Maine's Changing Hydrologic Cycle:

Drinking Water and Climate Variability

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Topics

1. Maine’s drinking water: uses and sources
2. Climate change and variability in the water cycle
3. Sea-level rise
4. Case study

Drinking water in Maine

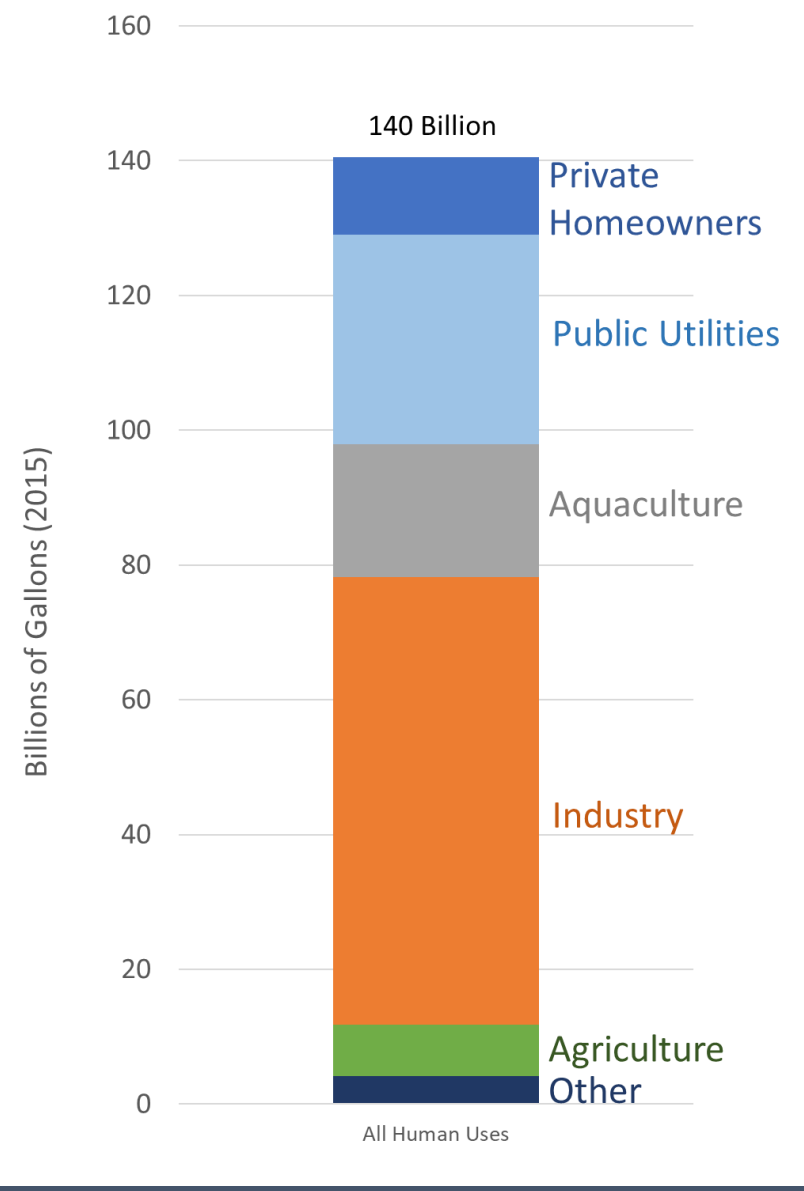
50% of Maine residents are on public water

50% of Maine residents use private wells

Wells and lakes are the two main water sources

Potable water withdrawals in Maine
(public water utilities + private domestic wells)
= 42 billion gallons per year (30% of all human use)

For groundwater only, potable water withdrawals
= 22 billion gallons per year (70% of all human groundwater use)

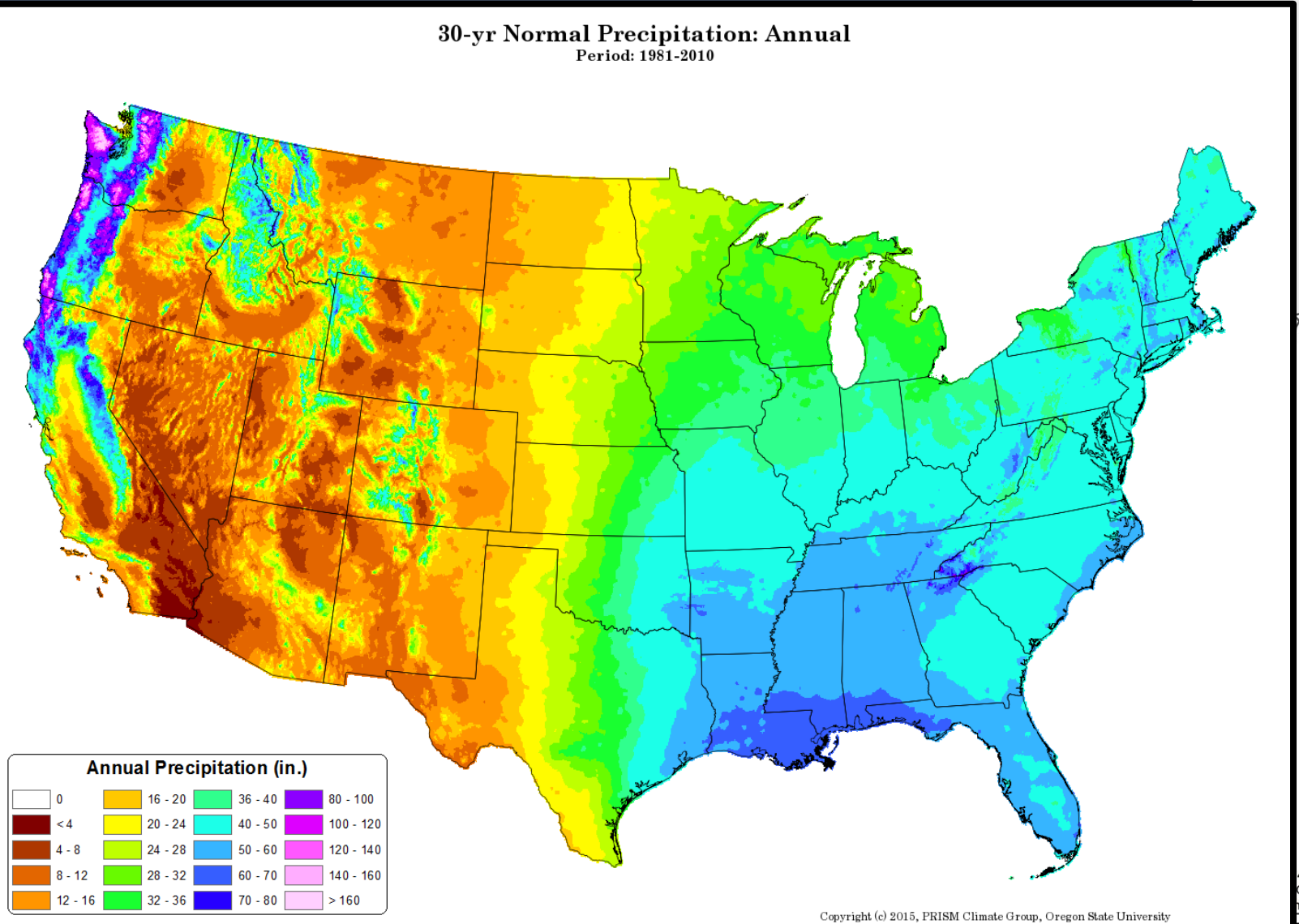


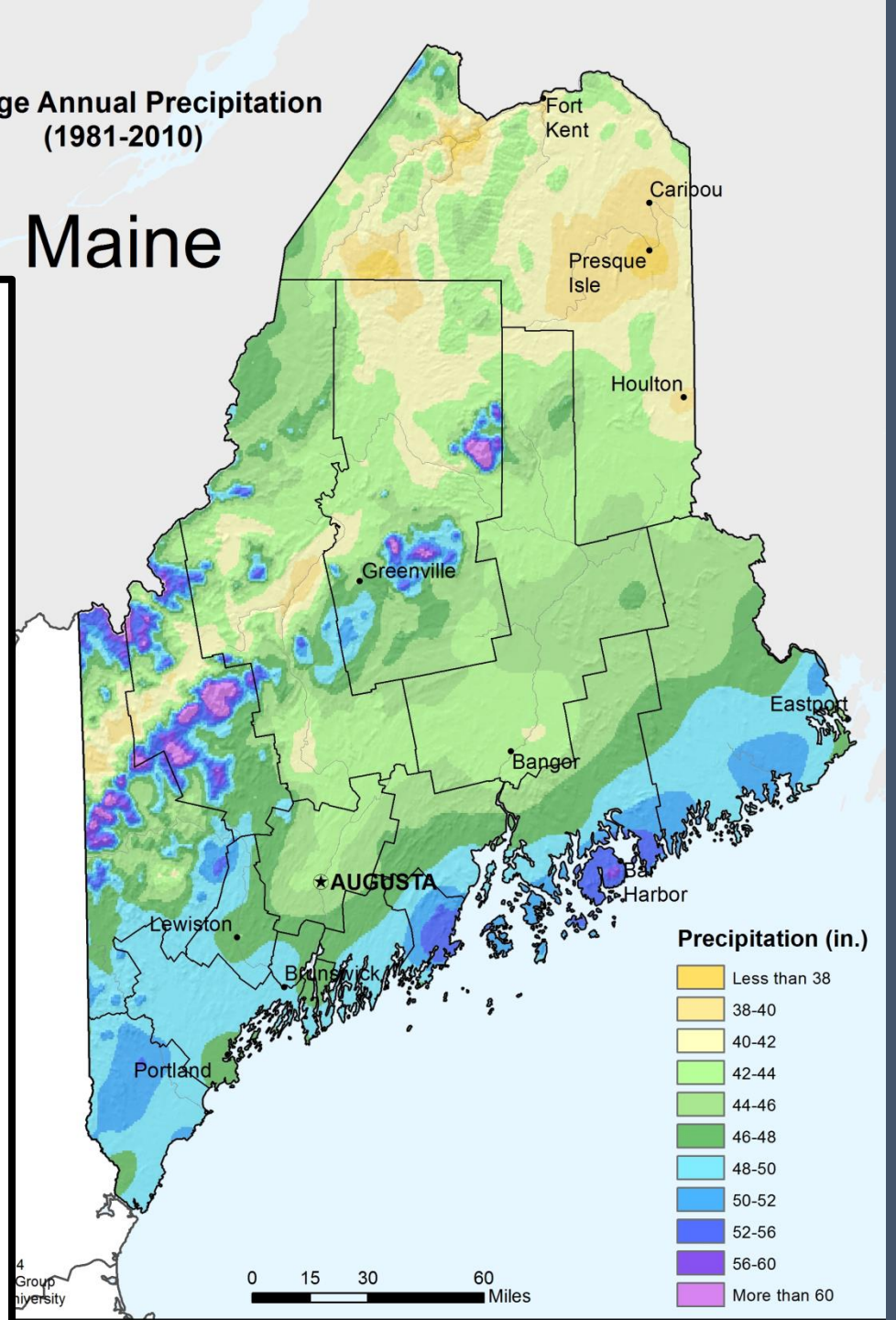
The hydrologic cycle begins with precipitation

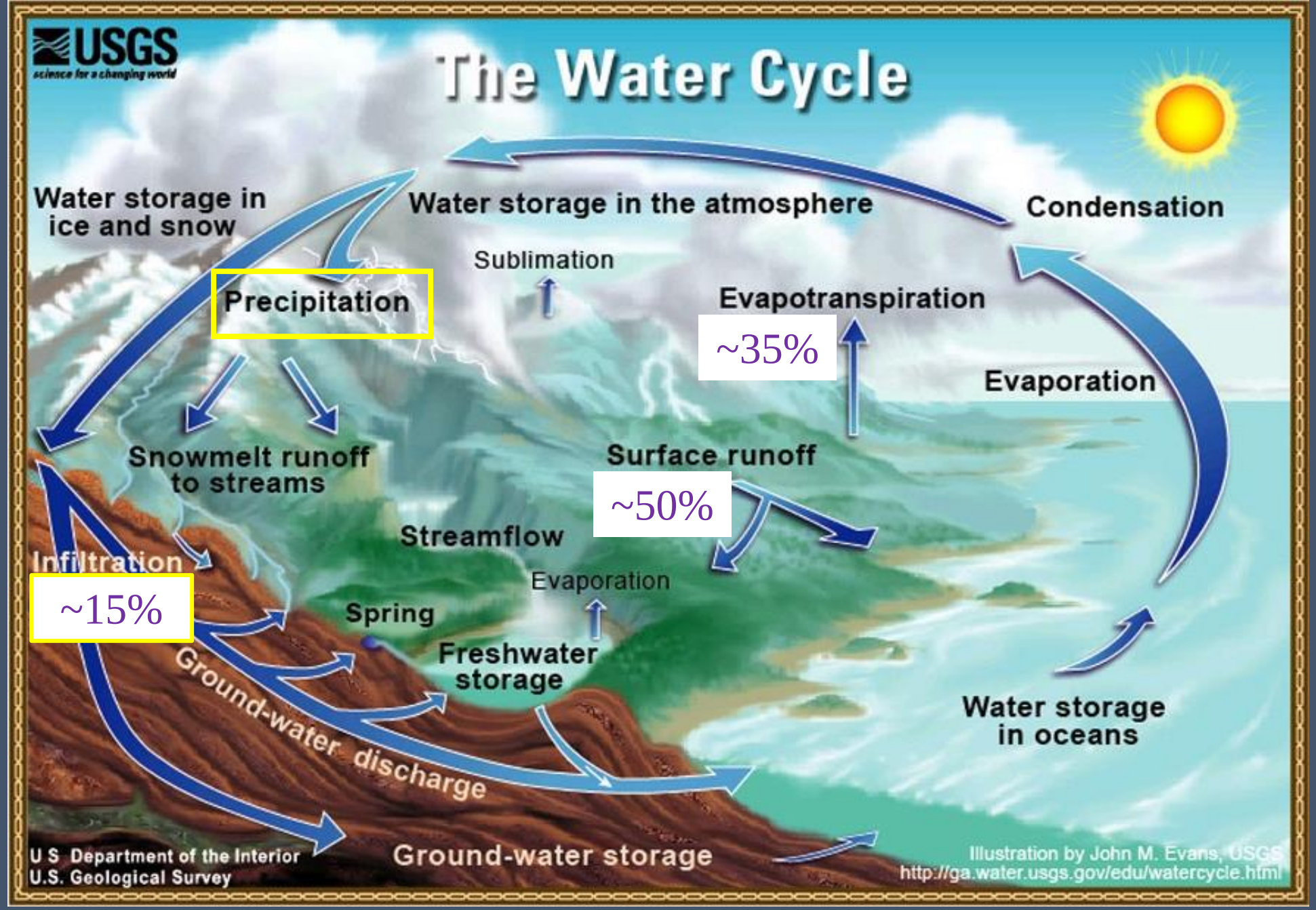
Rain

Snow

Maine Average:
45 inches/year (26 trillion gallons!)



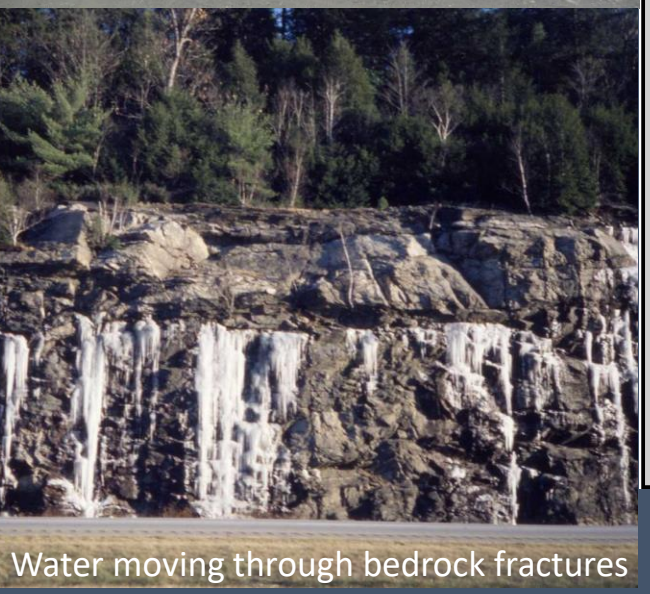




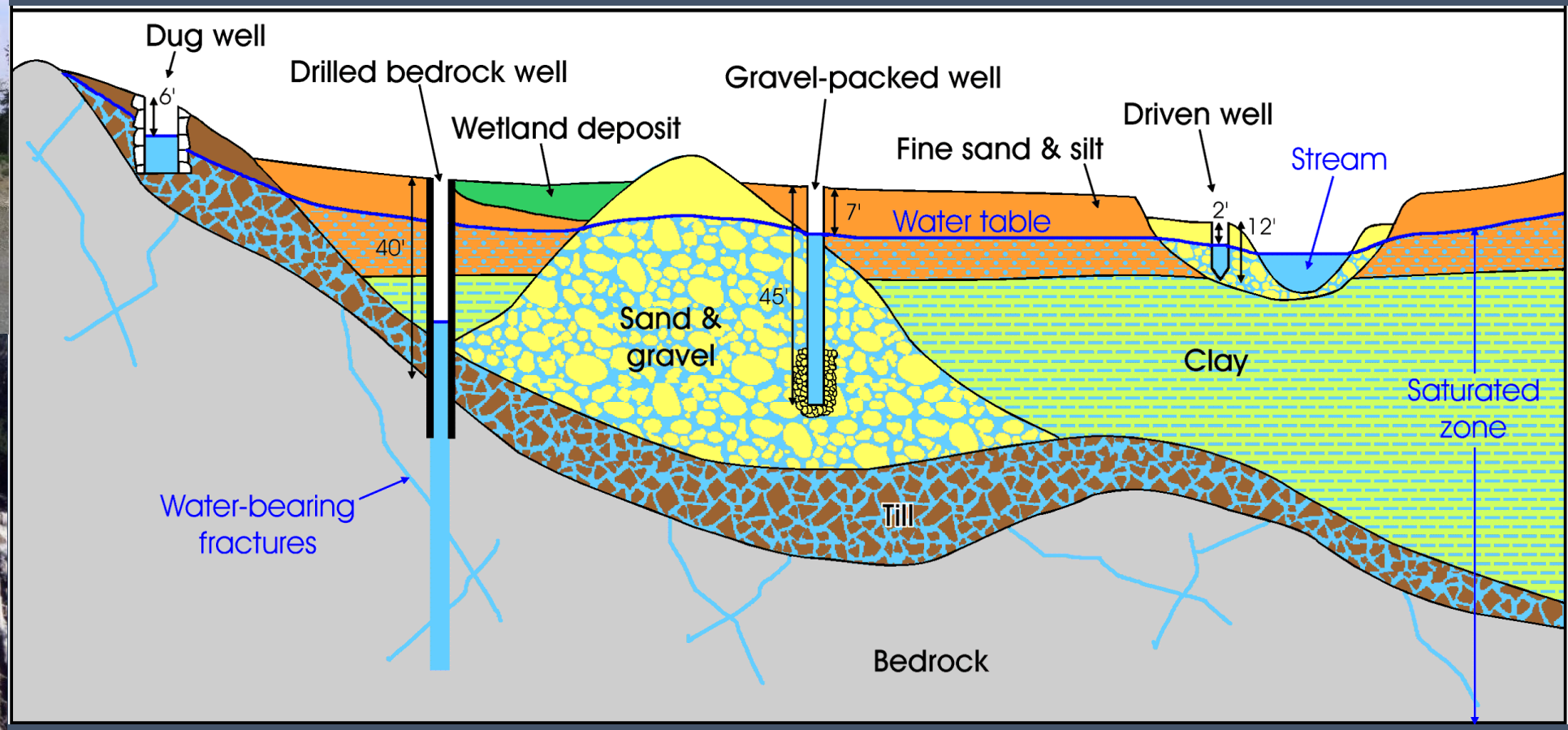
For areas of fractured rock with little cover, infiltration ~2-5%

Aquifers in Maine

Esker ridge of sand and gravel



Water moving through bedrock fractures



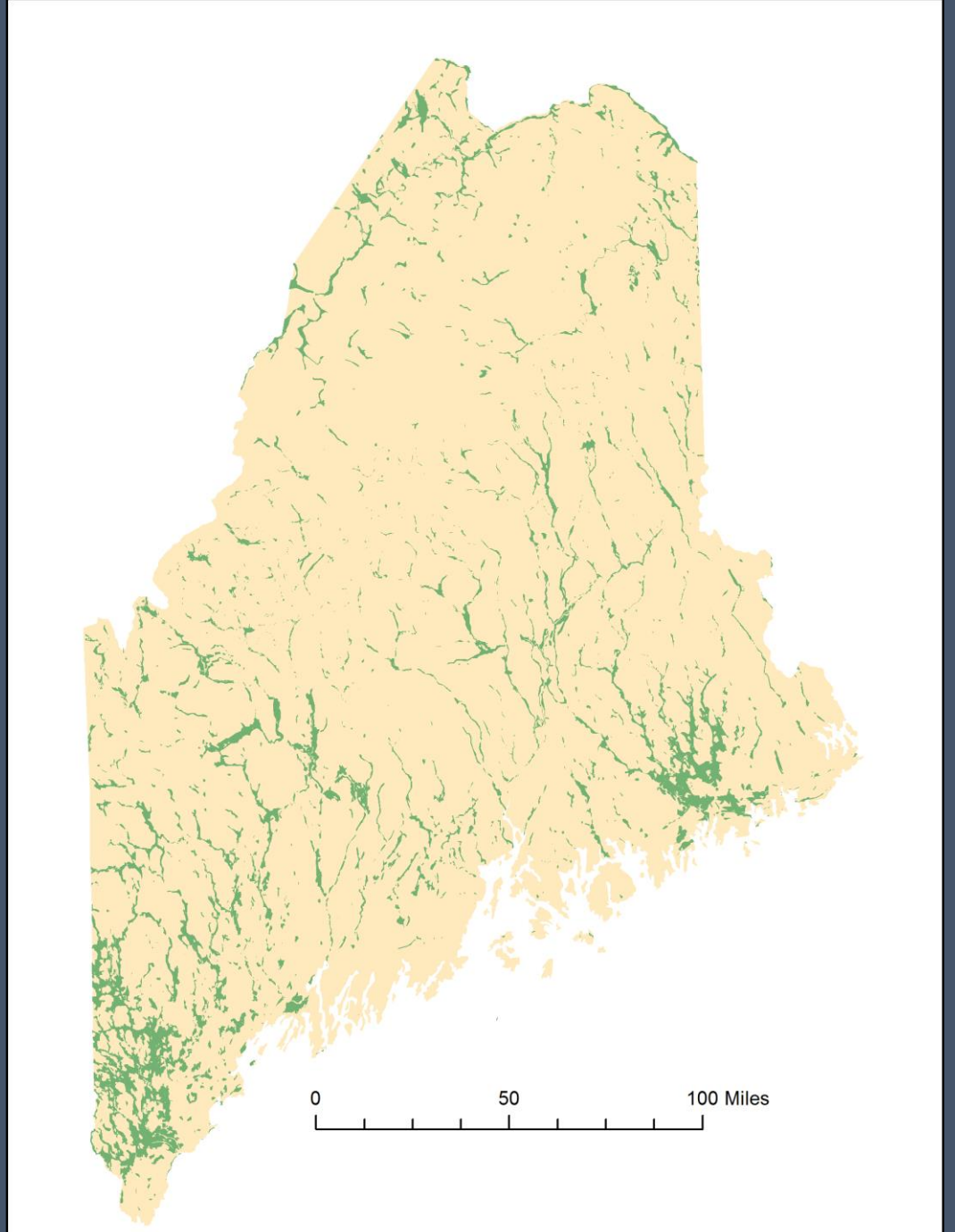
Maine Geological Survey

scale bar = 1-5 miles

Sand and Gravel Aquifer Distribution

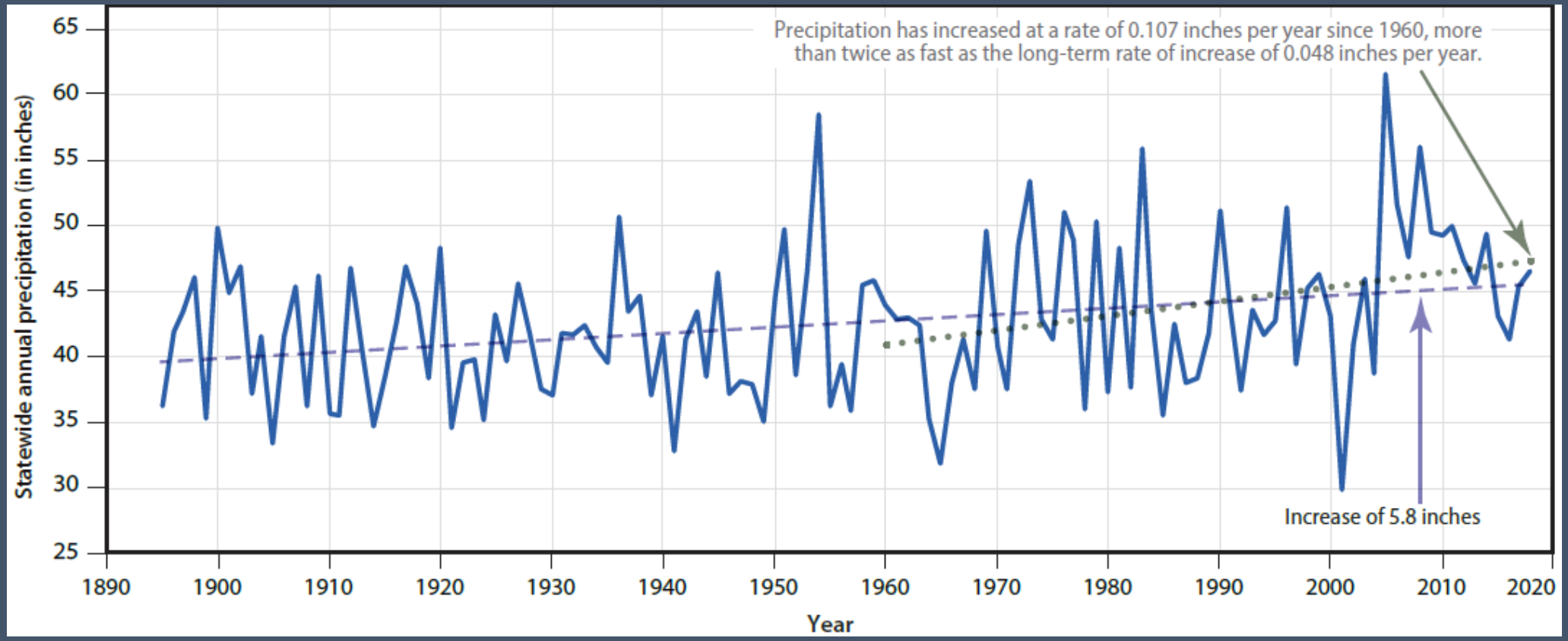
Distribution confined to:

- Stream valleys
- Glacial esker ridges
- Glacial fans, deltas, and outwash plains



Climate Change and Variability

…and their effects on the water cycle.

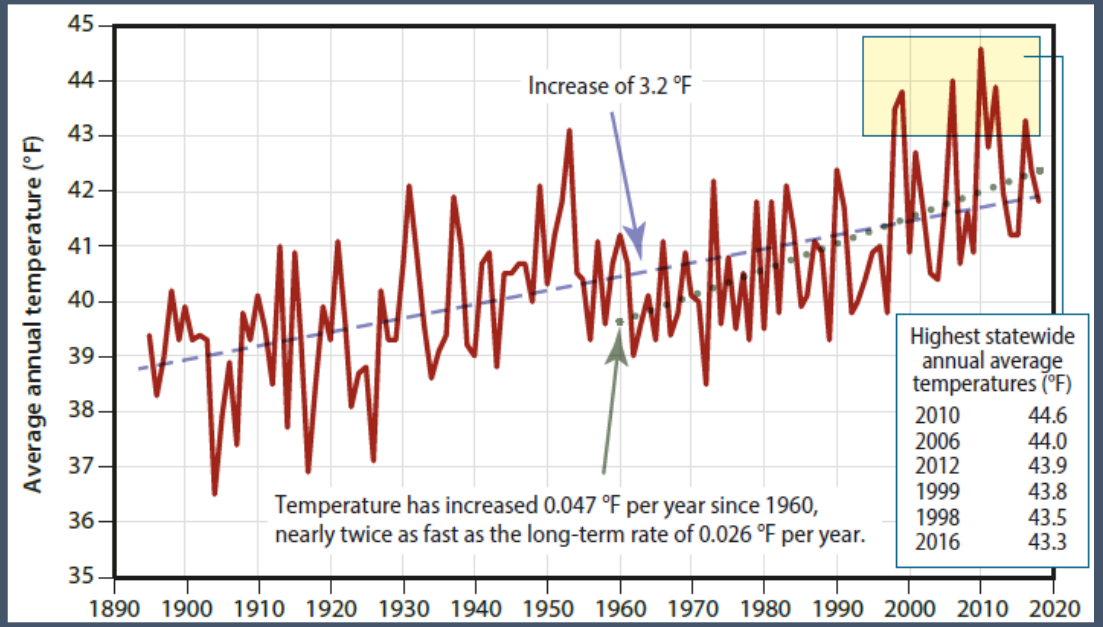


Fernandez et al. 2020, *Maine's Climate Future*

Increasing Temperature

Changes to the hydrologic cycle:

- longer growing seasons
- more evapotranspiration
- less winter snow storage
- earlier spring ice-out
- earlier or unpredictable river flows (floods)
- more runoff events during winter
- less frozen soil



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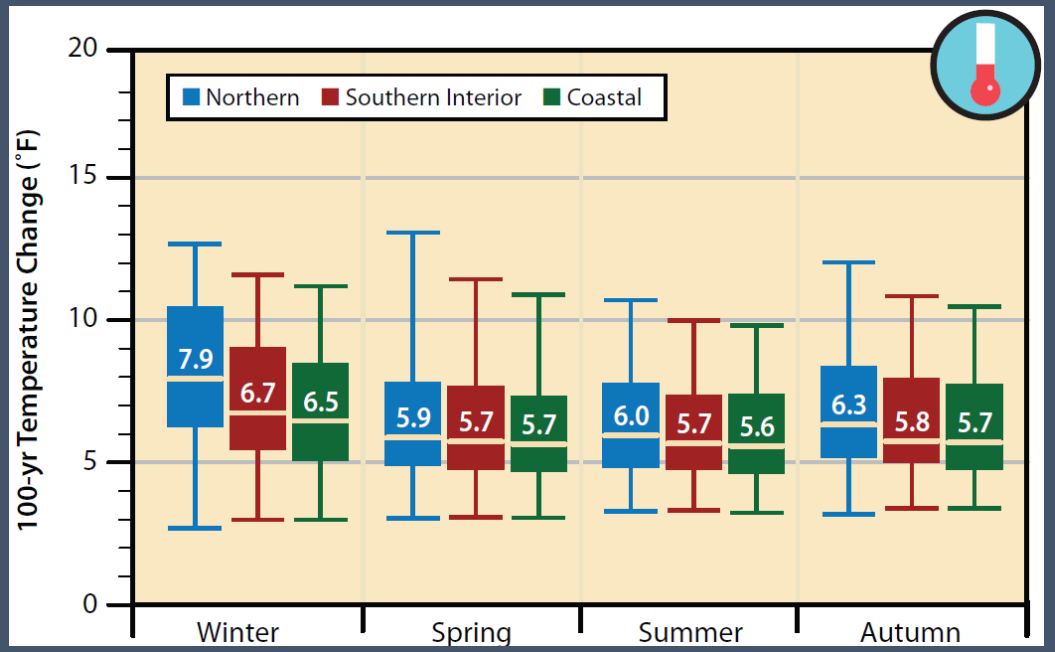
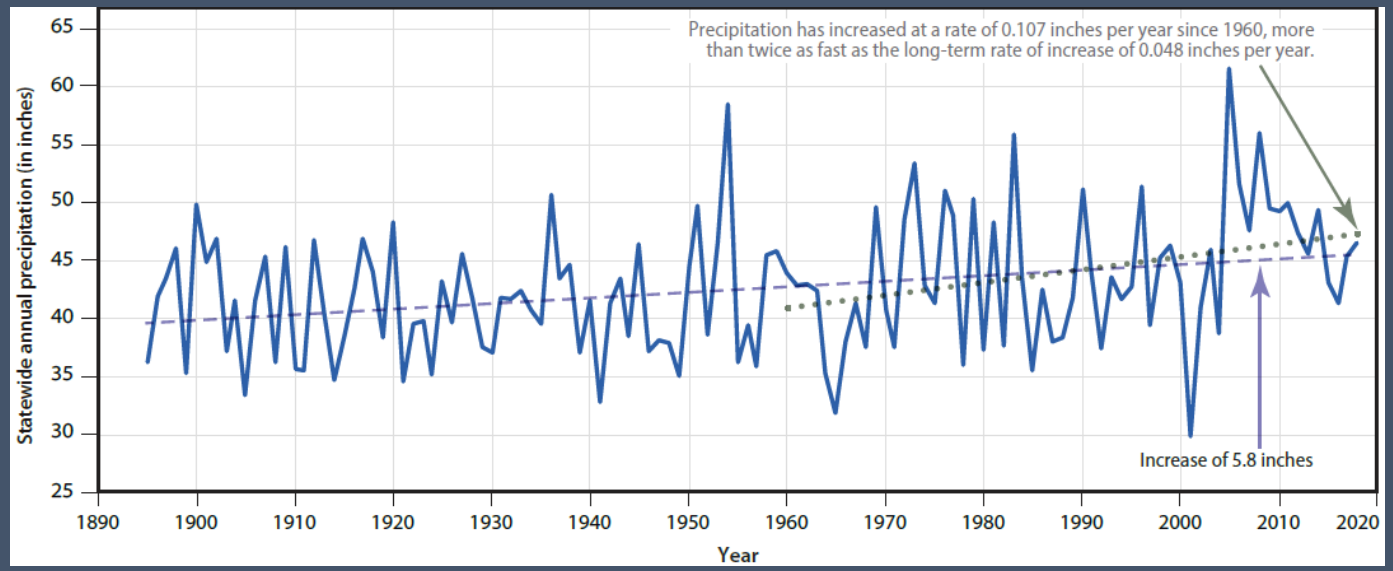


Jacobson et al. 2009, *Maine's Climate Future*

Increasing Precipitation

- More precipitation in fall, winter, spring
- Higher stream flows
- more saturated soil:
  - larger and more frequent runoff events
- Higher groundwater levels

- Greater variability in time



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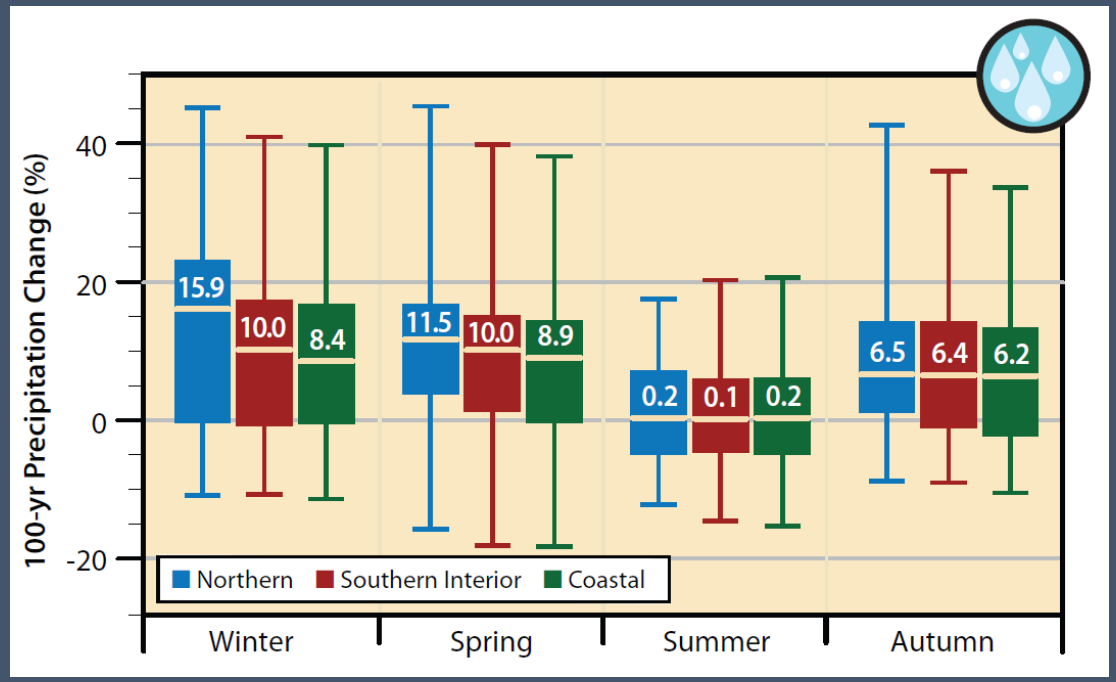
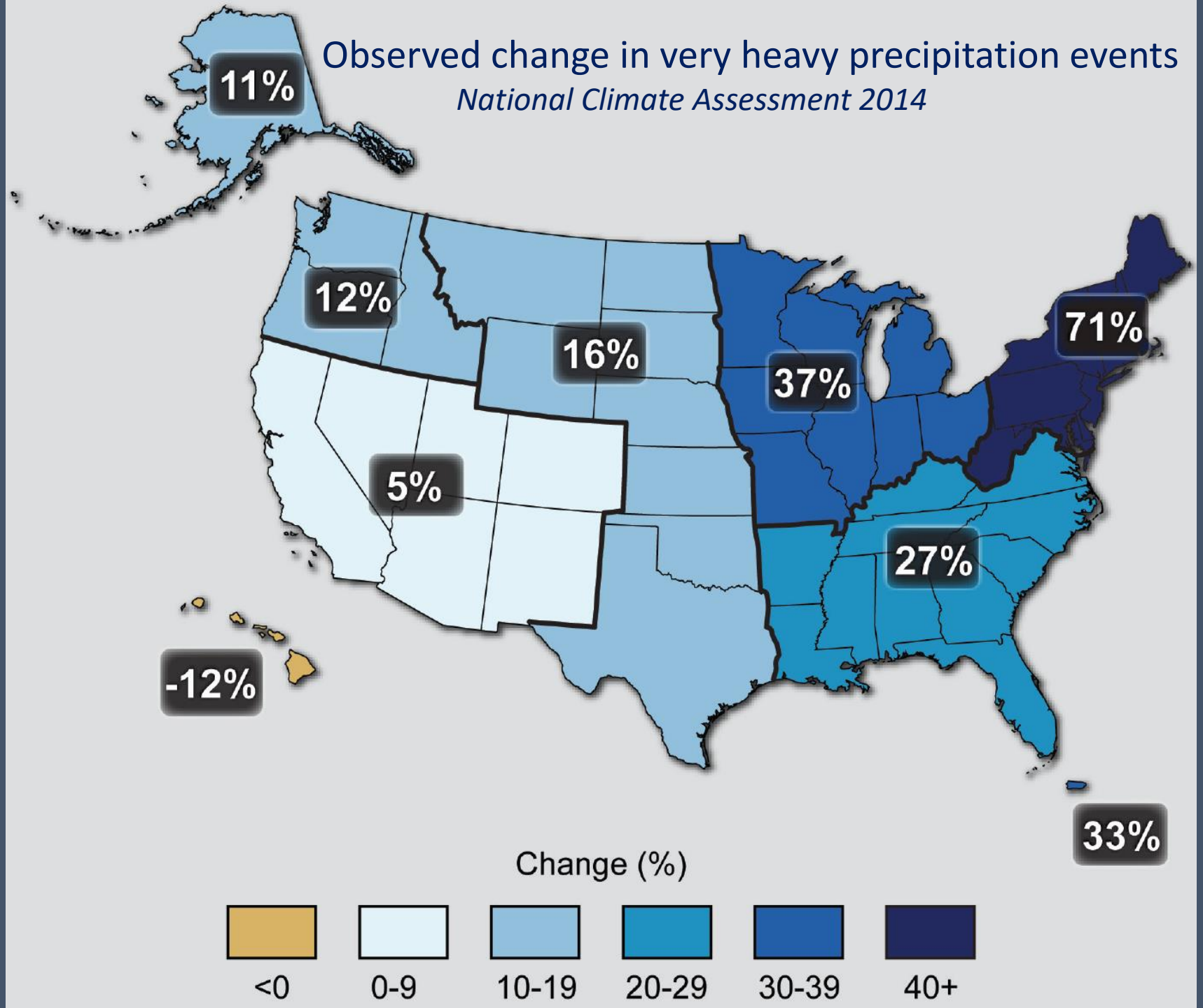


Jacobson et al. 2009, *Maine's Climate Future*

Observed change in very heavy precipitation events

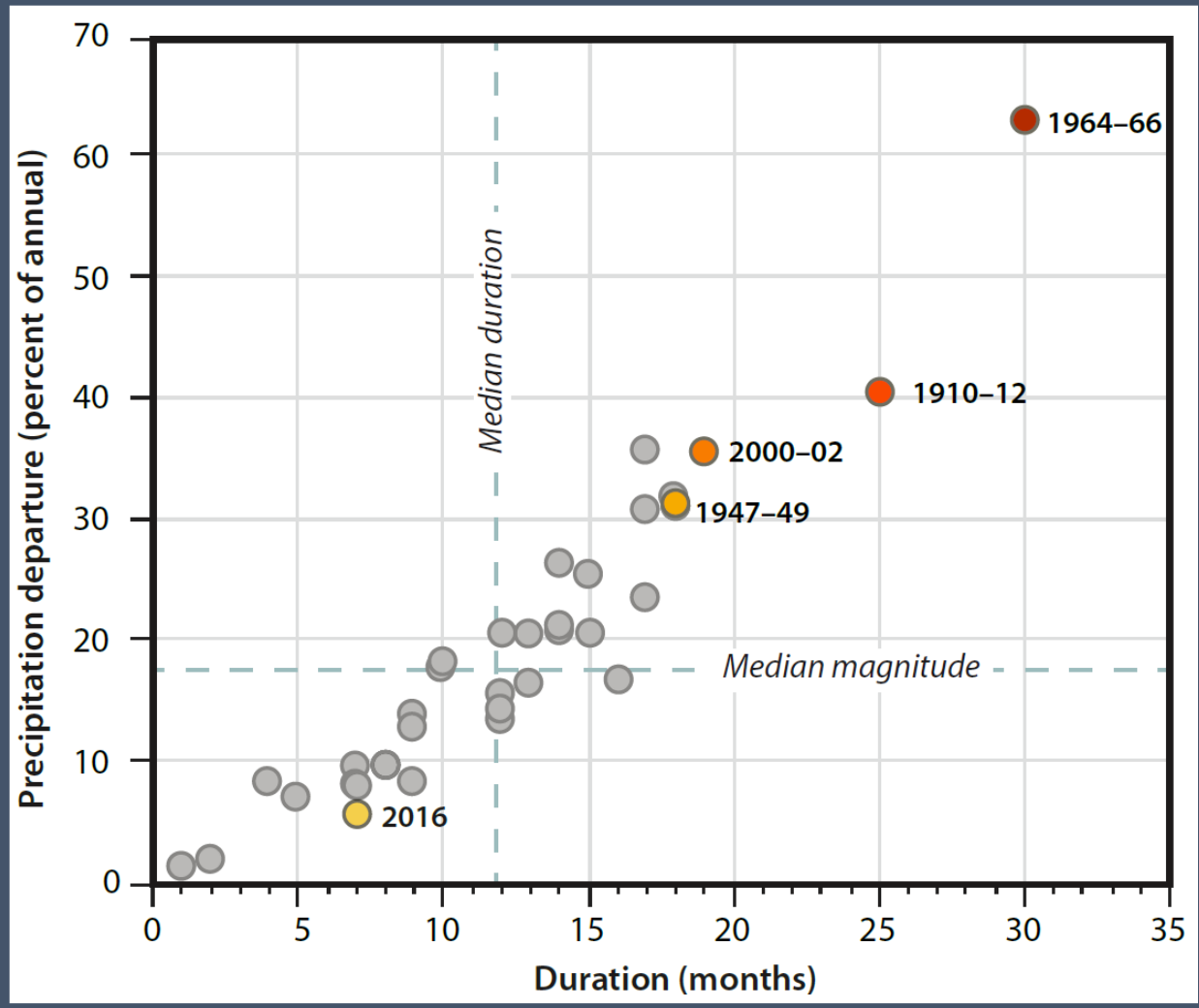
National Climate Assessment 2014



Drought

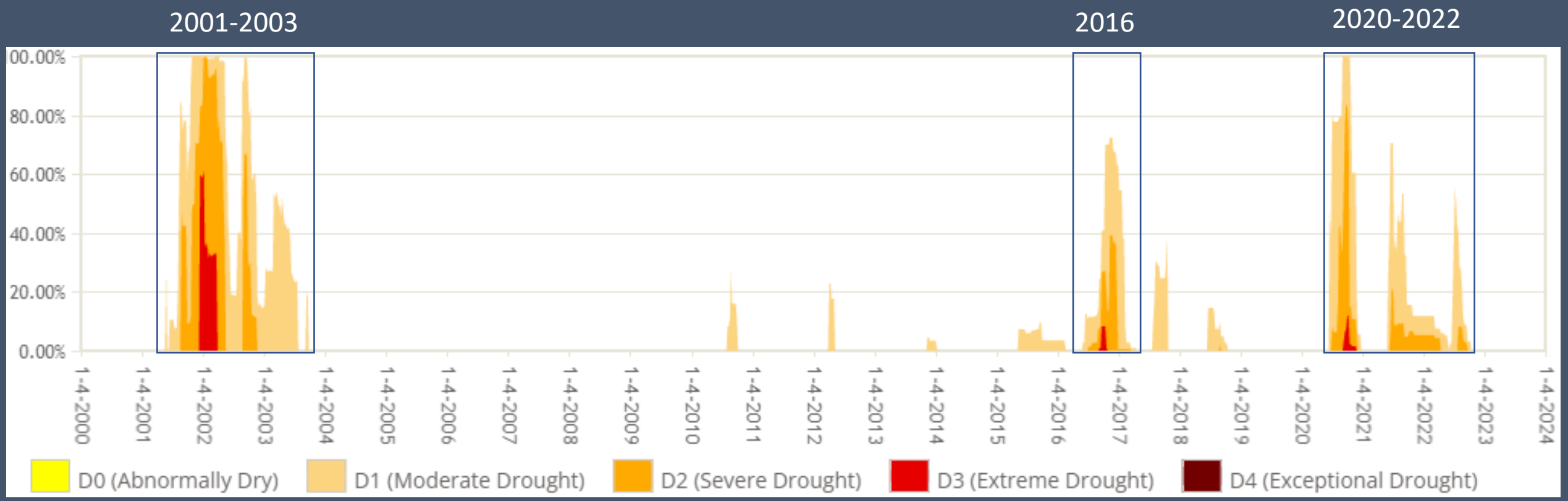
Short term droughts also affect Maine

- Stress agriculture, drinking water, ecosystems, and fire danger.
- Severity of short-term droughts may increase with higher temperatures and longer growing seasons.
- Some climate predictions suggest droughts will be more common

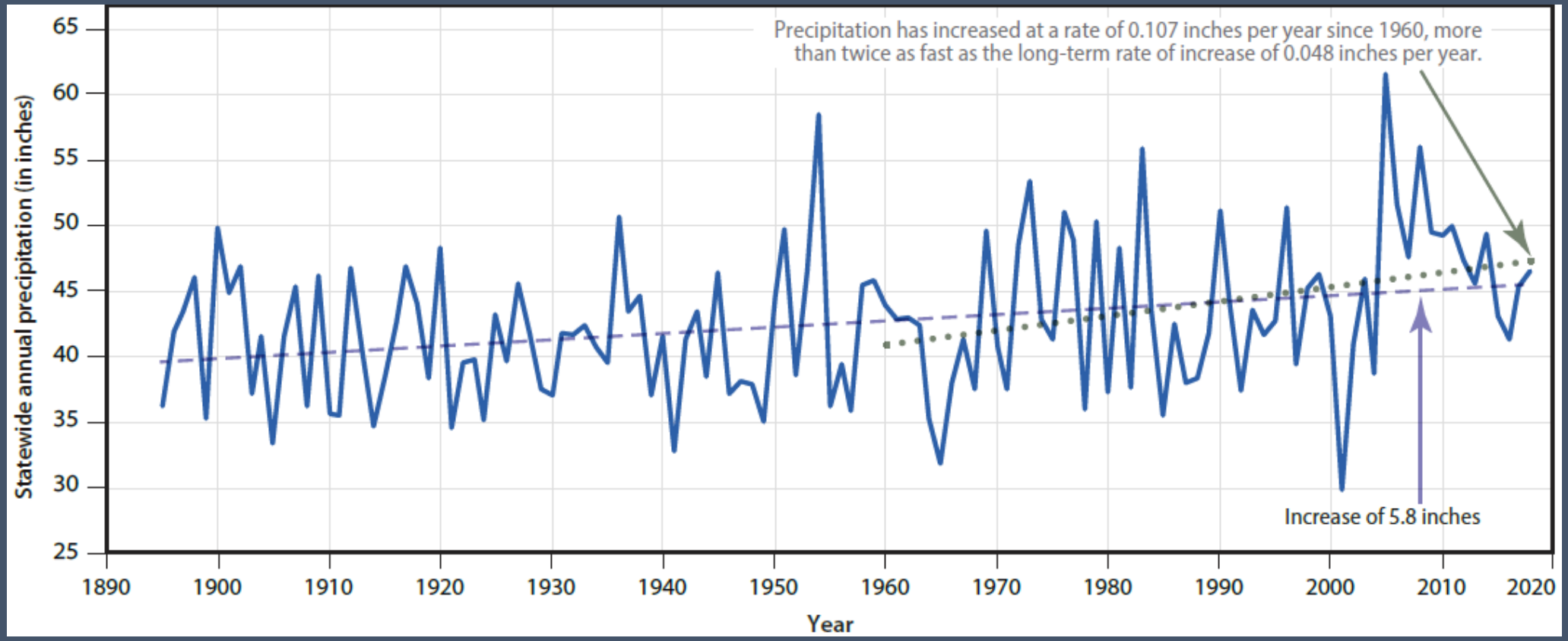


Fernandez et al. 2020, *Maine's Climate Future*

Recent Historic Droughts



- 1947-50, 1995, and 1999-2003 were Maine's most impactful droughts.
- 1963-69 was Maine's longest period (7 years) of drought.



Fernandez et al. 2020, *Maine's Climate Future*

Impacts of variability on water quality

Dry periods followed by rain events (“first flush events”)

- increase polluted runoff and groundwater discharge
- carry a larger than normal load of pollutants
  - soil and vegetation are dry and more susceptible to erosion
  - pollutants and septic effluent accumulate on and in soil during drought

More frequent and larger runoff events

- increase erosion and nutrient loads in surface water
- lead to eutrophication (too much nutrient) and algal blooms

Low surface water and/or higher air temperatures:

- higher water temperatures
- lower dissolved oxygen
- more algal blooms

Road salt

More winter precipitation events

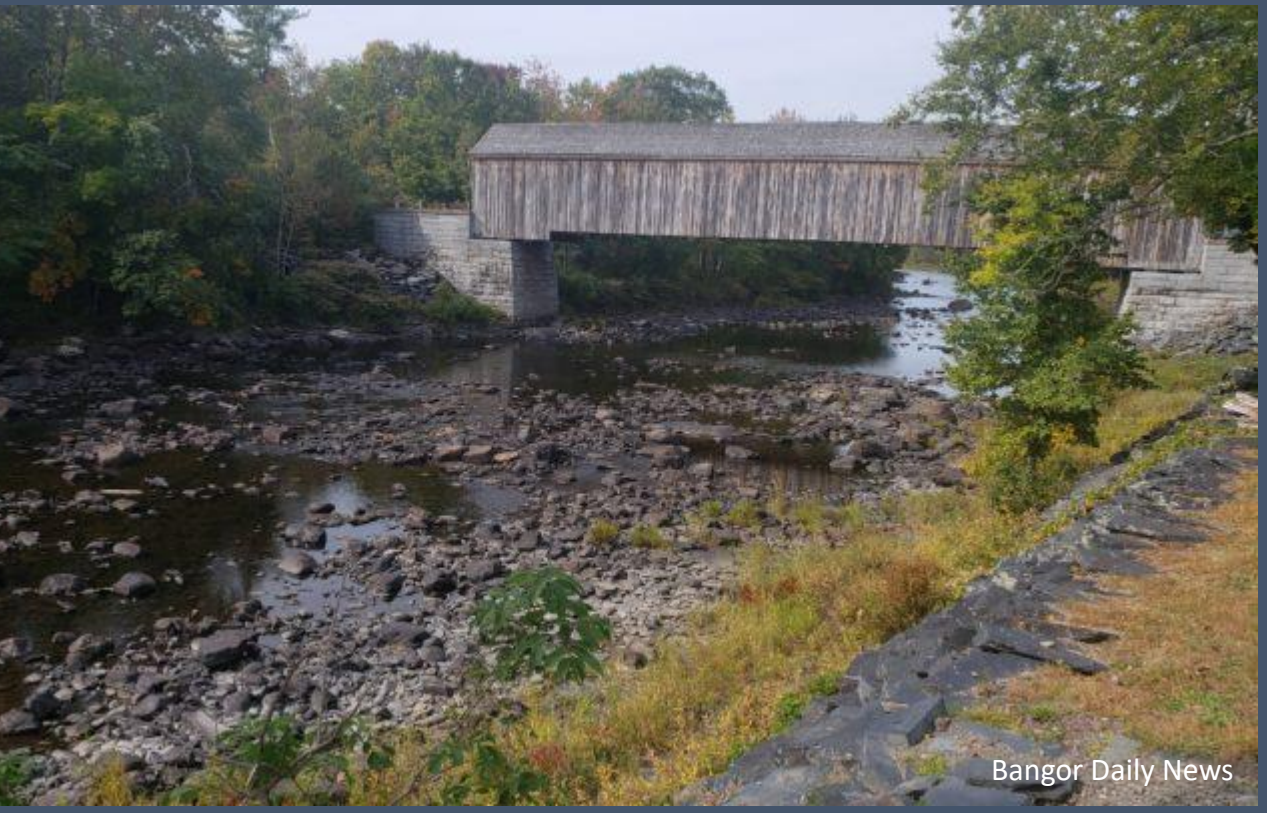
combined with

Warmer winter temperatures

→ more storms with more mixed precipitation

→ increasing road salt use

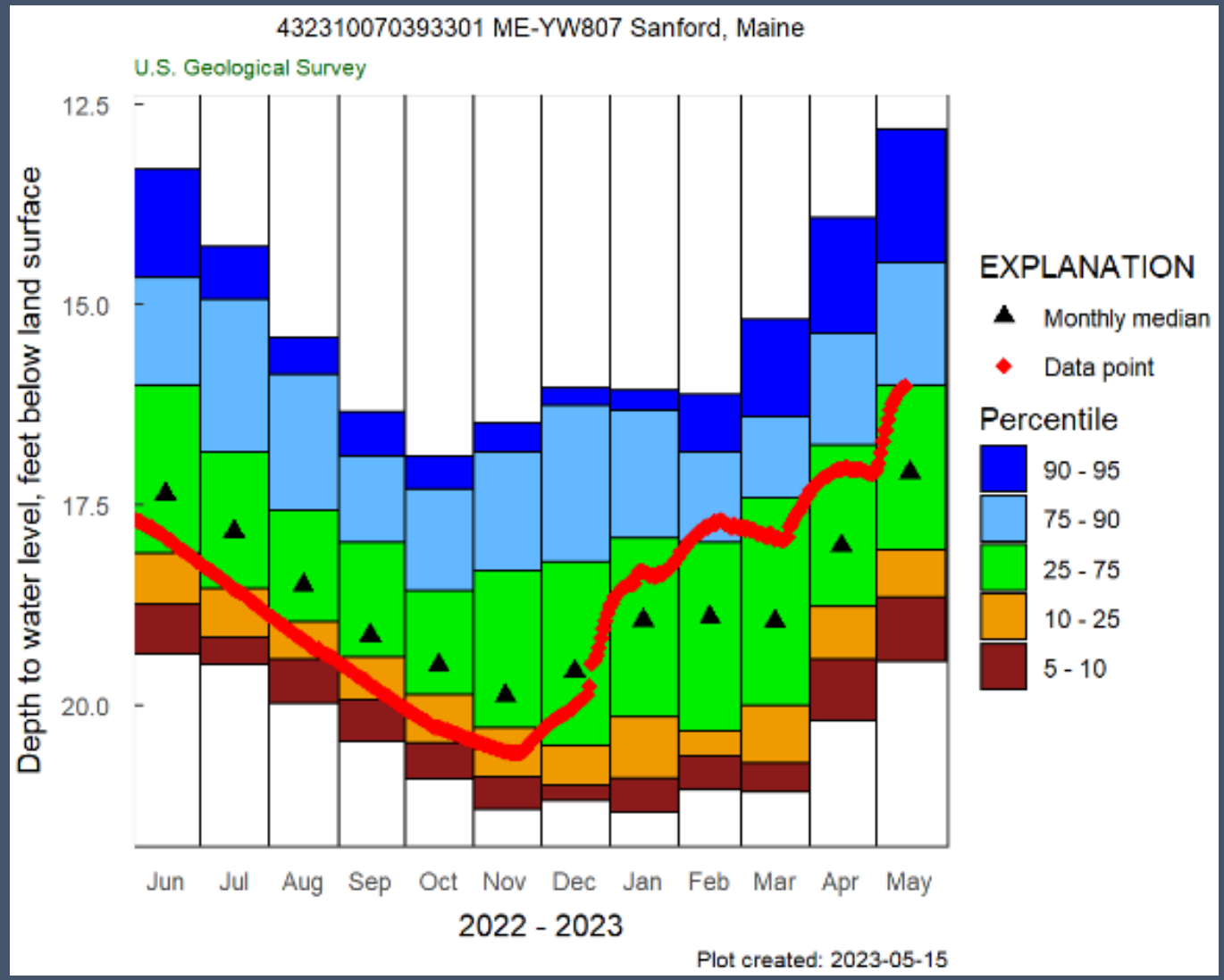
Impacts of variability on surface water quantity:
Drought (2020) and flood (2023)



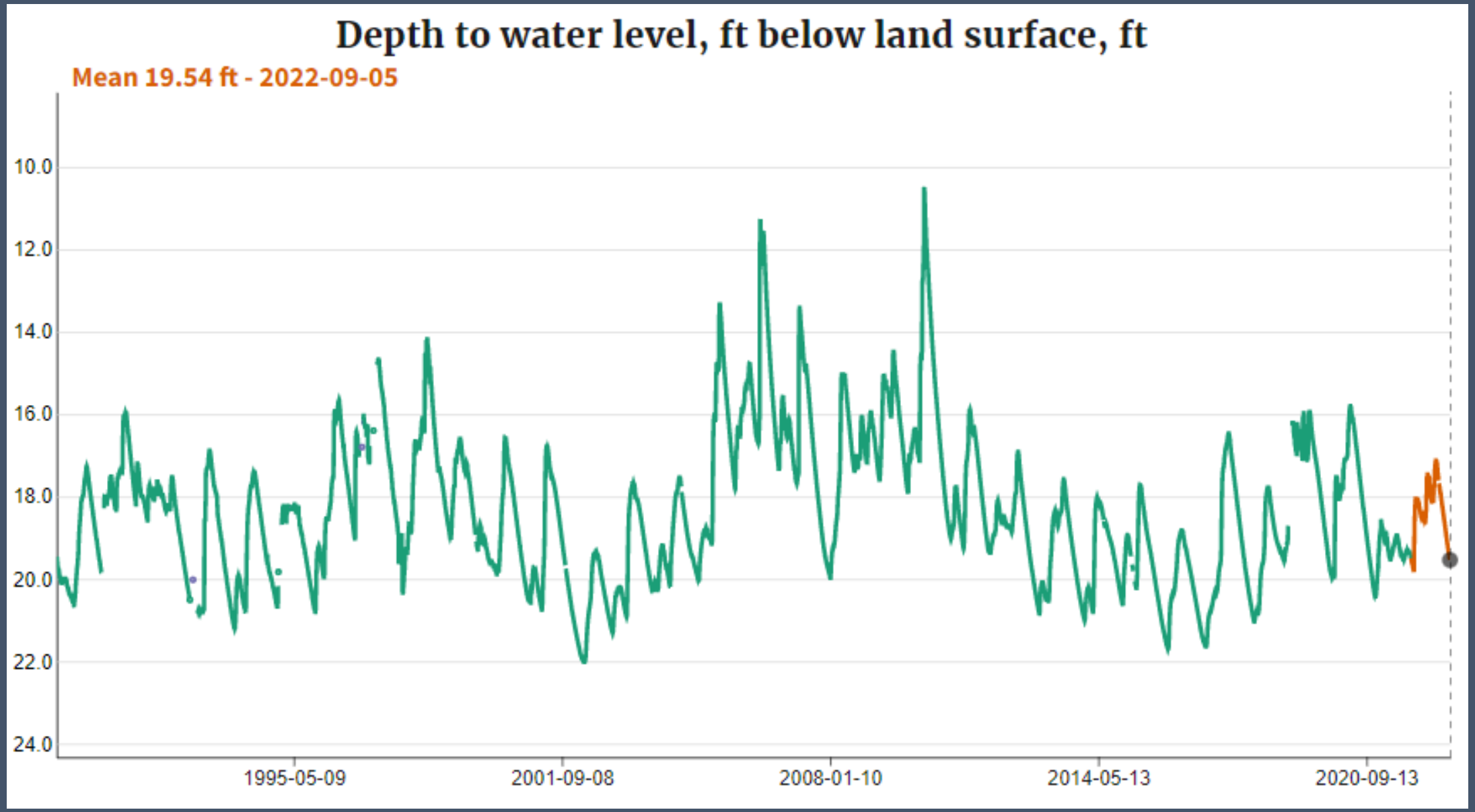
Route 156 Wilton, Maine, June 29, 2023 Photo by James Black.

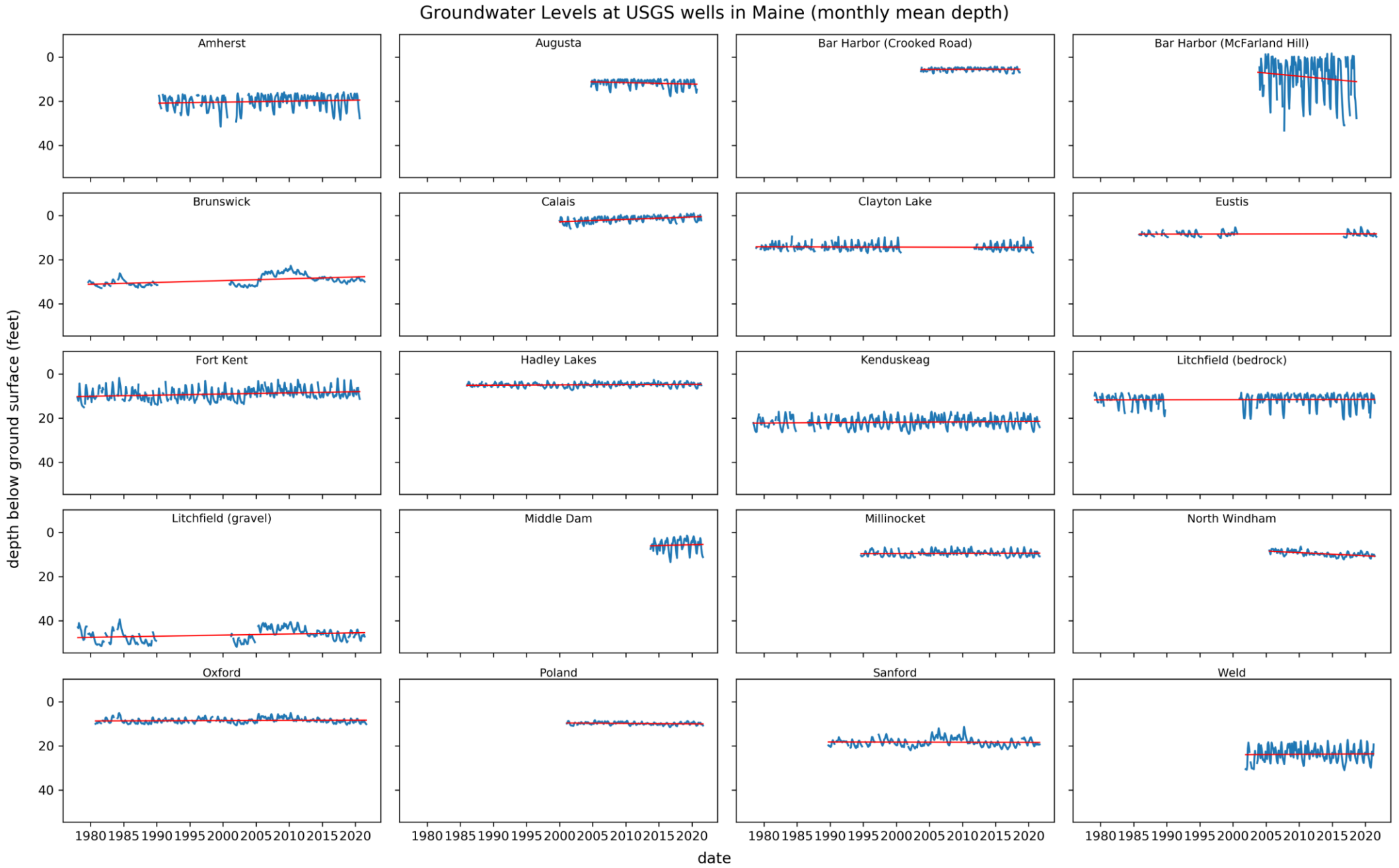
Impacts of variability on aquifer levels

Groundwater Levels, Sanford surficial well

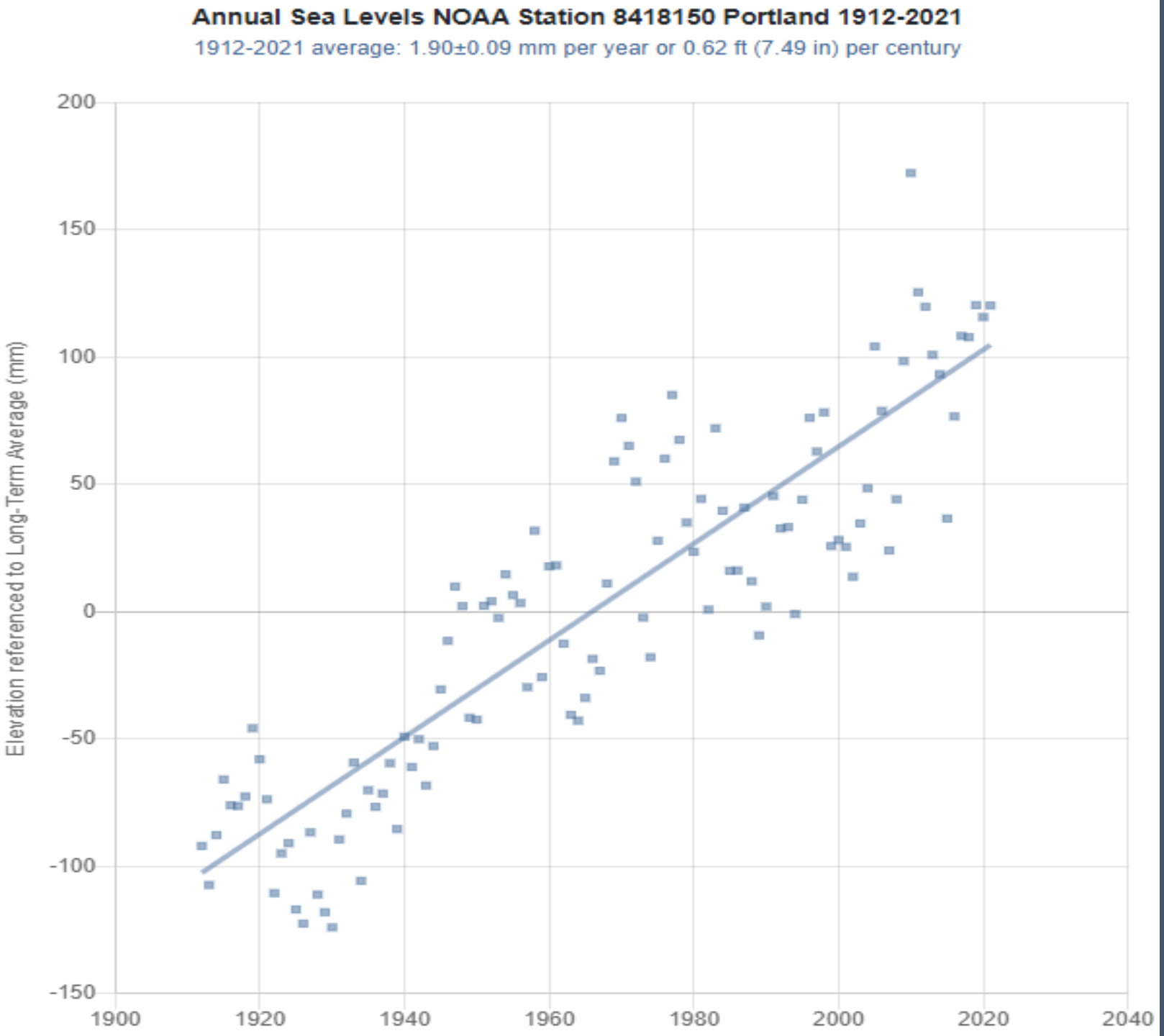


Long term record in Sanford sand plain

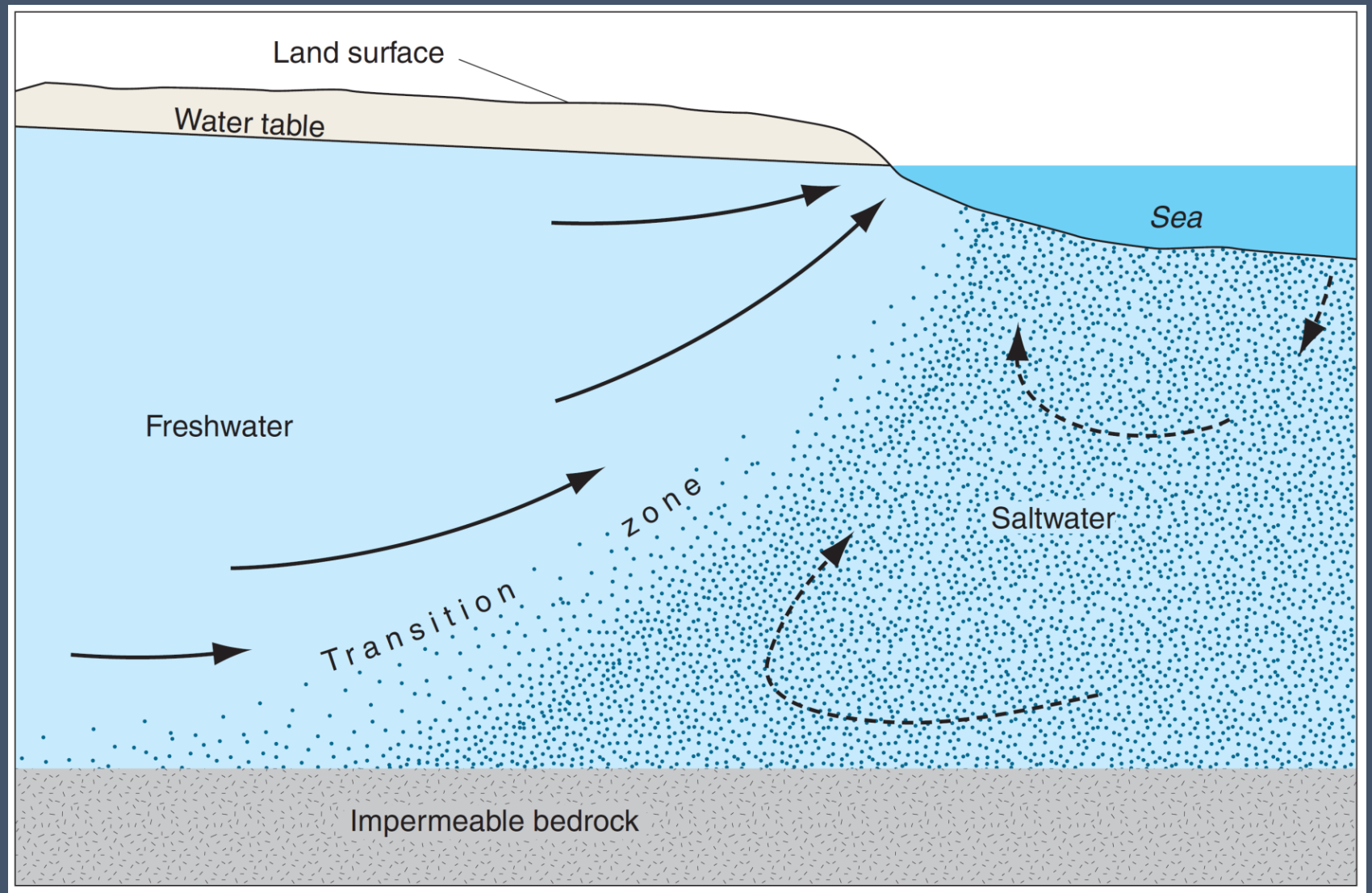



Groundwater Levels at USGS wells in Maine (monthly mean depth)
Amherst
Augusta
Bar Harbor (Crooked Road)
Bar Harbor (McFarland Hill)
Brunswick
Calais
Clayton Lake
Eustis
Fort Kent
Hadley Lakes
Kenduskeag
Litchfield (bedrock)
Litchfield (gravel)
Middle Dam
Millinocket
North Windham
Oxford
Poland
Sanford
Weld
depth below ground surface (feet)
0
20
40
1980 1985 1990 1995 2000 2005 2010 2015 2020
date

Sea-Level Rise

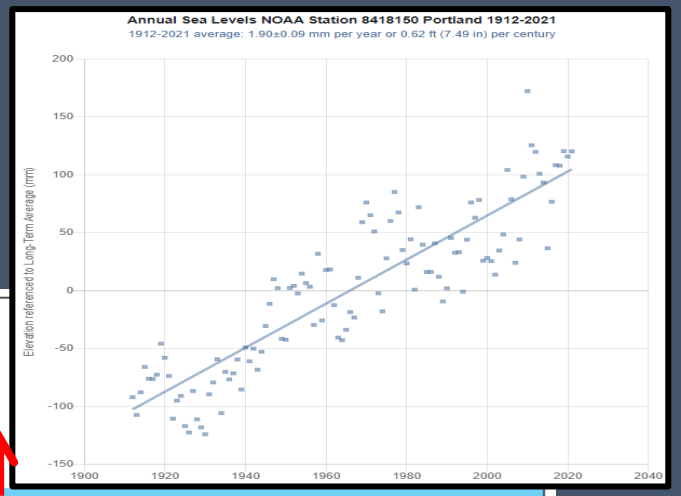


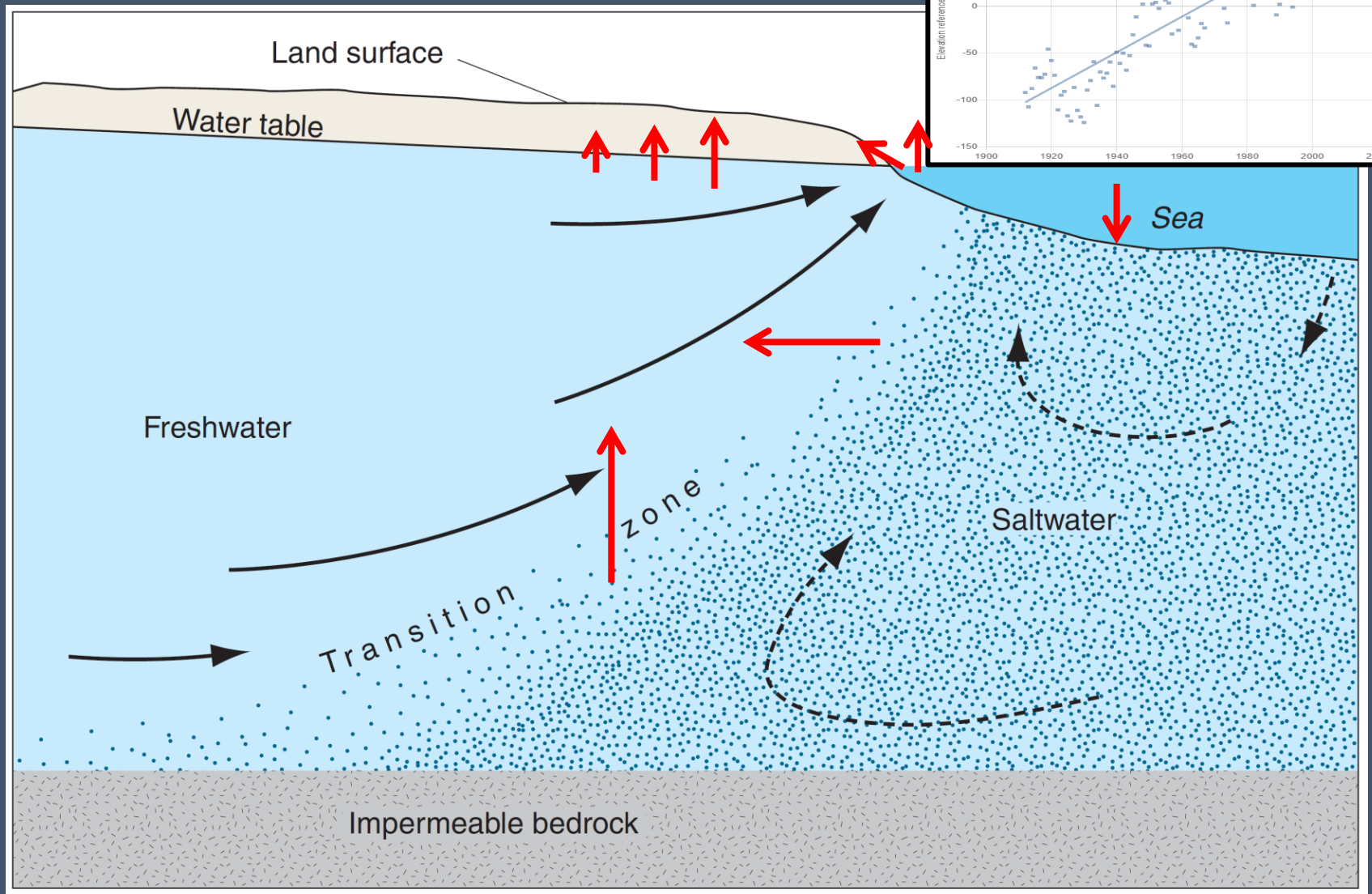
Freshwater and saltwater at the coast



Barlow 2003, USGS Circular 1262

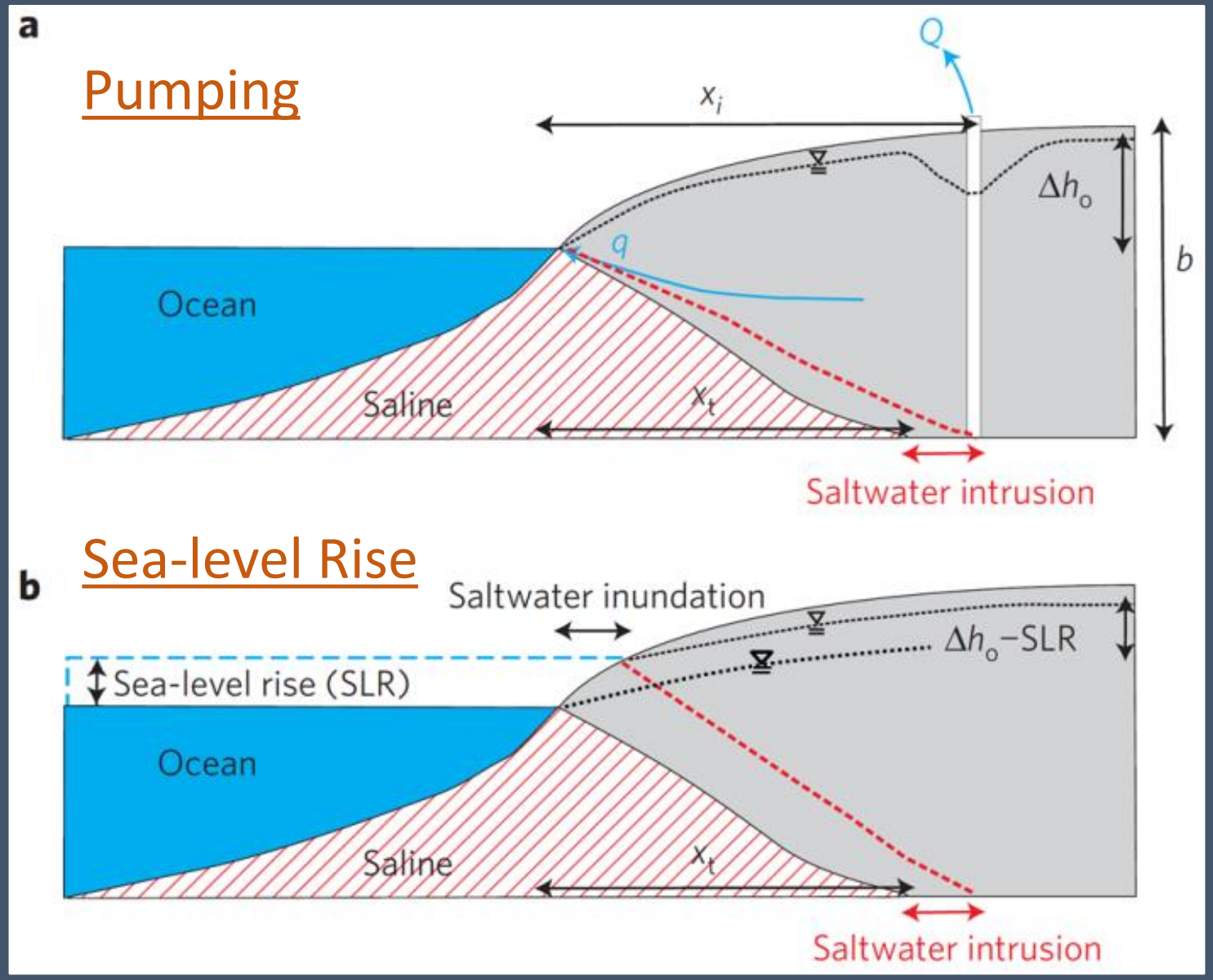
Sea-level rise?





Barlow 2003, USGS Circular 1262

Processes that affect the saltwater interface



Pumping or drought can:

- Lower the fresh groundwater table
- Shift the saltwater interface inland

Sea-level rise can:

- Shift the saltwater interface inland
- Raise the fresh groundwater table
- Flood the near-shore
- Erode the near-shore

Ferguson and Gleeson 2012, *Nature Climate Change* 2

Threats to infrastructure

From seawater intrusion into aquifers:

- salt contamination of drinking water supplies
- corrosion of pipes, foundations, and other subsurface infrastructure

From water-table rise:

- flooding and failure of septic systems and sewers
- saturation and premature failure of roadbeds, foundations, etc.
- saturation and remobilization of soil contamination

From land inundation:

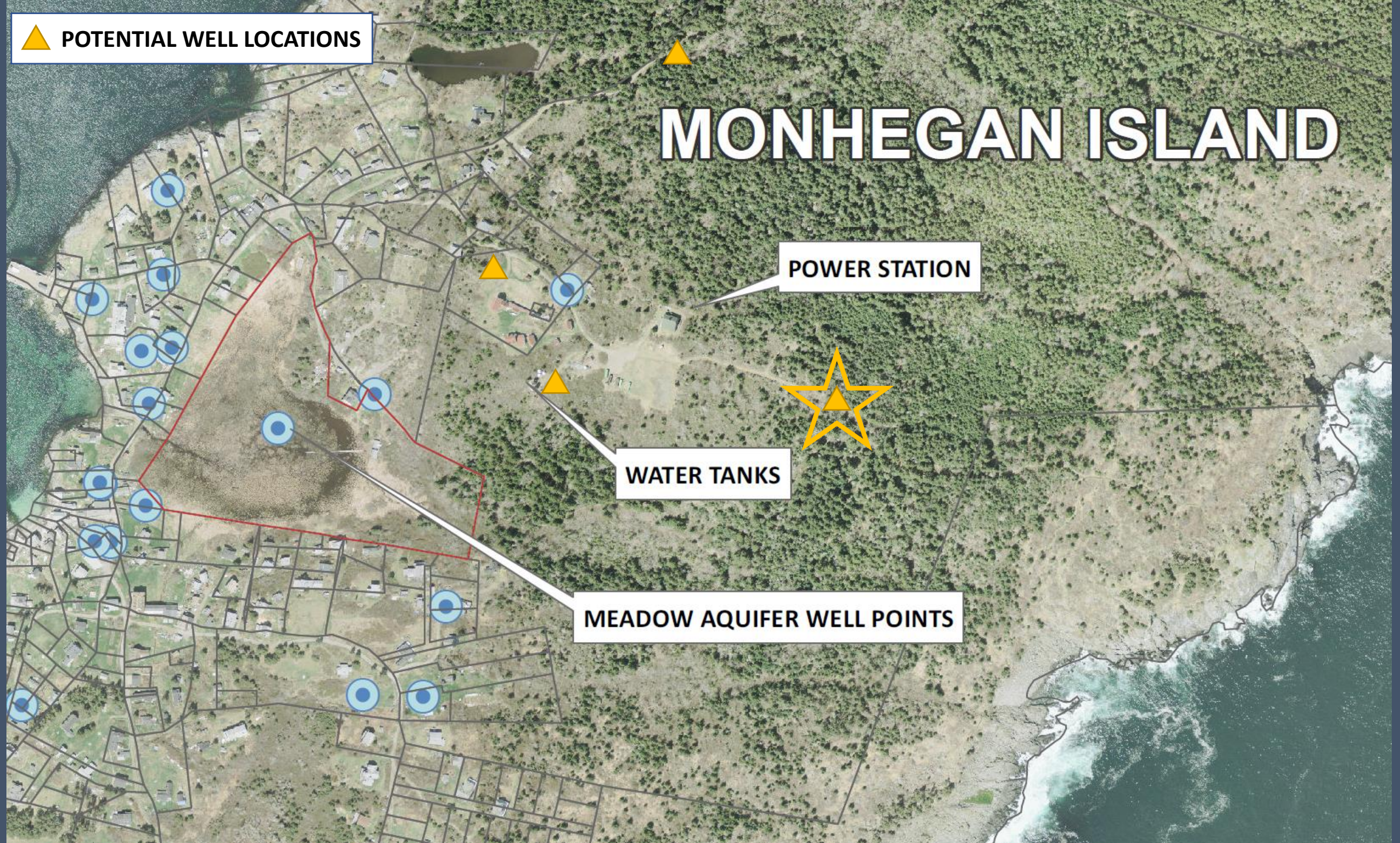
- coastal flooding and erosion
- salt contamination of drinking water supplies

Monhegan Island

Alternative Water Supply Feasibility Study

- Coastal Communities Grant Program (Maine Coastal Program), 2019-2021

1. Saltwater Intrusion Model
2. Bedrock characterization
3. Bedrock well feasibility study


POTENTIAL WELL LOCATIONS
MONHEGAN ISLAND
POWER STATION
WATER TANKS
MEADOW AQUIFER WELL POINTS

Summary of Future Water Challenges

Climate change

- Increasing temperatures
- Increasing precipitation (on average)
- More climate variability
  - more short-term droughts
  - higher intensity rainfall events and floods
- Sea-level rise
  - saltwater intrusion into coastal aquifers

Other human activity

- Sprawl and residential development
  - impervious area increases runoff and decreases infiltration
  - lawn pesticides and nutrients
  - fuel spills
  - well conflicts
- Increasing road transportation
  - deicing salt, petroleum products, metals, microplastics, etc.

Questions?

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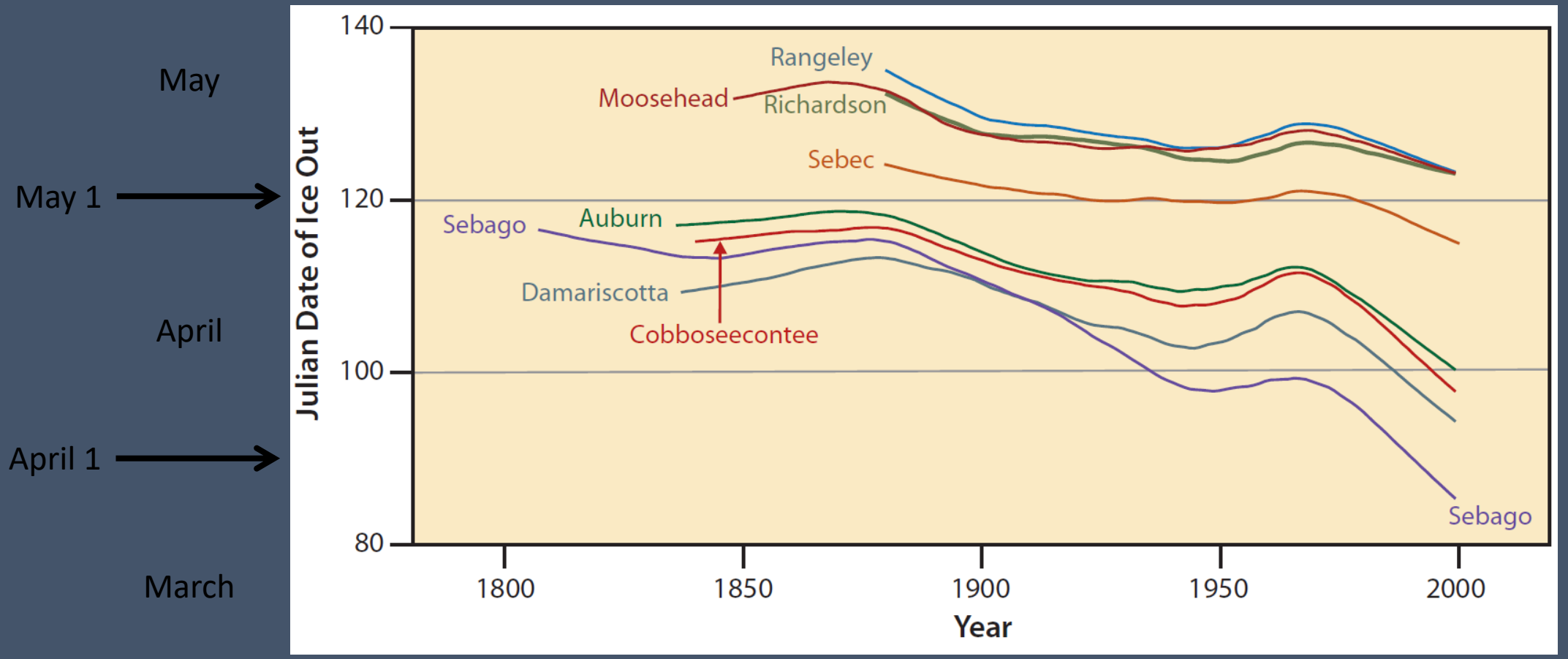
J.M.W. Turner

Ice-out timing

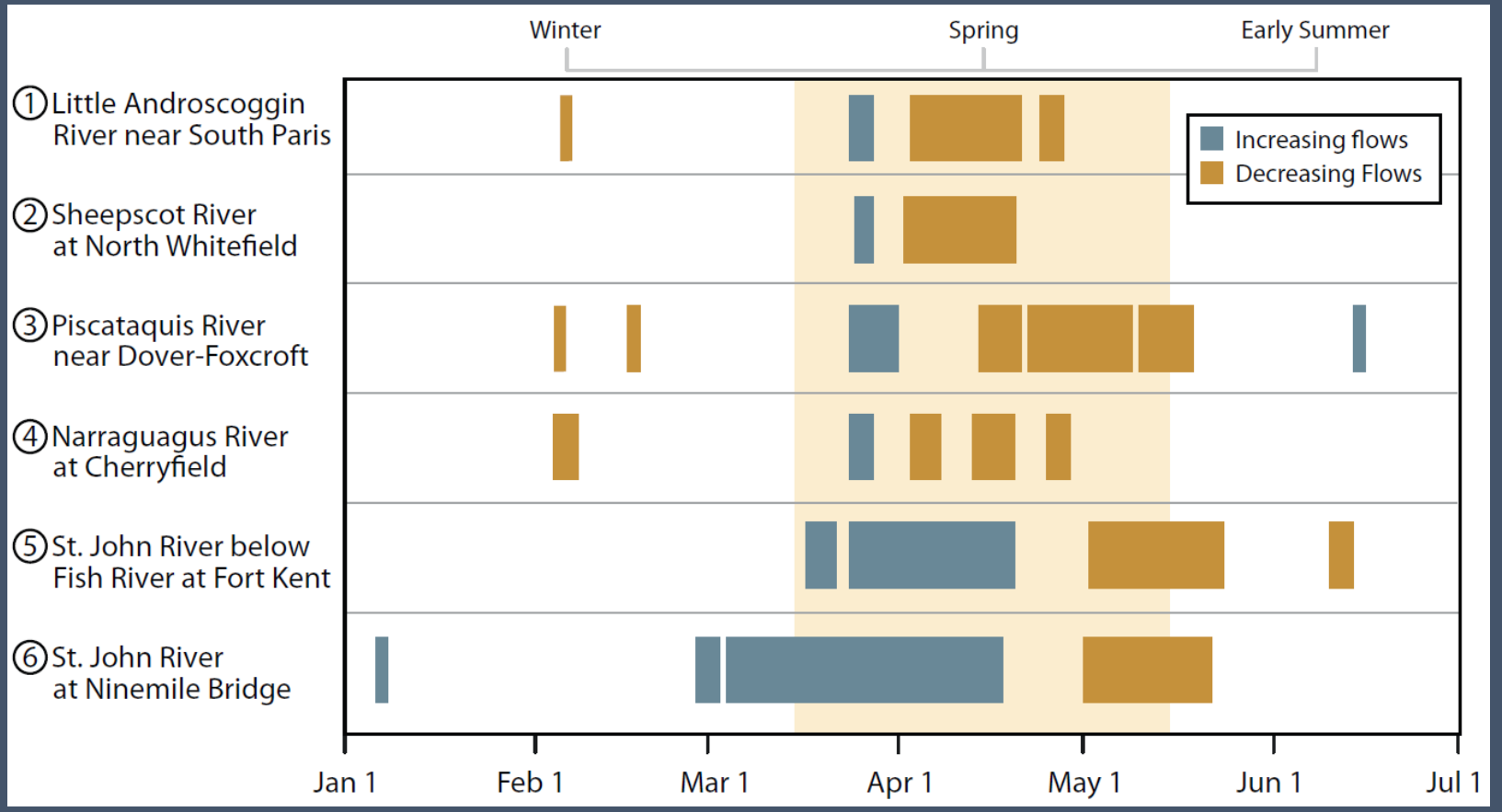
Ice-out date for eight Maine lakes:



Jacobson et al. 2009, *Maine's Climate Future: An Initial Assessment.*

River flow timing

Increasing and decreasing flows in Maine rivers, by season:



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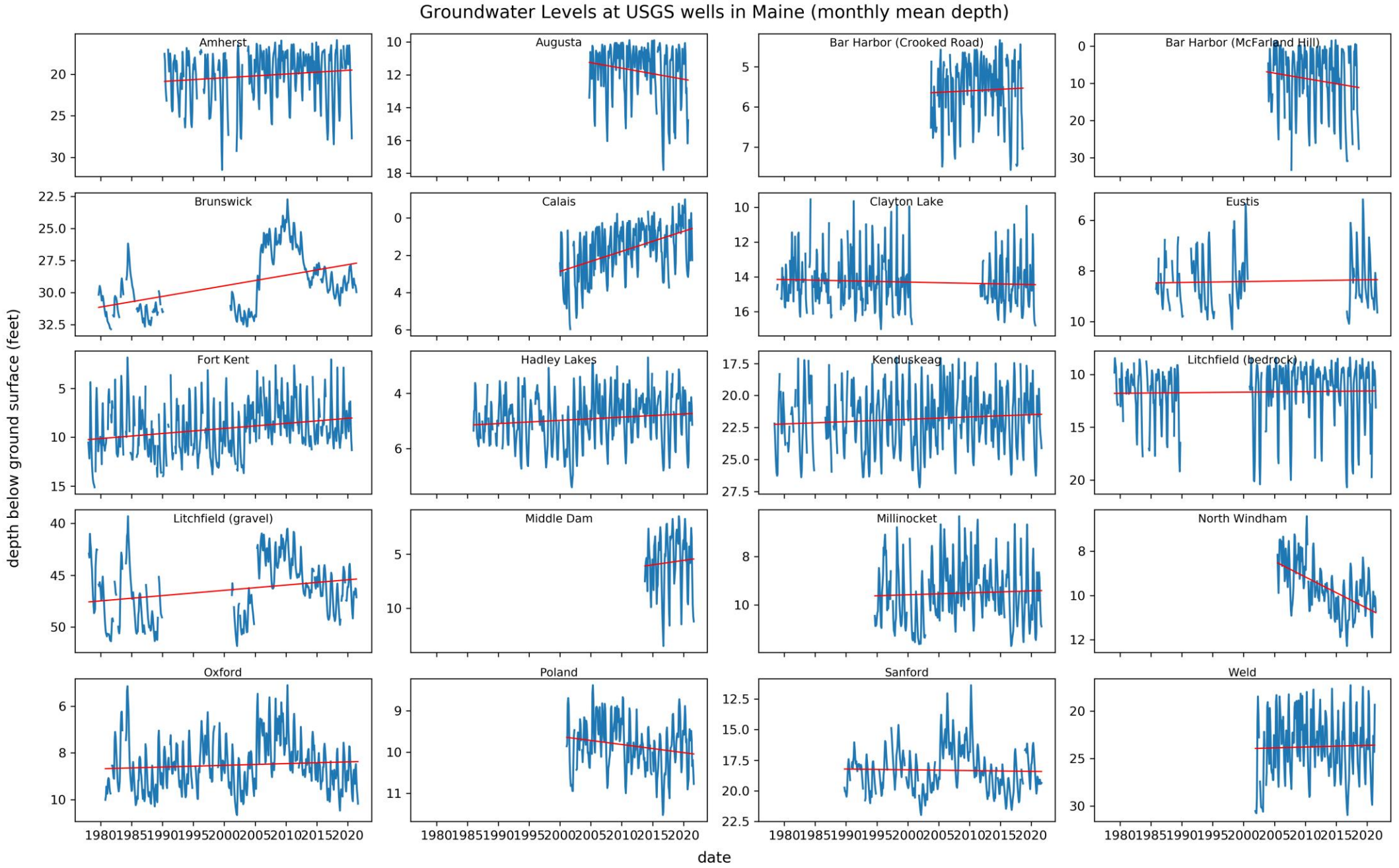
Groundwater Levels at USGS wells in Maine (monthly mean depth)
depth below ground surface (feet)
date
Amherst
Augusta
Bar Harbor (Crooked Road)
Bar Harbor (McFarland Hill)
Brunswick
Calais
Clayton Lake
Eustis
Fort Kent
Hadley Lakes
Kenduskeag
Litchfield (bedrock)
Litchfield (gravel)
Middle Dam
Millinocket
North Windham
Oxford
Poland
Sanford
Weld
1980 1985 1990 1995 2000 2005 2010 2015 2020