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


Glenn Hodgkins, USGS New England Water Science Center

# 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?

USGS

# Historical flood trends

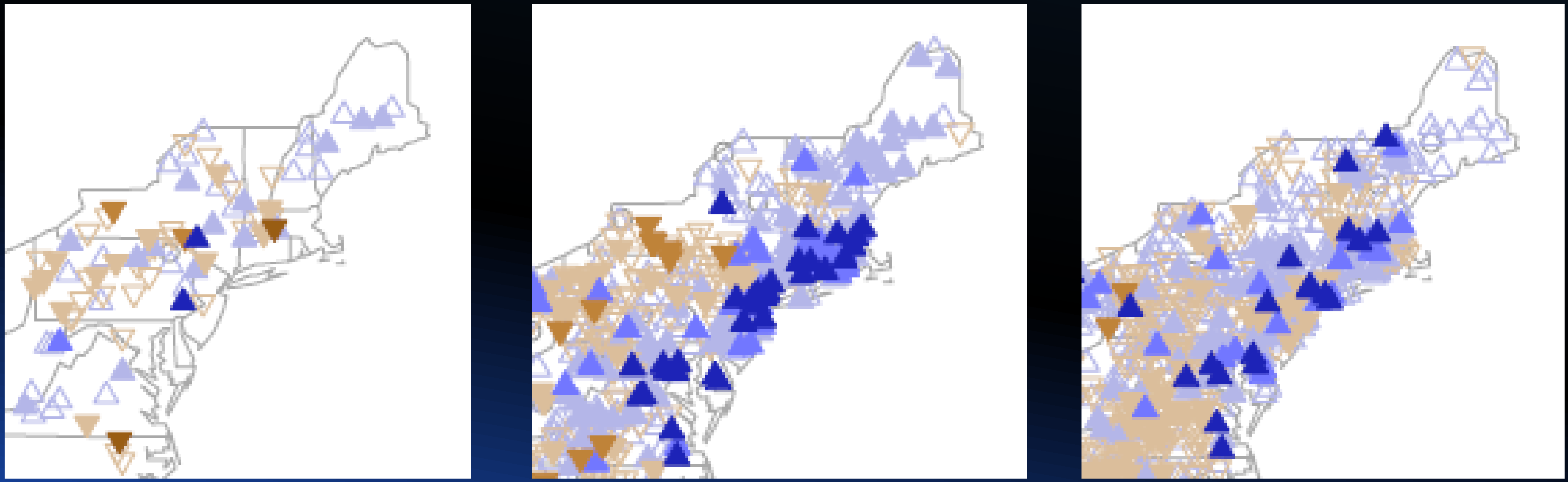
- Most flood-trend studies are based on annual peak flows or peaks over a threshold
- Annual peak flows tend to be mostly minor floods, with some moderate floods, and a few major floods

USGS

# 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

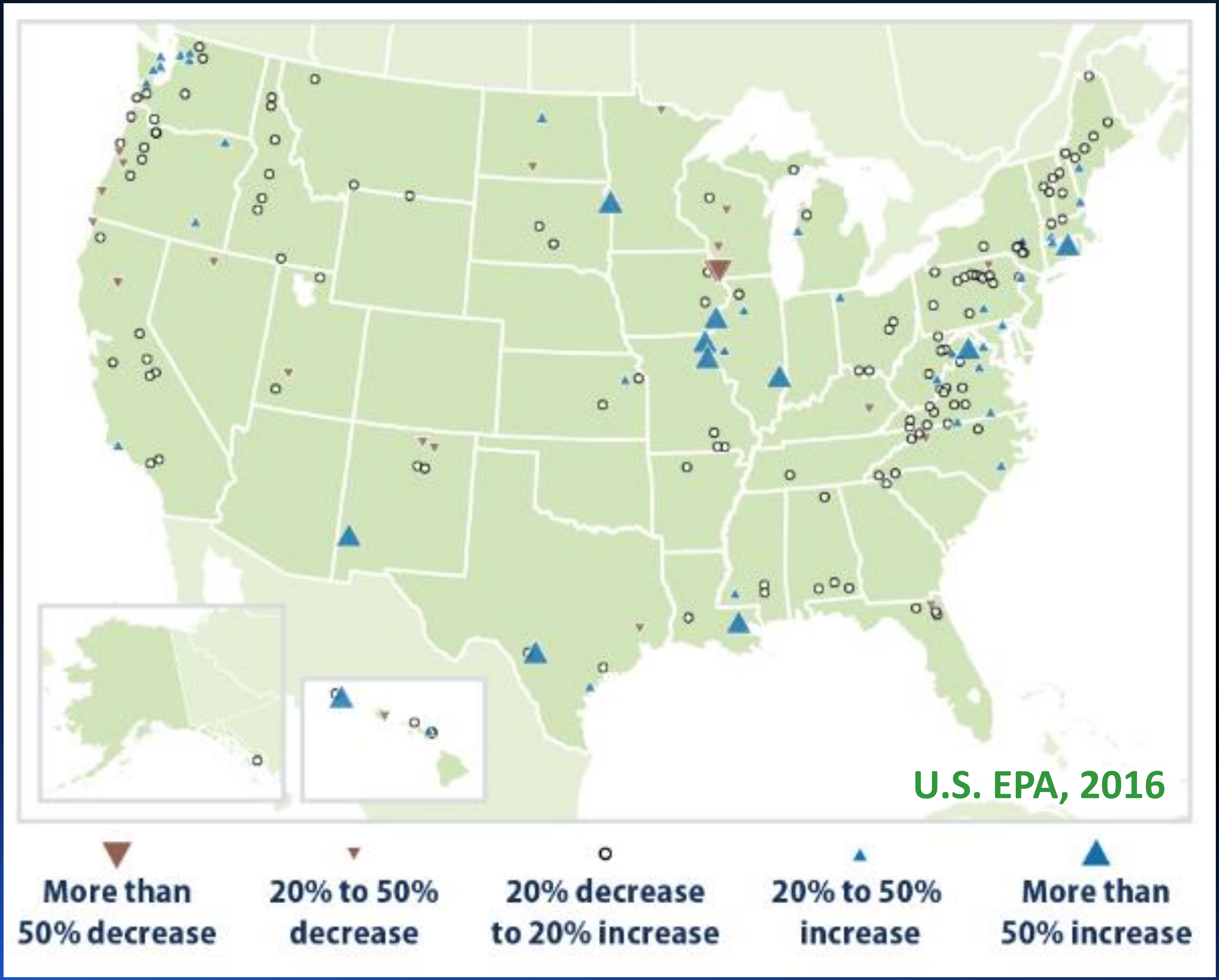


USGS

Provisional, subject to revision

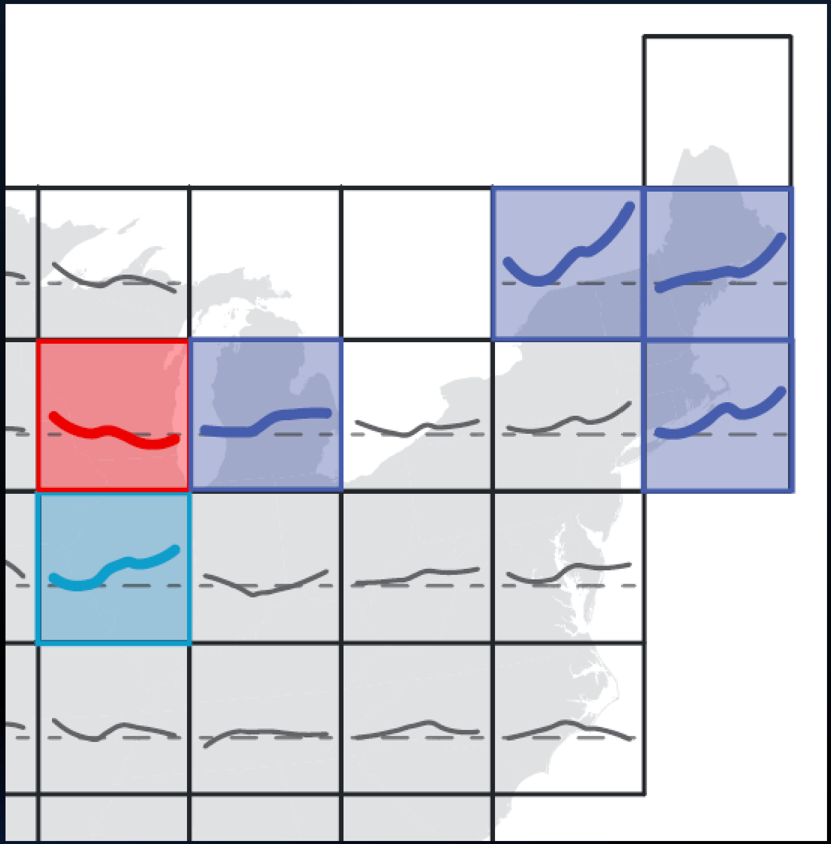
Hodgkins et al., in review

# Trends in 3-day peak flows, 1940-2014



# Historical trends: Peaks over threshold

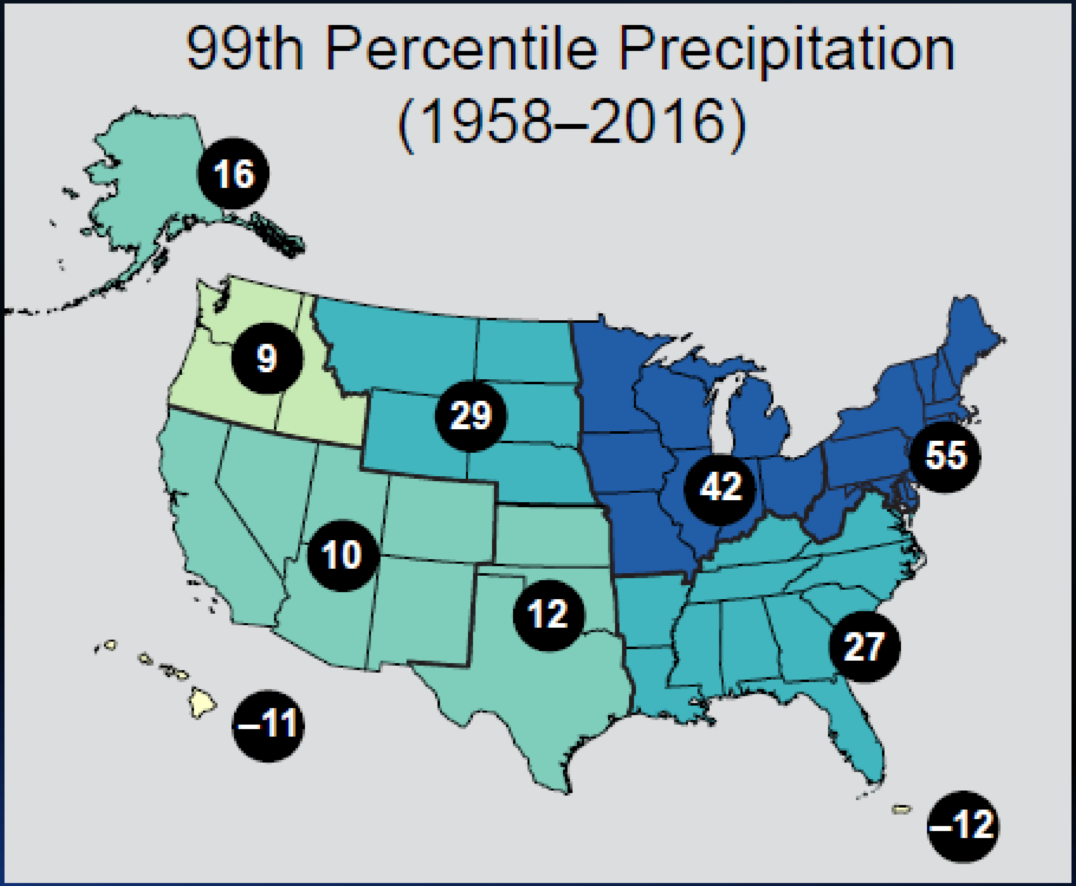
- Average of 2 peaks per year at each streamflow gage
- Gages grouped within grid cells
- Increasing *number* of peaks over threshold in Maine from 1940 to 2013
- Shaded grid cells represent significant trends



Archfield et al., 2016

USGS

# 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

USGS

# 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

USGS

# 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

**Temperature change**

| Precip Change | 0° F | +3.6° F | +7.2° F | +10.8° F |
|---|---|---|---|---|
| 0 % | 0 % | -12 % | -21 % | -20 % |
| +15 % | +26 % | +11 % | 0 % | +4 % |
| +30 % | +55 % | +39 % | +28 % | +32 % |

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

**Temperature change**

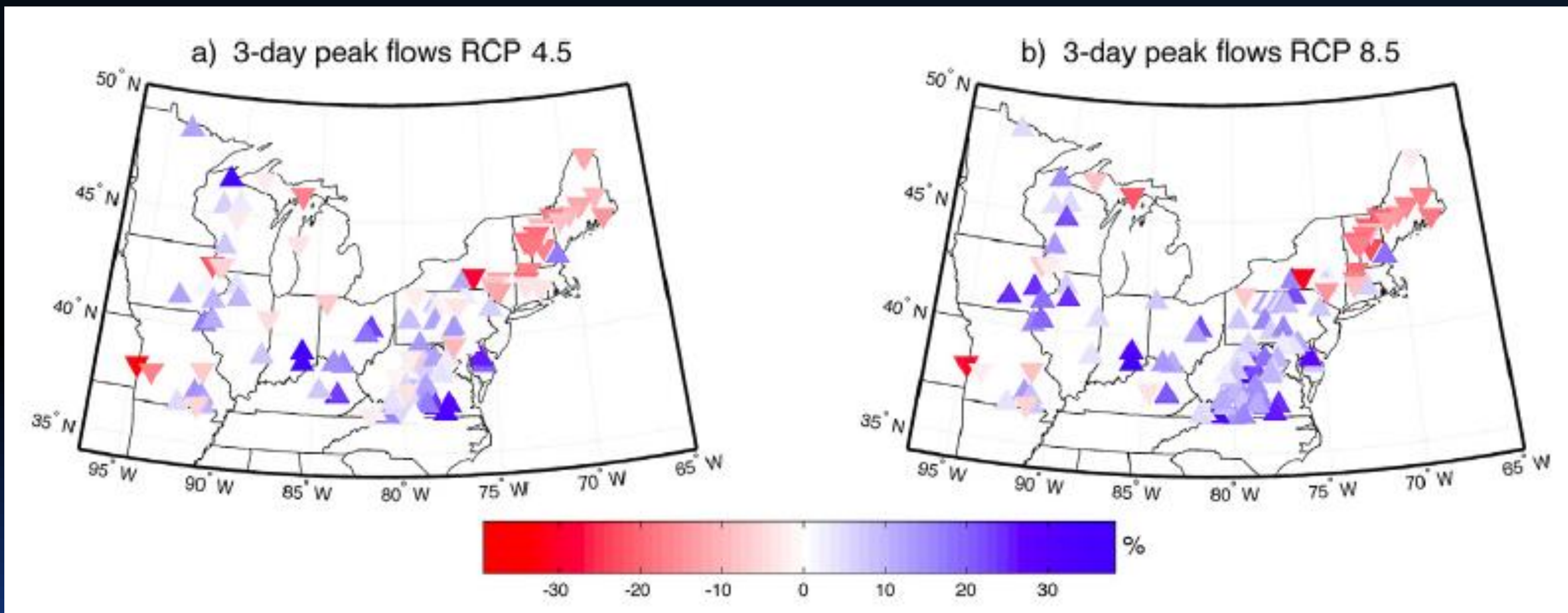
| Precip Change | 0° F | +3.6° F | +7.2° F | +10.8° F |
|---|---|---|---|---|
| **0 %** | 0 % | -42 % | -72 % | -89 % |
| **+15 %** | +17 % | -33 % | -67 % | -87 % |
| **+30 %** | +33 % | -22 % | -62 % | -86 % |

USGS MaineDOT

Hodgkins and Dudley, 2013

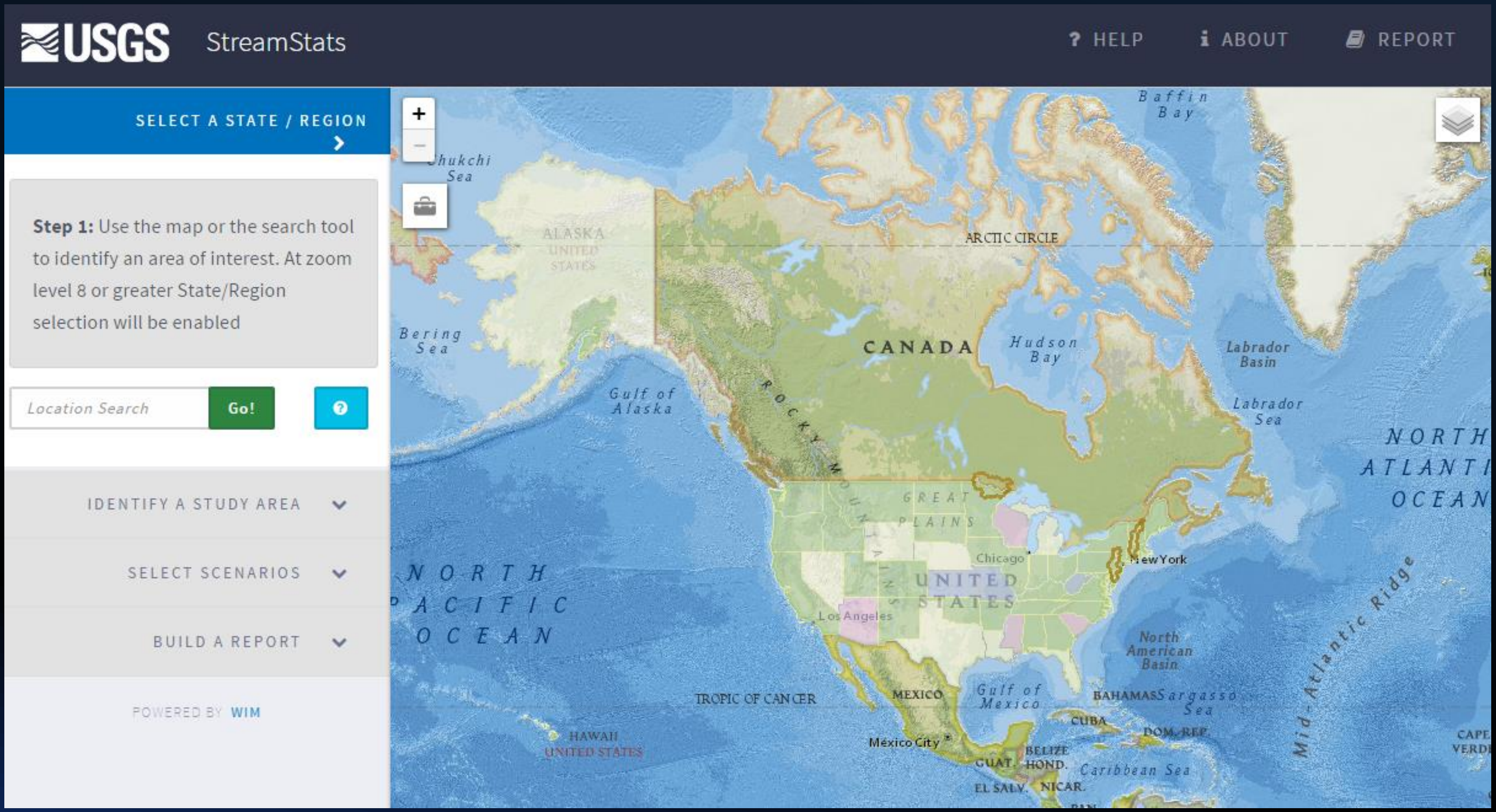
# Projected 100-year, 3-day peak flows

## 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

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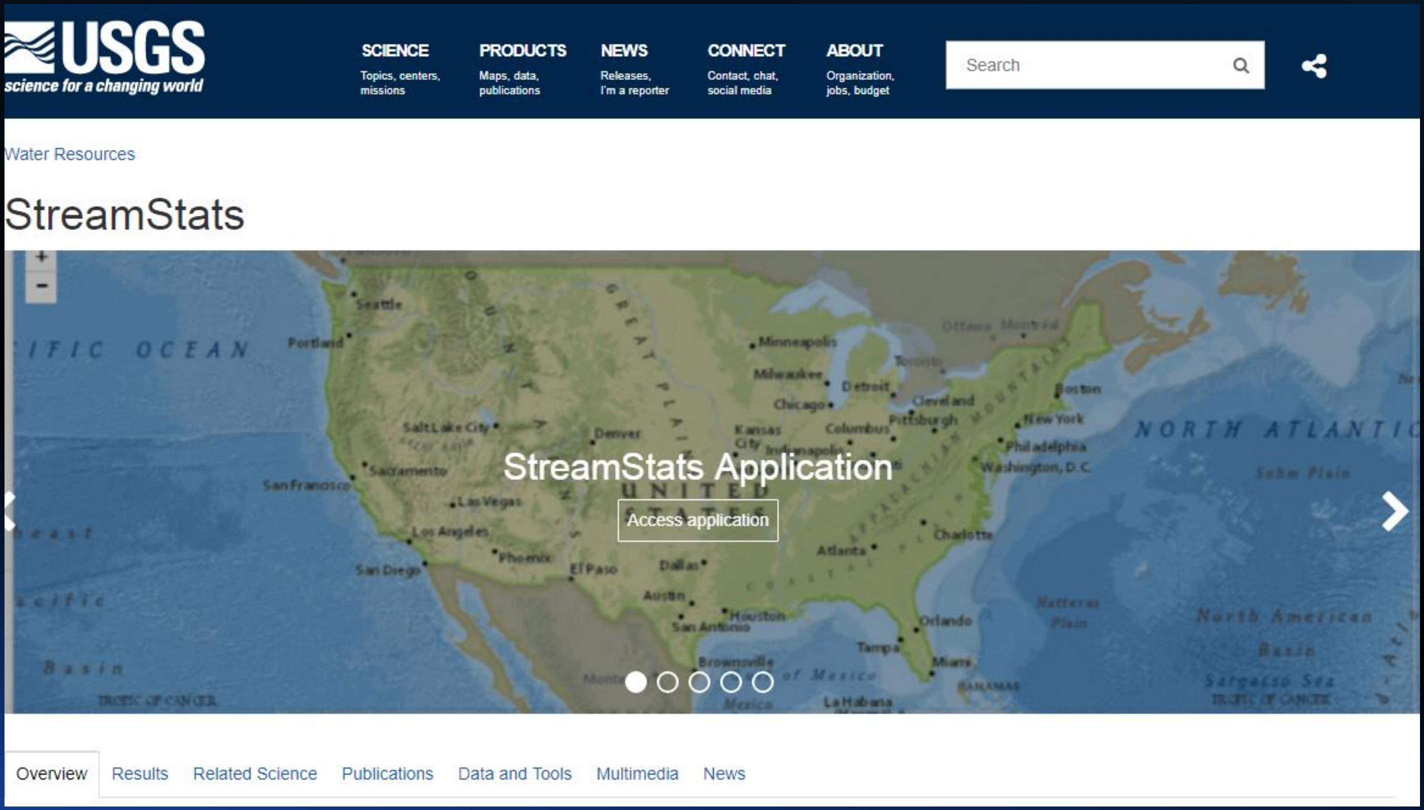
# USGS StreamStats

## http://streamstats.usgs.gov

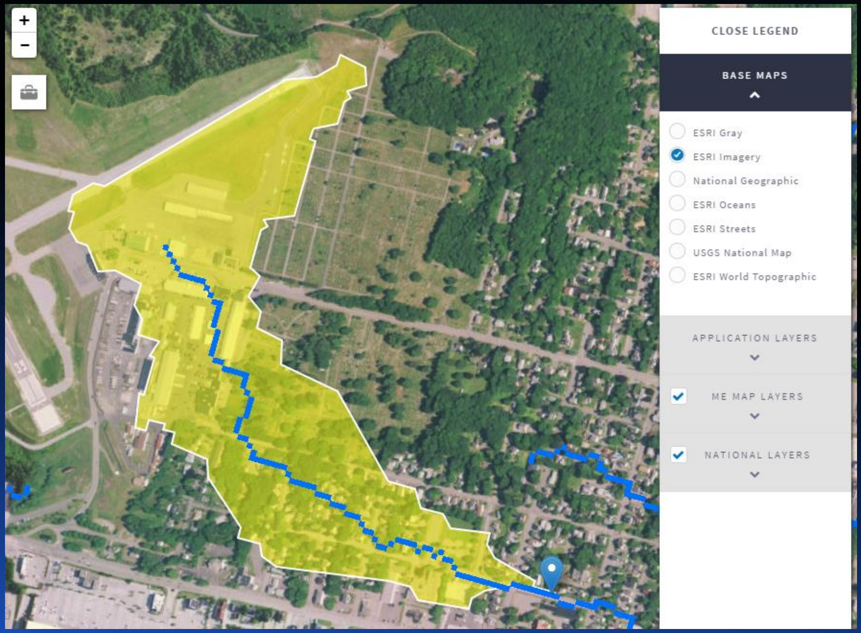
GIS-based Web application for calculating basin characteristics and streamflow statistics for user-selected sites on streams




USGS

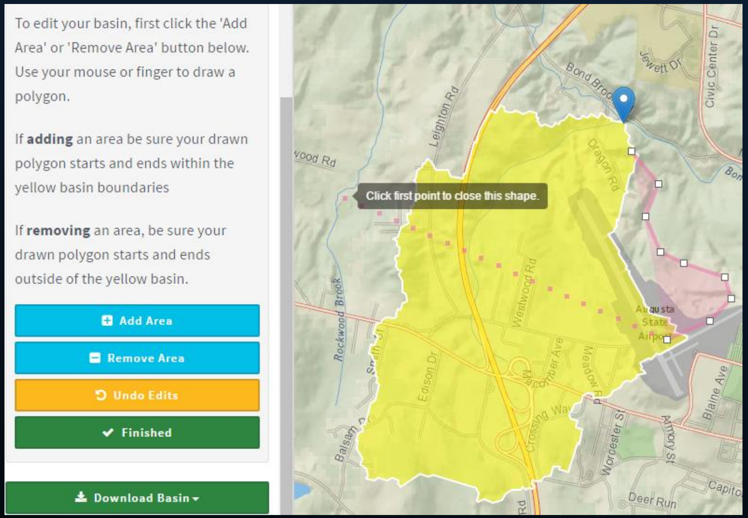
# StreamStats 4.0

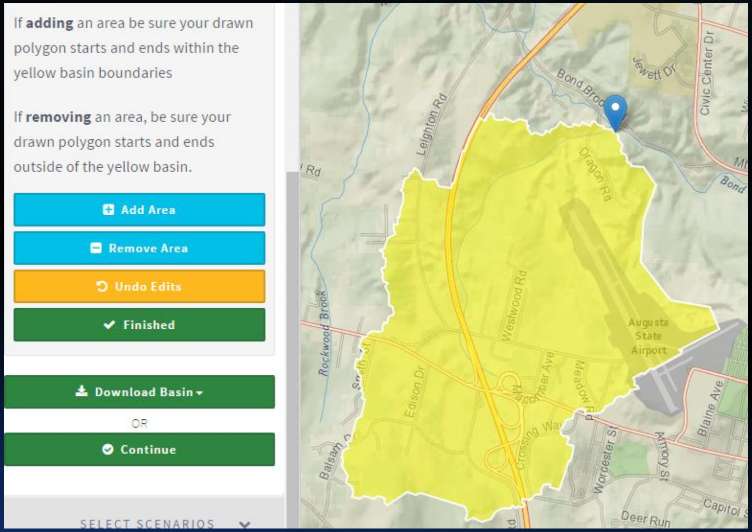
- Provides published basin characteristics & streamflow statistics at gaged locations
- Calculates basin characteristics & streamflow statistics at ungaged locations
  - Delineates watershed
  - Generates statistical flows using USGS peak flow regression equations



# 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

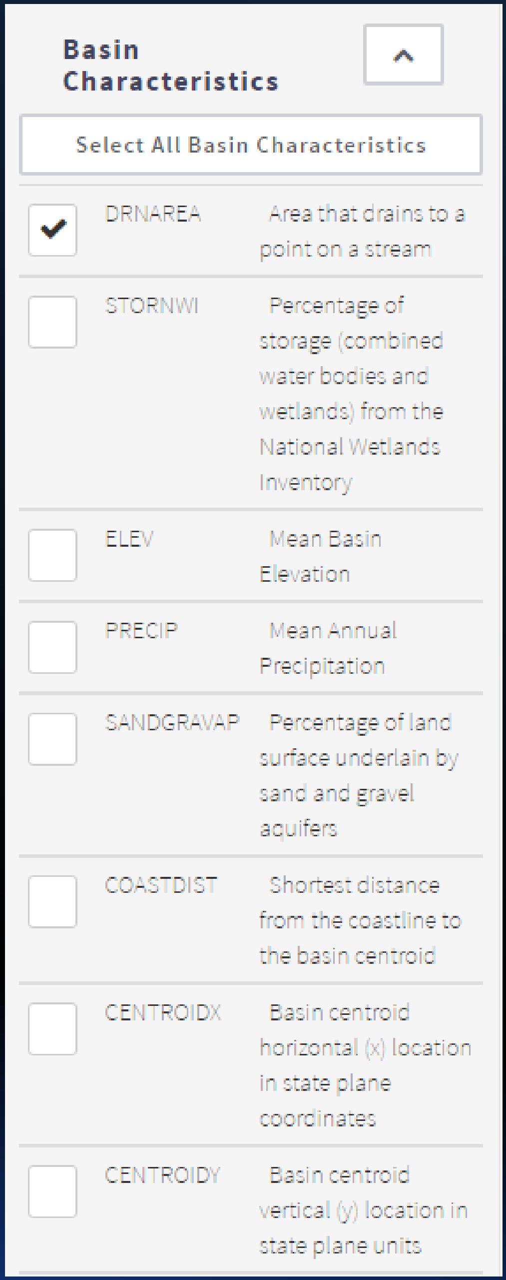



USGS

# 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)

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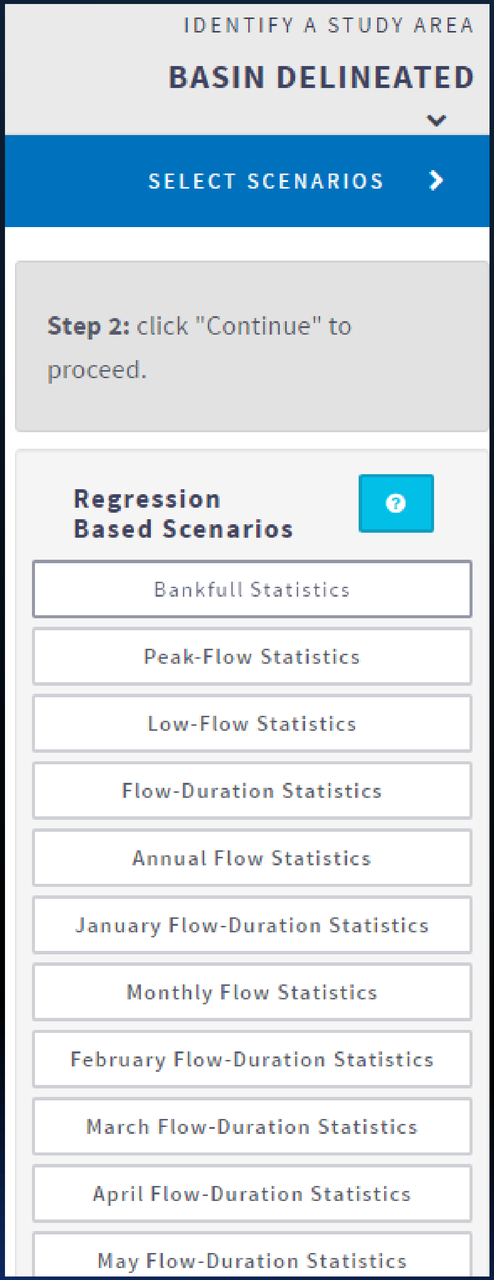
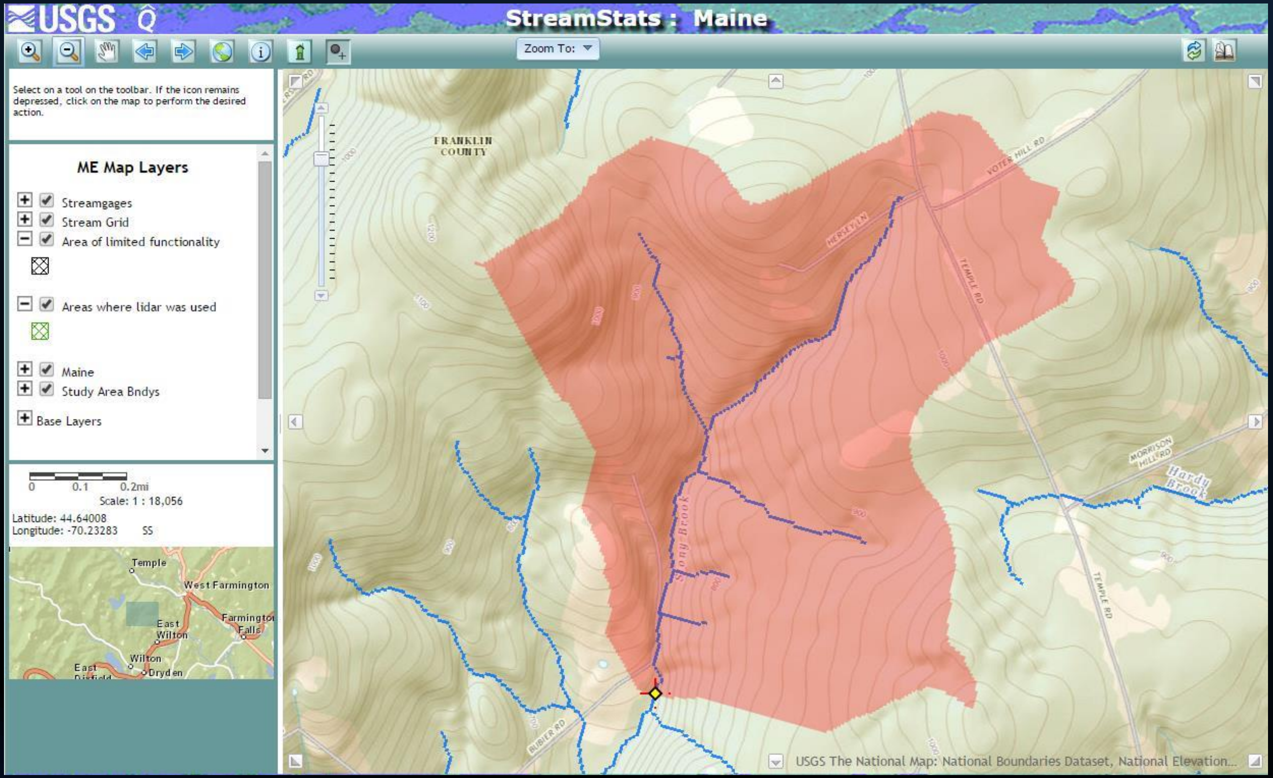
# Streamflow Statistics (currently in StreamStats)

- 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

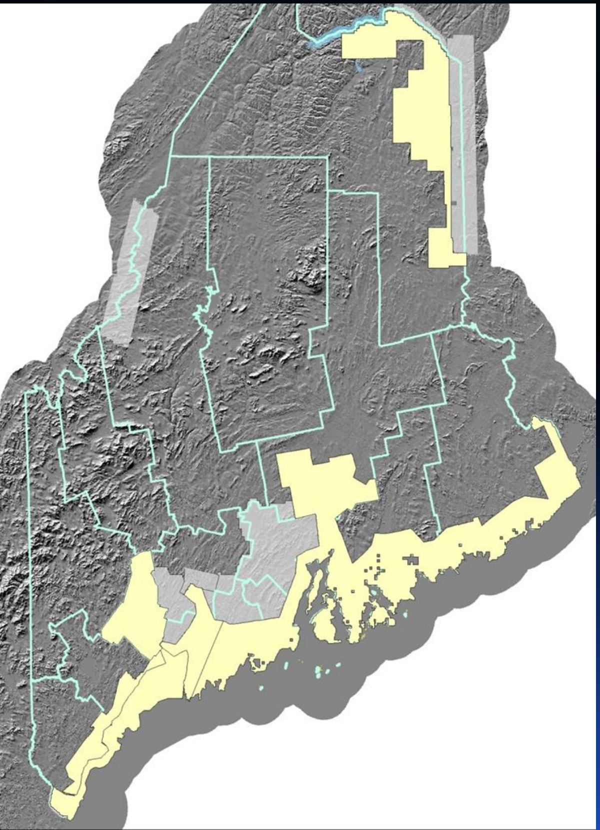



Delineates basins based on:

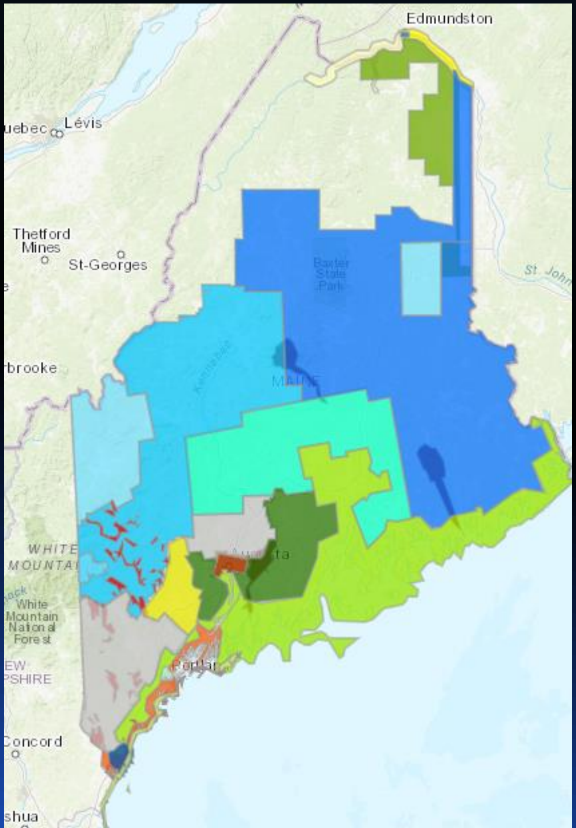
- 24K NHD
- 24K WBD
- 10M DEM or lidar

# Lidar Availability in Maine

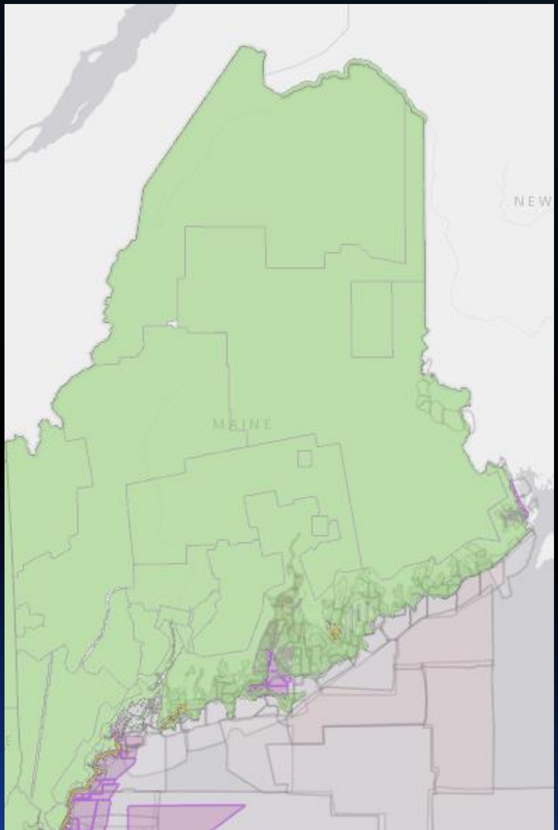
Currently in Streamstats



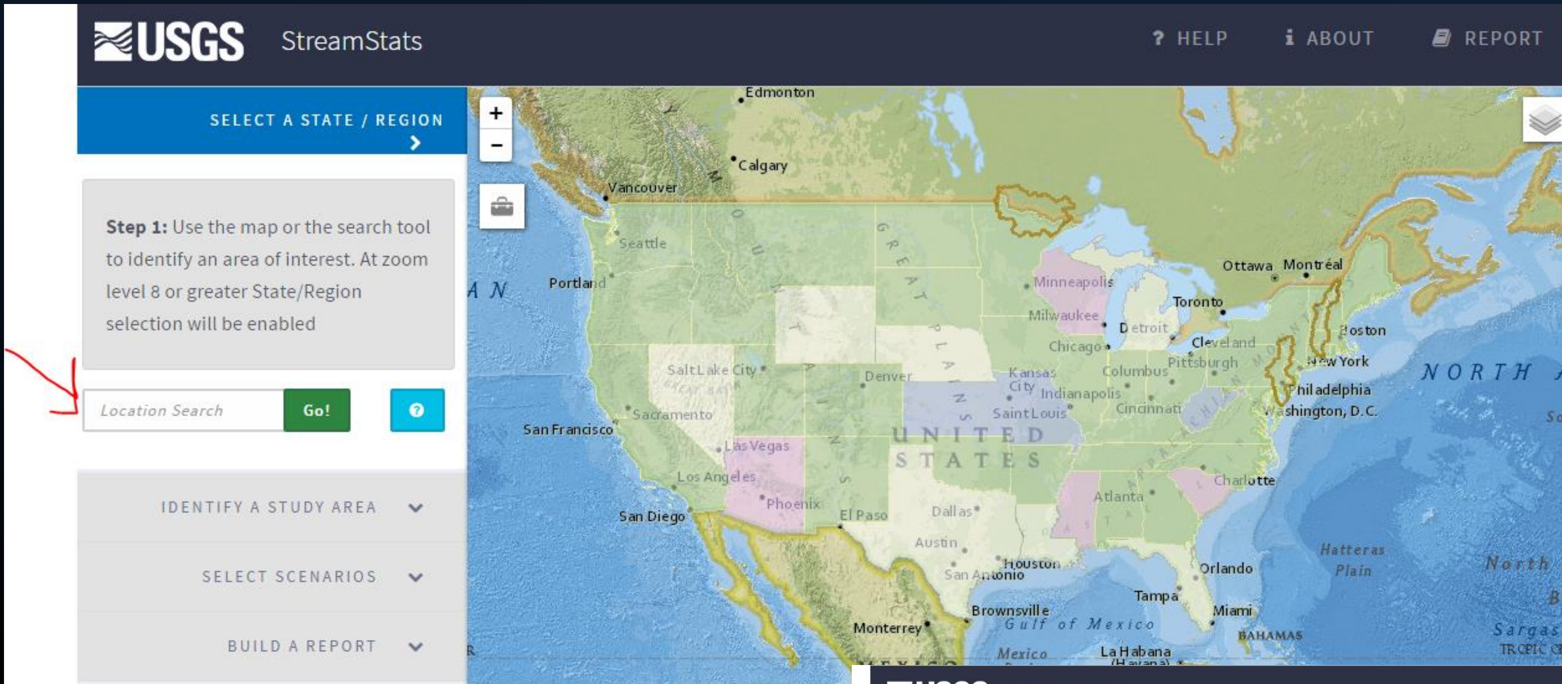
2019

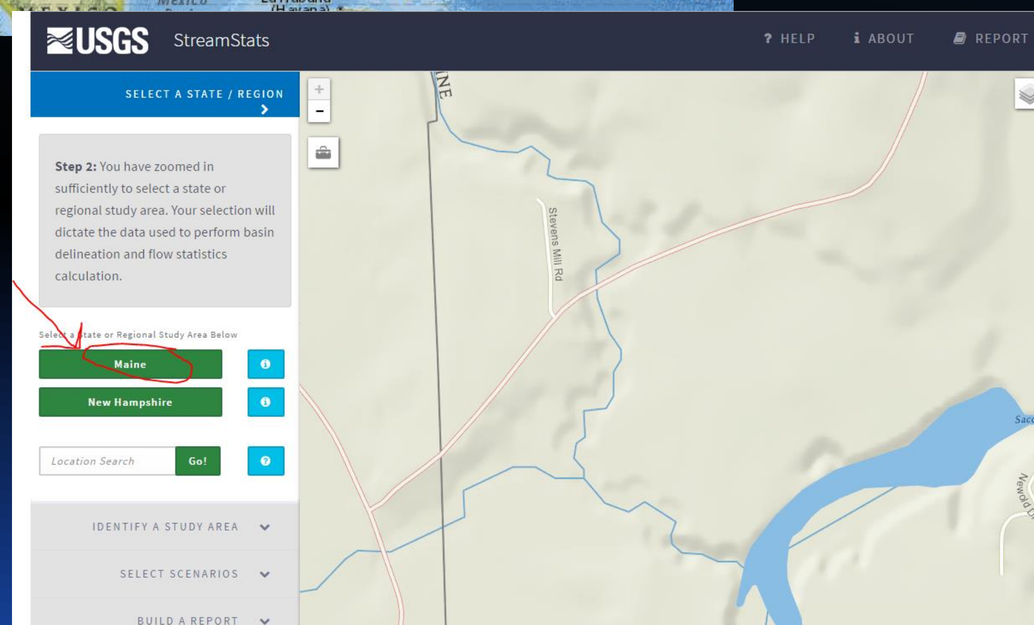


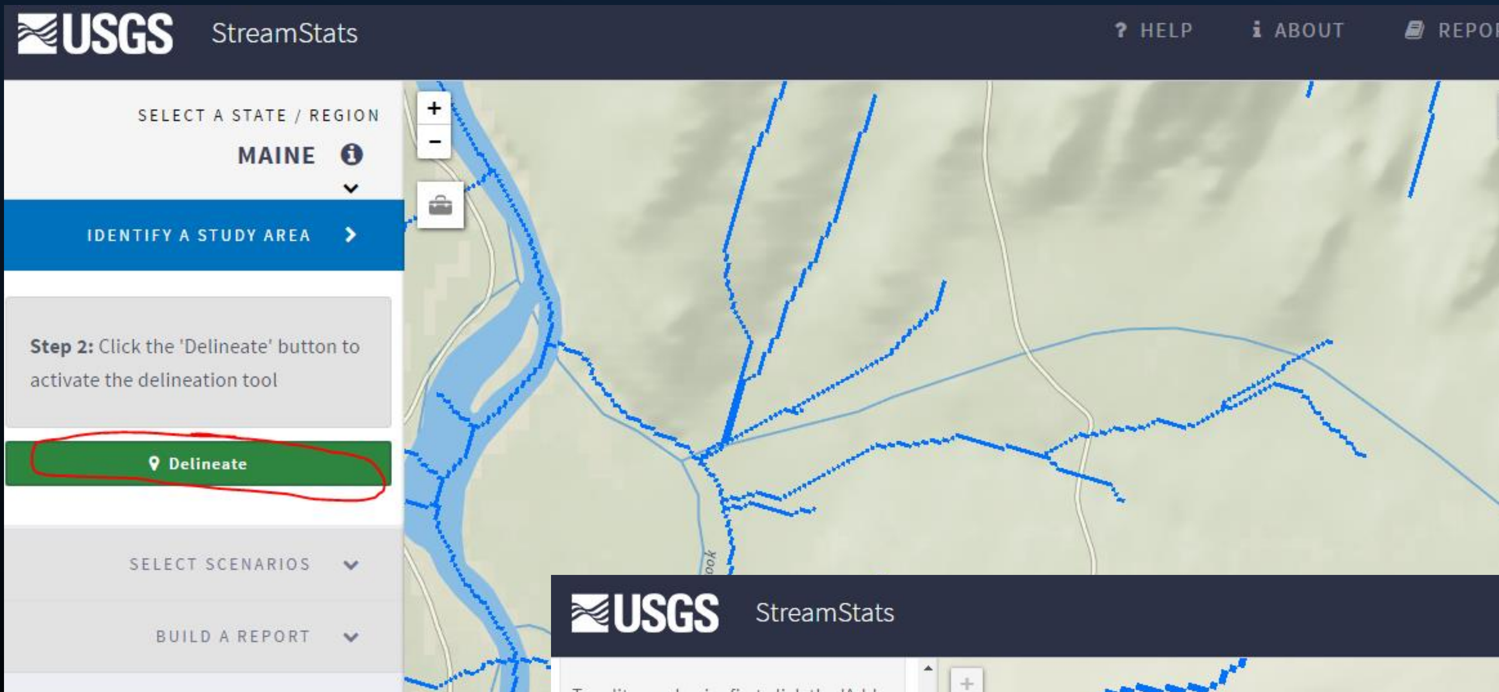

Projected 2020

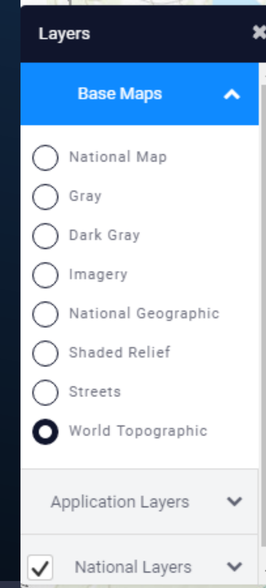


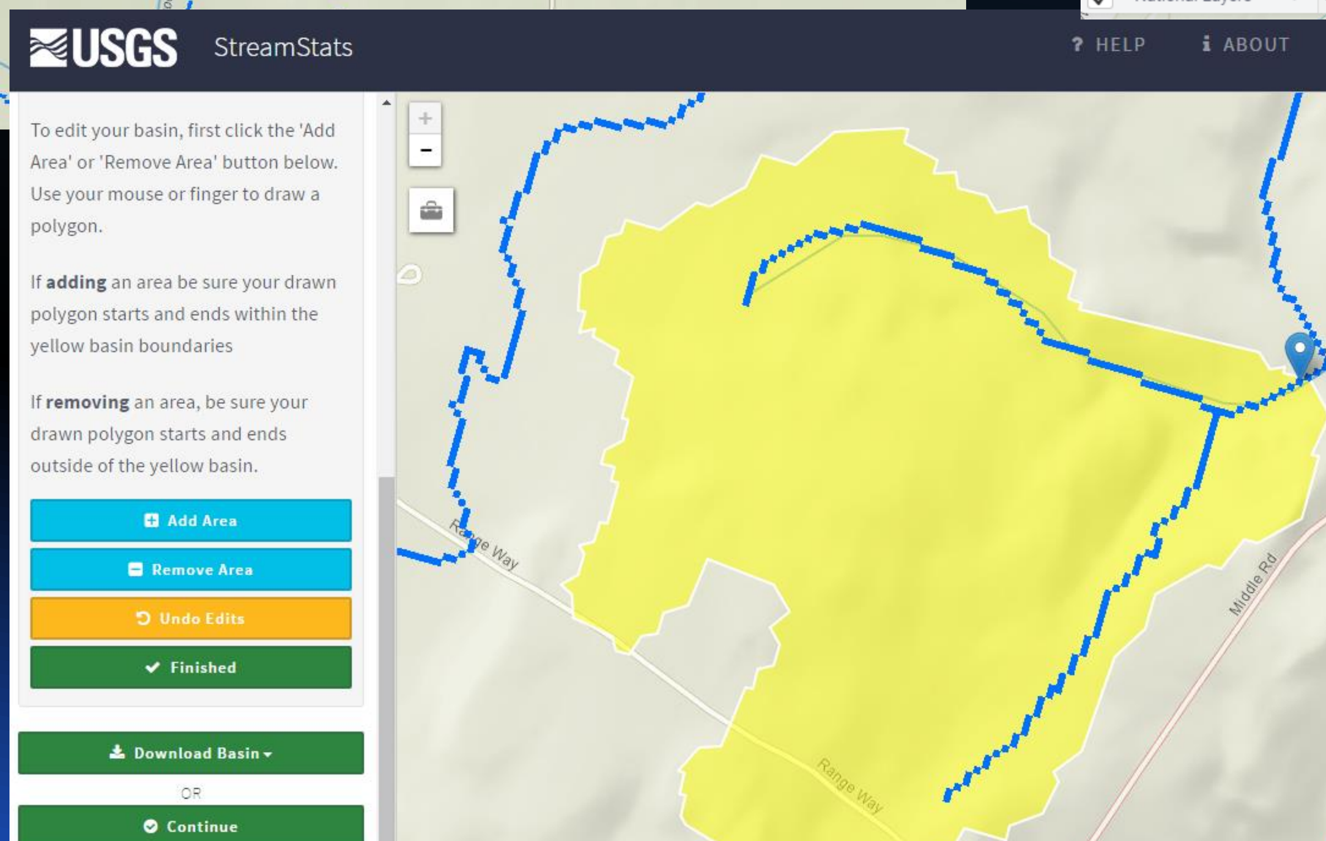
# StreamStats Version 4



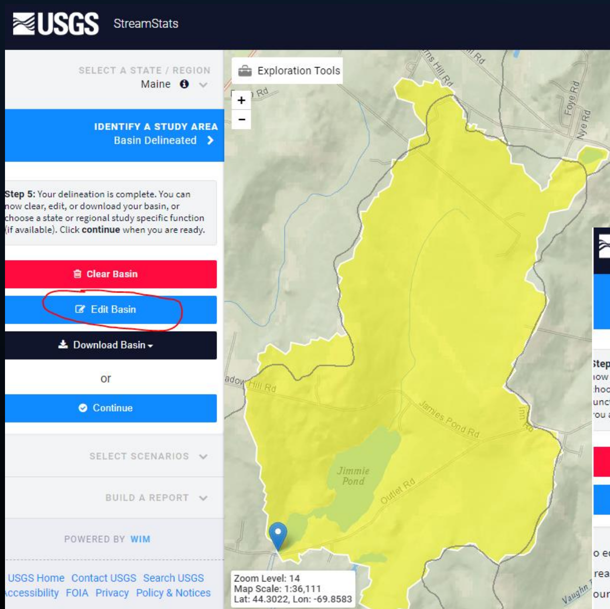



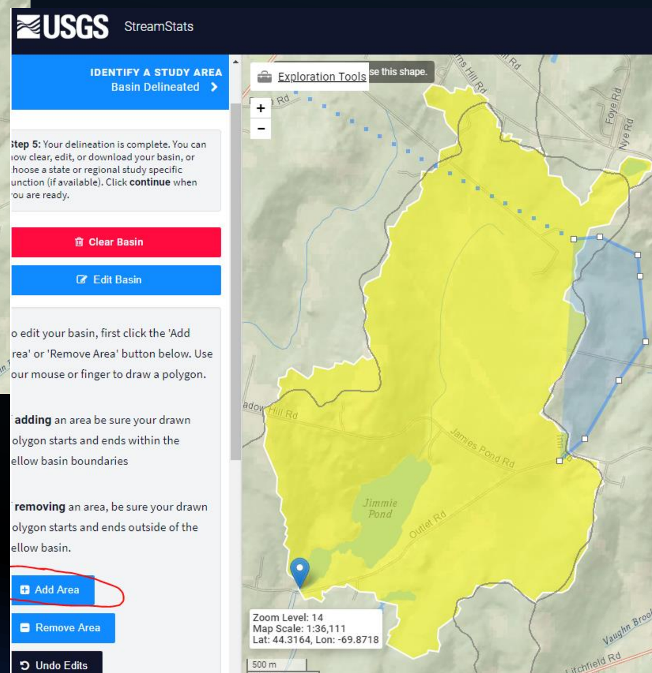

USGS StreamStats
? HELP
ABOUT
REPOR
SELECT A STATE / REGION
MAINE
IDENTIFY A STUDY AREA
Step 2: Click the 'Delineate' button to activate the delineation tool
Delineate
SELECT SCENARIOS
BUILD A REPORT

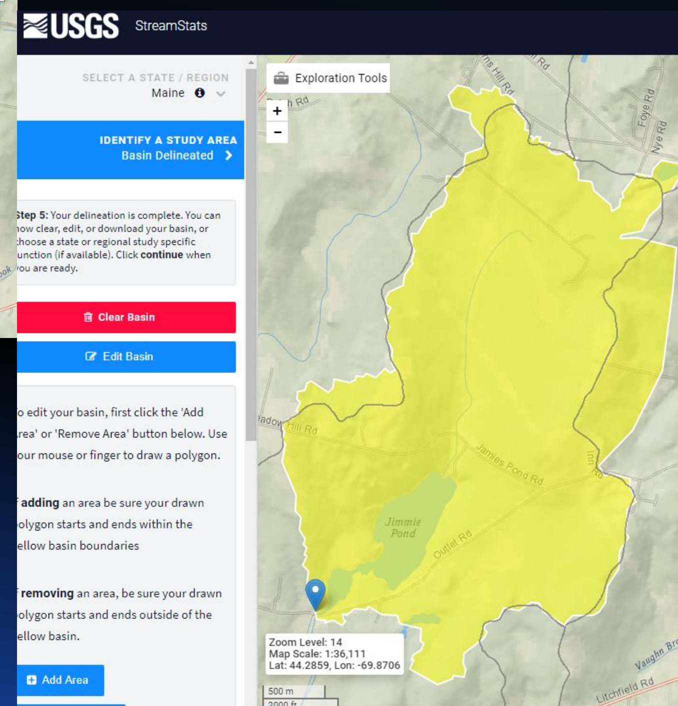

Layers
Base Maps
National Map
Gray
Dark Gray
Imagery
National Geographic
Shaded Relief
Streets
World Topographic
Application Layers
National Layers


USGS StreamStats
? HELP
ABOUT
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.
Add Area
Remove Area
Undo Edits
Finished
Download Basin
OR
Continue
Range Way
Middle Rd

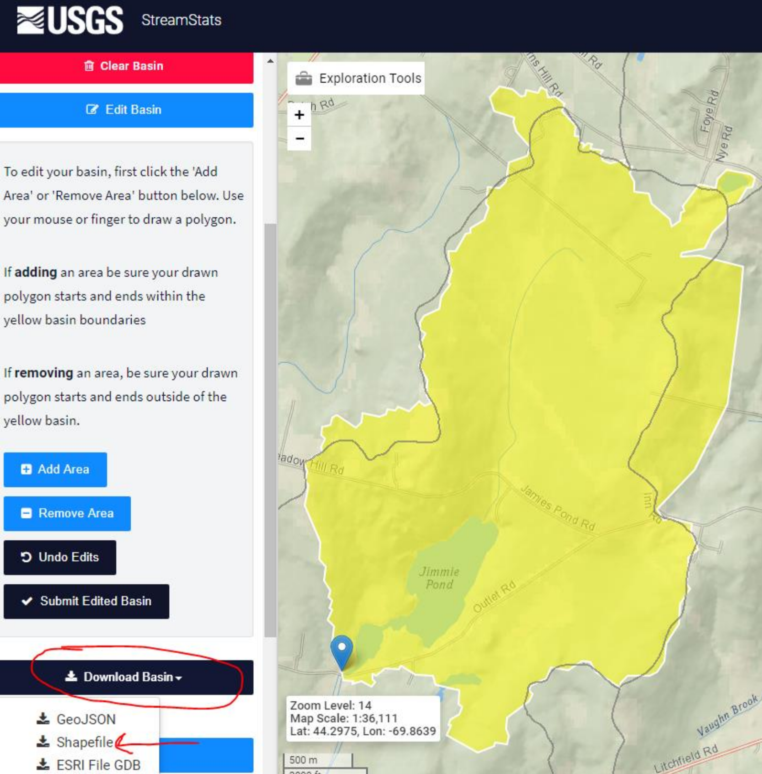
# Edit Basin Boundary



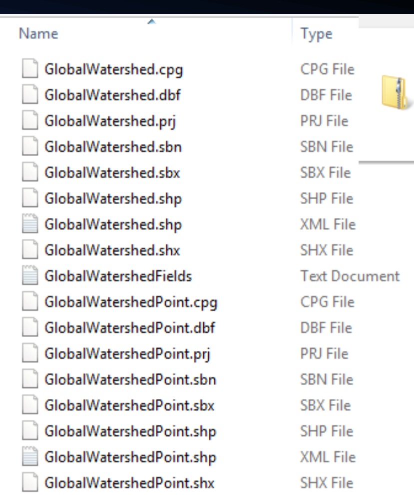



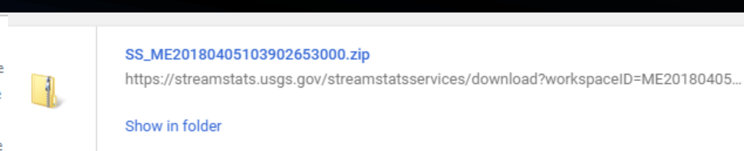
# Download Basin Delineation

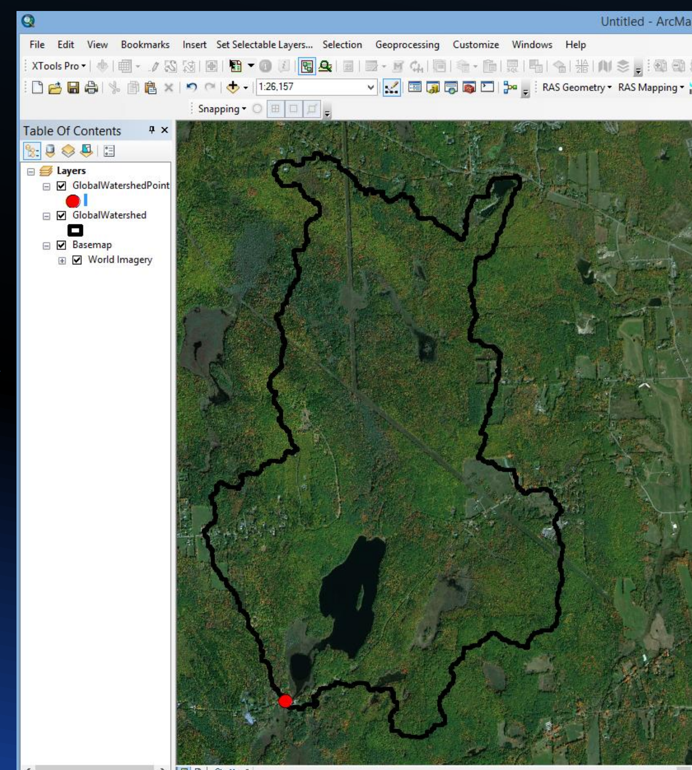



ArcGIS

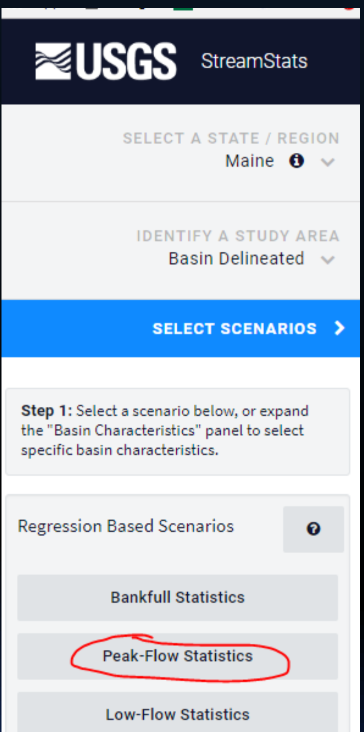
Zip file sent to download directory

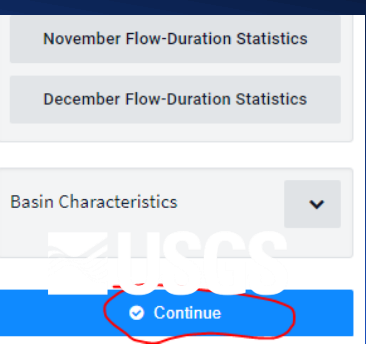


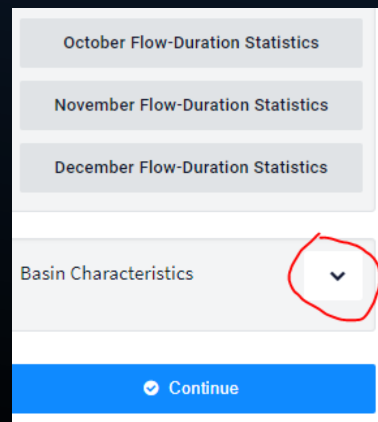



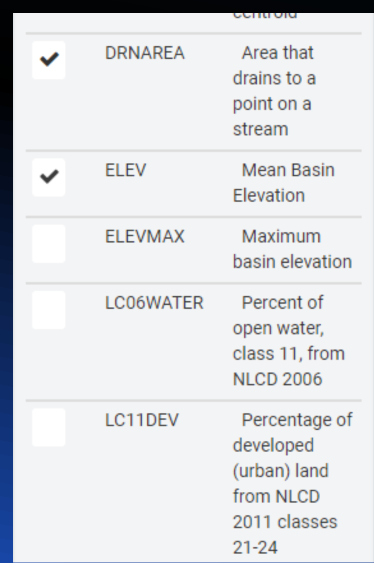



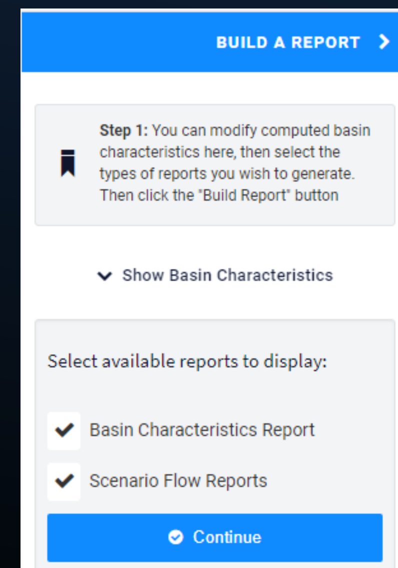
# Select Statistics & Basin Characteristics (Scenarios)

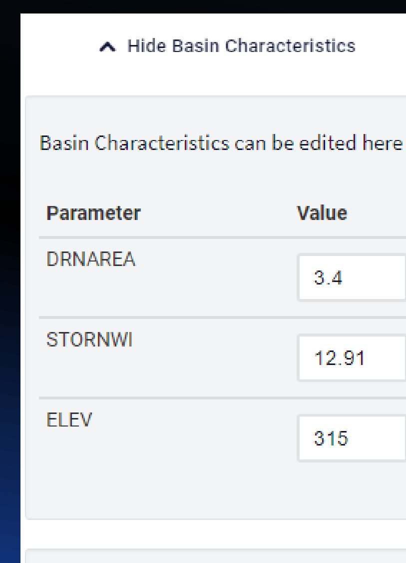


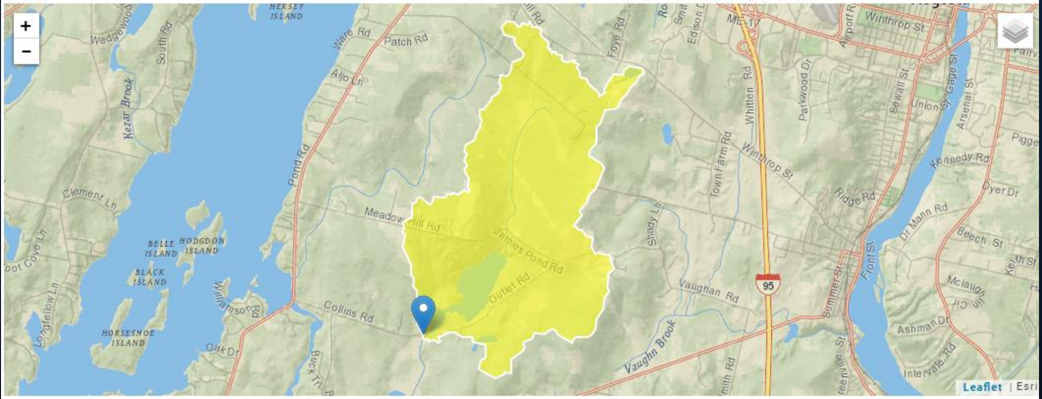



# StreamStats Report

| | |
|---|---|
| **Region ID:** | ME |
| **Workspace ID:** | ME20180405103902653000 |
| **Clicked Point (Latitude, Longitude):** | 44.27587, -69.86695 |
| **Time:** | 2018-04-05 06:39:19 -0400 |




Basin Characteristics

| Parameter Code | Parameter Description | Value | Unit |
|---|---|---|---|
| DRNAREA | Area that drains to a point on a stream | 3.4 | square miles |
| STORNWI | Percentage of strorage (combined water bodies and wetlands) from the Nationa Wetlands Inventory | 12.91 | percent |
| ELEV | Mean Basin Elevation | 315 | feet |

Peak-Flow Statistics Parameters [Statewide Peak Flow DA LT 12sqmi 2015 5049]

| Parameter Code | Parameter Name | Value | Units | Min Limit | Max Limit |
|---|---|---|---|---|---|
| DRNAREA | Drainage Area | 3.4 | square miles | 0.31 | 12 |
| STORNWI | Percentage of Storage from NWI | 12.91 | percent | 0 | 22.2 |

Peak-Flow Statistics Flow Report [Statewide Peak Flow DA LT 12sqmi 2015 5049]

PII: Prediction Interval-Lower, Plu: Prediction Interval-Upper, SEp: Standard Error of Prediction, SE: Standard Error (other -- see report)

| Statistic | Value | Unit | SEp |
|---|---|---|---|
| 1.01 Year Peak Flood | 32.9 | ft^3/s | 38 |
| 2 Year Peak Flood | 110 | ft^3/s | 34 |
| 5 Year Peak Flood | 172 | ft^3/s | 35 |
| 10 Year Peak Flood | 214 | ft^3/s | 37 |
| 25 Year Peak Flood | 281 | ft^3/s | 39 |
| 50 Year Peak Flood | 325 | ft^3/s | 41 |
| 100 Year Peak Flood | 380 | ft^3/s | 42 |
| 250 Year Peak Flood | 426 | ft^3/s | 44 |
| 500 Year Peak Flood | 508 | ft^3/s | 47 |

*Peak-Flow Statistics Citations*

**Lombard, P.J., and Hodgkins, G.A.,2015, Peak flow regression equations for small, ungaged streams in Maine— Comparing map-based to field-based variables: U.S. Geological Survey Scientific Investigations Report 2015–5049, 12 p.**

Download Basin ▾ | Download CSV

USGS

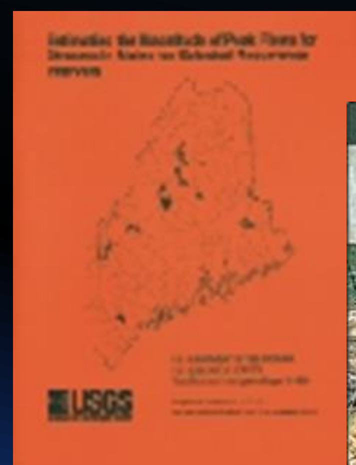
# USGS Regression Equations Inform StreamStats

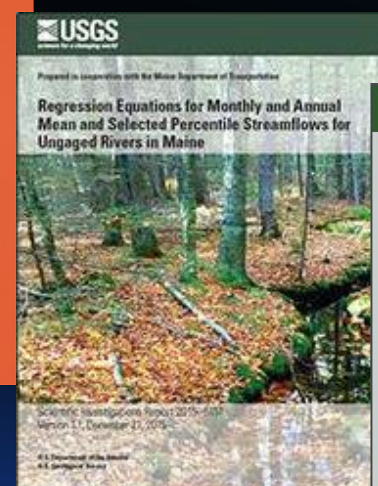
Peakflows: Hodgkins, 1999- currently being updated

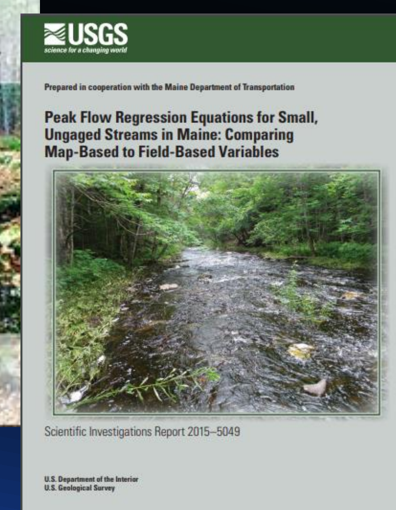
Monthly & Annual Mean & Selected Percentile Streamflows: Dudley, 2015

Peakflows for Small Watersheds: Lombard and Hodgkins, 2015

Regional Lowflows: multiple



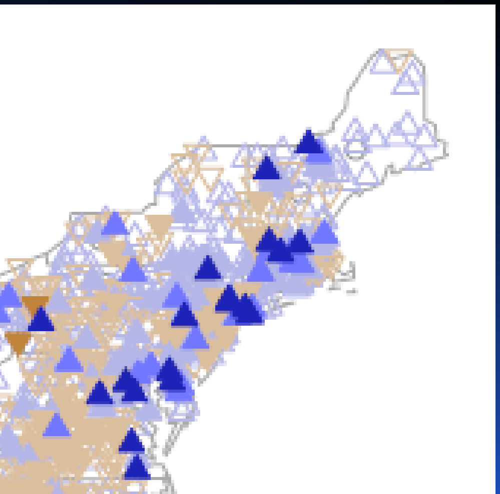



USGS

# 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



**Temperature change**

| Precip Change | 0° F | +3.6° F | +7.2° F | +10.8° F |
|---|---|---|---|---|
| 0 % | 0 % | -12 % | -21 % | -20 % |
| +15 % | +26 % | +11 % | 0 % | +4 % |
| +30 % | +55 % | +39 % | +28 % | +32 % |

# Maine StreamStats

## http://streamstats.usgs.gov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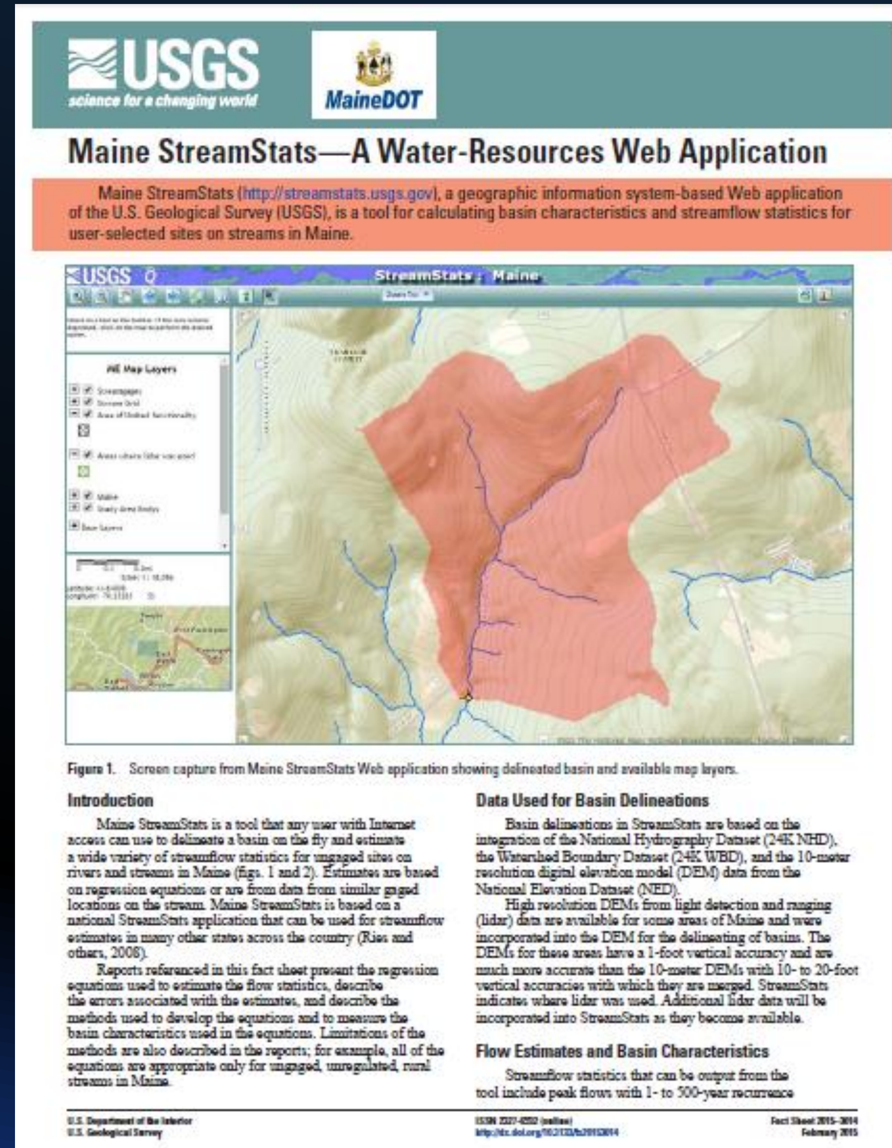
plombard@usgs.gov

USGS
science for a changing world

MaineDOT

# Maine StreamStats—A Water-Resources Web Application

Maine StreamStats (http://streamstats.usgs.gov), a geographic information system-based Web application of the U.S. Geological Survey (USGS), is a tool for calculating basin characteristics and streamflow statistics for user-selected sites on streams in Maine.



**Figure 1.** Screen capture from Maine StreamStats Web application showing delineated basin and available map layers.

## Introduction

Maine StreamStats is a tool that any user with Internet access can use to delineate a basin on the fly and estimate a wide variety of streamflow statistics for ungaged sites on rivers and streams in Maine (figs. 1 and 2). Estimates are based on regression equations or are from data from similar gaged locations on the stream. Maine StreamStats is based on a national StreamStats application that can be used for streamflow estimates in many other states across the country (Ries and others, 2008).

Reports referenced in this fact sheet present the regression equations used to estimate the flow statistics, describe the errors associated with the estimates, and describe the methods used to develop the equations and to measure the basin characteristics used in the equations. Limitations of the methods are also described in the reports; for example, all of the equations are appropriate only for ungaged, unregulated, rural streams in Maine.

## Data Used for Basin Delineations

Basin delineations in StreamStats are based on the integration of the National Hydrography Dataset (24K NHD), the Watershed Boundary Dataset (24K WBD), and the 10-meter resolution digital elevation model (DEM) data from the National Elevation Dataset (NED).

High resolution DEMs from light detection and ranging (lidar) data are available for some areas of Maine and were incorporated into the DEM for the delineating of basins. The DEMs for these areas have a 1-foot vertical accuracy and are much more accurate than the 10-meter DEMs with 10- to 20-foot vertical accuracies with which they are merged. StreamStats indicates where lidar was used. Additional lidar data will be incorporated into StreamStats as they become available.

## Flow Estimates and Basin Characteristics

Streamflow statistics that can be output from the tool include peak flows with 1- to 500-year recurrence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