Major riverine floods and climate change—more complicated than you may think

Glenn Hodgkins, USGS New England Water Science Center

Some information is preliminary and is subject to revision. It is being provided to meet the need for timely “best science.” The information is provided on the condition that neither the U.S. Geological Survey nor the U.S. Government may be held liable for any damages resulting from the authorized or unauthorized use of the information.
Outline

• Historical flood and precipitation trends
  – Focus on Northeast and Maine
  – USGS has been measuring streamflow in Maine for over 100 years
• Why are trends in historical heavy precipitation different than trends in flood flows?
• What will the future bring?
Historical flood trends

- Most flood-trend studies are based on annual peak flows or peaks over a threshold.
- Annual peak flows tend to be mostly minor floods, with some moderate floods, and a few major floods.
Trends in annual peak-flow magnitude

• Largely increases in Maine (some of them significant)
  • Blue triangles, increases; brown triangles, decreases
  • Open symbols, < 25%; light solid, increases 25-50%; Medium solid, 50-75%; dark solid, > 75%

1916-2015

1941-2015

1966-2015

Provisional, subject to revision

Hodgkins et al., in review
Trends in 3-day peak flows, 1940-2014

Historical trends: Peaks over threshold

- Average of 2 peaks per year at each streamflow gage
- Gages grouped within grid cells
- Increasing *number* of peaks over threshold in Maine from 1940 to 2013
- Shaded grid cells represent significant trends

Archfield et al., 2016
Historical precipitation trends

- Large increases (55%) in daily heavy precipitation in Northeast
- Why haven’t flood flows increased this much?

Easterling et al., 2017, 4th National Climate Assessment, Climate Change Special Report, Chapter 7
Why aren’t flood increases as big as heavy-precipitation increases?

• It’s not just about heavy rainfall
  – Snowpack and antecedent conditions can be important to floods in the Northeast

• Precipitation increases can be in seasons that don’t typically produce a lot of floods (Small et al., 2006; Frei et al., 2015)

• 99th percentile precipitation results in 99th percentile flow 36% of time in U.S. (Ivancic and Shaw, 2015)
  – 62% of time during wet periods
  – 13% of time during dry periods

• Different durations of heavy rainfalls are important for different sized basins
Potential future changes in design riverine peak flows in coastal Maine

- Example output from detailed rainfall-runoff model
  - Change in 100-year peak flows for Narraguagus River (Eastern Maine) based on selected temperature and precipitation changes compared to modeled peak flows with no changes

<table>
<thead>
<tr>
<th>Precip Change</th>
<th>0° F</th>
<th>+3.6° F</th>
<th>+7.2° F</th>
<th>+10.8° F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 %</td>
<td>0 %</td>
<td>-12 %</td>
<td>-21 %</td>
<td>-20 %</td>
</tr>
<tr>
<td>+15 %</td>
<td>+26 %</td>
<td>+11 %</td>
<td>0 %</td>
<td>+4 %</td>
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<tr>
<td>+30 %</td>
<td>+55 %</td>
<td>+39 %</td>
<td>+28 %</td>
<td>+32 %</td>
</tr>
</tbody>
</table>

Hodgkins and Dudley, 2013
Potential future changes in design peak flows in Maine

- Why do flood flows decrease with increasing temperature?
- Modeled maximum annual snowpack water-equivalent changes in Narraguagus River watershed

<table>
<thead>
<tr>
<th>Precip Change</th>
<th>0°F</th>
<th>+3.6°F</th>
<th>+7.2°F</th>
<th>+10.8°F</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
<td>-42%</td>
<td>-72%</td>
<td>-89%</td>
</tr>
<tr>
<td>+15%</td>
<td>+17%</td>
<td>-33%</td>
<td>-67%</td>
<td>-87%</td>
</tr>
<tr>
<td>+30%</td>
<td>+33%</td>
<td>-22%</td>
<td>-62%</td>
<td>-86%</td>
</tr>
</tbody>
</table>

Hodgkins and Dudley, 2013
Project 100-year, 3-day peak flows
Trends in magnitude by mid-century for different climate scenarios

Demaria et al., 2016
Calculating Peak flows using StreamStats

Pam Lombard, USGS New England Water Science Center
USGS StreamStats
http://streamstats.usgs.gov

GIS-based Web application for calculating basin characteristics and streamflow statistics for user-selected sites on streams
StreamStats 4.0

- Provides published basin characteristics & streamflow statistics at gaged locations
- Calculates basin characteristics & streamflow statistics at ungauged locations
  - Delineates watershed
  - Generates statistical flows using USGS peak flow regression equations
Maine StreamStats

- Delineate/Edit basin boundary
- Select/Modify basin characteristics
- Print map
- Measure distance between selected points
- Elevation plots between selected points
- Network navigation tools
Basin Characteristics (currently in StreamStats)

- Drainage Area
- % NWI wetlands
- % Sand & Gravel Aquifers
- Mean and Max Basin Elevation
- Mean Annual Precip
- Basin Centroid
- % Open Water
- Mean Basin Slope
- % of Hydrologic Soil Type A (STATSGO)
- % Urban Land (NLCD Land Class)
- % Impervious Area (NLCD)
Streamflow Statistics (currently in StreamStats)

- Peak flows (such as 100-year flood)
- Mean and median annual & monthly flows
- Lowflows: 7-day, 10-year low flow (7Q10)
- Flow durations (such as 90% duration flow)
- Bankfull (partial area of state)
StreamStats Data

Delineates basins based on:
- 24K NHD
- 24K WBD
- 10M DEM or lidar
Lidar Availability in Maine

Currently in Streamstats

2019

Projected 2020
StreamStats Version 4

**Step 1:** Use the map or the search tool to identify an area of interest. At zoom level 8 or greater State/Region selection will be enabled.

**Step 2:** You have zoomed in sufficiently to select a state or regional study area. Your selection will dictate the data used to perform basin delineation and flow statistics calculation.
Step 2: Click the 'Delineate' button to activate the delineation tool.

To edit your basin, first click the 'Add Area' or 'Remove Area' button below. Use your mouse or finger to draw a polygon.

If **adding** an area be sure your drawn polygon starts and ends within the yellow basin boundaries.

If **removing** an area, be sure your drawn polygon starts and ends outside of the yellow basin.
Download Basin Delineation

Zip file sent to download directory

ArcGIS
Select Statistics & Basin Characteristics (Scenarios)

- October Flow-Duration Statistics
- November Flow-Duration Statistics
- December Flow-Duration Statistics

Step 1: Select a scenario below, or expand the “Basin Characteristics” panel to select specific basin characteristics.

- Regression Based Scenarios
- Bankfull Statistics
- Peak-Flow Statistics
- Low-Flow Statistics

Control panel:
- DRNAREA: Area that drains to a point on a stream
- ELEV: Mean Basin Elevation
- ELEVMAX: Maximum basin elevation
- LC06WATER: Percent of open water, class 11, from NLCD 2006
- LC11DEV: Percentage of developed (urban) land from NLCD 2011 classes 21-24

Basin Characteristics can be edited here:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRNAREA</td>
<td>3.4</td>
</tr>
<tr>
<td>STORWNI</td>
<td>12.91</td>
</tr>
<tr>
<td>ELEV</td>
<td>315</td>
</tr>
</tbody>
</table>

Select available reports to display:
- Basin Characteristics Report
- Scenario Flow Reports
### Basin Characteristics

<table>
<thead>
<tr>
<th>Parameter Code</th>
<th>Parameter Description</th>
<th>Value</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRNAREA</td>
<td>Area that drains to a point on a stream</td>
<td>3.4</td>
<td>square miles</td>
</tr>
<tr>
<td>STORNWI</td>
<td>Percentage of storage (combined water bodies and wetlands) from the National Wetlands Inventory</td>
<td>12.91</td>
<td>percent</td>
</tr>
<tr>
<td>ELEV</td>
<td>Mean Basin Elevation</td>
<td>315</td>
<td>feet</td>
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</table>

### Peak Flow Statistics

#### Parameter Code: Parameter Name

<table>
<thead>
<tr>
<th>Parameter Code</th>
<th>Parameter Name</th>
<th>Value</th>
<th>Units</th>
<th>Min Limit</th>
<th>Max Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRNAREA</td>
<td>Drainage Area</td>
<td>3.4</td>
<td>square miles</td>
<td>0.31</td>
<td>12</td>
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<tr>
<td>STORNWI</td>
<td>Percentage of Storage from NWI</td>
<td>12.91</td>
<td>percent</td>
<td>0</td>
<td>22.2</td>
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</table>

#### Peak Flow Statistics Flow Report


<table>
<thead>
<tr>
<th>Statistic</th>
<th>Value</th>
<th>Unit</th>
<th>SEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.01 Year Peak Flood</td>
<td>32.9</td>
<td>ft^3/s</td>
<td>38</td>
</tr>
<tr>
<td>2 Year Peak Flood</td>
<td>110</td>
<td>ft^3/s</td>
<td>34</td>
</tr>
<tr>
<td>5 Year Peak Flood</td>
<td>172</td>
<td>ft^3/s</td>
<td>35</td>
</tr>
<tr>
<td>10 Year Peak Flood</td>
<td>214</td>
<td>ft^3/s</td>
<td>37</td>
</tr>
<tr>
<td>25 Year Peak Flood</td>
<td>281</td>
<td>ft^3/s</td>
<td>39</td>
</tr>
<tr>
<td>50 Year Peak Flood</td>
<td>325</td>
<td>ft^3/s</td>
<td>41</td>
</tr>
<tr>
<td>100 Year Peak Flood</td>
<td>380</td>
<td>ft^3/s</td>
<td>42</td>
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<tr>
<td>250 Year Peak Flood</td>
<td>426</td>
<td>ft^3/s</td>
<td>44</td>
</tr>
<tr>
<td>500 Year Peak Flood</td>
<td>508</td>
<td>ft^3/s</td>
<td>47</td>
</tr>
</tbody>
</table>

### Peak Flow Statistics Citations

USGS Regression Equations Inform StreamStats

Peakflows: Hodgkins, 1999 - currently being updated

Monthly & Annual Mean & Selected Percentile Streamflows: Dudley, 2015

Peakflows for Small Watersheds: Lombard and Hodgkins, 2015

Regional Lowflows: multiple
Peakflow Equations & Climate Change

• Equations assume stationarity (no trends)
  – Estimating largest peaks (100-yr)
  – Statewide equations
  – Some evidence of historical increases
  – Future trends uncertain

• Update equations every 20 years

<table>
<thead>
<tr>
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<th>Temperature change</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0°F</td>
</tr>
<tr>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>+15%</td>
<td>+26%</td>
</tr>
<tr>
<td>+30%</td>
<td>+55%</td>
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Maine StreamStats
http://streamstats.usgs.gov

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