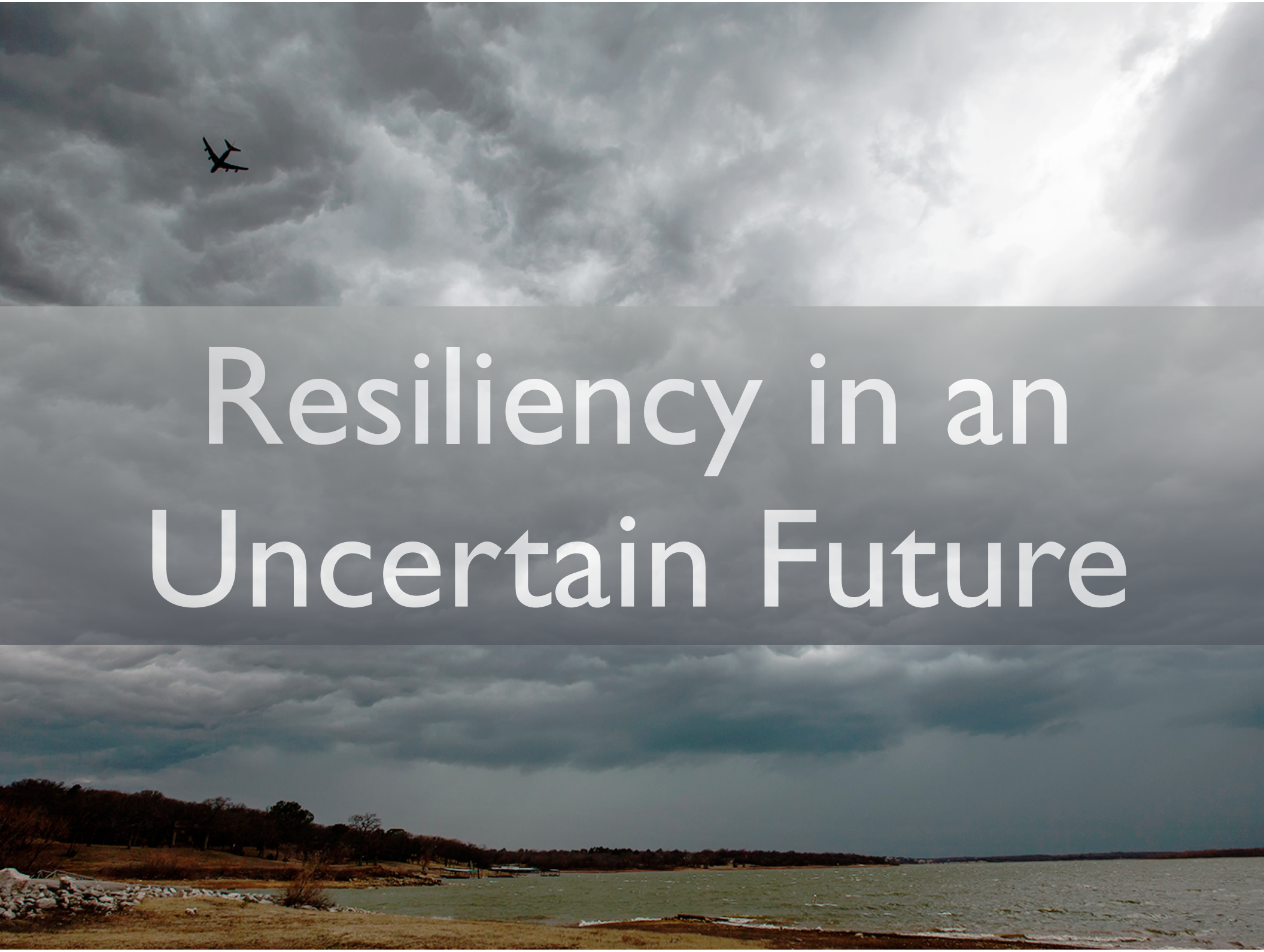

Resiliency in an
Uncertain Future

THE HARD SELL

Planning and investing in a distant future

Fewer options

Higher costs

Multiple options

Lower costs

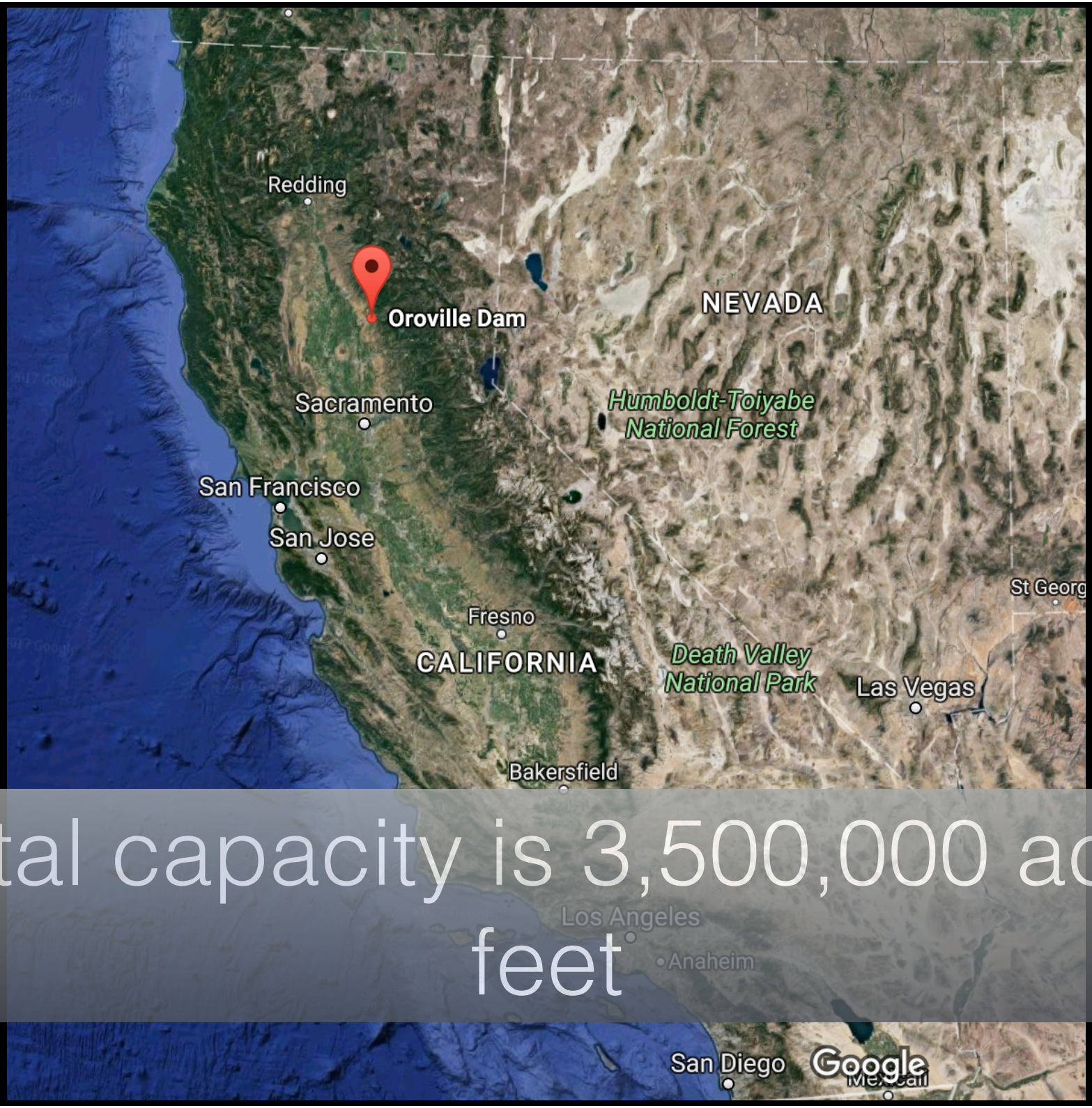
2017 2027 2037 2047

Highest costs

Fewest options

The story of the Oroville Dam

Oroville Dam constructed as the tallest dam in the country in 1968



Total capacity is 3,500,000 acre feet

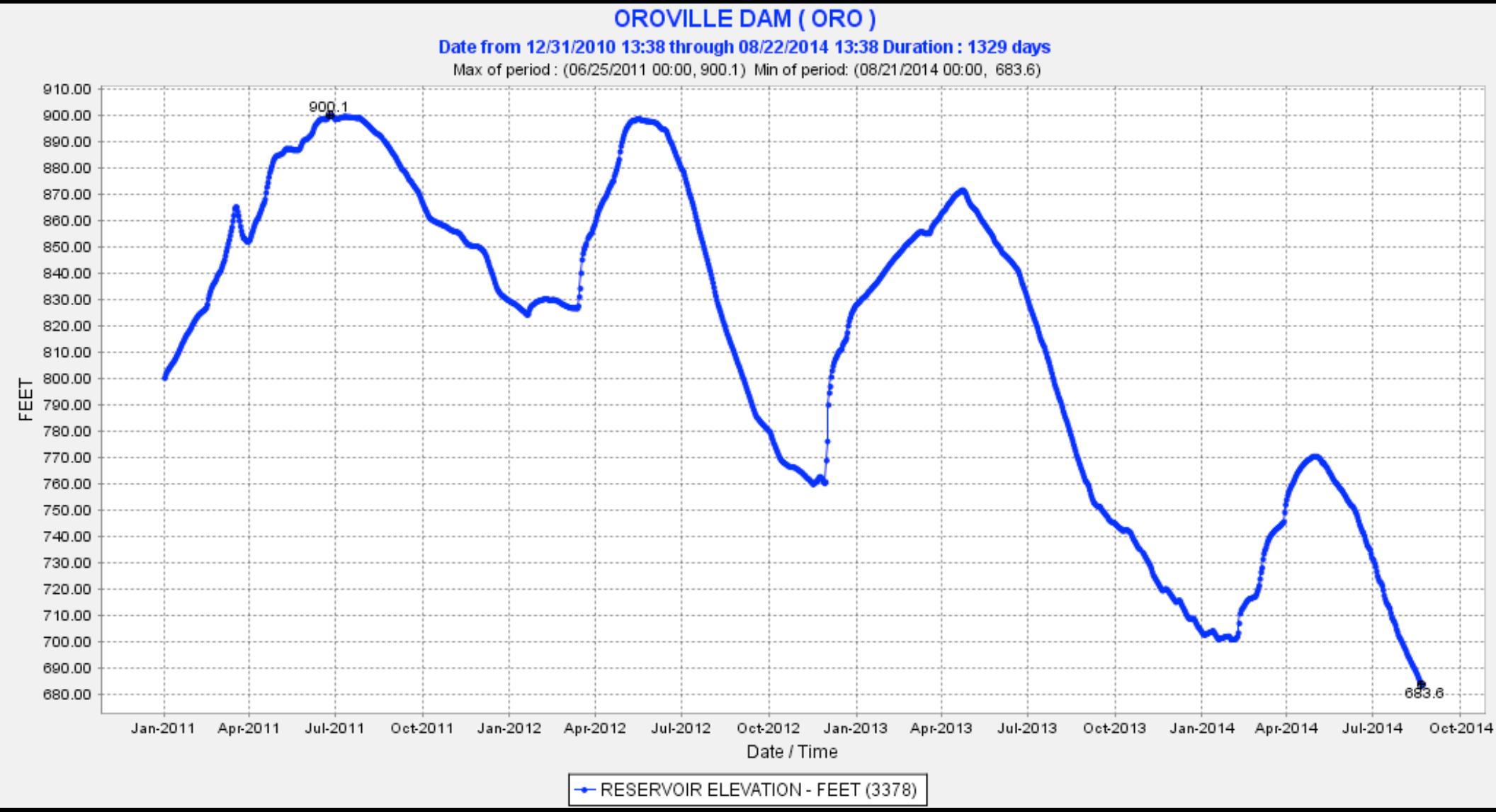
In 2000 concern was growing about the dam and its capacity to respond to a significant rain year.

In 2005, Friends of the River, Sierra Club and the South Yuba River Citizen's League charged that the emergency spillway at the Oroville Dam wasn't properly built and posed serious risks.

They sued.

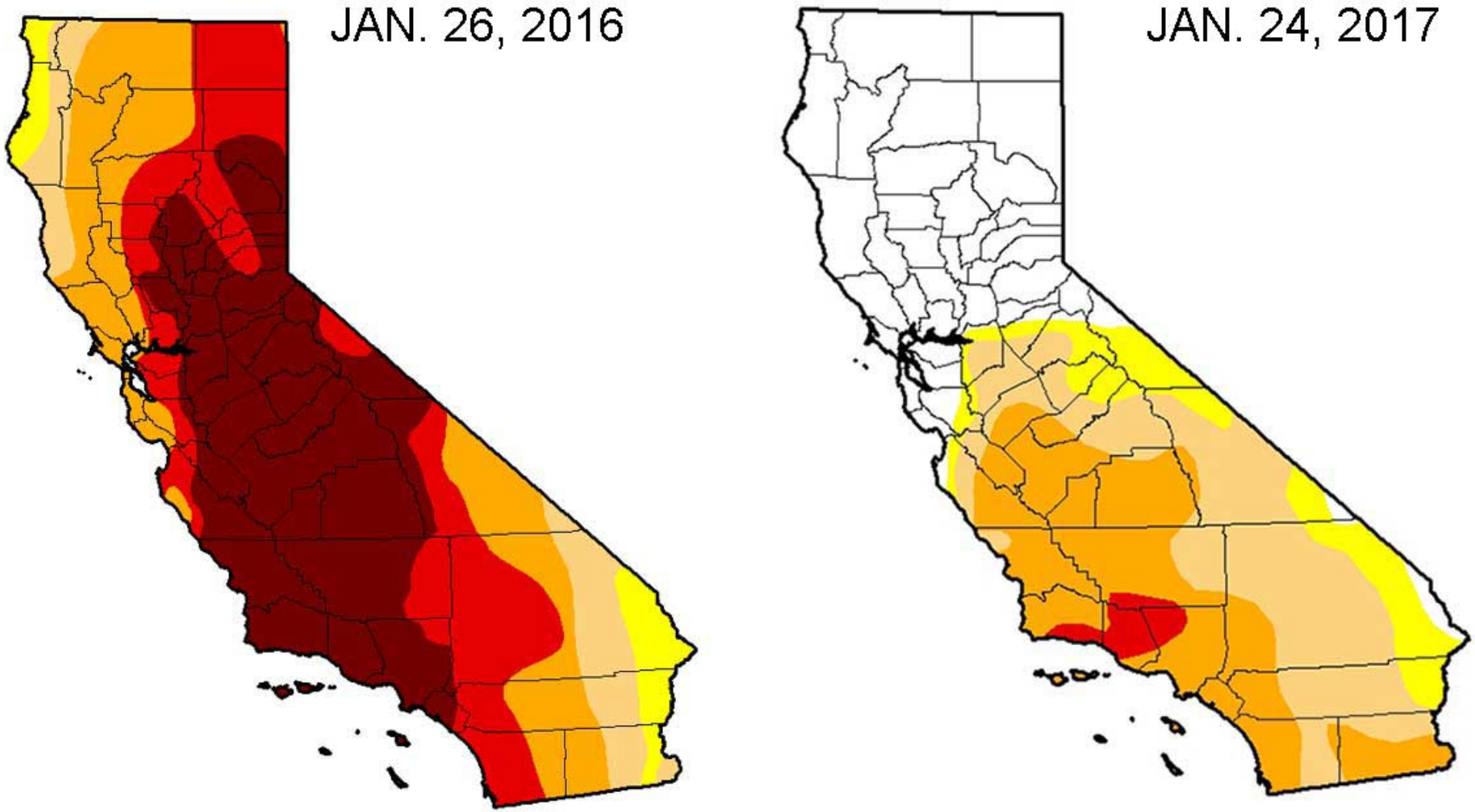
The state of California denied their claims as overblown and unfounded.

The state won.


OROVILLE DAM (ORO)
Date from 12/31/2010 13:38 through 08/22/2014 13:38 Duration : 1329 days
Max of period : (06/25/2011 00:00, 900.1) Min of period: (08/21/2014 00:00, 683.6)
FEET
910.00
900.00
890.00
880.00
870.00
860.00
850.00
840.00
830.00
820.00
810.00
800.00
790.00
780.00
770.00
760.00
750.00
740.00
730.00
720.00
710.00
700.00
690.00
680.00
900.1
683.6
Jan-2011
Apr-2011
Jul-2011
Oct-2011
Jan-2012
Apr-2012
Jul-2012
Oct-2012
Jan-2013
Apr-2013
Jul-2013
Oct-2013
Jan-2014
Apr-2014
Jul-2014
Oct-2014
Date / Time
RESERVOIR ELEVATION - FEET (3378)


2008


2016


JAN. 26, 2016
JAN. 24, 2017

100,000 cubic feet/second

But the rain kept coming


abc GMA
ADDITIONAL RAINFALL
THROUGH FRIDAY
<1/4"
1/4"-1/2"
1/2"-1"
1"-2"
2"-3"
3"-6"
6"+
Redding
Sacramento
San Francisco
Fresno
Santa Barbara
Los Angeles
San Diego
RAIN: LOCALLY 2"+
MUDSLIDES, FLOODING
MTN SNOW:
UP TO 4 FEET

San Jose

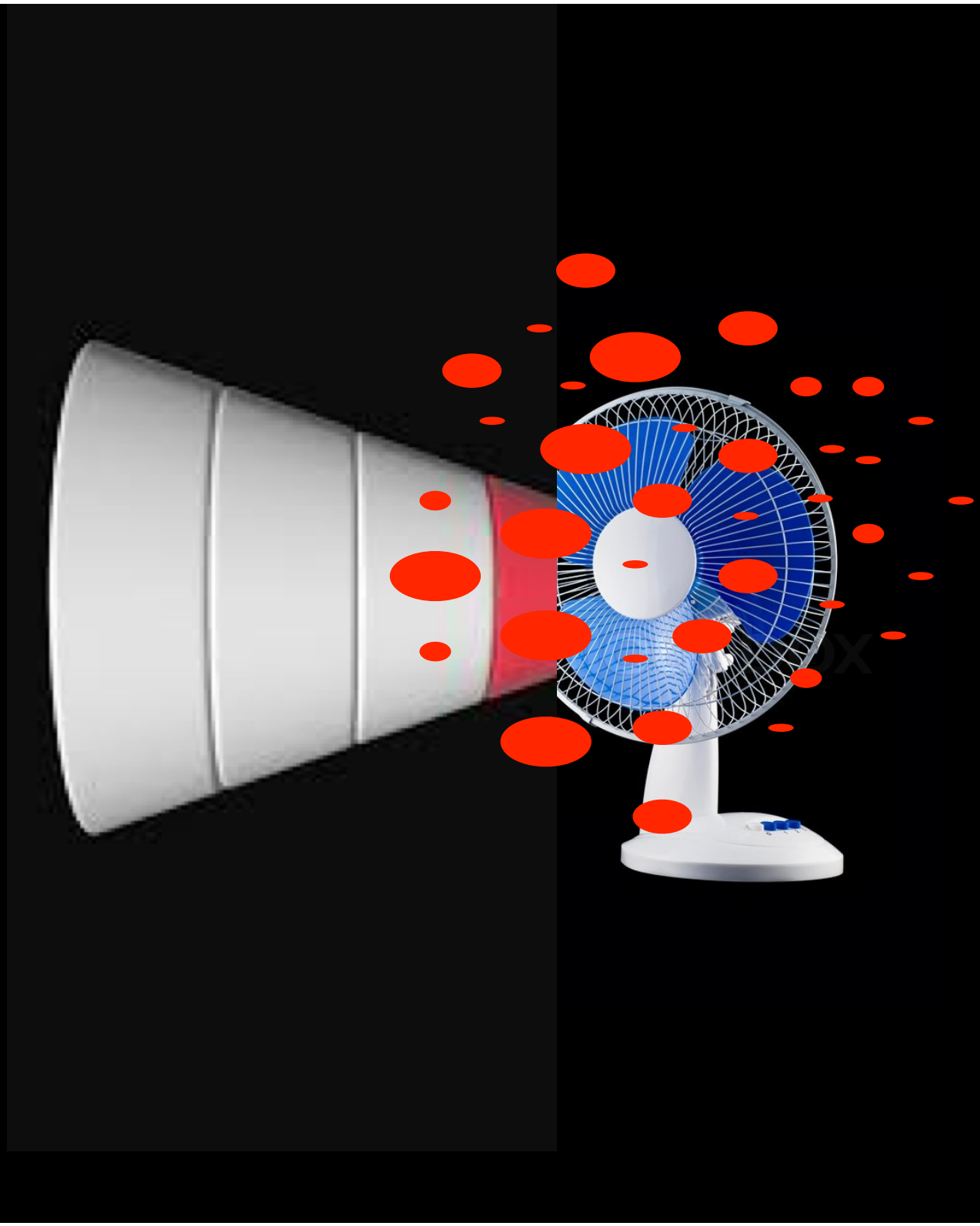

Enterprise-Record
ChicoER.com


OROVILLE DAM ON VERGE OF COLLAPSE
188,000 ORDERED TO EVACUATE

THE SACRAMENTO BEE 

California awards $275 million contract to repair Oroville Dam spillway

Not really

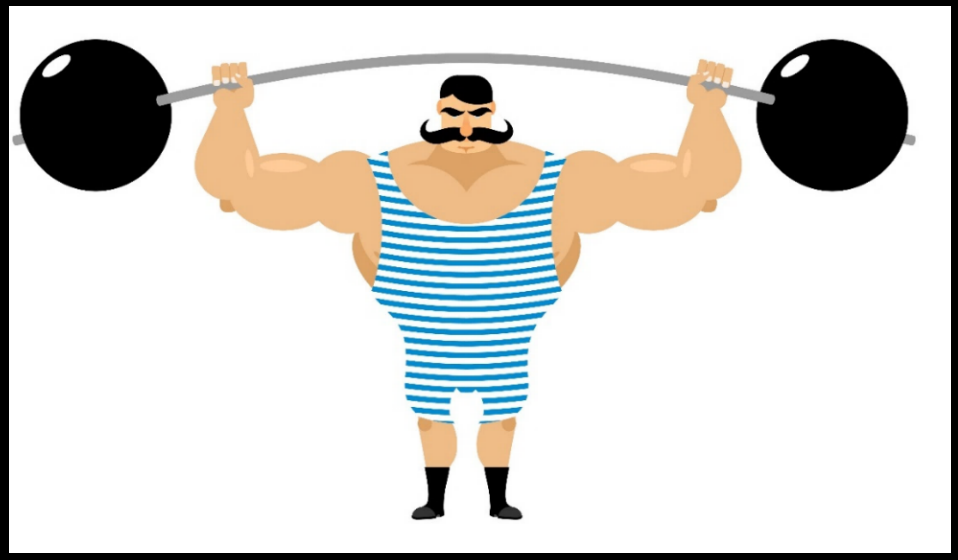



RESILIENCE
ADVERSE
EVENTS
THREATS
HARM
COAST
STRESS
CLIMATE
MODERATE
E.G
ACTUAL
NECESSARY
DESTRUCTION
HURRICANES
RESTORE
COMPONENTS
MEANS
VULNERABILITIES
REFERS
EXECUTE
MAINTAIN
SAFETY
PLAN
CENTRAL
ABILITY
HEALTH
EXTENT
DEGRADATION
REDUCTION
TAKE
SHIFT
CONSEQUENCES
ECOSYSTEM
WAYS
CAUSE
ONLINE
OCCUR
CHANGE
DEFINITION
RISK
AMOUNT
SIGNIFICANT
STRATEGIES
SERVICES
REDUCE
OPERATIONS
CAUSED
DISTURBANCE
EQUATION
EXTERNAL
INCLUDES
COMMUNITY
ADJUST
LOSS
SYSTEM
RECOVERS
RECOVERY
DISASTERS
CAPACITY
MITIGATE
ATTACK
ADAPT
REGARDLESS
OPPORTUNITIES
IMMEDIATE
NATIONAL
FUNCTIONS
DEFINED
COASTAL
EFFORTS
FUTURE
DISASTER
POTENTIAL
SUCCESSFULLY
RECOVER
EMOTIONS
CAPABILITY
ATTACKS
ABSORB
INCIDENTS
STRUCTURE
MUST
HAZARDS
DAMAGE
MINIMUM
MULTIHAZARD
EFFECTS
ORGANIZATIONS
INCREASE
INITIATIVES
ACCESS
WITHOUT
BASED
SOCIAL
INCIDENT
MAINTAINING
PREVENT

RESILIENCY:

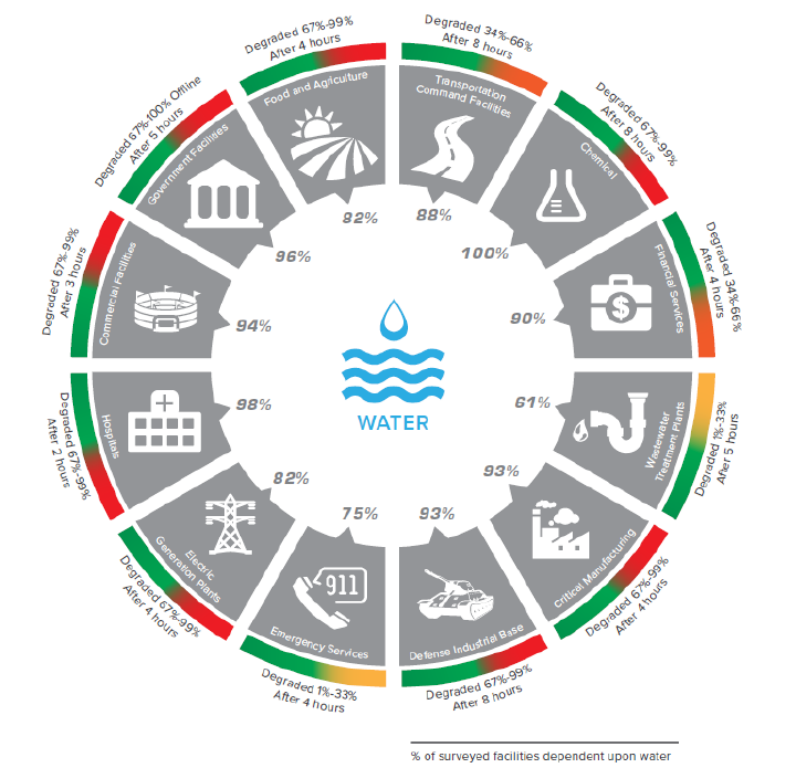
the ability of a person or organization to anticipate, prepare for, and respond to change and sudden disruptions in order to survive and prosper.

4 R's of Resiliency



Impacts to Critical Infrastructure

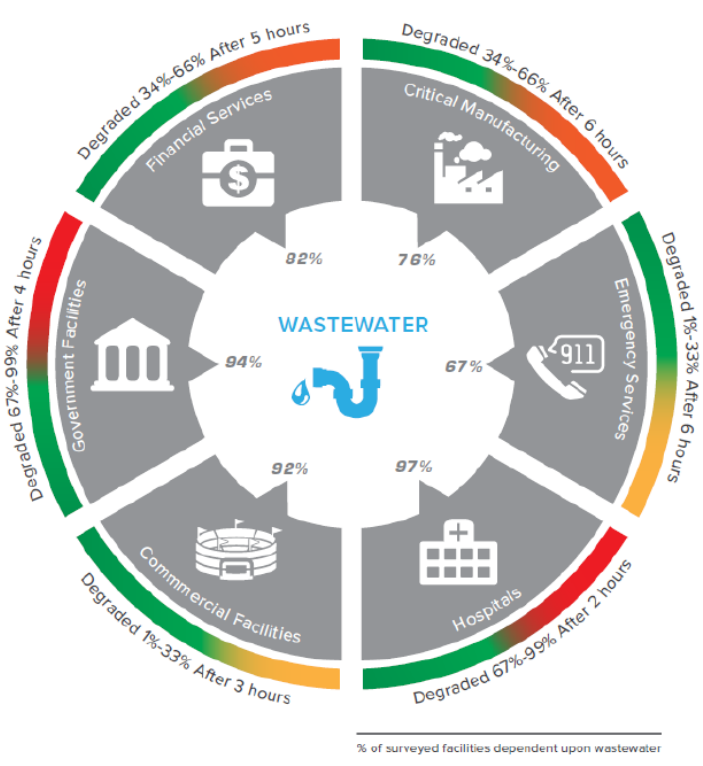
LOSS OF WATER SERVICES



Note: This data represents a majority (60 percent or greater) dependence on water.

FIGURE 3.—Critical Infrastructure Dependent on Water and Potential Functional Degradation Following a Loss of Water Services (Courtesy of DHS and Argonne National Laboratory).

LOSS OF WASTEWATER SERVICES



Note: This data represents a majority (60 percent or greater) dependence on wastewater services.

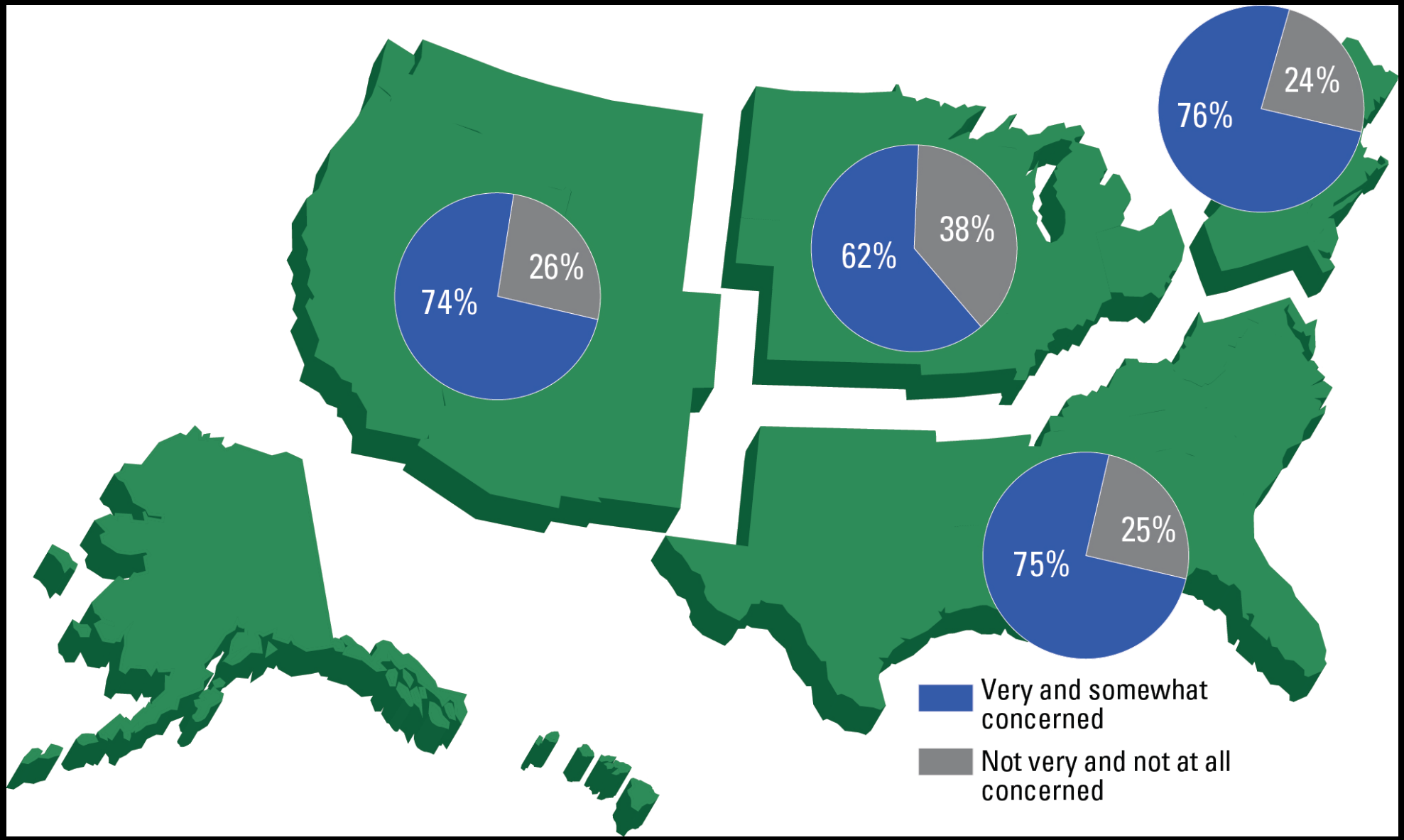
FIGURE 4.—Critical Infrastructure Dependent on Wastewater and Potential Functional Degradation Following a Loss of Wastewater Services (Courtesy of DHS and Argonne National Laboratory).

https://www.massport.com/media/266269/Report_Sector-Resilience-Report-Water-and-Wastewater.pdf

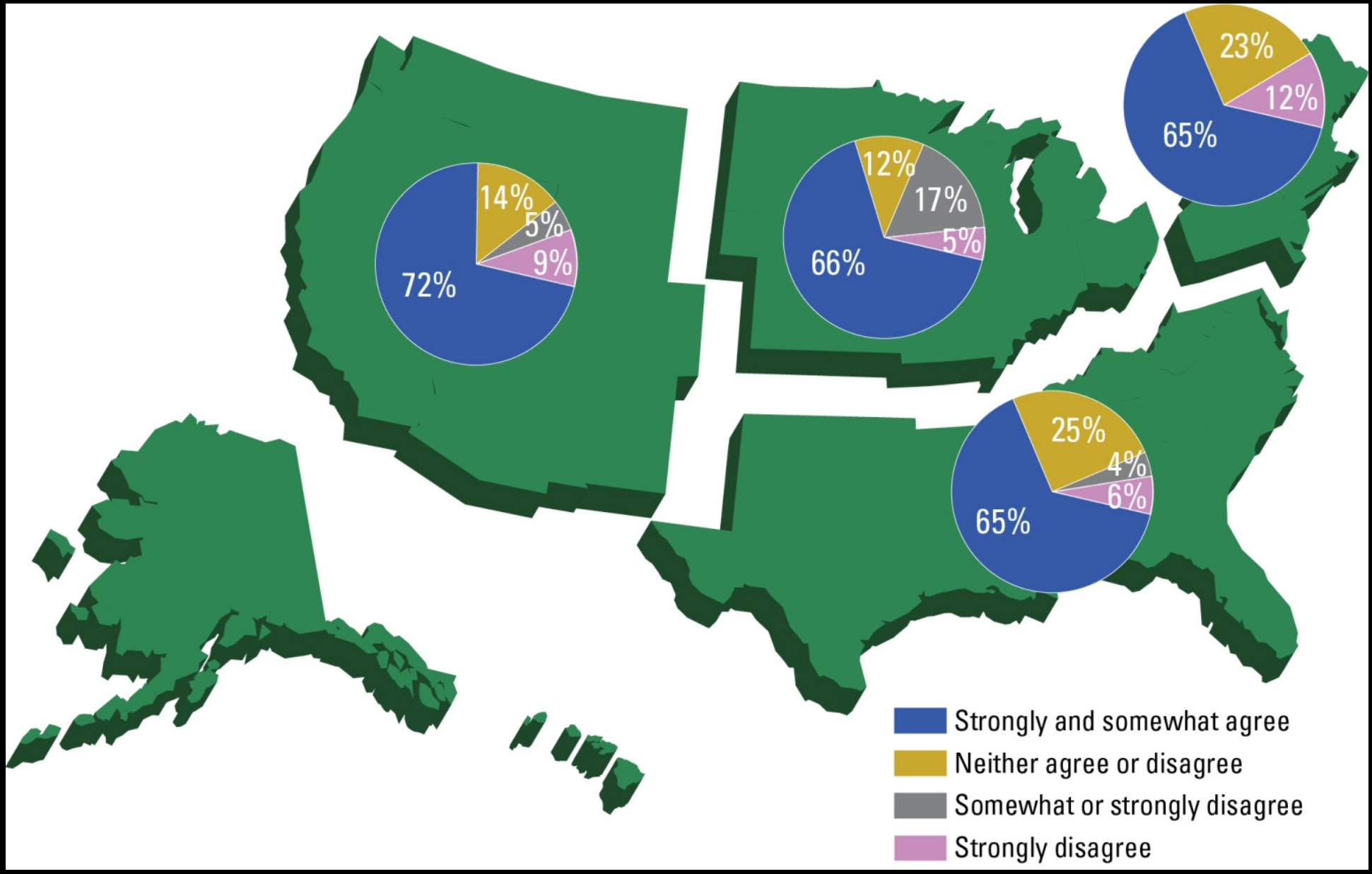
Impacts and Extreme Weather

How concerned are you that future extreme weather events will negatively impact your community water providers ability to provide safe, healthy drinking water?

Water Research Foundation, 2014

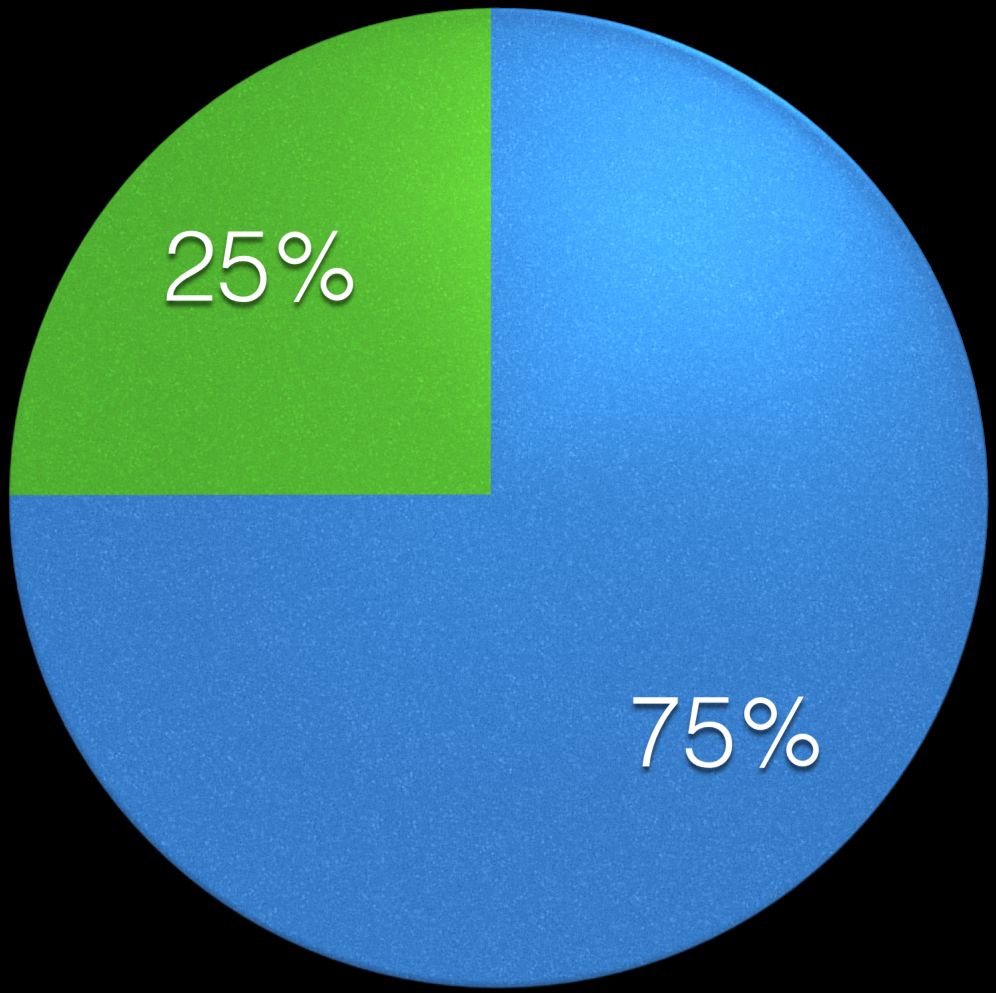


Climate change will have a significant impact on extreme weather events, causing changes in the severity of droughts, hurricanes, rainstorms, and heat waves

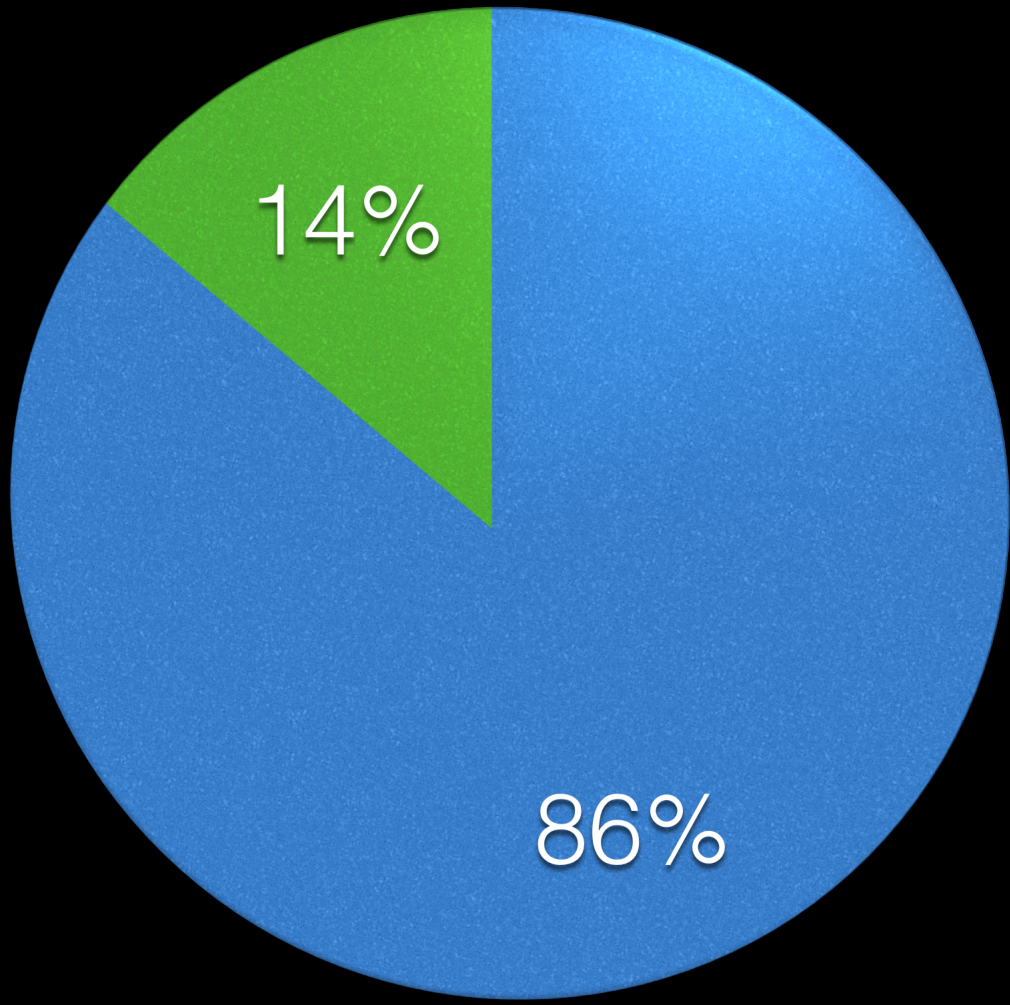


When planning for the future, how much attention do you think your water utility should give the following issues?

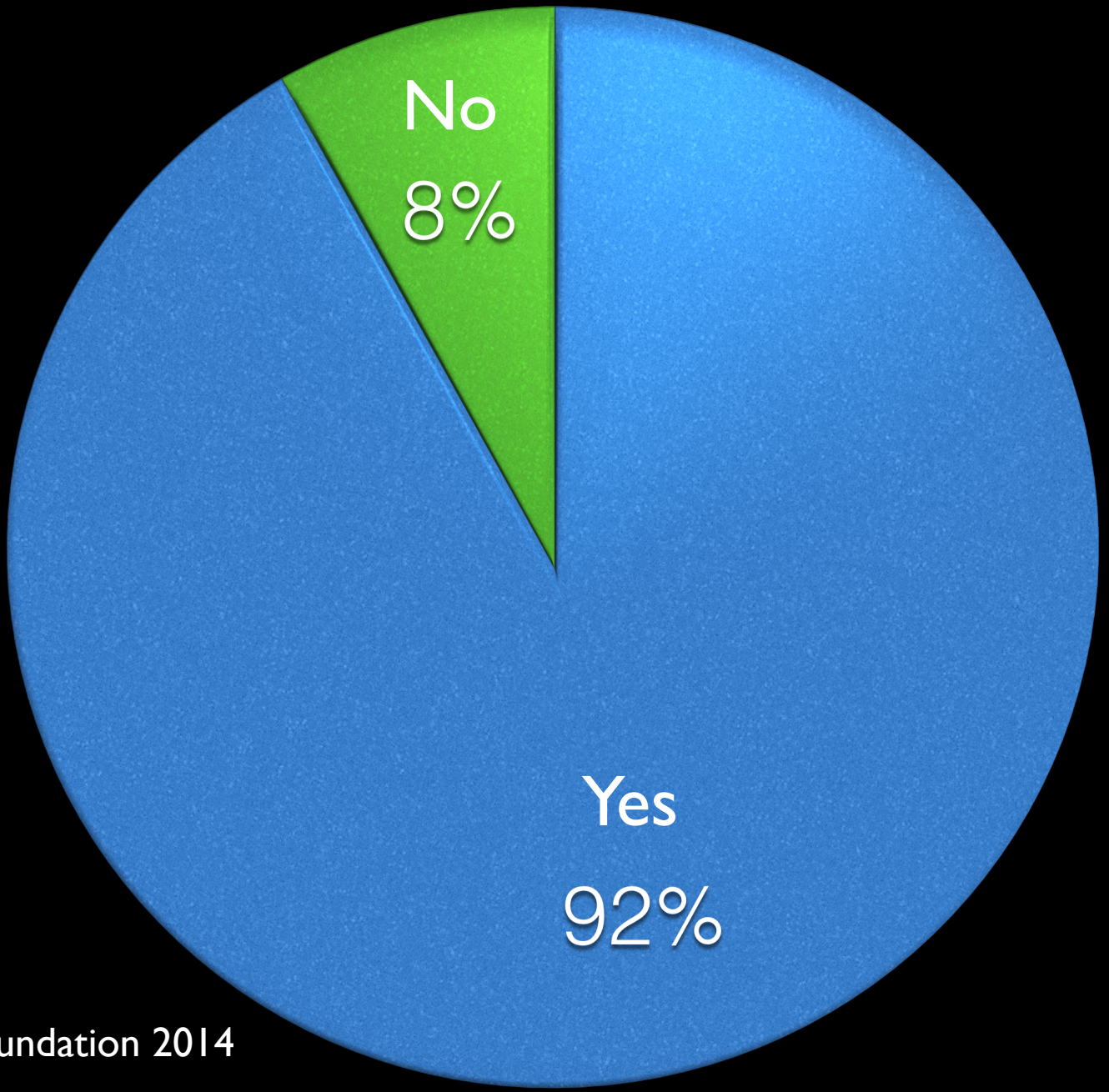
Climate Change



Extreme Weather Events



Should your community water utility play a role in helping the community prepare for climate impacts?

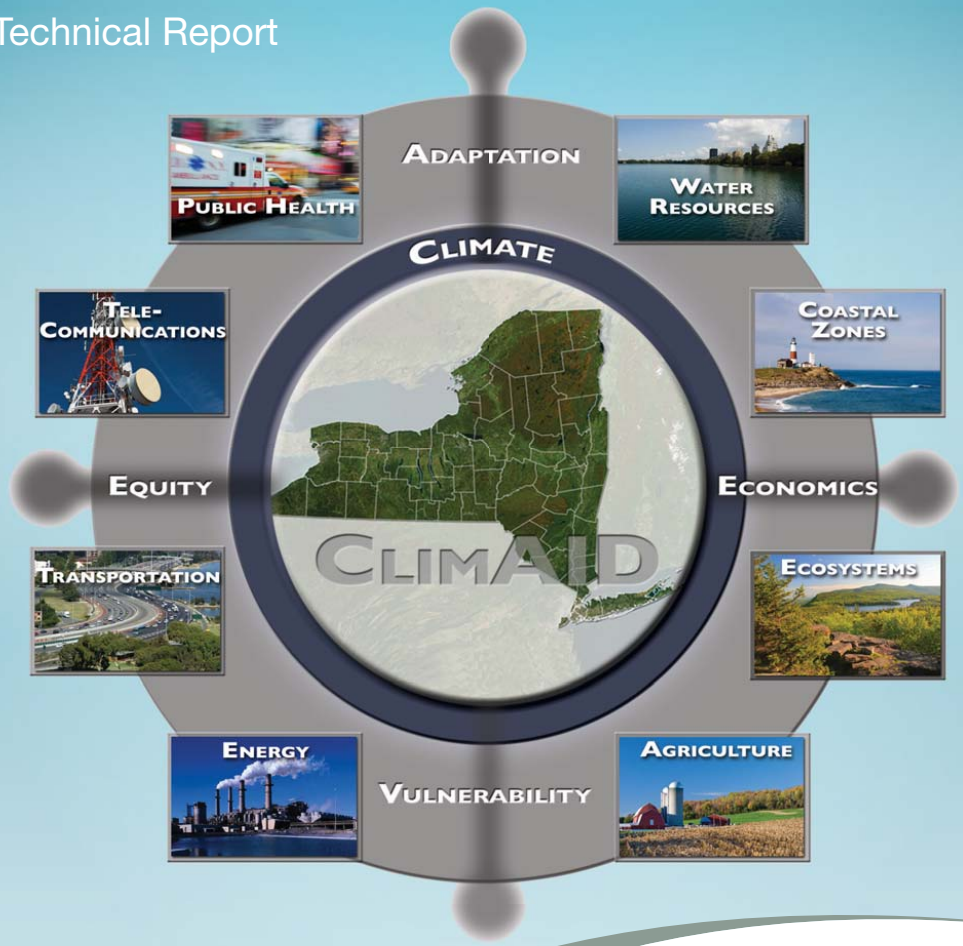


Water Research Foundation 2014

New York State Energy Research and Development Authority

Responding to Climate Change in New York State

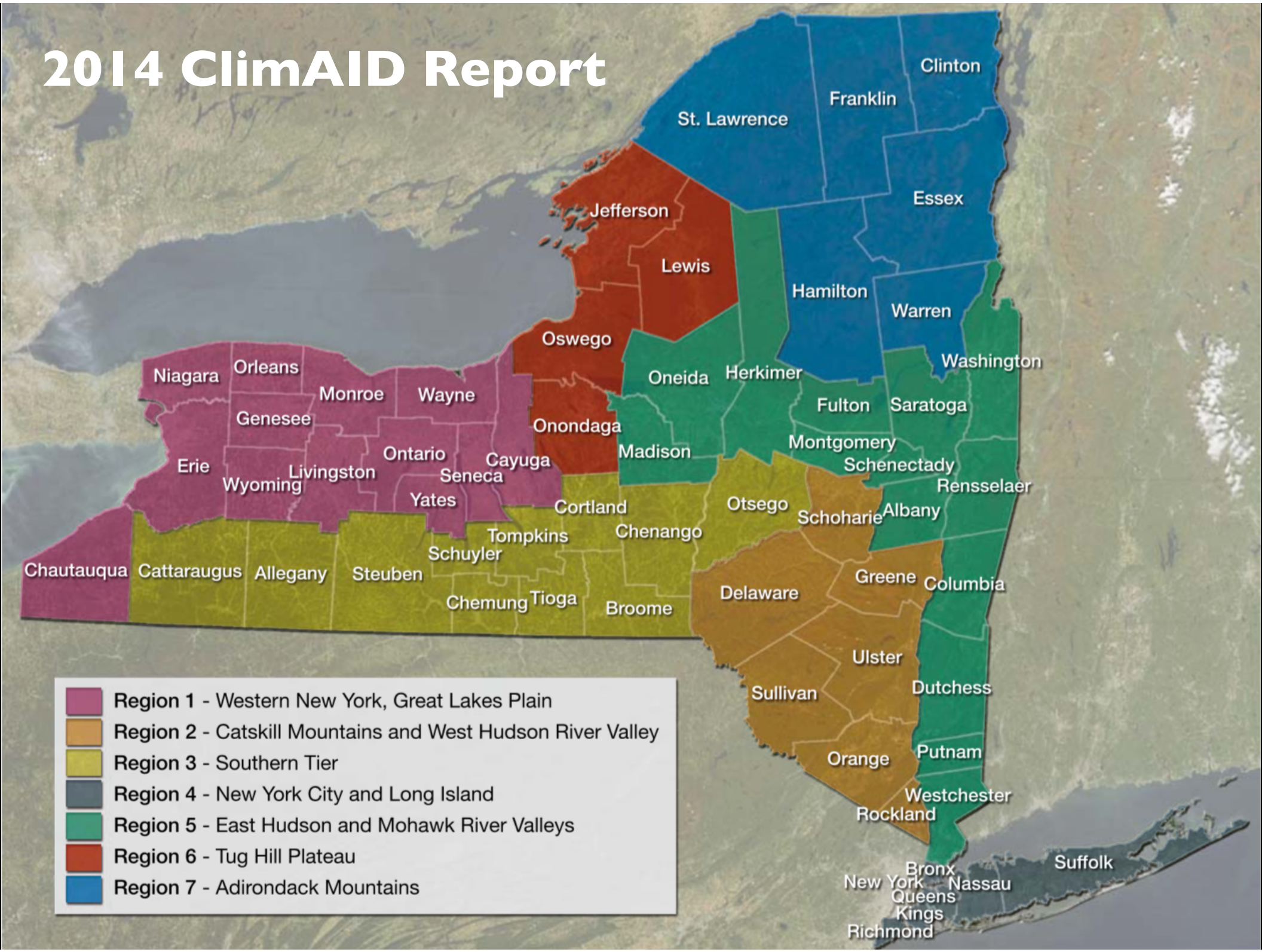
Technical Report



Final Report
No. 11-18

nyserda
Energy. Innovation. Solutions.

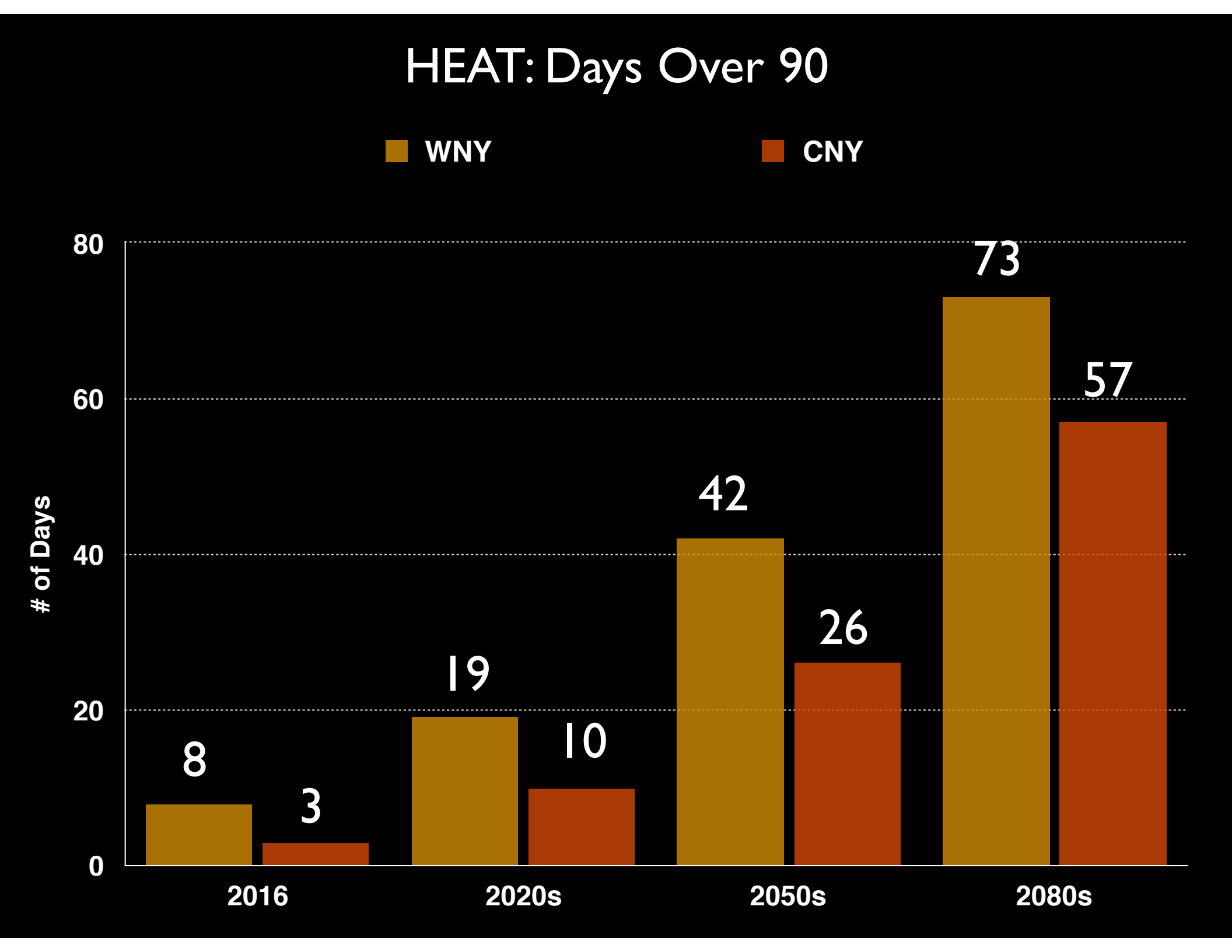
2014 ClimAID Report

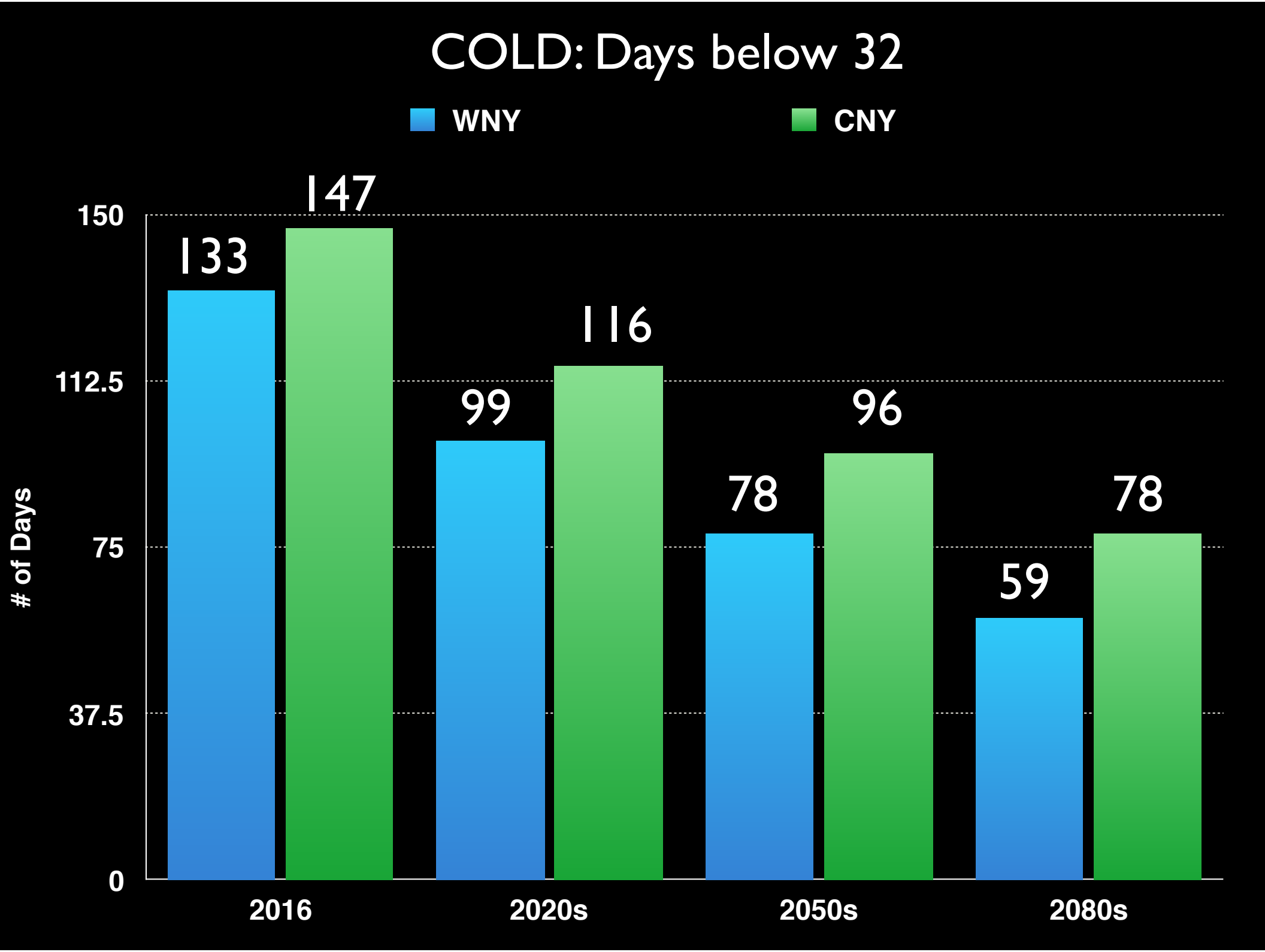


Less **COLD**

More HEAT

More PRECIPITATION


HEAT: Days Over 90
WNY
CNY
80
60
40
20
0
# of Days
8
3
19
10
42
26
73
57
2016
2020s
2050s
2080s

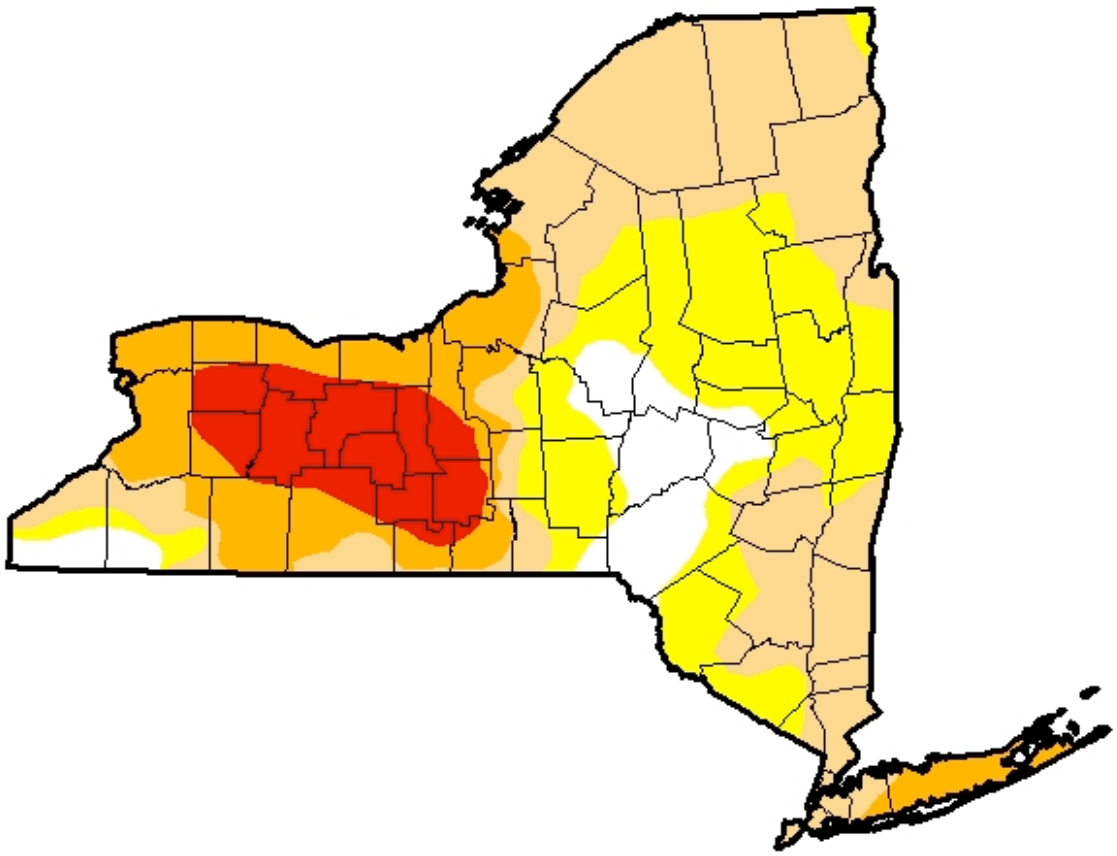

COLD: Days below 32
WNY
CNY
150
112.5
75
37.5
0
# of Days
133
147
99
116
78
96
59
78
2016
2020s
2050s
2080s


2% - 13% Increase in precipitation:
mostly in winter

Drier Summers/Fall

U.S. Drought Monitor

New York



September 27, 2016

(Released Thursday, Sep. 29, 2016)

Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	9.21	90.79	64.25	27.12	9.94	0.00
Last Week 9/20/2016	14.28	85.72	64.25	27.12	9.94	0.00
3 Months Ago 6/28/2016	8.15	91.85	16.14	0.00	0.00	0.00
Start of Calendar Year 12/29/2015	50.48	49.52	7.06	0.00	0.00	0.00
Start of Water Year 9/29/2015	37.33	62.67	5.18	0.00	0.00	0.00
One Year Ago 9/29/2015	37.33	62.67	5.18	0.00	0.00	0.00

Intensity:

- D0 Abnormally Dry
- D1 Moderate Drought
- D2 Severe Drought
- D3 Extreme Drought
- D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:
Chris Fenimore
NCEI/NESDIS/NOAA

	Category	Sensitivity to Climate Change	Population Served
1	Withdrawal from large water bodies	Low	2,000,000
2	New York City system	Moderate	9,300,000
3	Other reservoir systems	Moderate	1,300,000
4	Run-of-the-river on small drainage	High	62,000
5	Long Island groundwater	Moderate	3,200,000
6	Other primary aquifers	Moderate	650,000
7	Homeowner well water	Moderate to high	1,900,000
8	Other small water supply systems (groundwater/surface water)	Moderate to High	600,000
	Total		19,012,000

Some Impacts

Longer growing season

= higher water demand

Increased stream flows: late winter/ early spring

Impact on infrastructure

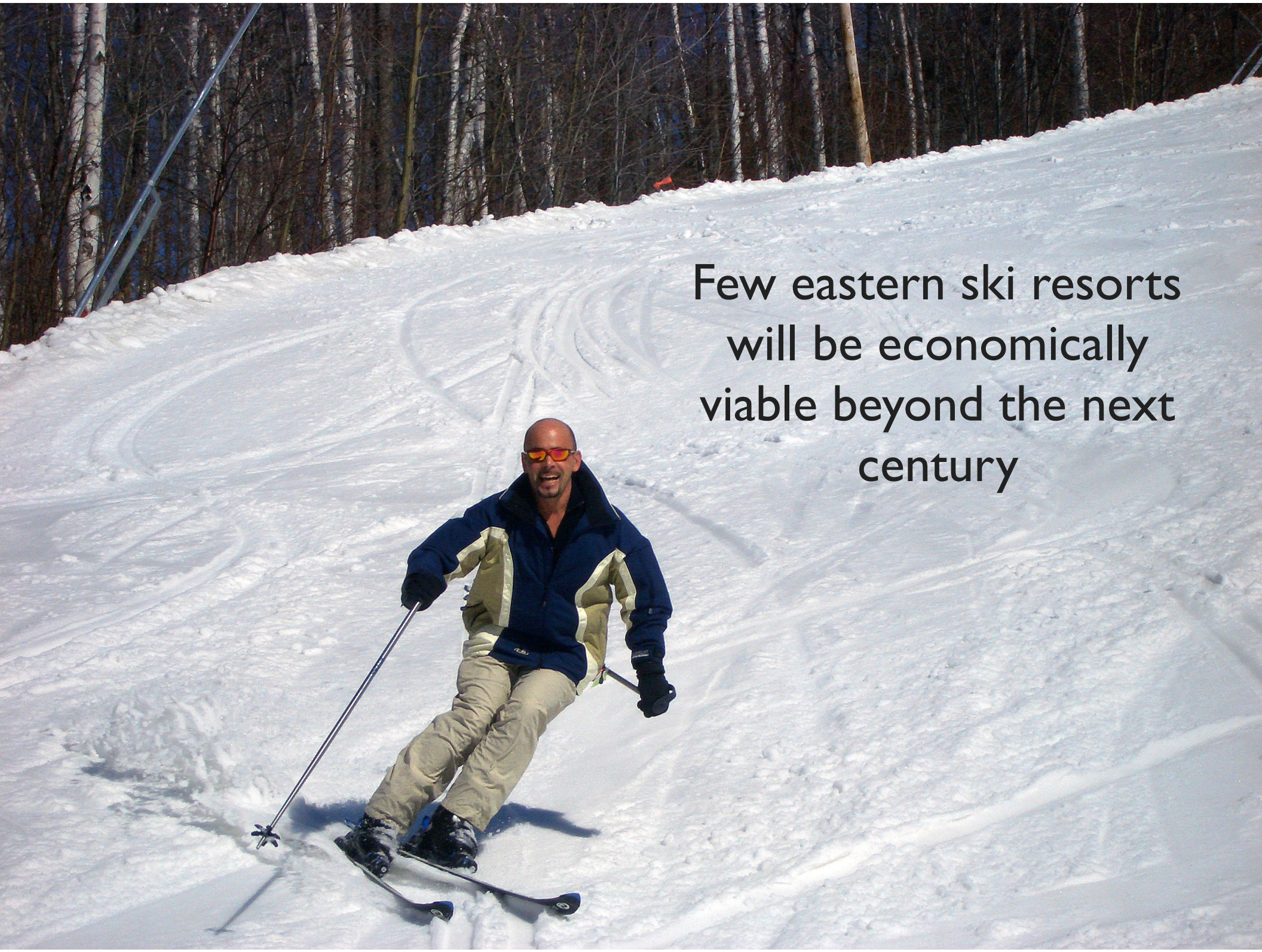
Warmer lakes and rivers

Algae blooms

Stressed species

Greater pathogen survivability

Reduced snow fall


Few eastern ski resorts
will be economically
viable beyond the next
century

Higher temperatures

Heat stress

Cardiovascular failure

Air quality/asthma

Water-borne diseases

Vector-borne diseases

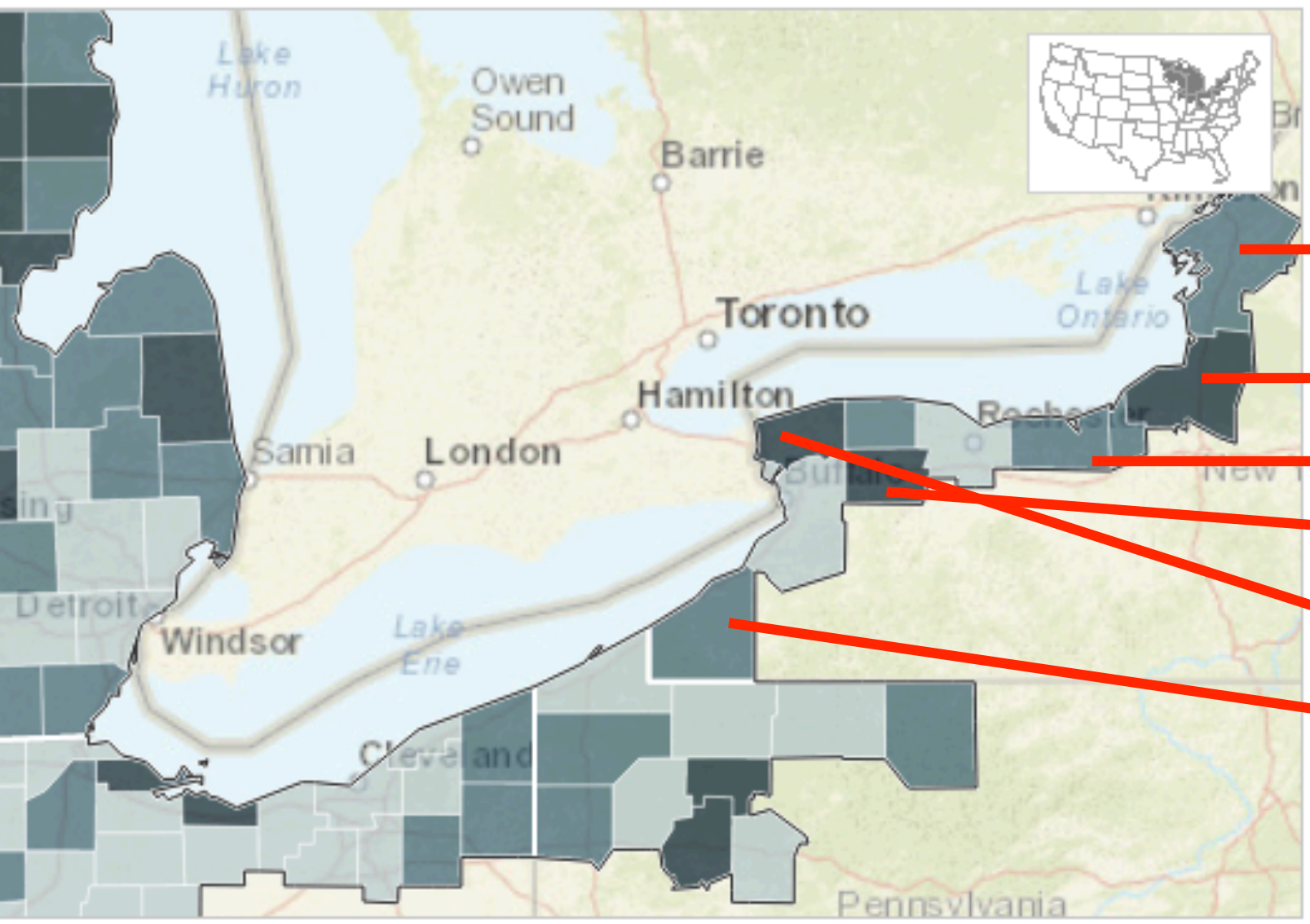
Impacts on Ecosystems / Wildlife

Emerald Ash Borer

Impacts on Ecosystems / Wildlife

Warming Adirondack lakes threaten trout survival

Impacts on local economies



Jefferson

Oswego

Wayne

Genesee

Niagara

Chautauqua

Most Dependent
Moderately Dependent
Least Dependent

Job dependence on climate vulnerable sectors:
Farming, timber, tourism

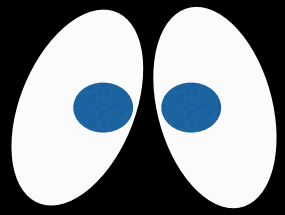
Source: University of Michigan

Impact on Agriculture

Reduced milk production

Increased weed growth

Reduced fruit quality



Summer blackout/brownouts

Resilient?

Adaptation Planning

Adaptation Planning Process Steps

https://www.epa.gov/sites/production/files/2015-04/documents/updated_adaptation_strategies_guide_for_water_utilities.pdf

Adaptation Options

Flooding Impacts

- Regional interconnections
- Alternative power supplies
- Monitor and inspect infrastructure
- Elevate or flood-proof assets
- Join a mutual aid network

Changes in Seasonal Runoff

- Monitor
- Incorporate predictions of snowpack and runoff changes into models
- Update drought contingency plans
- Diversify water supplies
- Increase storage capacity
- Establish regional interconnections

Increased Runoff

- Green infrastructure
- Distributed systems
- Invest in watershed management
- Model potential stormwater impacts to your service area
- Monitor runoff, vegetation and land use changes

Stressed Sewer Systems

- Green infrastructure
- Acquire and manage existing ecosystems
- Reduce infiltration and inflow by managing assets
- Increase capacity or capabilities of wastewater treatment system and facilities
- Model potential stormwater impacts to your service area

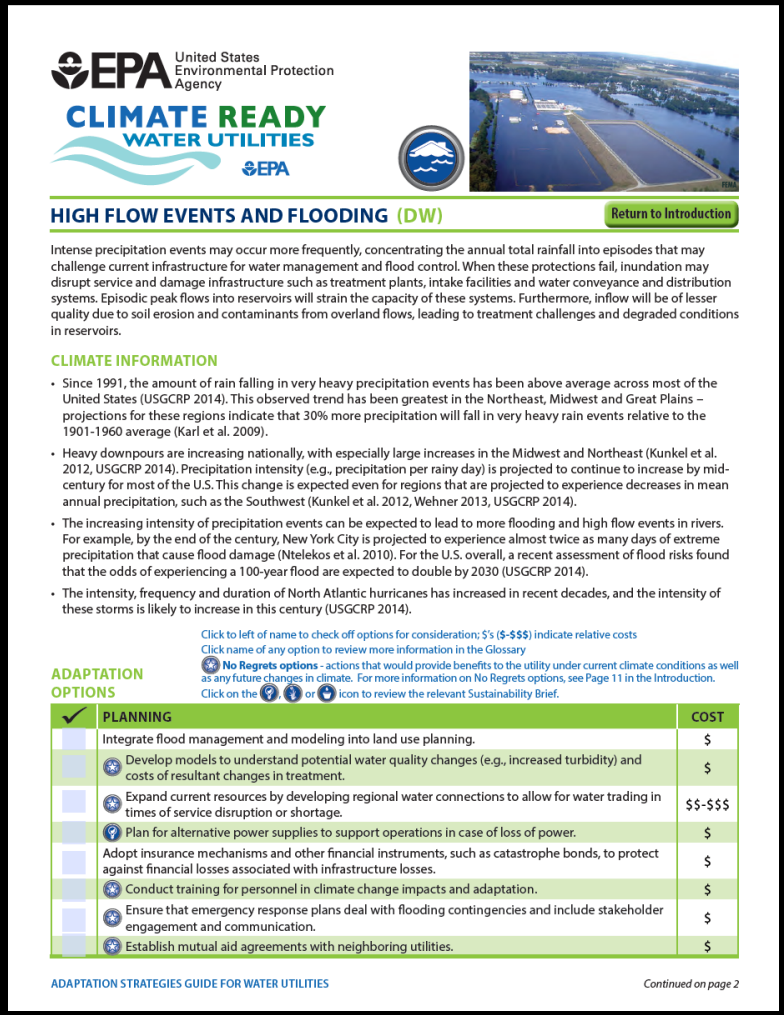
Community and Economic Impacts

- Collaborate Discuss adaptation options with local businesses
- Communicate adaptation activities and plans to customers
- Become marketers
- Raise rates in an affordable and responsible way

Tools & Resources

Adaptation Strategies Guide for Water Utilities

GROUP		DW	WW
Drought	Reduced groundwater recharge	1	
	Lower lake & reservoir levels	1	
	Changes in seasonal runoff & loss of snowpack	2	
Water Quality Degradation	Low flow conditions & altered water quality		2
	Saltwater intrusion into aquifers	1	
	Altered surface water quality	1	1
Floods	High flow events & flooding	2	2
	Flooding from coastal storm surges	2	2
Ecosystem Changes	Loss of coastal landforms / wetlands	2	2
	Increased fire risk & altered vegetation	1	1
Service Demand & Use	Volume & temperature challenges	2	2
	Changes in agricultural water demand	1	
	Changes in energy sector needs	1	
	Changes in energy needs of utilities	2	2



EPA United States Environmental Protection Agency

CLIMATE READY WATER UTILITIES

EPA

HIGH FLOW EVENTS AND FLOODING (DW)

Return to Introduction

Intense precipitation events may occur more frequently, concentrating the annual total rainfall into episodes that may challenge current infrastructure for water management and flood control. When these protections fail, inundation may disrupt service and damage infrastructure such as treatment plants, intake facilities and water conveyance and distribution systems. Episodic peak flows into reservoirs will strain the capacity of these systems. Furthermore, inflow will be of lesser quality due to soil erosion and contaminants from overland flows, leading to treatment challenges and degraded conditions in reservoirs.

CLIMATE INFORMATION

- Since 1991, the amount of rain falling in very heavy precipitation events has been above average across most of the United States (USGCRP 2014). This observed trend has been greatest in the Northeast, Midwest and Great Plains – projections for these regions indicate that 30% more precipitation will fall in very heavy rain events relative to the 1901-1960 average (Karl et al. 2009).
- Heavy downpours are increasing nationally, with especially large increases in the Midwest and Northeast (Kunkel et al. 2012, USGCRP 2014). Precipitation intensity (e.g., precipitation per rainy day) is projected to continue to increase by mid-century for most of the U.S. This change is expected even for regions that are projected to experience decreases in mean annual precipitation, such as the Southwest (Kunkel et al. 2012, Wehner 2013, USGCRP 2014).
- The increasing intensity of precipitation events can be expected to lead to more flooding and high flow events in rivers. For example, by the end of the century, New York City is projected to experience almost twice as many days of extreme precipitation that cause flood damage (Ntelekos et al. 2010). For the U.S. overall, a recent assessment of flood risks found that the odds of experiencing a 100-year flood are expected to double by 2030 (USGCRP 2014).
- The intensity, frequency and duration of North Atlantic hurricanes has increased in recent decades, and the intensity of these storms is likely to increase in this century (USGCRP 2014).

ADAPTATION OPTIONS

Click to left of name to check off options for consideration; $'s ($-$$$) indicate relative costs
Click name of any option to review more information in the Glossary
No Regrets options - actions that would provide benefits to the utility under current climate conditions as well as any future changes in climate. For more information on No Regrets options, see Page 11 in the Introduction.
Click on the or icon to review the relevant Sustainability Brief.

✓	PLANNING	COST
	Integrate flood management and modeling into land use planning.	$
	Develop models to understand potential water quality changes (e.g., increased turbidity) and costs of resultant changes in treatment.	$
	Expand current resources by developing regional water connections to allow for water trading in times of service disruption or shortage.	$$-$$$
	Plan for alternative power supplies to support operations in case of loss of power.	$
	Adopt insurance mechanisms and other financial instruments, such as catastrophe bonds, to protect against financial losses associated with infrastructure losses.	$
	Conduct training for personnel in climate change impacts and adaptation.	$
	Ensure that emergency response plans deal with flooding contingencies and include stakeholder engagement and communication.	$
	Establish mutual aid agreements with neighboring utilities.	$

Continued on page 2

https://www.epa.gov/sites/production/files/2015-04/documents/updated_adaptation_strategies_guide_for_water_utilities.pdf

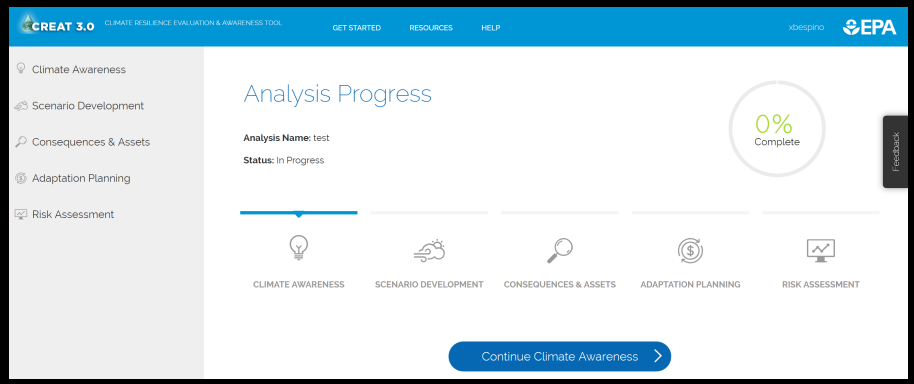
Climate Change Workshop Planner

https://workshopplanner.epa.gov/eewp/

https://www.epa.gov/crwu/plan-climate-change-your-utility

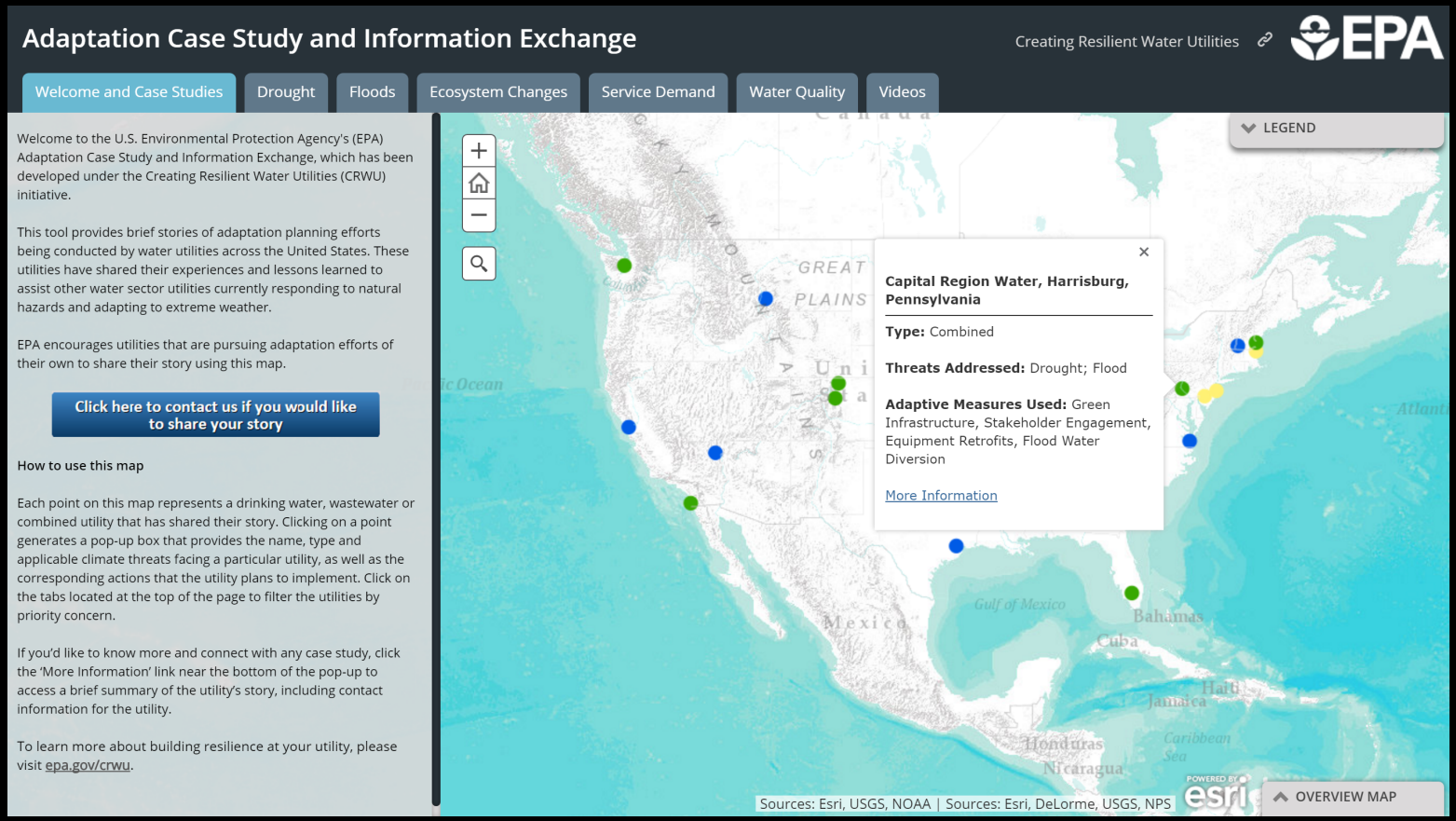
Climate Resilience Evaluation and Awareness Tool (CREAT)

- Risk assessment tool
- Helps utilities in adapting to extreme weather events through a better understanding of current and future climate conditions. https://youtu.be/fa0oK_jE8Zw



https://www.epa.gov/crwu/build-resilience-your-utility

Adaptation Case Studies

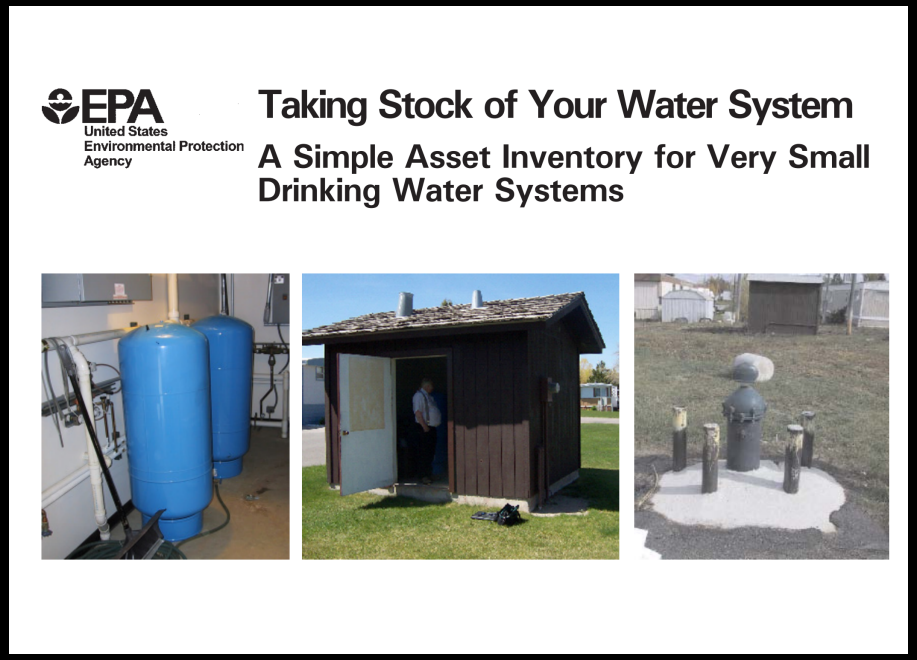


https://epa.maps.arcgis.com/apps/MapSeries/index.html?appid=bfe6b44929a8417b86aa7fd81d6857be

New Hampshire example- https://www.des.nh.gov/organization/divisions/water/dwgb/documents/wd-14-02.pdf

Asset Management Resources

https://www.epa.gov/sites/production/files/2015-04/documents/epa816k03002.pdf



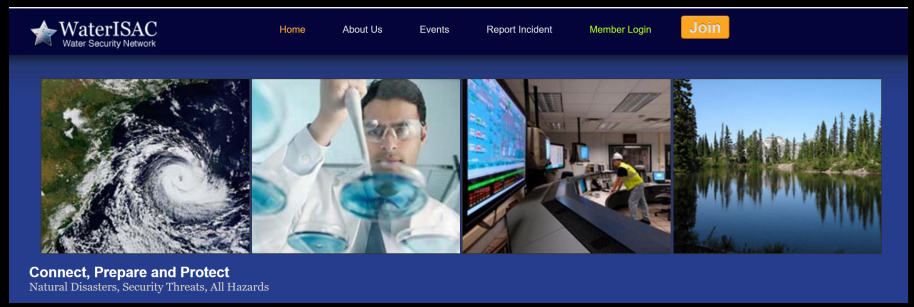
https://www.epa.gov/sites/production/files/2016-04/documents/am_tools_guide_may_2014.pdf

Information Sharing to Support Resilience

Water/Wastewater Agency Response Network (WARN)

Water Information Sharing and Analysis Center (WaterISAC)

https://www.waterisac.org/



https://www.awwa.org/resources-tools/water-knowledge/emergency-preparedness/water-wastewater-agency-response-network.aspx

Vulnerability Assessment

What futures threaten your community?

What assets are resilient?

What assets are vulnerable?

What assets are critical?

What happens to your community if they fail?

What stakeholders can help you reduce risk?

How Do

Less **COLD**

More HEAT

More PRECIPITATION

Impact your community?

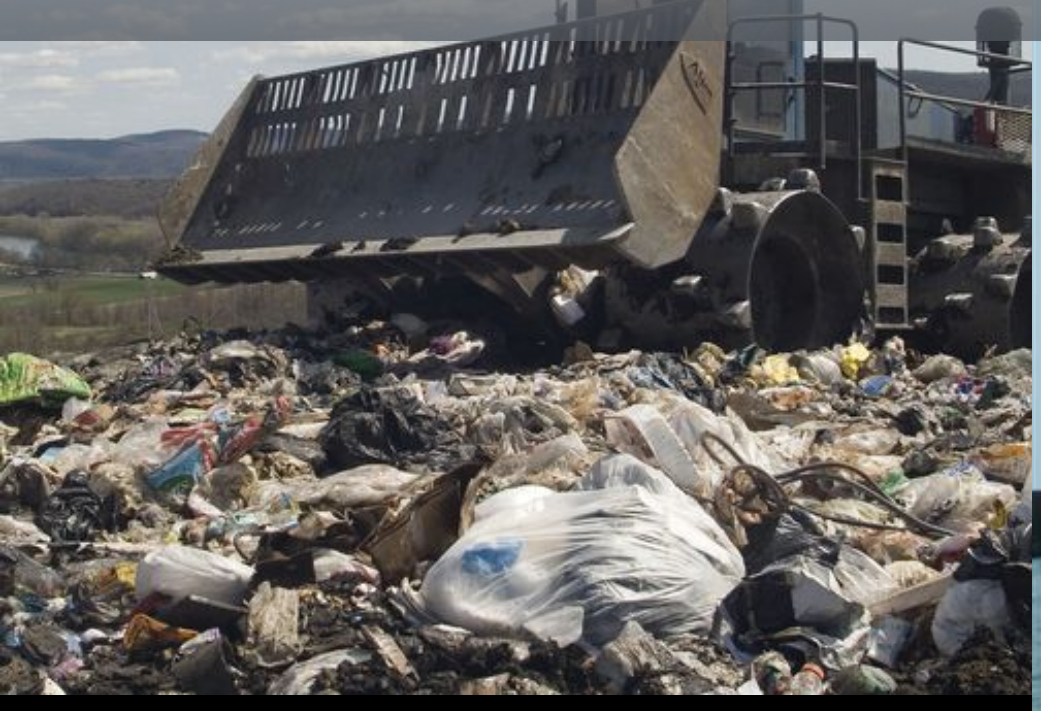
Vulnerability Assessment

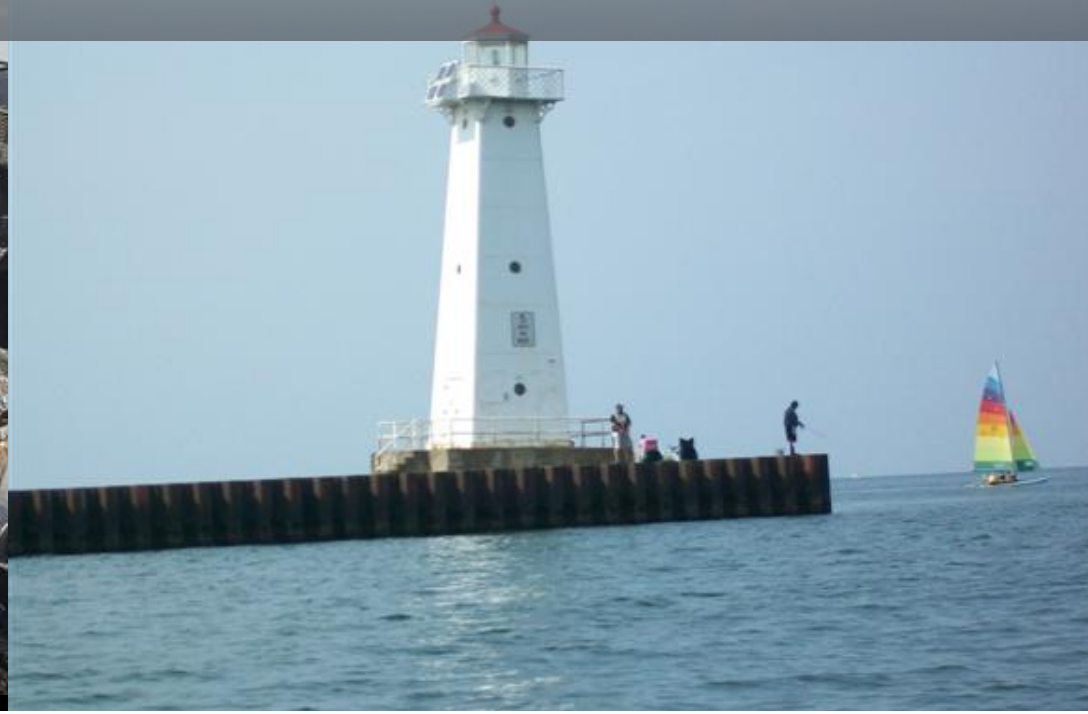
Climate Scenarios

	5th summer drought	5th year of 60 days over 90 degrees	5th winter with no snow	3rd year of severe winter flooding
Built Environment				
Utilities/ Communication				
Transportation				
Natural Environment				
Social Environment				
Economy				

Your assets

Built Environment





Utilities

Transportation

Natural Environment

Social Environment

Economy

Cultural?

	5th summer of drought	**5th winter with no snow**

What does **your** community look like under various futures?

	5th summer of drought	5th winter with no snow
Natural Environment	Lake temperatures up 10 degrees Trout dying	Pest infestations due to warmer weather
Economic	Recreational businesses losing money	Ski resorts remain closed Summer tourist season lasts longer

Climate Scenarios

	5th summer drought	5th year of 60 days over 90 degrees	5th winter with no snow	3rd year of severe winter flooding
Built Environment				
Utilities/ Communication				
Transportation				
Natural Environment				
Social Environment				
Economy				

Your assets