Climate Change, Water Infrastructure, and Technical Training Programs

The Impacts of Climate Change on Water-Related Illness and Water Infrastructure in the United States

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One Health and Integrated Climate and Weather Extremes Research

Climate Impacts on the Hydrologic Cycle

Warmer air can

hold

a lot more water vapor

With each additional 1˚ (C) of temperature, the atmosphere's capacity to hold water vapor increases by 7%

There is already 4% more water vapor over the oceans than there was only 30 years ago

Water-related Illness

Air and water temperatures, precipitation patterns, extreme rainfall events, and seasonal variations are all known to affect water-related Illness.

Waterborne Disease and Water Related Illness

- Waterborne disease are bacteria, virus, parasites transmitted through
  - drinking water
  - recreational water/occupational exposure
  - food contaminated with fecal pollution, or other bacteria or viruses
- Marine and Freshwater
- Chemical Contaminants

- Diarrhea, cryptosporidiosis, campylobacter, leptospirosis, Cholera, Vibriosis, Salmonella , Brucella
- Harmful Algal Bloom related
- Chemical Exposure

Precipitation Extremes: Heavy Rainfall, Flooding, and Droughts



- Projected increases in heavy rainfall, flooding, & drought in certain U.S. regions may increase people's exposure to a broad set of health hazards:
  - Flood hazards include drowning, injury, waterborne disease risk, potential indoor air quality problems from water intrusion into buildings
  - Drought-related hazards include wildfires, dust storms, extreme heat events, flash flooding, degraded water quality, and reduced water quantity.

US Global Change Research Program Climate and Health Assessment

- An Interagency product of the US Global Change Research Program (USGCRP),
  - 100+ authors,
  - National Academy Review
  - Public Input and Engagement
- Established by the US Global Change Research Act of 1990--Part of the National Climate Assessment (NCA) sustained assessment process
- Enhance understanding about the growing threat climate change poses to the health and well-being of Americans
- Inform decisions made by public health officials, planners, decision makers, and stakeholders

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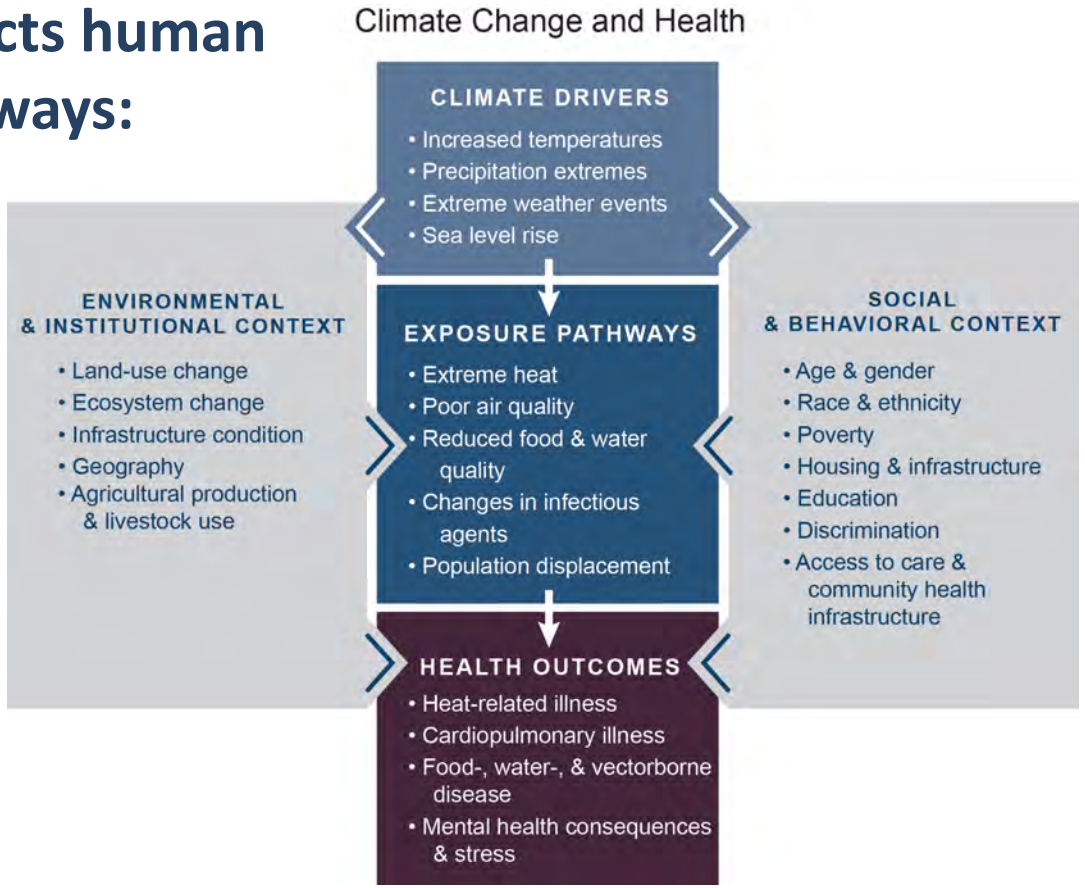
Climate change affects human health in two main ways:

1. Changing the severity or frequency of health problems that are already affected by climate or weather factors
2. Creating unprecedented or unanticipated health problems or health threats in places where they have not previously occurred.



Chapter 6: Water-Related Illness Authors

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Chapter 6: Water-Related Illness
A Framing Issue

Water, Water everywhere but not a common thread: Finding a more integrative framing

Water-borne disease, Harmful Algal Blooms, vibrios, marine, coastal, freshwater, recreational water, shellfish waters, fishing, boating, farming, drinking water, sewage, waste water, chemical contaminants, pathogens, viruses, bacteria

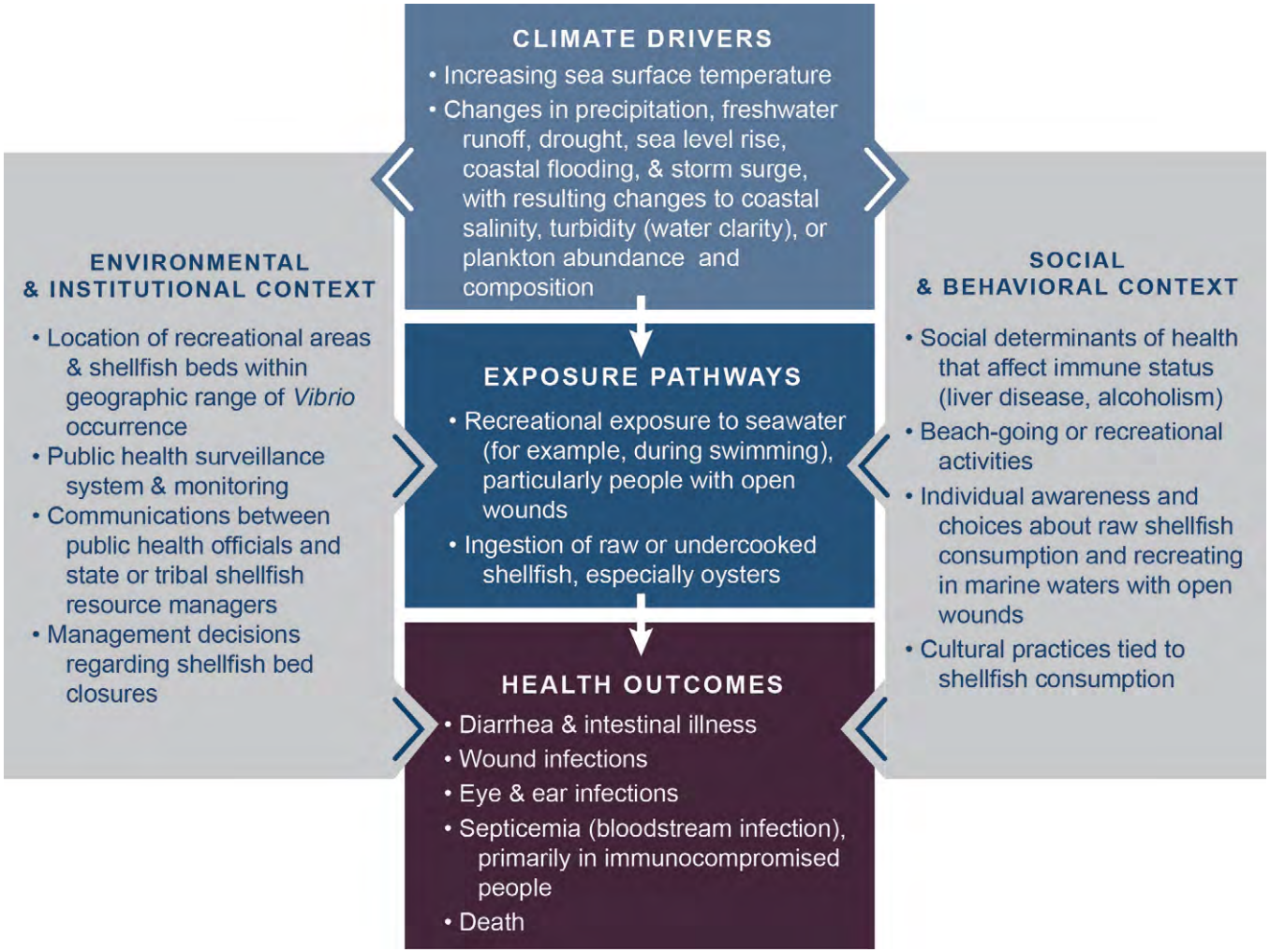
Sources of Water-Related Contamination

Exposure Pathways

(*Drinking Water, Recreational Waters, Fish and Shellfish*)

Health Outcomes

Climate Change and Health-Vibrio



Key Finding 1: Seasonal and Geographic Changes in Waterborne Illness Risk

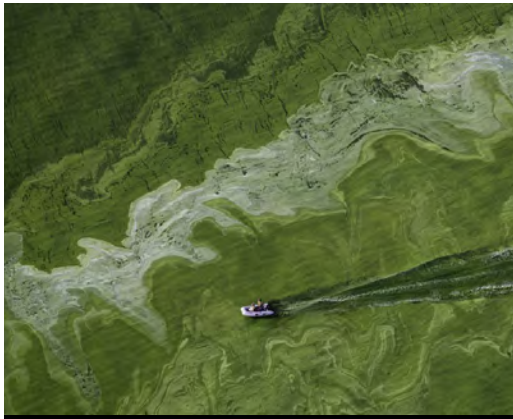
Harmful algal blooms and vibrio

Key Finding 2: Runoff from Extreme Precipitation Increases Exposure Risk

Farm and urban runoff

Key Finding 3: Water Infrastructure Failure

Combined sewer overflows, drinking water systems



Chapter 6

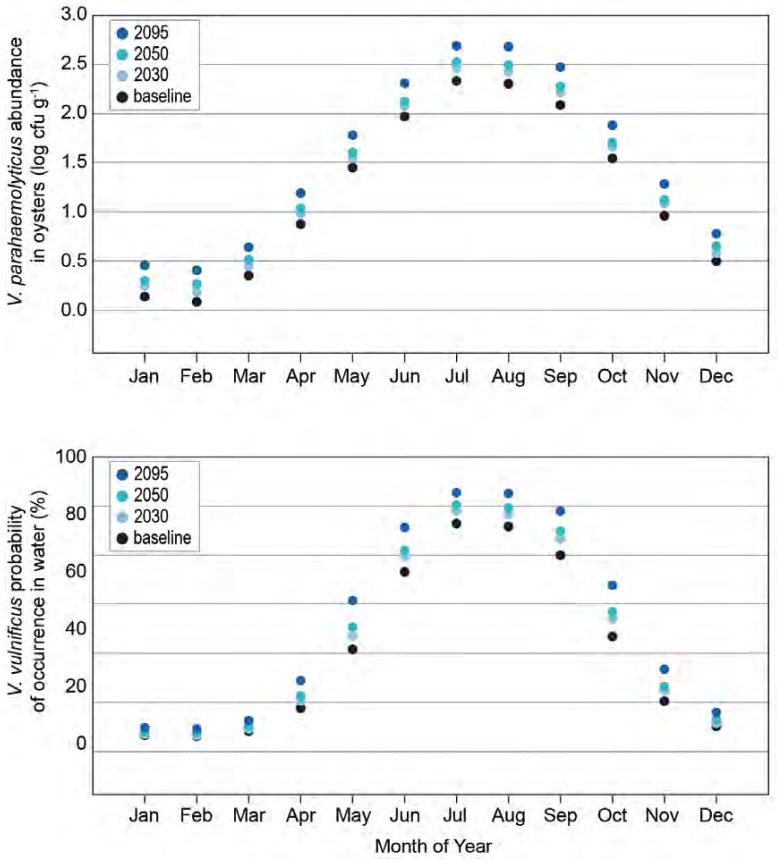
Key Finding 1:
Seasonal and Geographic Changes in Waterborne Illness Risk

Increases in water temperatures associated with climate change will alter the seasonal windows of growth and the suitable habitat range for

- freshwater and marine toxin-producing algae *[Very Likely, High Confidence],*
- certain naturally occurring Vibrio bacteria *[Very Likely, Medium Confidence],*
- and marine toxin-producing harmful algae *[Likely, Medium Confidence]*

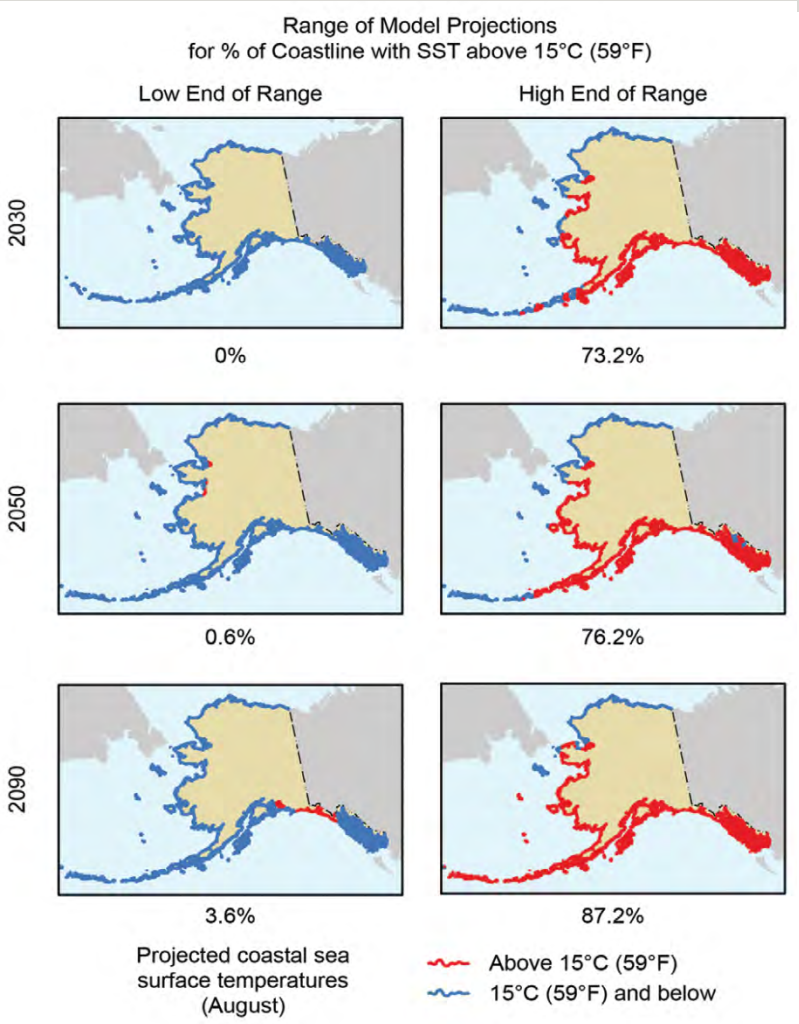
These changes will increase the risk of exposure to waterborne pathogens and toxins that can cause a variety of illnesses.

Projections of *Vibrio* Occurrence and Abundance in Chesapeake Bay



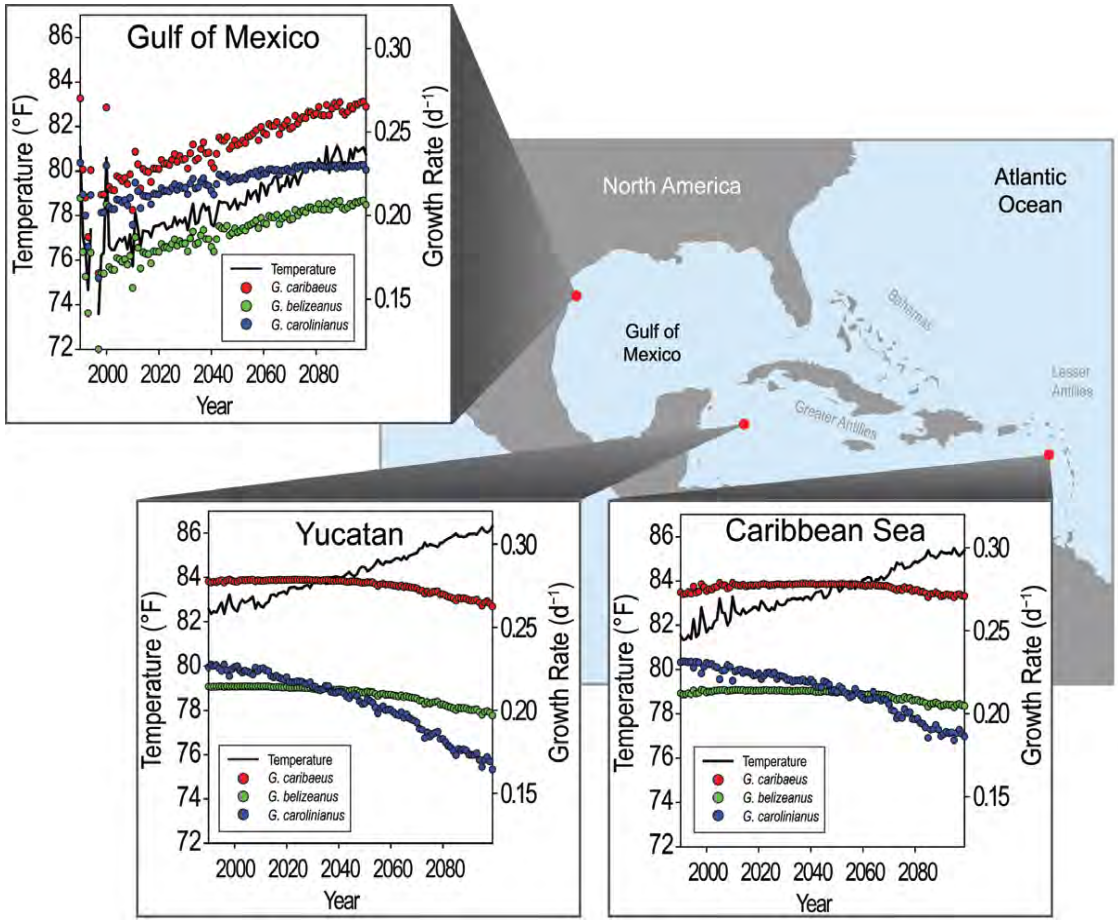
Quantitative projections of shifts in *Vibrio* seasonal abundance and geographic range

- *Vibrio* spp. cause illness through ingestion of contaminated shellfish or open wounds
- *Vibrio* strongly linked to sea surface temperatures
- Increases in abundance, geographic range, and seasonal extent of available habitat
- Chesapeake Bay *V. vulnificus* increase by 16% in shoulder months, similar increase for V. *parahemoliticus*
- Alaska habitat availability for vibrio increases by 60% by 2090
- Four climate model projections

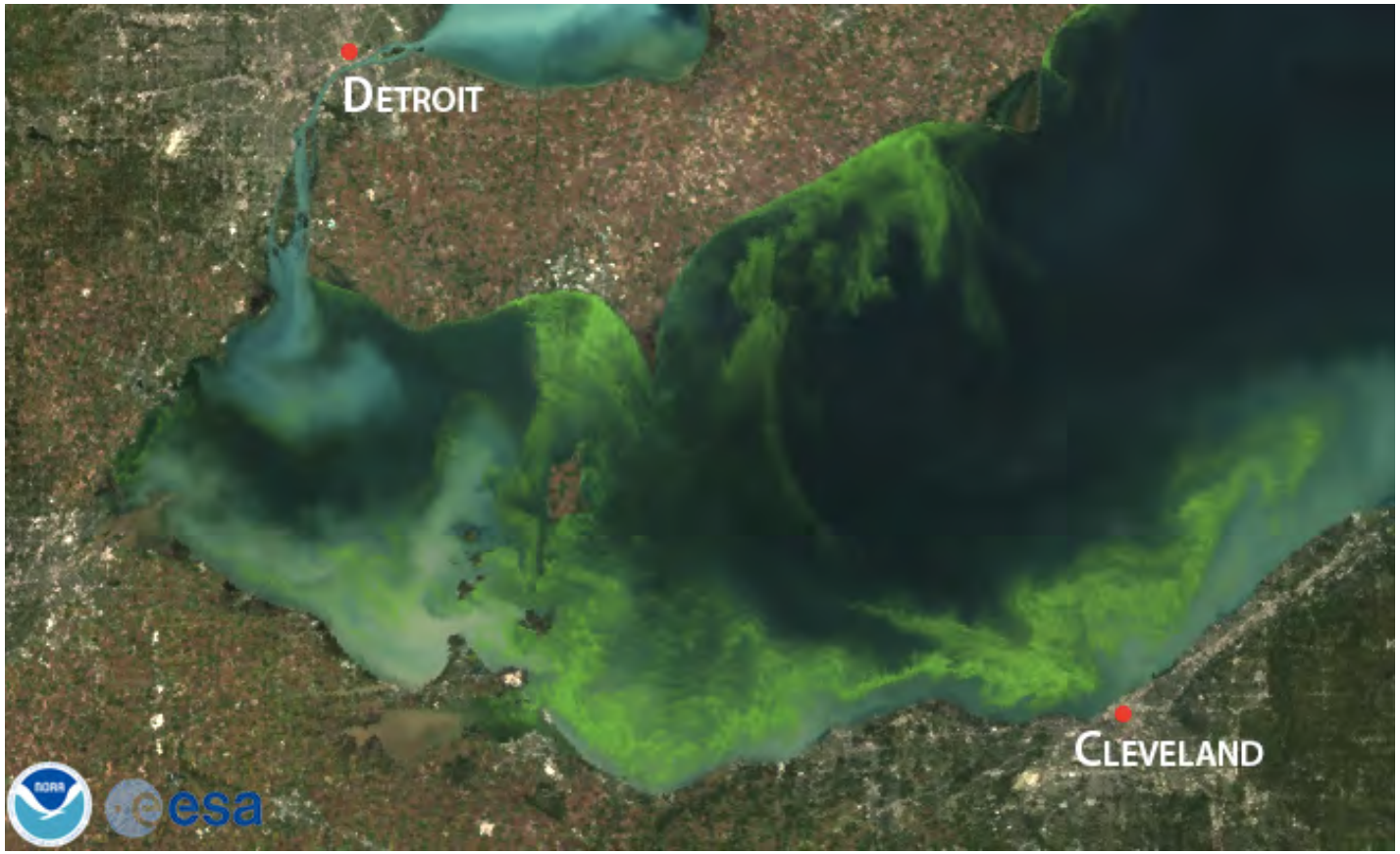


Quantitative Projections in shifts of *Gambierdiscus*

- Ciguaterra fish poising caused by consuming fish contaminated with toxins from dinoflagellates such as *Gambierdiscus*
- Well established link to water temperature
- Three different species, three water temperature buoys, 11 global climate model projections
- Substantial shifts in dominant species composition
- Northward expansion means dominant CFP toxins move into food web through different species
- Potential increase species in warming waters and decrease of some species where waters are warming less rapidly



Harmful algal blooms (HABs) driven by runoff and temperature



2011 and 2014 large microcystis blooms

Toledo- no drinking water for 500,000 people- levels 2x guidelines

Toxic Bloom in Lake Erie

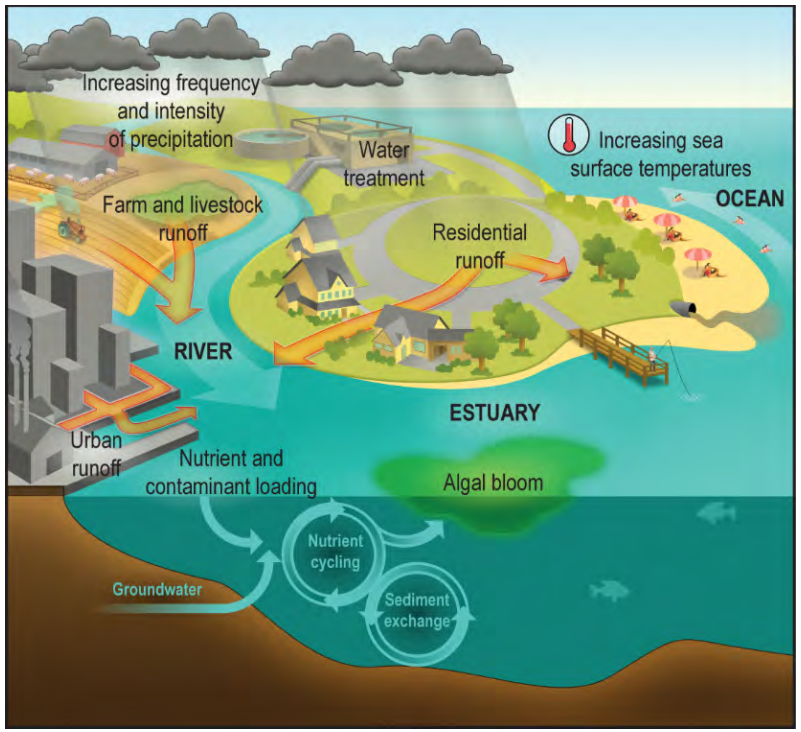
Toxic algae cocktail brews in Lake Erie- Dan Egan Journal Sentinel

Photo Credit: Peter Essick

Key Finding 2:
Runoff from Extreme Precipitation Increases Exposure Risk

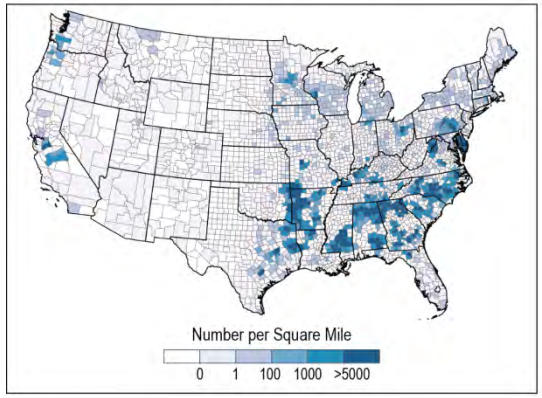
Runoff from more frequent and intense precipitation events will increasingly comprise recreational waters, shellfish harvesting waters, and sources of drinking water through increased introduction of pathogens and prevalence of toxic algal blooms *[High confidence].*

As a result, the risk of human exposure to agents of water-related illness will increase *[Medium Confidence].*

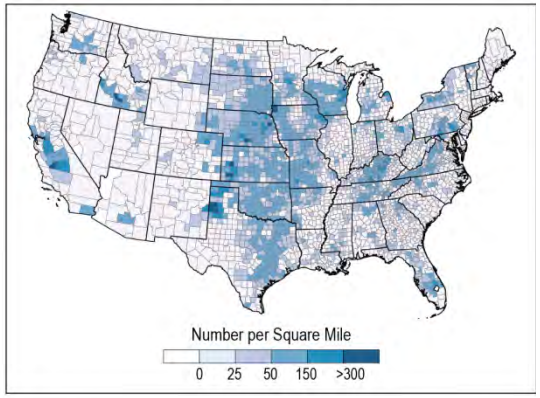


Agricultural Runoff

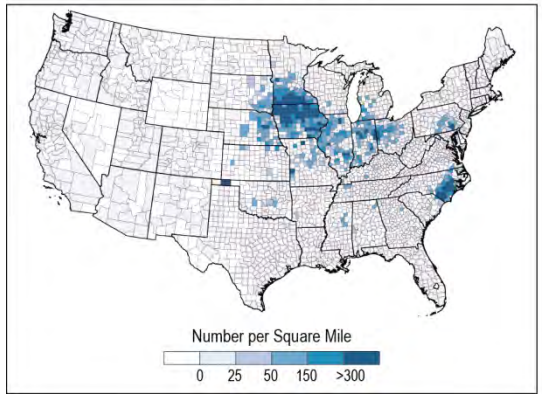
Number of Broilers and Other Meat-Type Chickens per Square Mile, 2012



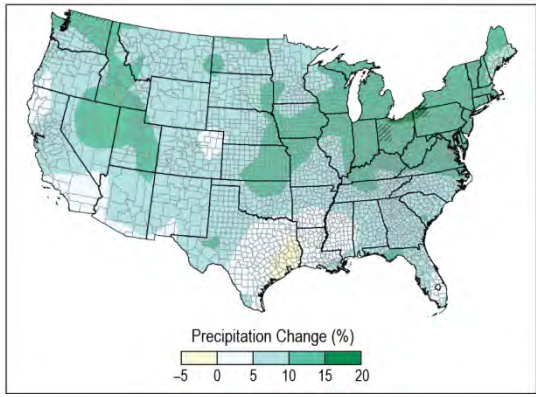
Number of Cattle and Calves per Square Mile, 2012



Number of Hogs and Pigs per Square Mile, 2012



Projected Changes in Heavy Precipitation



Pathogens from in agricultural runoff

Cryptosporidium
E. coli O157
Salmonella

Above: Changes in America's Dairyland foul the waters of Green Bay- Dan Egan, Journal Sentinel, Photo Mark Hoffman

Photo greatlakesinform.org

Flooding in Midwest

Key Finding 3:

Water Infrastructure Failure

Increases in some extreme weather events and storm surges will increase the risk that infrastructure for drinking water, wastewater, and stormwater, will fail due to either damage to or exceedance of system capacity, especially in areas with aging infrastructure *[High Confidence].*

As a result, the risk of exposure to water-related pathogens, chemical, and algal toxins will increase in recreational and shellfish harvesting waters, and in drinking water where treatment barriers break down *[Medium Confidence].*

Toledo's water crisis

An algal toxin in Lake Erie contaminated the drinking water used by Toledo and many of its suburbs in August, 2014. It prompted a "do not drink" advisory for parts of three days and fueled public discussions about what created the problem and how to prevent it from happening again.

Saturday, Aug. 2: City issues 'do not drink' water advisory

Waterborne disease linked to poor sanitation

Developing countries:
Urban areas lack infrastructure – open sewers and central sources of water


Cartagena, Columbia

1.5 million die annually, nearly half children under 5 years old

United States: recreational waters and drinking water - Outbreaks/illness (under-reported)

Cryptosporidium outbreak – largest in US history, 400,000 exposed

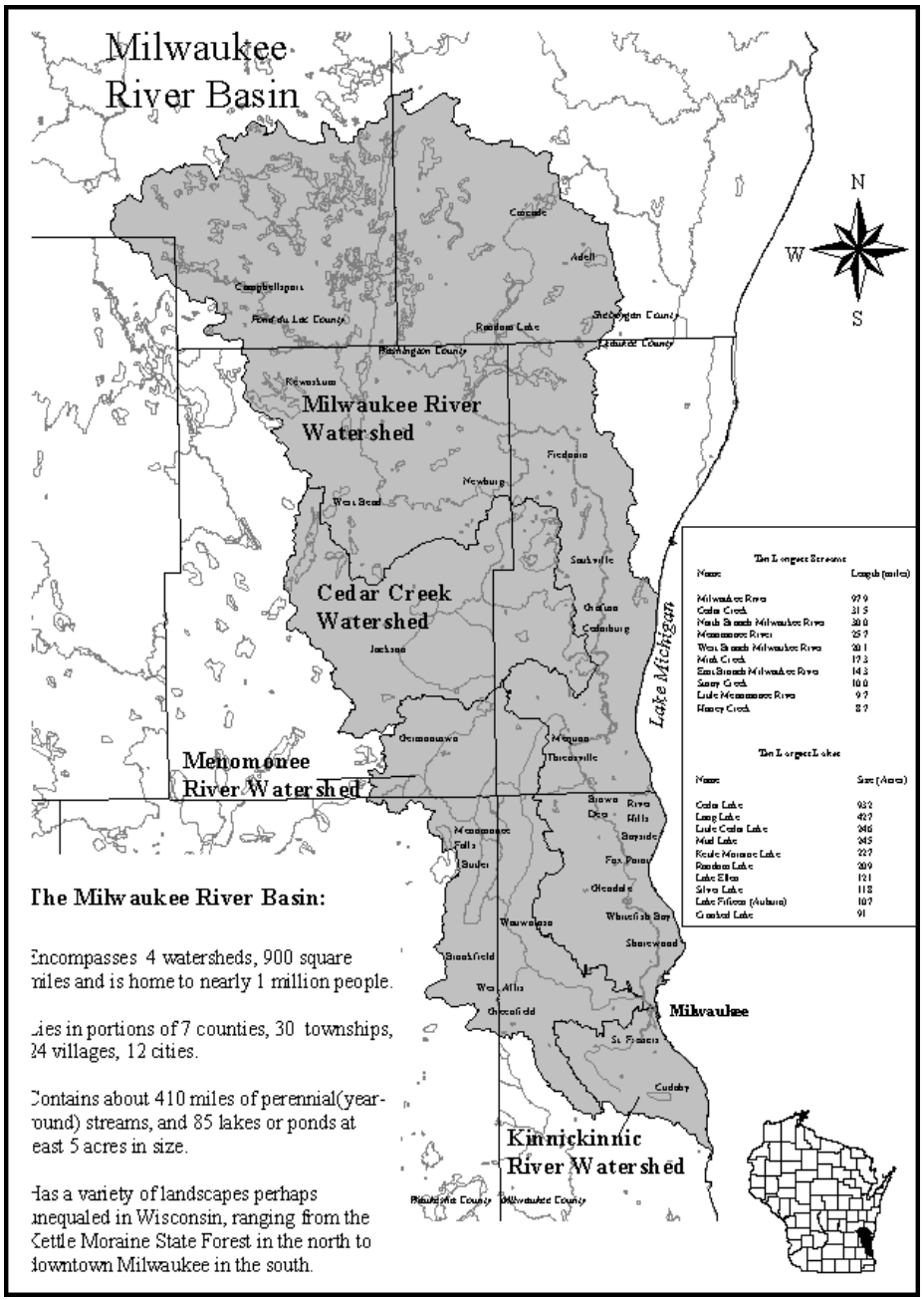
Newton et al. 2011 Chronic sewage contamination in the Great Lakes

HABs and Dead Zones in Great Lakes

Photo greatlakesinform.org

Great Lakes contains 20% of the Earth's fresh surface water

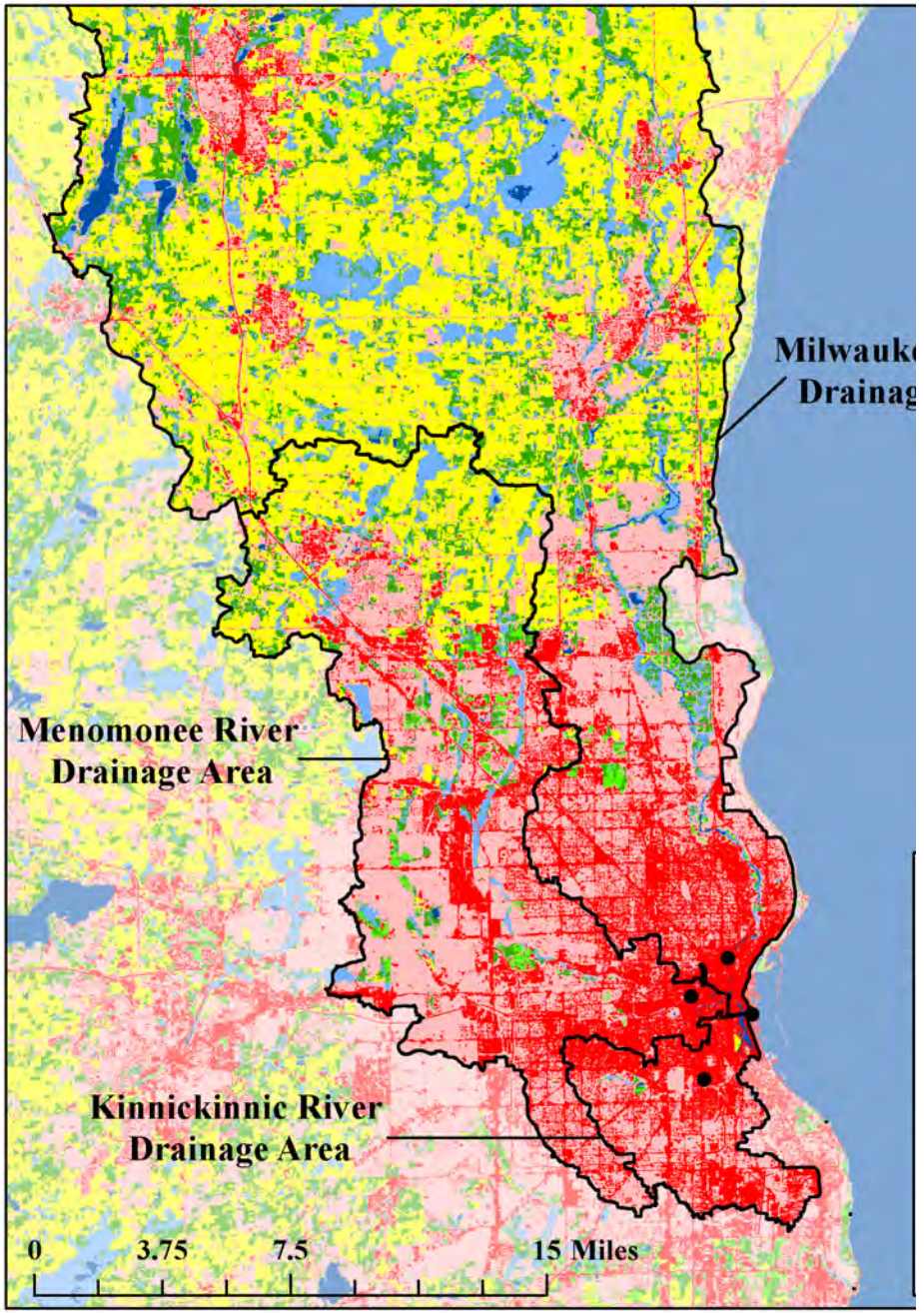
40 million people rely on Great Lakes for drinking water



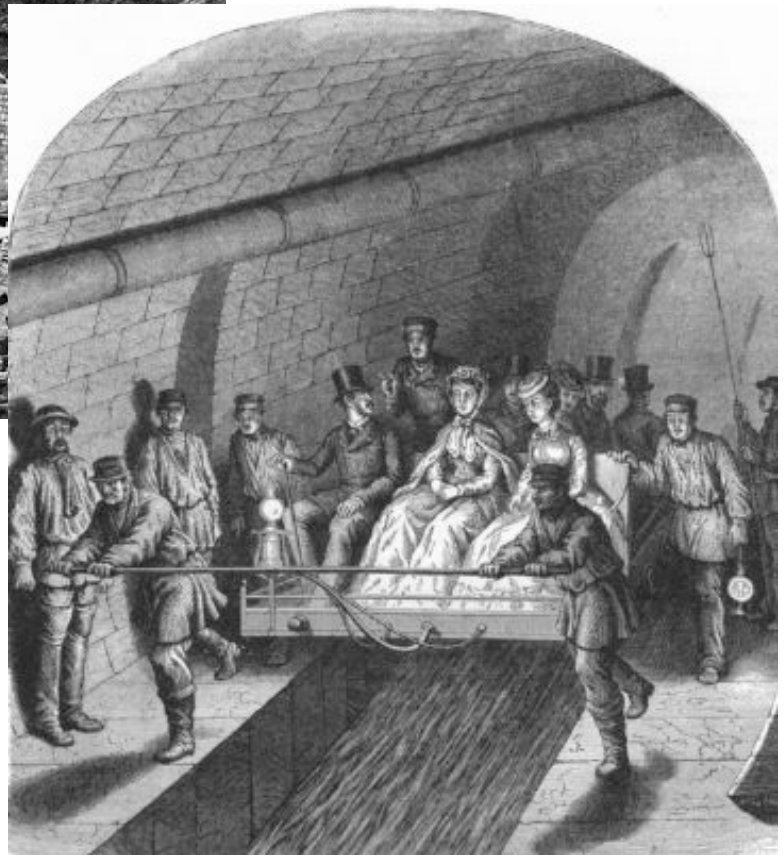
Contamination enters from the watershed

Some area highly urbanized
Sewage, Stormwater

Upstream agricultural runoff



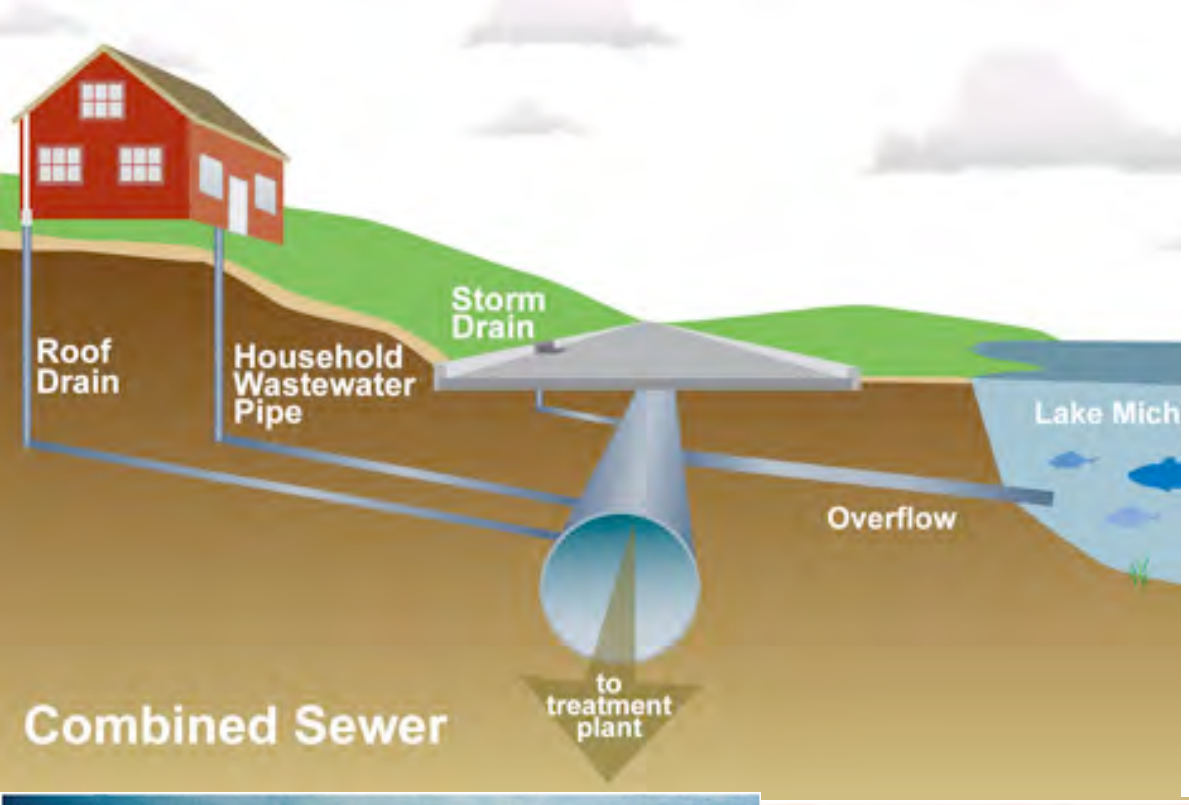
London 1858



Paris 1878

Urban sewer infrastructure

Sewers 101
(pre 1920s)

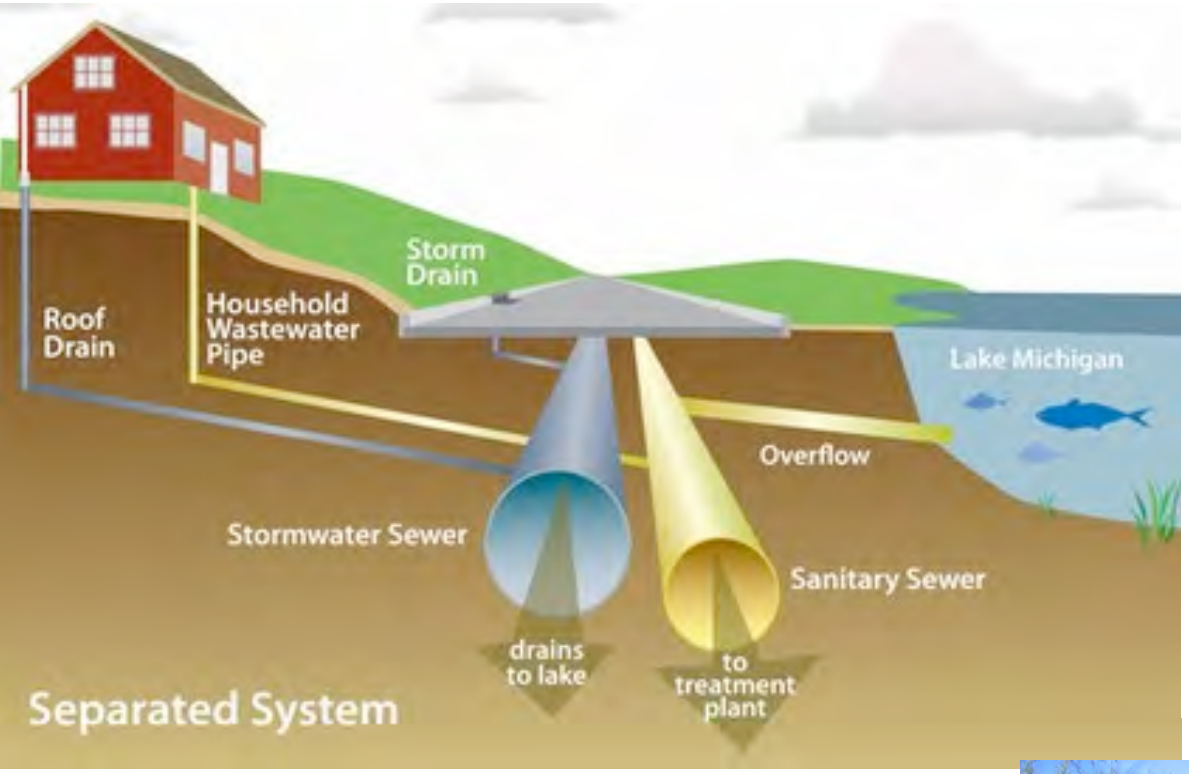


Combined Sewer Systems

Storm and sanitary in same pipe

Originally discharged to rivers, then connected to WWTPs

860 communities with combined sewers



Sewers 101
(post 1920)

Separated Sewer Systems

Stormwater discharged directly to rivers

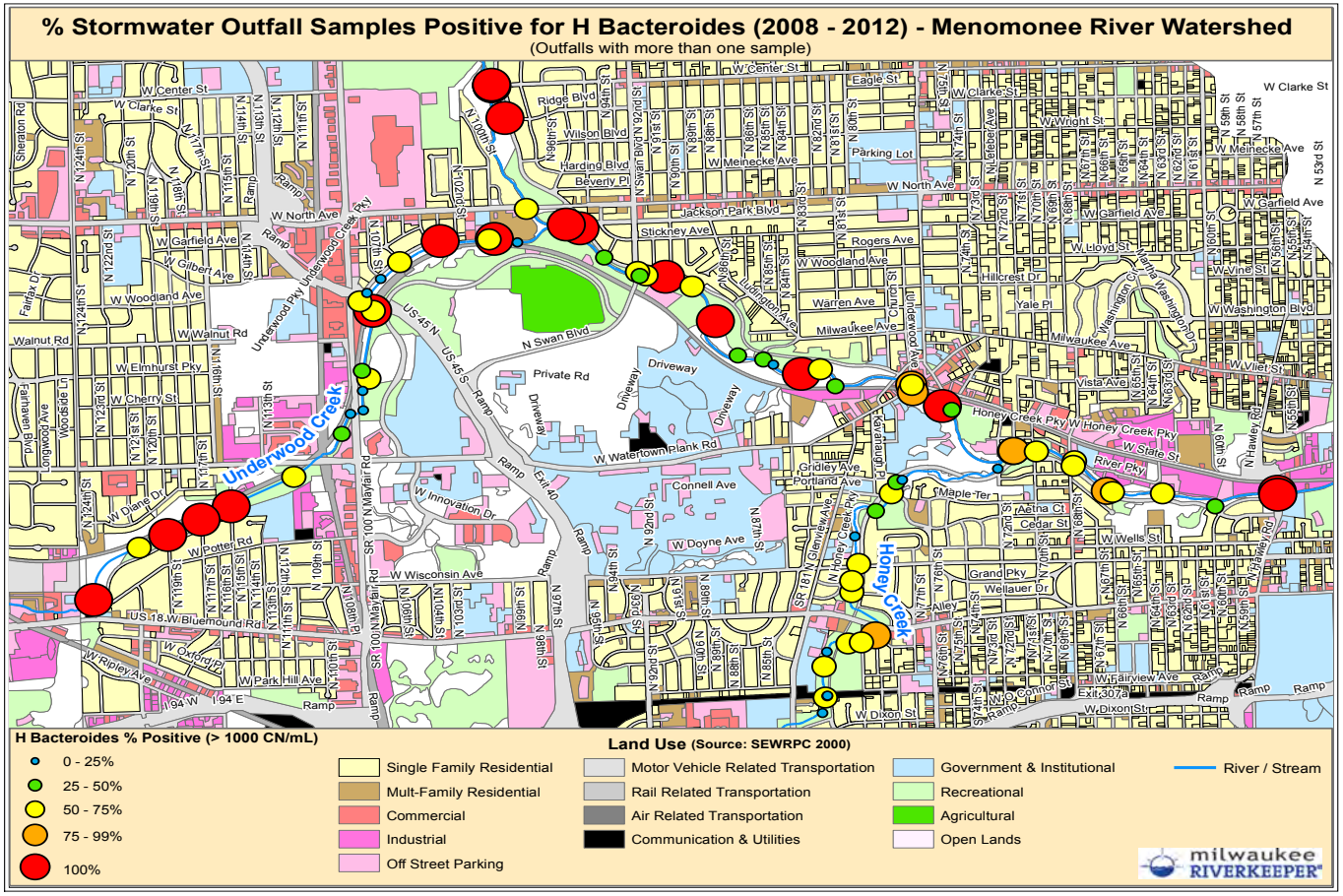
Sanitary sewage to WWTPs

Runoff released untreated directly to receiving waters

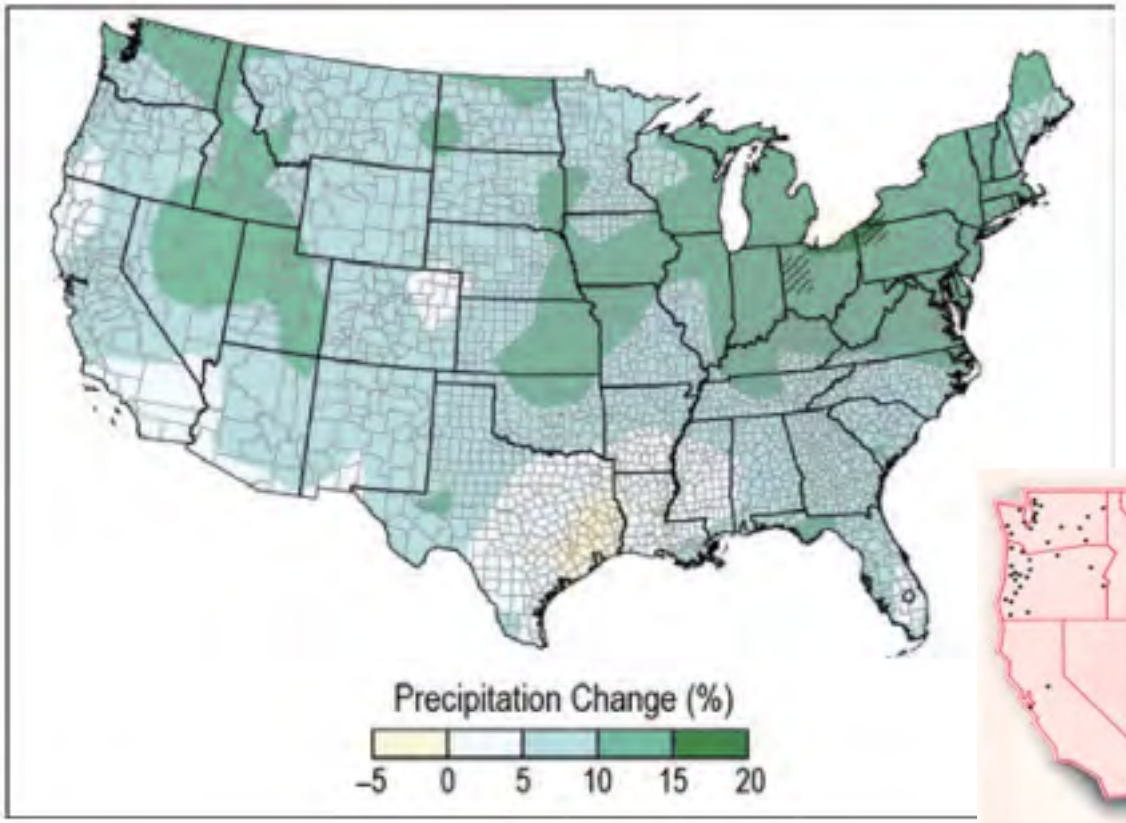
Stormwater Investigations

30% of stormwater outfalls show evidence of sewage contamination

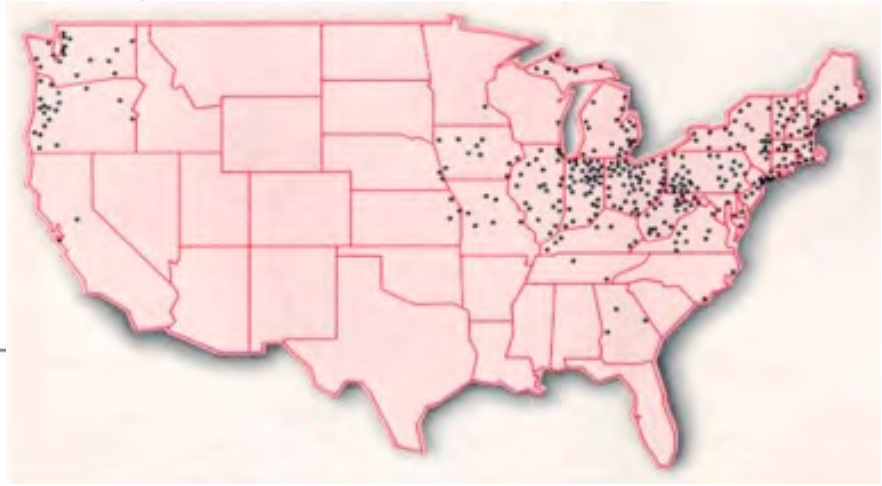
Pipes are on a 150 year replacement cycle



Increased precipitation in the NE and Midwest



Map of combined sewer systems

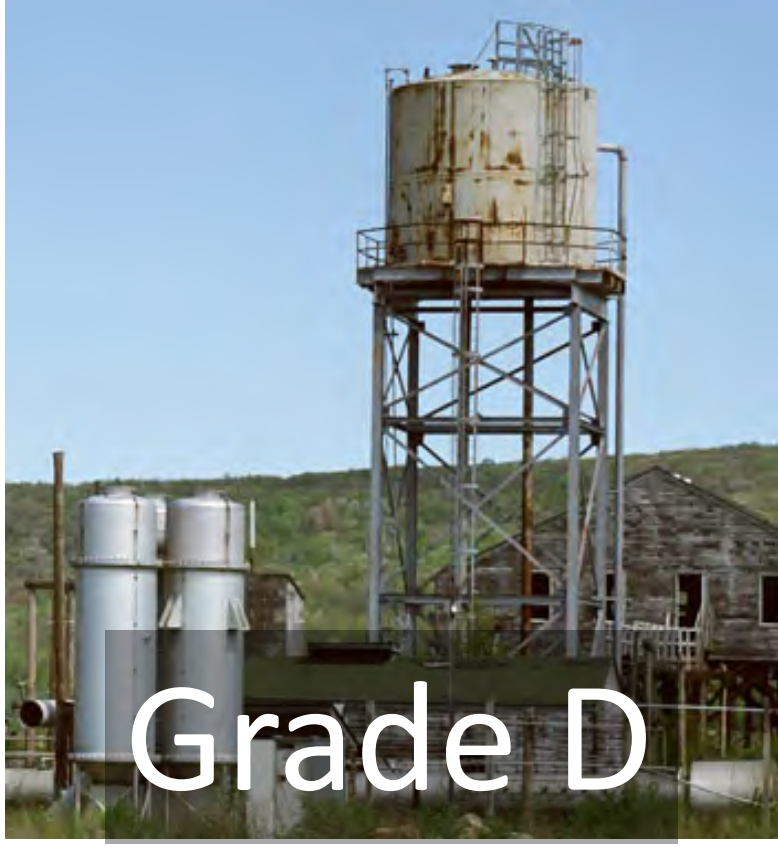


American Society of Civil Engineers

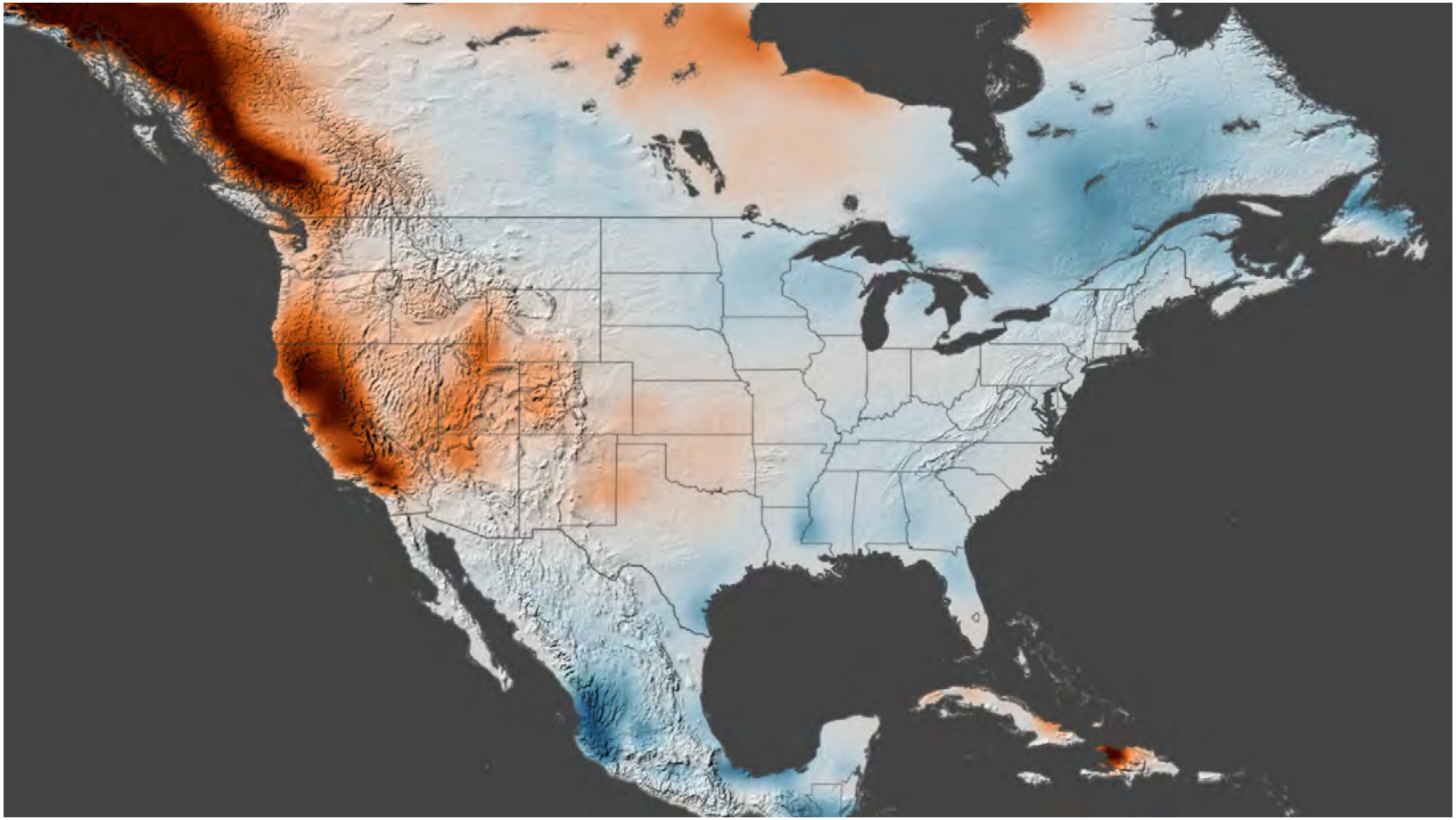
Infrastructure Report Card

Drinking water systems deteriorating

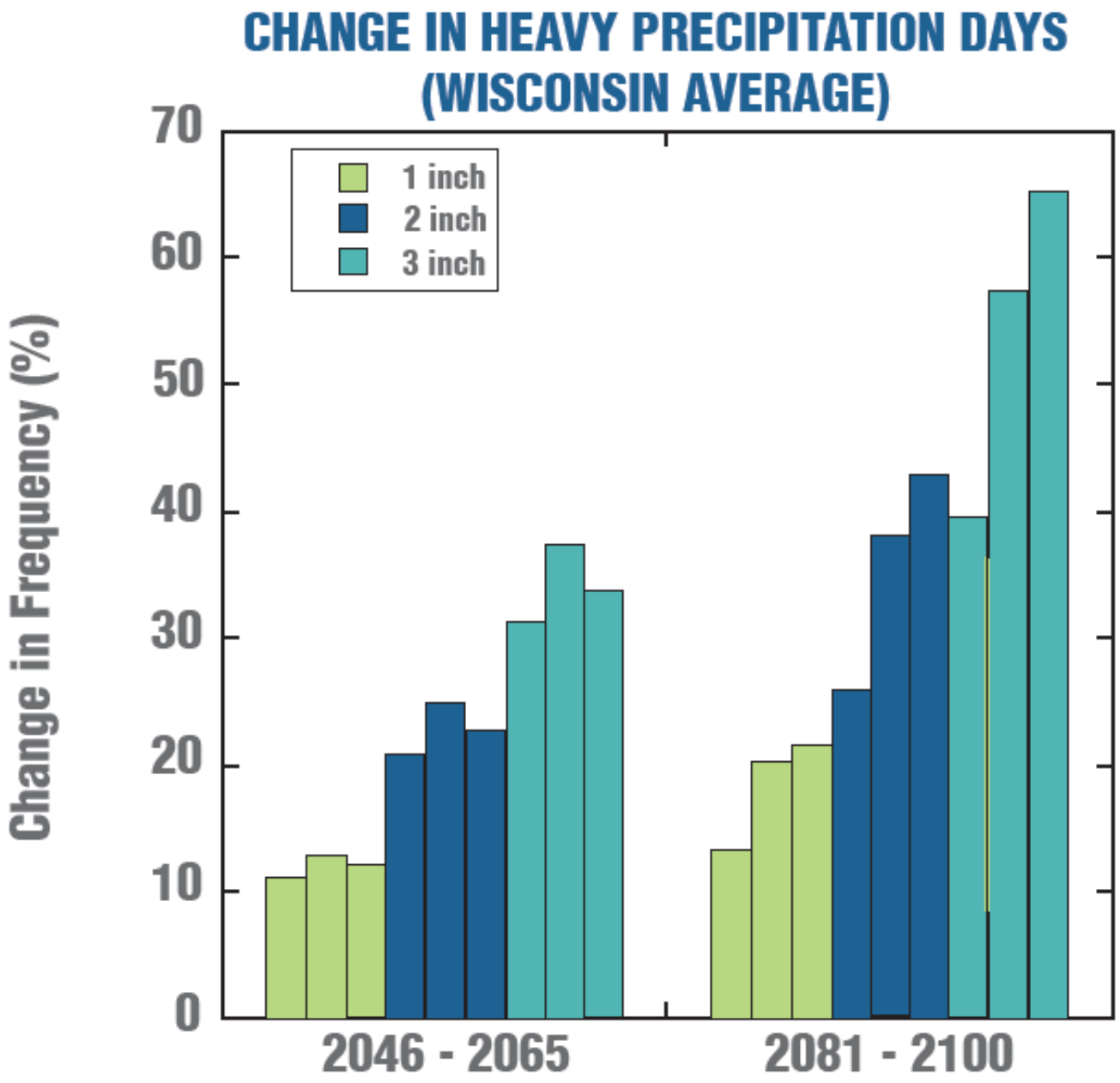
Sewer pipes fail before replaced: 150 year cycle



Water scarcity- decrease in water storage in US and globally

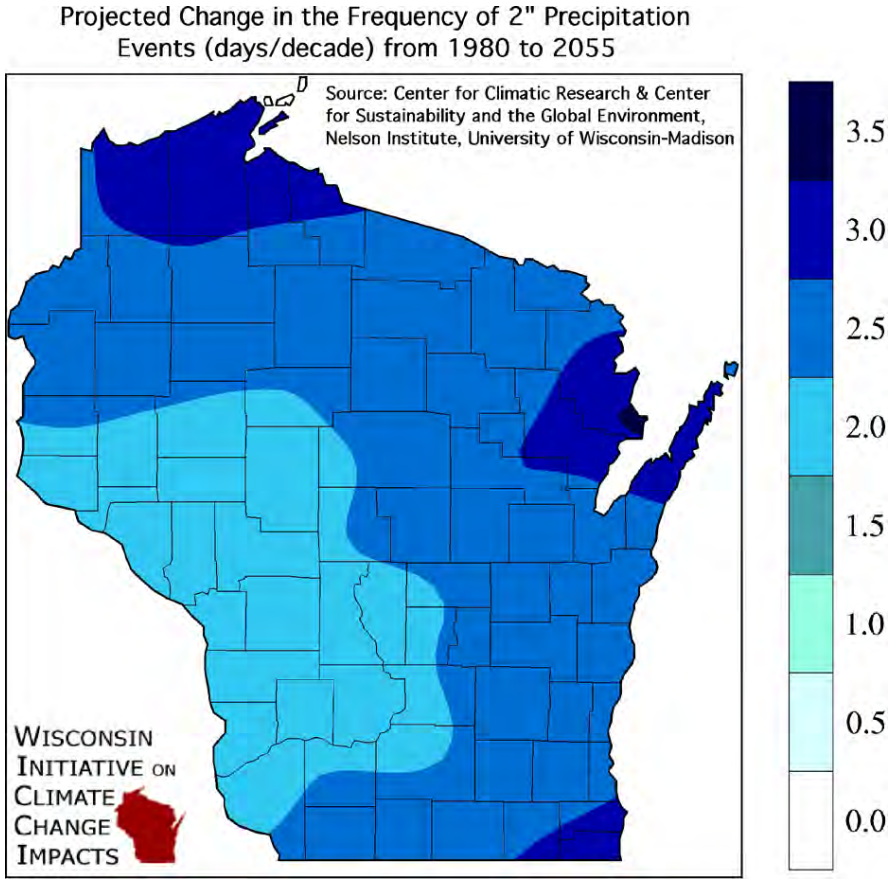


Predicting health effects of climate change



http://www.wicci.wisc.edu/climate-change.php

Increased frequency of intense rainfall projected for the Great Lakes



Large, intense rainfalls may affect combined sewer overflows

Winter rain rather than snow critical tipping point, not linear scale of impacts

Next steps: establish thresholds

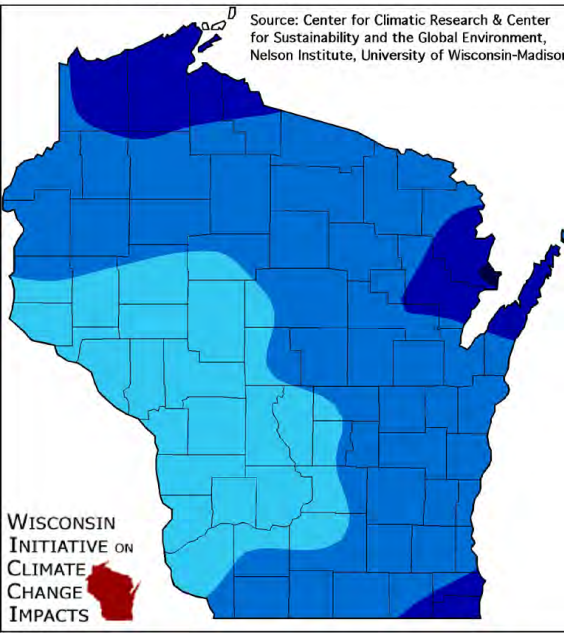
http://www.wicci.wisc.edu/climate-change.php

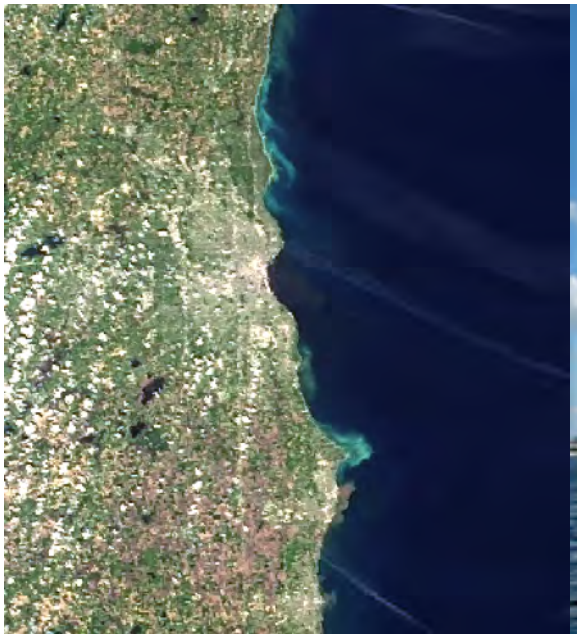
Extreme events and and the Great Lakes

Run conveyance model (MACRO) with current record (1940-2004) and downscaled climate projections data

Combined sewage overflows events may increase 37% in winter/spring time frame

Volume may increase by 20%





Innovative solutions

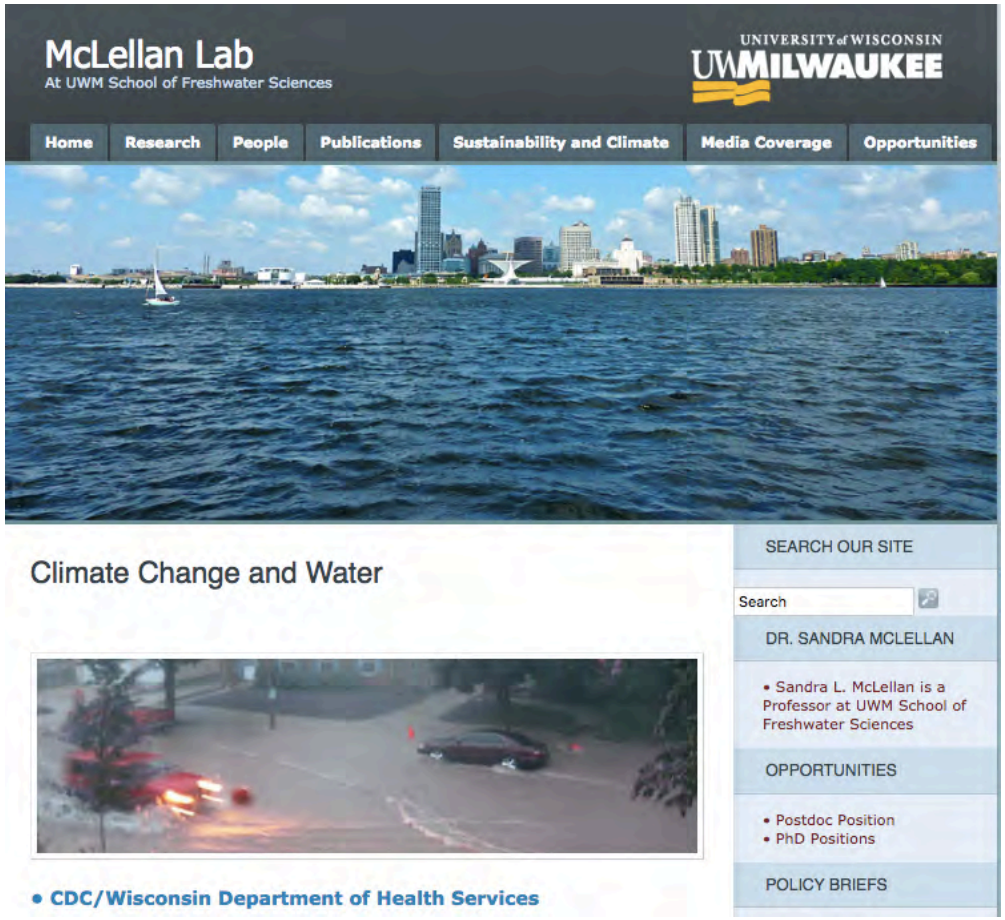
Rain drives most pathogens and pollution into the waterways- Green Infrastructure holds back water

School of Freshwater Sciences Green Roof
Photo credit: McLellan lab

Wired -NY's clever park will weather epic storms and rising seas, Photo: Timothy Schenck

can't simply recreate what was done in past

Solutions: need sound science, interdisciplinary approach, good planning, and educated citizens And a well-trained Work Force!!!



Research needs to quantify climate impacts

- Improved public health surveillance for water-related infectious diseases and expand monitoring and surveillance of surface and coastal water quality
- Improved understanding of how human behaviors affect the risk of waterborne diseases
- Predictive models to identify major areas of uncertainty and refine key research questions.
- Explore emerging issues including pathogens, chemical contaminants, interactions of temp and HABs

For Discussion

- What can we do to develop a proactive, health and environment beneficial work force?
- What are the most critical training needs, and for whom, by whom?
- Given what we already know about prominent pathways between water quality and health threats, where are the most critical research gaps that matter to communicating risk and ensuring public safety?
- What are the health outcomes we should be most focused on?
- What are the key monitoring and modeling priorities and how do they support early warning and implementation

Thank you!

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https://health2016.globalchange.gov

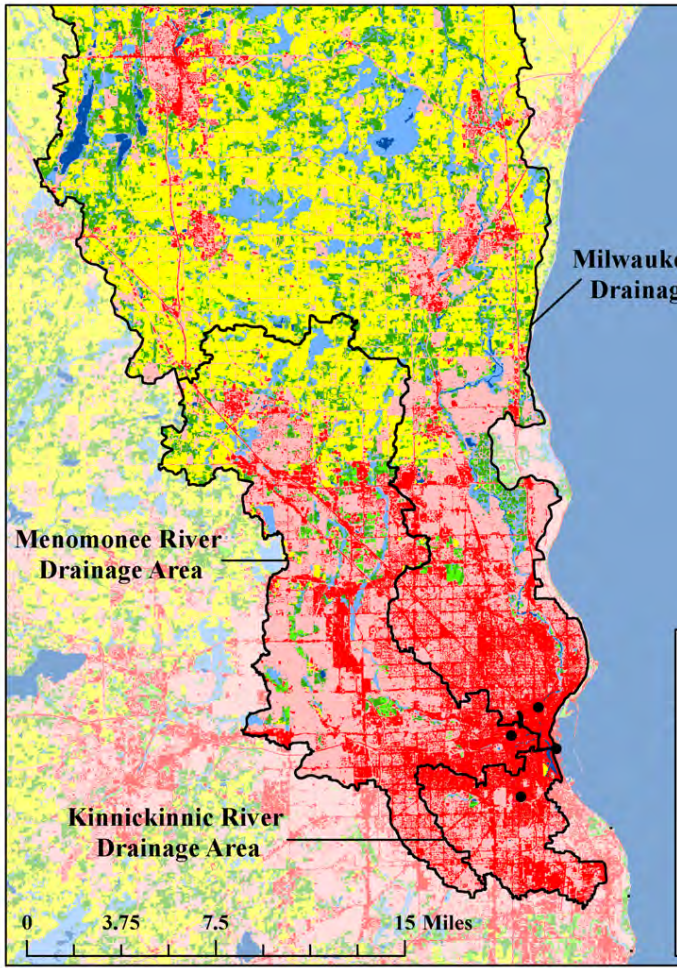
https://toolkit.climate.gov/

https://nccos-coastalscience-products-webstaging.azurewebsites.net/vibrioforecast

HABS: https://tidesandcurrents.noaa.gov/hab

1940's stormwater management

The Kinnickinnic River as it exists today (photo courtesy of MMSD)



1940's stormwater management

The Kinnickinnic River as i

Green flood plans and stream restoration

Table 1. Climate Sensitive Agents of Water Related Illness

Pathogen or Toxin Producer	Exposure Pathway	Selected Health Outcomes & Symptoms	Major Climate Correlation or Driver (strongest driver(s) listed first)
Algae: Toxigenic marine species of *Alexandrium, Pseudo-nitzschia, Dinophysis, Gambierdiscus; Karenia brevis*	**Shellfish Fish Recreational waters (aerosolized toxins)**	Gastrointestinal and neurologic illness caused by shellfish poisoning (paralytic, amnesic, diarrhetic, neurotoxic) or fish poisoning (ciguatera). Asthma exacerbations, eye irritations caused by contact with aerosolized toxins (*K. brevis*).	Temperature (increased water temperature), ocean surface currents, ocean acidification, hurricanes (*Gambierdiscus* spp. and *K. brevis*)
Cyanobacteria (multiple freshwater species producing toxins including microcystin)	**Drinking water Recreational waters**	Liver and kidney damage, gastroenteritis (diarrhea and vomiting), neurological disorders, and respiratory arrest.	Temperature, precipitation patterns
Enteric bacteria & protozoan parasites: *Salmonella enterica; Campylobacter* species; Toxigenic *Escherichia coli; Cryptosporidium; Giardia*	**Drinking water Recreational waters Shellfish**	Enteric pathogens generally cause gastroenteritis. Some cases may be severe and may be associated with long-term and recurring effects.	Temperature (air and water; both increase and decrease), heavy precipitation, and flooding
Enteric viruses: enteroviruses; rotaviruses; noroviruses; hepatitis A and E	**Drinking water Recreational waters Shellfish**	Most cases result in gastrointestinal illness. Severe outcomes may include paralysis and infection of the heart or other organs.	Heavy precipitation, flooding, and temperature (air and water; both increase and decrease)
Leptospira and *Leptonema* bacteria	**Recreational waters**	Mild to severe flu-like illness (with or without fever) to severe cases of meningitis, kidney, and liver failure.	Flooding, temperature (increased water temperature), heavy precipitation
Vibrio bacteria species	**Recreational waters Shellfish**	Varies by species but include gastroenteritis (*V. parahaemolyticus*, *V. cholerae*), septicemia (bloodstream infection) through ingestion or wounds (*V. vulnificus*), skin, eye, and ear infections (*V. alginolyticus*).	Temperature (increased water temperature), sea level rise, precipitation patterns (as it affects coastal salinity)