

Flooding in the lower Snohomish:

Sea Level Rise, Flooding, and Inundation



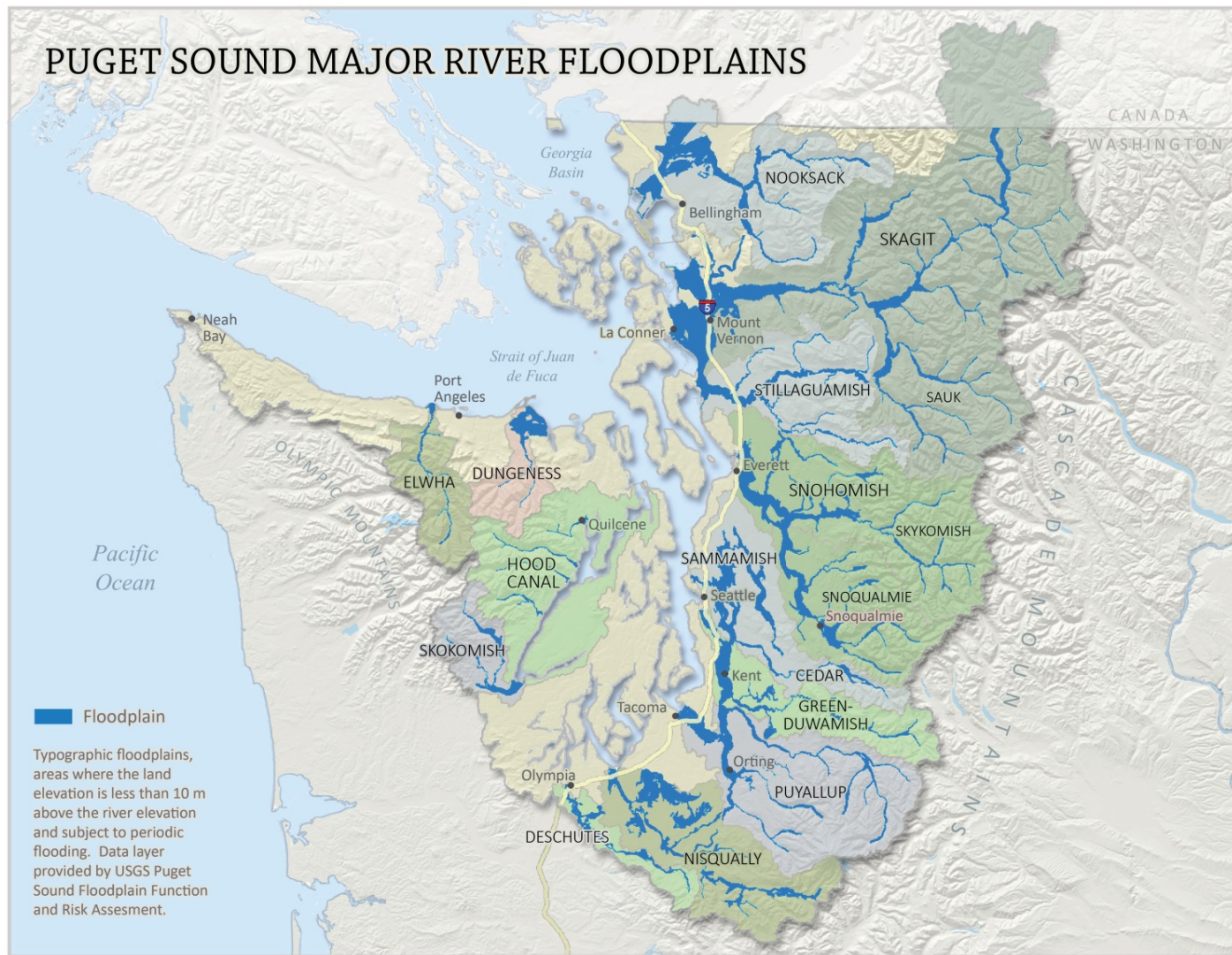
Source: WSDOT

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Se-Yeun Lee, UW SEFS
Kris Johnson, TNC
Ray Walton, WEST consultants



Climate Science in the
Public Interest

PUGET SOUND MAJOR RIVER FLOODPLAINS



Floodplains by Design

• REDUCING RISK, RESTORING RIVERS •

In the Northwest, we expect flood risk to be particularly sensitive to climate change.

Why?

- | | |
|----------------------------------|---------------------|
| <i>1. Sea Level Rise:</i> | Coastal floodplains |
| <i>2. Storms:</i> | Heavier rain events |
| <i>3. Snow:</i> | Rising snowlines |

What's missing:

1. Need to look at *inundation*: which areas are flooded?
2. Consider *combined effects* of sea level and streamflow

e.g.: Skagit River:

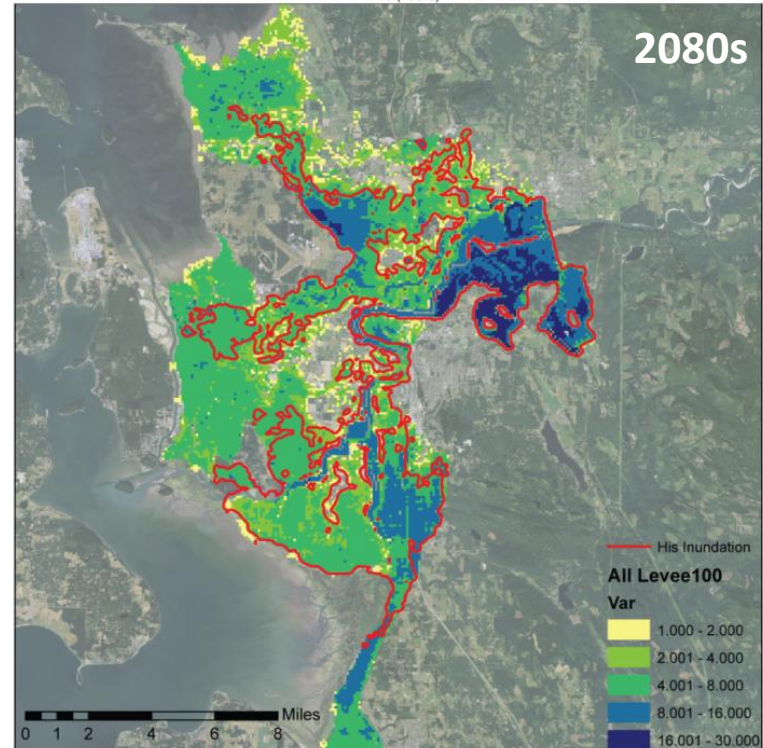
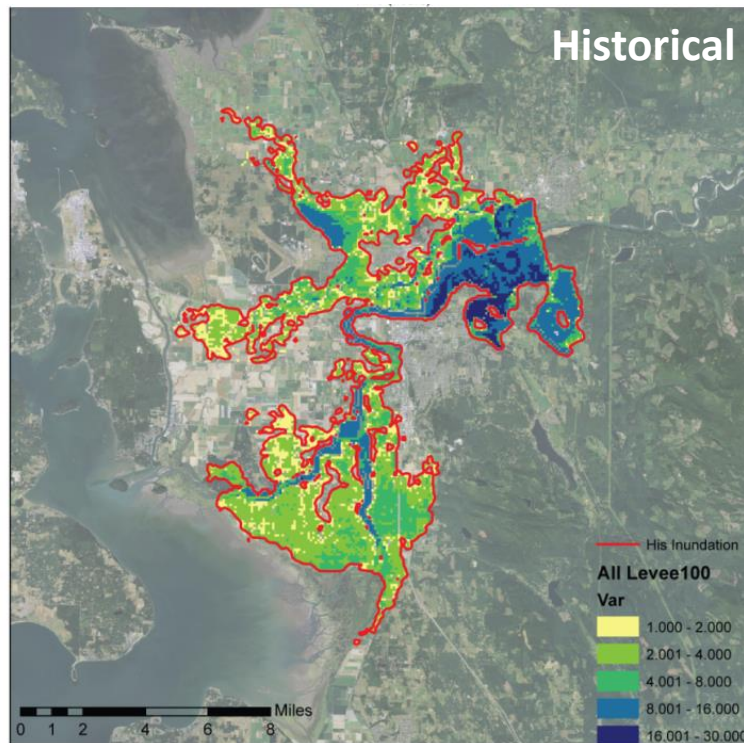
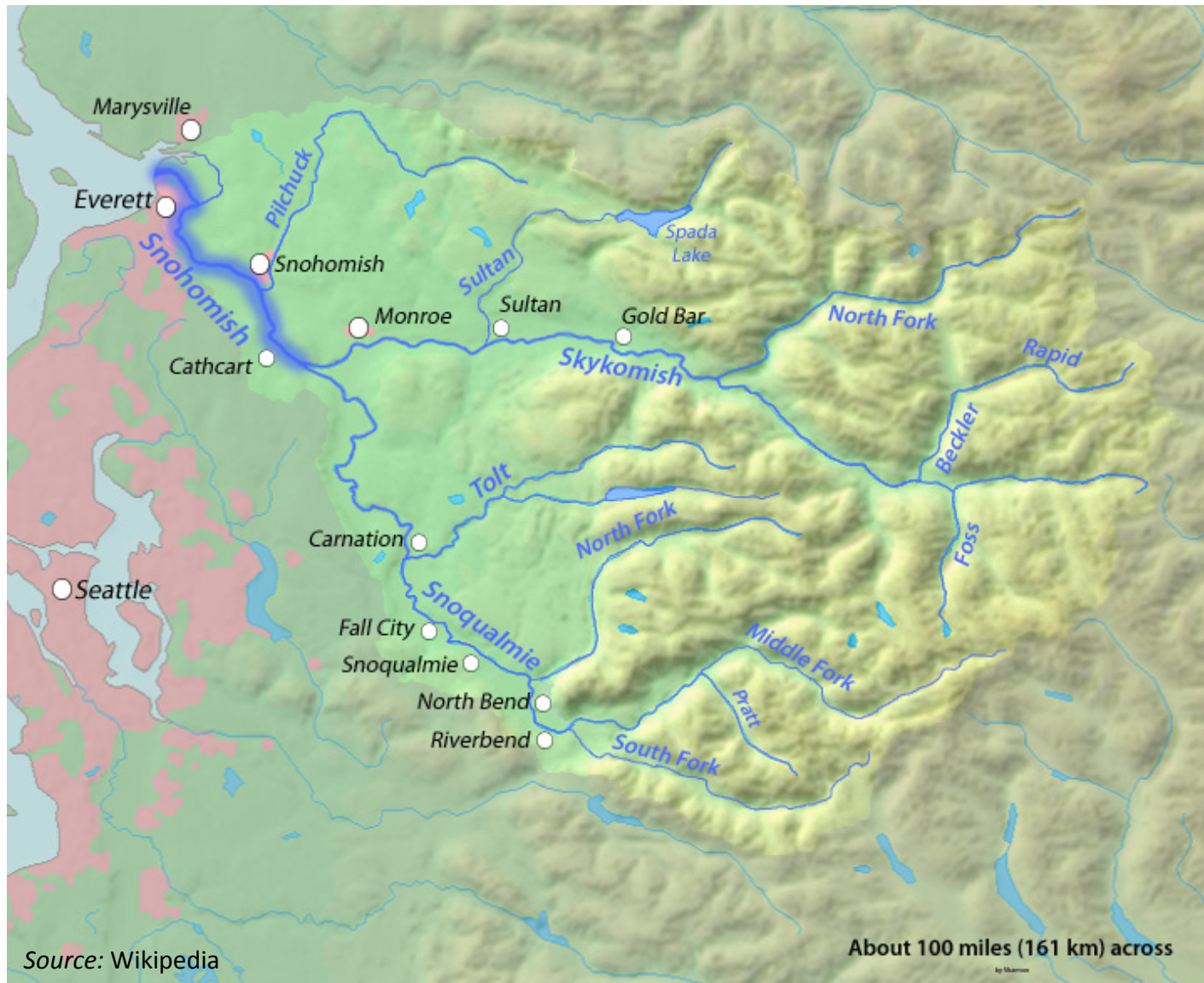


Figure Source: Joe Hamman, UW

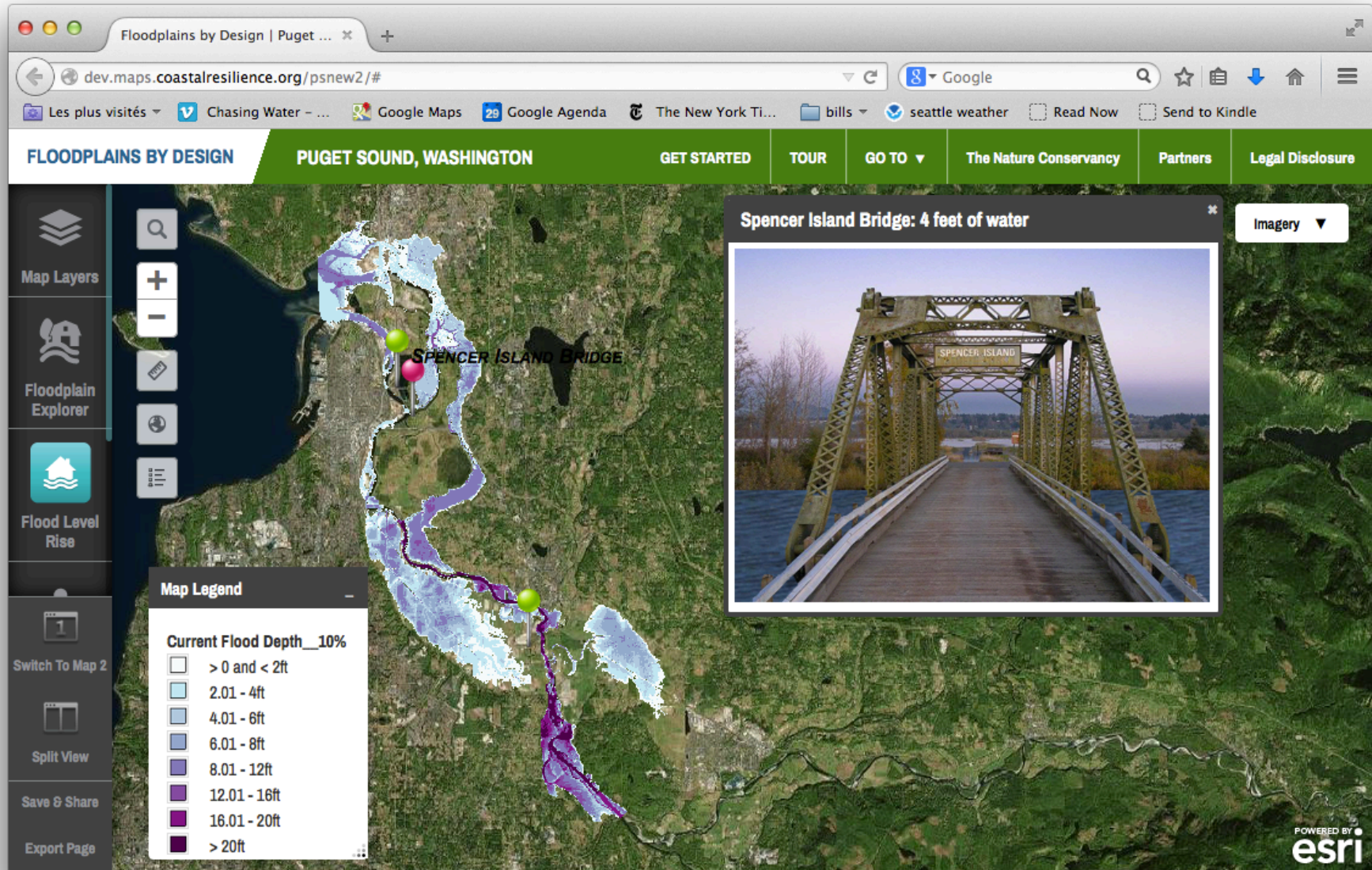
Lower Snohomish River Basin



WEST
Consultants, Inc.

Preview: Results

10-year Flood,
Historical (1980s)



www.maps.coastalresilience.org/pugetsound

Coastal Flooding =

Storm Surge +

Tides +

Waves +

Freshwater Runoff +

Sea Level Rise



Storm Surge

Storm Surge, Seattle (peak annual, rel. to MHHW)

10-year	+24 inches
100-year	+32 inches

← Highly correlated with
Everett gauge ($r^2 = 0.98$)

Based on the “skew surge,”
estimated using observed and
predicted tides from Seattle

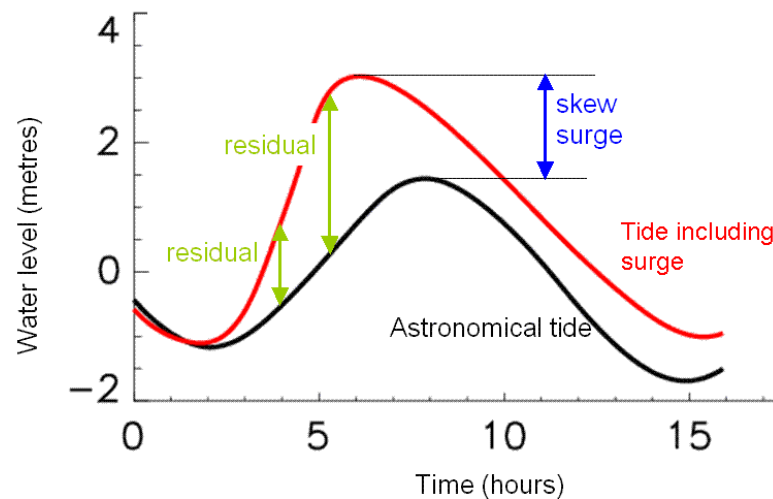


Figure Source: McMillan et al., 2011

Coastal Flooding =
Storm Surge* +
Tides +
Waves +
Freshwater Runoff +
Sea Level Rise

**Current projections do not show a change in storm surge*

Coastal Flooding =

Storm Surge +

Tides +

~~Waves +~~ (sheltered by Whidbey Island to the West)

Freshwater Runoff +

Sea Level Rise

Coastal Flooding =

Storm Surge +

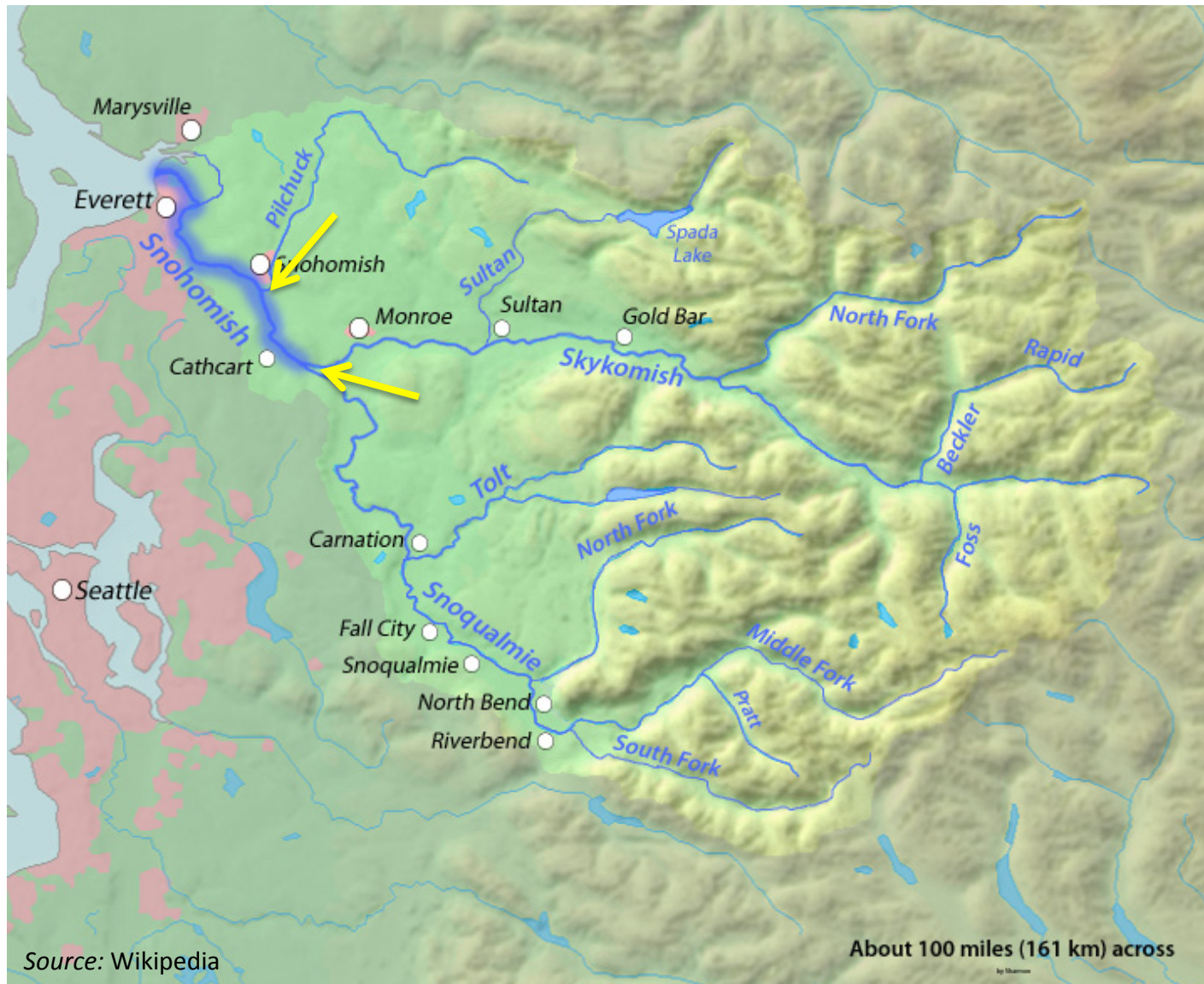
Tides +

Waves +

Freshwater Runoff +

Sea Level Rise

Lower Snohomish River Basin



Peak streamflow projections

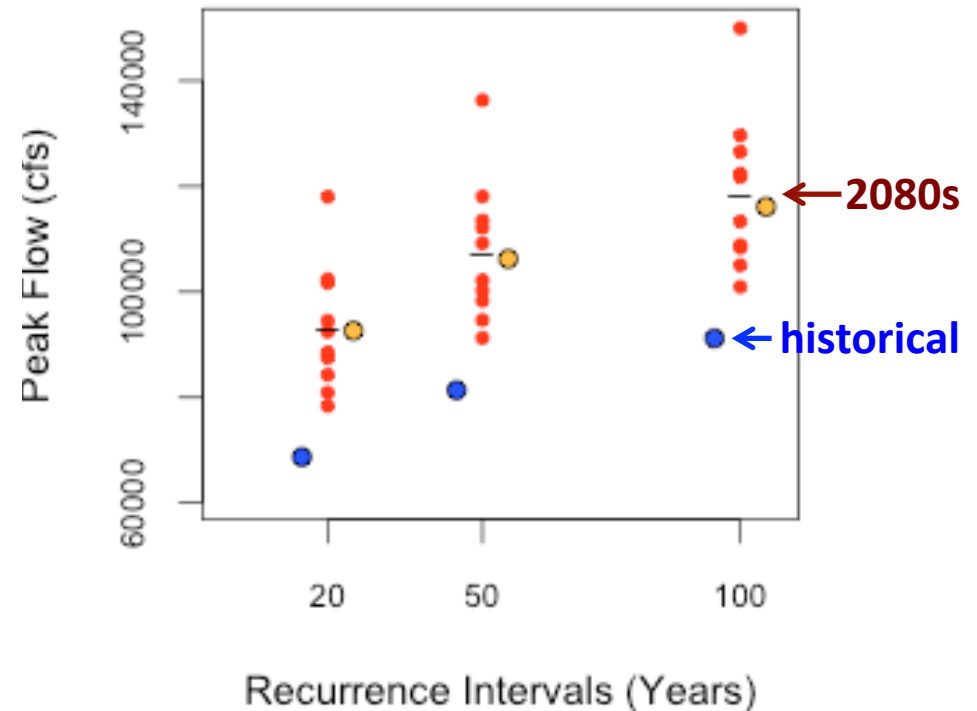


By the 2080s, the historical 100-year event is projected to occur every 30 years.



<http://warm.atmos.washington.edu/2860/>

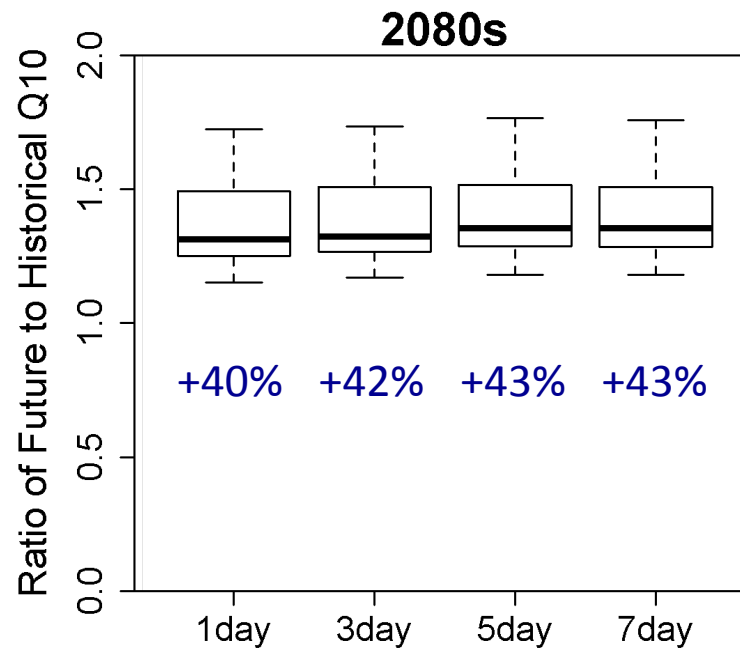
**Change in Peak Streamflow
Snohomish at Monroe**



Supported by Ecology (HB2860), BPA, NWPCC, ODWR, BC Ministry of Enviro

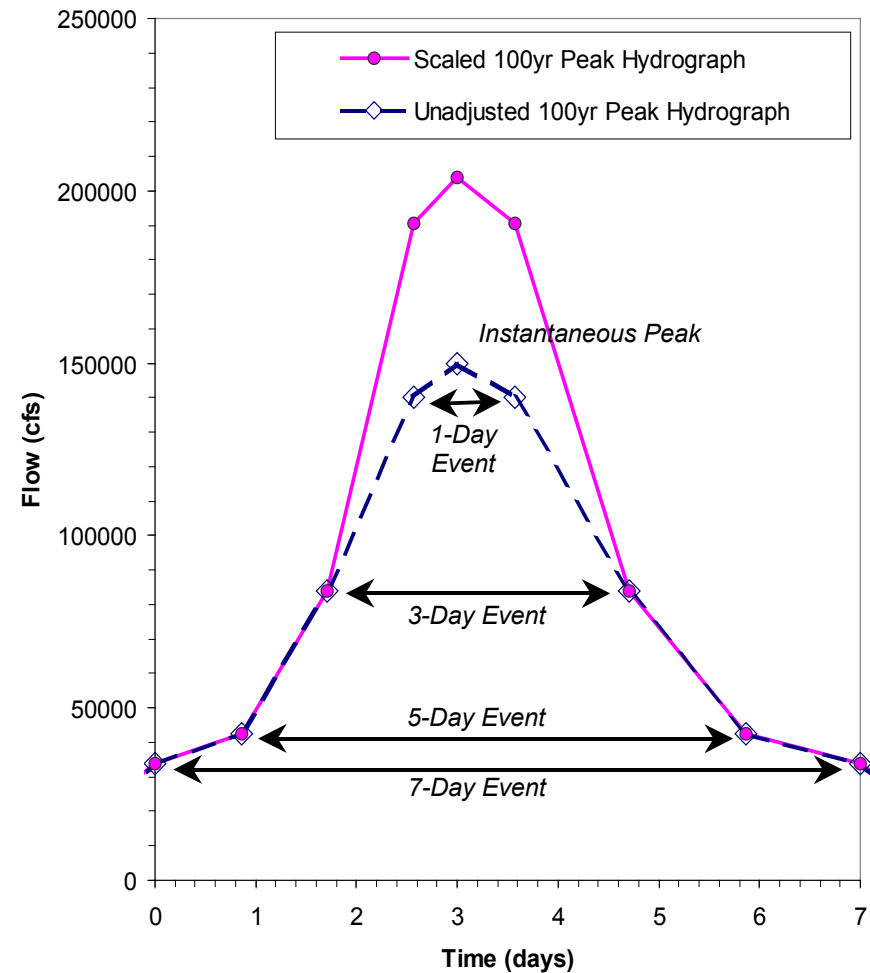
Synthetic peak flow hydrograph

e.g.: 10-year event,
Snohomish R. at Monroe:



Pilchuck:

+25% +25% +24% +24%



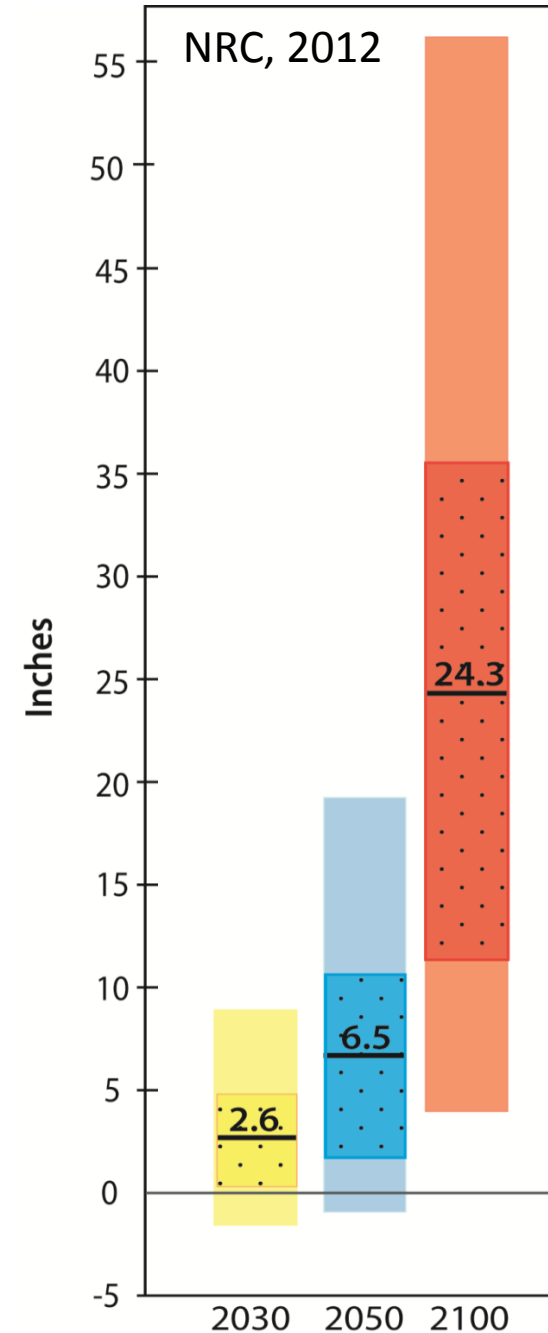
Source: Snohomish County, Restudy Flood Insurance Study, 2001

Coastal Flooding =
Storm Surge +
Tides +
Waves +
Freshwater Runoff +
Sea Level Rise

Sea Level Rise

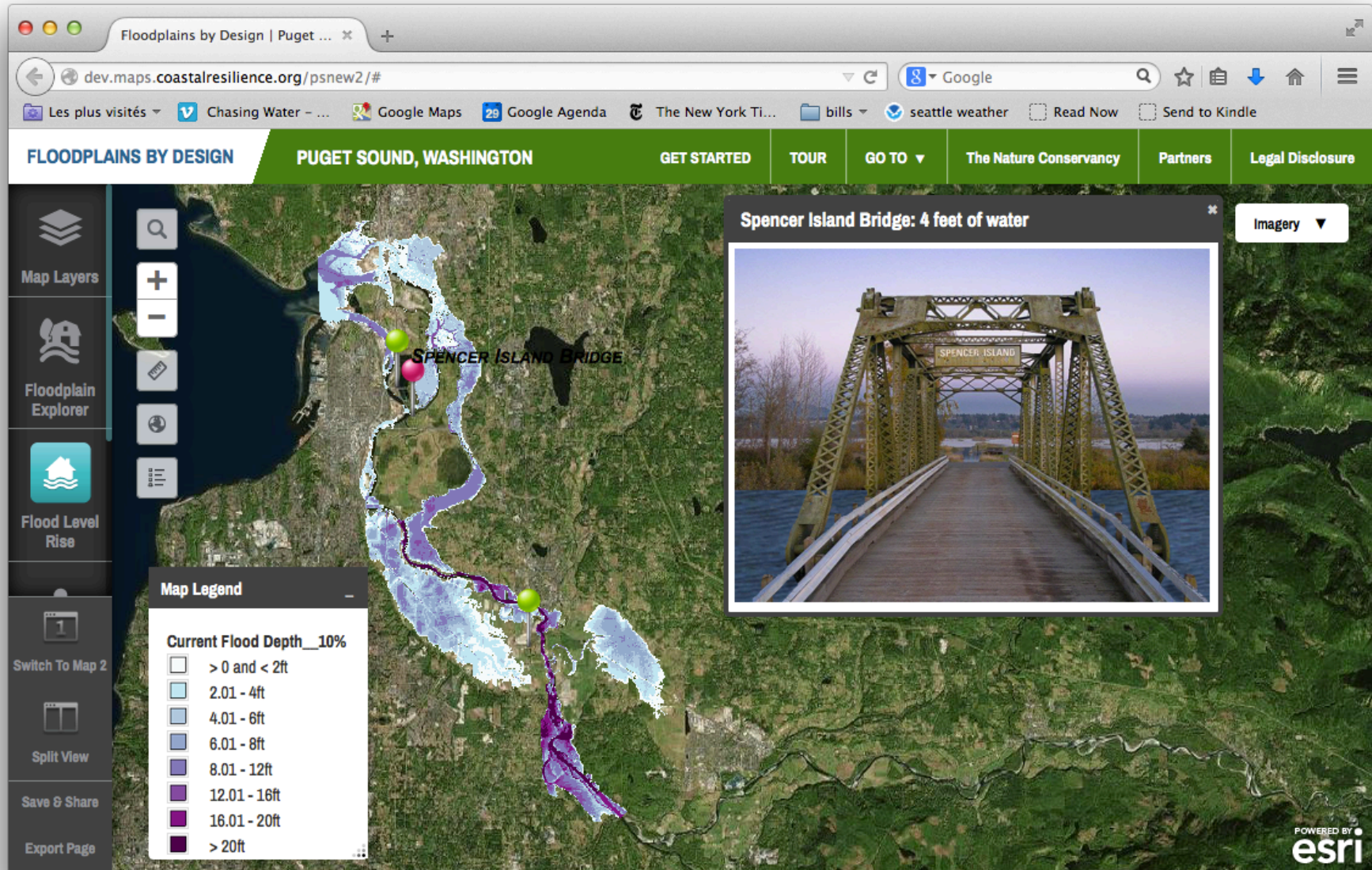
<i>Projected Range, Snohomish</i> <i>Relative to 2000 (NRC, 2012)</i>	
2040s	+5.5 to +9.1 inches
2080s	+13.2 to +25.3 inches

*Based on estimated subsidence rate of
1 mm/yr for Anacortes, WA (NRC 2012)*



Results

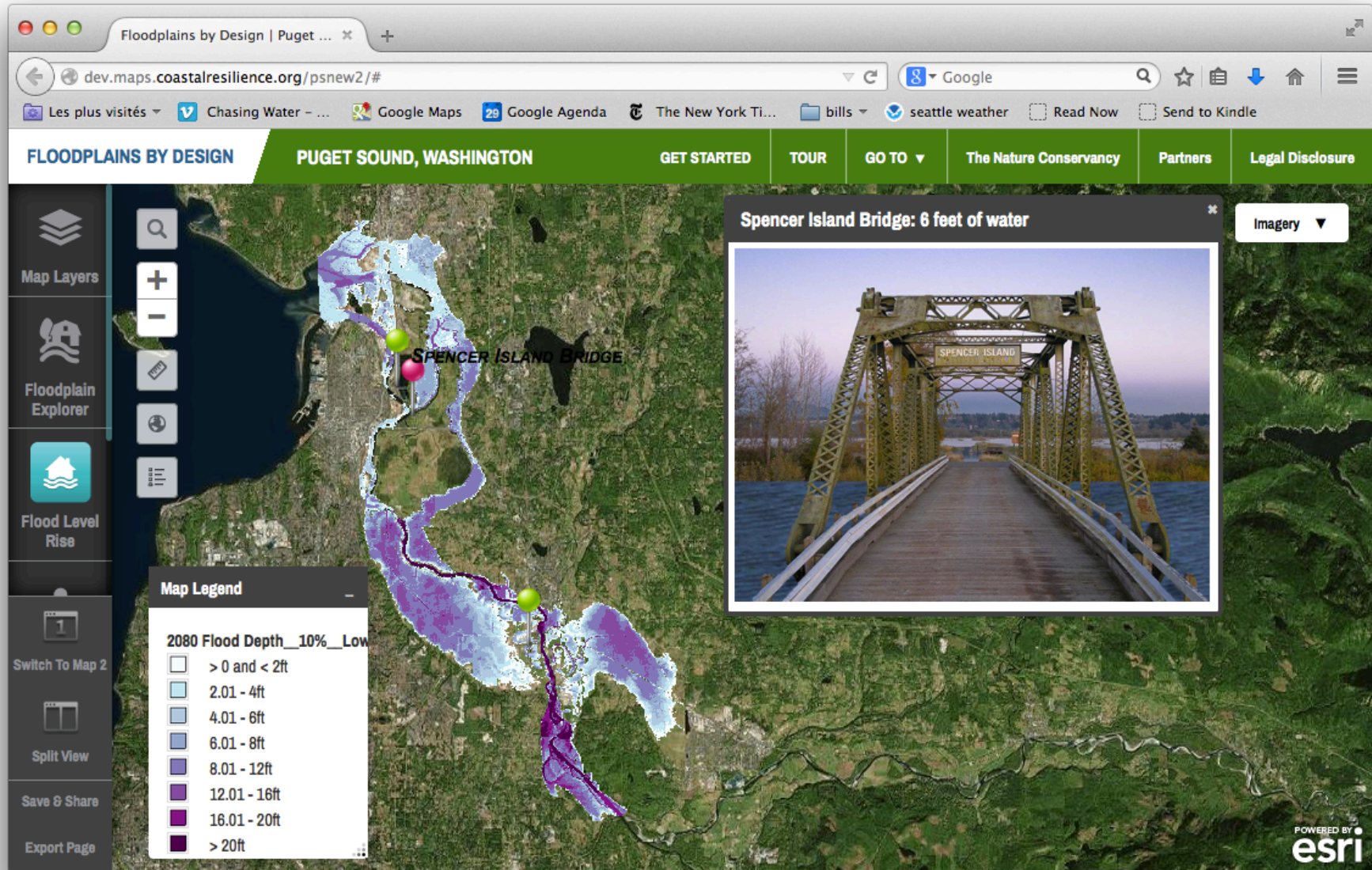
10-year Flood, Historical (1980s)



www.maps.coastalresilience.org/pugetsound

Results

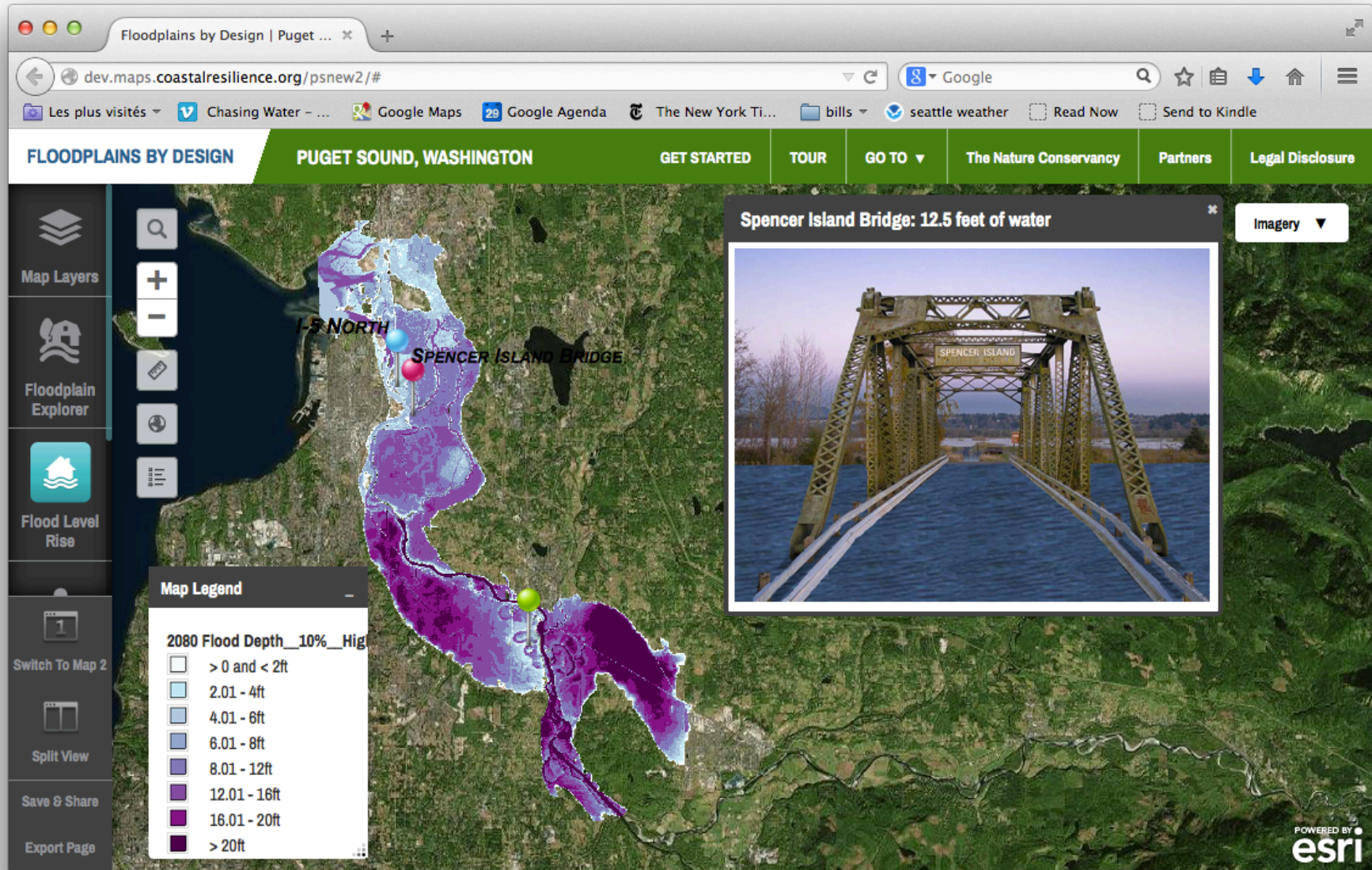
10-year Flood,
A1b 2080s, Low



www.maps.coastalresilience.org/pugetsound

Results

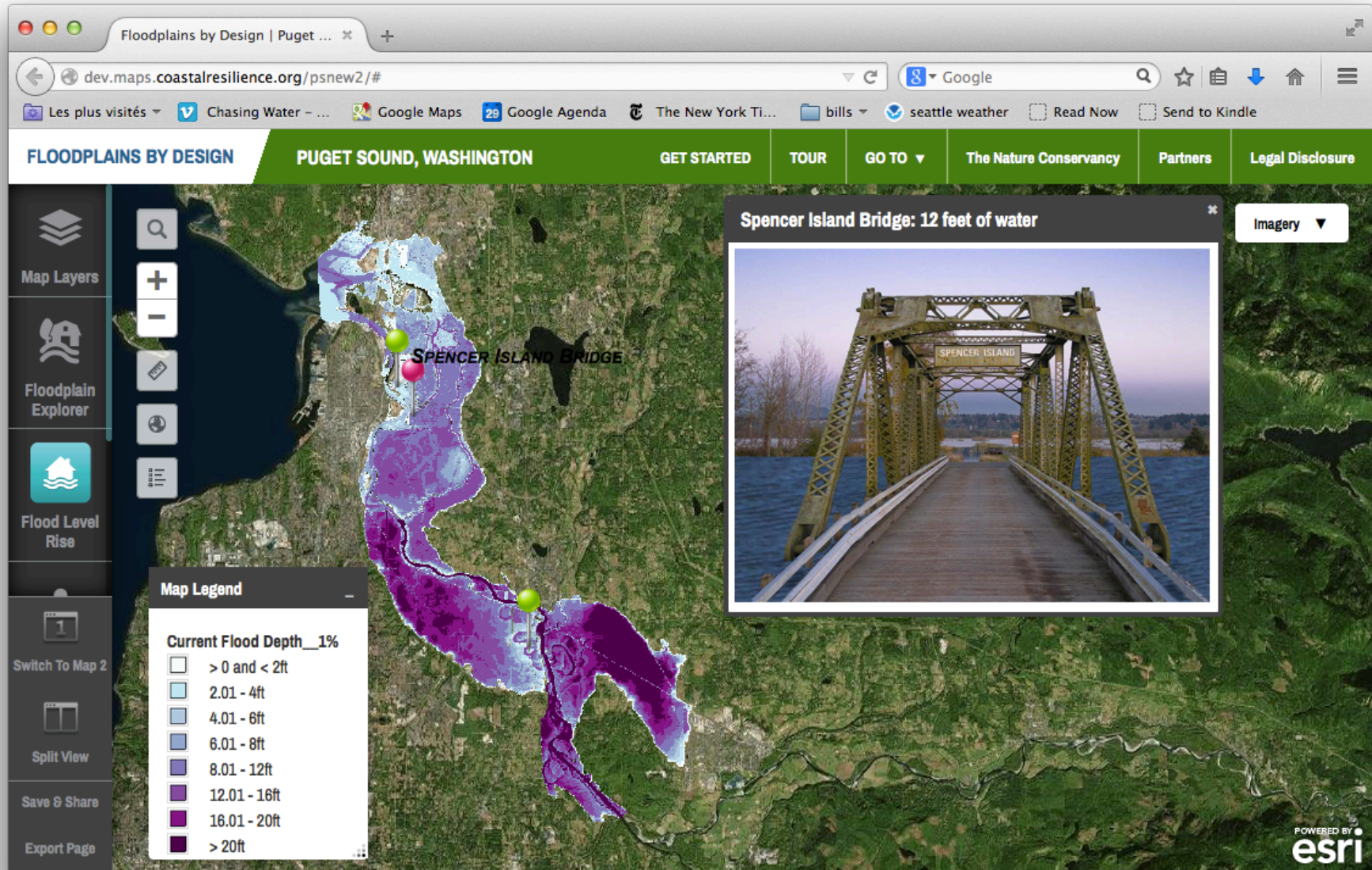
10-year Flood,
A1b 2080s, High



www.maps.coastalresilience.org/pugetsound

Results

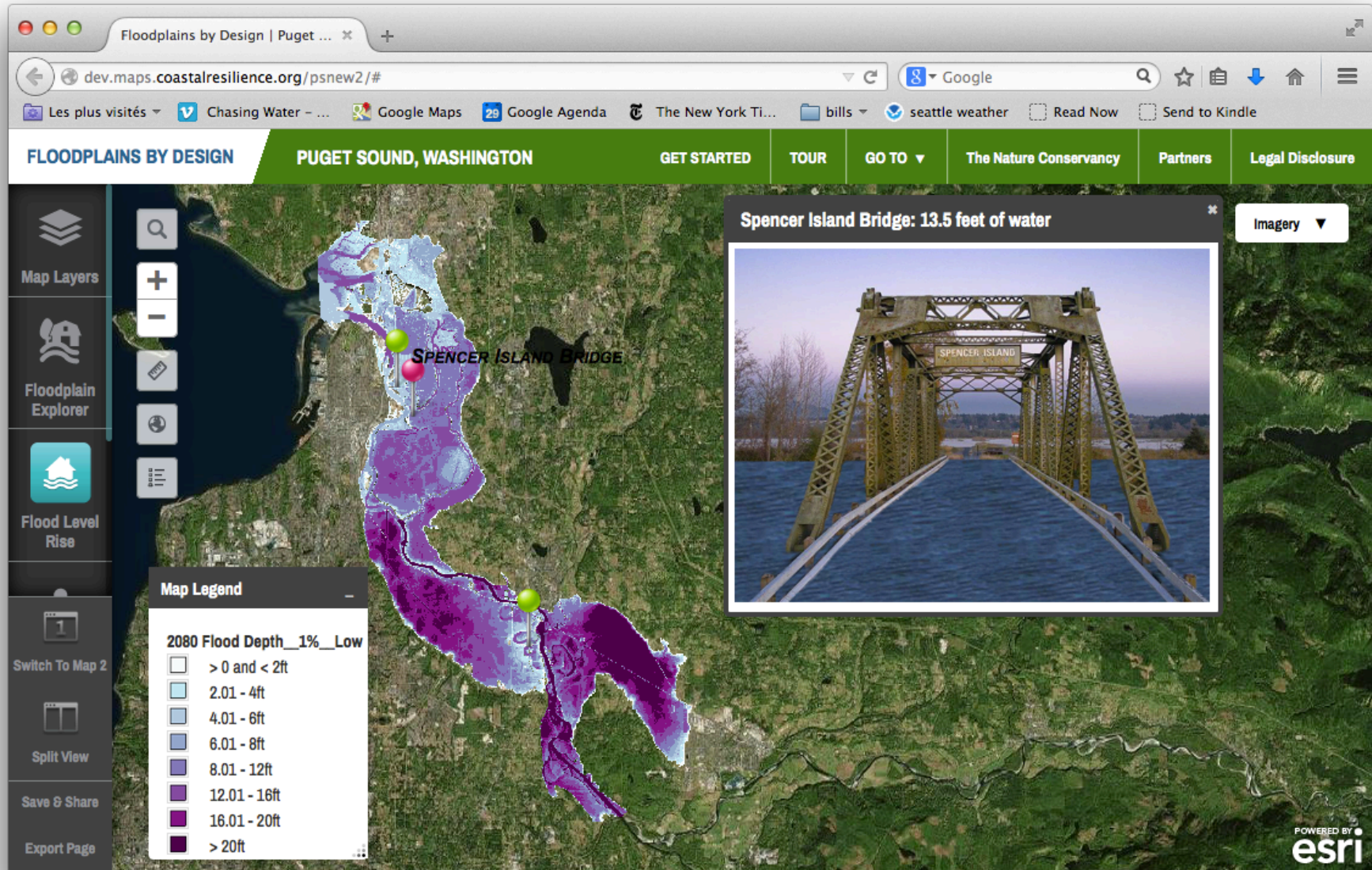
100-year Flood, Historical (1980s)



www.maps.coastalresilience.org/pugetsound

Results

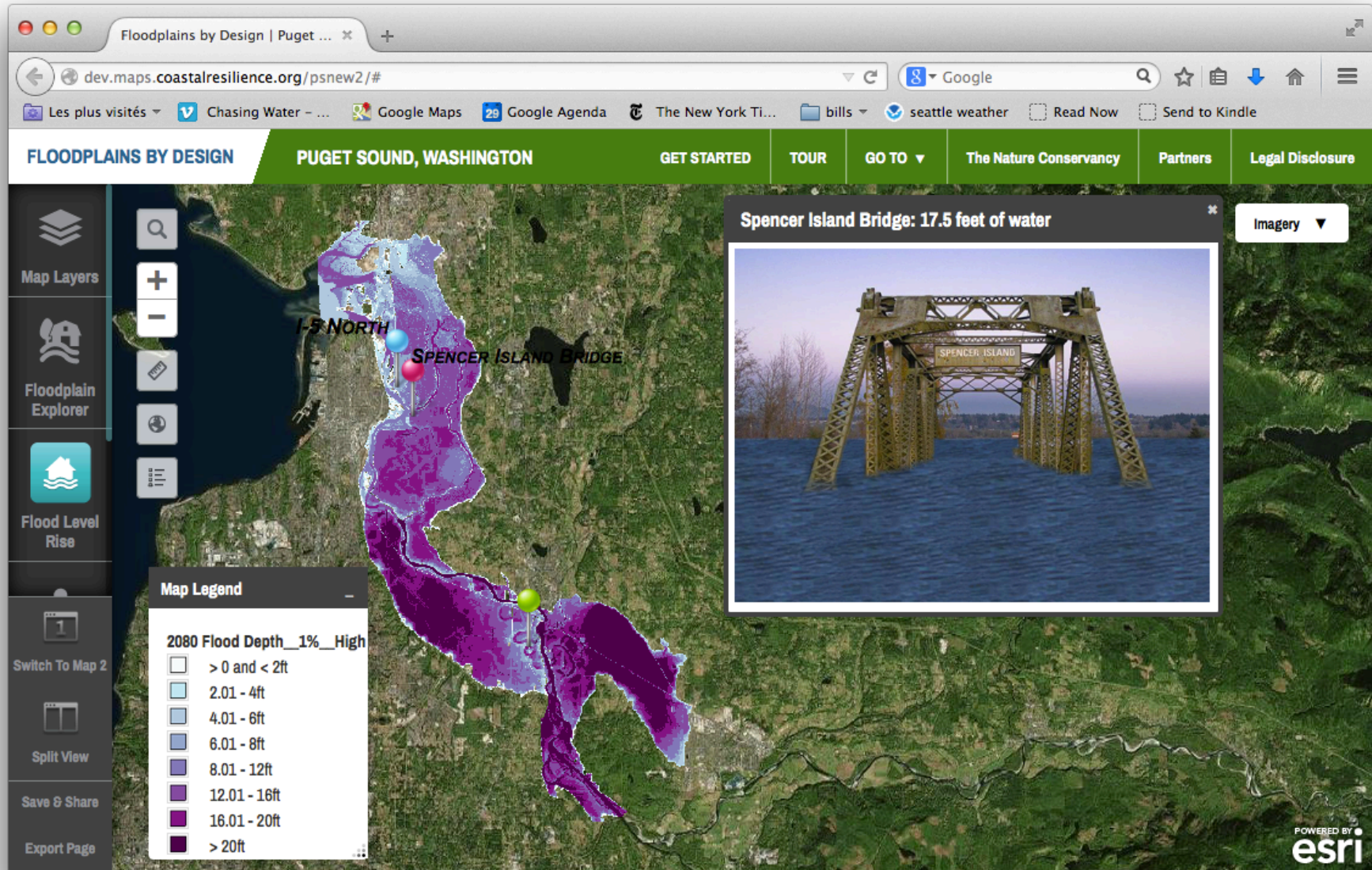
100-year Flood,
A1b 2080s, Low



www.maps.coastalresilience.org/pugetsound

Results

100-year Flood,
A1b 2080s, High



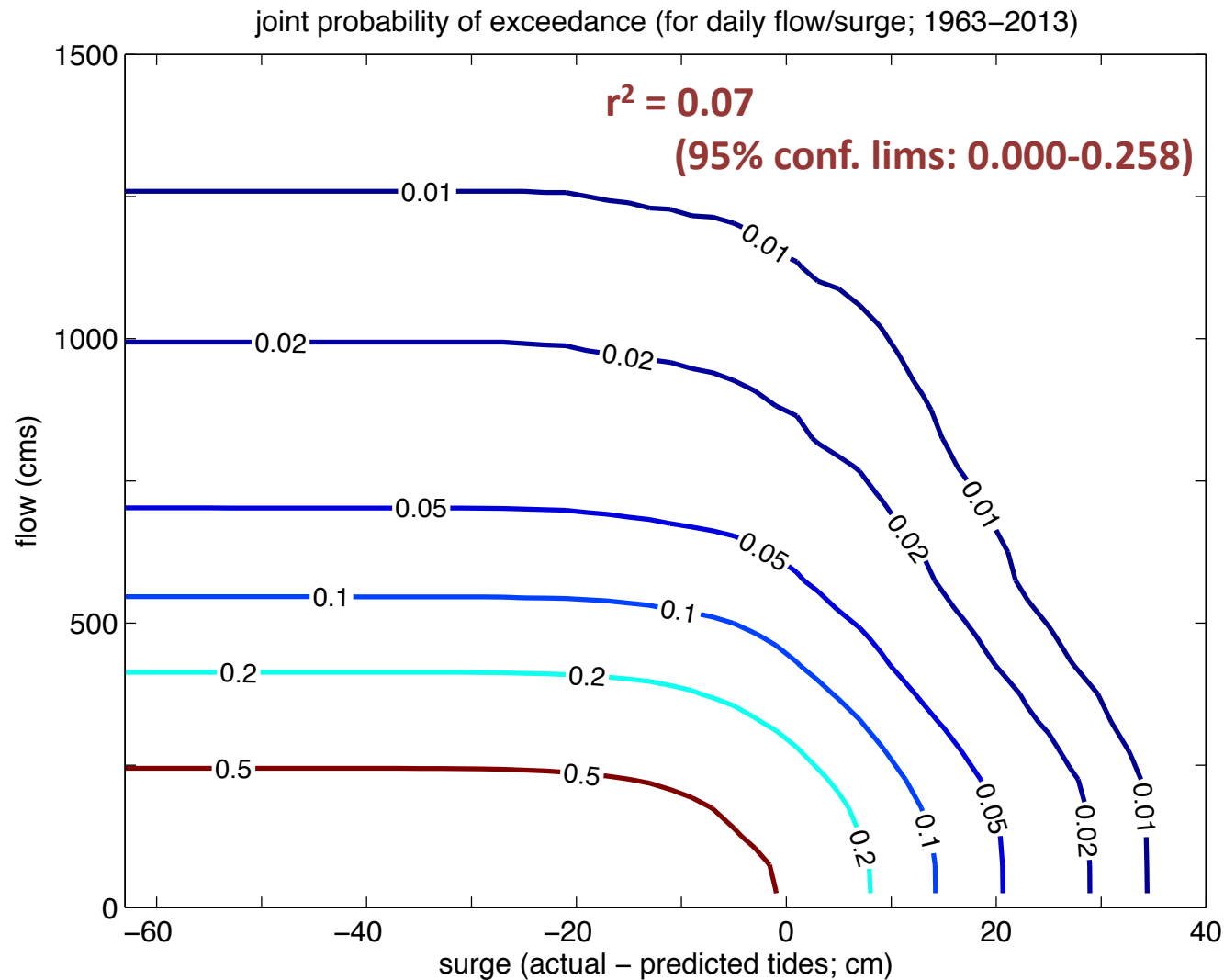
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*Climate Science in the
Public Interest*

UW Climate Impacts Group
www.cses.washington.edu/cig

Surge and Peak Streamflow are *uncorrelated* in the Snohomish

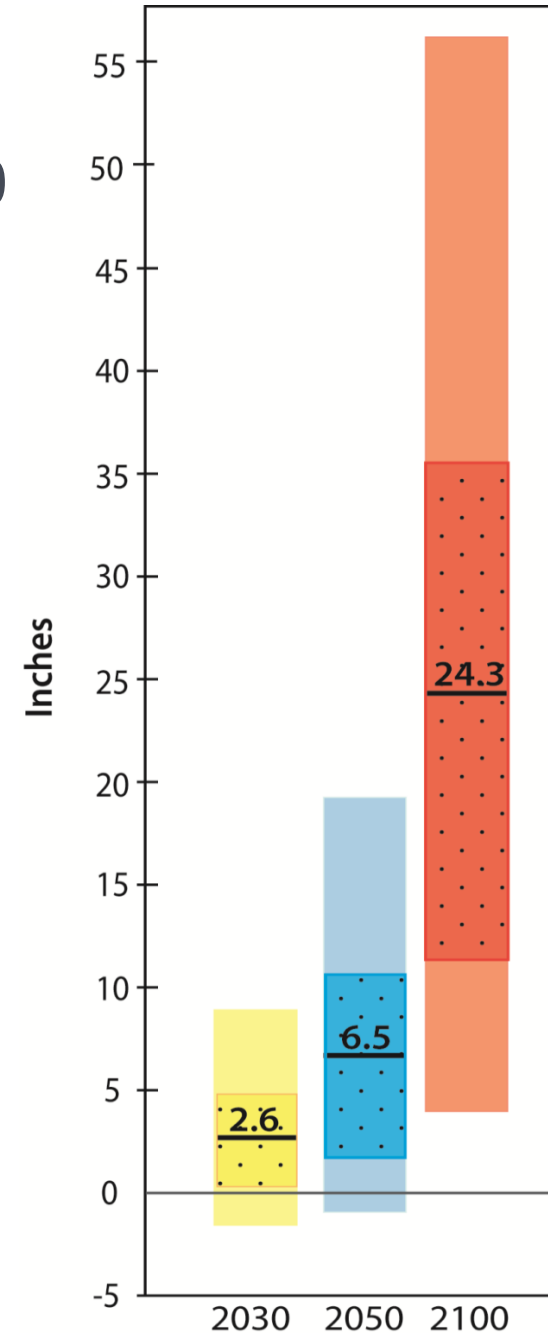




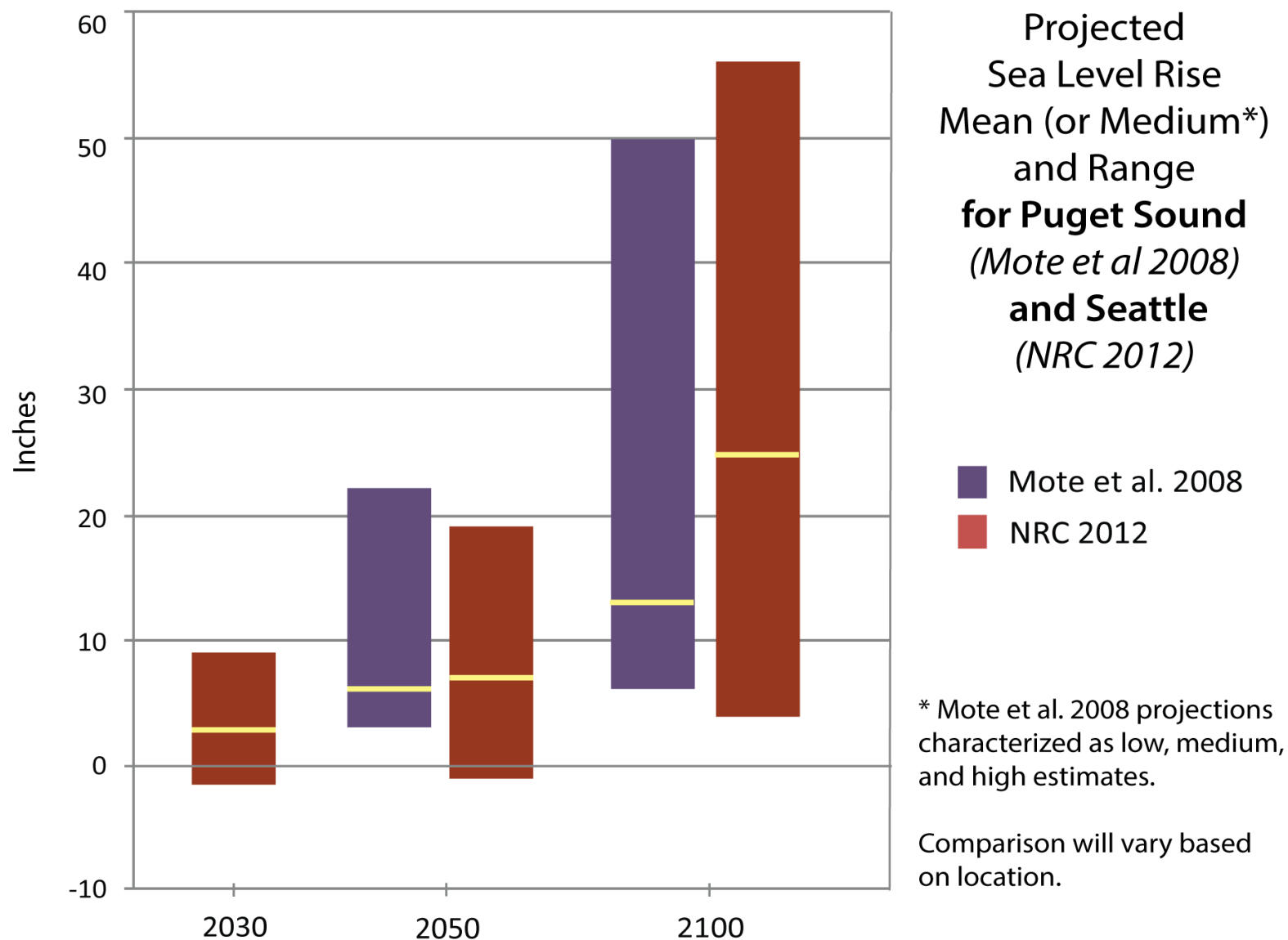
1. Sea Level Rise:

Projected in All Scenarios by 2100

<i>Projected Range, Seattle</i> <i>Relative to 2000 (NRC 2012)</i>	
2030	-1.5 to +8.8 inches
2050	-1.0 to +18.8 inches
2100	+3.9 to +56.3 inches

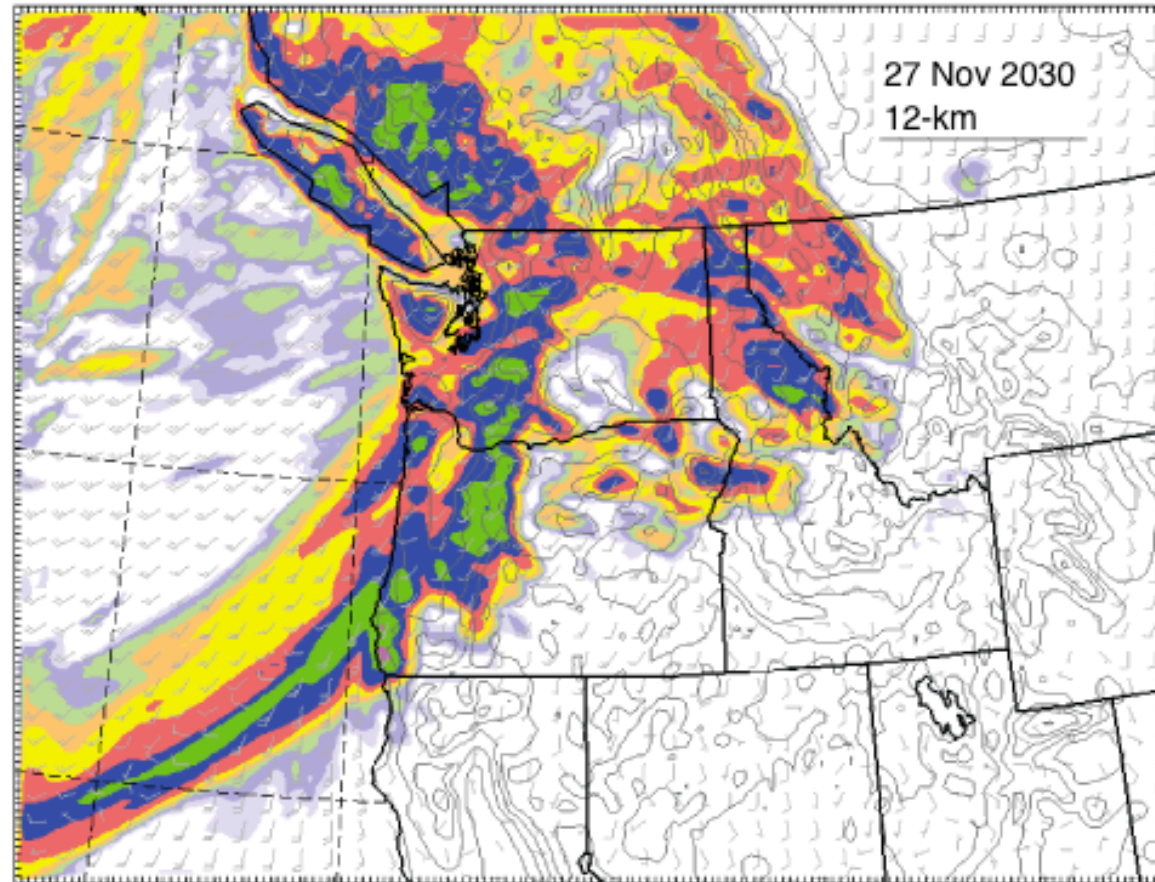


NRC 2012 vs. Mote et al. 2008



2. Storms:

There is growing evidence that the frequency and intensity of severe storms will increase.



Simulated future storm from the WRF regional model.

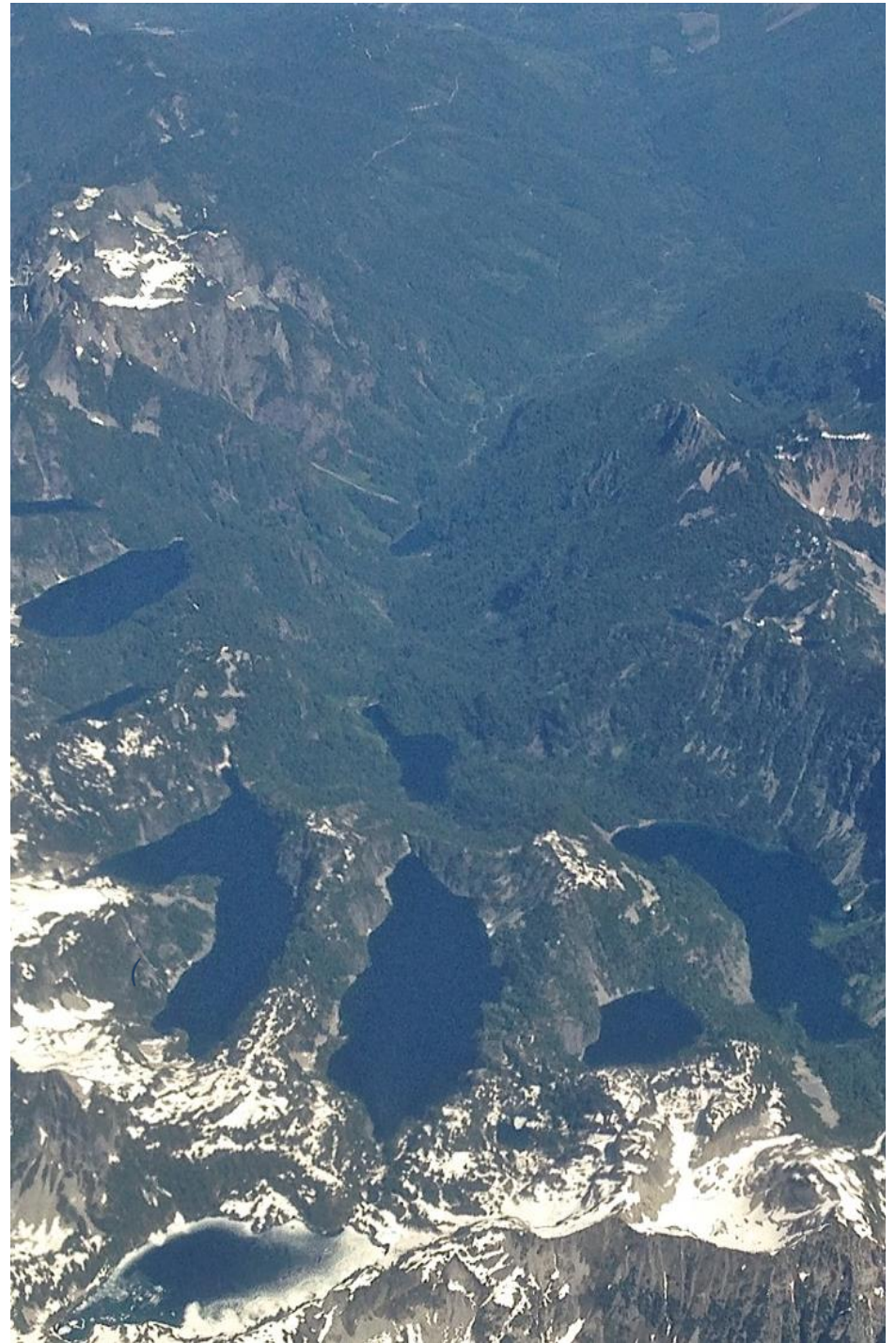
Salathé et al., in press, 2014

3. *Snow:*

Our primary mechanism
for storing water – snow
– is sensitive to
warming.

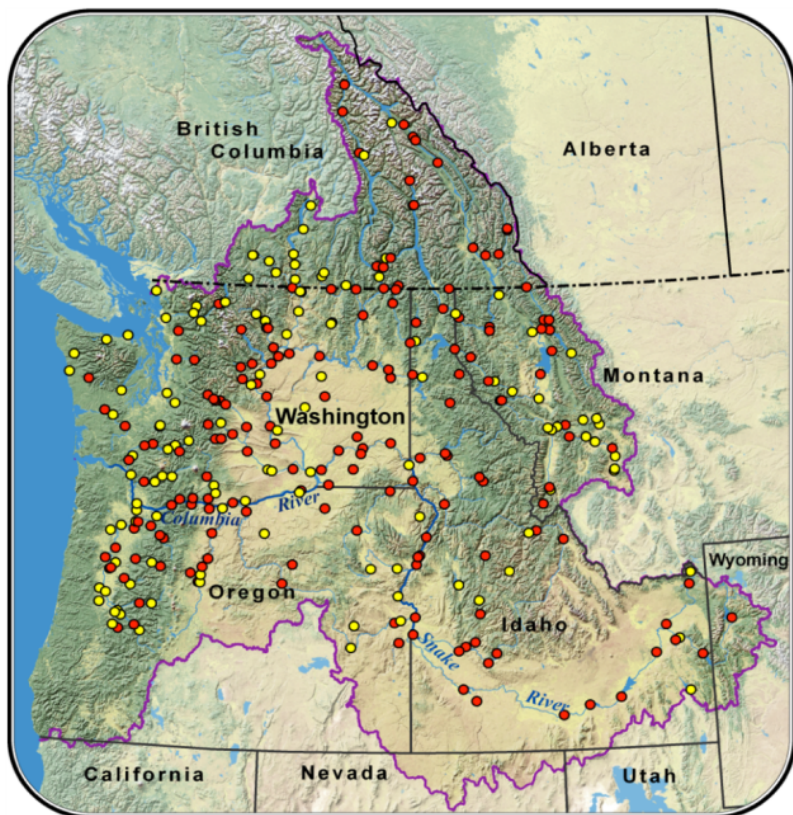
The Cascade and Olympic
Mountains have the highest
fraction of “warm snow”
(snow falling between 27-32°F)
in the continental U.S.

(Mote et al. 2008)



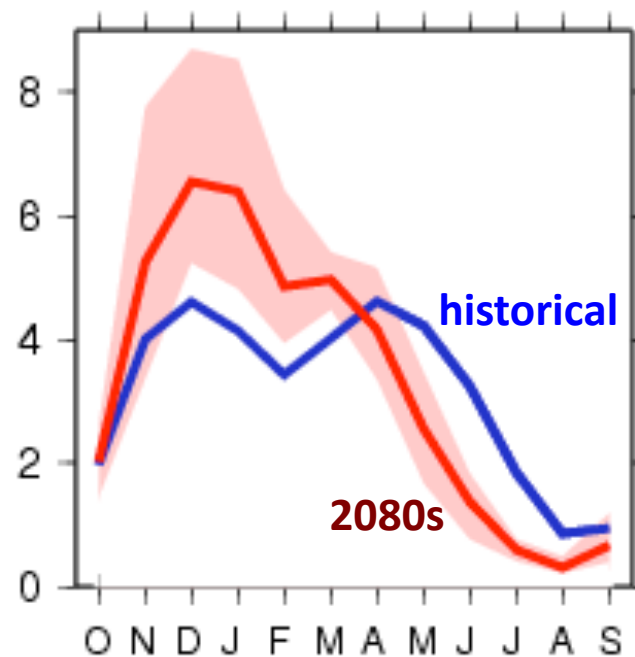


Higher peak streamflow



<http://warm.atmos.washington.edu/2860/>

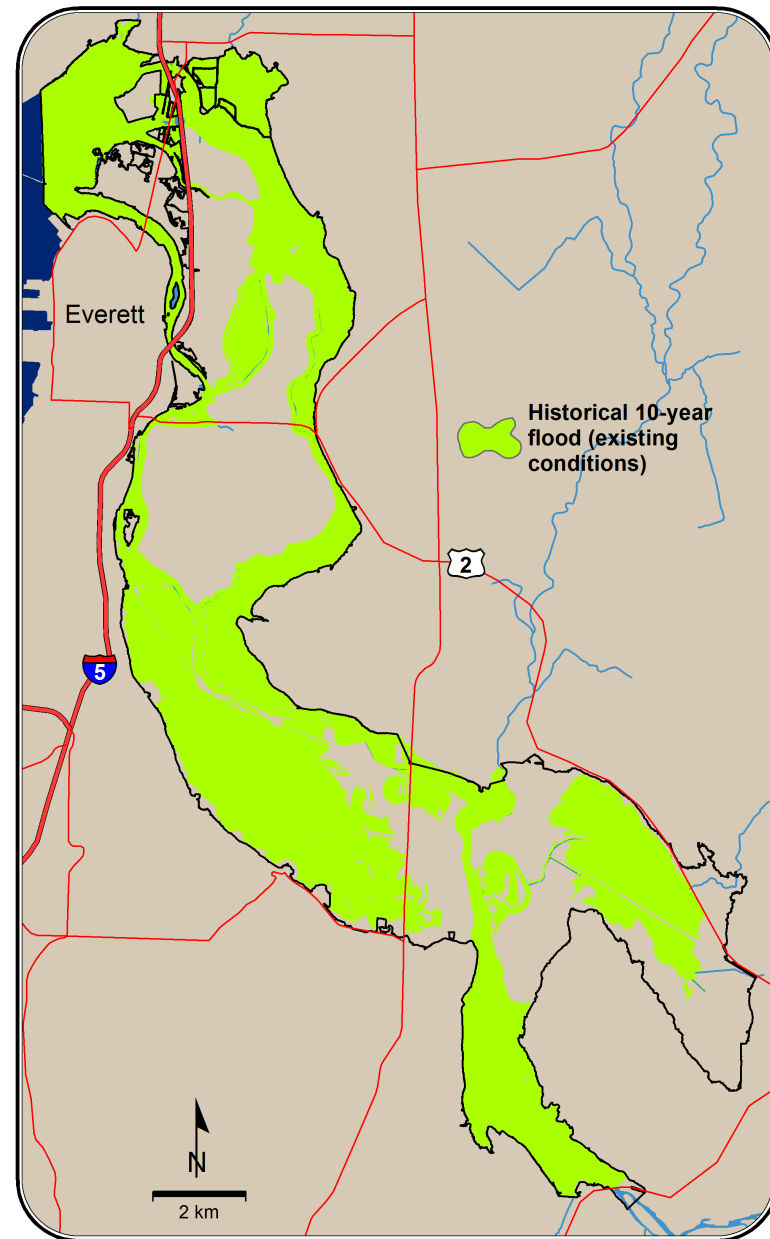
***Change in Monthly Streamflow
Snohomish at Monroe***



Supported by Ecology (HB2860), BPA, NWPCC, ODWR, BC Ministry of Enviro

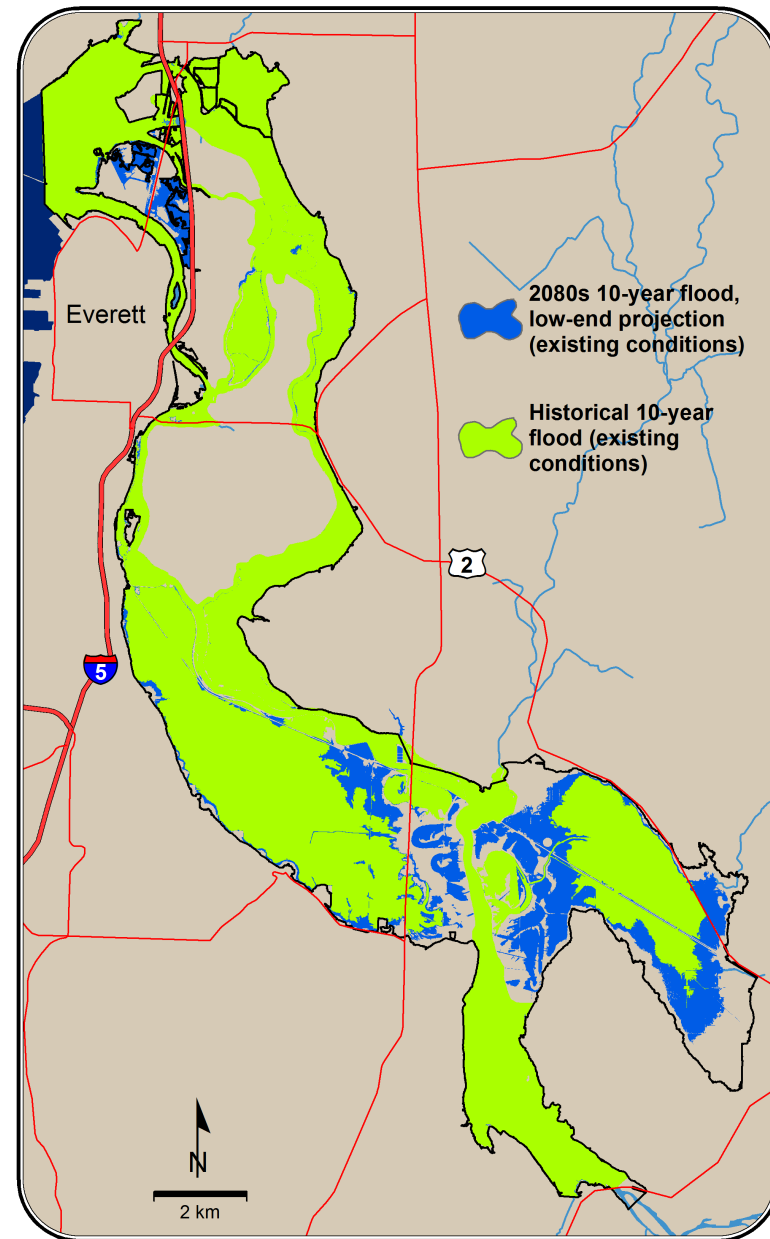
Flooded Area

10-year Flood
Historical (1980s)



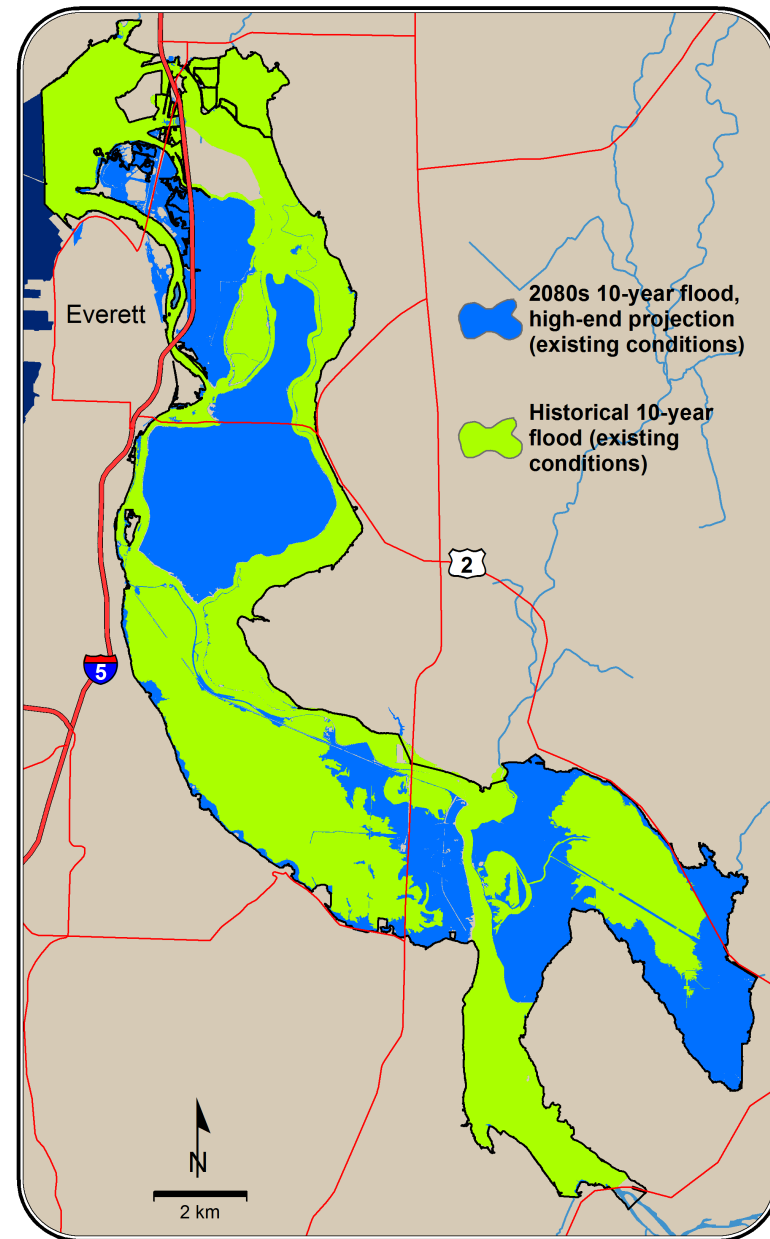
Flooded Area

10-year Flood
2080s, Low



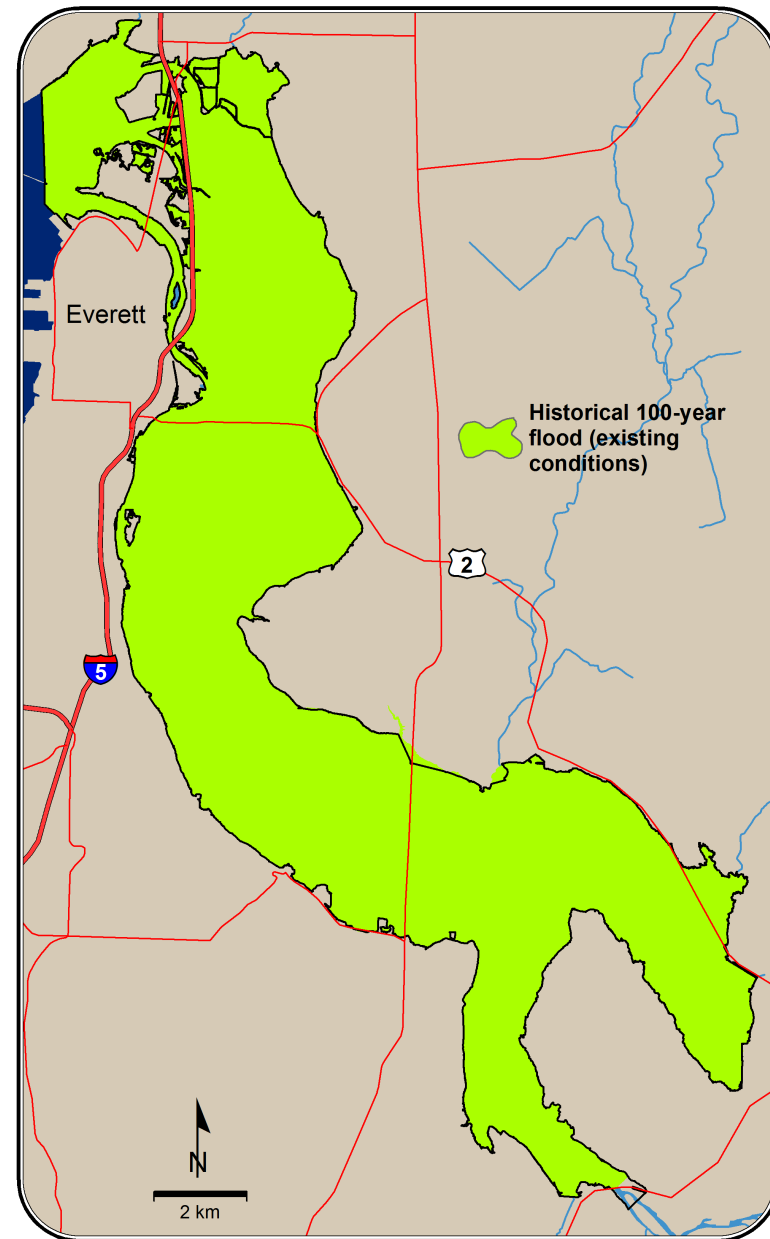
Flooded Area

10-year Flood
Historical



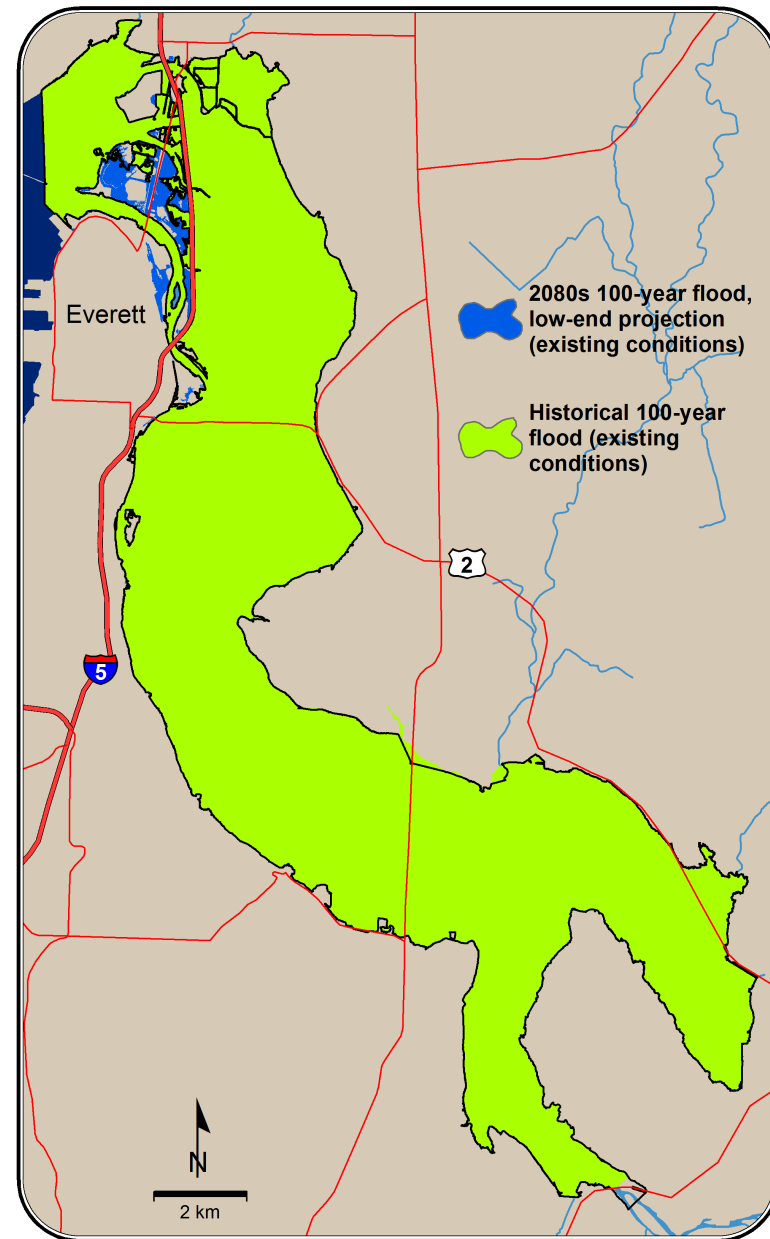
Flooded Area

100-year Flood
Historical (1980s)



Flooded Area

100-year Flood
2080s, Low



Flooded Area

100-year Flood
Historical

