Green Infrastructure Champion Training: Part 10
“Using Green Infrastructure to Promote Climate Resiliency”

May 22, 2020
Duke Farms
Hillsborough, NJ
Via Webinar 10 am - noon

Rutgers Cooperative Extension Water Resources Program
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Green Infrastructure Champions Program

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Chat with “smellor”
Special Thanks to Dr. David A. Robinson
Distinguished Professor, Department of Geography
& New Jersey State Climatologist
Rutgers University

Little Falls, NJ
11 August 2018

(Miguel Galo, Special to NorthJersey.com)
Climate or Weather???

Weather refers to the short-term phenomena

Climate refers to the long-term patterns
Better yet!

Climate is your personality.....

Weather is your mood......
The Earth's Climate

- The climate includes many components of the Earth's system and interactions between them.
Diversity: local controls on NJ’s weather and climate

Altitude
Latitude
Surface Conditions
Land-Water Contrasts

Ludlum 1983
Land cover matters!

Trenton

Great Swamp
Heat waves and human health

https://en.wikipedia.org/wiki/New_Jersey

10 PM 25 July 2012

https://en.wikipedia.org/wiki/New_Jersey
As does proximity to water

Sea Breeze and backdoor cold front:

April 10, 2013
3 PM
A precipitation rich state......

......most often
NJ Monthly Precipitation Departures: Mar 2018 – Feb 2019

2nd wettest November
8th wettest September
Wettest fall on record
Sometimes too much...

Brick Township: 13 August 2018
However sometimes too little......
Appreciating Variations & Extremes
NJ Monthly Temperature Departures: Mar 2018 – Feb 2019

Records based on observations dating back to 1896

- 4th warmest May
- 2nd warmest August
- 3rd warmest September
- 5th warmest summer
Causes of climate change
Natural mechanisms influence climate

Natural mechanisms

Changes in solar output

Changes in the amount of volcanic aerosols in the atmosphere

Internal variability of the coupled atmosphere-ocean system (e.g., ENSO, monsoon systems, NAO)
Human factors also influence climate

Non-natural mechanisms

Changes in the concentrations of atmospheric greenhouse gases

Changes in aerosols and particles from burning fossil fuels and biomass coal (sulfate aerosols) – cooling
biomass (black carbon) – warming

Changes in the reflectivity (albedo) of Earth’s surface and the hydrologic cycle

Atmospheric CO₂ at Mauna Loa Observatory

Scripps Institution of Oceanography
NOAA Earth System Research Laboratory

PARTS PER MILLION


Smoke from fires in Guatemala and Mexico (May 14, 1998)
Physical Changes

- Deforestation
- Replace/transform natural landscape
- Urbanization
- Irrigation
- Harvesting
- Intensification

Feedbacks

- Energy Balance Changes
- Net Radiation and Partitioning Changes
- Boundary Layer Moisture changes
- Surface temperature changes
- Roughness change
- Albedo change
- Precipitation

Effects/Impacts

- Basinscale Hydrological changes
- CO2 changes (storage/emissions)
- snow cover

Teleconnections

Dev Niyogi, Purdue U.

http://landsurface.org/
Is climate presently changing in NJ & elsewhere?

Preponderance of evidence suggests climate change is occurring and humans are responsible for a significant portion of recent changes

1. Theory
2. Observations
3. Models
The Earth reflects radiation not absorbed by the atmosphere & surface (lost heat).

Strong **greenhouse gases** delay the exit of absorbed radiation back to the space (enhancing atmosphere & surface temperatures).
WE CAN WARM THE WORLD ON COAL.
New Jersey annual temperature: 1895-2018

Long-term upward trend of 2.2° F per 100 years

6 of the 7 warmest years have occurred since 2006

2012 was the warmest year on record

data source: National Centers for Environmental Information
A shift in the distribution of summer temperatures in the Northern Hemisphere
Where the anthropogenic-generated heat is going

Nuccitelli et al., 2012
Hot outside?

shut up

Stuff
New Jersey annual precipitation: 1895-2018

2018: wettest on record

Large decadal variability (early 1960s drought, wet 1970s, very wet in last decade)

Most of the upward trend comes from changes in spring and fall

data source: National Centers for Environmental Information
Increase in frost-free season length

1991-2012 relative to 1901-1960

National Climate Assessment, 2014
Arctic Sea Ice

Stroeve et al EOS 2008
Peruvian Terminus Retreat

Courtesy of L. Thompson
Ice loss from the two polar ice sheets

Based on GRACE satellite observations

From Wouters et al, 2013
Human and natural influences on 20th century global temperature

adapted from Huber and Knutti, 2012
Our climate future
New Jersey's future climate

- Rising temperatures
- Steady or increasing precipitation
- Increasing variability and extremes
  - storms, flood, drought, heat
- Rising sea level
A change in extremes?

Manville

17 September 1999
# 2 crest 21.0’ (nearby Blackwells Mills: 1921-present)

16 April 2007
# 3 crest 19.2’

14 March 2010
# 6 crest 16.2’ (1 May 2014 #7 crest 15.9’)

28 August 2011
# 1 crest 21.2’
**Future sea level in NJ: Miller & Kopp**

<table>
<thead>
<tr>
<th></th>
<th>Total cm</th>
<th>Total inches</th>
<th>Total feet</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>2050 best</strong></td>
<td>40</td>
<td>16</td>
<td>1.3</td>
</tr>
<tr>
<td>2050 low</td>
<td>23</td>
<td>9</td>
<td>0.7</td>
</tr>
<tr>
<td>2050 high</td>
<td>60</td>
<td>24</td>
<td>2.0</td>
</tr>
<tr>
<td><strong>2100 best</strong></td>
<td>96</td>
<td>38</td>
<td>3.1</td>
</tr>
<tr>
<td>2100 low</td>
<td>50</td>
<td>20</td>
<td>1.6</td>
</tr>
<tr>
<td>2100 high</td>
<td>147</td>
<td>58</td>
<td>4.8</td>
</tr>
</tbody>
</table>

All values with respect to a year 2000 baseline.

Based in the slightly lower melting figures of Shepherd et al. (2012), subsidence rates of 1-2 mm/yr in excess of global, and dynamic oceanographic effects.
Seaside Heights

1 foot (likely by ~2040)
3 feet (likely by 2090s)
6 feet (~5% chance by 2100)

Impacts of a changing climate
Weather & climate impact all aspects of life in NJ

- Agriculture/horticulture
- Ecology
- Water resources
- Public health & safety
- Energy
- Transportation
- Commerce
Potential climate change impacts

**Climate Changes**
- Temperature
- Precipitation
- Sea Level Rise

**Health Impacts**
- Weather-related Mortality
- Infectious Diseases
- Air Quality-Respiratory Illnesses

**Agriculture Impacts**
- Crop yields
- Irrigation demands

**Forest Impacts**
- Change in forest composition
- Shift geographic range of forests
- Forest Health and Productivity

**Water Resource Impacts**
- Changes in water supply
- Water quality
- Increased Competition for water

**Impacts on Coastal Areas**
- Erosion of beaches
- Inundate coastal lands
- Costs to defend coastal communities

**Species and Natural Areas**
- Shift in ecological zones
- Loss of habitat and species

*United States Environmental Protection Agency*
A dilemma

Passaic flooding: March 2011
Managing climate change
Is there something we should be doing about this climate dilemma?
Challenges Requiring Attention

- **Knowledge**: Develop a better understanding of the details of future climate change.
- **Mitigation**: Reduce emissions of carbon dioxide and other greenhouse gases.
- **Adaptation**: Increase the resilience of society to climate change.
- **Activism/Leadership**: Raise public awareness of the challenges posed by climate change and the need to mitigate and adapt. Participate... vote.
Once again thanks to Dave Robinson for letting me use his slides!
david.robinson@rutgers.edu
njclimate.org
So what did we learn?
Climate change ... it’s real, it’s happening now, and it’s affecting New Jersey.
Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding
What do we do now?

• Reduce carbon emissions
• Convert to alternative sustainable fuels (solar and wind)
• Pray
• Manage stormwater runoff more effectively using sustainable practices
• Work together – only through cooperative and collaborative partnership will be successful
Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding
Rainwater Harvesting - Functions

• Collecting, filtering and storing water from roof tops, paved and unpaved areas for multiple uses.
• Harvested water can be used for nonpotable or potable purposes after testing and treatment.
• Surplus water after usage can be used for recharging groundwater.
• Systems can range in size from a simple PVC tank or cistern to a contractor designed and built tank/sump with water treatment facilities.
Rainwater Harvesting – Components
Sizing

- The rule of thumb is 600 gallons of water per inch of rain per thousand square feet of catchment area.
- Not all the rain that falls can actually be collected. Efficiency is usually presumed to be 75% depending on system design and capacity.
Sizing Formula

Here is the basic formula for calculating the potential amount that can be collected:

\[
(Catchment \ area) \times (inches \ of \ rain) \times (600 \ gallons) \times (.75)
\]

\[\frac{1,000 \ square \ feet}{1,000 \ square \ feet} \]
Design Example

The sample roof shown below has a catchment area that is 40 feet wide and 30 feet long. Hence, it has a 1,200 square feet roof (40 feet wide x 30 feet long). Assume that it rains 2 inches. We can now plug this information into our general formula (see equation above).

- Catchment Area = 1,200 square feet
- Amount of Rain = 2 inches
- Gallons of water collected per inch of rain per 1,000 square feet = 600 gallons
- Percent Efficiency = 75% or 0.75

\[
\frac{(1,200 \text{ square feet}) \times (2 \text{ inches of rain}) \times (600 \text{ gallons}) \times (0.75)}{1,000 \text{ square feet}} = 1,080 \text{ gallons}
\]
First Flush Diverter or Roof Washer

The rule of thumb is one to two gallons of roof washer capacity for every 100 square feet of catchment area.

- A one foot length of 6 inch diameter PVC pipe holds 1.5 gallons.
- A one foot length of 4 inch diameter PVC pipe holds 0.66 gallons.
Construction

• The most stable place to position the cistern is against a stable wall on level ground as close to the downspout as possible.
• Gravity moves water downhill. Be sure there is available space for a downward pitch in all pipes.
• The cistern on its platform is the highest point of the garden but the lowest point of the system.
• The overflow pipe should be directed toward a rain garden not toward pathways or structures.
• The overflow pipe should flow from the cistern’s highest point.
• The spigot should be at the cistern’s lowest point.
Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding
KNOWN: The New Jersey Water Quality Design Storm is 1.25 inches of rain over two-hours and 90% of New Jersey rainfall events come in storms of less than 1.25 inches of rain

UNKNOWN: If “heavy rains become more intense” due to climate change in New Jersey, how much will the New Jersey Water Quality Design Storm increase?
1.25" becomes what?
1.50"?
1.75"?
2.00"?
The scientists just say it will be “more” but how do we design for “more”
What if we size our green infrastructure practices for the next higher design storm – the two-year storm (3.3 inches of rain over 24-hours)?
<table>
<thead>
<tr>
<th>Parameters</th>
<th>Two-hour design storm</th>
<th>24-hour design storm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainfall total</td>
<td>1.25 inches</td>
<td>3.3 inches</td>
</tr>
<tr>
<td>Drainage area</td>
<td>1,000 sq.ft.</td>
<td>1,000 sq.ft.</td>
</tr>
<tr>
<td>Infiltration during the storm</td>
<td>None</td>
<td>0.5 to 1.0 in/hr</td>
</tr>
<tr>
<td>Cost basis</td>
<td>Surface area</td>
<td>Surface area</td>
</tr>
</tbody>
</table>
Climate Resilient Rain Garden

- **200 sq.ft.**
  - 0.0 in/hr
  - 2-YR STORM 3.3” over 24-hr
  - $2,000

- **260 sq.ft.**
  - 1.0 in/hr
  - Drainage area = 1,000 sq.ft.
  - $2,000

- **350 sq.ft.**
  - 0.5 in/hr
  - 2-YR STORM 3.3” over 24-hr
  - $2,600

- **Depth = 6.0 INCHES**

WATER QUALITY STORM 1.25” over 2-hr

$3,500
Climate Resilient Rain Garden

260 sq.ft.  
1.0 in/hr

Depth = 6.0 INCHES

2-YR STORM  
3.3” over 24-hr

$2,600

260 sq.ft.  
0.5 in/hr

Depth = 9.0 INCHES

2-YR STORM  
3.3” over 24-hr

$2,600
## Results

<table>
<thead>
<tr>
<th>Rain Garden Surface Area (sq. ft.)</th>
<th>Rain Garden Depth (in.)</th>
<th>Rain Garden Storage Volume (cu. ft.)</th>
<th>Rain Garden Capacity for 2-hr Rainfall (in.)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>6</td>
<td>100</td>
<td>1.25</td>
<td>2,000</td>
</tr>
<tr>
<td>260</td>
<td>6</td>
<td>130</td>
<td>1.56</td>
<td>2,600</td>
</tr>
<tr>
<td>350</td>
<td>6</td>
<td>175</td>
<td>2.10</td>
<td>3,500</td>
</tr>
<tr>
<td>260</td>
<td>9</td>
<td>195</td>
<td>2.34</td>
<td>2,600</td>
</tr>
</tbody>
</table>
What if we combined roadside rain gardens with street trees?
Climate Change in New Jersey

- More warm extremes and fewer cold extremes
- Heavy rains become more intense
- More frequent dry spells
- Rising sea level with increased frequency and intensity of coastal flooding
Examples of Measures Under Consideration
Structural Measures

- Inlet Storm Surge Barriers
- Interior Bay Closures
- Raised Roads and Rails
- Levees
- Floodwalls (Permanent)
- Deployable Floodwalls
- Crown Walls
- Beach Restoration/Groins/Breakwaters
- Bulkheads
- Seawalls
- Revetments
- Stormwater System Drainage Improvements
Natural and Nature-Based Features

- Living Shorelines
- Reefs
- Wetland Restoration
- Submerged Aquatic Vegetation (SAV) Restoration
- Green Stormwater Management
Figure 9-2: Examples of Management Measures across Coastal Landscape

- Flood Warning & Evacuation
- Relocation
- Acquisition
- Elevated Building
- Drainage Improvements
- Levee
- Floodwall
- Shoreline Stabilization
- NNB Forest
- NNB Beach & Dune Restoration
- Breakwaters Groins

+ Programmatic Measures
Design Guidelines for Porous Asphalt with Subsurface Infiltration

Riverjacks open into recharge bed

Porous asphalt pavement

Uniformly graded stone aggregate with 40% void space for stormwater storage and recharge

Uncompacted subgrade is critical for proper infiltration

Filter fabric lines the subsurface bed
WE ARE DONE!
Congratulations!

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