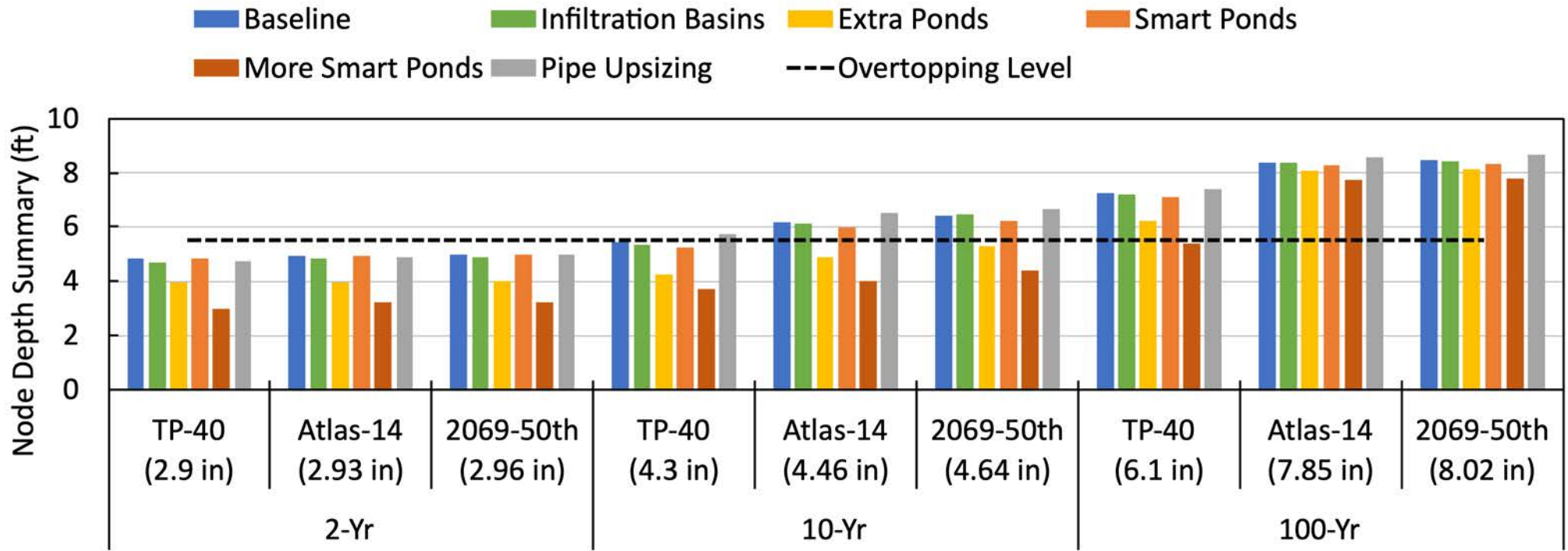
- Many points in all three watersheds predicted to flood for 10-yr or greater storms
- **More Smart Ponds** > Extra Ponds > Converting Existing to Smart Ponds > all the other options
- There is **not** much flooding help with a 100-yr event

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>



Rochester

Node SP113



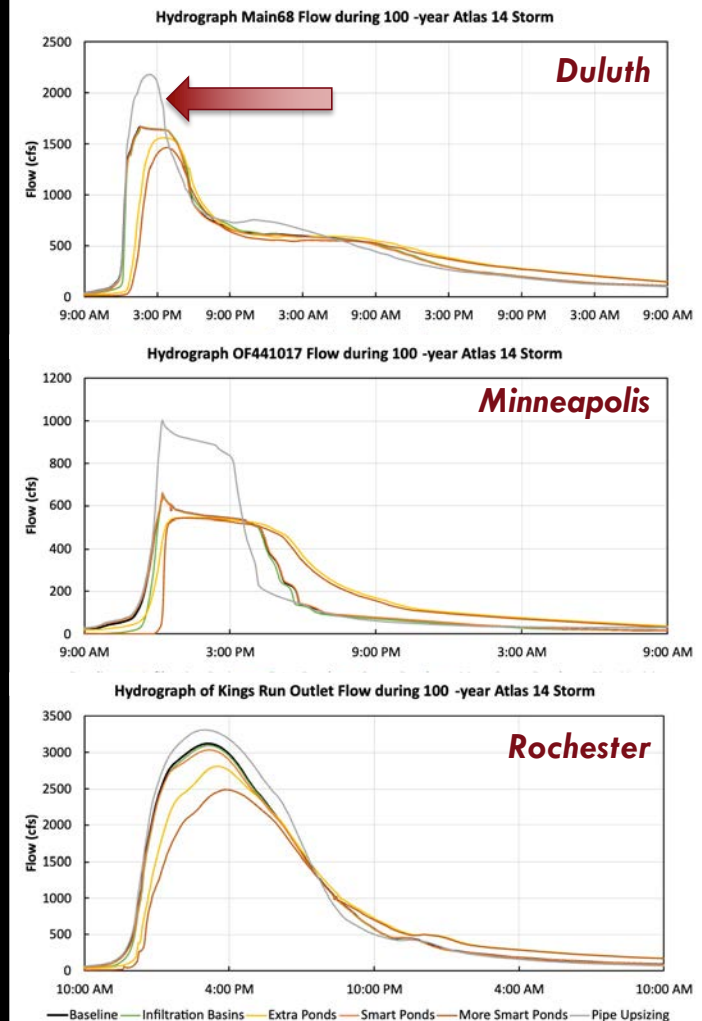
Pipe Upsizing DIDN'T reduce flooding

Adaptation Strategies Results

Hydrographs (aka peak flow and timing)

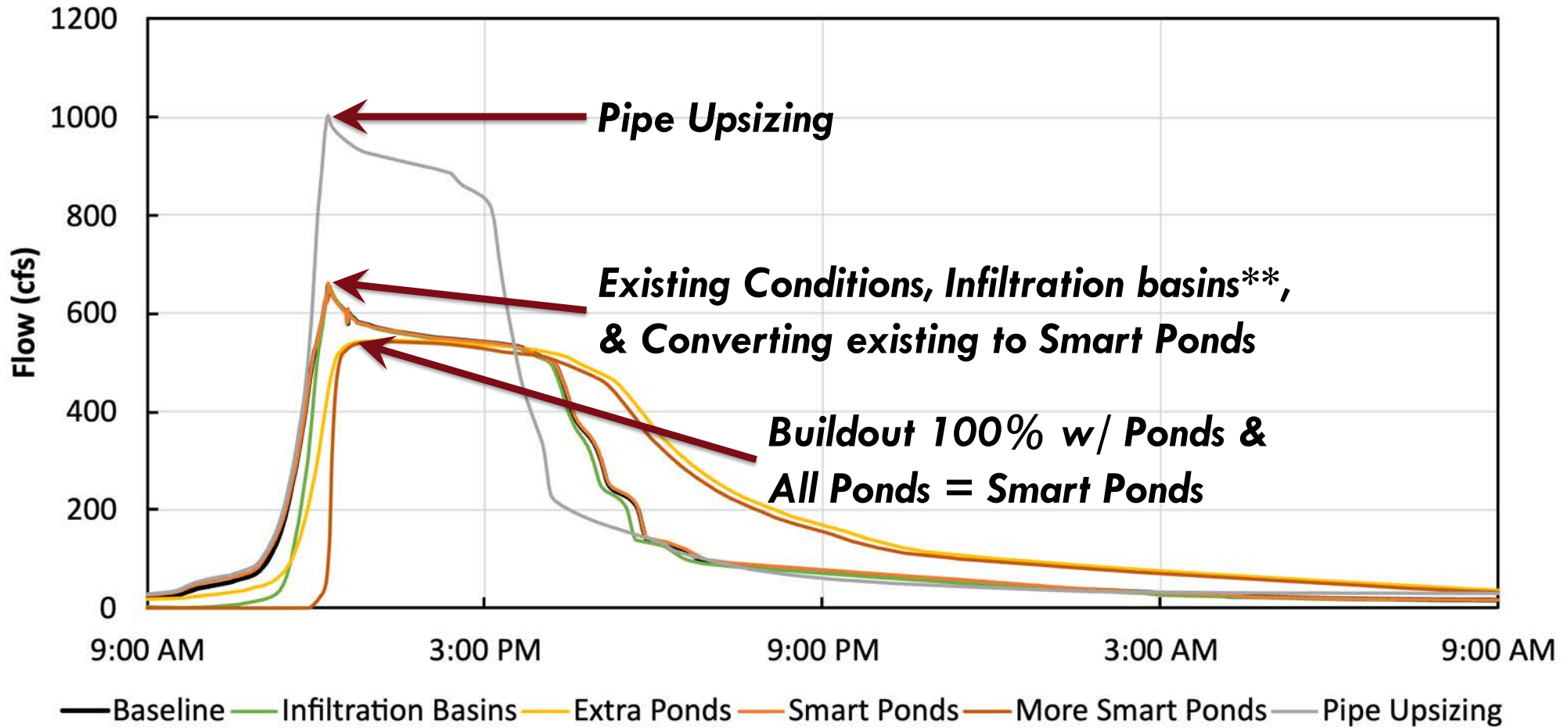
- Pipe upsizing increases the peak flow by ~30%

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>



Minneapolis

Hydrograph OF441017 Flow during 100 -year Atlas 14 Storm

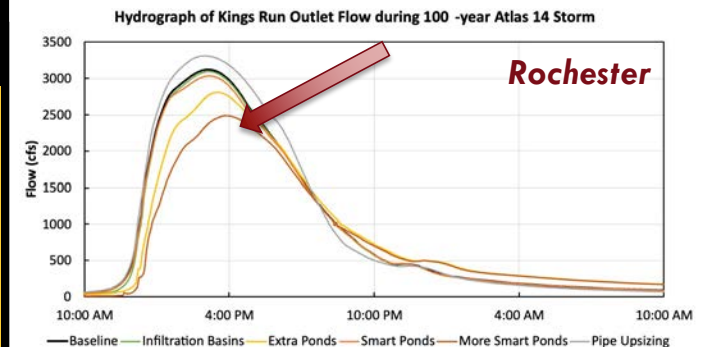
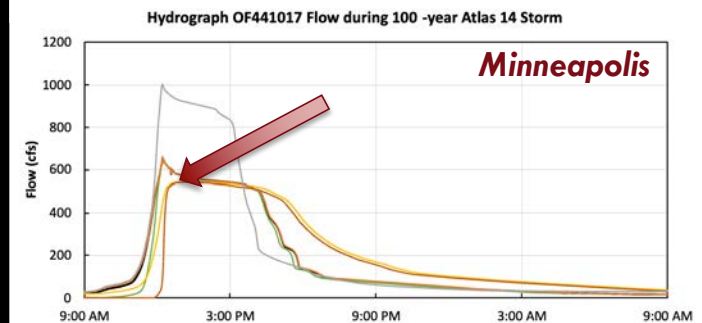
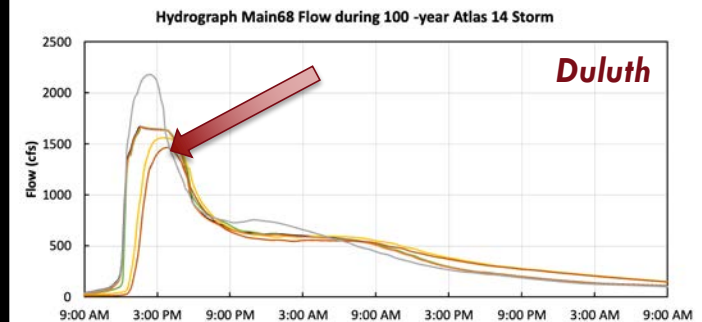


Adaptation Strategies Results

Hydrographs (aka peak flow and timing)

- Pipe upsizing increases the peak flow by ~30%
- Extra Storage & More Smart Storage **delay** and **reduce** the peak flow

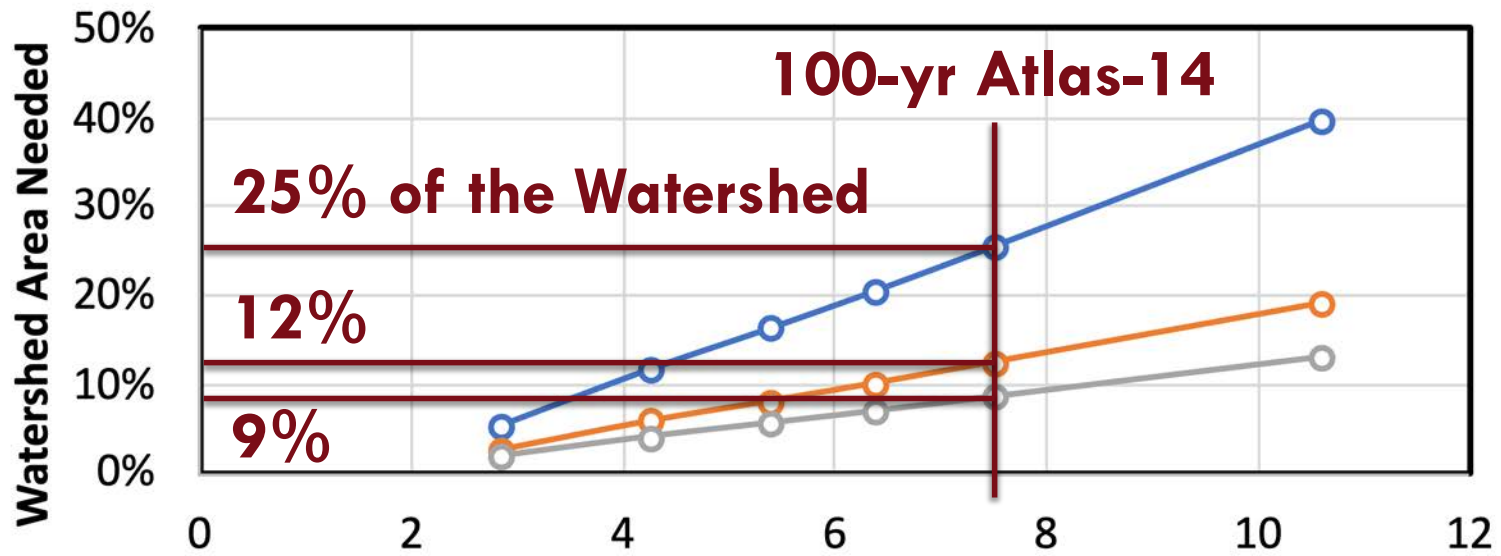
Conventional Design Is NOT ENOUGH To Prevent Flooding!



What would it take? (aka Future-Proof)

b)

Minneapolis 1NE



Typical Stormwater Design = 1-5% Watershed Area

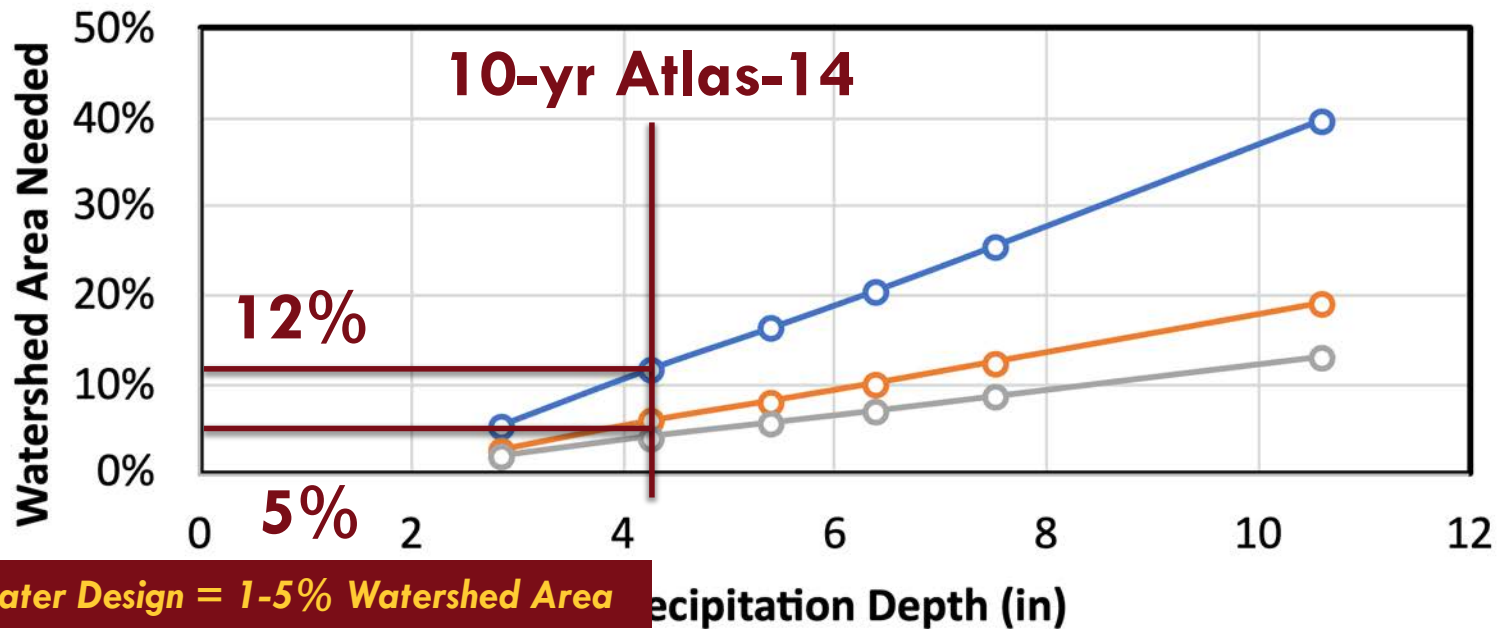
—○— Infiltration Basins —○— Extra Ponds —○— More Smart Ponds

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

What would it take? (aka Future-Proof)

b)

Minneapolis 1NE



—○— Infiltration Basins —○— Extra Ponds —○— More Smart Ponds

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

Comparisons & Implications

Flood mitigation: Most to Least effective strategies for reducing node depth, flood duration, and peak flow

1. **More Smart Ponds** (*all impervious treated by smart ponds*)
2. **Extra Ponds** (*all impervious treated by not smart ponds*)
3. **Underground Storage** (*same as extra ponds, but underground*)
4. **Smart Ponds** (*retrofit existing ponds to be smart*)
5. **Infiltration Basins** (*aka green infrastructure*)
6. **Baseline** (*aka keep existing conditions*)
7. **Pipe Upsizing**

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023

Summary Comparisons & Implications

Flood mitigation

1. More Smart Ponds
2. Extra Ponds
3. Underground Storage
4. Smart Ponds
5. Infiltration Basins
6. Baseline
7. Pipe Upsizing

- What about Cost?

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023

Cost Comparison for all watersheds

Strategy	Number Added	Total Cost (\$ Million)
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NOTES: 20-year lifecycle Cost. All costs exclude land costs

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023



Cost Comparison for all three watersheds

Strategy	Number Added	Total Cost (\$ Million)
Baseline	(O&M)	\$1.9 – \$7.6 M
Smart Ponds	16 – 62 (retrofit)	\$5.2 – \$19.2 M
New Ponds	74 – 180	\$19.6 – \$49.7 M
More Smart Ponds	16 – 62 Retrofit + 74 – 180 New	\$47.7 – \$120 M
Rain Gardens (10k s.f.)	127 – 241	\$74.3 – \$152.4 M
Pipe Upsizing	(various)	\$53.9 M – \$256.6 M

NOTES: 20-year lifecycle Cost. All costs exclude land costs

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023

Summary Comparisons & Implications

Flood mitigation

1. More Smart Ponds
2. Extra Ponds
3. Underground Storage
4. Smart Ponds
5. Infiltration Basins
6. Baseline
7. Pipe Upsizing

Considering Cost

1. Baseline
2. Smart Ponds
3. Extra Ponds
4. Pipe Upsizing
5. More Smart Ponds
6. Infiltration Basins
7. Underground Storage

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023

Is our Modeling Correct?

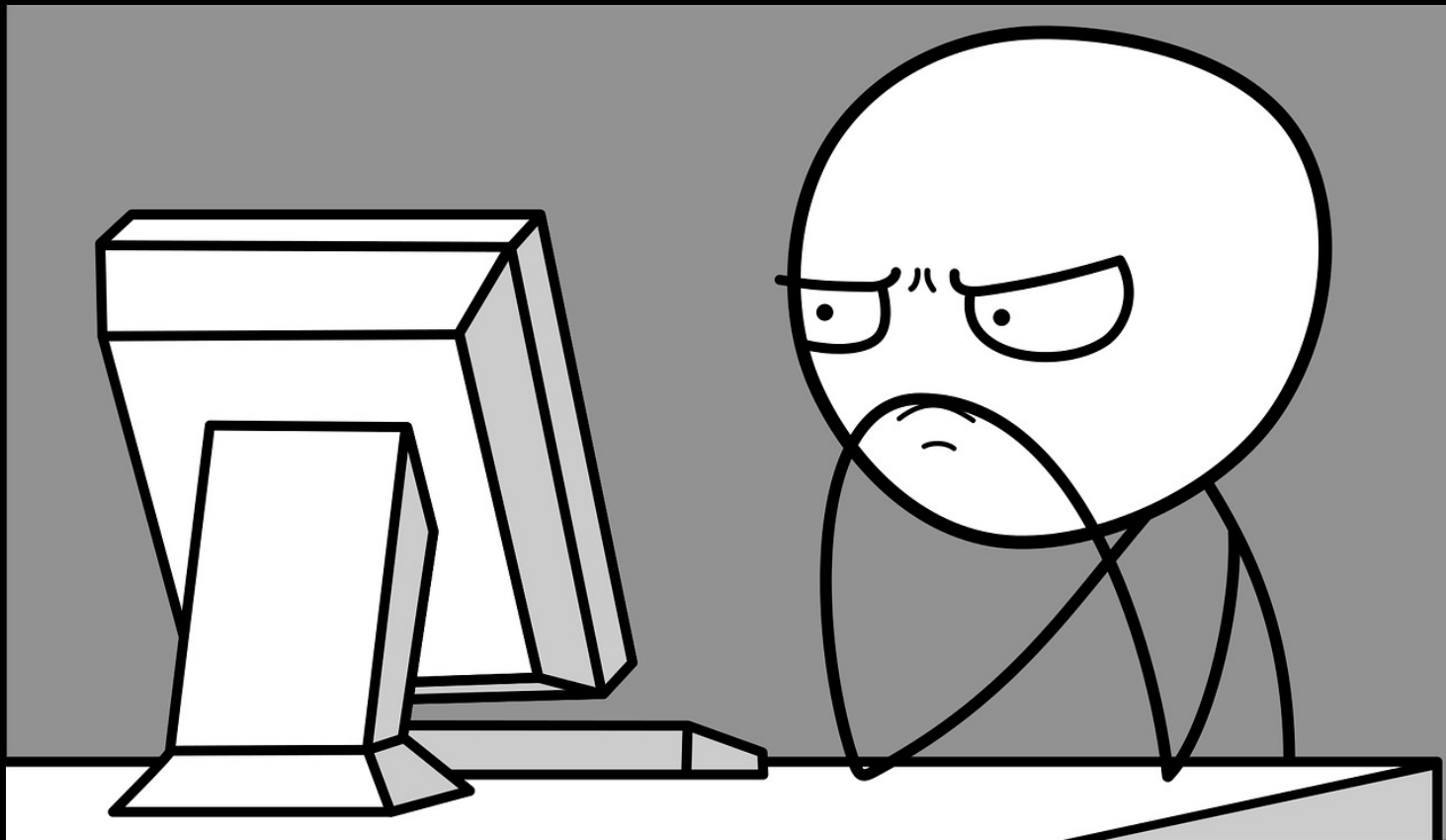


Image courtesy: <https://bcacademictchnology.wordpress.com/2020/11/05/basic-troubleshooting-faqs-from-the-renegade-hub/>

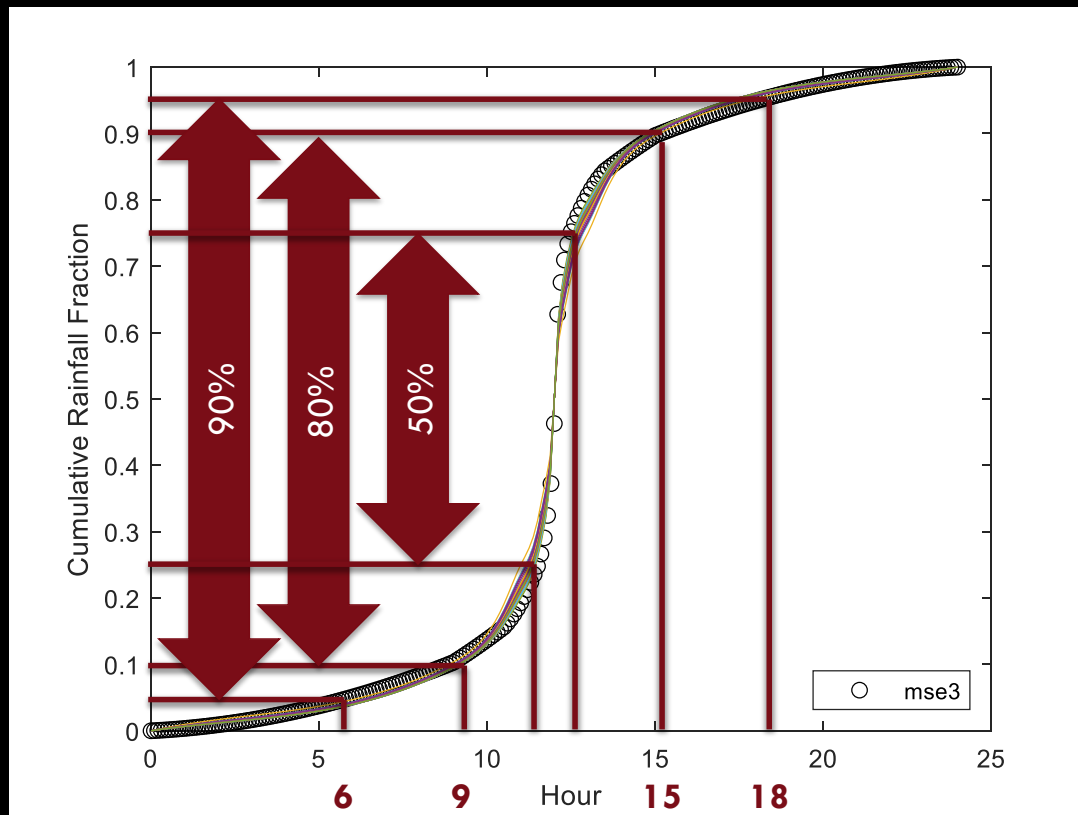
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MSE3 Influence of Rainfall Distribution



90% of rainfall occurs in ~12 hours

80% of rainfall occurs in ~6 hours

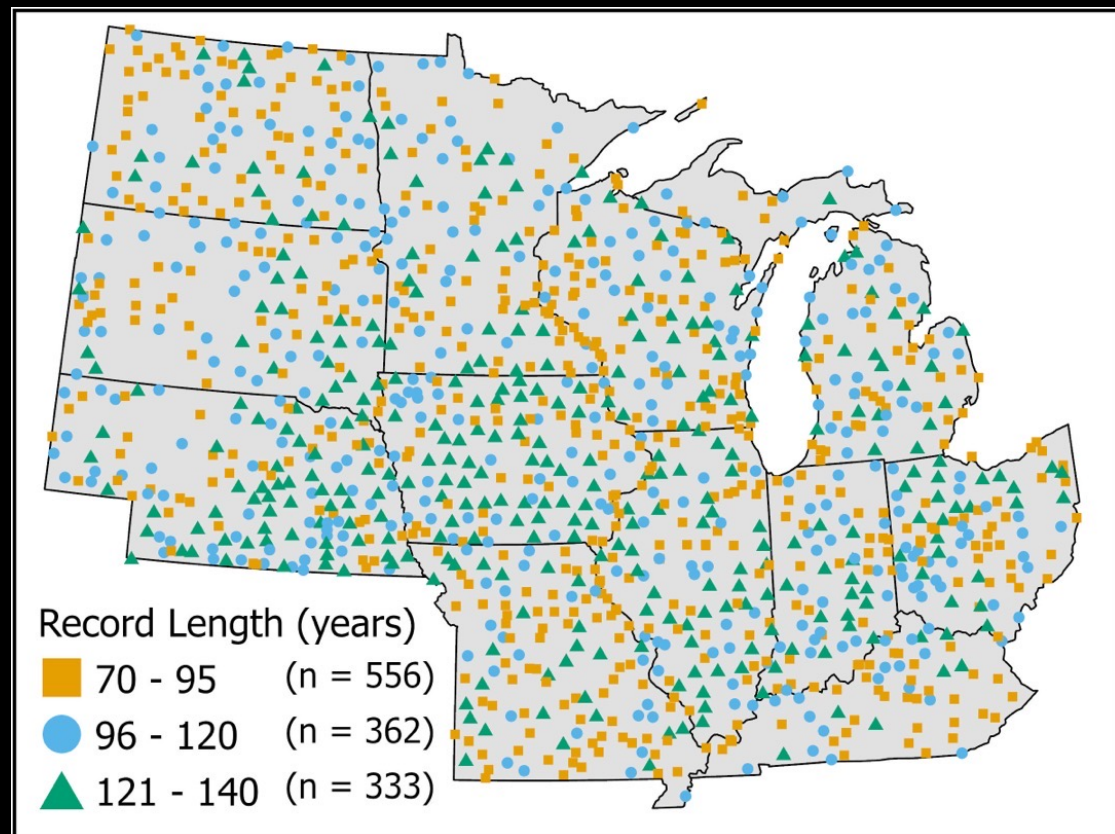
50% of rainfall occurs in ~1 hour

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

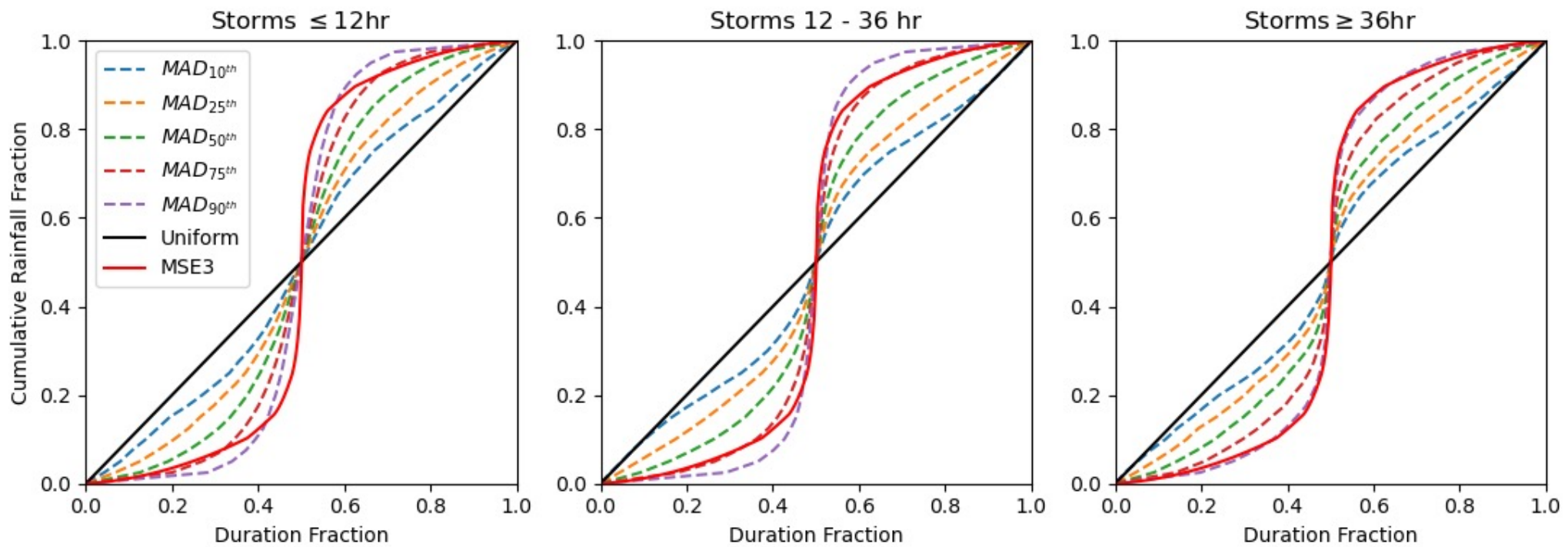
Let's Test the MSE3

Data

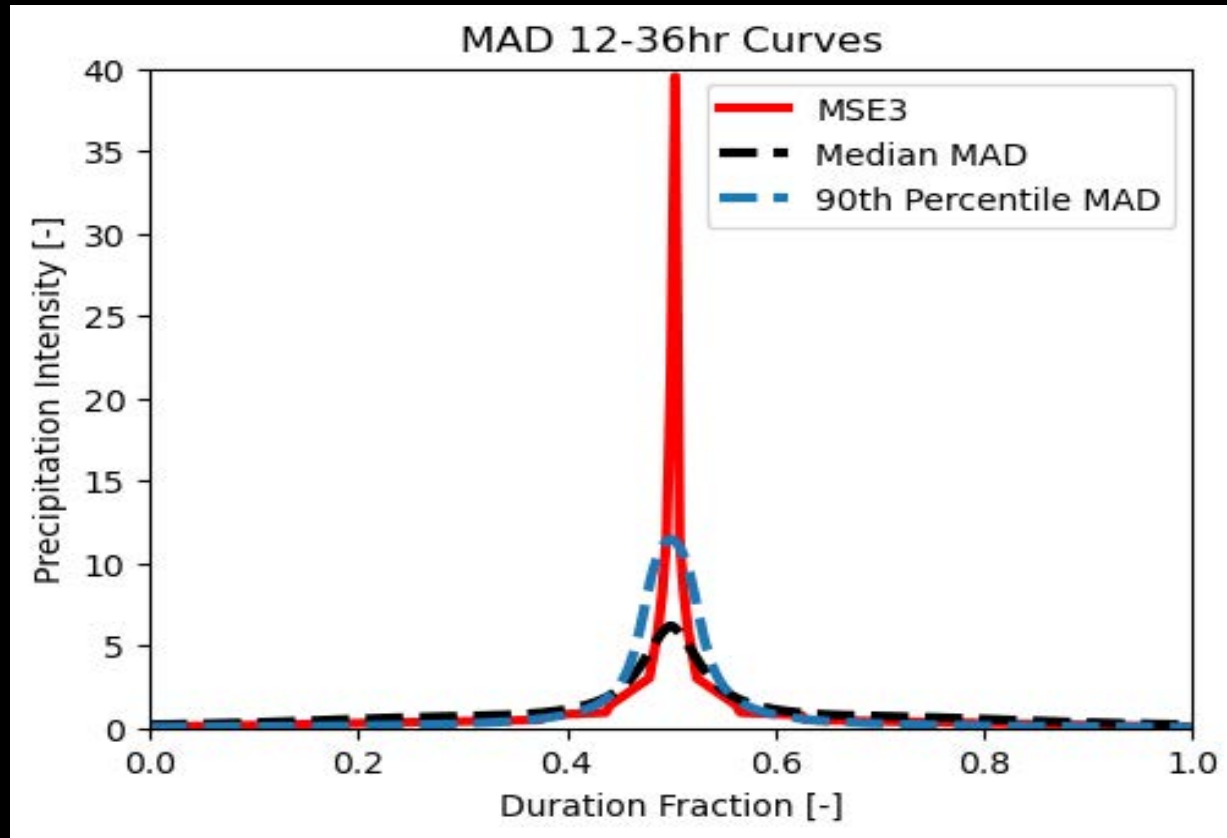
- NCEI Global Historical Climatology Network
 - Daily Records
- 1,251 Stations
 - Minimum 70yr Record
 - Avg. 102yr Record



Minimum Duration of Accumulation (MDoA) Derived Storm Curves

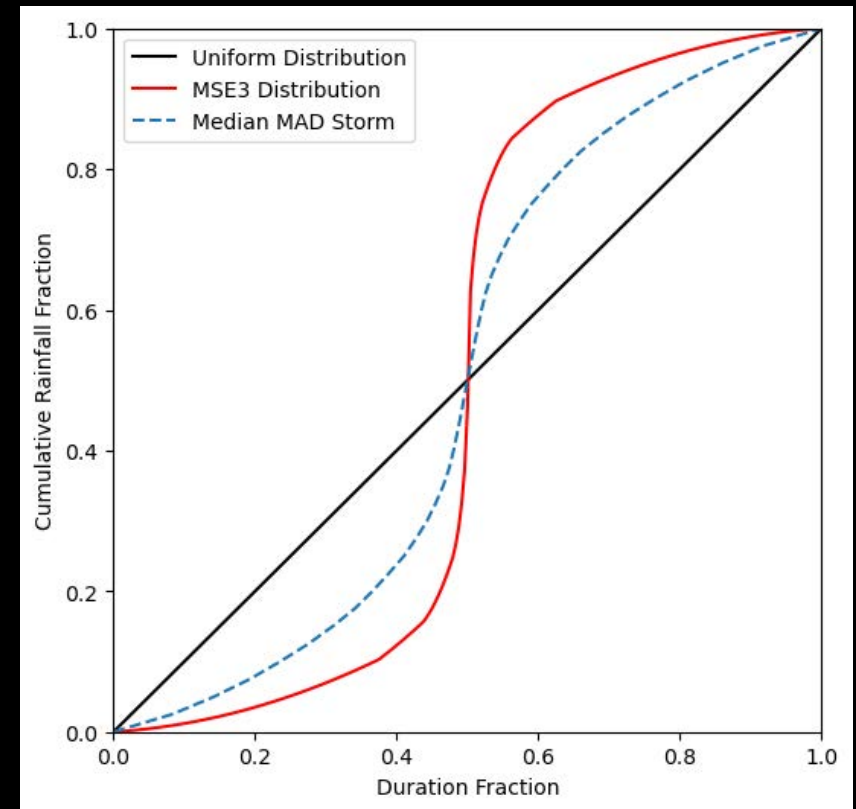


Comparison of Precipitation Intensity



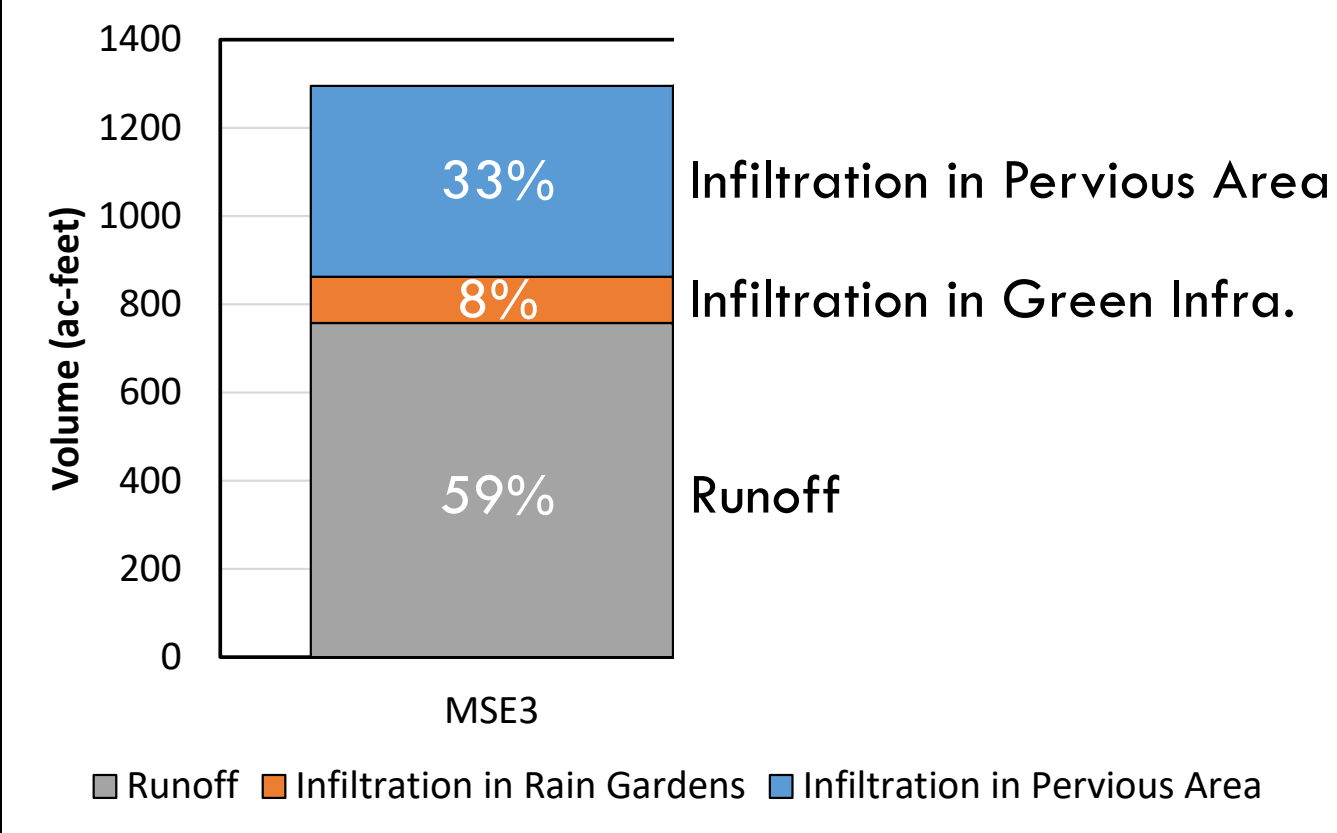
Why Use an MDoA Derived Storm?

- Lower Risk Circumstances
 - Low Risk to Life
- Infiltration Applications
 - Intensity Sensitive
- Water Quality Modeling
 - Contact Time
- Ensemble Modeling
 - Risk Evaluation



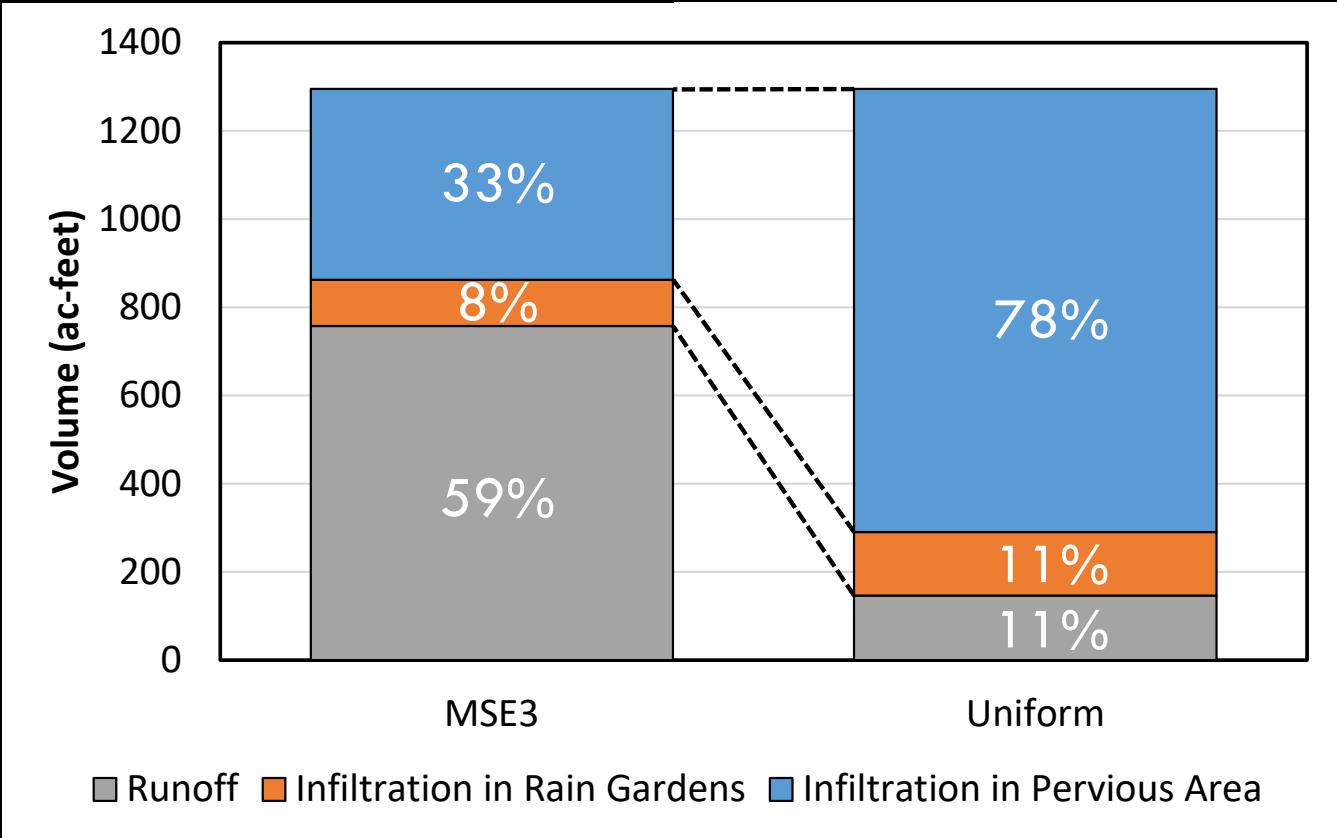
Influence of Rainfall Distribution

24 hr Duration
100 yr Storm
Minneapolis NE1
Watershed



Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

Influence of Rainfall Distribution



+132% infiltration in pervious areas

+37% infiltration in rain gardens

-81% Runoff

Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

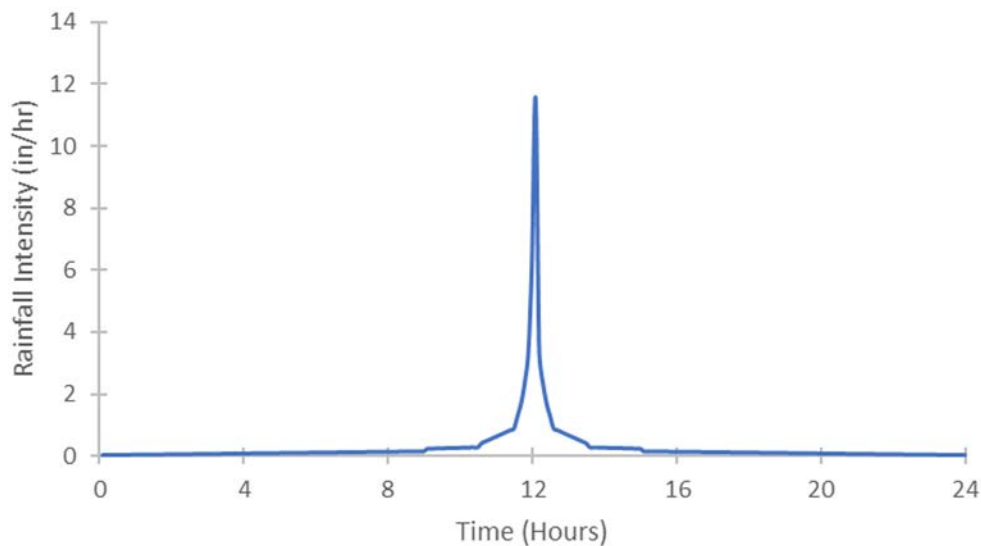
Example: 2012 Duluth Storm

- High monetary damage
 - >\$100 Million
- Rainfall occurred over 2 days



Comparison of MSE3 and Duluth Real Storm

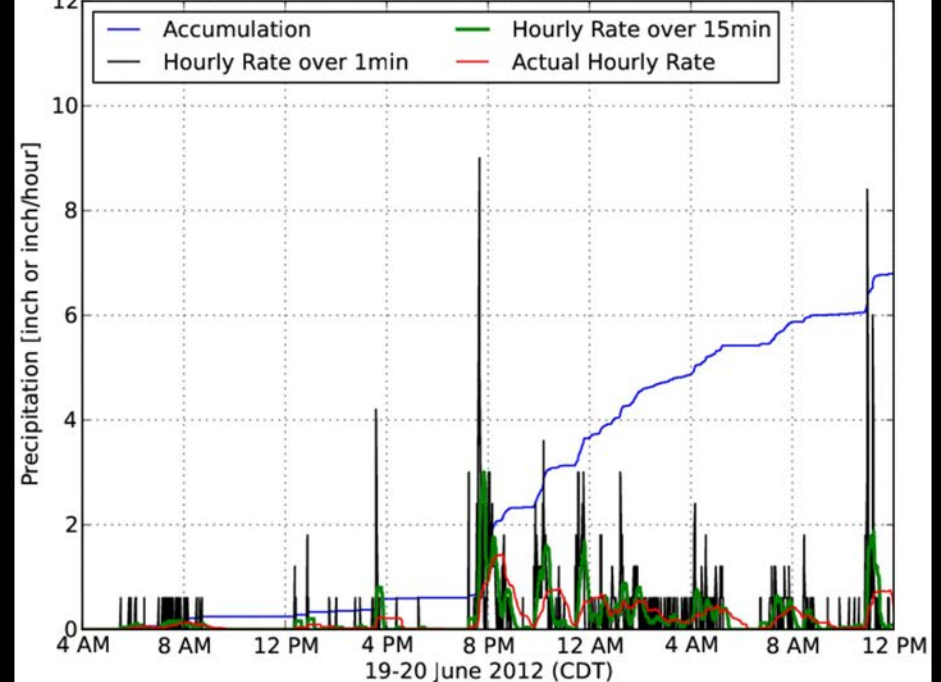
Precipitation Intensity of a 7-inch event following the MSE3 24-Hour Storm Distribution



Design Storm = MSE3 Distribution

- Single Intense Peak
- 80% of Rain in 6 hours; 50% in 1 Hour

19-20 June 2012 Duluth, MN (KDLH) One Minute Rainfall



Source: Daryl Herzmann, https://www.weather.gov/dlh/june2012_duluth_flood

Real Storm = 2012 Duluth Storm Distribution

- Multiple Intense Peaks over 2 days
- Longer duration, antecedent dry time, low intensity

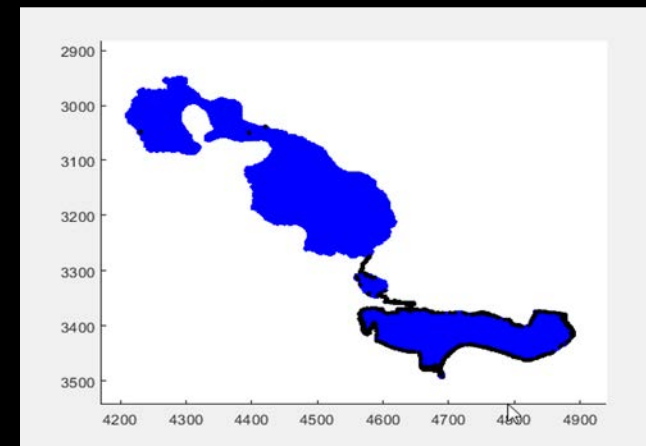
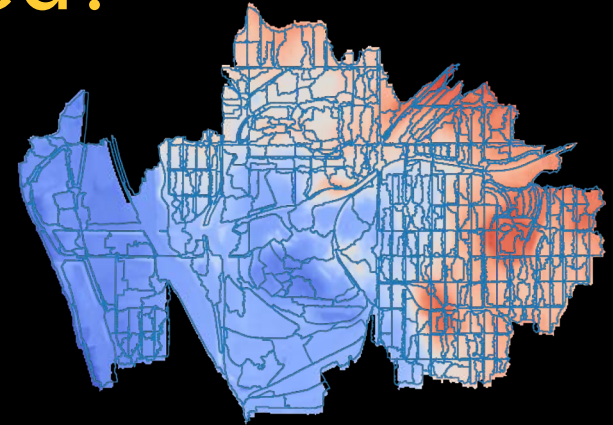
What have we learned?

Model Caveats:

- Current models were **not calibrated for large, low frequency, extreme events** (surface storage, routing, and flood depth)
 - good relative comparison, not predictive accuracy
- **Overland flow paths misrepresented** in existing models (see previous bullet)
 - current research into GIS tools to improve surface storage and routing

But, we have learned:

- **Type II and MSE3 disadvantages the benefits of pervious infiltration and green infrastructure**

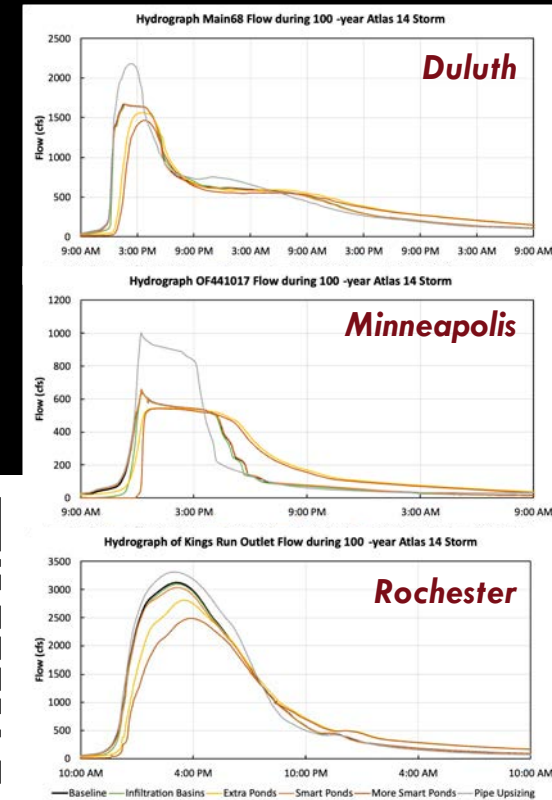


Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>

What have we learned?

Adaptation Strategies

- Current design philosophy is not sufficient to prevent flooding from 10-year and larger design storm events
- Overall most cost-effective climate change adaptation strategy = more storage for untreated impervious surfaces
- Property in fully developed watersheds for new stormwater infrastructure may be costly
- Smart storage does not require new land → relatively low-cost alternative for watersheds with existing storage systems



Erickson et al., (2023). "Climate Change Adaptation of Urban Stormwater Infrastructure." MnDOT Report no. MN 2023-21, Minneapolis, MN. June 2023. <https://z.umn.edu/climate-adaptation>


Stormwater UPDATES Newsletter



Stormwater UPDATES

Climate Change Adaptation of Urban Stormwater Infrastructure

Three Case Studies of Stormwater Infrastructure in Minnesota Watersheds




In June 2023, we released a report of interest to stormwater managers in Minnesota. Using past, present, and future climate model-based predictions, along with population growth predictions, we analyzed the current stormwater management infrastructure of three urban watersheds in Minnesota to see how they would hold up in future "peak flooding" events.

Our intention was not to develop specific adaptation plans for Minneapolis, Duluth, and Rochester, but to generate guidelines for Minnesota watersheds in general as we face climate

Stormwater UPDATES

Minnesota Stormwater Seminar Series: Defining the footprint of sediment in green stormwater infrastructure

Please join us THIS WEEK **in person or online** on **December 14, 2023 at 10am CST** for the next Minnesota Stormwater Seminar Series event - a monthly experience featuring national, state, and local experts on stormwater and green infrastructure. This seminar series is a partnership between the University of Minnesota's St. Anthony Falls Laboratory and Water Resources Center, and the Minnesota Pollution Control Agency, and made possible through the Minnesota Stormwater Research and Technology Transfer Program in collaboration with the Minnesota Stormwater Research Council.



Title: Defining the footprint of sediment in green stormwater infrastructure

Speaker:

- **Dr. Virginia Smith**, Associate Professor of Civil and Environmental Engineering and a principal investigator in the Villanova Center for Resilient Water Systems, Villanova University.

Invited Panelists:

- **Ab Fleming**, Sustainable Landcare Manager + Lead Trainer, Metro Blooms

Stormwater UPDATES

Upcoming Stormwater Conferences, Presentations, Workshops, and Webinars




Photo Courtesy: ASCE EWRI

We hope you can join us at any (or all) of the upcoming knowledge transfer events over the next few months! The following is a list of events at which stormwater and water

Stormwater UPDATES

How to Grow Plants in Biofiltration Basins while Minimizing Phosphorus in Runoff



When seeking to solve problems caused by built environments, mimicking natural environments is a logical way to go. For example, we look to plants—especially native species with their deep root systems—to help control erosion and filter contaminants in urban biofiltration basins. But the organic materials (compost) needed for plants to thrive can actually increase phosphorus in runoff, leading to harmful algae blooms (HABS) in our lakes.

Signup at <https://stormwater.safl.umn.edu/>

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Minnesota Stormwater Seminar Series

YouTube Channel: <http://z.umn.edu/swsrecord> or
<https://www.youtube.com/@MNStormwaterSeminar/videos>



Past National Speakers:



...and more to come!

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Thanks for your attention! Questions?

John Gulliver gulli003@umn.edu



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