BRIEFING: CLIMATE CHANGE PROJECTIONS

OFFICE OF CHEHALIS BASIN TECHNICAL TEAM

June 24, 2022

DEPARTMENT OF ECOLOGY
State of Washington
OFFICE OF CHEHALIS BASIN

PURPOSE OF MEETING

- Brief board members on climate change methodologies and results that have informed decision-making to date
- Discuss most recent climate change methodologies and results for high and low flows
- Provide information for future Board discussions

PRESENTATION OVERVIEW

- High-level overview of climate change models for the Chehalis Basin Strategy
- Background and history on the use of climate change models for the Chehalis Basin Strategy
- Climate change methodology/results for various Strategy elements
- Next steps for climate change modeling, not including the Final EISs

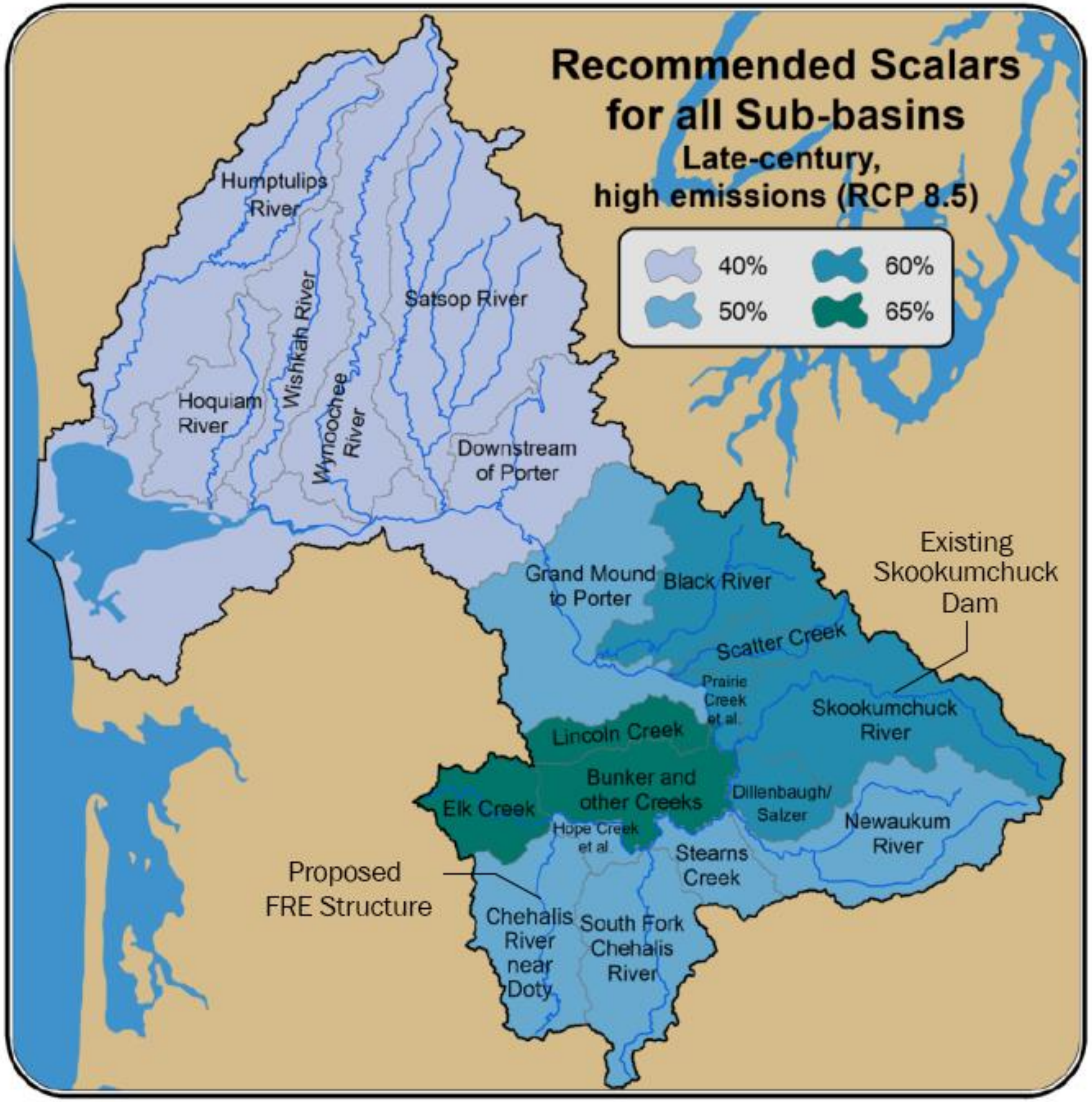
OVERVIEW OF CLIMATE CHANGE MODELS FOR CHEHALIS BASIN STRATEGY

CLIMATE CHANGE MODELING FOR THE CHEHALIS BASIN STRATEGY

STRATEGY ELEMENT	YEAR(S)	CLIMATE MODELING COMPLETED	PURPOSE
Programmatic SEPA EIS	2017	Yes	Planning
Phase 1 Aquatic Species Restoration Plan	2019	Yes	Planning
Project-level Draft SEPA EIS	2020	Yes	Planning
Local Actions Program	2020-2021	Yes	Planning
Project-level Final SEPA EIS	2021-Present	Yes	Planning
Chehalis River Basin Comprehensive Flood Hazard Management Plan Update	2021	Yes	Planning
Skookumchuck dam evaluation	2021-Present	Yes	Planning
LAND	2022-Present	Yes	Planning

CLIMATE CHANGE MODELING FOR THE CHEHALIS BASIN STRATEGY (CONTINUED)

STRATEGY ELEMENT	YEAR(S)	CLIMATE MODELING COMPLETED	PURPOSE
North Shore Levee and North Shore Levee West Segment	2020-Present	No, but used FEMA's mapped Special Flood Hazard Area and considered sea level rise	Design
Project-level Draft NEPA EIS	2020	No, but climate variability considered	Planning
CFAR	2020-Present	No, but accounts for climate effects in 3' freeboard standard	Planning/Design
On-the-ground Aquatic Species Restoration Projects	2017-Present	No, but consider future climate change conditions based on previous modeling	Design
Flood Authority Local Projects	2017-Present	No, but considers FEMA's mapped Special Flood Hazard Area	Design


Recommended Scalars for all Sub-basins
Late-century, high emissions (RCP 8.5)
40%
60%
50%
65%
Humptulips River
Wishkah River
Satsop River
Hoquiam River
Wynoochee River
Downstream of Porter
Grand Mound to Porter
Black River
Existing Skookumchuck Dam
Scatter Creek
Prairie Creek et al.
Skookumchuck River
Lincoln Creek
Bunker and other Creeks
Elk Creek
Dillenbaugh/ Salzer
Newaukum River
Hope Creek et al.
Stearns Creek
Proposed FRE Structure
Chehalis River near Doty
South Fork Chehalis River

PEAK FLOWS FOR CLIMATE CHANGE CONDITIONS (100-YEAR FLOOD)

STRATEGY ELEMENT	MID CENTURY	LATE CENTURY
Programmatic SEPA EIS	---	+66% (basin-wide)
Phase 1 Aquatic Species Restoration Plan	+12%	+26%
Project-level Draft SEPA EIS	+12%	+26%
Local Actions Program	---	+40% to 65% spatially varied basin-wide*
Project-level Final SEPA EIS	+23 to 37% spatially varied basin-wide**	+40% to 65% spatially varied basin-wide**
LAND	+23 to 37% spatially varied basin-wide*	+40% to 65% spatially varied basin-wide*
Skookumchuck dam evaluation (TBD)	+23 to 37% spatially varied basin-wide*	+40% to 65% spatially varied basin-wide*

**Could be higher or lower depending on location in the basin*

***Final SEPA EIS will look at mid-century and late-century based on specific locations in the study area*

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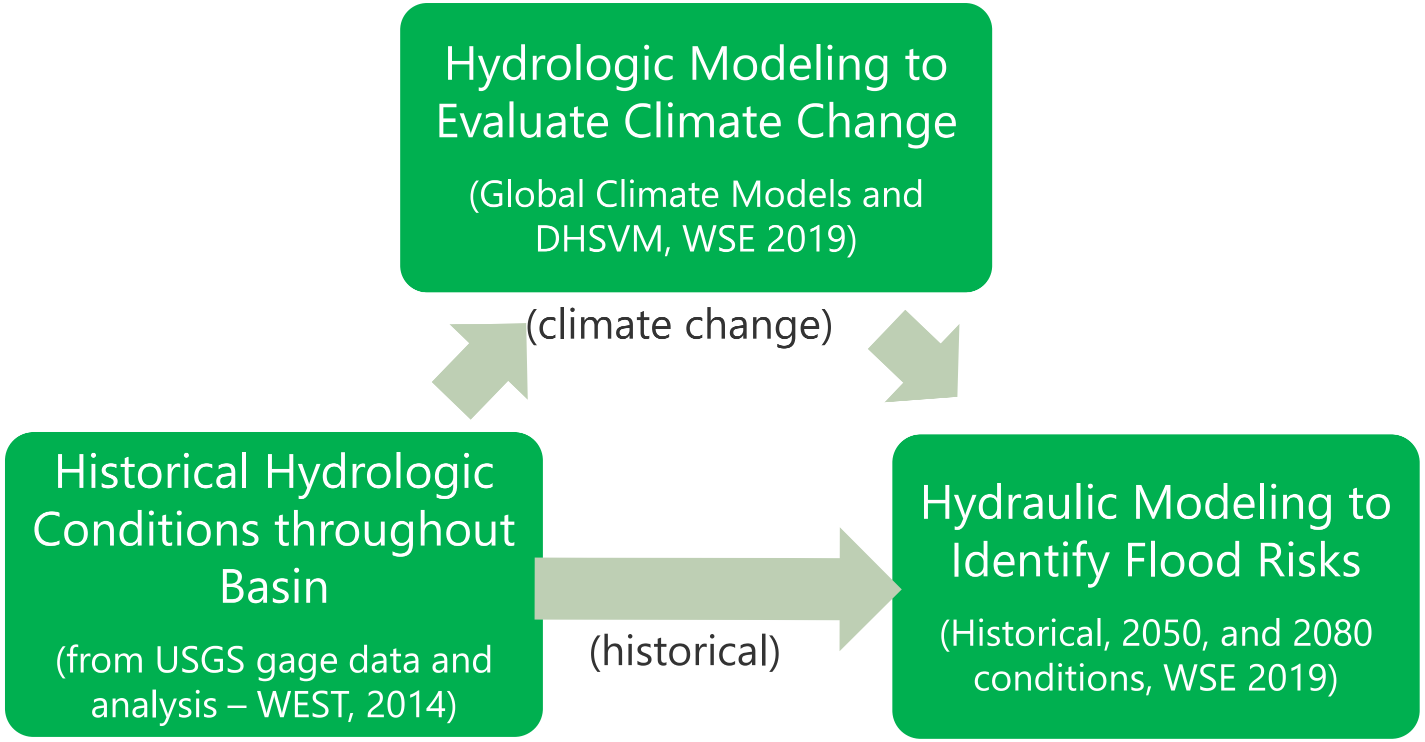
QUESTIONS?

CLIMATE CHANGE MODELS BY STRATEGY ELEMENT

OVERVIEW



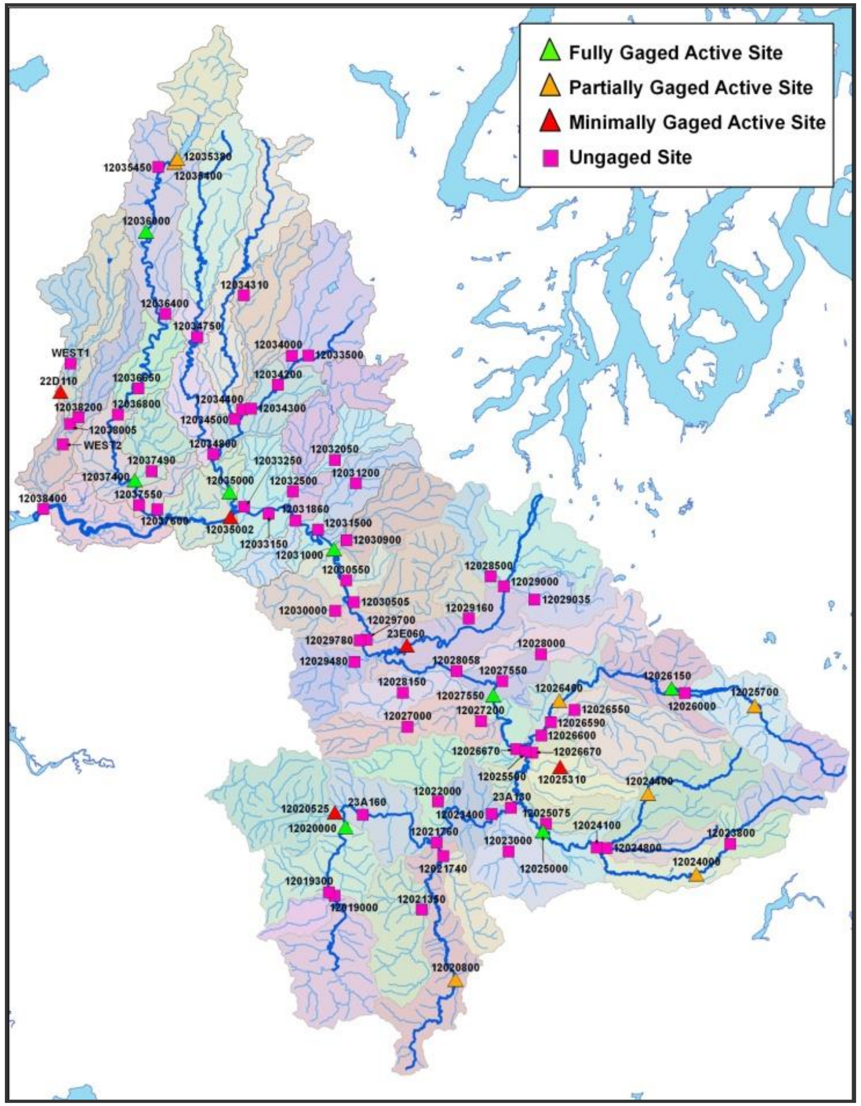
- Hydrology
  - Current Conditions (USGS Data)
  - Consideration of Climate Change (Hydrologic Modeling)
- Floodplain Analyses
  - RiverFlow2D Hydraulic Modeling

EXISTING CONDITIONS HYDROLOGY

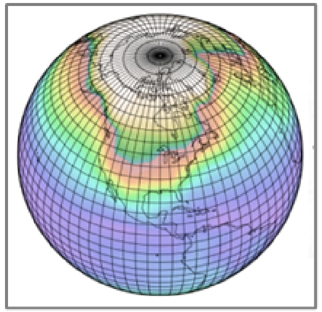
Basinwide Hydrology (WEST Consultants under contract to USACE, 2014)

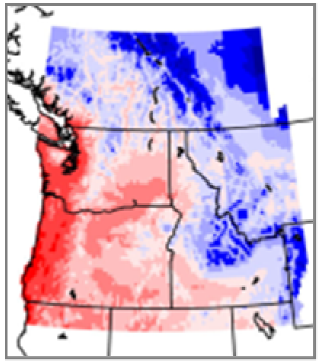
- New Flood Frequency Analyses
  - 17 gaged sites
  - 66 ungaged sites
- Historical Data for February 1996, Dec 2007, and Jan 2009 Calibration Events
- Design Flood Hydrology (peaks, timing, and volumes) for 1.5- through 500-year events

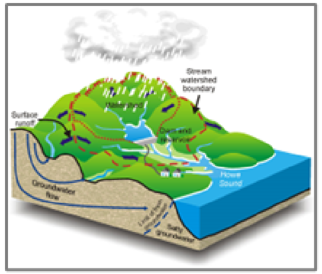
*Hydrology was peer reviewed by USACE, State Agencies, and ITR Team



TYPICAL APPROACH TO CLIMATE CHANGE EVALUATIONS:







Global Climate Scenarios → Regional Climate Scenarios → Impacts Modeling → Planning & Design

Year	Project	Method	100-year Flow	Uses	Notes
2014	Chehalis River Basin Flood Hazard Mitigation	Literature Review (mostly CIG State of the Science Report)	18% Increase	Flood reduction alternatives analysis	All return periods scaled by same amount
2014	Chehalis River Basin Flood Hazard Mitigation	Discussions with Alan Hamlet on forthcoming research	90% Increase	Bracket a potential high-end projection	Detailed analysis not available, simply Alan's guesstimate based on his research
2016	Chehalis Basin Strategy	UW Climate Impacts Group, VIC hydrologic modeling, 10 MACA statistically downscaled data sets, bias corrected, averaged across basin	66% Increase	Programmatic EIS, Flood retention facility evaluation	2-year: 16% increase 10-year: 35% increase 20-year: 45% increase 100-year: 66% increase 500-year: 94% increase
2018	Chehalis Basin Strategy	UW CIG provided 2 dynamically downscaled Global Climate Model meteorological projections, WSE used DHSVM hydrologic model to estimate flow increases	26% Increase	Draft SEPA EIS, ASRP, EDT	Averaged across all quantiles and locations, termed a median climate change projection
2019	Chehalis Basin Strategy	UW CIG provided corrected GFDL dynamically downscaled Global Climate Model projection, WSE used DHSVM hydrologic model to estimate flow increases	50% Increase on average	Informational Only	Averaged across all quantiles and locations, Not used for analysis but used to put the 26% climate change projection in context as median
2021	Chehalis Basin Strategy	CIG provided corrected GFDL dynamically downscaled Global Climate Model projection, WSE used DHSVM hydrologic model to estimate flow increases	Spatially Varied Increase ranging from 40% to 65%	Final SEPA EIS, Final NEPA EIS, ASRP, LAND, Late century floodplain mapping	Averaged across all recurrence intervals but varied by location in the basin

APPROACH TO CLIMATE CHANGE MODELING

Low end and median climate change projections (2018-2019)

Global Climate Models (GCMs)

ACCESS 1.0 (low end)

GFDL (mid to high range)

Dynamical downscaling to Chehalis Basin using WRF mesoscale model:

ACCESS 1.0

GFDL (initial)

DHSVM Hydrological Modeling of Chehalis River basin with first two dynamically downscaled data sets

Flood Frequency Analysis at 15 locations throughout the basin for the two dynamically downscaled data sets

- Mid-century versus historical
- Late-century versus historical

Mid century and Late-century scalars determined from flood frequency analysis:

- ACCESS 1.0 (11 to 13% increase at mid or late century)
- Initial GFDL (12% increase at mid century and 26% increase at late-century)

Mid century and Late-century scalars applied uniformly to RiverFlow2D hydraulic model inputs.

- 12% increase representing mid-century low end and mid-range climate projection and late century low end climate projection
- 26% increase representing late century mid-range climate projection

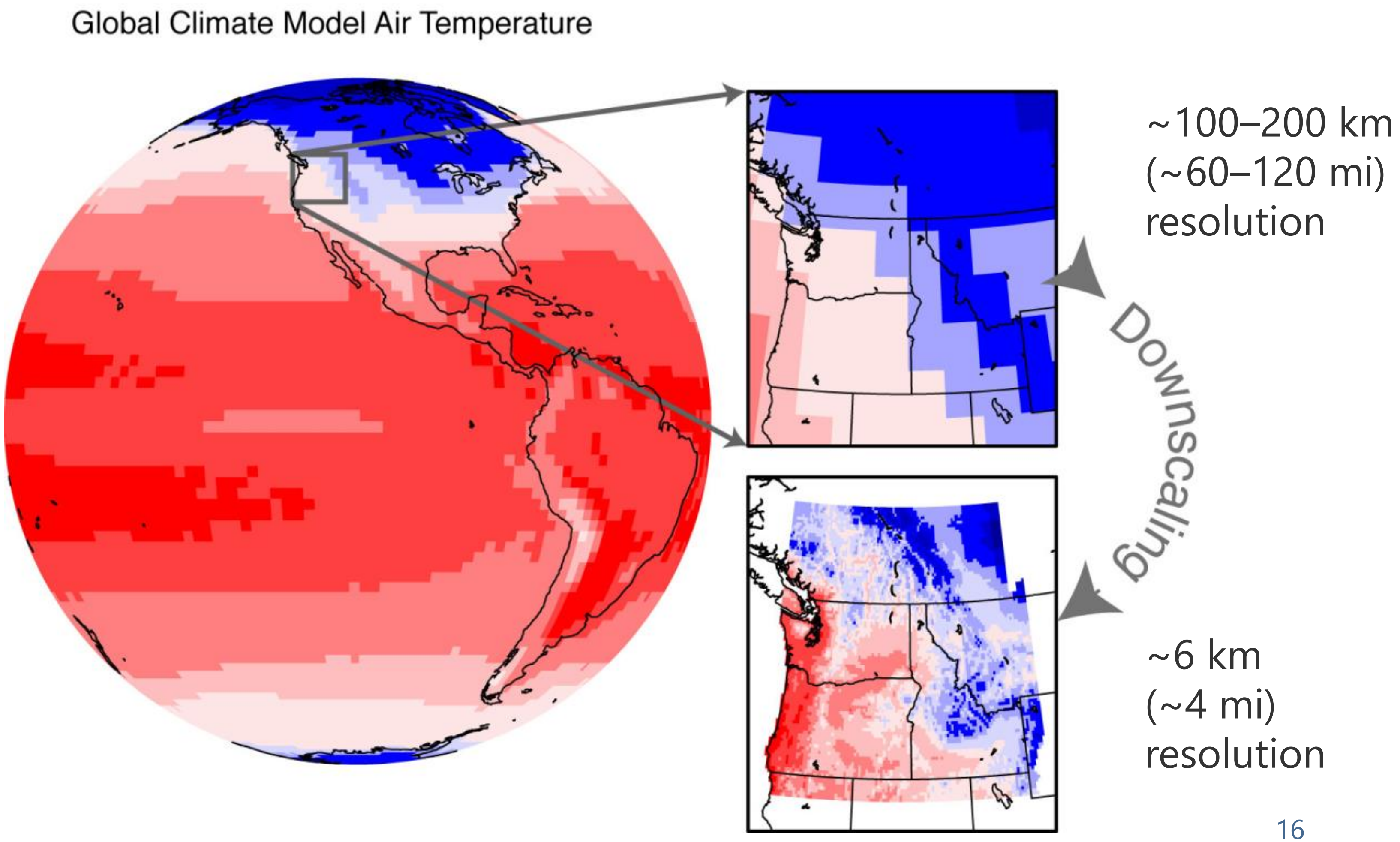
GCMS AND DOWNSCALING

"GCM":

Global Climate Model

"Downscaling":

Translating from coarse GCM scales to fine scales needed to assess impacts



PROJECTIONS USED IN SEPA DRAFT EIS

- Projections from two GCMs used
  - ACCESS 1.0, RCP 4.5 (low-end GCM, low greenhouse gas scenario)
  - GFDL CM3, RCP 8.5 (high-end GCM, high greenhouse gas scenario)

- These GCM projections were “dynamically downscaled” using a Regional Climate Model (“WRF”), because research indicates *this approach is better than statistical downscaling at capturing changes in precipitation extremes*

- ONLY TWO DYNAMICALLY DOWNSCALED PROJECTIONS WERE AVAILABLE IN 2019 – More available now

APPROACH TO CLIMATE CHANGE MODELING

High end climate change projections (2021)

Additional dynamical downscaling to Chehalis Basin using WRF:

Corrected GFDL (high end)

DHSVM Hydrological Modeling of Chehalis River basin with corrected GFDL dynamically downscaled data set

Flood Frequency Analysis at 15 locations throughout the basin

Mid century versus historical

Late-century versus historical

Precipitation Frequency Analysis for 12 dynamically downscaled GCMs for numerous subbasins throughout the basin

- Mid century versus historical
- Late-century versus historical

Mid century and Late-century scalars and spatial distribution determined from flood frequency analysis of corrected GFDL (high end) climate projection and precipitation frequency analysis of 12 GCMs:

- Average 29% increase at mid century
- Average 50% increase at late century

Mid century and Late-century scalars applied spatially distributed to RiverFlow2D hydraulic model inputs.

- 29% average increase representing mid-century high end climate projection
- 50% increase representing late century high end climate projection

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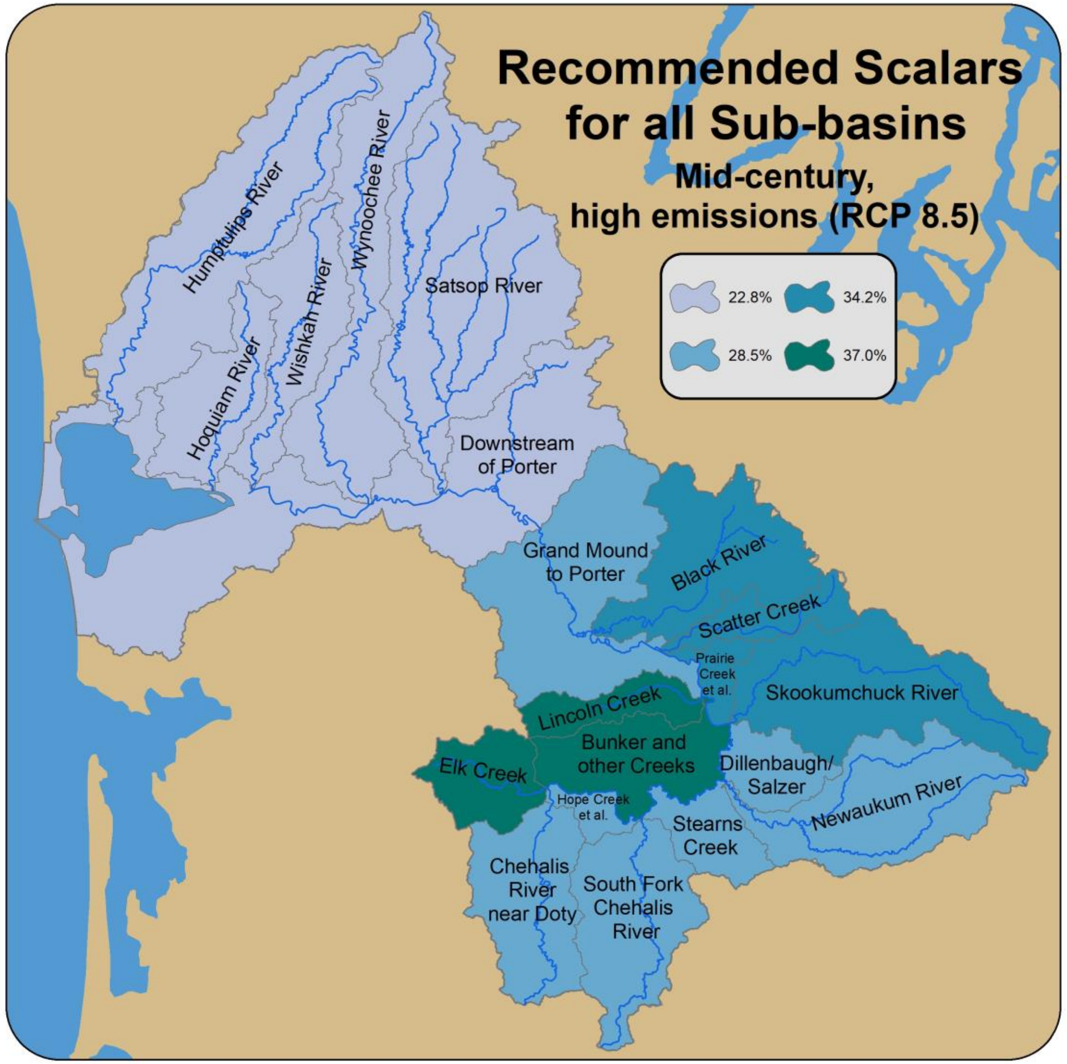
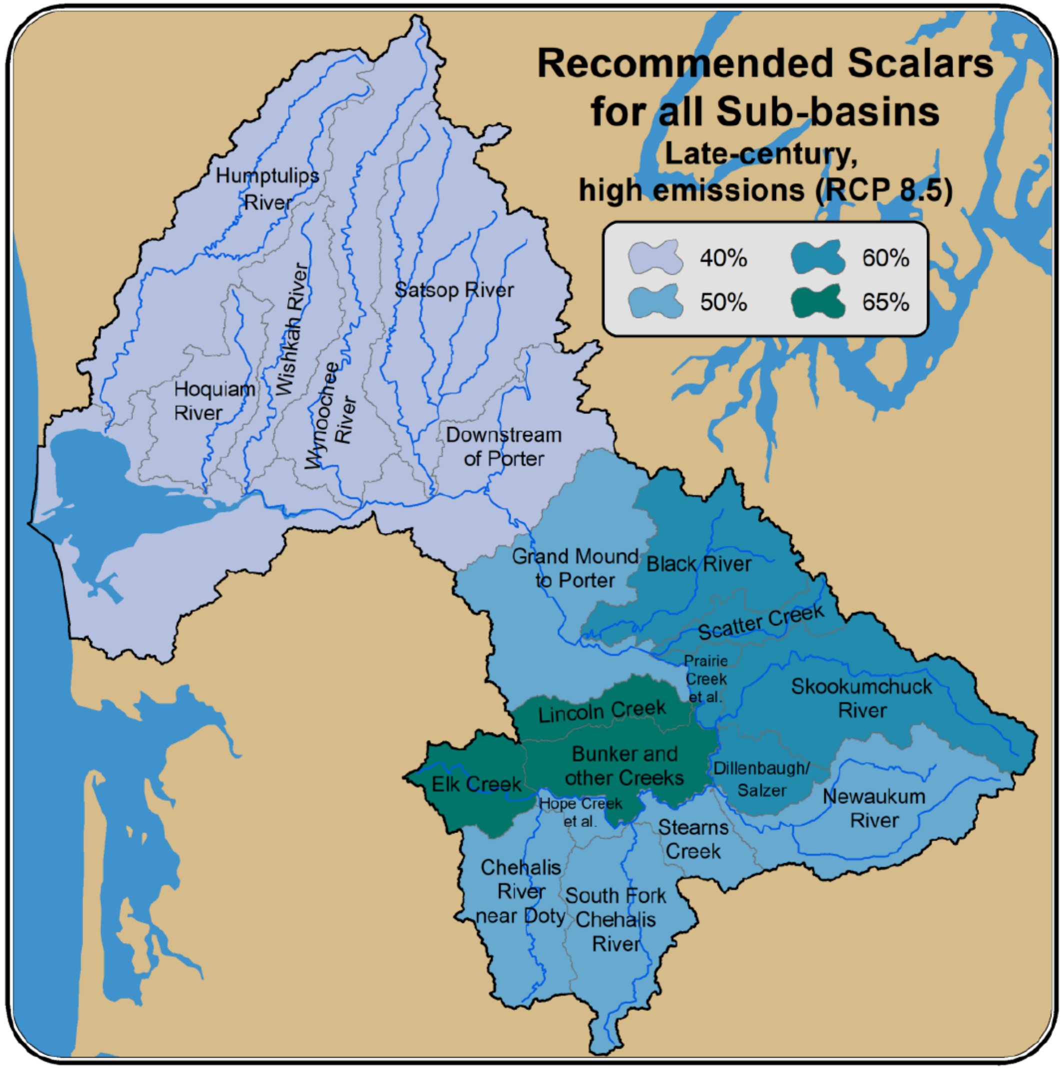
CLIMATE SCALARS USED IN LATEST MODELING





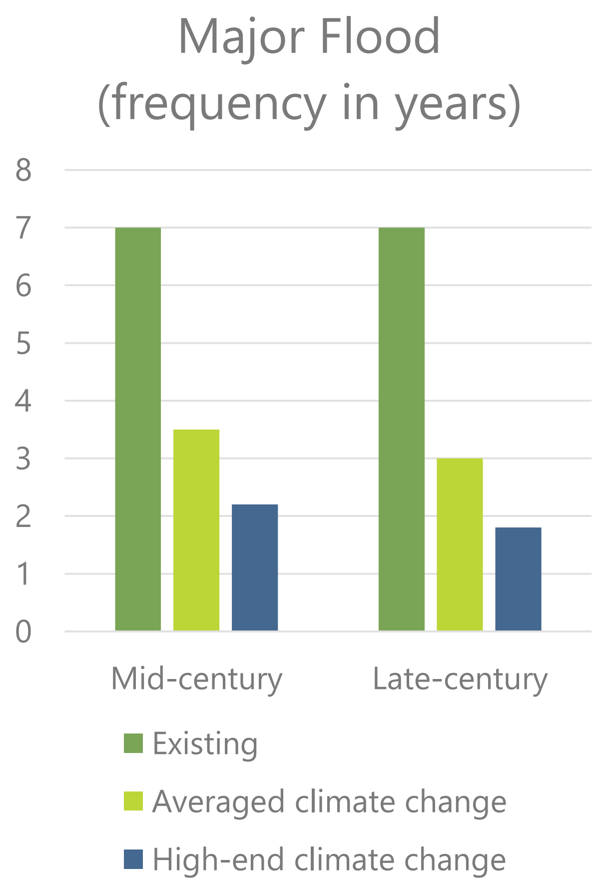
QUESTIONS?

RESULTS OF LATEST CLIMATE CHANGE ANALYSIS

- Mid-century (high end climate change)
  - Peak flow increases
    - +37% at FRE site
    - +49% at Grand Mound
  - Wintertime average flow increases: +13%
  - Summertime flow decreases: -22%

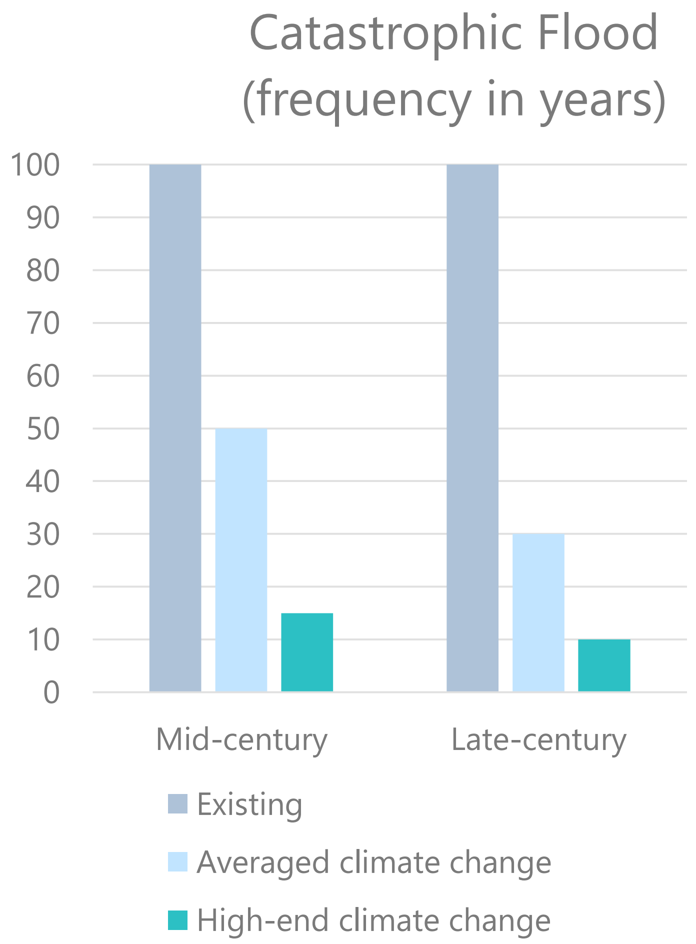
- Late-century (high end climate change)
  - Peak flow increases
    - +50% at FRE site
    - +66% at Grand Mound
  - Wintertime average flow increases: +17%
  - Summertime flow decreases: -30%

FREQUENCY OF FLOOD EVENTS AND DAM OPERATIONS



Using climate change predictions from the Climate Impacts Group, increased precipitation is expected to **increase** the number of flood events.

This would result in triggering the use of the dam **more frequently** than under current conditions.



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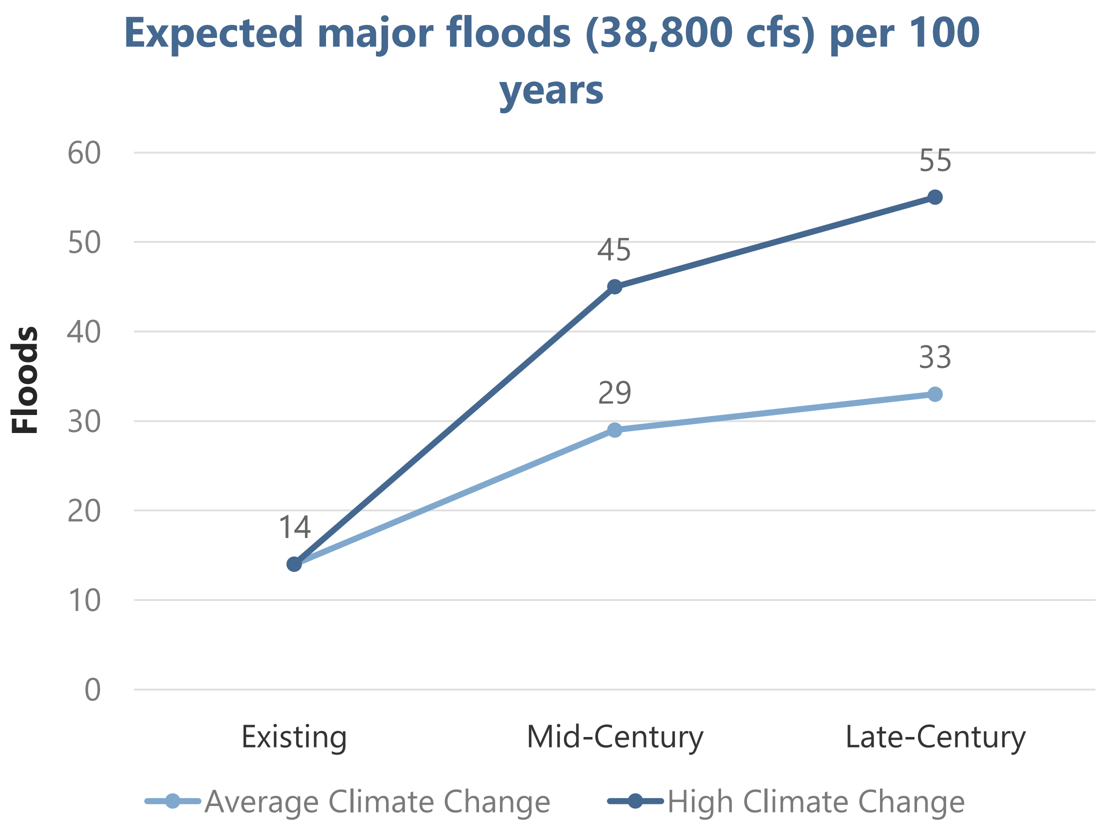
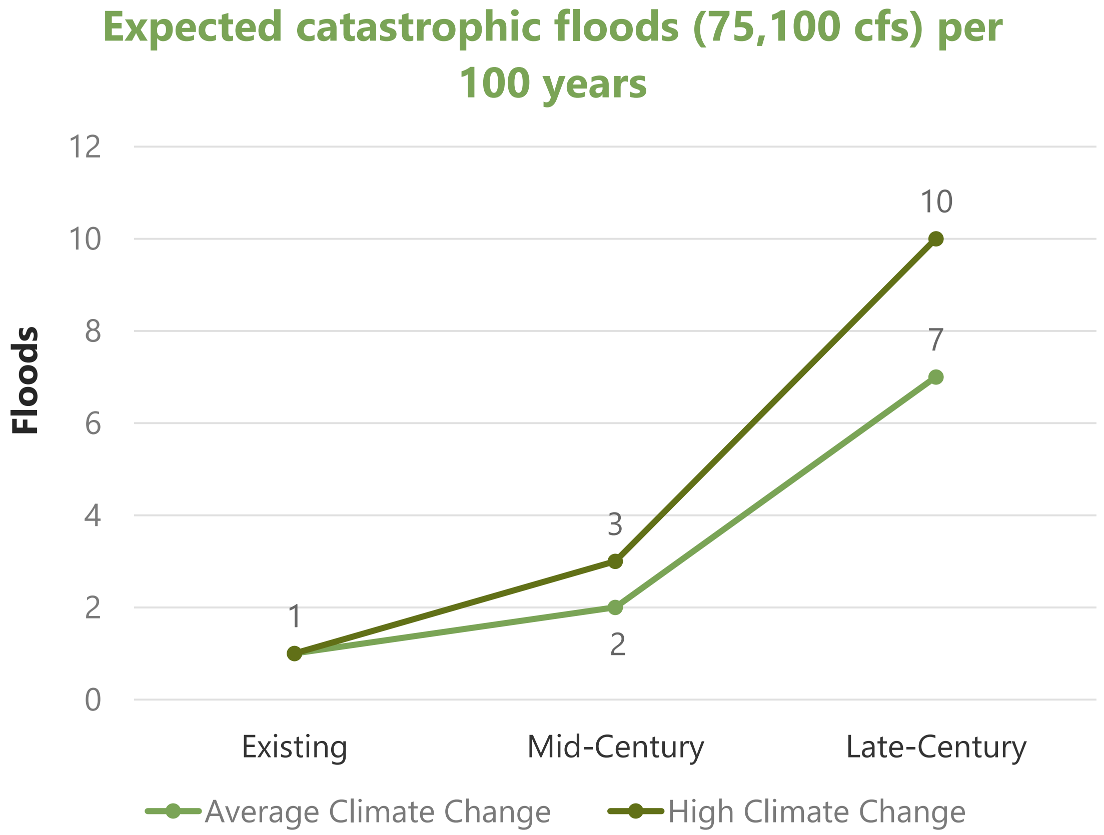
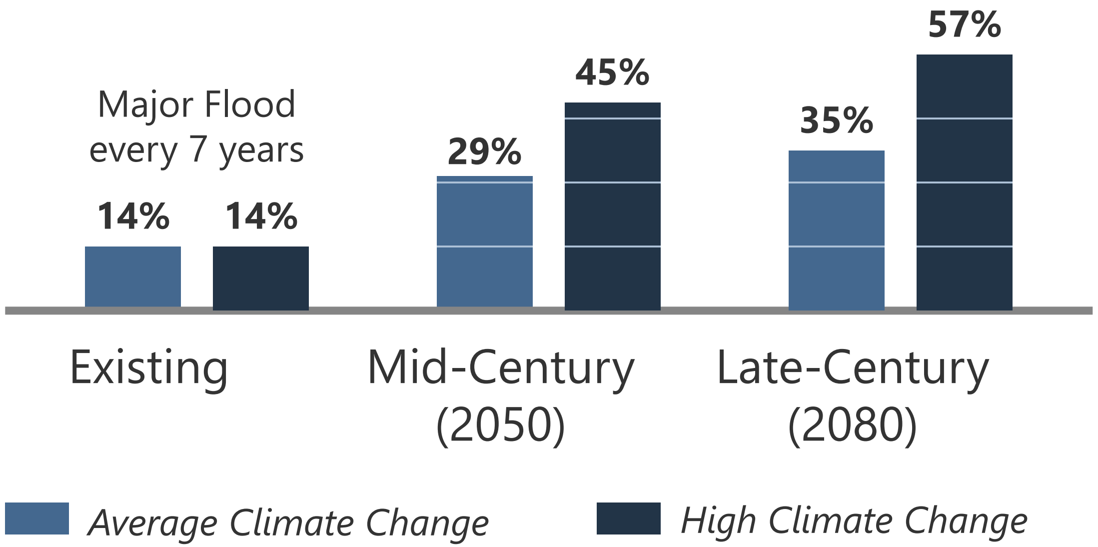
FREQUENCY OF FLOOD EVENTS AND DAM OPERATIONS



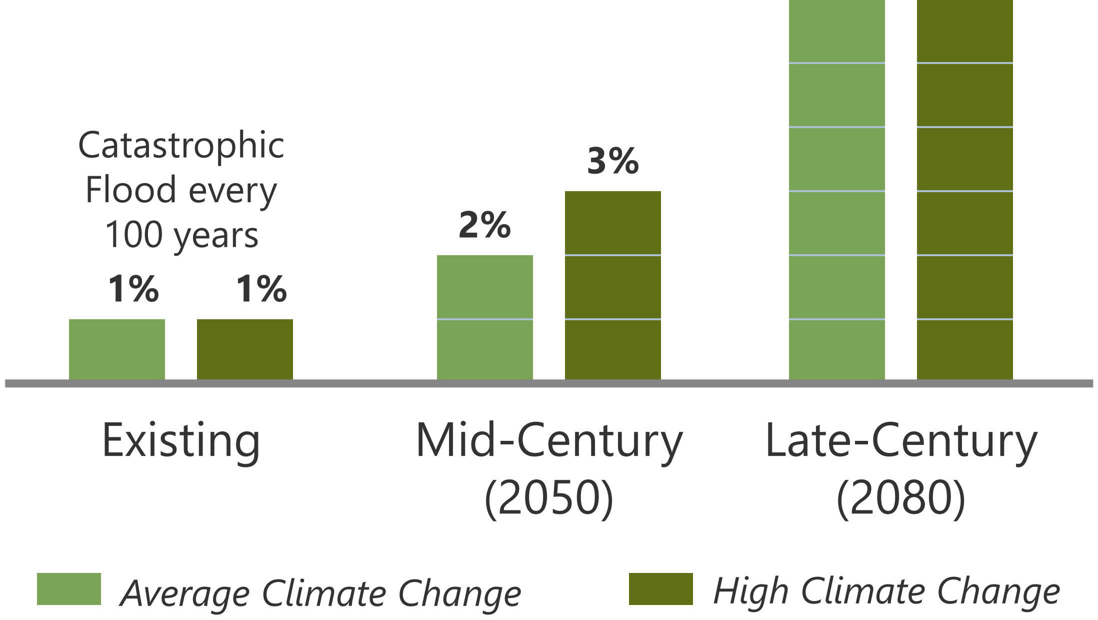


FREQUENCY OF FLOOD EVENTS AND DAM OPERATIONS

Percentage increase in **major flood** frequency compared to *existing frequency*



Percentage increase in **catastrophic flood** frequency compared to *existing frequency*



STREAMFLOW CHANGES

- Methodology developed in 2019 maintained with updates from climate change/hydrologic models
  - Peak flow increases
  - Seasonal flow adjustments (Winter or Nov-Apr; Summer or May-Oct)
  - Adjustments applied to existing flow data (October 1988 to September 2018)

STREAMFLOW CHANGES – SUMMER ADJUSTMENTS

- Calculated changes for May to October applied directly to streamflows

CLIMATE CHANGE SCENARIO	SUMMER FLOW CHANGE
Mid-century averaged	-11%
Mid-century high-end	-22%
Late-century averaged	-16%
Late-century high-end	-30%

STREAMFLOW CHANGES – WINTER ADJUSTMENTS

- Highest flows from November to April increased by peak
- Other winter flows increased by lower value

CLIMATE CHANGE SCENARIO	PEAK WINTER FLOW CHANGE	NON-PEAK WINTER FLOW CHANGE
Mid-century averaged	+12%	+3%
Mid-century high-end	Location dependent	+9%
Late-century averaged	+26%	+3%
Late-century high-end	Location dependent	+11%

CLIMATE CHANGE IN ASRP (2018-19)

- Climate change hydrologic and hydraulic model outputs incorporated into EDT and NOAA life-cycle models to evaluate effects of climate change on aquatic species
- Model outputs used to adjust various parameters in EDT/NOAA models:
  - Monthly flows for mid- and late century (both high and low flows) based on 12% and 26% increased estimates
  - Associated changes from high and flow flows to bed scour, large wood, fine sediment, substrate embeddedness, habitat types, and channel width
- Also used WDFW Thermalscape temperature model (existing and late-century conditions)

QUESTIONS?

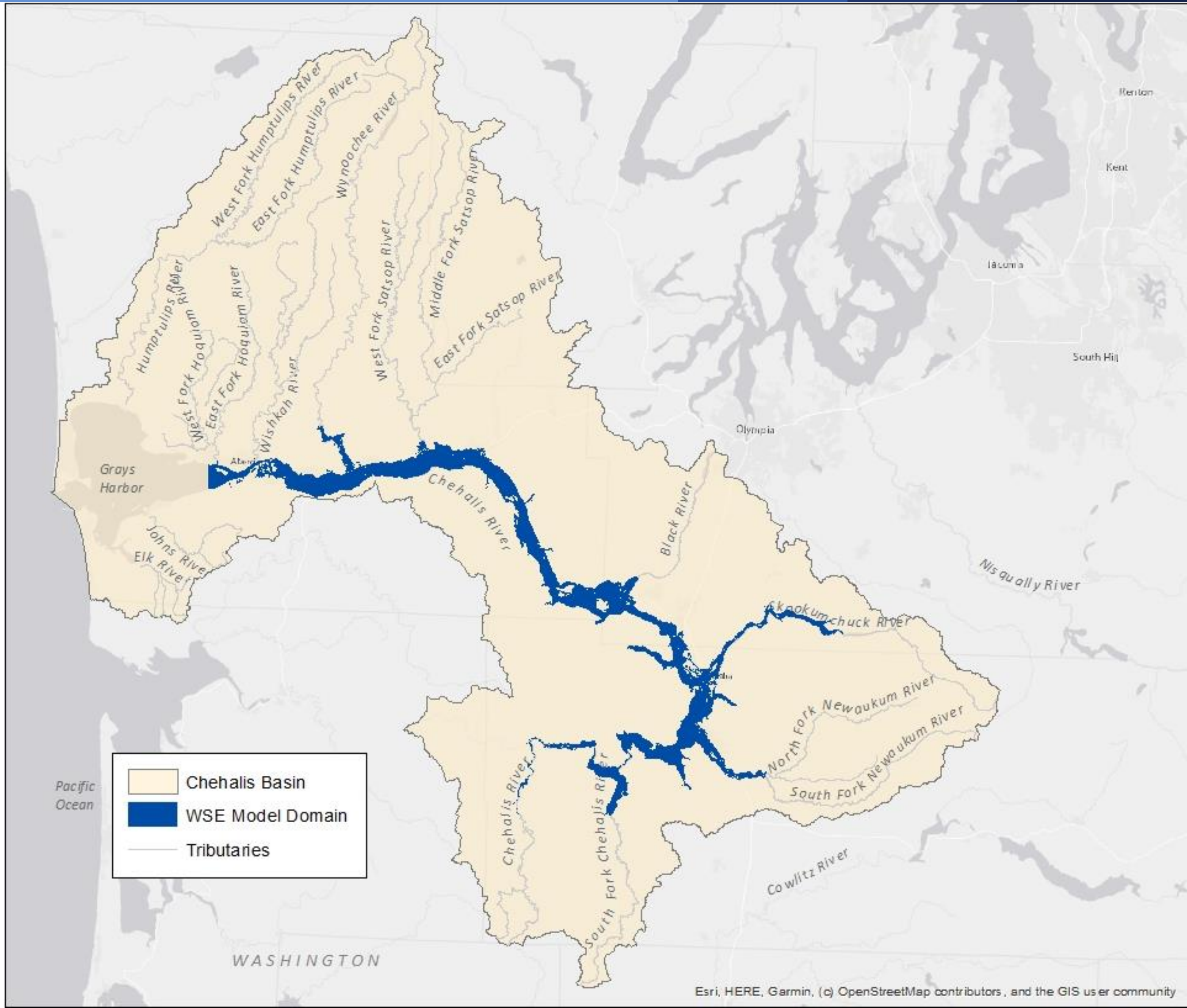
NEXT STEPS

- Are there additional questions that can be answered at future Board meetings?
- Is there additional information that would support your discussions on the use of climate change modeling for future Board decision-making?

QUESTIONS OR DISCUSSION

HYDRAULIC MODELING AND ANALYSIS

- **RiverFlow2D Hydraulic Model** (WSE, 2019)
  - Includes 108 miles of Chehalis River and significant portions of many tributaries
  - 2012 – 2019 LiDAR and bathymetry for mainstem
  - Older topo and bathymetry for most tributaries



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MAINSTEM HYDRAULIC MODELING

- Calibrated to Feb 1996, Dec 2007, and Jan 2009 flood events
- Simulated range of flood events, with and without the Dam, with several climate change scenarios
- Hydraulic model output includes detailed depth, velocity, water surface elevation, etc. in SMS

Flood Event	Climate Scenario	No Action	With Project
2-year	Historical Climate Conditions	X	
	Mid Century Conditions (+12%)	X	
	Late Century Median Conditions (+26%)	x	x
	Spatially Distributed Mid-Century High End		
	Spatially Distributed Late-Century High End	X	X
10-year	Historical Climate Conditions	x	x
	Mid Century Conditions (+12%)	x	x
	Late Century Median Conditions (+26%)	x	x
	Spatially Distributed Mid-Century High End	X	X
	Spatially Distributed Late-Century High End	X	X
20-year	Historical Climate Conditions		
	Mid Century Conditions (+12%)		
	Late Century Median Conditions (+26%)	x	x
	Spatially Distributed Mid-Century High End		
	Spatially Distributed Late-Century High End	X	X
100-year	Historical Climate Conditions	x	x
	Mid Century Conditions (+12%)	x	x
	Late Century Median Conditions (+26%)	x	x
	Spatially Distributed Mid-Century High End	X	X
	Spatially Distributed Late-Century High End	X	X
500-year	Historical Climate Conditions	X	
	Mid Century Conditions (+12%)		
	Late Century Median Conditions (+26%)	x	x
	Spatially Distributed Mid-Century High End		
	Spatially Distributed Late-Century High End	X	X
February 1996	Observed historical flows	x	
December 2007	Observed historical flows	x	
January 2009	Observed historical flows	x	

X = archived in in 20-026 Project Files
x = archived in 15-033 Project Files
Updated: 03/11/22

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