

ONLINE COURSE

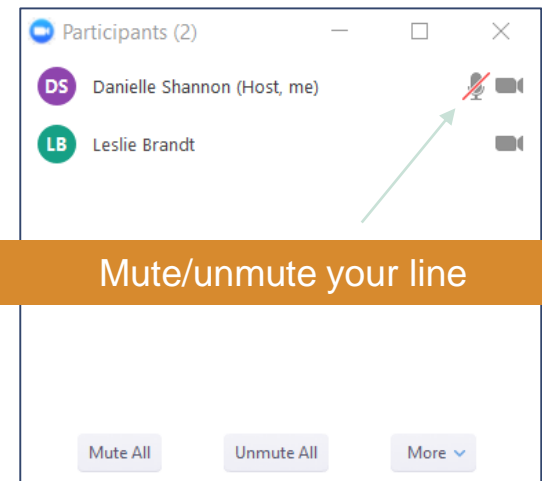
URBAN FORESTED WATERSHEDS ADAPTATION PLANNING AND PRACTICES

Session 5: Step 4 Review and Step 5 Intro

Tuesday, December 4, 2018 @ 11 am ET

Web session etiquette. Please:

- If you are using a phone, turn off your computer speakers to avoid feedback and terrible noises.
- Mute your line unless you are speaking to the group.



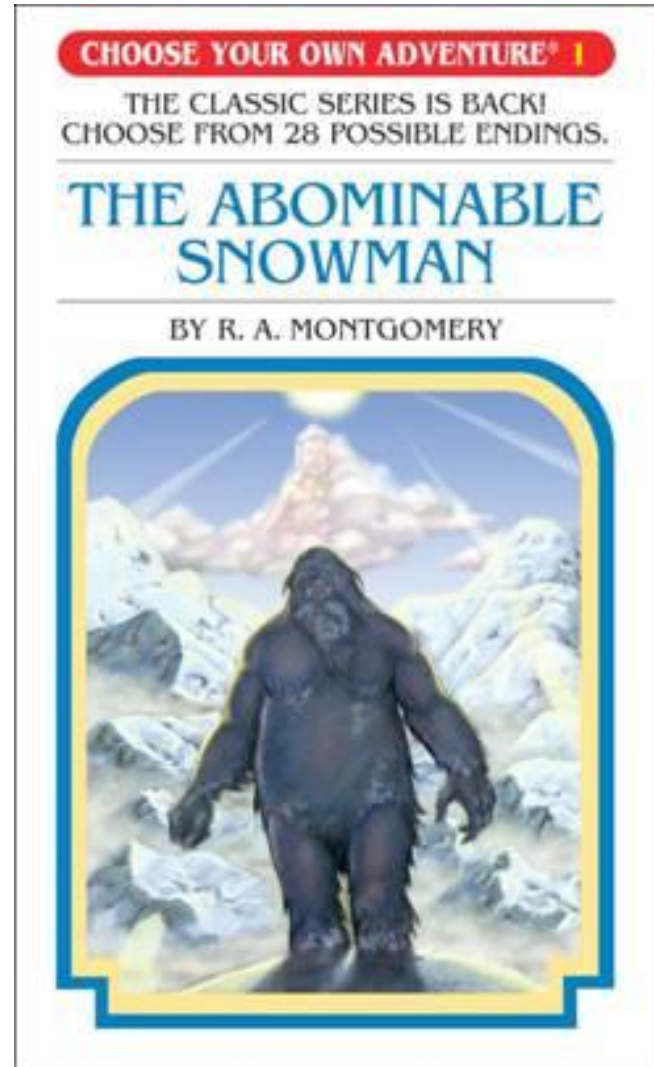
Today's Agenda

Discussion:

- Step 4 review
- Discussion: how are you adapting your forests to a changing climate?

Lecture:

- Step 5: Monitoring
- Website demo and homework



Step 4: IDENTIFY adaptation approaches and tactics for implementation.

Key Question:

What actions can enhance the ability of the ecosystem to adapt to anticipate changes *and* meet management goals?

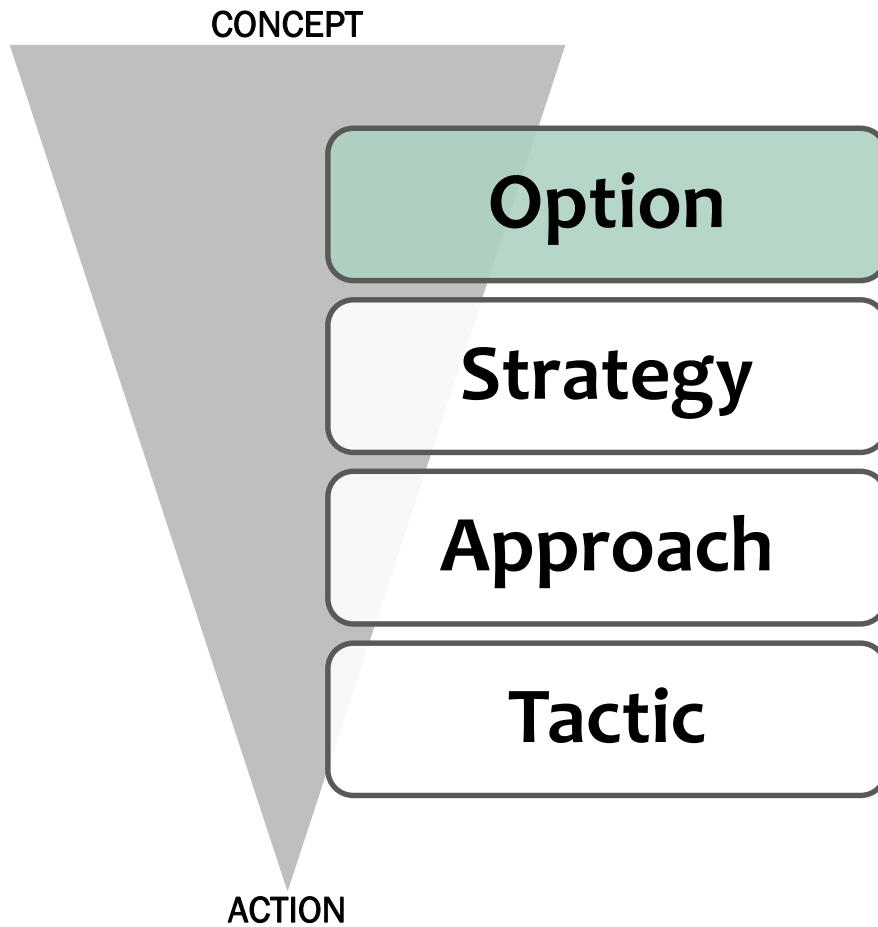
Adaptation Strategies & Approaches



A “menu” of possible actions that allows you to decide what is most relevant for a particular location and set of conditions.

*Find in: Step 4 of online workbook, Chapter 3-4 of FAR , or
www.adaptationworkbook.org/niacs-strategies
www.adaptationworkbook.org/niacs-strategies/urban*

Adaptation Strategies and Approaches

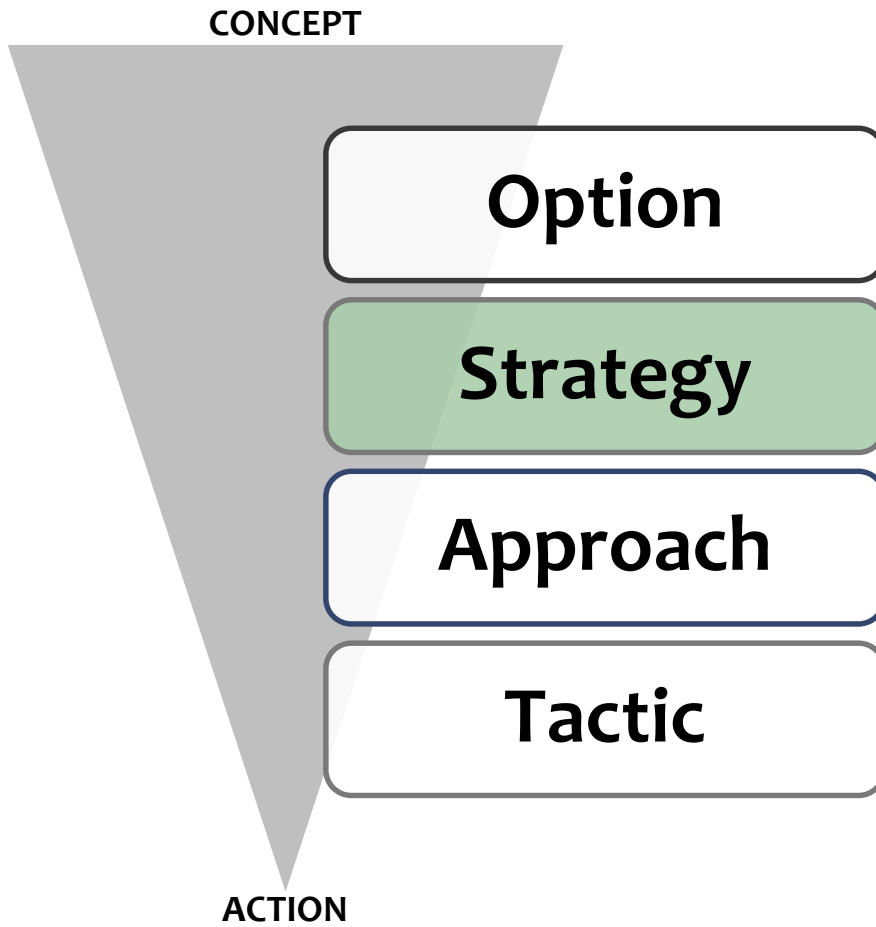


Big ideas

- Increase **resistance**
- Build **resilience**
- Facilitate **transition**

See Step 4 Course Materials for a recorded presentation that provides more details

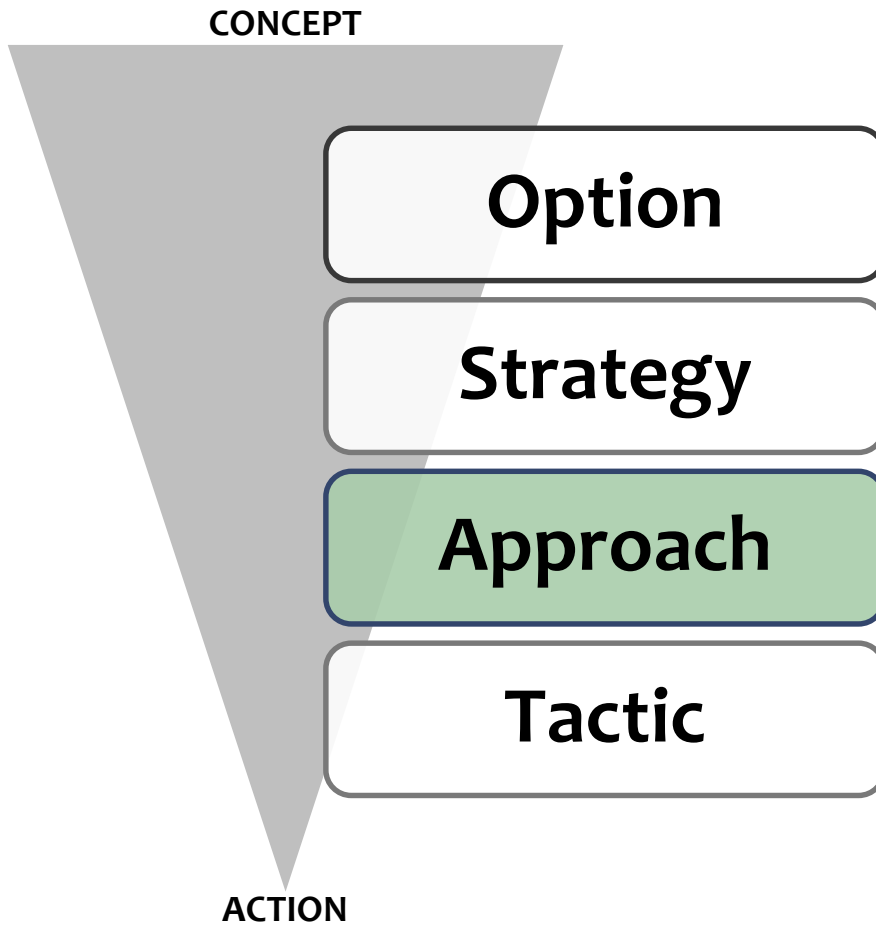
Adaptation Strategies & Approaches



Broad adaptation responses

- Sustain fundamental ecological functions
- Reduce the impact of existing biological stressors
- Maintain and enhance species and structural diversity
- Facilitate community adjustments through species transitions

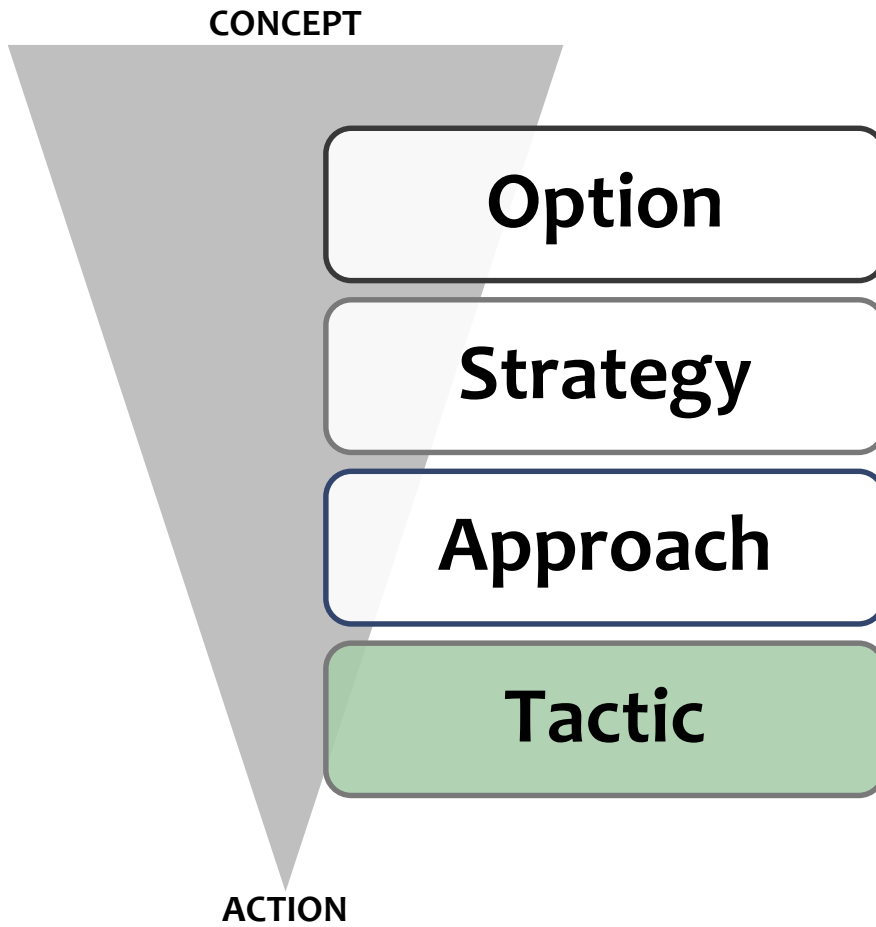
Adaptation Strategies & Approaches



More specific actions

- Promote diverse age classes
- Maintain and restore diversity of native tree species
- Identify and move species to sites that are likely to provide future habitat

Adaptation Strategies & Approaches



Prescriptive actions selected by producer that are designed for individual site conditions and management objectives

→ YOU DECIDE!

Adaptation Strategies & Approaches

Management Goals
& Objectives



Climate Change
Impacts



Challenges &
Opportunities



Intent of Adaptation
(**Option**)



Make Idea Specific
(**Strategy, Approach**)

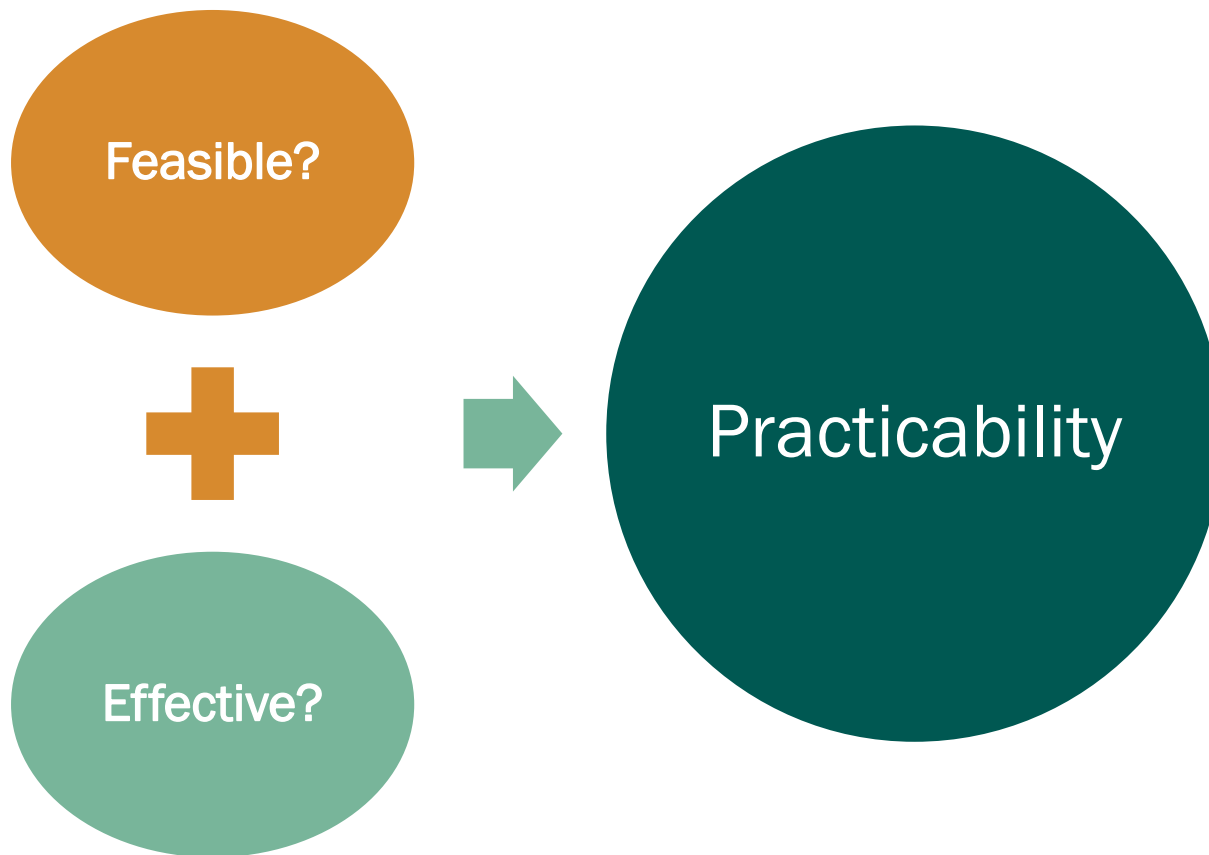


Action to Implement
(**Tactic**)



Why it's important:
Helps connect the dots
from broad concepts
to specific actions for
implementation.

Step 4: IDENTIFY adaptation approaches and tactics for implementation.



Key Strategies You Selected:

Urban Forest

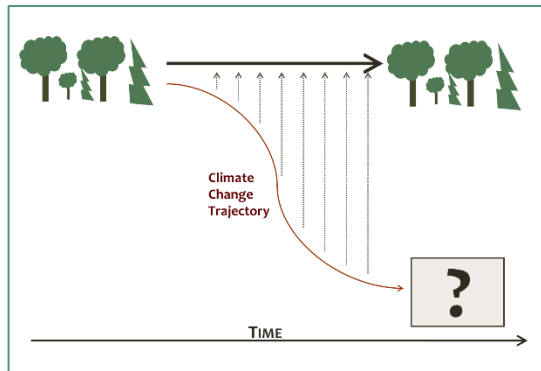
- 1: Sustain or restore fundamental ecological functions
- 2: Reduce the impact of biological stressors
- 3: Reduce the risk and long-term impacts of severe disturbances
- 4: Maintain or create refugia
- 5: Maintain and enhance species and structural diversity
- 6: Increase ecosystem redundancy across the landscape
- 7: Promote landscape connectivity
- 8: Maintain and enhance genetic diversity
- 9: Facilitate composition adjustments through species transitions
- 10: Realign urban ecosystems after disturbance

Watershed

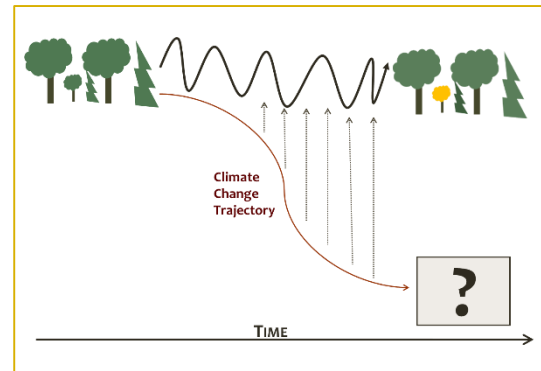
- 1: Sustain fundamental hydrologic processes
- 2: Maintain and enhance water quality
- 3: Maintain or restore forests and vegetative cover
- 4: Facilitate forest ecosystem adjustments through species transitions
- 5: Accommodate altered hydrologic processes
- 6: Design and modify infrastructure to accommodate future conditions

What Options did you select?

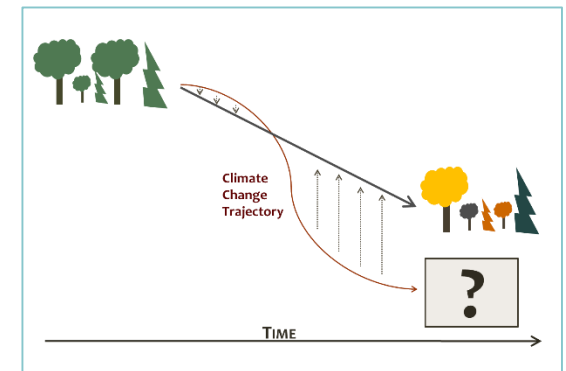
RESISTANCE



RESILIENCE



TRANSITION



**Tactics you evaluated but did not
select?**

What are some new tactics or strategies you developed that you were not doing before?

**Were there challenges you had that
could not be addressed?**

Do others have ideas?

Were there tactics you developed that did not align with any of the strategies or approaches?

**Any innovative ideas you've heard
about that others are doing?**



Step 5: MONITOR and evaluate effectiveness of implemented actions.

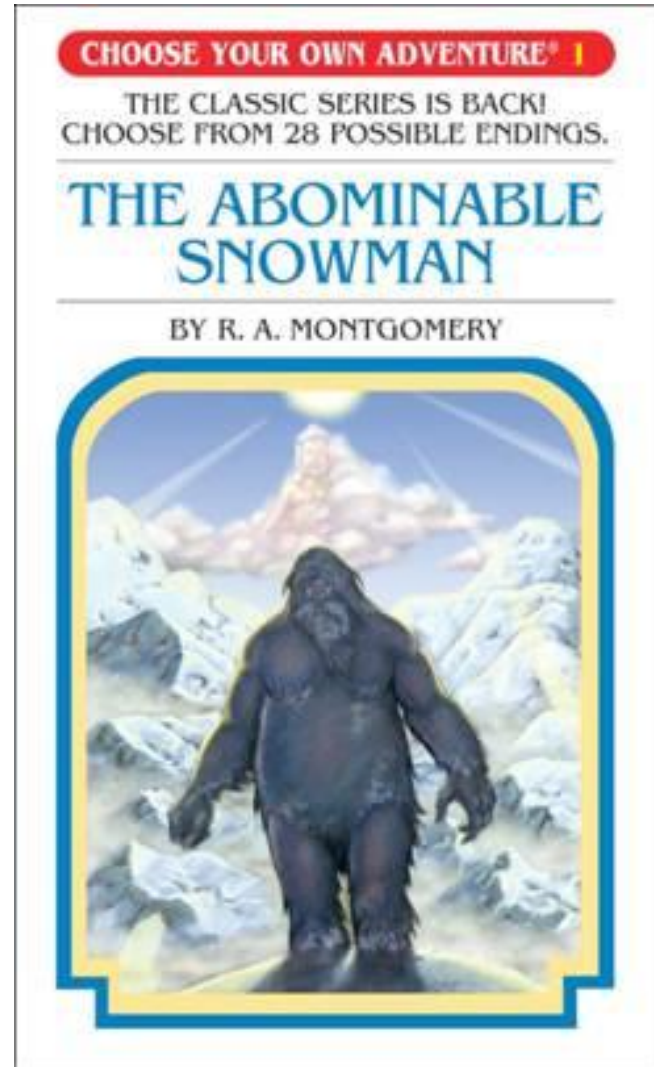
Today's Agenda

Discussion:

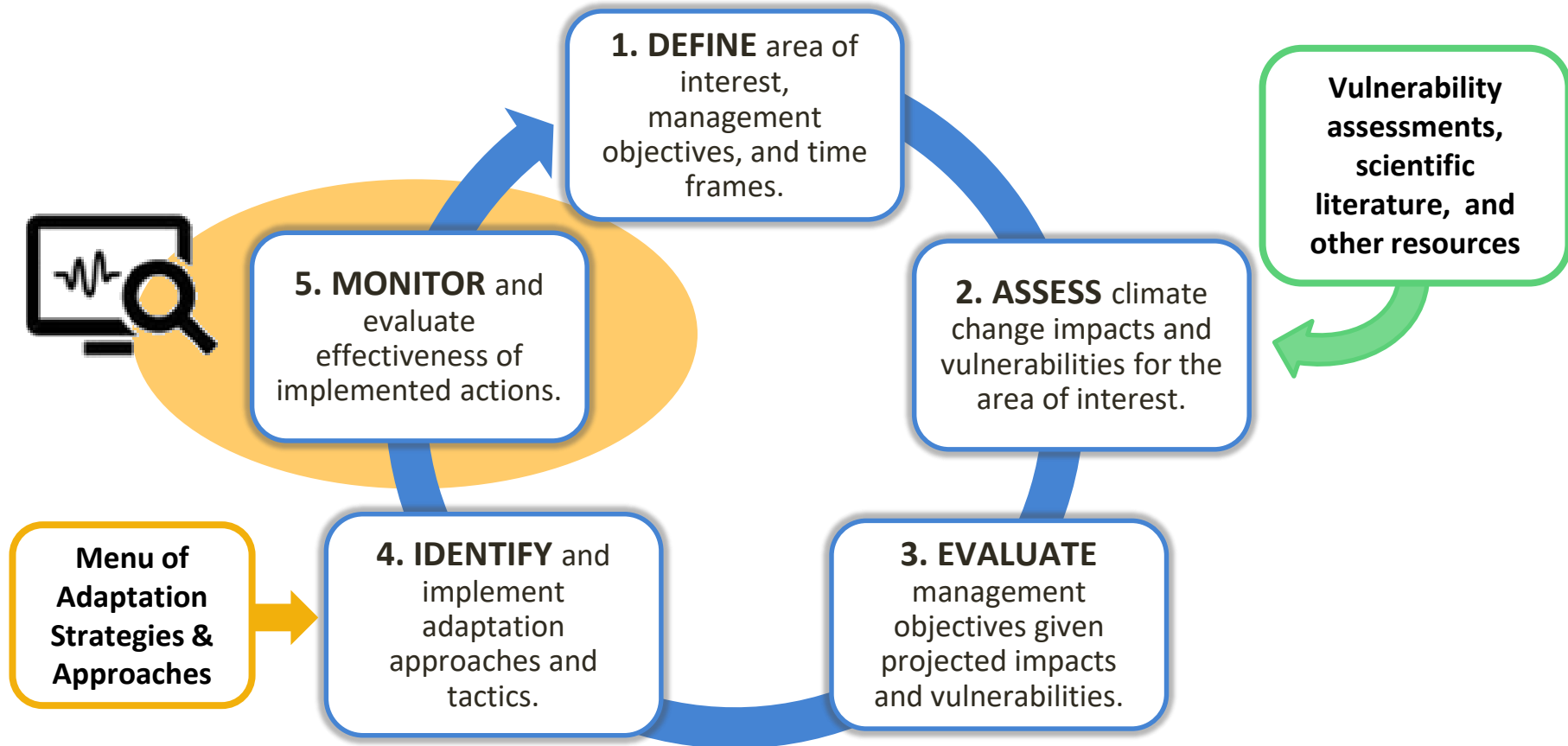
- Step 4 review
- Discussion: how are you adapting your forests to a changing climate?

Lecture:

- Step 5: Monitoring
- Website demo and homework



Today – Step 5!



A FEW THOUGHTS ABOUT MONITORING...

Be VERY CLEAR about your **objectives**! What question you are asking guides your monitoring approach:

Scientific research = Is this outcome statistically significant compared to a control? Could we expect similar results elsewhere?

Impact/ response monitoring = What changes are occurring?

Implementation monitoring = Did we do the action?

Effectiveness monitoring = Did our actions actually have the desired effect?

Course Material Landing Page

The screenshot shows a course material landing page. On the left is a dark sidebar with a navigation menu. The main content area is white with a dark header. The page title is 'Monitoring Plan instructions'. Below the title is a section for 'Step 5 Course Materials' with instructions to view session 5 slides and complete homework 5. A large grey rectangular area is present below the text. At the bottom of the page are navigation links for 'Previous Homework 4' and 'Next Homework 5'. The URL 'https://adaptationworkbook.org/niacs-project-ui' is visible at the bottom left.

Resources

- Chicago project
- Progress Summary
- Step 1
 - Define Management Topics
 - Management Goals and Objectives
 - Homework 1
- Step 2
 - Climate Impacts and Vulnerability
 - Vulnerability Determination
 - Homework 2
- Step 3
 - Evaluate Objectives
 - Homework 3
- Step 4
 - Adaptation Actions
 - Tactic Recommendations
 - Homework 4
- Step 5
 - Monitoring Plan
 - Homework 5
 - Homework 6
- Export and Share Plan

Monitoring Plan instructions

Step 5 Course Materials

View Session 5 slides.

After you complete Step 5, be sure to do Homework 5. Do not complete Homework 6 until the last week of the course.

If you encounter technical issues with the Workbook or have suggestions for improvements, send us an email using [this link](#).

« Previous
Homework 4

Next »
Homework 5

<https://adaptationworkbook.org/niacs-project-ui>

Step 5 Landing Page

Step 5: Monitor and evaluate effectiveness of implemented actions

Monitoring is critical for understanding if management actions are effective over time, or if management should be altered in the future to account for new information. The final step of the Adaptation Workbook is to identify monitoring items that may be used to answer these kinds of questions.

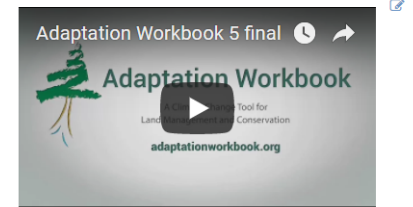
The outcome of this step is a list of monitoring questions that will help you evaluate the effectiveness of your adaptation actions. Try to think of at least one monitoring question for each of your management objectives. You should especially consider monitoring questions that will help assess the effectiveness of your recommended adaptation tactics.





Time and resources can often limit monitoring efforts, so **focus on creating a monitoring plan that is realistic and feasible.**

For example:

If you're assisting with the green infrastructure design for a new development and your objective is to reduce stormwater runoff by 50%, you may have designed an adaptation tactic to incorporate pervious pavements and structural soils for stormwater interception. An appropriate monitoring variable would be inflow and outflow of water through the system during storm events.

 [Monitoring Plan Resources](#)



-  A red triangle indicates fields are incomplete
-  An orange triangle indicates fields are partially complete
-  Hover to learn more about a particular item
-  Expand/collapse a section

[« Previous](#)
Homework 4

[Next »](#)
Homework 5

- Resources
- Chicago project
- Progress Summary
- Step 1
 - Define Management Topics
 - Management Goals and Objectives
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- Step 2
 - Climate Impacts and Vulnerability
 - Vulnerability Determination
 - Homework 2
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 - Homework 3
- Step 4
 - Adaptation Actions
 - Tactic Recommendations
 - Homework 4
- Step 5
 - Monitoring Plan
 - Homework 5
 - Homework 6
- Export and Share Plan

Add a Monitoring Variable

The screenshot shows a software interface with a dark sidebar on the left and a main content area on the right. The sidebar contains a list of navigation items: Resources, Chicago project, Progress Summary, Step 1 (Define Management Topics, Management Goals and Objectives, Homework 1), Step 2 (Climate Impacts and Vulnerability, Vulnerability Determination, Homework 2), Step 3 (Evaluate Objectives, Homework 3), Step 4 (Adaptation Actions, Tactic Recommendations, Homework 4), Step 5 (Monitoring Plan, Homework 5, Homework 6), and Export and Share Plan. The 'Monitoring Plan' item is highlighted with an orange arrow. The main content area has a header with 'Monitoring Plan instructions' and 'Step 5 Course Materials', both with dropdown arrows. Below this is a section titled 'Monitoring Variables' with the text '0 monitoring variables'. A large orange arrow points from the text to a button labeled 'Add A Monitoring Variable' with a plus icon. At the bottom left of the main area is a 'Previous' button with a double-left arrow and 'Homework 4' below it. At the bottom right is a 'Next' button with a double-right arrow and 'Homework 5' below it.

Resources ▾

Chicago project

Progress Summary

Step 1

Define Management Topics

Management Goals and Objectives

Homework 1

Step 2

Climate Impacts and Vulnerability

Vulnerability Determination

Homework 2

Step 3

Evaluate Objectives

Homework 3

Step 4

Adaptation Actions

Tactic Recommendations

Homework 4

Step 5

Monitoring Plan

Homework 5

Homework 6

Export and Share Plan

Monitoring Plan instructions

Step 5 Course Materials

Monitoring Variables

0 monitoring variables

Add A Monitoring Variable +

« Previous
Homework 4

Next »
Homework 5

Add a Monitoring Variable

The screenshot displays a software interface for creating a monitoring plan. A central dialog box titled "Monitoring Variable" is open, allowing users to define a new monitoring item. The dialog contains three text input fields, each with a save icon in the top right corner:

- Monitoring Variable:** Identify items that will help evaluate whether you have achieved your management objectives or if you are making progress toward those objectives. For example, you may care about survival of planted seedlings if your project will include tree planting.
- Criteria For Evaluation:** Identify a value or threshold that is meaningful for this monitoring item. For example, you may have a goal of 70% seedling survival after 3 years if your project will include tree planting.
- Monitoring Implementation:** Describe how and when will this information be gathered. For example, you may monitor seedling survival every June for 5 years after planting.

At the bottom of the dialog is a prominent orange "Save" button. The background interface shows a sidebar on the left with navigation options such as "Resources", "Chicago project", "Progress Summary", and "Step 5 Cour". The main area on the right features a button labeled "Add A Monitoring Variable" with a plus icon. Navigation controls at the bottom include "« Previous Homework 4" and "Next » Homework 5".

Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Variable

Items that can tell you whether you have achieved your management goals & objectives.

If possible, use an item that also helps evaluate a particular tactic.

For example:

- Planted seedling survival

Step 5: MONITOR and evaluate effectiveness of implemented actions.

Evaluation Criteria

What is success?

What you're monitoring or measuring. What are the units on your data?

For example:

- 60% survival of non-local genotypes.

Step 5: MONITOR and evaluate effectiveness of implemented actions.

Monitoring Implementation

How the monitoring will actually get done.

Use existing monitoring when possible!

For example:

- Regular post-planting stocking surveys.
- Supplemental surveys at 10 years.

Add a Monitoring Variable

The screenshot displays a software interface for creating a monitoring variable. A central dialog box titled "Monitoring Variable" is open, featuring three text input fields:

- Monitoring Variable:** Survival of newly planted street trees
- Criteria For Evaluation:** 70% survival at 5 years
- Monitoring Implementation:** Homeowner calls, annual checks.

A prominent orange "Save" button is located at the bottom of the dialog. The background interface includes a sidebar on the left with a navigation menu (e.g., "Chicago project", "Step 5 Course") and a main content area with a "Monitoring Variable" section and an "Add A Monitoring Variable" button.

Apply to Objectives

- Resources
- Chicago project
- Progress Summary
- Step 1
 - Define Management Topics
 - Management Goals and Objectives
 - Homework 1
- Step 2
 - Climate Impacts and Vulnerability
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- Step 4
 - Adaptation Actions
 - Tactic Recommendations
 - Homework 4
- Step 5
 - Monitoring Plan
 - Homework 5
 - Homework 6
- Export and Share Plan

Monitoring Plan instructions

Step 5 Course Materials

Monitoring Variables

1 monitoring variables

Monitoring Variable: Survival of newly planted street trees

Applicable to 2 objectives

Monitoring Variable



Survival of newly planted street trees

Criteria For Evaluation

70% survival at 5 years

Monitoring Implementation

Homeowner calls, annual checks.

Does this monitoring variable apply to these objectives?  



No Yes

Management Topic: Park > Goal:

Objective: Have no more than 20 percent of a family, 10 percent of a genus and 5 percent of a species

No Yes

Management Topic: Park > Goal:

Objective: Increase the percent of species that are native or expected to gain habitat in the area.

Add Another Monitoring Variable 

<< Previous

Homework 4

Next >>

Homework 5

Homework

- Resources
- Chicago project
- Progress Summary
- Step 1
 - Define Management Topics
 - Management Goals and Objectives
 - Homework 1
- Step 2
 - Climate Impacts and Vulnerability
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 - Monitoring Plan
 - Homework 5
 - Homework 6
- Export and Share Plan

Homework 5

What are the key questions you'll want to be able to answer to determine the effectiveness of your recommended tactics for climate change adaptation? What are the metrics needed to answer these questions, and how/when will you collect the necessary measurements?

What are the key questions you'll want to be able to answer to determine the effectiveness of your recommended tactics for climate change adaptation? What are the metrics needed to answer these questions, and how/when will you collect the necessary measurements?

Monitoring and Evaluating Effectiveness: rate how strongly you agree/disagree with the following statements.

	Disagree					Agree				
I can identify monitoring metrics to assess the effectiveness of my management tactics.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
I understand how the measurements collected through my monitoring plan could help me adjust future management.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

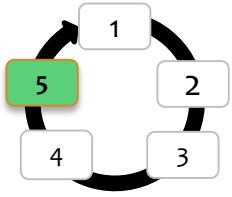
What information do you already have to help you measure the effectiveness of your climate adaptation tactics?

What information do you already have to help you measure the effectiveness of your climate adaptation tactics?

« Previous
Monitoring Plan

Next »
Homework 6

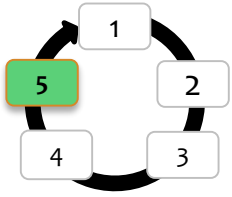
EXAMPLES



Step 5: MONITOR and evaluate effectiveness of implemented actions.

Twentymile Creek and Marengo River Priority Watershed project

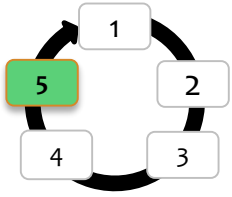
Monitoring Item	Monitoring Metric	Criteria for Evaluation
Brook Trout pop (+other spp)	# fish (size, pop, catch/effort)	Maintaining or increasing populations
Channel stability	Detecting changes to Bankfull width, depth, and area	Maintaining stable channels – no change in width: depth ratio
Water temperature	Summer max, max weekly mean	Cold: < 23 C for annual max Cool: < 26 C for annual max



Step 5: MONITOR and evaluate effectiveness of implemented actions.

City of Columbia, MO: Street Tree Management Plan

Monitoring Item	Monitoring Metric	Criteria for Evaluation
Street Tree Survival	% survival at 3 years	70% street tree survival at 3 years.
Species Diversity	Biannual inventory of the percentage of trees that belong to a family	no more than 10% of street trees may belong to a single family
Invasive species	Presence/absence of invasive vegetation at recently disturbed sites after 1 year.	Absence of invasive species



Step 5: MONITOR and evaluate effectiveness of implemented actions.

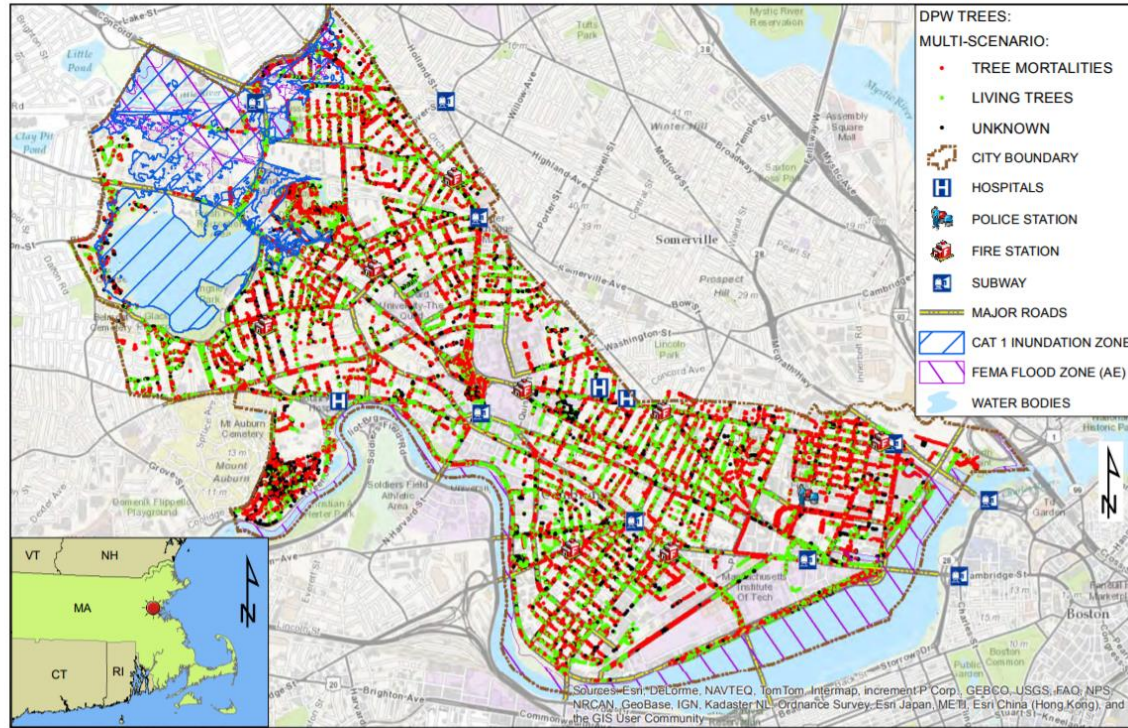
City of Goshen, IN: Goshen Tree Benefits Campaign

Monitoring Item	Monitoring Metric	Criteria for Evaluation
Whip and seedling survival	Survival (mapped using Treekeeper)	50% survival at 3 years.
Survival of balled and burlapped trees and larger plantings	Survival (mapped using Treekeeper)	85% after 3 years.
% tree canopy	Urban tree canopy assessment (remote sensing)	25% by 2025, 30% by 2030, 35% by 2035, 40% by 2040, 45% by 2045.

MONITORING TOOLS

Street Tree Vulnerability Assessment

CAMBRIDGE URBAN FOREST: TREE MORTALITIES BASED ON CUMULATIVE EFFECTS



US ARMY CORPS OF ENGINEERS
ENGINEERING RESEARCH & DEV. CNTR
MA SPF, NAD 83
DATE: 3/3/2014

0 0.5 1 2 Miles
1 inch equals 3,000 feet

SOURCES:
ESRI ARCGIS ONLINE
CAMBRIDGE GIS/DIV. ITD
FEMA, NOAA, MASS GIS

http://www.cambridgema.gov/CDD/Projects/Climate/~/_/media/42F2847A3DCB4706BB5981D66D0AB157.ashx

LiDAR Mapping



Citizen Science in Lombard, Philadelphia, Grand Rapids, and Malmo Sweden

Novice:

- 1 year of experience or less (volunteers, interns)

Intermediate:

- 1-3 years experience (volunteers, interns)

Expert:

- experienced urban forest researchers and certified arborists

Methods

- Volunteers received 6-7 hours of training led by experts
- Field guide provided
- Field work carried out without supervision
- Trees observed by 1 expert, 3 novices, and 3 intermediates
 - Results compared between novice/intermediate and expert
- Field crew questionnaire
 - Characteristics, level of training of participants

Citizen science is good for:

- Classifying site type and land use
- Dieback rating (especially low, high)
- Genus ID (especially common ones like Acer, Gleditsia, Tilia)
- Number of stems
- DBH within 1 inch (2.54 cm)

Did not work as well for:

- Crown transparency
- Wood condition
- Classifying trees in middle dieback categories
- Species ID
- Identifying less common genera (Amelanchier, Prunus, Syringa)
- Species within genera
- DBH of multistemmed trees
- Radial growth monitoring

My City's Trees: Urban FIA

MY CITY'S TREES

CITY: no selection | THEME: no selection | CLASSES: no selection

MY CITY MY AREA

0 ACRES 0% 0 ACRES
AREA

0 PEOPLE 0% 0 PEOPLE
POPULATION

0 PLOTS 0% 0 PLOTS
PLOTS

SELECT A CITY

SELECT A THEME

SELECT CLASSES

INVENTORY STATISTICS

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Generate Report

<http://tfsfrd.tamu.edu/mycitystrees>

Zoom in on a city

MY CITY'S TREES

CITY: Austin | THEME: no selection | CLASSES: no selection

MY CITY | **MY AREA**

Austin	Austin	
195,223 ACRES	100%	195,223 ACRES
AREA		
790,390 PEOPLE	100%	790,390 PEOPLE
POPULATION		
206 PLOTS	100%	206 PLOTS
PLOTS		

SELECT A CITY

- AUSTIN
- HOUSTON

SELECT A THEME

- LAND COVER
- CITY GROWTH
- WATERSHED

INVENTORY STATISTICS

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Generate Report

<http://tfsfrd.tamu.edu/mycitystrees>

Get Inventory Summaries

✕
MY CITY'S TREES
🏠

CITY: Austin | THEME: no selection | CLASSES: no selection

MY CITY Austin

195,223 ACRES **100%** 195,223 ACRES
AREA

790,390 PEOPLE **100%** 790,390 PEOPLE
POPULATION

206 PLOTS **100%** 206 PLOTS
PLOTS

SELECT A CITY
SELECT A THEME

COUNT
CARBON
VALUE
LEAVES
ENERGY
RUNOFF
POLLUTION
HEALTH

Tree counts (live trees at least 1" in diameter and dead trees at least 5" in diameter)

SPECIES	MILLION TREES	PERCENT	TREES PER PERSON
Ashe juniper	13.32	39%	16.8
cedar elm	4.58	14%	5.8
live oak	2.86	8%	3.6
60 more	13.10	39%	16.6
<i>All</i>	<i>33.86</i>	<i>100%</i>	<i>42.8</i>

100%

MY CITY: 33.86 MILLION TREES

MY AREA: 33.86 MILLION TREES

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Generate Report

<http://tfsfrd.tamu.edu/mycitystrees>

Download Reports

MY CITY'S TREES

REPORT

Urban Forest Benefits

Austin

Selected Area

Austin is comprised of 195,223 acres with a population of 790,390 people. The city is divided into 8 land cover classes. This report contains information for a selected area consisting of the following 8 classes: Developed - Open, Developed - Low, Developed - Medium, Developed - High, Deciduous/Mixed Forest, Evergreen Forest, Shrub/Herbaceous, and Water/Barren. These classes cover 195,223 acres, which is 100 percent of the city. A total of 790,390 people live in the selected area, which is 100 percent of the entire city population. A total of 206 locations were sampled in the urban forest inventory, of which 206 plots were located in the selected area.

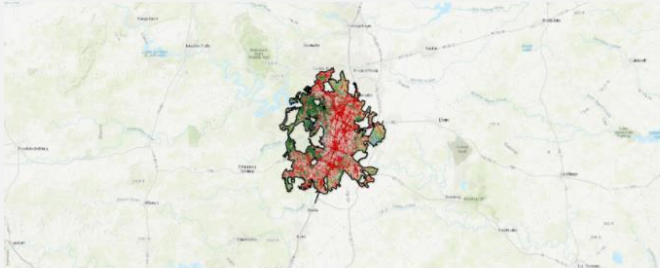


Figure 1. Map of Austin and selected land cover classes.

Table 1. Distribution of area and population by selected land cover classes.

Class	Area (acres)	Percent of City Area (%)	Population (people)	Percent of City Population (%)	Plots
Developed - Open	28,382	15	178,070	23	51

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Generate Report

<http://tfsfrd.tamu.edu/mycitystrees>

I-Tree Landscape

i-Tree Landscape v3.0.1 Home Project Menu i-Tree Feedback

Start on **Main**, then explore the map layer tabs.

Main Canopy & Land Forest Risk Health Risk Future Climate

Wildfire +

Hardiness Zones -

Plant Zones ?

Climate Hot Spots -

2060 Forests Temperature ?

Transparency 0 %

2060 Forests Precipitation ?

Predicted temperature and precipitation based on **CCSM4.0** from National Center for Atmospheric Research.

Disease - Forest Pests -

Armillaria Root Disease (Armillaria s ?)

Transparency 0 %

Annosus Root Disease (Heterobasid ?)

Beech Bark Disease (Neonectria faç ?)

Butternut Canker (Sirococcus clavig ?)

Bur Oak Blight (Tubakia iowensis) ?

Chestnut Blight (Cryphonectria para ?)

Find Locations Explore Location Data See Tree Benefits Prioritize Tree Planting Generate Res

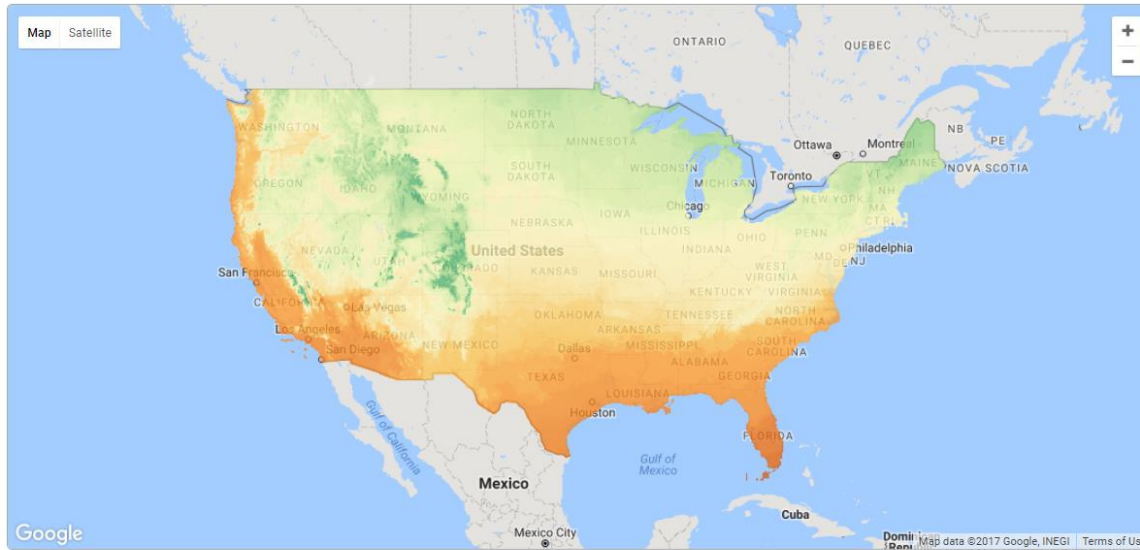
The following descriptions provide a general overview of the steps involved in completing an analysis with i-Tree Landscape. Visit the [Help](#) page for more details and a thorough To!

Let's Get Started!

<https://landscape.itreetools.org/maps/>

USA National Phenology Network

Phenology Maps



Select Gridded Layer

More Info on Phenology Maps

Category

Spring Indices, Historical Annual

Layer

First Leaf - Spring Index

Year

2016

Opacity



Range

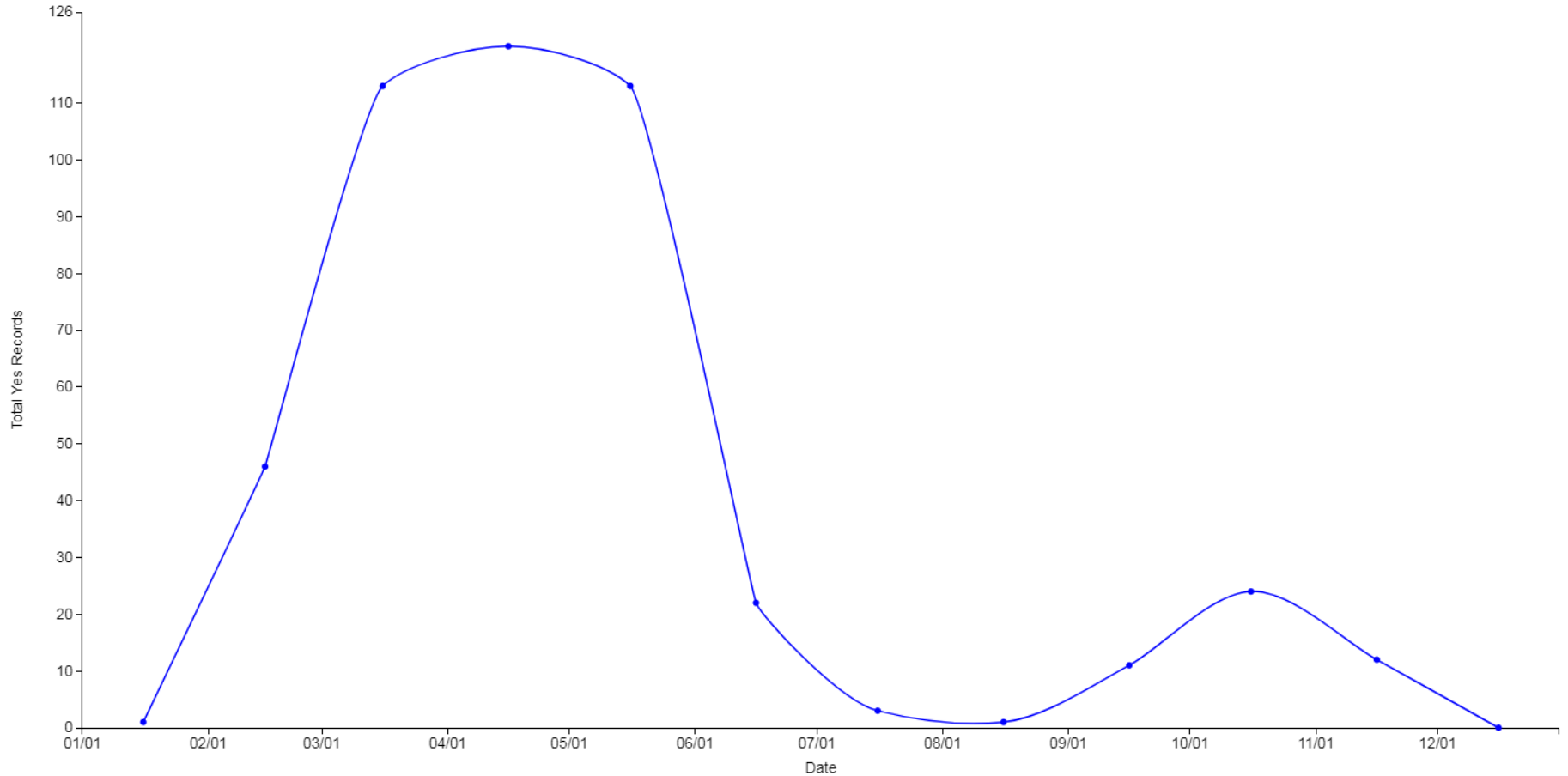


This layer is an annual representation of the days of year that the requirements for the first leaf Spring Index were met, averaged for Red Rothomagensis lilac, Arnold Red honeysuckle and Zabelii honeysuckle; available from 1981 to last year, calculated using PRISM Tmin and Tmax data. The Extended Spring Indices are models that predict the "start of spring" (timing of leaf out or bloom) at a particular location. Unless otherwise stated, all data, metadata and related materials are considered to satisfy the quality standards relative to the purpose for which the data were collected. Although these data and associated metadata have been reviewed for accuracy and completeness and approved for release by the U.S. Geological Survey (USGS), no warranty expressed or implied is made regarding the display or utility of the data on any other system or for

<https://www.usanpn.org/data/visualizations>

USA National Phenology Network

Activity Curves ● 2013: Red maple - Breaking leaf buds



USA National Phenology Network, www.usanpn.org

<https://www.usanpn.org/data/visualizations>

Caroline Lake State Natural Area Adaptation Demonstration

Major concerns: Forest composition could become less diverse given climate changes

How can we better use forest inventory data to tell us:

- Are forests are at risk from climate change?
- Are management actions reducing risk?



Matt Dallman (TNC), find project at forestadaptation.org/node/659

Climate-informed inventory: New Risk Metrics

Northern Hardwood Stand:

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)
Sugar maple	79.0	117.1	100.0	40.8
White ash	33.1	30.7	96.2	17.9
American basswood	18.5	23.7	73.1	12.3
Yellow birch	7.7	12.4	53.8	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5
Red maple	4.2	8.6	42.3	5.0
Northern red oak	1.5	0.7	42.3	3.2
American elm	0.4	0.4	34.6	2.4
Paper birch	1.9	5.3	11.5	2.0
Black ash	1.5	2.6	7.7	1.2
Black cherry	0.4	0.2	15.4	1.1
Eastern hemlock	1.2	1.9	3.8	0.8
Quaking aspen	0.8	0.6	7.7	0.8
Total	160.2	220.3		100.0

Climate-informed inventory: New Risk Metrics

Northern Hardwood Stand: Low (PCM B1)

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)
Sugar maple	79.0	117.1	100.0	40.8	0.8	No Change	0.0
White ash	33.1	30.7	96.2	17.9	1.6	Increase	0.0
American basswood	18.5	23.7	73.1	12.3	1.1	No Change	0.0
Yellow birch	7.7	12.4	53.8	7.0	0.8	Decrease	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5	1.0	No Change	0.0
Red maple	4.2	8.6	42.3	5.0	1.0	No Change	0.0
Northern red oak	1.5	0.7	42.3	3.2	1.3	Increase	0.0
American elm	0.4	0.4	34.6	2.4	2.3	Increase	0.0
Paper birch	1.9	5.3	11.5	2.0	0.7	Decrease	2.0
Black ash	1.5	2.6	7.7	1.2	0.7	Decrease	1.2
Black cherry	0.4	0.2	15.4	1.1	2.4	Large Increase	0.0
Eastern hemlock	1.2	1.9	3.8	0.8	1.2	Increase	0.0
Quaking aspen	0.8	0.6	7.7	0.8	0.6	Decrease	0.8
Total	160.2	220.3		100.0		Proportion at-risk:	11.0

Climate-informed inventory: New Risk

Metrics

Northern Hardwood Stand:

Low (PCM B1)

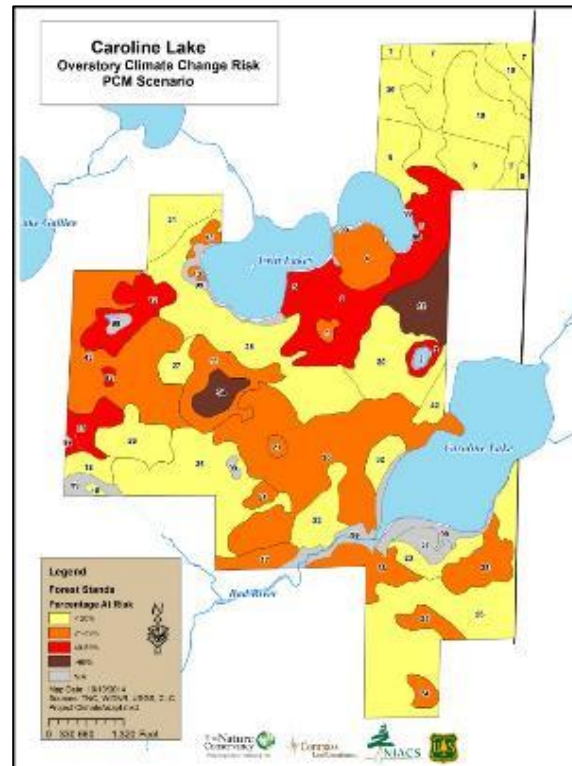
High (GFDL A1F1)

Species	Basal Area	Stems Per Acre	Freq. (%)	Proportion of Stand (IV %)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)	Future: Current Habitat	Change Class	At-risk Proportion of Stand (%)
Sugar maple	79.0	117.1	100.0	40.8	0.8	No Change	0.0	0.3	Large Decrease	40.8
White ash	33.1	30.7	96.2	17.9	1.6	Increase	0.0	1.9	Increase	0.0
American basswood	18.5	23.7	73.1	12.3	1.1	No Change	0.0	1.4	Increase	0.0
Yellow birch	7.7	12.4	53.8	7.0	0.8	Decrease	7.0	0.2	Large Decrease	7.0
Bigtooth aspen	10.0	16.1	15.4	5.5	1.0	No Change	0.0	0.4	Large Decrease	5.5
Red maple	4.2	8.6	42.3	5.0	1.0	No Change	0.0	0.6	Decrease	5.0
Northern red oak	1.5	0.7	42.3	3.2	1.3	Increase	0.0	1.1	No Change	0.0
American elm	0.4	0.4	34.6	2.4	2.3	Increase	0.0	3.2	Large Increase	0.0
Paper birch	1.9	5.3	11.5	2.0	0.7	Decrease	2.0	0.2	Large Decrease	2.0
Black ash	1.5	2.6	7.7	1.2	0.7	Decrease	1.2	0.6	Decrease	1.2
Black cherry	0.4	0.2	15.4	1.1	2.4	Large Increase	0.0	1.4	Increase	0.0
Eastern hemlock	1.2	1.9	3.8	0.8	1.2	Increase	0.0	0.4	Large Decrease	0.8
Quaking aspen	0.8	0.6	7.7	0.8	0.6	Decrease	0.8	0.2	Large Decrease	0.8
Total	160.2	220.3		100.0			Proportion at-risk: 11.0			Proportion at-risk: 63.0

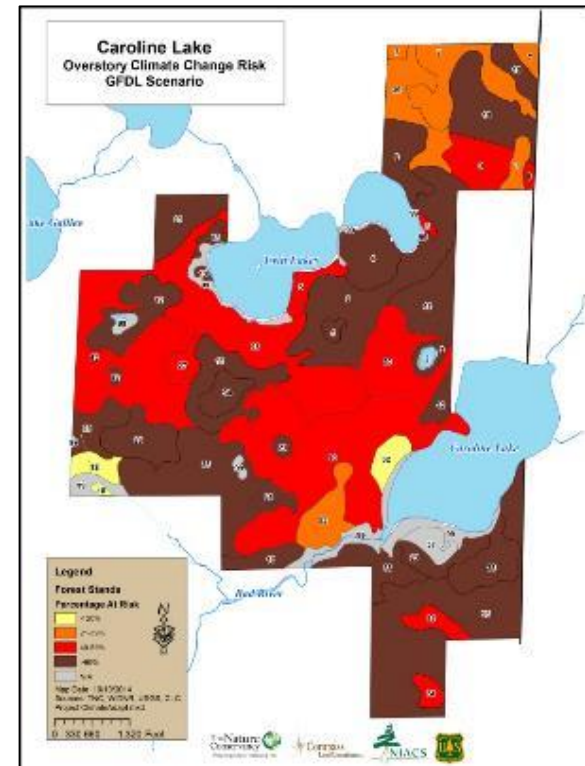
Climate-informed inventory: Risk Maps

Risk by stand:
overstory

Low (PCM B1)



High (GFDL A1F1)

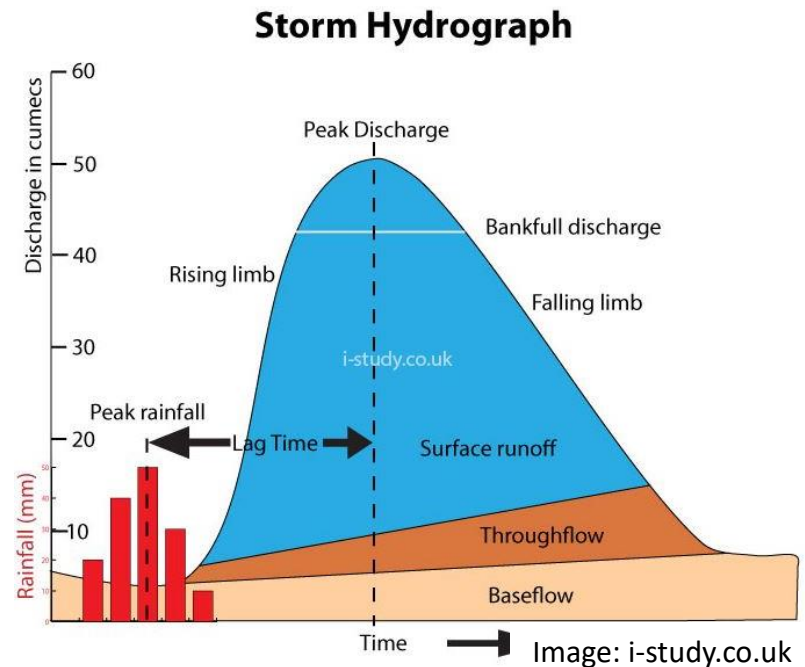


“100 year” storms and floods

- Current streamflow
- Using stream channel capacity to manage future risks to infrastructure
- Terminology
- Future projected 100y flow
- Tools you can use

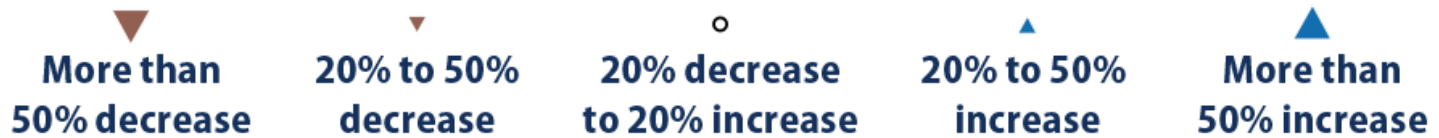
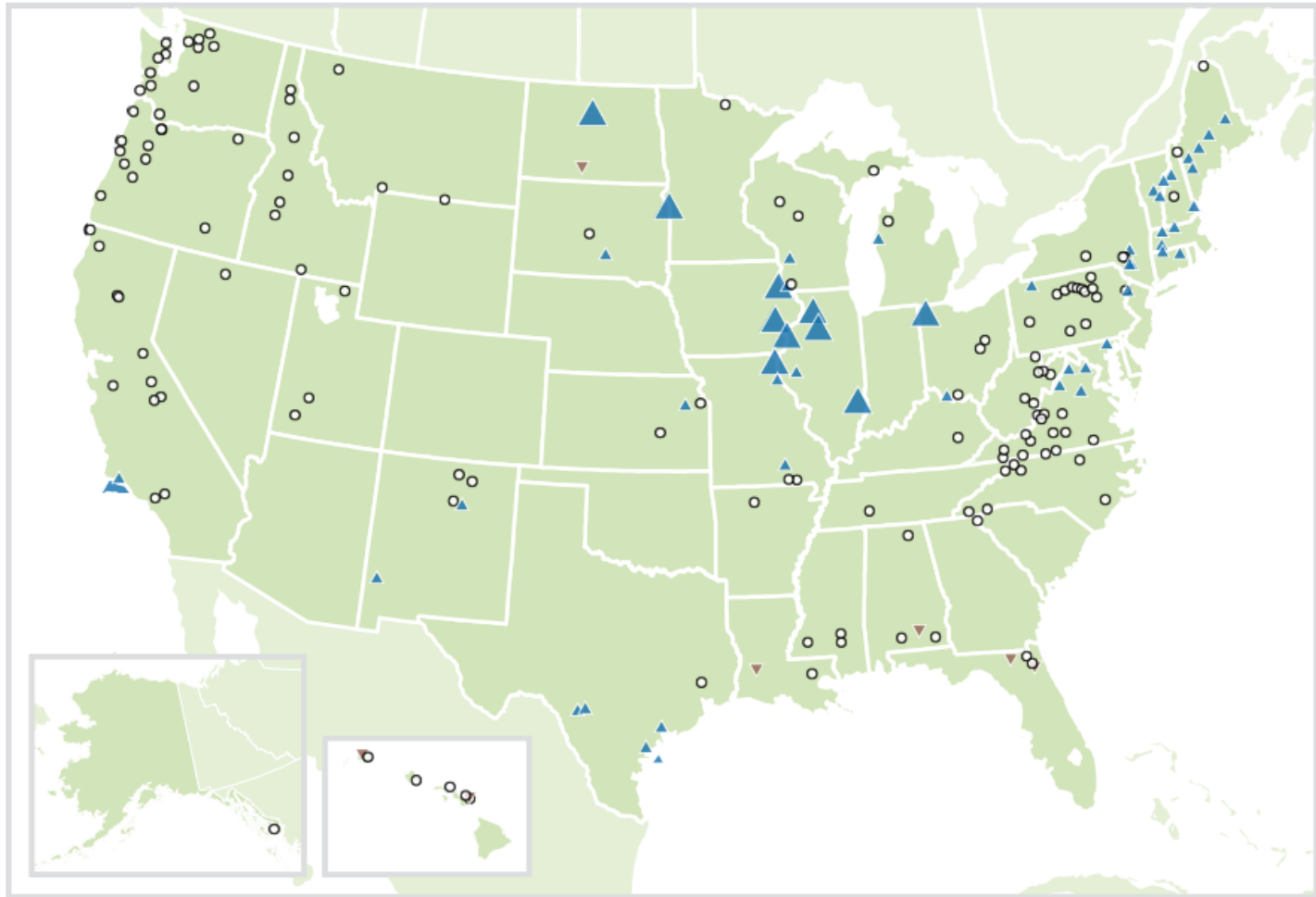


Image: American Forests



Wobus et al, 2017; Mills et al, 2018

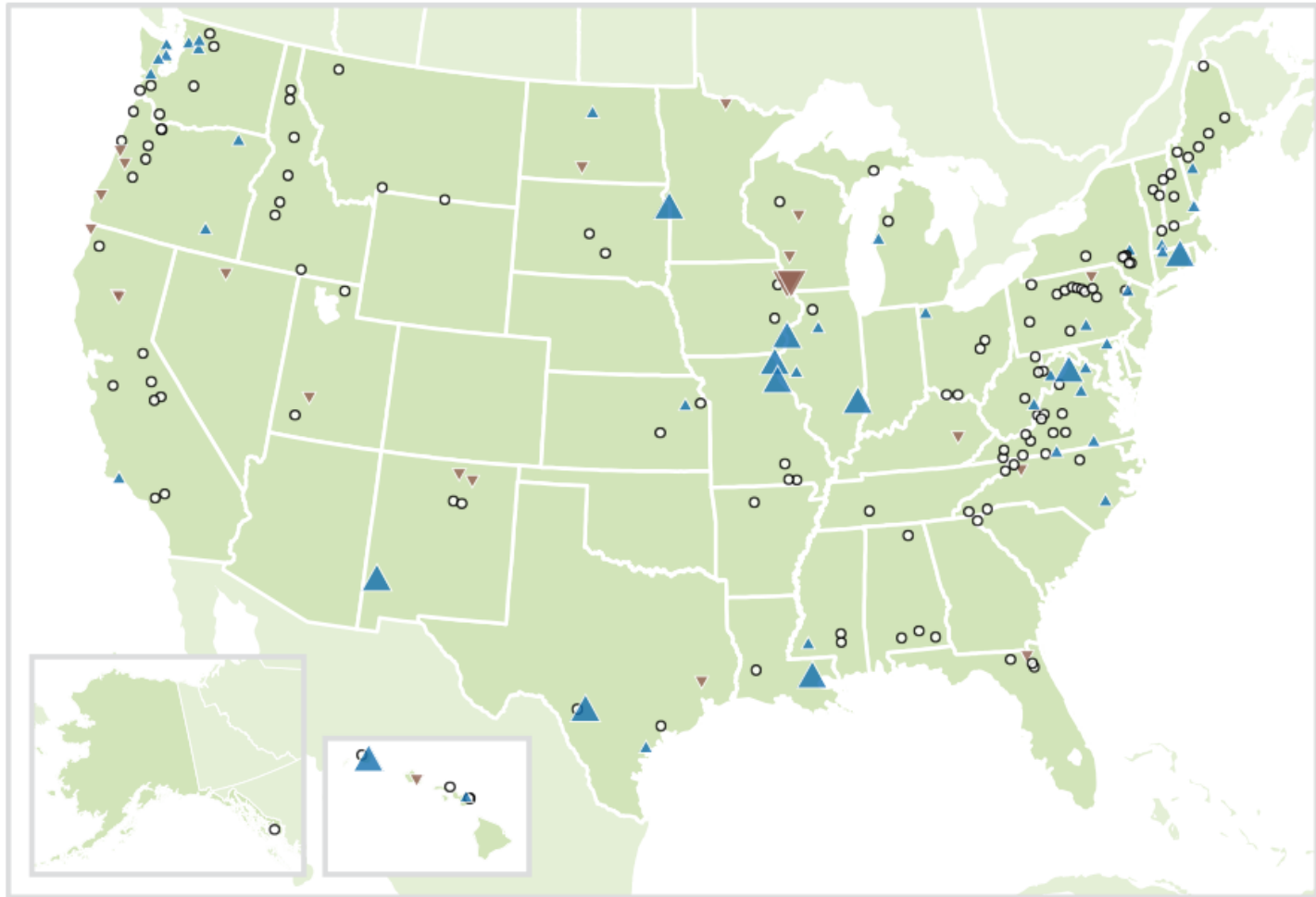
Annual Average Streamflow in the United States, 1940–2014








Data source: USGS (U.S. Geological Survey). 2016. Analysis of data from the National Water Information System. Accessed May 2016.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Three-Day High Streamflows in the United States, 1940–2014

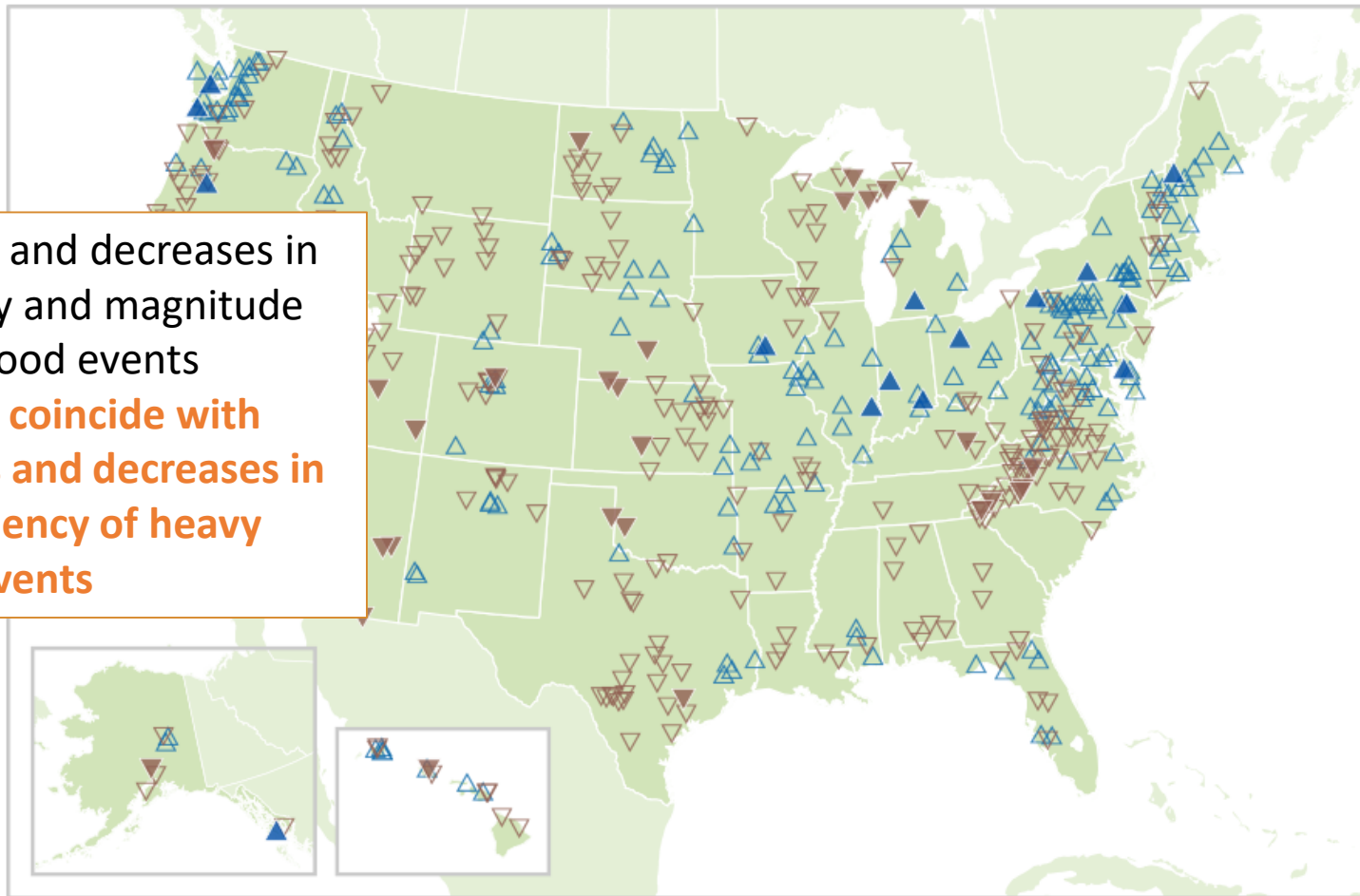


 **More than 50% decrease**  **20% to 50% decrease**  **20% decrease to 20% increase**  **20% to 50% increase**  **More than 50% increase**

Data source: USGS (U.S. Geological Survey). 2016. Analysis of data from the National Water Information System. Accessed May 2016.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Change in the Magnitude of River Flooding in the United States, 1965–2015



Significant decrease

Insignificant decrease

Insignificant increase

Significant increase

Data source: Slater, L., and G. Villarini. 2016 update and expansion to data originally published in: Mallakpour, I., G. Villarini. 2015. The changing nature of flooding across the central United States. *Nature Climate Change* 5:250–254.

For more information, visit U.S. EPA's "Climate Change Indicators in the United States" at www.epa.gov/climate-indicators.

Climate change and flooding

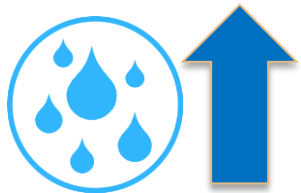
A changing climate... Non stationary conditions

- Warming temperatures
 - Earlier snowmelt in the spring
 - Storm systems generate more rain because warm air holds more moisture than cold air.
- Seasonal floods are expected to arrive earlier in the spring
- More heavy summer rainfall events

While no single storm or flood can be attributed directly to global warming, changing climate conditions are at least partly responsible for past trends and the increasing frequency of major flood events.

Take home Message: Reimagine “normal” storms, and “normal” flows.

Future Climate: Precipitation

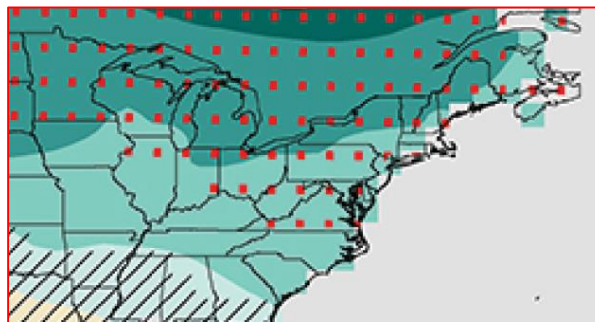


More rain in **winter** and spring

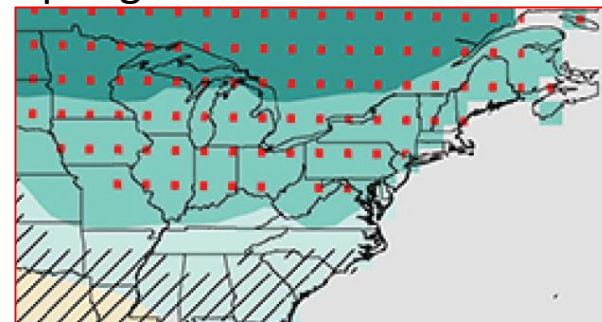
High Certainty:

- More rainfall annually & some seasons
- Potential for more frequent & intense heavy rains
- Reduced snowpack, earlier melting

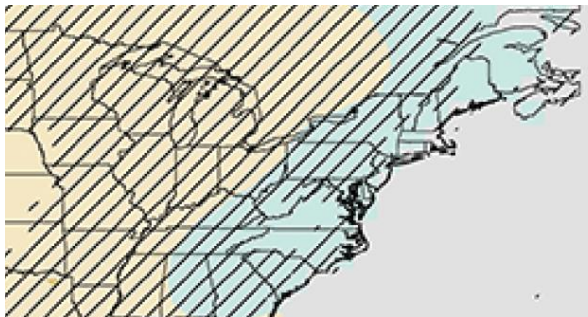
Winter



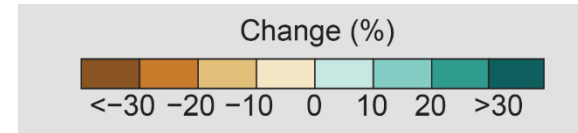
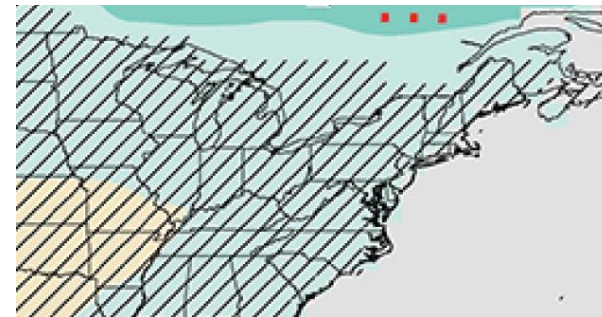
Spring



Summer



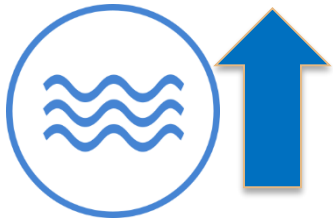
Fall



2070-2099 percent change relative to the 1976–2005 average. RCP8.5.

Stippling indicates that changes are assessed to be large compared to natural variations

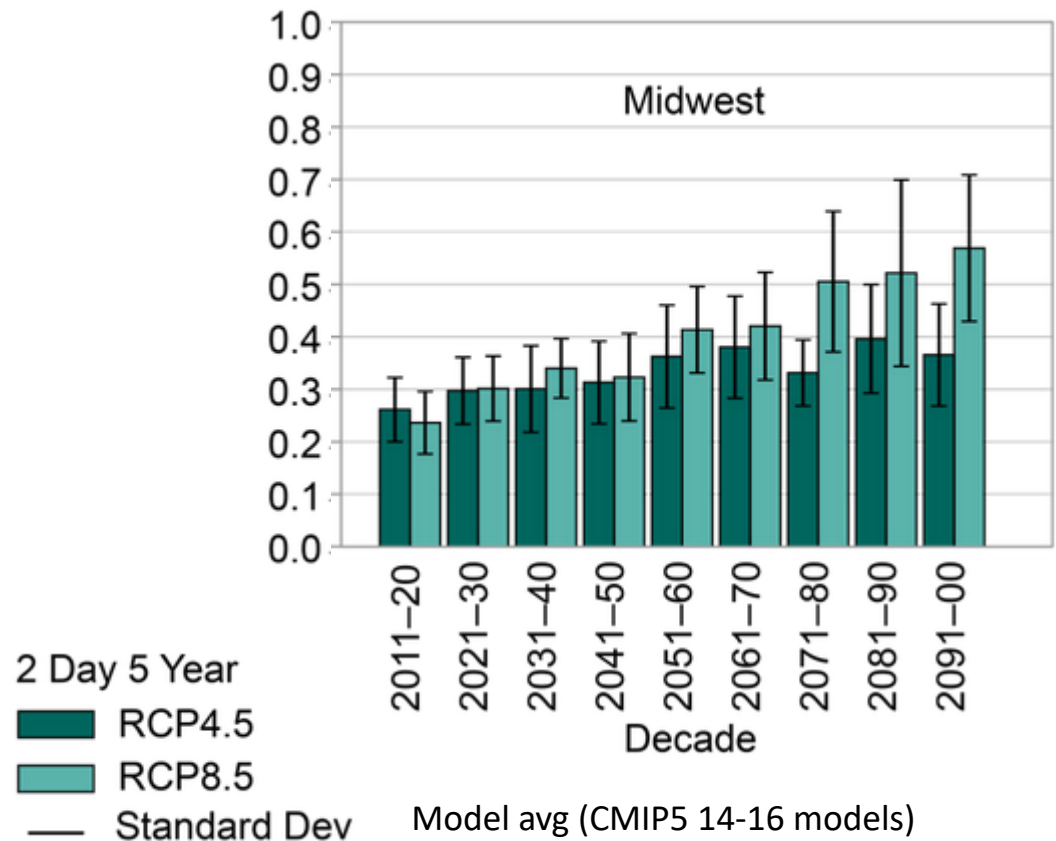
Future Climate: Increases in extreme events



Frequency of regional extreme precipitation events

- Slight increase in the very lightest precipitation days
- Large increase in the heaviest days
- “Uncertainty for each specific duration grows as the **return period increases**, specifically for short-duration storms.” - Sarhadi and Soulis, (2017). doi.org/10.1002/2016GL072201

Heavy precipitation 2006–2100

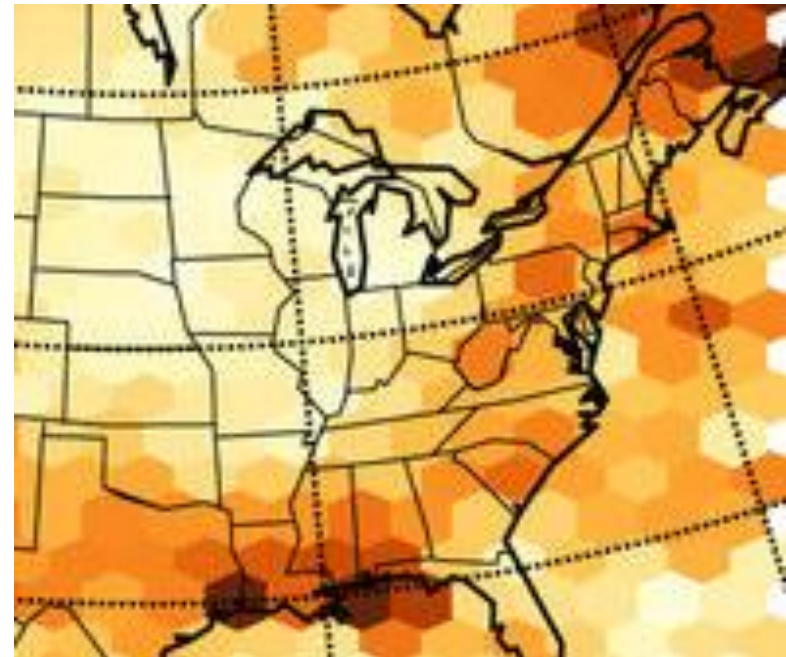
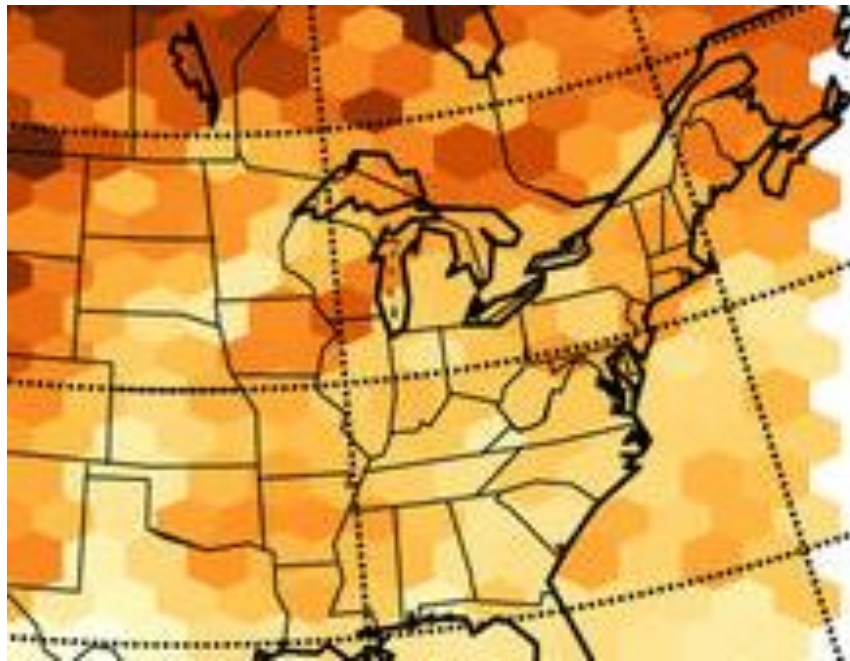


Future Climate: Increases in extreme events

Frequency & intensity of hourly heavy precip. will increase 1-2 times

times
Winter (DJF)

Summer (JJA)



Future increases in 99th% of hourly precipitation event intensities by 2100
Relative to January 2001 - 2013

Prein et al 2017. doi:[10.1038/nclimate3168](https://doi.org/10.1038/nclimate3168).

Streams change over time: Channel capacity

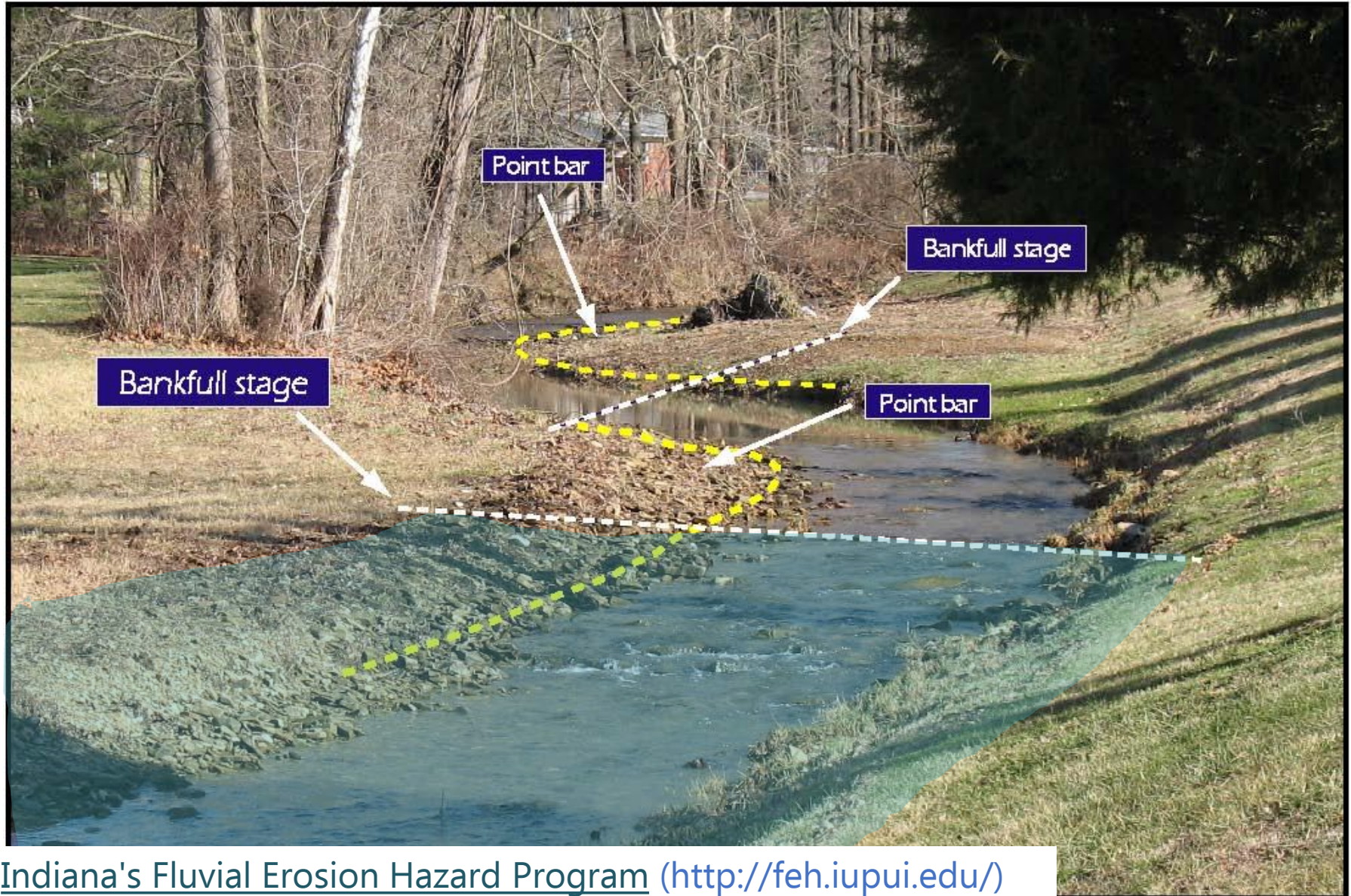
Recall Step 2:
Unique Site
characteristics

- Traditional hydrological modelling **assumes that the catchment does not change...**
- Understanding the **natural capacity** of your stream can reduce risks and mitigate infrastructure losses
 - Channel geometry (width, mean, depth, cross-sectional area) and discharge
 - Future changes in streamflow are expected to alter channel morphology



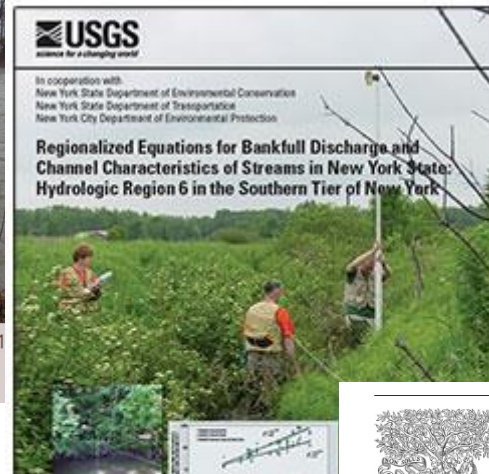
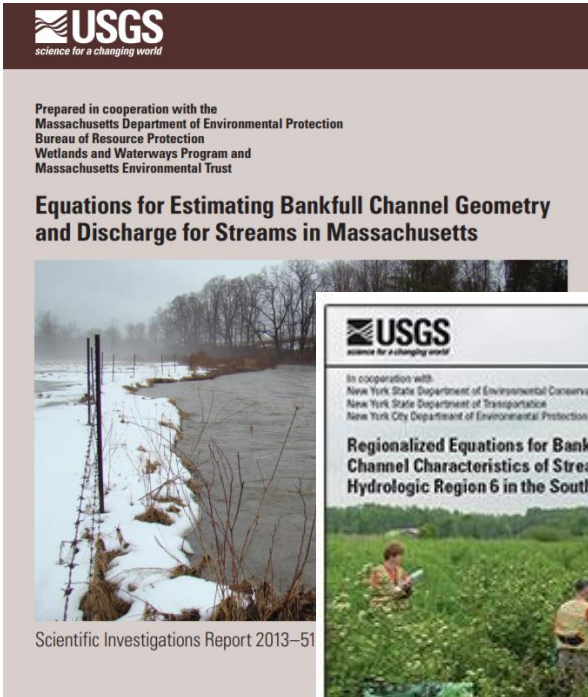
- **Bankfull discharge** is the streamflow that occurs when the stream fills its channel and any additional discharge will result in the stream overflowing its banks.
 - 1-2 year flow
 - Moves the most sediment over time and shapes the stream channel
 - “Channel forming flow”

Understanding local channel capacity can help managers recognize areas prone to natural stream-erosion



Indiana's Fluvial Erosion Hazard Program (<http://feh.iupui.edu/>)

Find #s based on current -



“If culverts built today cannot accommodate future channel conditions, then climate change could indirectly create barriers ..and consequent loss habitats”
Wilhere et al 2017

Chequamegon-Nicolet National Forest:
Marengo and Twentymile Creek Watersheds
forestadaptation.org/cnnf-water



Find resources to help incorporate climate change into future infrastructure decisions



ELSEVIER

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng



Research paper

Incorporating climate change into culvert design in Washington State, USA



George F. Wilhere^{a,*}, Jane B. Atha^a, Timothy Quinn^a, Ingrid Tohver^b, Lynn Helbrecht^a

^a Washington Department of Fish and Wildlife, 600 Capitol Way North, Olympia, WA, 98501, USA

^b Climate Impacts Group, University of Washington, John Wallace Hall, 3737 Brooklyn Ave. NE, Seattle, WA, 98105, USA

<https://doi.org/10.1016/j.ecoleng.2017.04.009>

Hydrologic Frequency Terminology

100-Year –

Event that occurs on average every 100 years

- Average Recurrence Interval
- Commonly used term, included in NOAA Atlas 14

1% Annual Chance –

Event that has a 1% chance of being exceeded in any year

- Average Exceedance Probability (AEP)
- Common term used to delineate special flood hazard areas in federal flood insurance rate maps
- FEMA & USGS use this term

1% AEP flood: With observed or modeled data, a 1% AEP flood defines both a flow volume (E.g. 10,000 cubic feet per second) and an expected return interval or frequency for that flow volume (on average, once every 100-y)

Recurrence intervals and probabilities of occurrences

Recurrence interval, in years	Probability of occurrence in any given year	Percent chance of occurrence in any given year
100	1 in 100	1
50	1 in 50	2
25	1 in 25	4
10	1 in 10	10
5	1 in 5	20
2	1 in 2	50

Does a 100-year storm always cause a 100-year flood?

No. Several factors can independently influence the cause-and-effect relation between rainfall and streamflow.

- **Extent of rainfall in the watershed**
- **Soil saturation before the storm**
- **Watershed size and duration of the storm**

Learn more →

<https://water.usgs.gov/edu/100yearflood.html>

Predicting future flood risks in the 100-y floodplain


Climate change impacts on flood risk and asset damages within mapped 100-year floodplains of the contiguous United States

Cameron Wobus¹, Ethan Gutmann², Russell Jones¹, Matthew Rissing¹, Naoki Mizukami², Mark Lorie¹, Hardee Mahoney¹, Andrew W. Wood², David Mills¹, and Jeremy Martinich³

¹Abt Associates, 1881 Ninth Street, Suite 201, Boulder, CO 80302, USA

²National Center for Atmospheric Research, 3450 Mitchell Lane, Boulder, CO 80301, USA

³US Environmental Protection Agency, Climate Change Division, 1200 Pennsylvania Ave NW, Washington, DC 20460, USA

- 
- Used National Flood Insurance Program (NFIP) – geospatial data on 100yr floodplains - “regulatory floodplain” that requires flood insurance

Modeling approach:

- Modeled both the **frequency**, and **magnitude** of high flow events with a 1% annual exceedance probability (AEP) threshold by 2100
- Quantify damages from “100-year” (1% annual exceedance probability, or AEP) floods nationwide
 - Only modeled 100-yr – yet, larger floods will be more damaging
- 1,000 model runs for high emissions (RCP 8.5), low (RCP 4.5) to develop trends

<https://doi.org/10.5194/nhess-17-2199-2017>

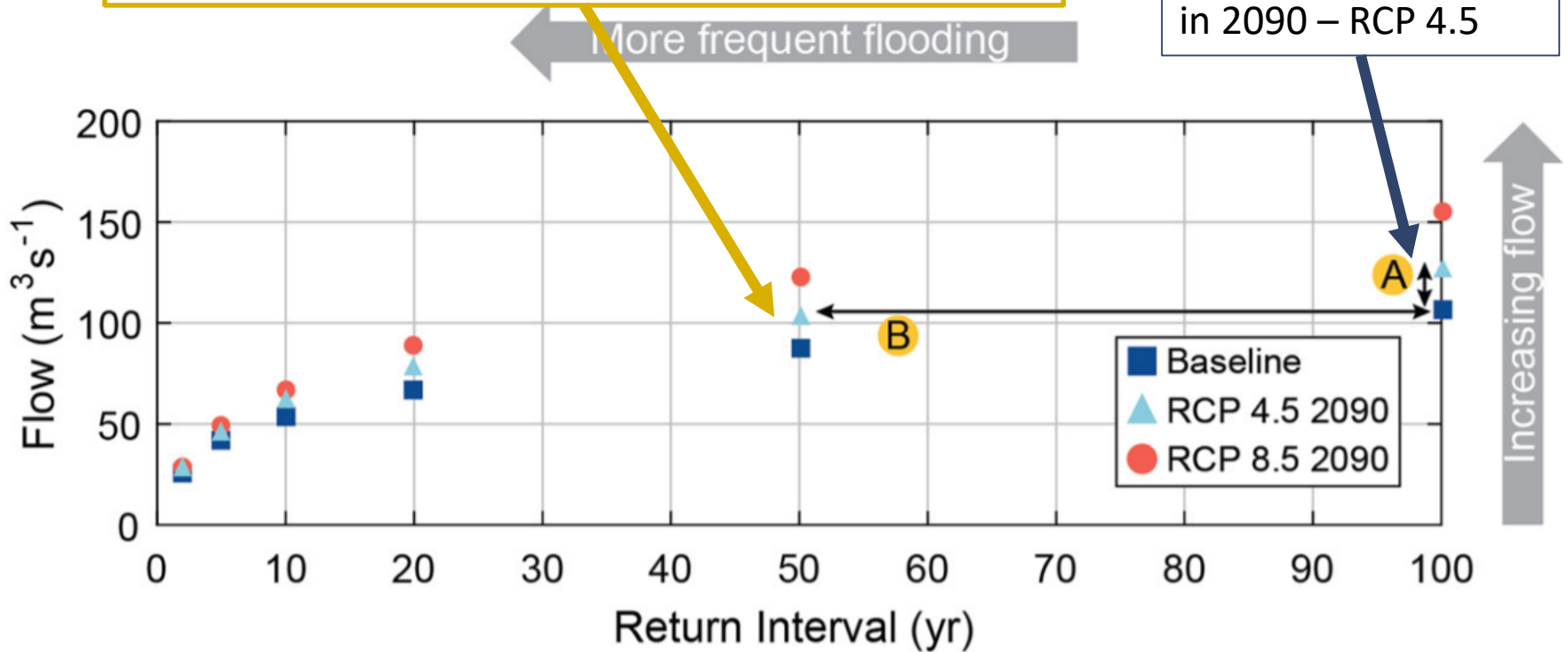
Wobus et al, 2017

Bigger flow volume for more frequent events

The 100 m³s⁻¹ flow baseline 1% AEP flood **becomes twice** as frequent by end of century (shift from 100-y to 50-y average return interval – RCP 4.5)

Larger flow volumes

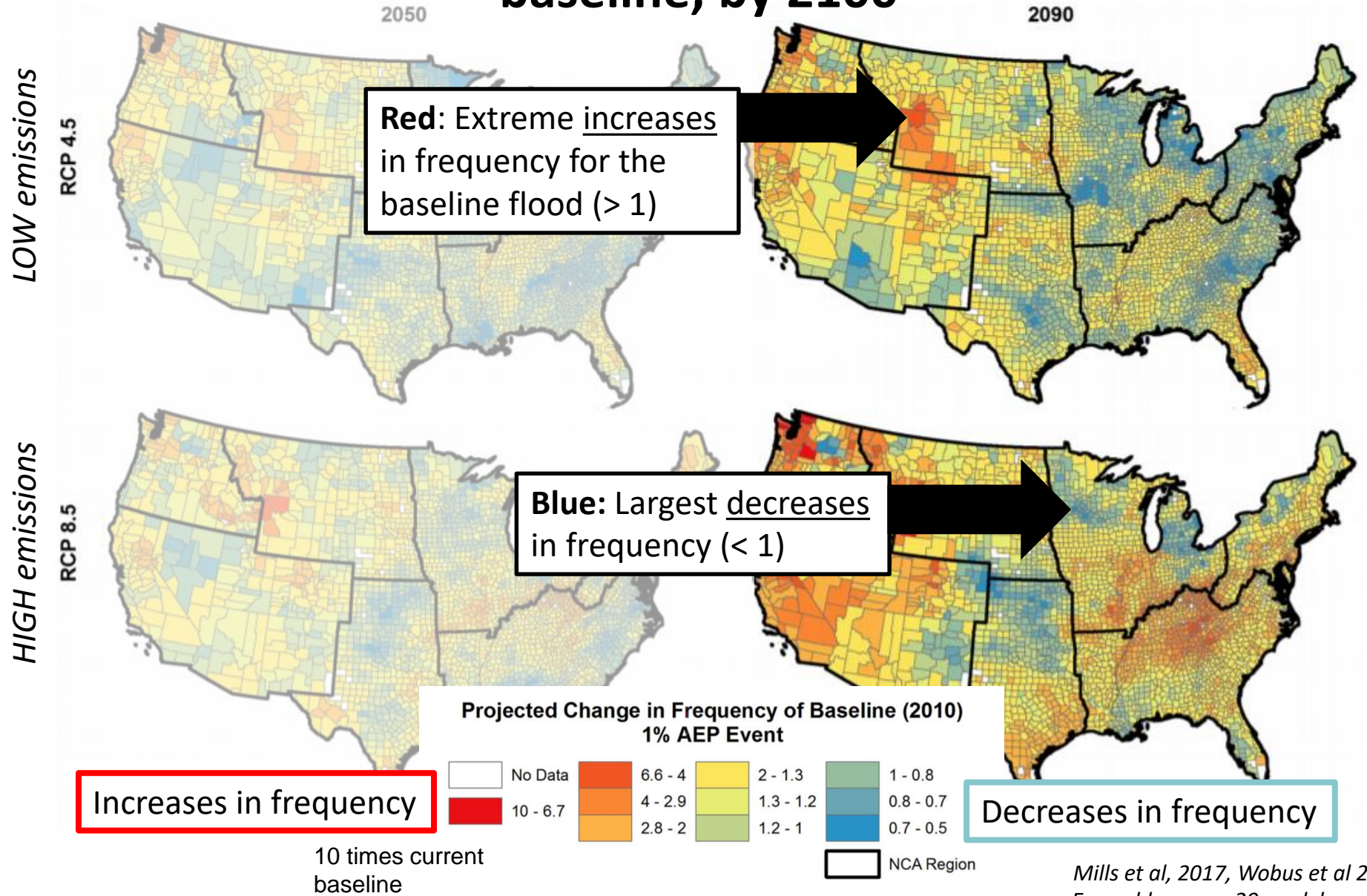
100-y return interval [1% AEP event] **becomes 25% larger** in 2090 – RCP 4.5



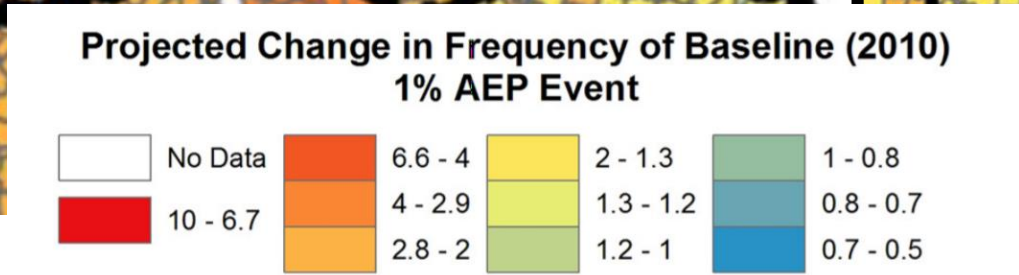
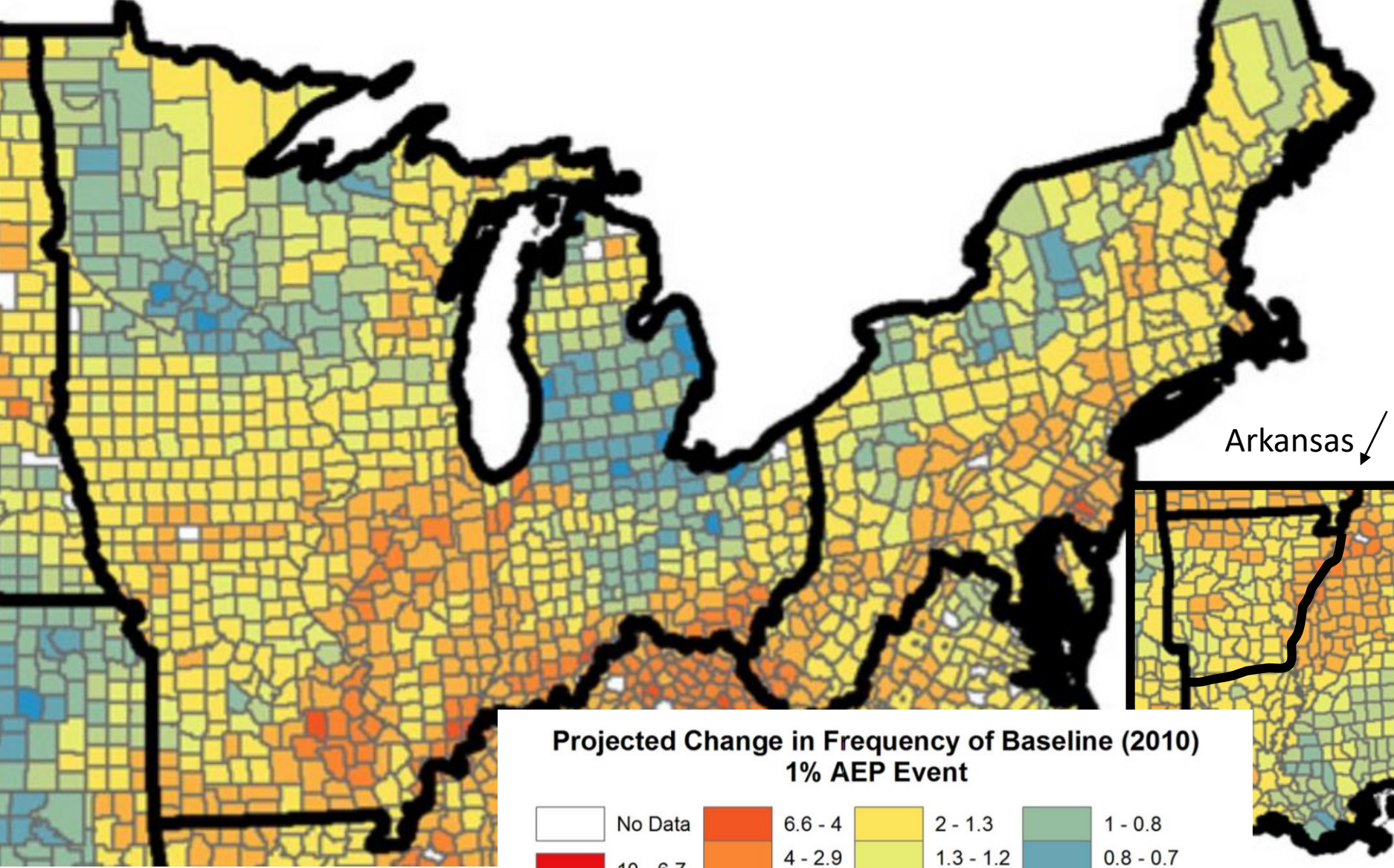
**Example of change in inland flooding for one river reach.*

- Modeled future flows
- Found flow and flood magnitude increased in some cases.

Change in frequency of annual 1% (100 year) event from baseline, by 2100



Projected change in the frequency of baseline 1% annual exceedance probability (AEP) floods. Map shows 2090 - RCP 8.5 (High emissions, business as usual scenario)



Mills et al, 2017,
Wobus et al 2017
Ensemble mean,
29 models

Increases in frequency (>1)

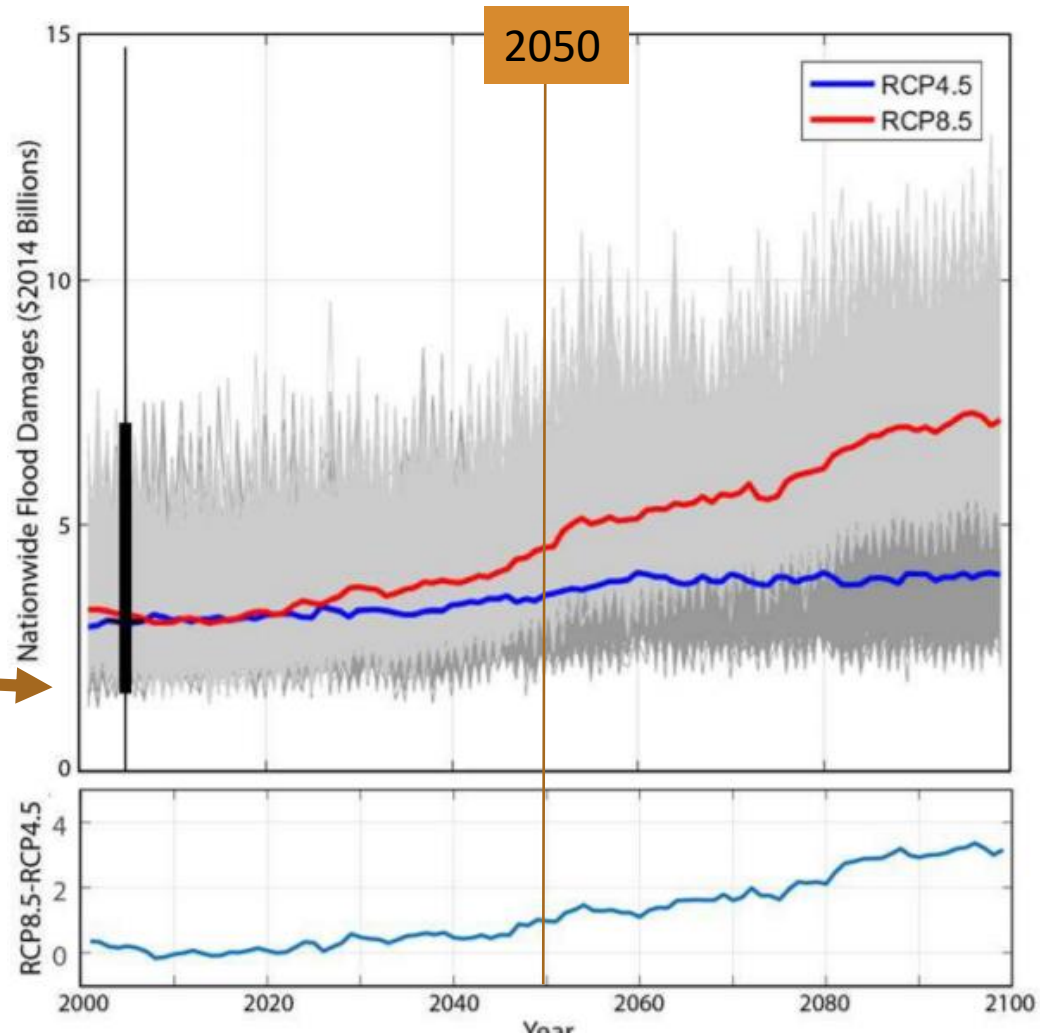


Decreases in frequency (<1)

Projected Flood damages (\$ cost)

(Wobus et al, 2017)

- High emissions: Flood damages exceed low emissions by ~\$3B/year in 2100
- Gray lines show results from 1,000 simulations for RCP 4.5 and RCP 8.5
- Emissions scenarios diverge primarily after 2050



**in 2014 dollars*

Stream channels are dynamic, and change over time...

Recall Step 2:
Unique Site
characteristics

- Any changes in a river channel's capacity (i.e., the depth, width, and roughness) may significantly **alter the frequency of local flooding above set flood levels** (even in the absence of any changes in discharge) (Slater et al, 2015)
 - Stream channels evolve, aggrade, degrade, narrow, widen.
- Particularly in locations that have experienced major changes in channel capacity due to urbanization or water regulation



Image: Cuyahoga Soil & Water Conservation District

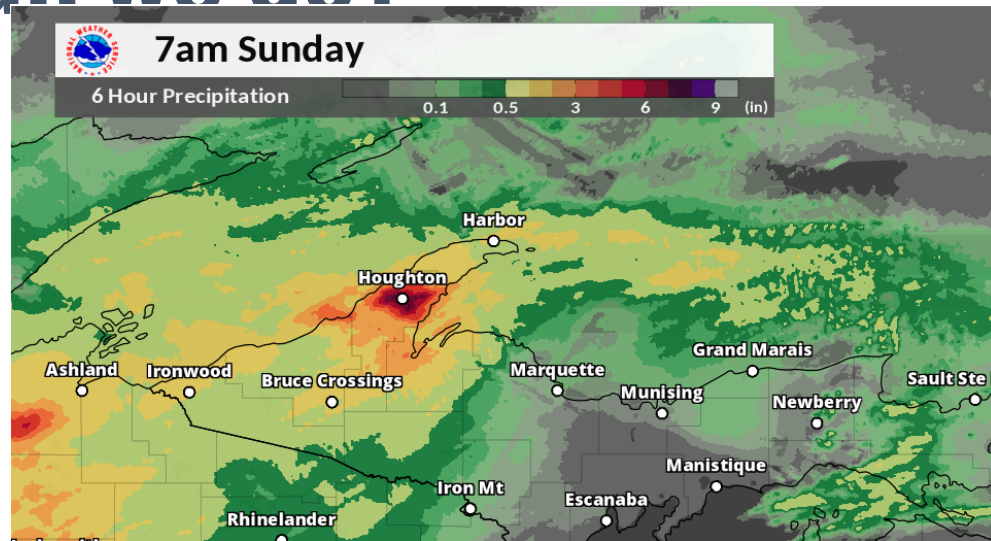
Read more on this concept:

Slater, L. J., M. B. Singer, and J. W. Kirchner (2015), Hydrologic versus geomorphic drivers of trends in flood hazard, *Geophys. Res. Lett.*, 42, 370–376, doi:10.1002/2014GL062482.

What can we do?

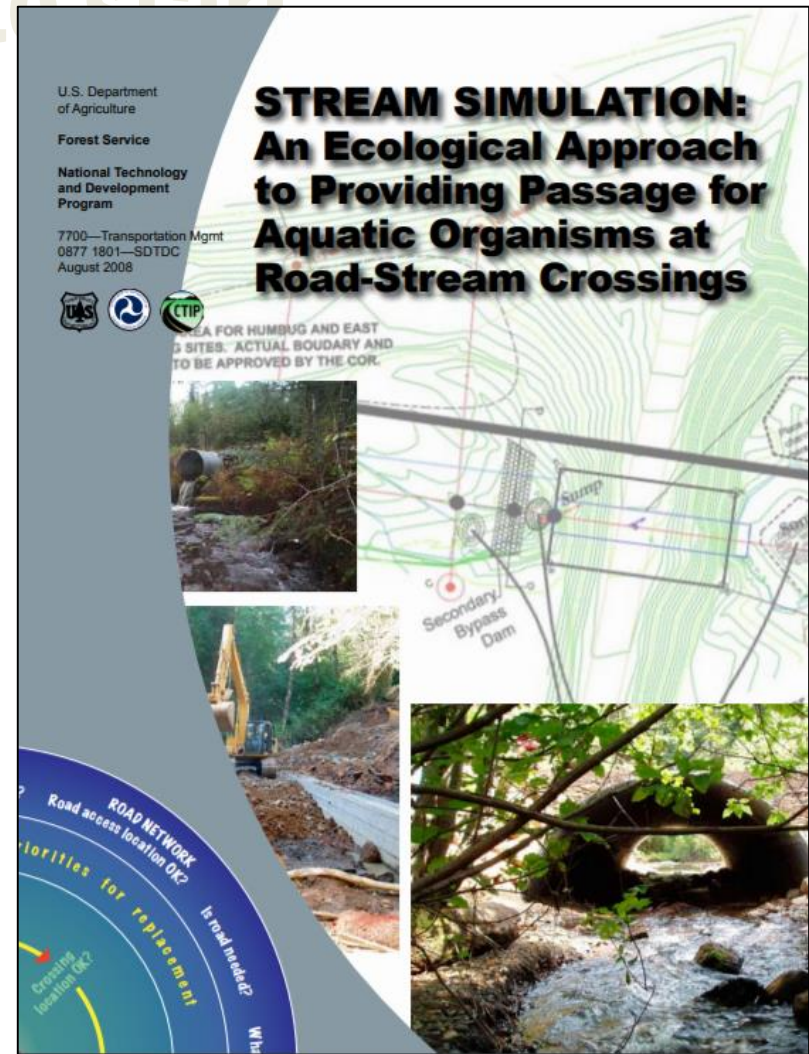
- ~~Leave?~~
- ~~Pretend it's not happening?~~
- Embrace uncertainty

- Reframe our idea of “future conditions”
- Get out in front and address the problem in planning... now



Where to start

- Understand the channel capacity at your site
- Learn how to incorporate ecological considerations into road-stream crossing designs to accommodate changing hydrology



USDA FS Stream Simulation tool

https://www.fs.fed.us/eng/pubs/pdf/StreamSimulation/hi_res/%20FullDoc.pdf

Where to start: Evaluate storm frequency – tool: NOAA Atlas 14

- NOAA has updated precipitation frequency (PF) estimates for the U.S (P_{min} , P_{max} , P_{avg})
- Updates are noteworthy:**
 - Atlas 14 includes most recent 30 years of precipitation data**
 - And includes more weather stations than previous efforts.**
- Gridded precipitation-frequency estimates at 30 arc-seconds resolution
- Provides estimates of 500-yr and 1000-yr events

NOAA's National Weather Service
Hydrometeorological Design Studies Center
Precipitation Frequency Data Server (PFDS)

Home Site Map News Organization

NOAA ATLAS 14 POINT PRECIPITATION FREQUENCY ESTIMATES: KS

Data description
Data type: Units: Time series type:

Select location

1) Manually:

a) By location (decimal degrees, use "-" for S and W): Latitude: Longitude:

b) By station (list of KS stations):

c) By address:

2) Use map (if ESRI interactive map is not loading, try adding the host: <https://js.arcgis.com/> to the firewall, or contact us at hdsc.questions@noaa.gov):

Map

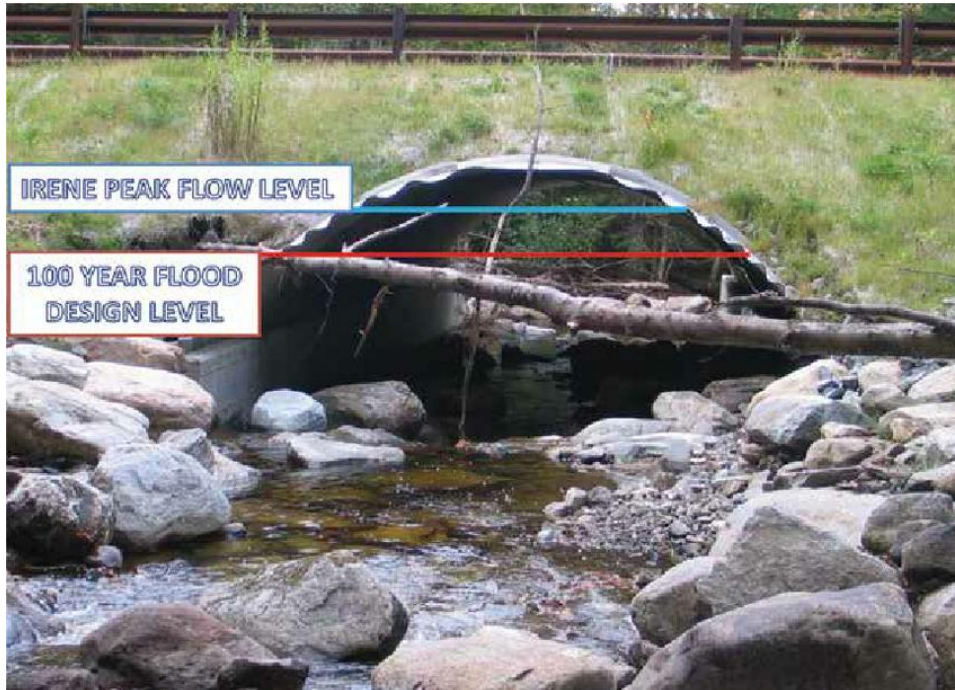
a) Select location
Move crosshair or double click

b) Click on station icon
 Show stations on map

Location information:
Name: Bronson, Kansas, USA*
Latitude: 35.0000°
Longitude: -95.0000°
Elevation: 1035.83 ft **

<http://hdsc.nws.noaa.gov/hdsc/pfds/>

Where to start: Evaluate storm frequency - NOAA Atlas 14



- Atlas 14 can replace older technical reports when making infrastructure sizing and design decisions for conveyance and detention.
- Likely - Precipitation Frequency estimates used for stormwater management **do not accurately reflect the depths falling during precipitation events** –
 - Climate change projections indicate rainfall volumes will continue to increase over the next 50 years
 - Start with Atlas 14, incorporate other considerations.

Expected “normal” rainfall amount

Case study: Ann Arbor, MI

(Older technical report vs. Atlas 14)

Bulletin 71/Atlas 14

[% change]

	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%]

Huron River Watershed – Stormwater Guide

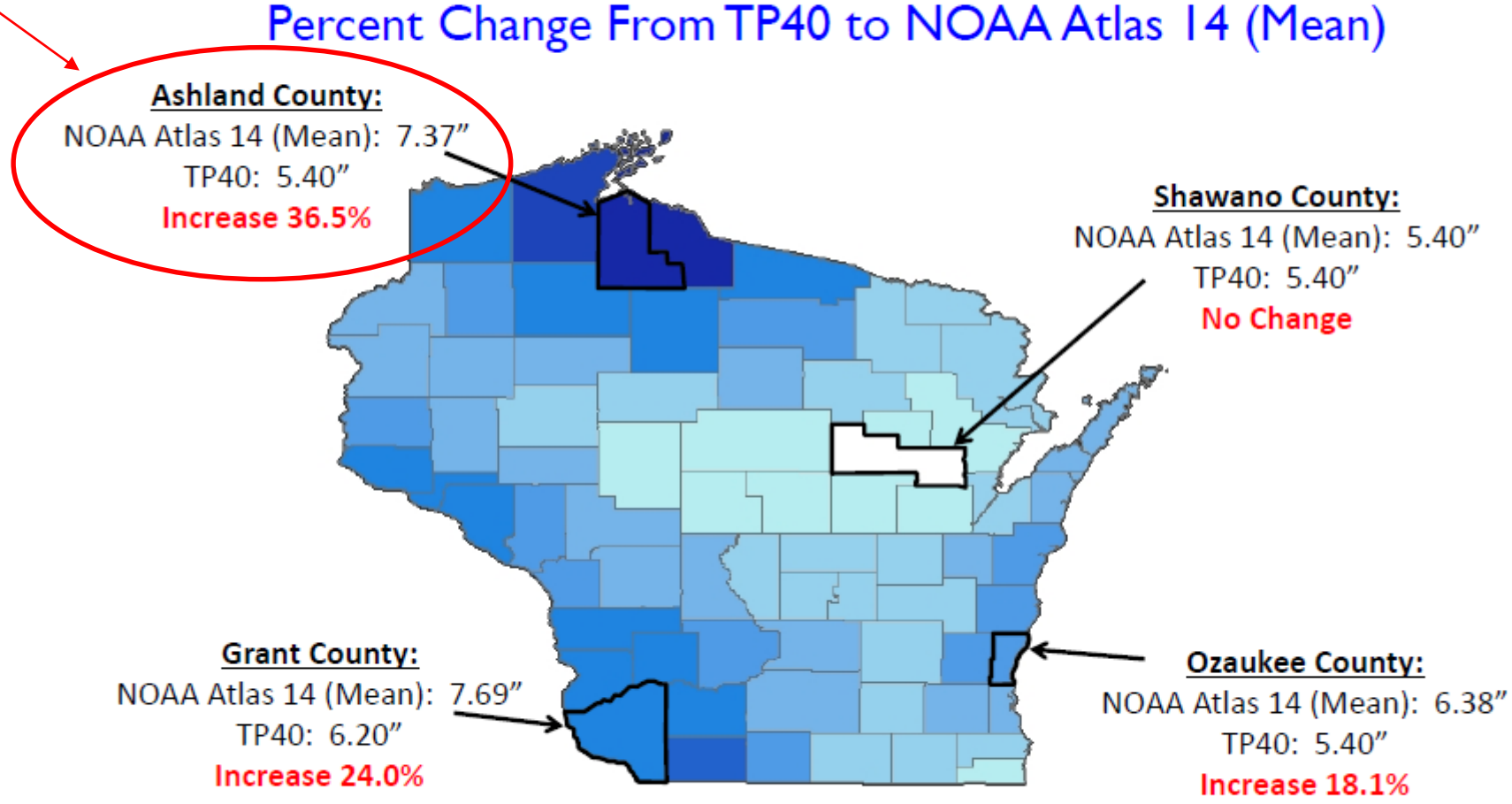
<https://www.hrwc.org/wp-content/uploads/2016/02/Stormwater-and-Climates-Guide-1.pdf>

*Atlas 14 prediction:
Changes storm
estimates*



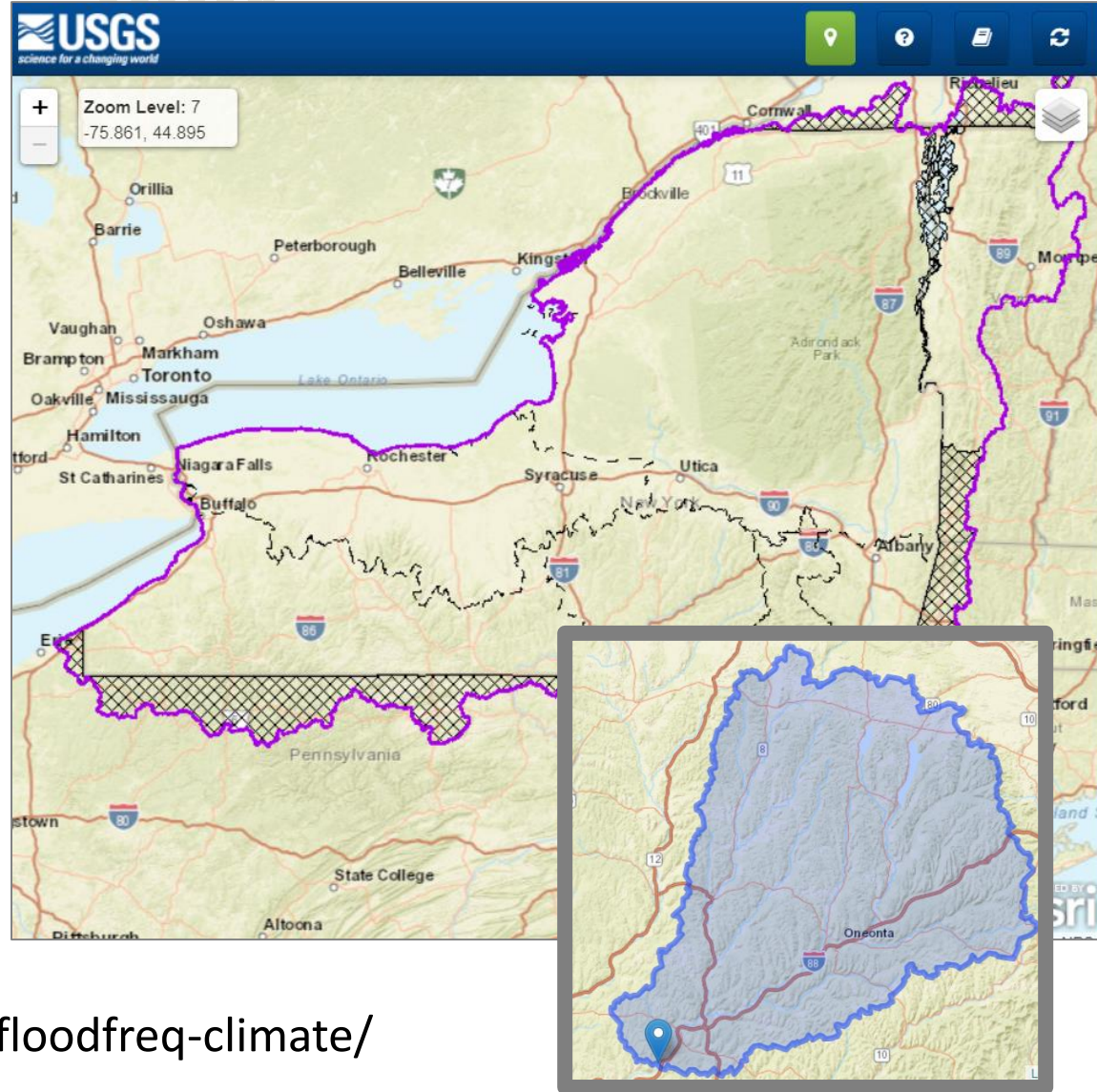
NOAA Atlas 14 Versus TP40 Precipitation Depths

100-Yr, 24-Hr Precipitation Depths Percent Change From TP40 to NOAA Atlas 14 (Mean)



Tool: USGS Future Flow – NY state

- Get future flow predictions for your watershed
- Flood regressions and climate change scenarios – future peak flows
- Estimate flows (cfs, and % change)



<https://ny.water.usgs.gov/maps/floodfreq-climate/>

To-do list for next week:

- **Complete Step 5:** Monitor and evaluate effectiveness
- **Complete the Homework** section after Step 5
- Recommended readings:
 - Roman et al. 2017
 - Janowiak et al. 2017
- **Come to Session 6 (Tuesday, December 11)** ready to discuss your monitoring!

Thanks everyone!

Troubleshooting? Stay on the line.