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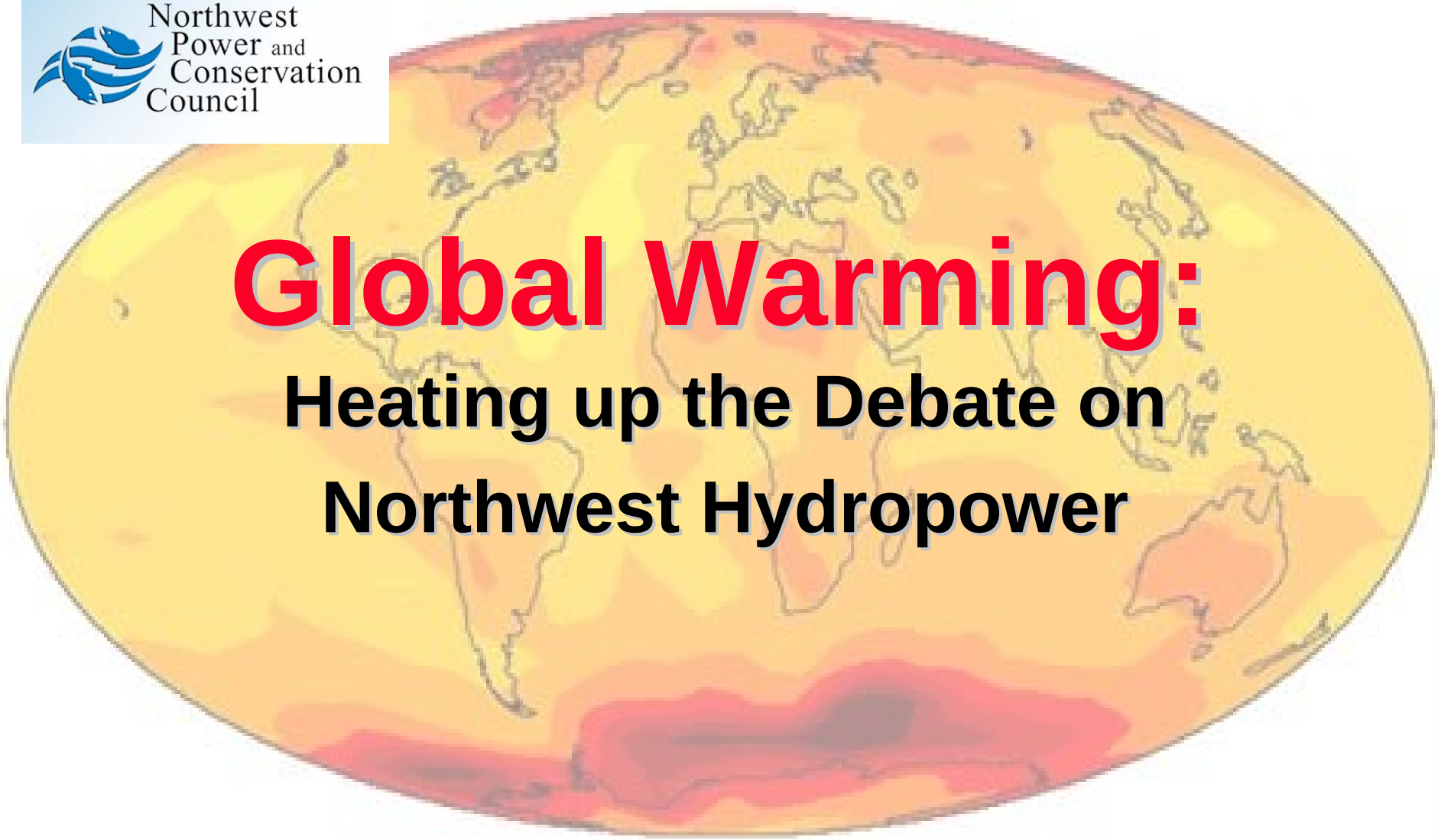


Global Warming:

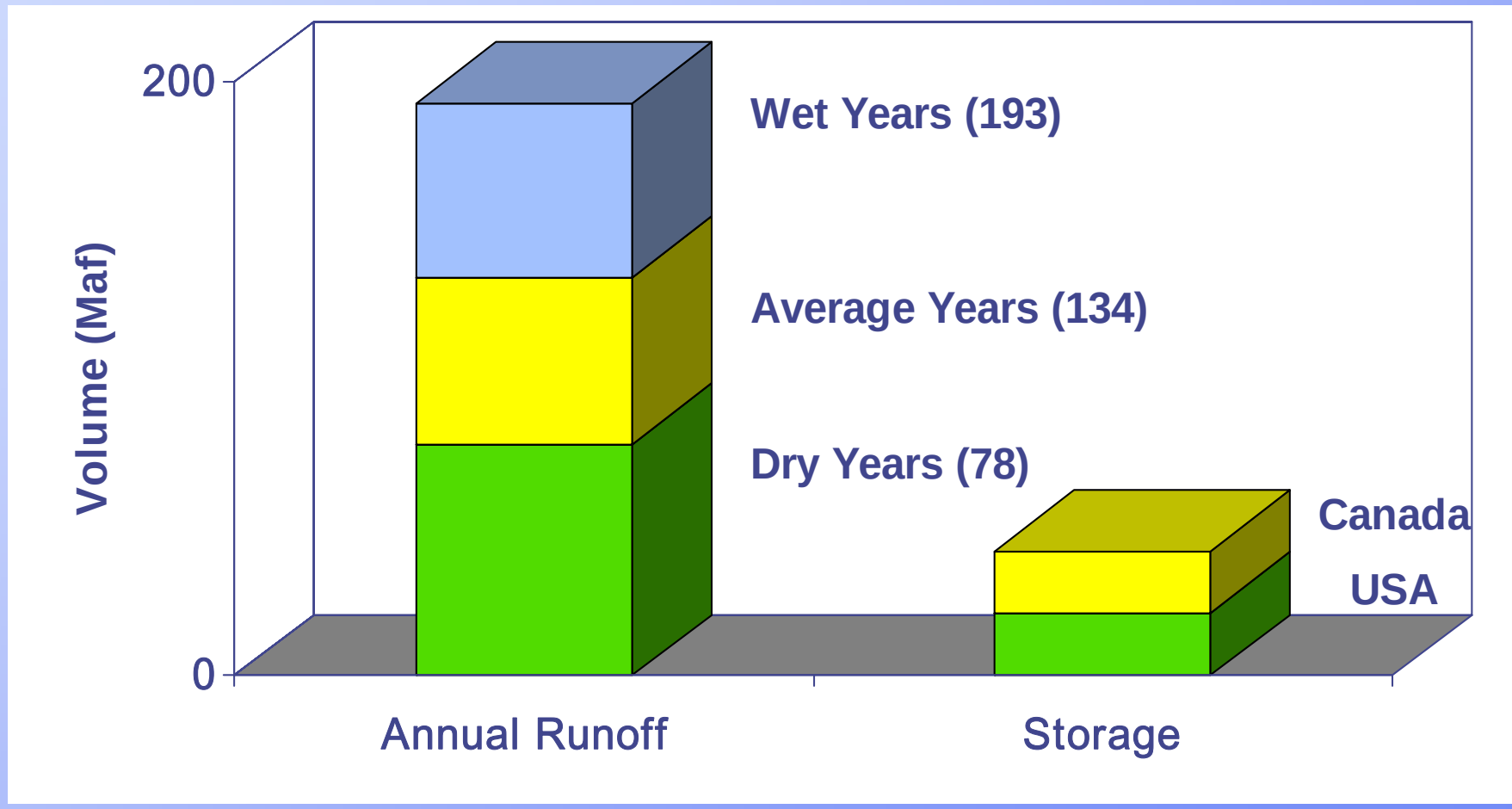
Heating up the Debate on Northwest Hydropower

October 27th 2005

Seattle, Washington

Columbia River Hydroelectric System

Reservoirs hold 30% of the Average Runoff Volume



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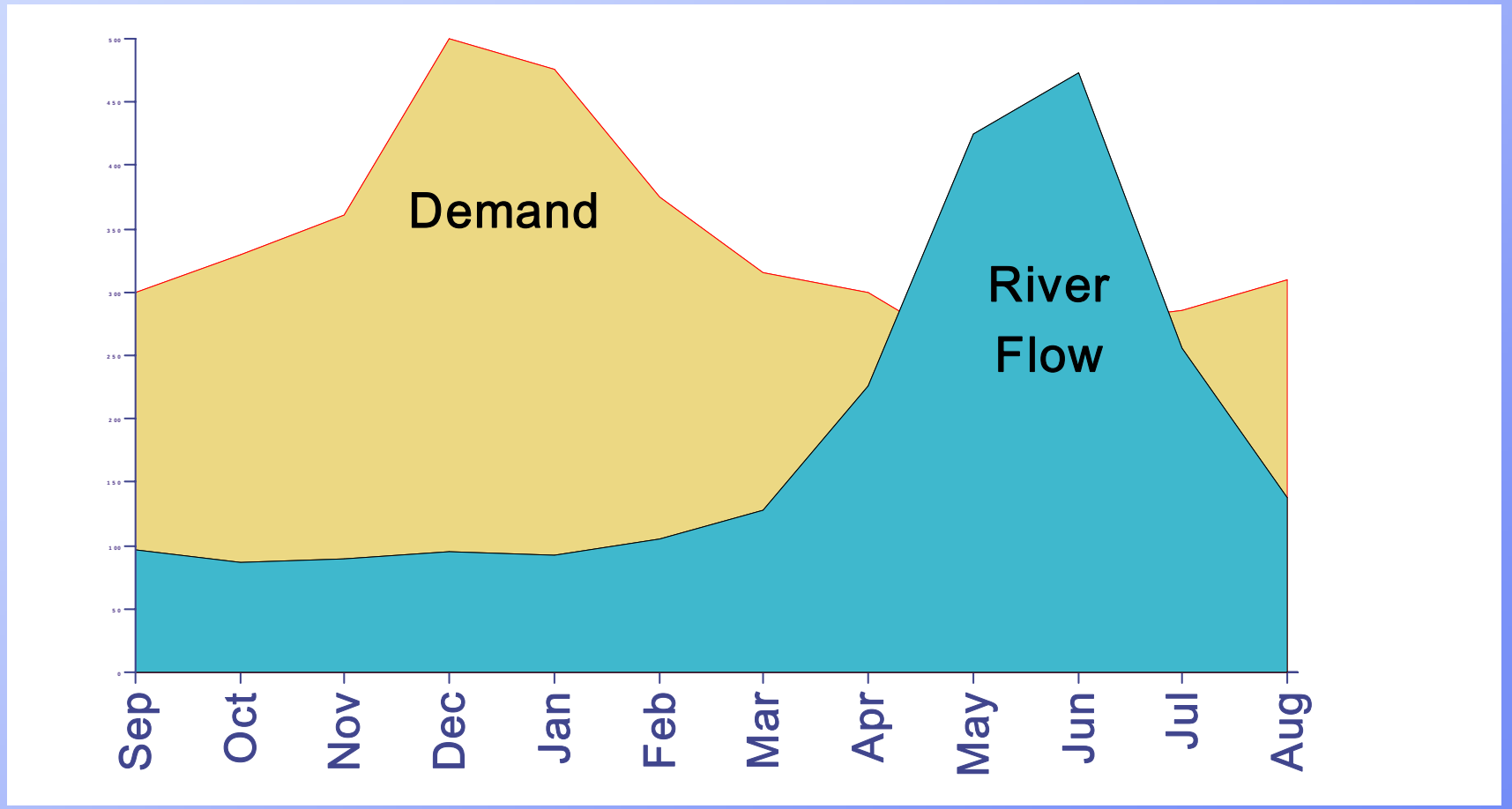
River Flows and Electricity Demand peak in different months



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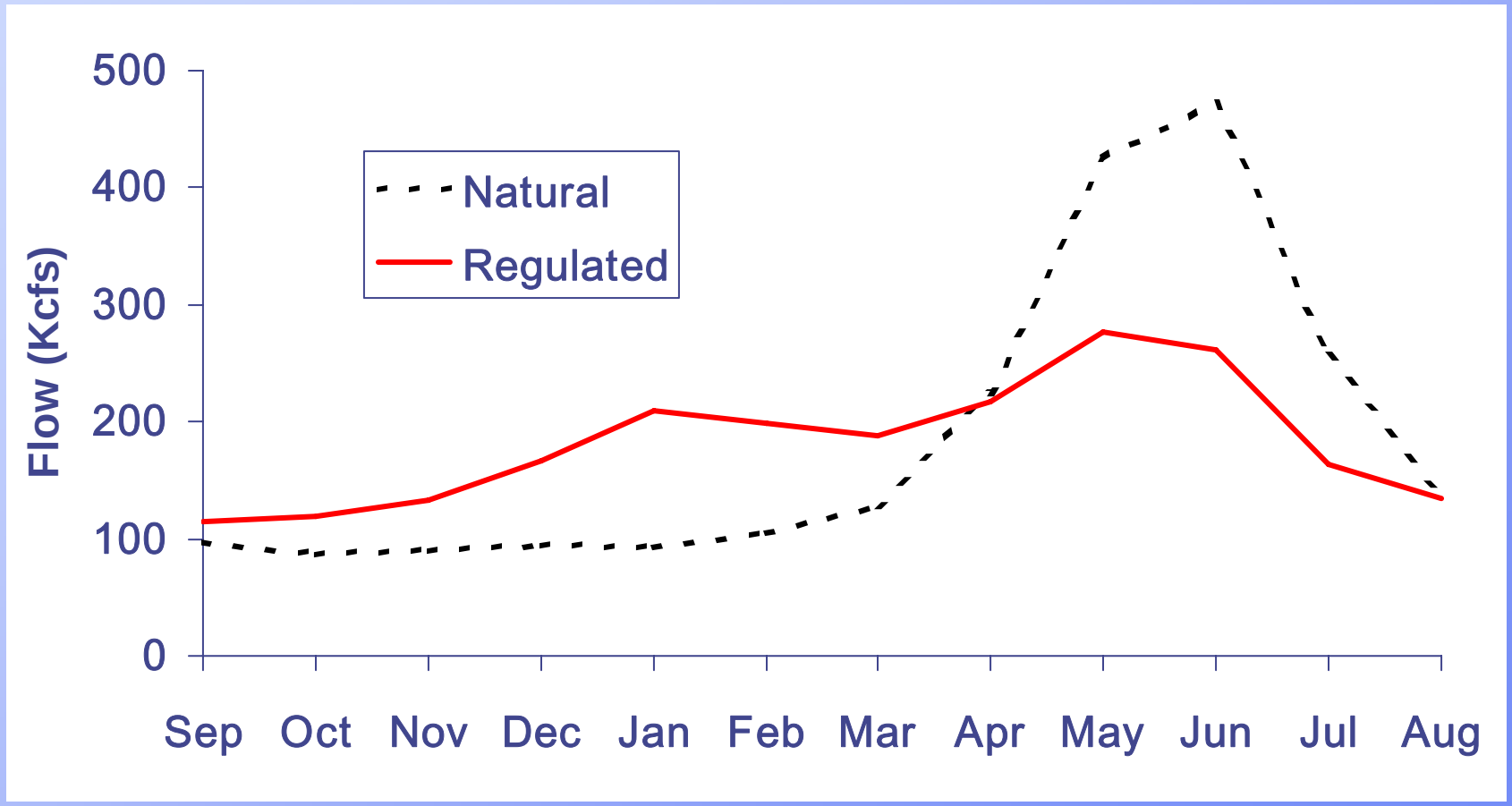
Using Reservoir Storage to change the shape of River Flows



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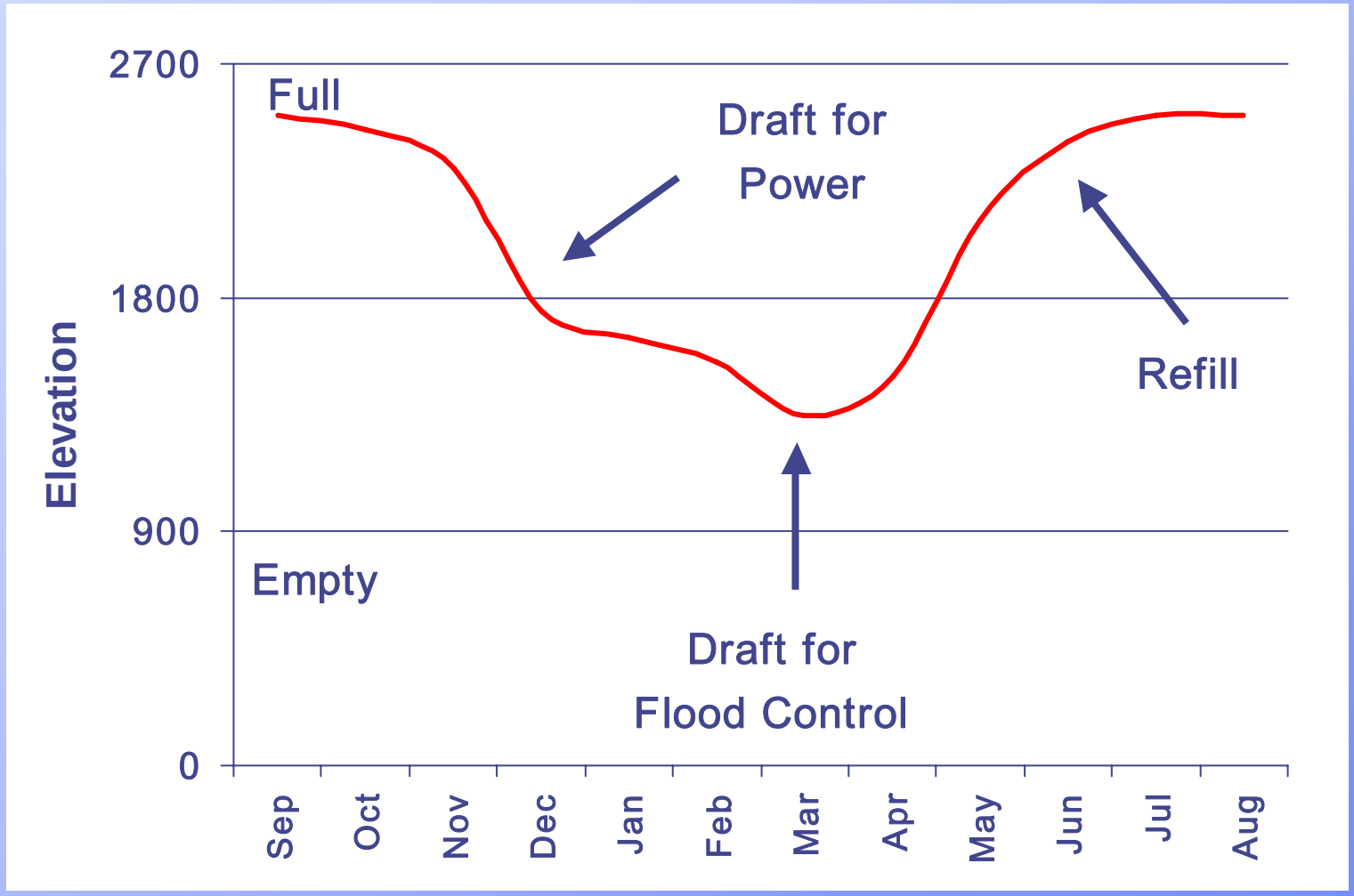
Typical Reservoir Operation



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How Climate Change affects the Hydroelectric System

- Changes in temperature affect electricity demand
- Changes the timing and form of precipitation affect river flows

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Global Warming Scenarios & Temp Impacts

JISAO Climate Impacts Group, University of Washington

Runoff Scenarios	**Conditions**	
HC	Warm and Wet	
MPI	Warm and Dry	
COMP	Combination	
Average Forecasted Temperature Change		
Temperature	**2020**	**2040**
Degrees C	+1.7	+2.3
Degrees F	+3.1	+4.1

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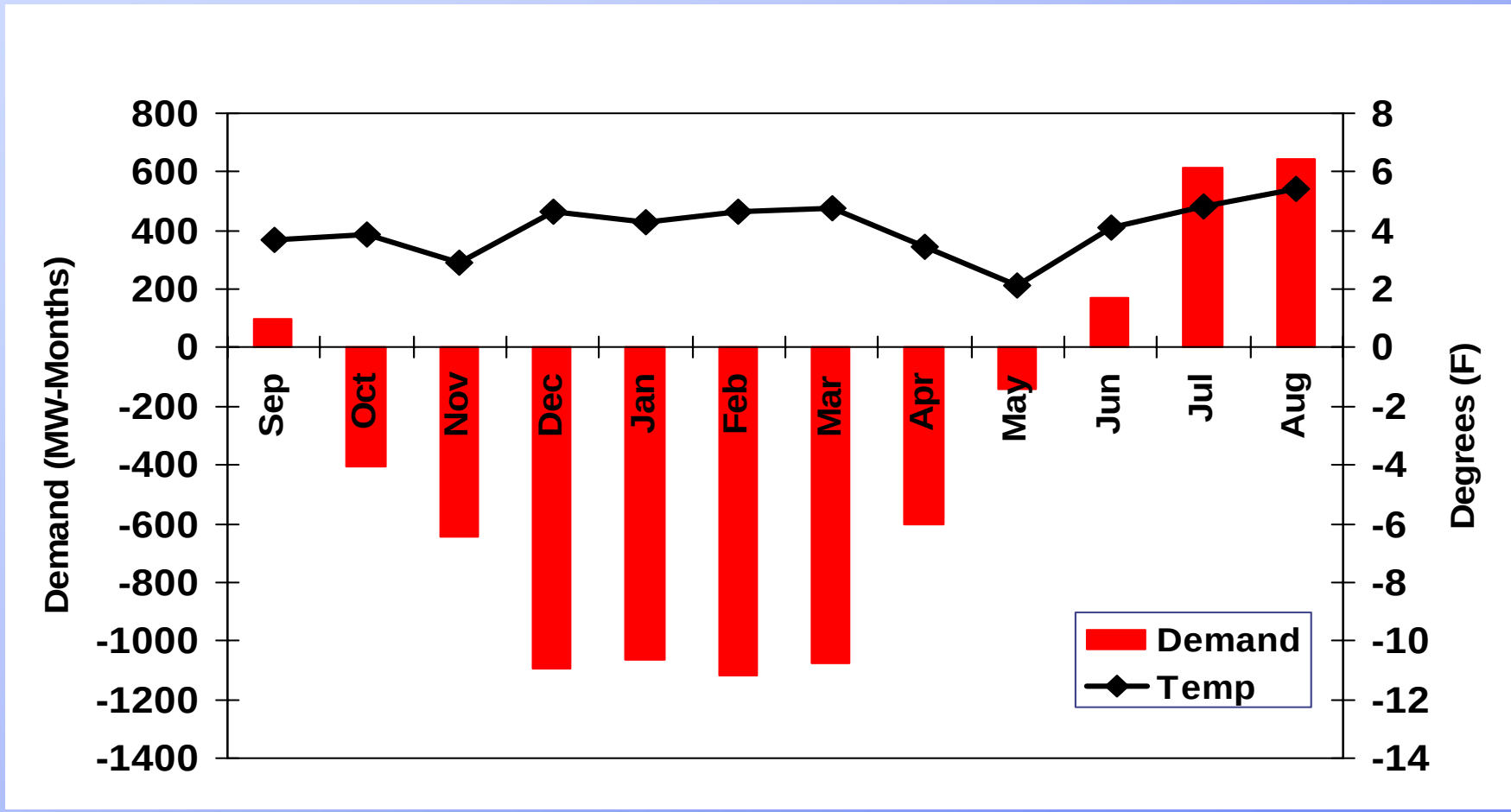
Relationship between Change in Temperature and Change in Demand



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Global Warming Impacts to the Hydro System

JISAO Climate Impacts Group at the University of Washington

- More rain, less snow – resulting in higher streamflows in winter
- Spring runoff peaks about ½ month earlier
- Less snowpack – resulting in lower streamflows in summer

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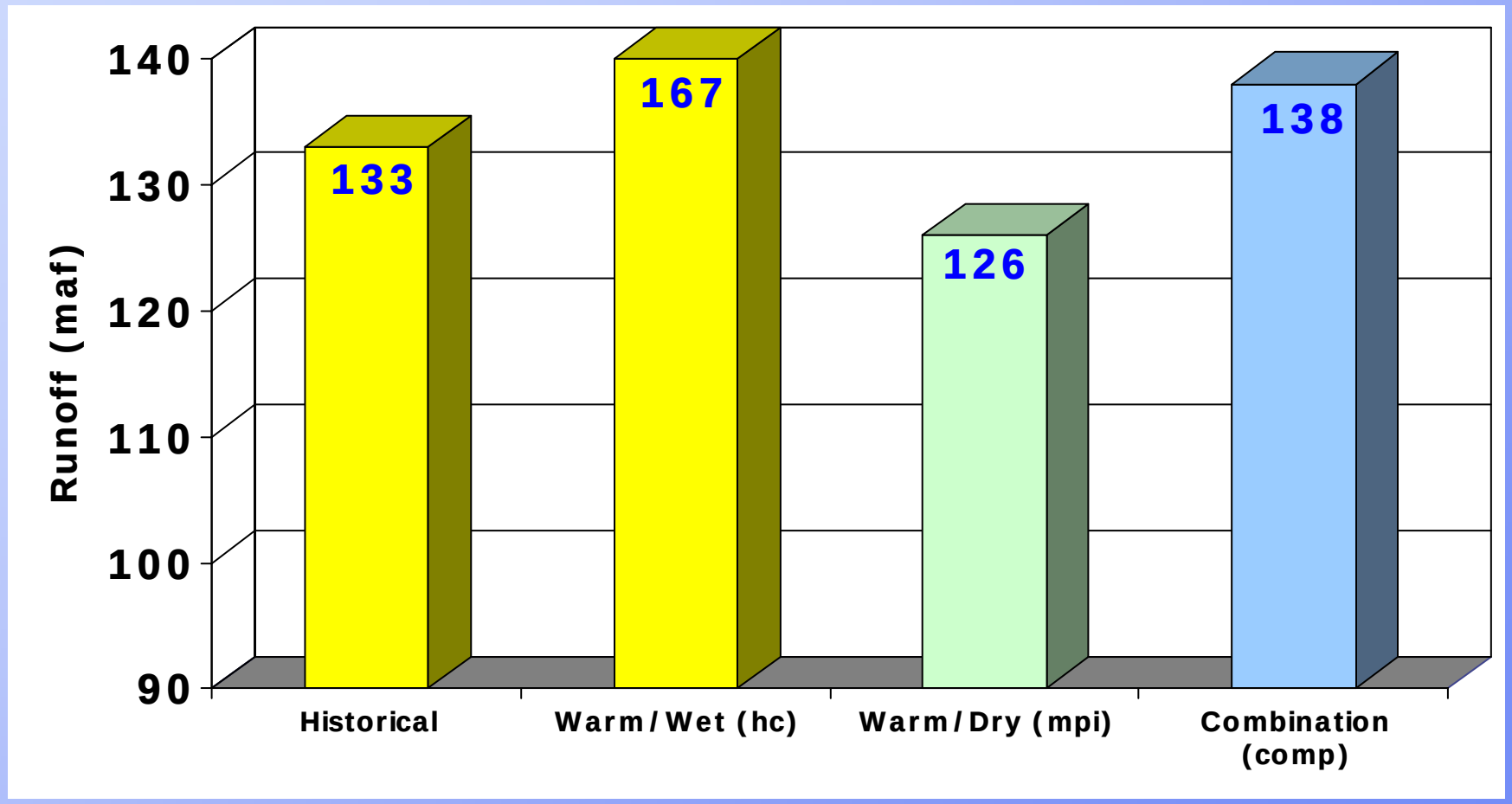
2020 Annual Runoff Volume @Dalles

JISAO Climate Impacts Group, University of Washington



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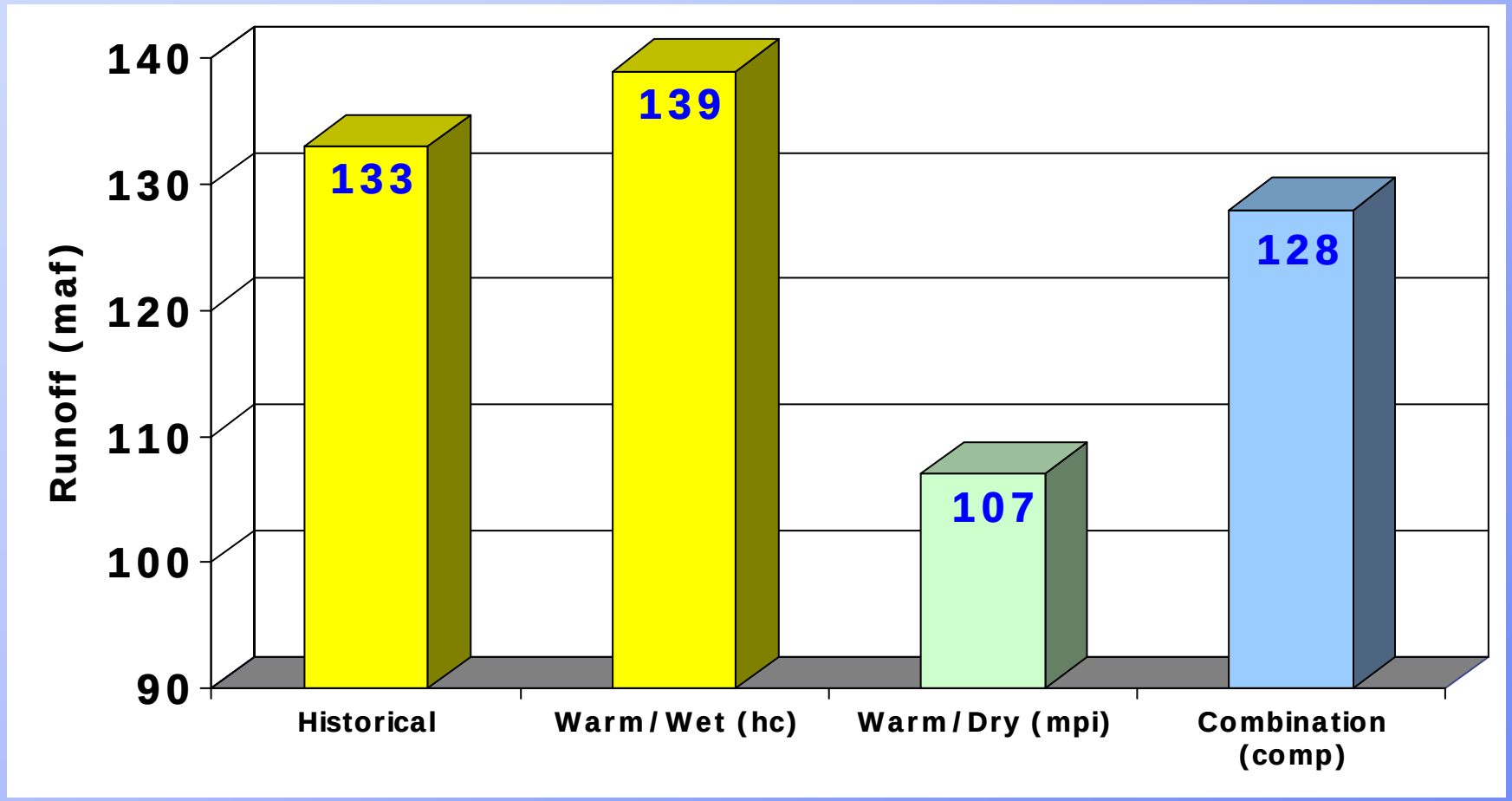
2040 Annual Runoff Volume @Dalles

JISAO Climate Impacts Group, University of Washington



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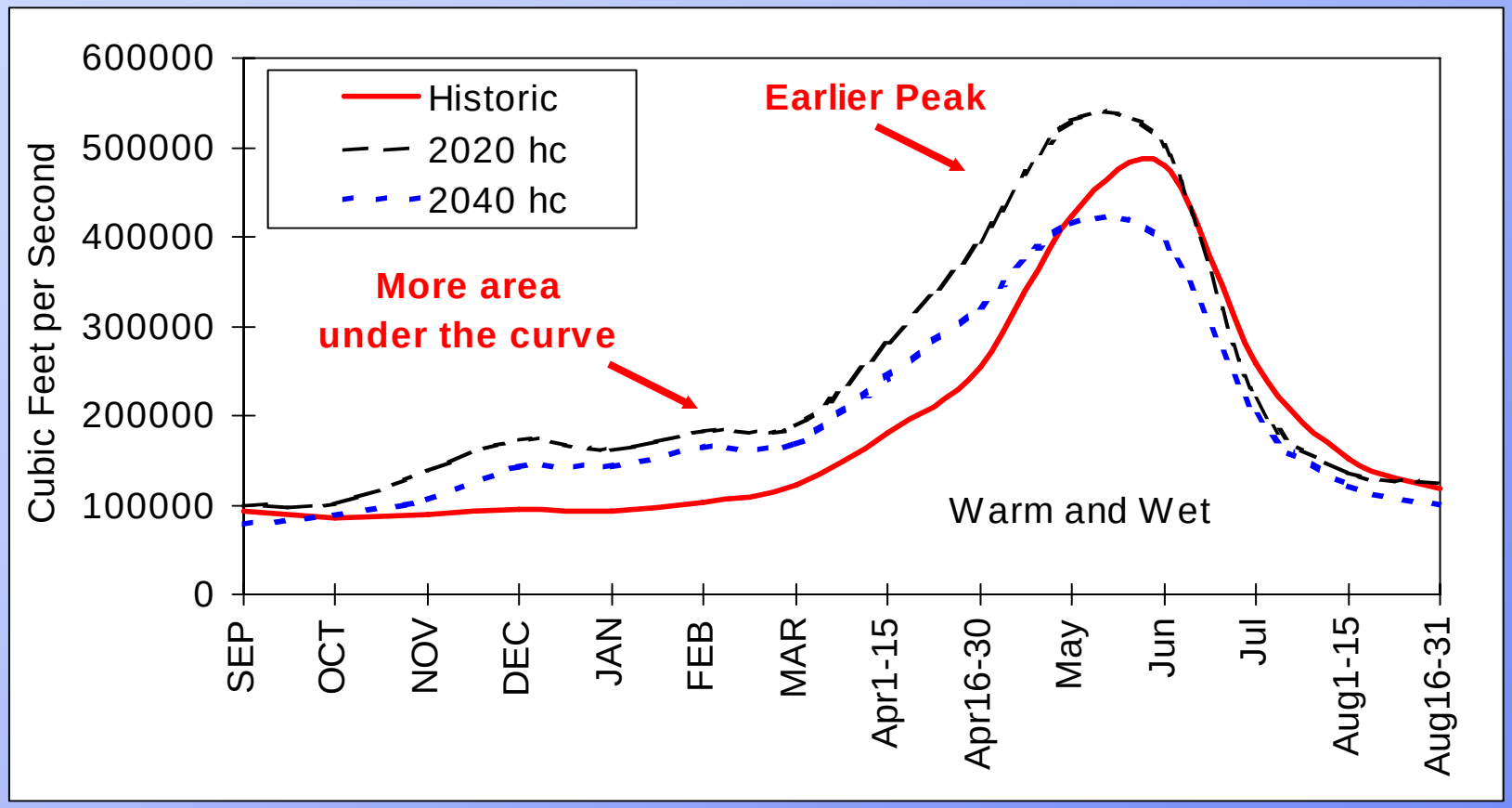
Unregulated Streamflows – HC scenario

(at The Dalles, 30-78 runoff conditions)



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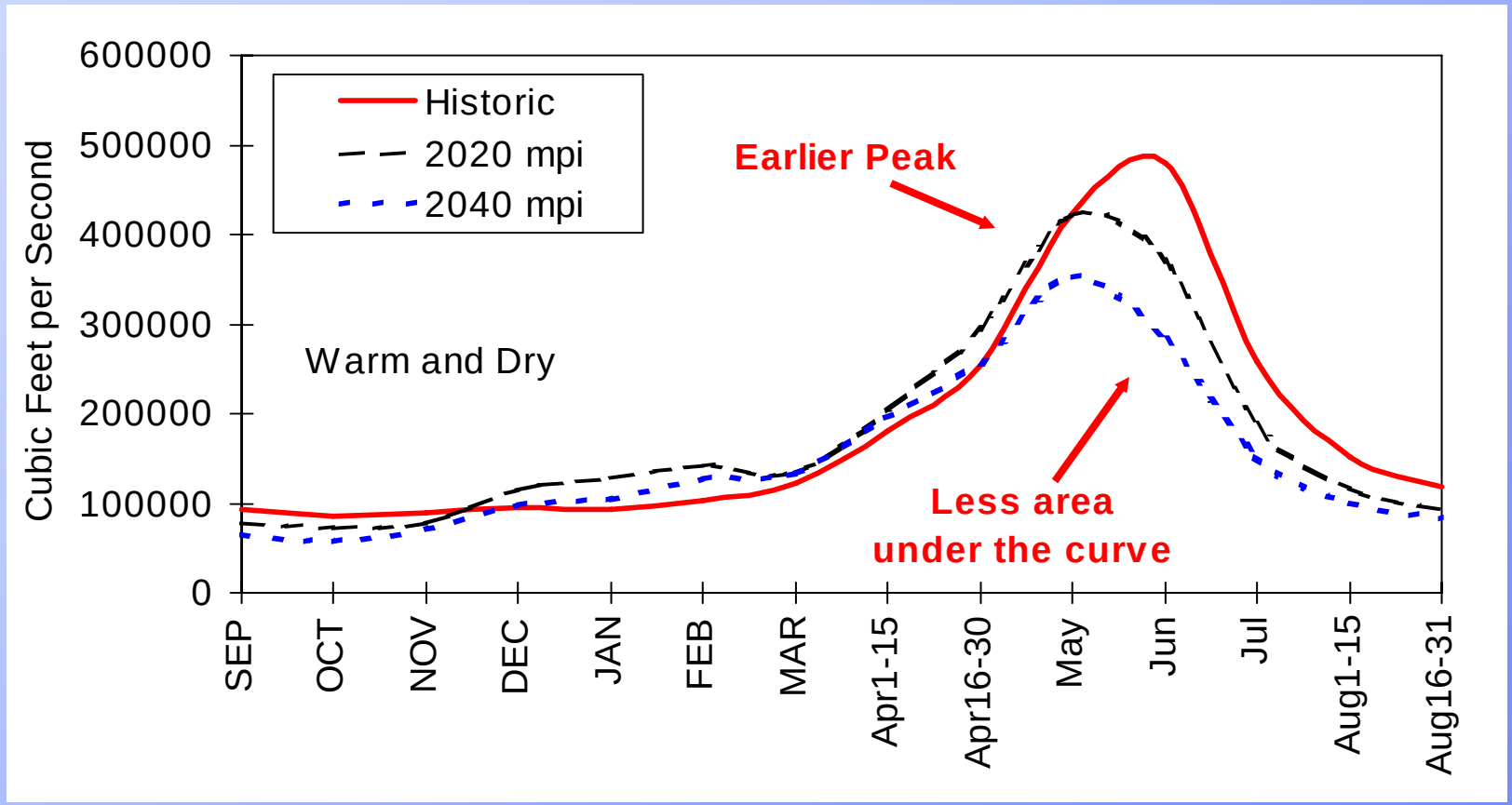
Unregulated Streamflows – MPI scenario

(at The Dalles, 30-78 runoff conditions)



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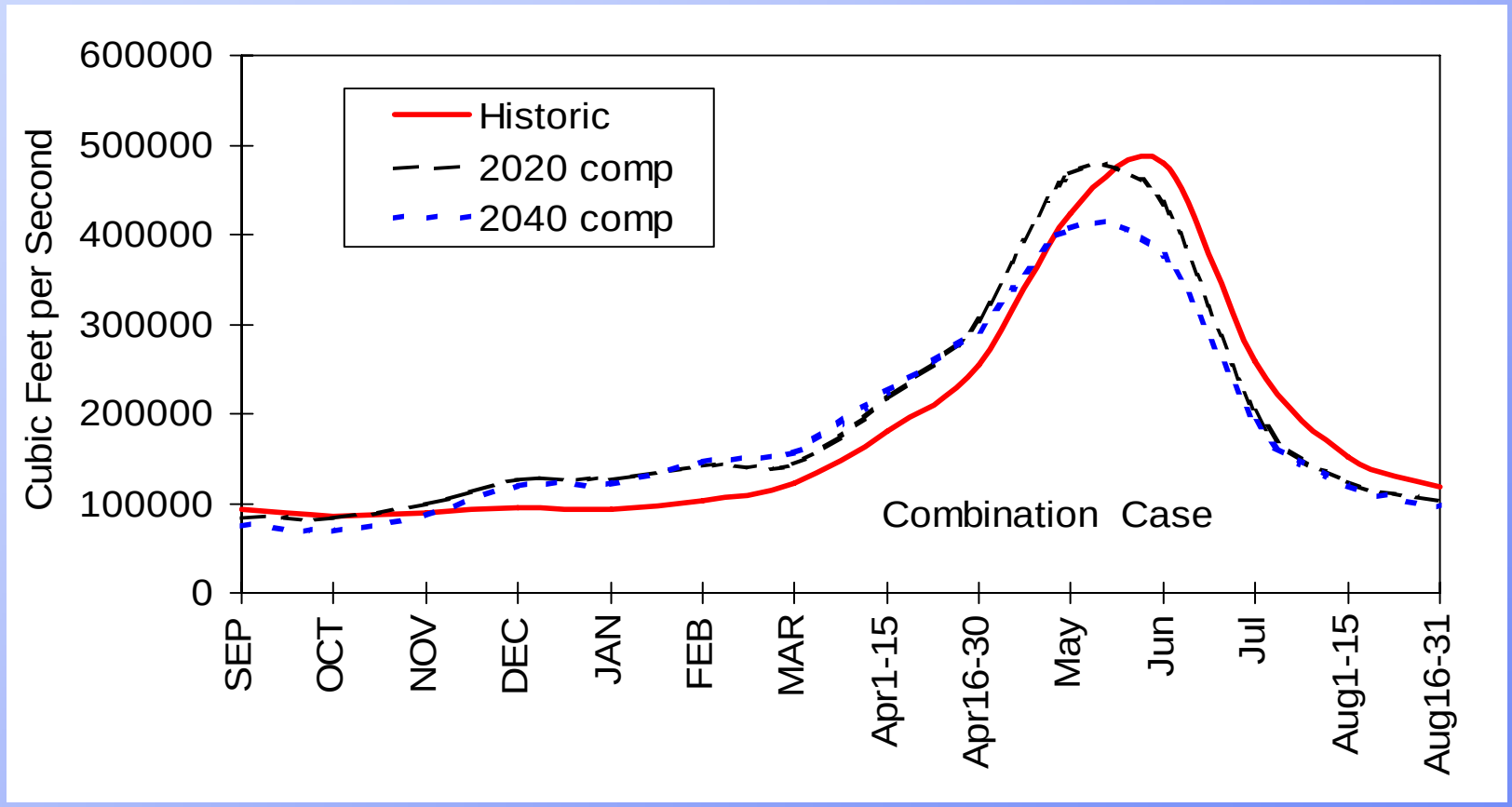
Unregulated Streamflows – COMP scenario

(at The Dalles, 30-78 runoff conditions)



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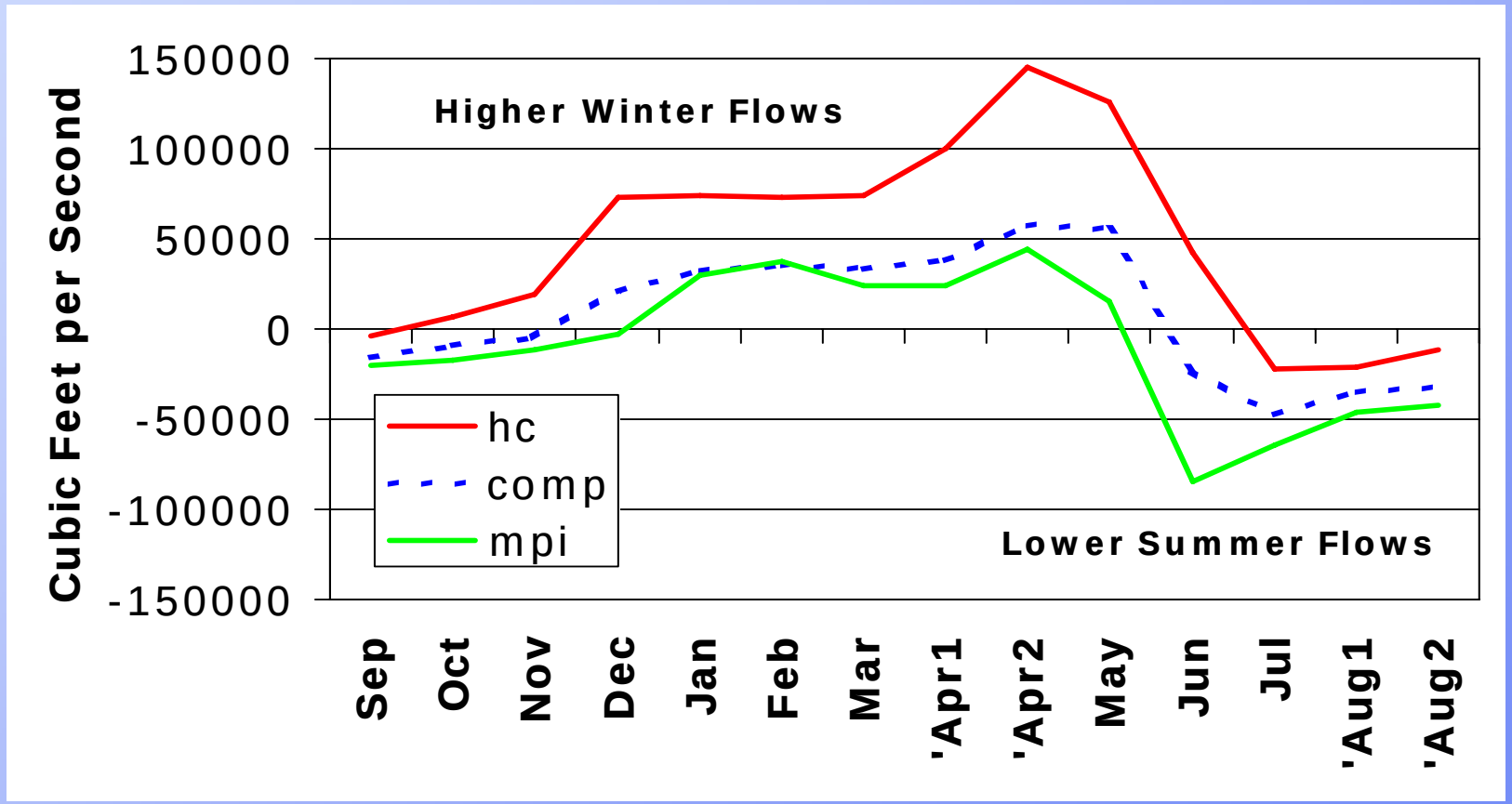
Change in Regulated Flow at The Dalles
for 2020 due to Global Warming (30-78)



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Annual Energy and Cost Impacts

(No mitigating actions taken)

	Annual Energy (average MW)		Annual Benefit (Millions)	
	2020	**2040**	**2020**	**2040**
Warm/Wet (HC)	2000	300	$800	$170
Combo (COMP)	200	-500	$70	- $160
Warm/Dry (MPI)	-700	-2000	- $230	- $730

For perspective, BPA's annual net revenue requirement is on the order of $3.5 billion.

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Summary of Impacts

- Each case shows a better situation in winter, with less demand and more hydro generation
- Each case points to potential summer problems
  - Less hydro generation while demand increases
  - Lower river flows for anadromous fish
  - Potentially higher water temperatures
- Financial impacts vary depending on the change in annual runoff volume (fuel for the hydro system)
  - **Based on more recent data, it appears more likely that runoff volume will decrease over time**
  - This translates into a regional cost

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Potential Mitigating Actions

1. Adjust hydro operating guidelines (rule curves) to assure that reservoirs are full by the end of June
2. Allow reservoirs to draft below the biological opinion limits in summer months
3. Negotiate to use more Canadian water in summer
4. Use increased winter streamflows to refill reservoirs (US and Canadian)
5. May have to develop more non-hydro resources to replace winter hydro generation and to satisfy higher summer needs

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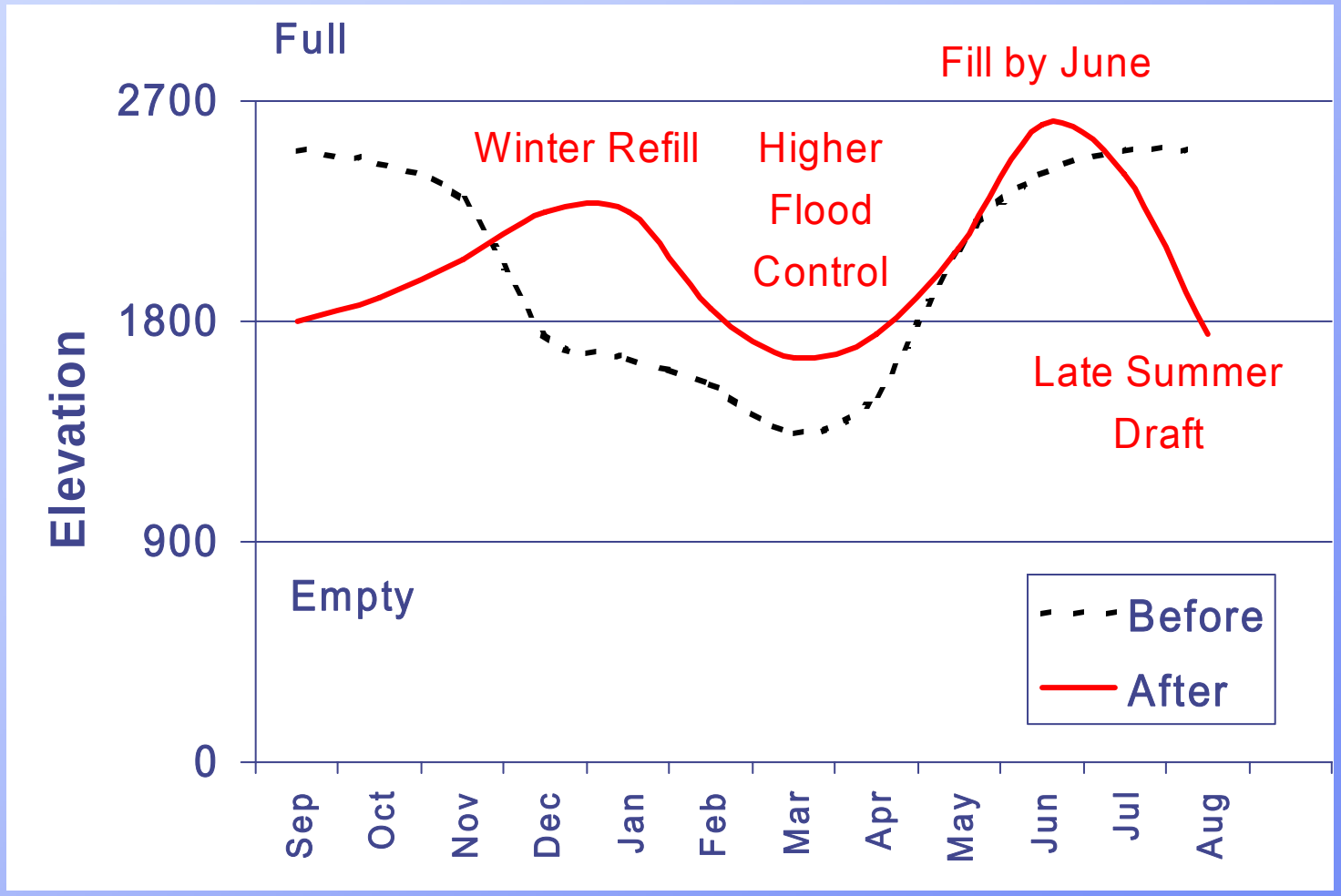
Changes in Reservoir Operation



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Adaptive Management Approach

- Recognize that there will be no “bright line” to trigger mitigating actions
- Build compensating measures into the development of rule curves and long-term resource planning processes
- Mitigating actions will occur naturally, as conditions change

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Examples of What Can be Done

- Flood control curves will automatically adjust to new forecasts for runoff volume and timing
- End-of-summer drafting limits can be made adjustable, based on runoff forecast
- Current winter refill curves (for flow augmentation volumes) can be started earlier
- Work with Canadians to use a similar strategy for their planning
- Resource expansion and conservation strategies will include revised hydro generation

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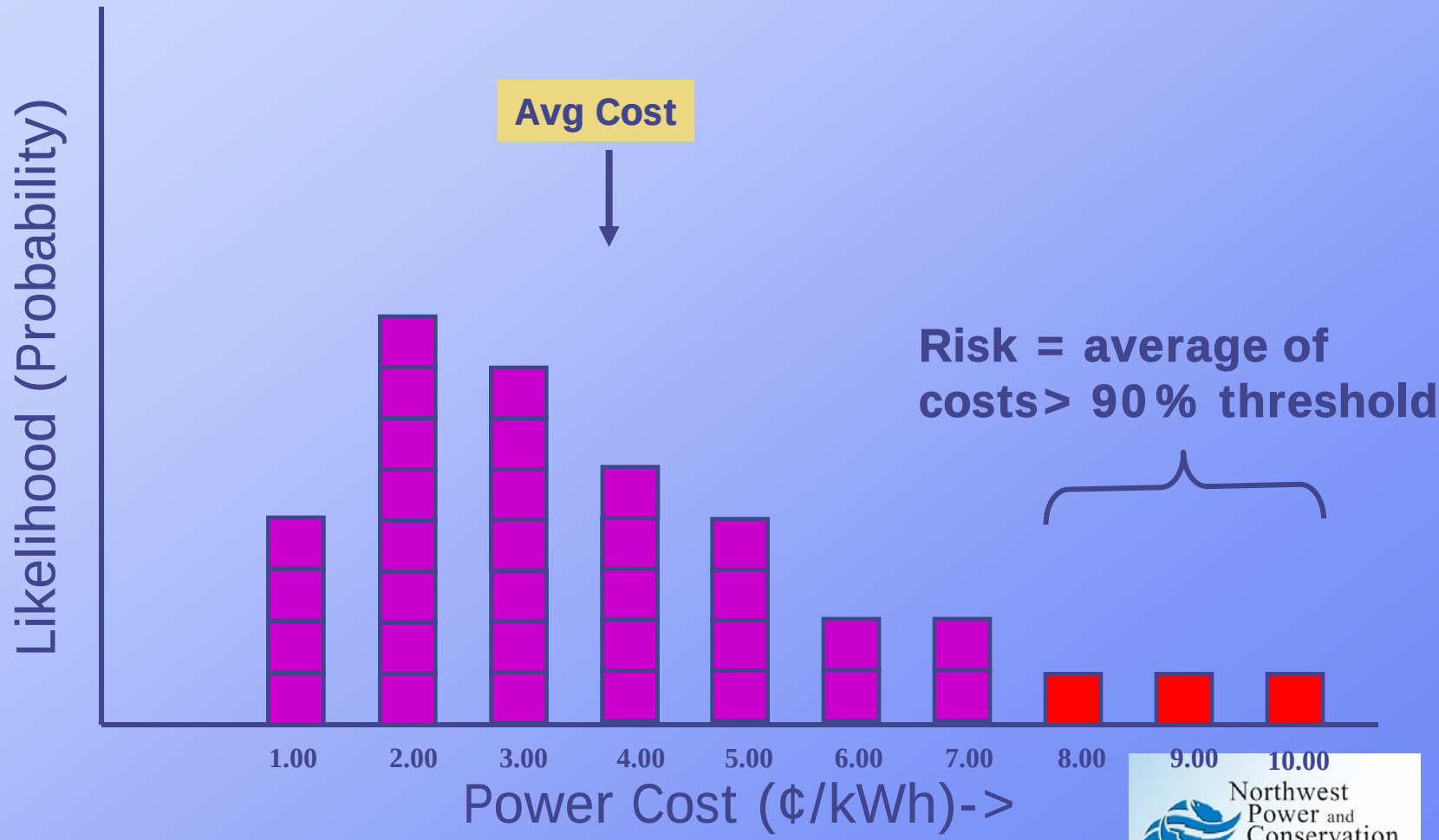
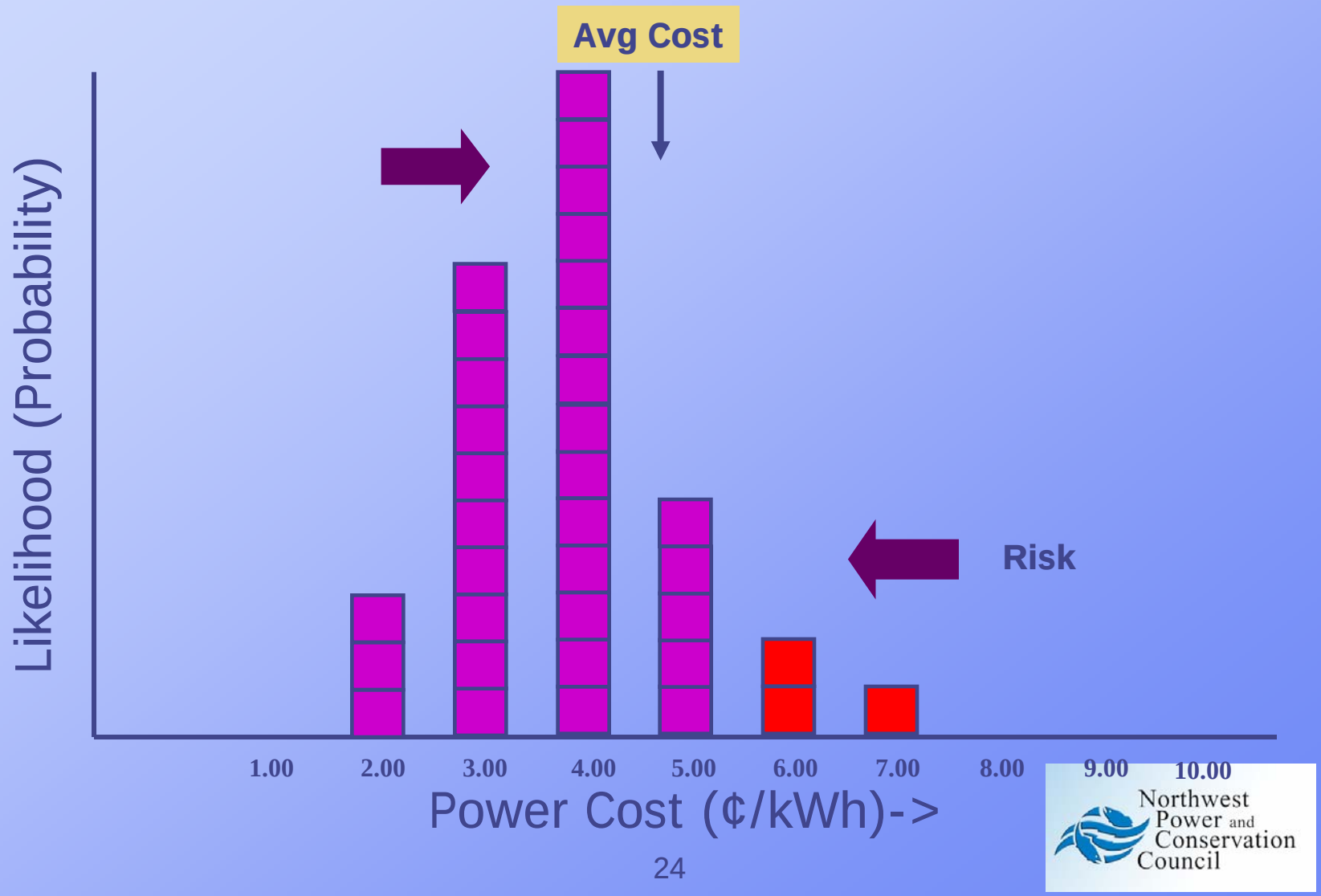
Integrating Climate Change into Planning

Risk and Expected Cost Associated With A Resource Plan



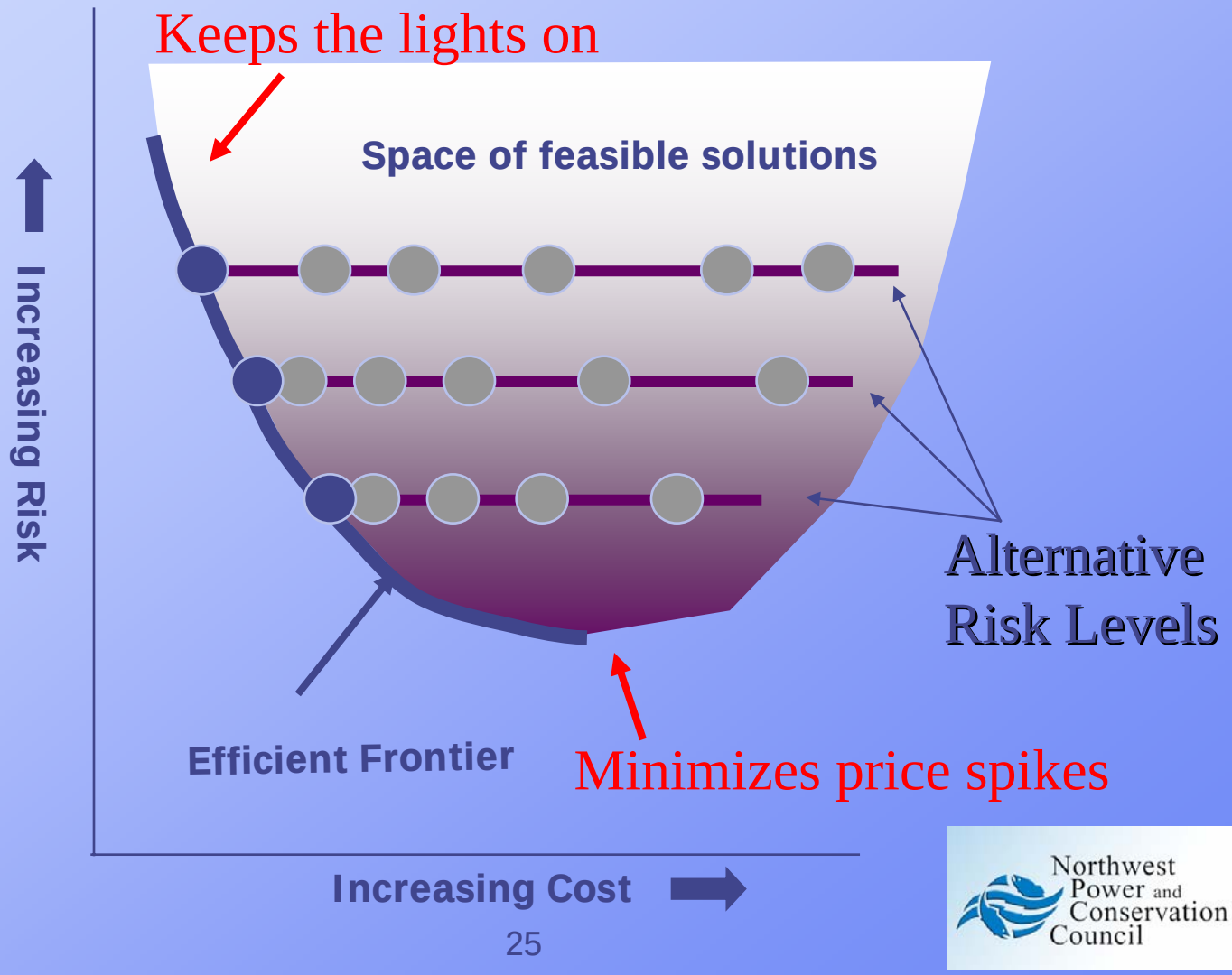
Integrating Climate Change into Planning

A Different Plan: The Trade-off Higher Avg Cost but Lower Risk



Integrating Climate Change into Planning

Efficient Frontier



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Integrating Climate Change into Resource Planning

- Can do scenario analysis, looking at "snapshots" of different futures with different climate change (yet to do)
- Better approach is to develop a probability distribution for likely future streamflow conditions and incorporate this as a random variable into the model (yet to do)
- It will be interesting to see how climate change may affect resource development

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