IMPLICATIONS OF PRECIPITATION CHANGES IN SOUTHEAST MICHIGAN AND OPTIONS FOR RESPONSE: A GUIDE FOR MUNICIPALITIES

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IMPLICATIONS OF NOAA ATLAS 14: PRECIPITATION-FREQUENCY ATLAS OF THE UNITED STATES FOR STORMWATER MANAGEMENT

Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a summary of a new precipitation frequency analysis that improves design storm definitions to reflect the full historical record of precipitation data.

What is it?

NOAA's Hydrometeorological Design Studies Center has updated precipitation frequency estimates (with 90% confidence intervals) for Michigan in Volume 8 of NOAA Atlas 14[1]. This analysis, released in 2013, incorporates precipitation data through 2011 and utilizes more data from more weather stations than previous efforts. Event storms have changed in magnitude with implications for stormwater management. The Atlas is now the official U.S. Government source of precipitation frequency estimates.

What does it replace?

Currently within Michigan, rainfall depth-frequency data used in stormwater management comes from table 3.1 in *Computing Flood Discharges for Small Ungaged Watersheds*[2] provided by the Michigan Department of Environmental Quality (MDEQ). This table uses data from the *Rainfall Frequency Atlas of the Midwest*[3], more commonly known as Bulletin 71 – a NOAA publication from 1992. Over the next several years, MDEQ will be revising storm definitions based on data from NOAA Atlas 14 which will become the standard for relevant regulation, permits and recommended best practices. However, municipalities can start making stormwater management and infrastructure decisions based on the improved data today.

What is different?

The primary differences between Atlas 14 and Bulletin 71 are; 1) the inclusion of the most recent 30 years of precipitation data, and 2) the number of stations included in the analysis. Atlas 14 also provides estimates of 500-yr and 1000-yr events. In Southeast Michigan, all storm event definitions have *increased* in depth. Twenty four weather stations in Southeast Michigan were used in the analysis. NOAA has not aggregated data into regions. Instead data is accessed by station. Below is a table for the Ann Arbor station to illustrate the change in storm event size between Atlas 14 and Bulletin 71.

Ann Arbor precipitation totals from Bulletin 71 and Atlas 14 (Bulletin 71/Atlas 14) in inches, for various design storms along with percent change between the two in brackets. All percent change values are positive which means they are larger in Atlas 14. (*Ann Arbor station data is used throughout this resource kit as an example of how precipitation patterns are changing in southeast Michigan because of the quality of data records. Please consult NOAA Atlas 14 for additional data*.)

	1-Yr	2-Yr	5-Yr	10-Yr	25-Yr	50-Yr	100-Yr
1-hr	0.88/0.969 [10%]	1.06/1.14 [8%]	1.29/1.44 [12%]	1.47/1.70 [16%]	1.69/2.07 [22%]	1.87/2.38 [27%]	2.05/2.69 [31%]
12-hr	1.63/1.82 [12%]	1.97/2.06 [5%]	2.39/2.50 [5%]	2.72/2.90 [7%]	3.13/3.54 [13%]	3.46/4.09 [18%]	3.79/4.68 [23%]
24-hr	1.87/2.09 [12%]	2.26/2.35 [4%]	2.75/2.83 [3%]	3.13/3.26 [9%]	3.60/3.93 [9%]	3.98/4.50 [13%]	4.36/5.11 [17%]

Where can I access the report and data?

NOAA has created a point-and-click website providing access to reports, data, and GIS and cartographic maps (http://hdsc.nws.noaa.gov/hdsc/pfds). The Precipitation Frequency Data Server is a public portal that allows users to download precipitation frequency-depth data in various formats via a map interface or manual selection of location. Data are available in tabular and graphical formats. Temporal distributions of heavy rainfall and annual exceedance probabilities are also available.

How can it be used?

Using the best available information for the management of stormwater will increase the useful life of infrastructure and protect communities and water resources from unnecessary risk. The increase in volume of rain falling in most design storms has real consequences for the capacity of stormwater systems. Practitioners (e.g. municipalities and counties) need to start accounting for these changes. Atlas 14 can replace Bulletin 71 and Computing Flood Discharges for Small Ungaged Watersheds when making infrastructure sizing and design decisions for conveyance and detention. Local policy and regulations can be modified using the new storm definitions. New data can be used to redefine floodplains. Finally, the data can be used to communicate trends in rainfall that challenge conventional wisdom in the practice of stormwater management.

Summary

Precipitation Frequency estimates currently used for stormwater management do not accurately reflect the depths falling during precipitation events in southeast Michigan. In reality rainfall depths are greater (3 -32%) than what is being designed for, especially for the largest storms. Climate change projections indicate rainfall volumes will continue to increase. This has implications for how rainfall is managed. Atlas 14 provides improved storm definitions that will allow appropriate adjustments to stormwater management systems and elucidate trends in rainfall that are expected to continue into the future. Adding in an additional margin of safety will help insure decisions with long-term implications accommodate expected changes in precipitation.

References

1.Perica, et al. 2013. NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA National Weather Service. Silver Spring, Maryland.

2.Sorrell and Richard, Computing Flood Discharges for Small Ungaged Watersheds. Michigan Department of Natural Resources and Environment, June 22, 2010. Lansing, Michigan.

3. Huff and Angel, 1992. Rainfall Frequency Atlas of the Midwest (Bulletin 71). Illinois State Water Survey, Champaign, Illinois.

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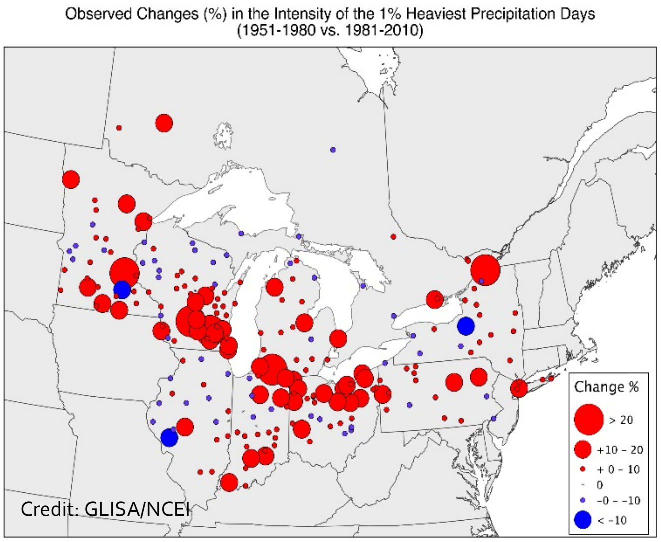
Changing Precipitation in Southeast Michigan

Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a summary of climate change in southeast Michigan as indicated by the historical data record and climate models designed to predict future trends.

The form, amount, and timing of precipitation in the Great Lakes region is changing. In Southeast Michigan, total precipitation has increased, the strongest storms have become stronger and more frequent, and snow has been replaced with rain.

Total Precipitation	**Increased by 15% across Southeast Michigan and 44% in Ann Arbor.[1]** **In the future, the wet season may get wetter as the dry season gets drier.**
Heavy Storms	**Heavy storms have become stronger and more frequent throughout the region.[2]** **Larger storms have grown faster than total precipitation, meaning more precipitation is concentrated in heavier events.**
Seasonal Patterns	**Shortening winters yield less snow accumulation and rain instead of snow in the fall and spring.**

Total Precipitation
Total Precipitation has changed in the Great Lakes region over the last several decades. Most areas are receiving more precipitation now than in the past, and Southeast Michigan is in line with this regional trend. Annual precipitation totals increased by about 12% from 1950-2014 but the magnitude of the change varies from location to location. Total annual precipitation in Ann Arbor has increased by 44% while in other nearby areas it has only increased slightly. Climate scientists anticipate the broader regional trend will continue or accelerate, with approximately 5-25%[3] more precipitation falling on the region through most of the coming century.



Extreme Precipitation

Heavy and extreme precipitation events have become dramatically more frequent in the Great Lakes region. The amount of precipitation falling in the most intense 1% of precipitation events increased by 37% in the Midwest and 71% in the Northeast from 1958 through 2012.[4] In the extreme western extent of the Great Lakes region, as much as 50% of annual total precipitation falls during 10 days of the year. Ann Arbor has seen a 48% increase in the number of daily precipitation events that exceed 1.25" of precipitation (above which nuisance and problematic flooding occur).

Seasonal Patterns

Even as most climate models project that total annual precipitation will rise in the Southern Great Lakes basin, many models also suggest that summer precipitation will remain stable or decline in the future. This could lead to a polarizing of the wet and dry seasons in the region, with more precipitation falling from autumn through spring and less precipitation falling during the summer.

Winters have become shorter throughout the region. In the Midwest, the freeze-free season has grown by 9 days and in the Northeast by 10. Warmer winter temperatures have reduced snow accumulation totals by melting snow more quickly and replacing snowfall with rain. This trend is projected to accelerate rapidly. By the end of the century, the region could see 1-2 months less of freezing temperatures[4], substantially altering the nature of winter precipitation in many locations.

Geographic Patterns

Precipitation has changed throughout the Great Lakes region, but the changes are uneven. Some communities have recorded large changes while others have been relatively stable, and there are some exceptions to the overall regional trends.

Increasing precipitation totals and changes in extreme precipitation have been greatest across the southern areas of the Great Lakes basin. Nearer Lake Superior, across the Upper Peninsula of Michigan, Northern Wisconsin, and Northern Minnesota, precipitation has actually declined slightly.

Lake-effect snowfall has increased, particularly in northern areas of the region as snowfall in the southern areas has declined. Warmer lake surface water and less ice cover on the lakes allows for more evaporation and more fuel for lake-effect snow, while warmer temperatures to the south simply reduce the chance of precipitation falling as snow rather than rain.

Notes

1. Based on changes in the linear best-fit of annual precipitation totals from 1950-2014.

2. Ann Arbor has seen a 48% increase in days exceeding 1.25" of precipitation, based on changes in linear best-fits of annual values from 1951-2014.

3. Based on values from CMIP3, CMIP5, and NARCCAP projections for late-mid or end of century.

4. From the National Climate Assessment, 2014.http:// nca2014.globalchange.gov

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Changes to Key Storm Definitions and Implications for Decision Making

Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a review of what design storms are used to inform stormwater management and the degree to which these design storm definitions have changed in the new NOAA Atlas 14 analysis of precipitation data.

Bulletin 71 vs. NOAA Atlas 14

Design storm events are mathematical/statistical representation of precipitation events based on historical records. They are often described by the probability of occurring once within a given number of months or years. Technical Paper 40[1] and Bulletin 71[2] are two rainfall frequency data resources often used in the Midwest region of the US. Both resources utilized data published by the National Oceanic and Atmospheric Administration (NOAA) in 1992. The new Atlas 14 Volume 8[3] was released by NOAA in April 2013 based on the most recent 30 years of precipitation data. Atlas 14 provides precipitation estimates for duration of 5-minutes through 60-days over recurrence intervals of 1-year through 1000 years. Compared to Bulletin 71, **Atlas 14 estimates are 3% to 35% higher across all recurrence intervals and durations, for the Ann Arbor area.** The increase is notably higher for shorter-duration less frequent storms.

Common Storm Definitions: How much has changed?

Certain storm event sizes are used for stormwater management regulations and infrastructure design. The following design storms are used to describe the level of service required for the stormwater drainage system (all figures are for the Ann Arbor area):

References

1. Hershfield, D.M., Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years, Technical Paper 40, U.S. Dept. of Commerce, Weather Bureau, Washington, D.C., May 1961.

2. Huff and Angel, 1992. Rainfall Frequency Atlas of the Midwest (Bulletin 71). Illinois State Water Survey, Champaign, Illinois.

3. Perica, et al. 2013. NOAA Atlas 14 Volume 8 Version 2, Precipitation-Frequency Atlas of the United States, Midwestern States. NOAA National Weather Service. Silver Spring, Maryland.

First Flush (first 1" of runoff)	The delivery of a highly concentrated pollutant loading during the early stages of a storm, due to the washing effect of runoff on pollutants that have accumulated on the land. The EPA, MDEQ, and WCWRC now all define the first flush as the runoff from the first inch of precipitation. 85% of stormwater water quality pollutant loading occurs during the 1" and smaller rains, therefore infiltration of the first 1" of runoff can address pollutant loading. Storms with 1" or more rainfall are more frequent.
2-Year 24-Hour or "bankfull" (2.35" in Atlas 14, 2.26" in Bulletin 71, a 4% increase)	A condition where flow completely fills the stream channel to the top of the bank. In undisturbed watersheds, this occurs on average every 2 years and controls the shape and form of natural channels, more than any other event size over time. The bankfull storm is used to help design outlet restrictions for detention ponds in an effort to avoid having the increased runoff from development cause an increase in the frequency of the bankfull condition.
10 year (10%), 12-hr (2.91" in Atlas 14, 2.72" in Bulletin 71, a 7% increase)	This storm represents the typical level of service currently being provided by many communities for their storm drain designs. In other words most communities size new storm conveyance systems to carry the 10% 12-hour event without reaching full capacity. Storm conveyance systems are typically expected to be over capacity in storms larger or more intense than this.
100-Year 24-Hour (5.11" in Atlas 14, 4.36" in Bulletin 71, a 17% increase)	This storm significantly exceeds what is typically designed for in a stormwater drainage system, but it is used for FEMA flood insurance studies and it defines the floodplain boundary. Flood insurance is required when structures are located within the inundation zone of this storm event. This event is also used to size stormwater detention basins and outlet structures by Water Resource and Drain Commissioners.
500-Year 24-Hour (6.74" in Atlas 14)	This storm significantly exceeds what is typically designed for in a stormwater drainage system, but it is used for evaluation of stormwater systems as part of this analysis for FEMA flood insurance study. Critical Facilities typically may not be constructed in the inundation zone of this storm event.

Better Preparing Our Communities

Local, County, and State governments should adopt the 2013 NOAA Atlas 14, Volume 8 precipitation frequency estimates for stormwater management regulation, infrastructure design, and floodplain mapping. The estimates that most agencies are currently using is over 30 years old and is resulting in stormwater infrastructure being undersized. This increases property damage and cost when flooding occurs and means our floodplain areas may be underestimated. **Please note:** Adopting the new NOAA precipitation frequency estimates will only bring municipalities and counties up-to-date with weather observations, it will not take into account the increases due to climate change. Where possible, local governments should consider adding an additional margin of safety to infrastructure projects in anticipation of increasing annual rainfall and larger extreme events.

Examples

Washtenaw County Water Resources Commissioners Office has adopted new Stormwater Rules regulating stormwater management on new and redevelopment projects using NOAA Atlas 14 storm definitions. The City of Ann Arbor is reevaluating its floodplain map using a model that predicts inundation areas for the 100 year (17% increase) and 500 year (new event definition) events from Atlas 14 to identify new vulnerabilities.

Access to the data

NOAA has created a point-and-click website providing access to reports, data, and GIS and cartographic maps (http://hdsc.nws.noaa.gov/hdsc/pfds).

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ISSUES IN STORMWATER MANAGEMENT: FLOODPLAINS

Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a description of how floodplains and floodplain management will be affected by climate change.

Defining the Floodplain
All Federal Emergency Management Agency (FEMA) flood maps within the Huron River watershed are currently based on a 24-hour 1% annual chance event of 4.36 inches of rain. This event size is based on the 1992 document Rainfall Frequency Atlas of the Midwest (Bulletin 71). The data in the bulletin is now over 30 years old. In 2013 NOAA published Atlas 14 Volume 8 (version 2) which redefines the 24-hour 1% annual chance event for the Ann Arbor area as 5.11 inches of rain. This is a 17.2 % increase and does not take into account future climate change. Due to impervious surfaces and piped stormwater conveyance systems, the increased rainfall intensity will result in even higher increases in peak discharges within floodplains (in the 25% range), which will result in higher floodplain elevations and larger floodplains. This trend will continue as we experience further climate change.

Actions
The following represents a list of options to mitigate impacts associated with an expanding floodplain.

1. **Adopt the 2013 NOAA Atlas 14 precipitation frequency estimates** – Local and County governments should adopt these current precipitation frequency estimates for stormwater management regulation and infrastructure design. State agencies should also move to these current standards for floodplain mapping. Adopting the new NOAA precipitation frequency estimates will only bring us up to date with weather observations, it will not take into account the future changes.
2. **Revise Flood Insurance Rate Maps** – Communities and Counties could work with the State and FEMA to expedite Flood Insurance Rate Map revisions to represent the current NOAA Atlas 14 precipitation frequency estimates. Again, this would not take into account future climate change; just bring the maps up to date.
3. **Add a 15 to 20 % safety factor to stormwater management requirements** – In addition to adopting the 2012 NOAA Atlas 14 precipitation frequency estimates, counties and communities could add a 15 to 20 percent safety factor to rain event sizes. This action would take into account the expected future increases in precipitation intensity, and ensure that new stormwater infrastructure is capable of handling future events.
4. **Regulate to the 0.2% annual chance event** – FEMA and State law requires communities to regulate to the 1% annual chance event. Based on

the current NOAA precipitation estimates the 0.2% event is approximately 30% larger than the 1% event. As climate change continues the 1% event will increase and at some point equal the current 0.2% event. Since the 0.2% floodplain boundaries are shown on flood insurance rate maps, communities could chose to regulate to that event. This would take into account that the future 1% storm will be larger and adds a safety factor.

5. **Encourage or require Green Infrastructure (GI)** – GI is an adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. The common denominator with most GI is stormwater infiltration. Even though GI is typically thought of as a water quality technique, the infiltration process is also a water quantity control. Reducing runoff quantity will help reduce downstream flooding.

Dive Deeper
The No Adverse Impact Tool Kit can be found on the ASFPM web site at:
http://www.floods.org/index.asp?menuID=460&firstlevelmenuID=187&siteID=1e

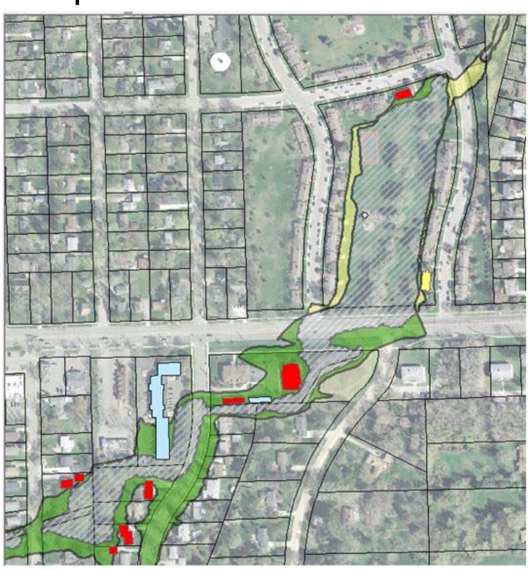
NOAA Atlas 14 data and analysis
http://hdsc.nws.noaa.gov/hdsc/pfds

Considerations

Climate change will amplify the need for sound floodplain management techniques and mitigation. The Association of State Floodplain Managers (ASFPM) recommends an approach they call No Adverse Impact, which includes actions such as:

A. Prepare flood studies using future conditions hydrology
B. Zoning overlay districts to restrict floodplain development
C. Prohibit building in the floodway
D. Higher regulatory standards for building and development codes
E. Prohibiting new critical facilities in hazard areas
F. Greenway establishment
G. Transfer of development rights programs

Example



Floodplain map showing the change in inundated area between FEMA floodplain maps and the City of Ann Arbor's Stormwater Model. FEMA maps use the 0.2% chance storm definition from Bulletin 71 data. The Ann Arbor model uses the 0.2% chance storm definition from Atlas 14. New data results in a larger area of inundation which includes eight new structures in this section of the river.

Structures in effective and modelled floodplain
Structures model removed from floodplain
Structures model added to floodplain

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Issues in Stormwater Management: Detention and Conveyance

Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a summary of stormwater detention and conveyance considerations as rainfall volumes and patterns change.

Detention and Conveyance Standards

Stormwater rules established by municipalities in the State of Michigan rely on storm definitions from the 1992 document Rainfall Frequency Atlas of the Midwest (Bulletin 71). Detention and conveyance standards do not accommodate design storms as defined in NOAA's Atlas 14, released in 2013 which incorporates rainfall data through 2010. New storm definitions show increases in rainfall on an order of magnitude that will impact the function of detention and conveyance infrastructure. The 2-year 24-hour event used to design outlet restrictions for detention ponds increased from 2.26" to 2.35" inches (4%). Stormwater systems are typically designed to accommodate the 10-year 1-hour, 2-hour or 6-hour event which have increased by 16%, 14% and 11%, respectively. The result will be increased frequency and extent of flooding and surface ponding. This trend is expected to continue as we experience further climate change.

Actions

The following represents a list of options to mitigate impacts of increased precipitation associated with stormwater detention and conveyance systems:

1. **Adopt the 2013 NOAA Atlas 14 precipitation frequency estimates** – Local and County governments should adopt these current precipitation frequency estimates for stormwater management regulation and infrastructure design. Adopting the new NOAA precipitation frequency estimates will only bring us up to date with weather observations, it will not take into account the future changes.
2. **Periodically revisit rainfall data and design storm definitions** – While NOAA Atlas 14 is a significant improvement to precipitation frequency estimates, it is still a snapshot in time. Periodically updated estimates will improve the suitability of infrastructure and planning decisions based on the best available information and allow stormwater systems to evolve as the climate changes.
3. **Add a 15 to 20 % safety factor to stormwater management requirements** – In addition to adopting the 2013 NOAA Atlas 14 precipitation frequency estimates, counties and communities could add a 15 to 20 percent

safety factor to rain event sizes. This action would take into account the expected future increases in precipitation intensity, and ensure that new stormwater infrastructure is capable of handling future events.

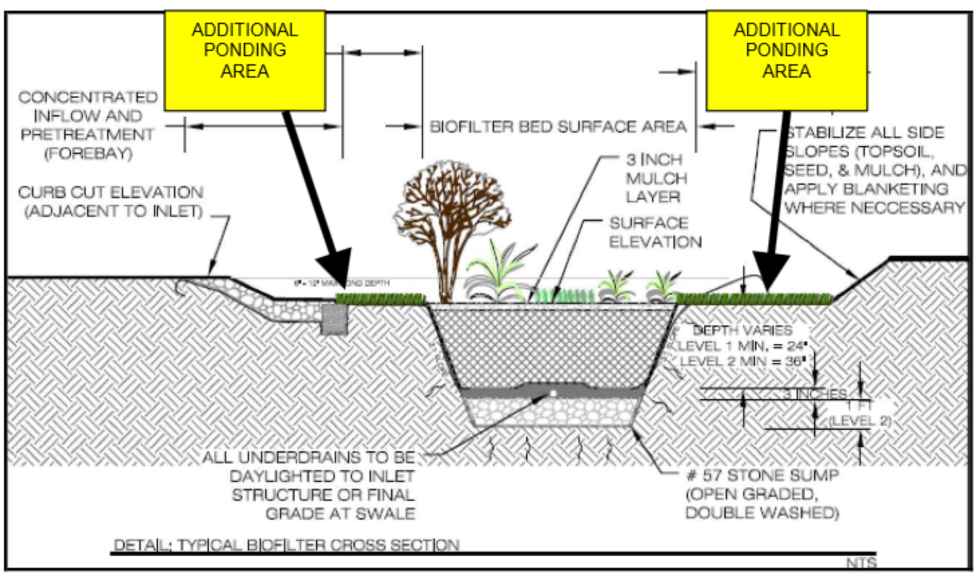
4. **Treat stormwater onsite to the degree possible** – Requiring infiltration on new developments and redevelopments as well as providing incentives to retrofit existing development will reduce demands on the stormwater system.
5. **Implement LID practices at the site scale** – LID practices (including Green Infrastructure) encourage more infiltration, storage and treatment. Reductions in the volume of stormwater runoff can be achieved such that resulting run off volumes are more consist to those the system was designed to handle.
6. **Adapt planting plans over time** -- changes in precipitation and temperature will likely affect which species will succeed or become an invasive nuisance.
7. **Modify designs to prevent bypass during high volume rainfall events** -- for example, consider reallocating storage at bioretention facility rethinking vulnerable flow path elements. Add additional temporary storage.

Dive Deeper
NOAA Atlas 14 data and analysis
hdsc.nws.noaa.gov/hdsc/pfds

The Tree resilience toolkit has information on suitable trees to southeast Michigan as climate changes www.hrwc.org/tree-toolkit

Adapting Stormwater Management for Climate Change in: Low Impact Development in Coastal South Carolina: A Planning and Design Guide
www.northinlet.sc.edu/LID/FinalDocument/loRes/Appendix%20G%20low%20res.pdf

Example
Changes in the volume and duration of a rainfall event can be managed in a bioretention facility by increasing the surface area allocated for above soil storage to create a holding zone to capture water when soil becomes temporarily saturated. Below is an example of a design that accomplishes this.



Adaptation of a bioretention facility
Additional surface ponding area has been incorporated while the surface area and volume of soil media remains the same.

Virginia Department of Conservation and Recreation. 2010a. Design specification no. 9: Bioretention. Version 1.8. April 13. Richmond, VA: Virginia Department of Conservation and Recreation.

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Solutions in Stormwater Management: Green Infrastructure

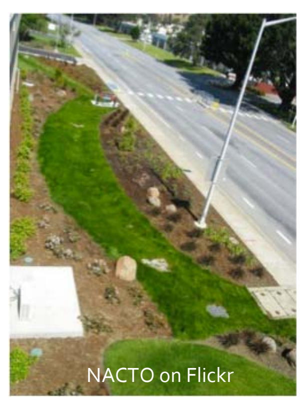
Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a description of Green Infrastructure and how it can be used to improve stormwater management in a changing climate.

Green Infrastructure vs. Grey Infrastructure

In recent years, the concept of Green Infrastructure (GI) has moved from broad regional planning discussions about natural resource conservation to specific uses in stormwater treatment. Naturally-occurring GI, such as wetlands and meandering streams, can be mimicked inhuman-constructed GI for the purpose of managing stormwater. Designers and engineers now construct bioswales, rain gardens, green roofs, pervious pavement, and various site-specific infiltration designs. The point of these projects is to draw stormwater into the groundwater instead of piping it (in conventional grey infrastructure) quickly into streams.

Green Infrastructure is not merely rain gardens and bioswales. Each of these features were formerly described as Low Impact Development (LID), or the implementation of best management practices at the site-specific level. GI, like grey infrastructure, expands the same idea to a community-wide scope. Its focus is on the planned, strategic placement of LID features and on the accounting of reduced stormwater volume and pollutant loads those features provide. It requires planning and inter-jurisdictional communication, in some cases.

The bottom-line is that using GI for stormwater management is cheaper than grey approaches. GI is designed to capture, treat and infiltrate runoff from the majority of storms or the first inch or so from larger storms. Each GI application is smaller than conventional, centralized detention ponds or underground storage, but many more applications are distributed over the management area. When combined, GI practices reduce the volume that needs to be stored in conventional ponds and vaults, substantially reducing the overall cost.


NACTO on Flickr

Green Infrastructure as Climate Change Adaptation

Making Green Infrastructure a part of a municipal stormwater management approach provides a number of climate adaptation benefits. The flexible, distributed nature of GI allows a manager to use it to supplement an existing grey system to adjust storage capacity. Adding a little extra storage capacity may allow the system to better withstand the more frequent larger storms that are part of the climate change scenario. GI can be focused on drainage areas that are currently under capacity for targeted adaptation. Further, GI provides better infiltration of smaller storms into groundwater. This additional groundwater volume improves stream conditions during the longer drought periods that are also predicted. Finally, the vegetation used in GI practices is adapted to fluctuating conditions and should be more resilient to other climate change impacts, thereby providing stable habitat for local wildlife.

Not a Silver Bullet

Green Infrastructure practices are not the perfect solution to all climate and general stormwater stresses, however. To be part of an effective stormwater and adaptation strategy, GI requires careful planning and practice placement. GI practices have a different range of physical characteristics to consider than conventional storage and piping. By its nature, GI is distributed across a wide area and is more challenging to maintain than a single structure. Probably the most challenging drawback is that GI practices are not designed to capture and store the larger storms. Rather, they capture and infiltrate smaller storms or the initial runoff from larger storms. GI may need to be supplemented with grey storage systems to accomplish all goals. Finally, current regulatory and management rules and structures may need to be altered to accommodate GI as a partial stormwater solution. Education may be needed to make the newer approach acceptable across various interests.

Dive Deeper
Resources for GI practices are plentiful on the internet. A good place to start is U.S. EPA's GI site:
http://water.epa.gov/infrastructure/greeninfrastructure/

The Huron River Watershed Council has compiled resources that are locally relevant, including tools for finding examples and mapping opportunities.
www.hrwc.org/green-infrastructure

NOAA Atlas 14 data and analysis
hdsc.nws.noaa.gov/hdsc/pfds

How To Develop a Green Infrastructure Strategy

If a municipality is interested in employing a GI strategy to partially address stormwater management and climate adaptation goals, a few basic steps that should be taken:

1. Develop an inventory of stormwater infrastructure assets and needs. A system inventory is important for identifying where GI would be needed to improve storage capacity and groundwater recharge, and where it is feasible.
2. Develop a GI plan. The plan should identify what types and where GI practices can be located. Projects can then be developed on a priority or opportunistic basis.
3. Identify a funding mechanism. Ideally, the municipality already has a direct funding mechanism like a stormwater utility to pay for infrastructure improvements. If not, advanced planning for project funding is important for implementation. Established funding can help leverage additional grant funds for projects.
4. Utilize NOAA Atlas 14 data for project design and consider adding a margin of safety to accommodate future increases in precipitation volumes and intensities.
5. Plan for maintenance. GI projects require regular maintenance (at least in initial years) that is different than for conventional practices. A staffing plan will be needed if GI implementation is ramped up. GI practices that are not properly maintained become community blemishes.

Example

Installation of a "green street" with bioswales in sidewalk extensions and residential rain gardens reduced bankfull runoff volume by 60%, reduced flood frequency to 1%, and reduced phosphorus runoff by 92%.

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Solutions in Stormwater Management: Stormwater Rules

Across the region, patterns in precipitation have been changing. Historical records and projected trends indicate that these changes require modifications to the practice of stormwater management. Below is a description of how one county revised standards and rules to improve the design of stormwater management systems.

In 2014, the Washtenaw County Water Resources Commissioner's (WCWRC) office completed an effort to improve stormwater standards for new and redevelopments. The revised standards utilize NOAA Atlas 14 precipitation data and design storms and call for more on-site management of stormwater than previously.

Why revise stormwater standards?
The previous standards were finalized in 2000 and much has been learned since then about controlling stormwater runoff for water quality treatment and flood control. New techniques have been developed that were not addressed in the 2000 rules and better precipitation data has become available. Also, some issues were routinely discovered in the permit review process that staff believed could be better addressed prior to project design.

How were the standards revised?

Staff at the WCWRC office did extensive research on national best practices and policies and compiled these by application. Staff also evaluated the design review process and noted numerous problems in the design and development processes that led to suboptimal stormwater controls. All this research was developed into several draft revisions that were shared with stakeholders and practitioners for feedback and "groundtruthing." Final draft rules were presented in a series of workshops, where additional feedback was gained before the rules were finalized in August of 2014.

How did the Standards change?
The most significant changes fall into 5 categories:

- The permit review process. The new rules require a pre-design meeting. This is done to identify potential problems and determine potential solutions ahead of time, to avoid conflict and revision delays.
- Updated design storms. See the description under Atlas 14 use below.
- New infiltration requirements. The new rules require design of and use of infiltration practices to capture and treat the first-flush, or first 1" of developed site runoff.

Dive Deeper

Washtenaw County Water Resources Commissioner's *Rules and Guidelines - Procedures and Design Criteria for Stormwater Management Systems*

http://www.ewashtenaw.org/government/drain_commissioner/dc_webPermits_DesignStandards/dc_Rules/frontpage

NOAA Atlas 14 data and analysis
hdsc.nws.noaa.gov/hdsc/pfds

- Use of different models for stormwater storage sizing in the application process. The new rules use an application process that explicitly uses the NRCS Curve Number Method for calculating site runoff and required treatment and storage volumes. Focus on the model rather than a standard storage design allows developers to have flexibility in stormwater design and get credit for infiltration volume.
- New best management practices are highlighted. The new rules provide examples for a wide range of stormwater treatment practices and how they can be used to meet the new requirements. The rules make it easy for practitioners to find practices for their designs that will work for their particular site, maximize infiltration and water quality treatment, and potentially save money.

How was Atlas 14 data used and why?
The Atlas 14 storm intensity and rainfall frequency curves are incorporated into the new design storm values. Two storm sizes are used in the rules: the bankfull (50% or 2-year recurrence interval) event, and the 1% or 100-year recurrence interval event. The 50%, 24-hour storm event (increased from x to 2.35") is used in sizing water quality treatment and infiltration designs. The 1%, 24-hour storm event (increased from x to 5.11") is used in sizing storage for flood protection. These figures were updated from the previous atlas figures and are built into sizing calculations in the application. Because Atlas 14 events are larger, new designs require a greater volume of treatment and storage.

How do the new standards help communities adapt to climate change?
These new standards apply to all new development and redevelopment projects under county jurisdiction. Designs will result in a greater amount of stormwater storage, infiltration and treatment – helping communities to reduce runoff from more and larger storm events and increase stream baseflows to help protect them from longer periods of drought.

Example
An examination of a housing development in Washtenaw County indicated that the new standards would have resulted in design changes to provide 29% more stormwater storage and complete infiltration of the first inch of rain.


Roadside rain gardens. Credit: HRWC

The City of Ann Arbor changed their official code to align with the WCWRC new stormwater rules expanding the reach of the rules and ensuring Ann Arbor developments adhere to improved standards even if county rules change.