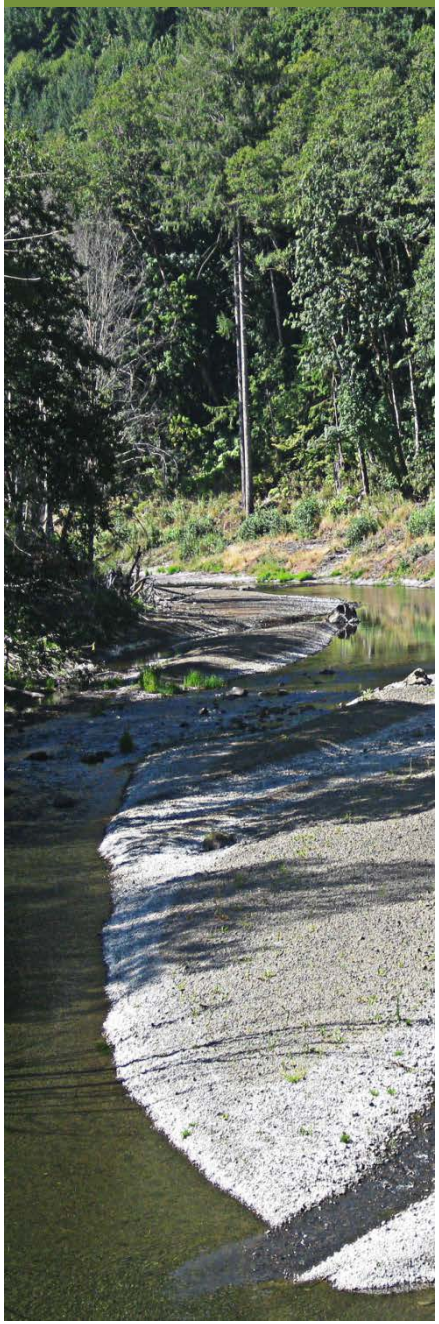
Chehalis Basin Strategy: Reducing Flood Damage and Enhancing Aquatic Species

Water Retention

Policy Workshop

September 25-26, 2014

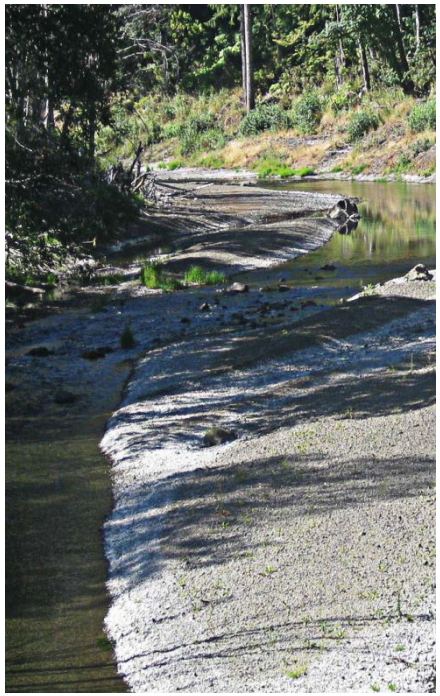


Water Retention

- Work Completed:
  - Hydrology, Preliminary Operations Plan – Anchor QEA
  - Preliminary Dam and Fish Passage Design – HDR
  - Hydraulics and Floodplain Impacts – WSE
  - Geomorphology – Watershed GeoDynamics, Anchor QEA
  - Geotechnical – Shannon & Wilson
  - Water Quality – Anchor QEA, Stillwater Sciences
  - Environmental, Fisheries – Anchor QEA, ICF, BioAnalysts

Operations and Hydrology

Anchor QEA, WSE



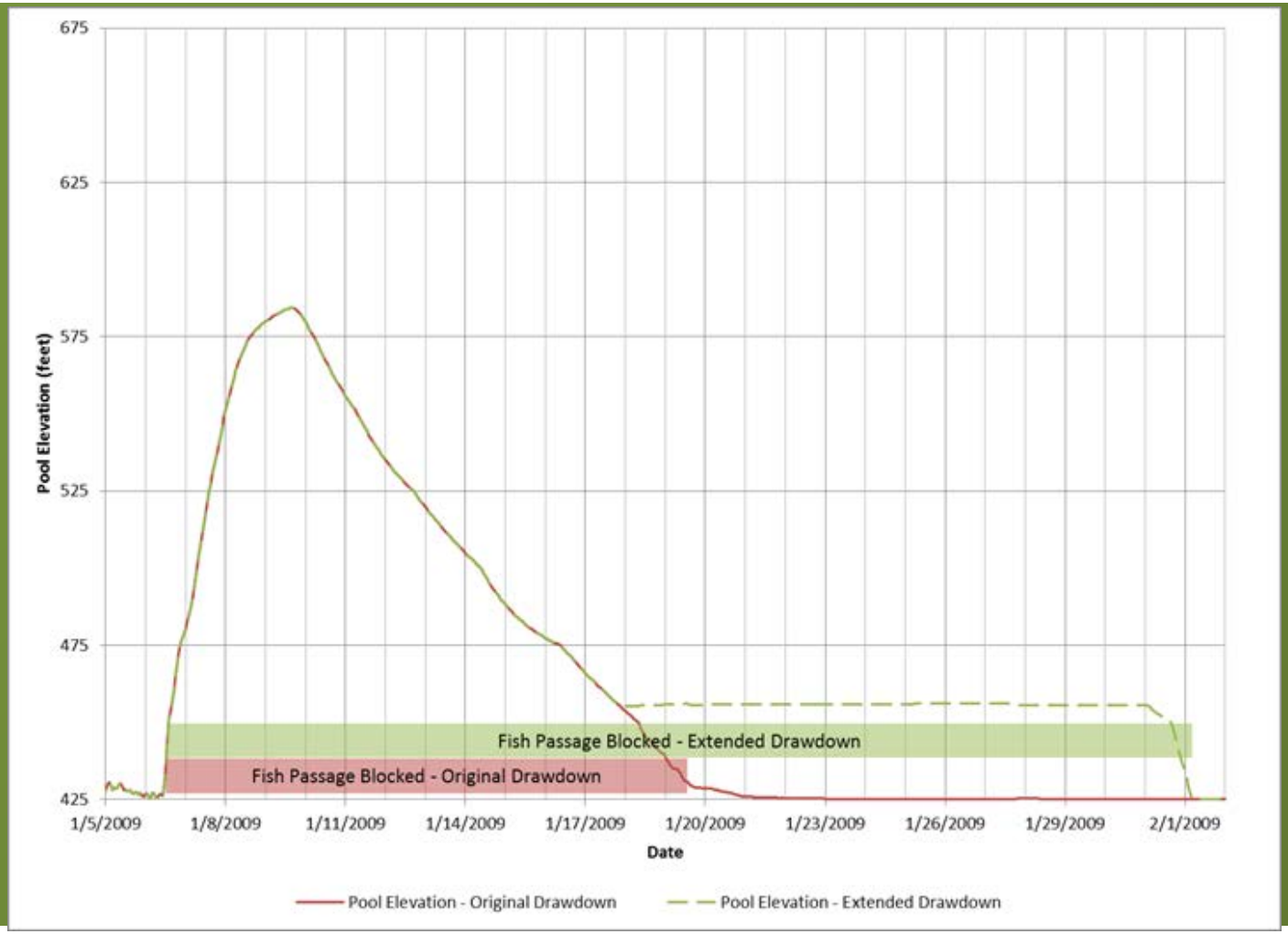
Operational Goals

- Provide flood reduction in downstream areas
- Preserve geomorphic processes downstream
- Maintain slope stability in reservoir
- Keep rate of change in flows downstream within accepted limits
- Store water during winter and release during summer (Multi-purpose Alternative)
- Provide for debris management/removal in reservoir after floods

Proposed Operating Rules – Flood Retention Only

- Available flood storage capacity = 65,000 acre-feet
- Operate the facility without impounding water except during a potentially damaging flood
- Begin storing when Grand Mound flows are predicted to be above the “Major Flood” (38,800 cfs) within 48 hours
- Reduce reservoir outflow at a rate of 200 cfs/hr until reaching 300 cfs
- Maintain reservoir pool for additional 2 weeks for debris management

FRO Reservoir Pool Elevations with Additional Time for Debris Mgmt



Analysis of Fish Passage Blockages and Delays – FRO including Climate Change

FLOOD RETENTION ONLY SCENARIO	NUMBER OF TIMES RESERVOIR IMPOUNDS WATER AND BLOCKS FISH PASSAGE (OUT OF 24 YEAR PERIOD)	% OF TIME FISH PASSAGE BLOCKED (OUT OF TOTAL TIME IN 24 YEAR PERIOD)	% OF TIME FISH PASSAGE BLOCKED IN YEARS RESERVOIR IMPOUNDS WATER	% OF TIME FISH PASSAGE IMPAIRED (>2,000 CFS) OUT OF TOTAL TIME IN 24 YEAR PERIOD	% OF TIME FISH PASSAGE IMPAIRED (>2,000 CFS) WITHOUT THE FRO RESERVOIR
Current Conditions – no extra holding time for debris mgmt	9	0.9%	3-6%	2.5%	2.7%
Current Conditions - with extra holding time for debris mgmt	9	1.5%	6-8%	2.4%	2.7%
Climate Change – 18% Increase, with extra holding time	13	3.4%	6-13%	3%	4%
Climate Change – 90% Increase, with extra holding time	31	9.7%	2-29%	5%	9%

Change in Dam/Fish Passage System with Additional Time for Debris Mgmt

- WDFW requested a CHTR (upstream trap and haul) facility be added to the FRO Alternative
- Cost of CHTR is $13M, cost was added to project costs and carried forward by economists

Operating Rules – Multi-purpose

- The Multi-Purpose facility would have a conservation pool of 65,000 acre-feet and a flood storage pool also with 65,000 acre-foot capacity.
- The conservation pool would be utilized to provide instream flows during period of low flow (typically summer).
- The flood storage pool would capture high flows to reduce downstream flooding with similar operations as the Flood Retention Only Reservoir

Operating Rules – Multi-purpose

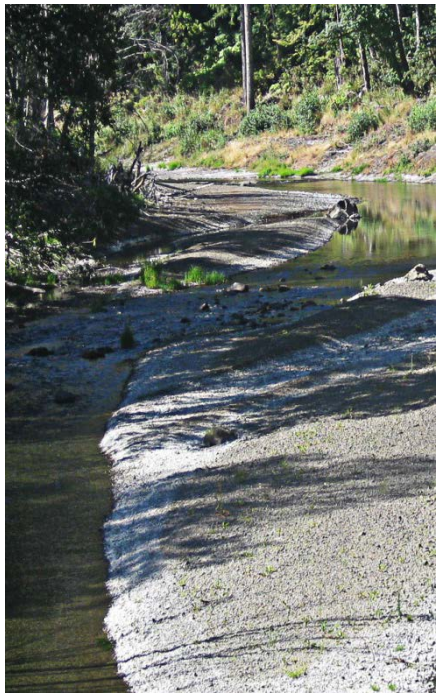
- Instream Flows
  - Minimum releases for instream flows are proposed

TIME PERIOD	FLOW
Jan-Feb	290 cfs
Mar-Jun 15	250 cfs
Jun 16-Aug 15	190 cfs
Aug 16-Dec 15	160 cfs
Dec 16-31	290 cfs

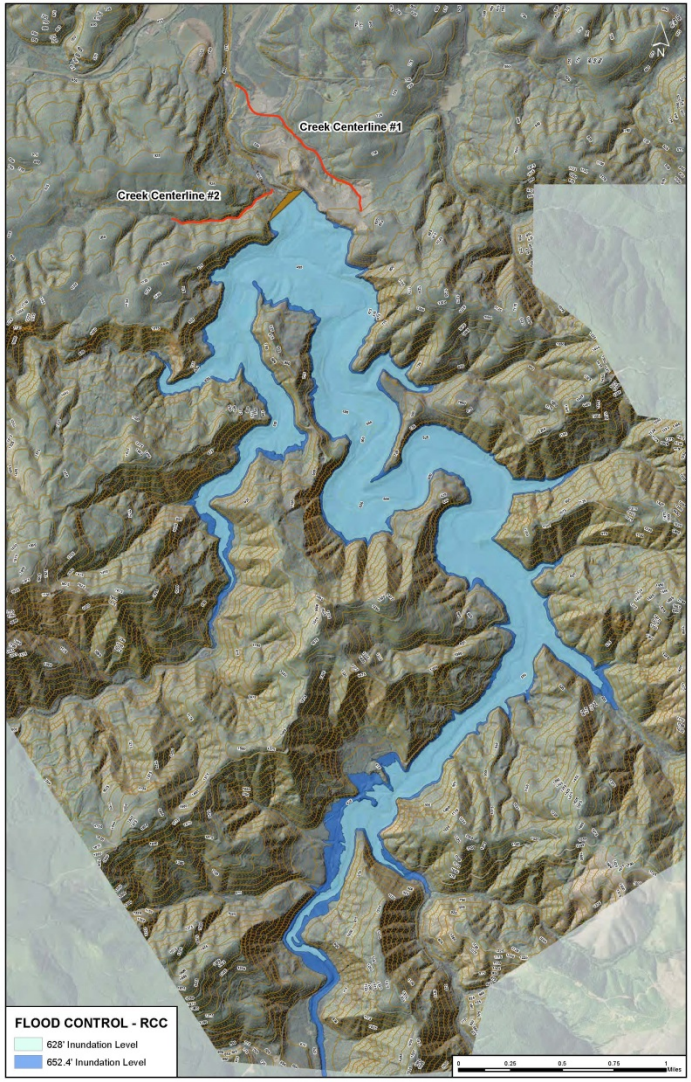
  - During drought years, reservoir releases are reduced by 20% to prevent the reservoir from completely running out

Dam and Fish Passage Design

HDR

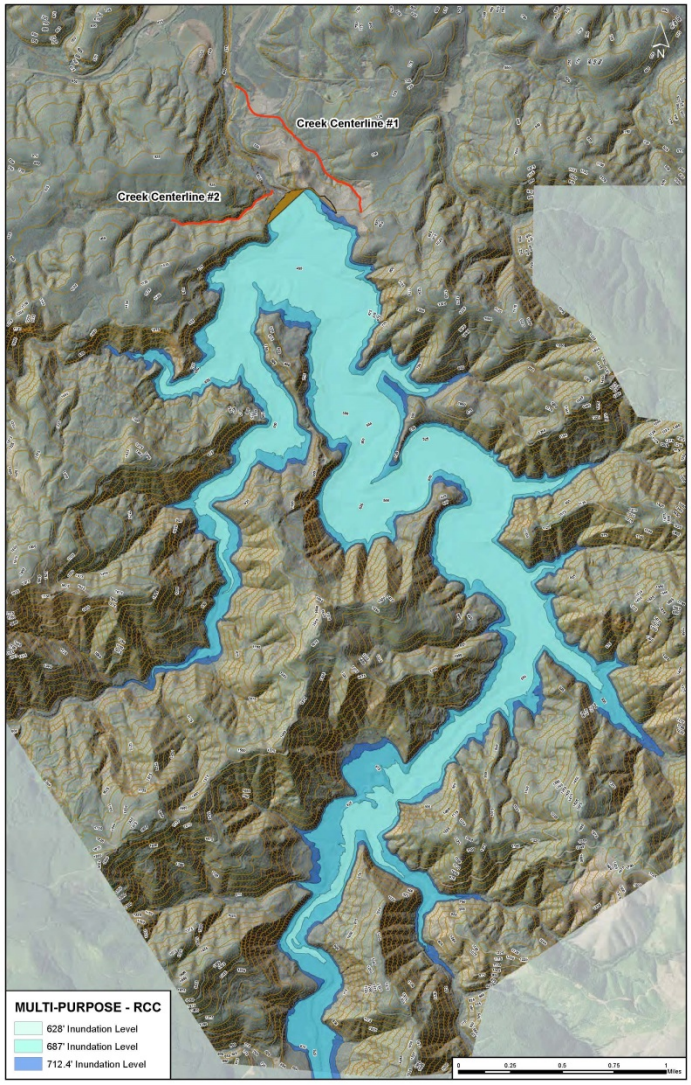


Flood Retention Only Reservoir



- Dam Height = 227’
- Spillway Crest Elev. = 628
- Dam Crest Elev. = 654
- Area = 860 Acres
- River Inundation Length = 6.8 mi

Multi-purpose Reservoir Overview



- Dam Height = 287’
- Spillway Crest Elev. = 687
- Dam Crest Elev. = 714
- Area = 1,307 Ac
- River Inundation Length = 7.5 mi

Dam and Fish Passage Options Studied

Dam Structures

- Flood Retention RCC
- Multi-Purpose RCC
- Multi-Purpose Rockfill

Fish Passage

- Upstream Passage
  - CHTR Facility
  - Conventional Fishway
  - Experimental Fishway
- Downstream Passage
  - Combination Collection Facilities
  - Forebay Collector

Examples of Integrated Dam/Fish Passage Alternatives

- **Alternative A:**
  - FR-RCC
  - CHTR Facility (upstream passage) added recently
- **Alternative B:**
  - MP-RCC Dam
  - CHTR Facility (upstream passage)
  - Combination Collector Facilities (downstream passage)
- **Alternative C:**
  - MP-RCC Dam
  - Conventional Fishway (upstream passage)
  - Forebay Collector (downstream passage)
- **Alternative D:**
  - MP-Rockfill Dam
  - Experimental Fishway (upstream passage)
  - Forebay Collector (downstream passage)

Construction Cost Estimates - Class 4 Cost Estimate Assumptions

- Expected Accuracy Range: -20% to +40%
- 2014 Dollars
- Included in Cost Estimates
  - Base Construction Cost
  - Contingencies for:
    - Design Unknowns (i.e. bridges, roads, landslide stabilization, debris management provisions)
    - Construction Change Orders/Claims
    - Design and Site Investigations
    - Permitting
    - Construction Management and Engineering Support

Dam and Fish Passage Structure Costs

Dam Type	Lower Bound Cost, $M	Average Cost, $M	Upper Bound Cost, $M
FR-RCC	228	280	333
MP-RCC	276	336	395
MP-Rockfill	412	491	570

Costs for RCC dams reduced from earlier estimates as a result of updated material costs provided by Shannon & Wilson study of material sources

Climate Change Flood Retention Scenarios, Dam Size and Cost Impacts

Scenario 1

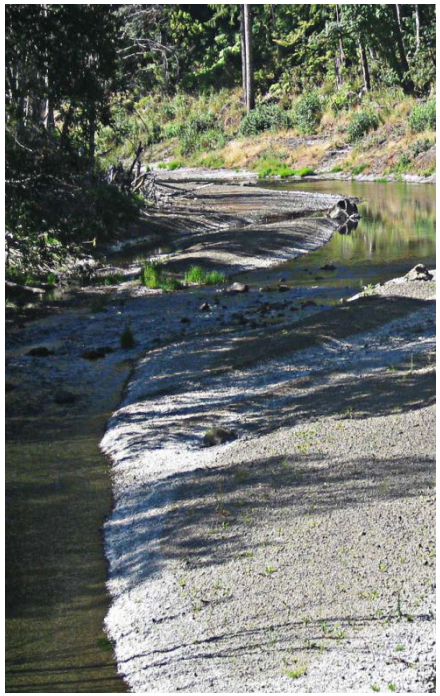
- 18 percent increase in Chehalis River flows
- 10,000 AF increase in flood retention storage – to 75,000 AF
- Increase in dam height 9 feet to 239 feet
- Increase in cost = $23M from FRO-RCC

Scenario 2

- 90 percent increase in Chehalis River flows
- 65,000 AF increase in flood retention storage – to 130,000 AF
- Increase dam height 57 feet to 287 feet
- The same height as the non-climate change MP dam
- Increase in cost = $123M from FRO-RCC

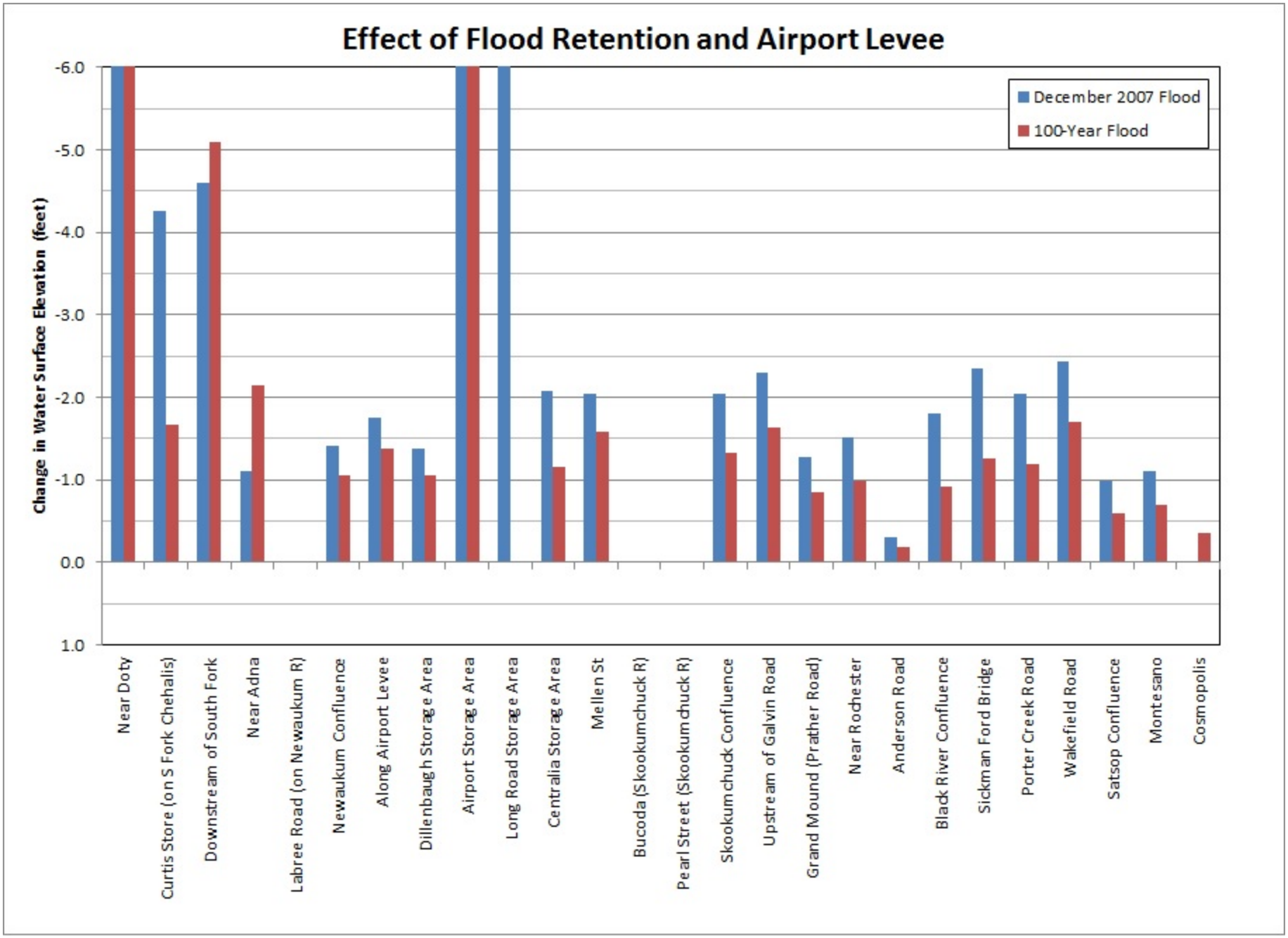
Hydraulics and Floodplain Impacts

WSE



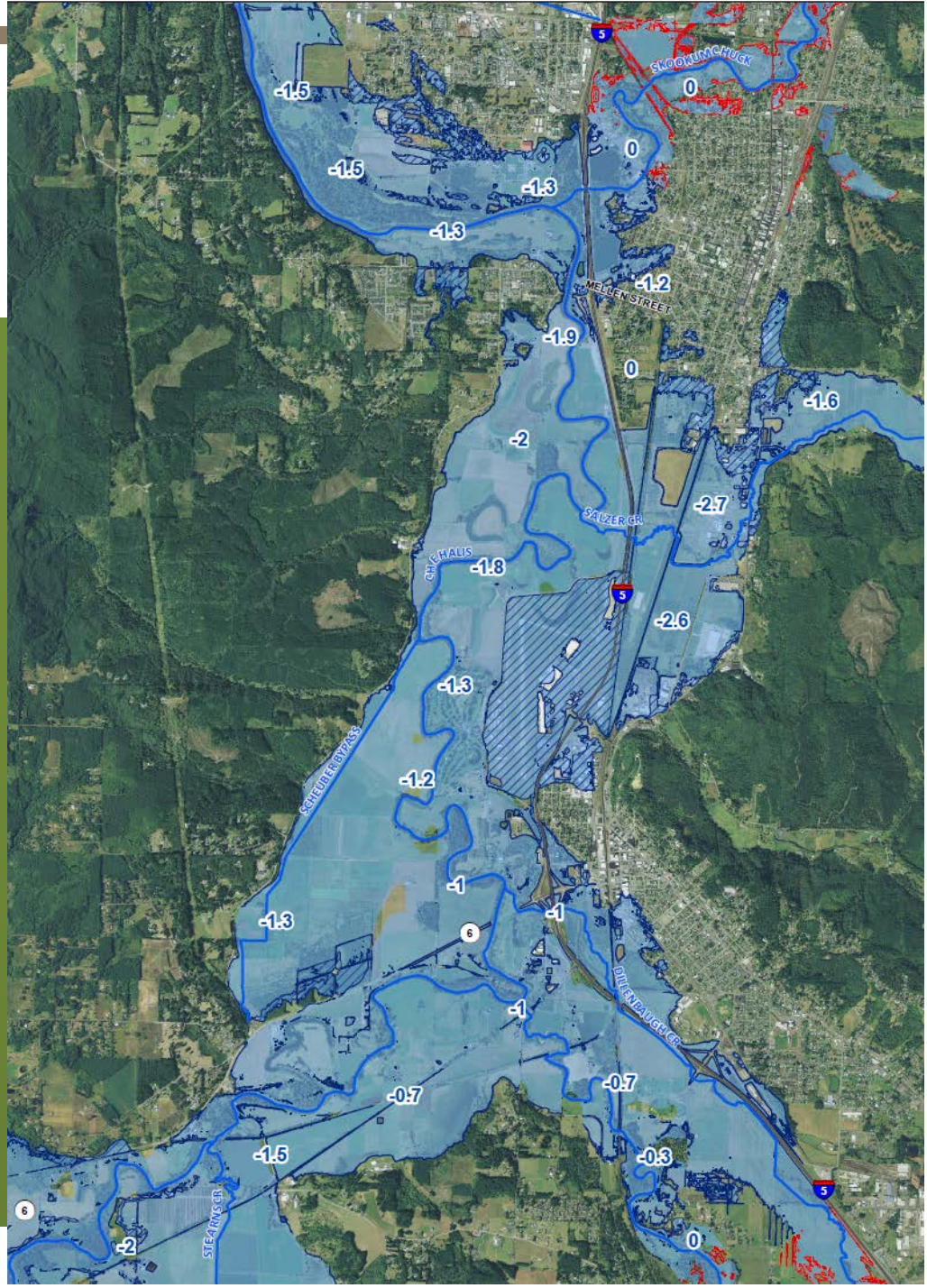
Flood Reduction Benefits

- Same for FRO and MP alternatives
- HEC-RAS model was used to route floods through Chehalis River and its floodplain
- Desktop and partial field survey of structures was performed to determine structure elevation


Effect of Flood Retention and Airport Levee
December 2007 Flood
100-Year Flood
Change in Water Surface Elevation (feet)
-6.0
-5.0
-4.0
-3.0
-2.0
-1.0
0.0
1.0
Near Doty
Curtis Store (on S Fork Chehalis)
Downstream of South Fork
Near Adna
Labree Road (on Newaukum R)
Newaukum Confluence
Along Airport Levee
Dillenbaugh Storage Area
Airport Storage Area
Long Road Storage Area
Centralia Storage Area
Mellen St
Bucoda (Skookumchuck R)
Pearl Street (Skookumchuck R)
Skookumchuck Confluence
Upstream of Galvin Road
Grand Mound (Prather Road)
Near Rochester
Anderson Road
Black River Confluence
Sickman Ford Bridge
Porter Creek Road
Wakefield Road
Satsop Confluence
Montesano
Cosmopolis

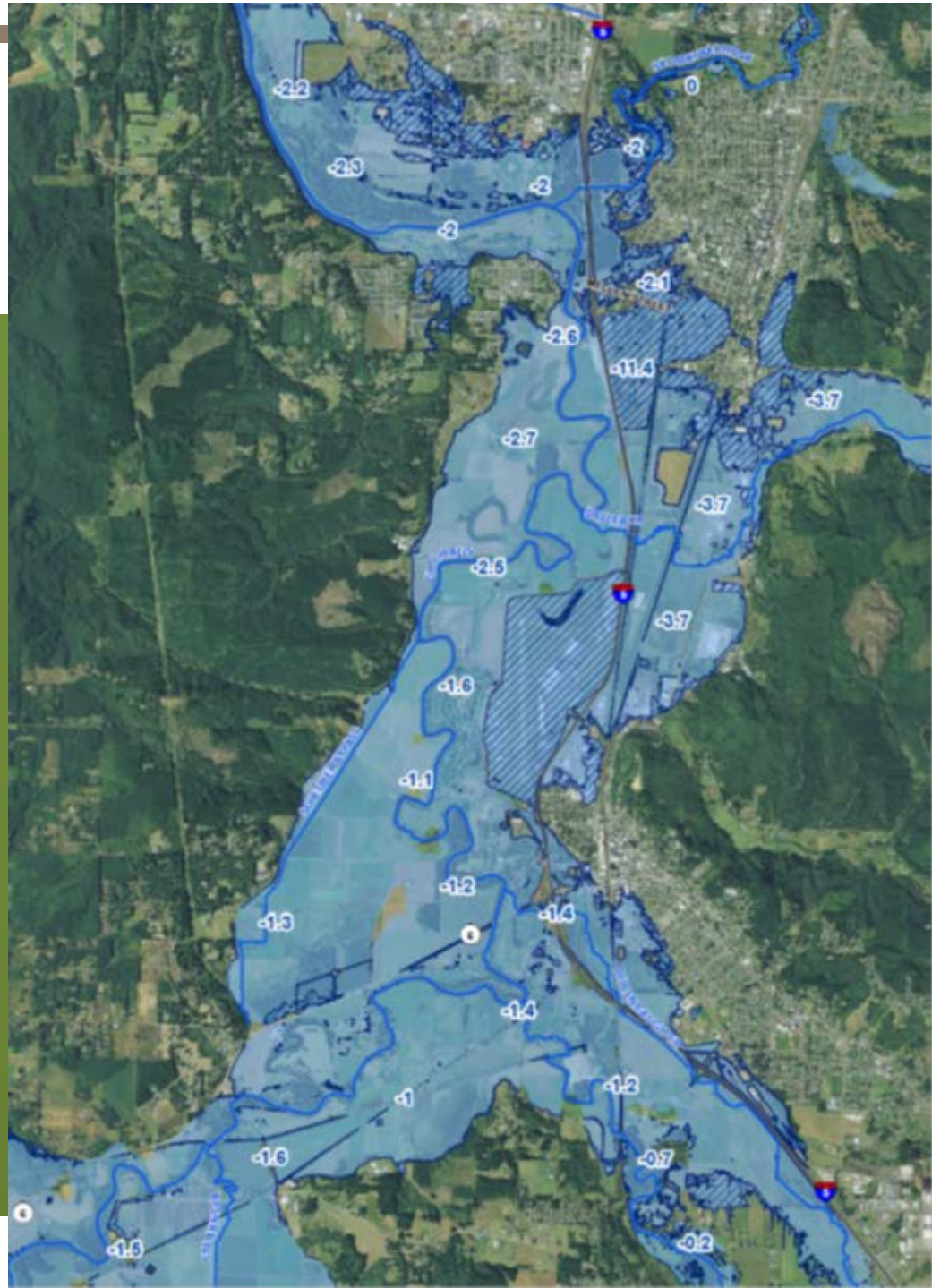
Floodplain Map

- Flood reduction shown for 100-year flood with dam



Floodplain Map

- Flood reduction shown for 2007 event with dam



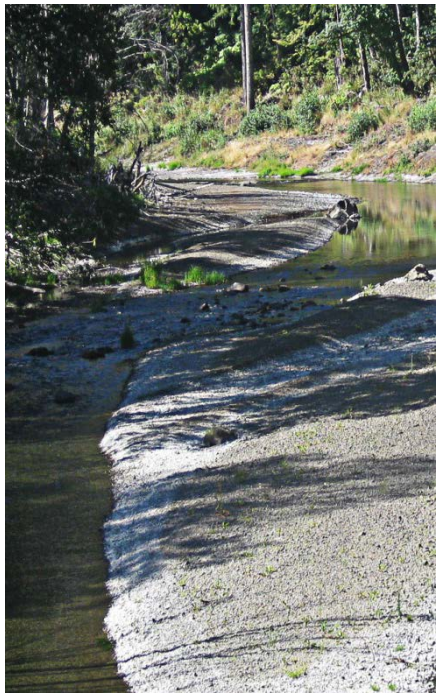
Flood Reduction for Floodplain Structures

Number of Structures	Baseline			With Dam and Airport Levee		
	Dec 07	500-Year	100-Year	Dec 07	500-Year	100-Year
Flooded	2040	3633	1385	749	2025	820
>1.0 feet	1370	2743	825	436	1300	458
>2.0 feet	813	1912	488	242	757	237
>3.0 feet	469	1159	290	137	466	112
>4.0 feet	262	662	151	62	298	53
>5.0 feet	163	383	76	27	153	23
Assessed Value of Improvements Inundated ($Million)	$239	$411	$137	$64	$206	$73

Flood damage and flood reduction benefits will be discussed in floodproofing and economics presentations on Sept 26

Geomorphology

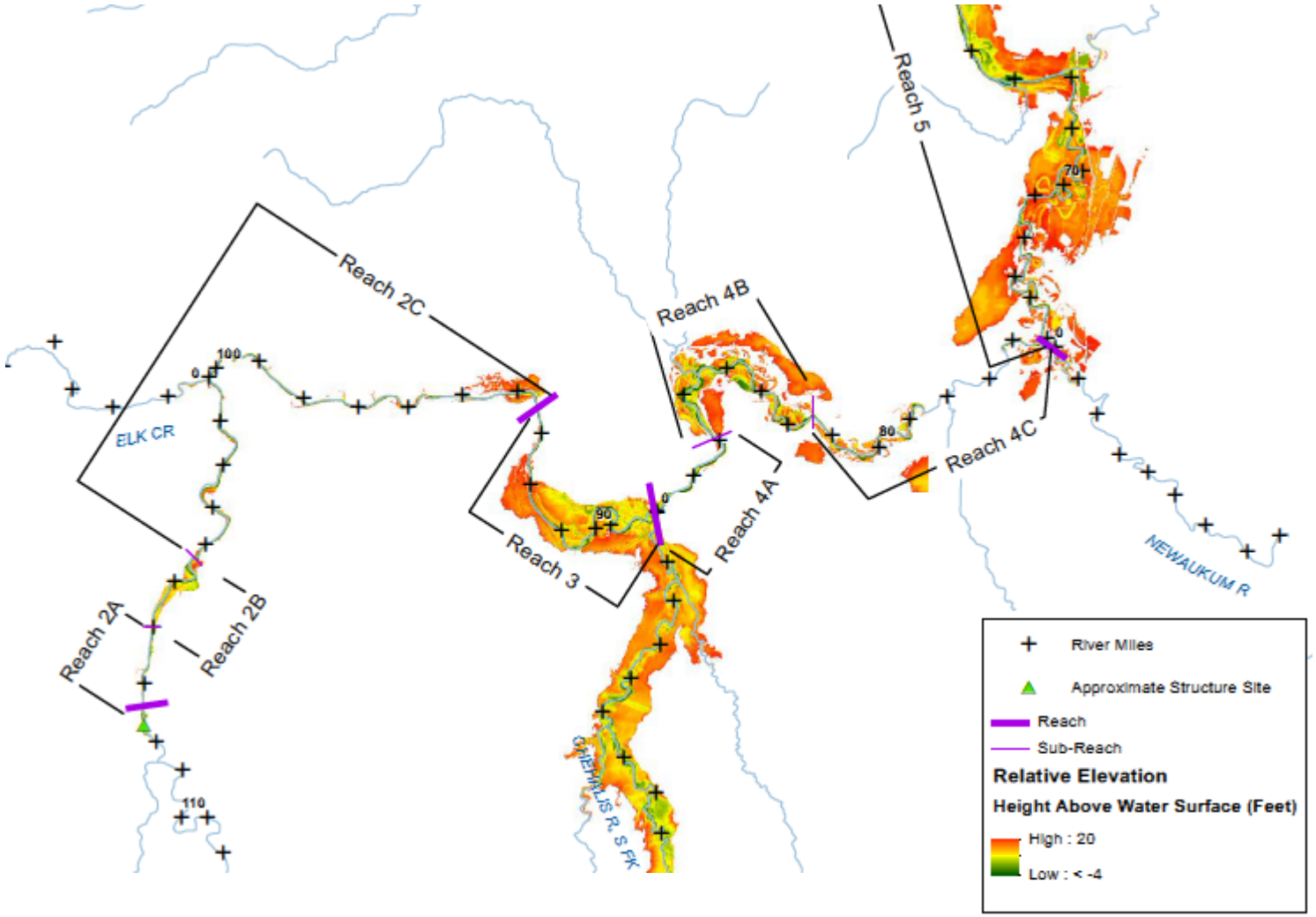
Watershed GeoDynamics, Anchor QEA



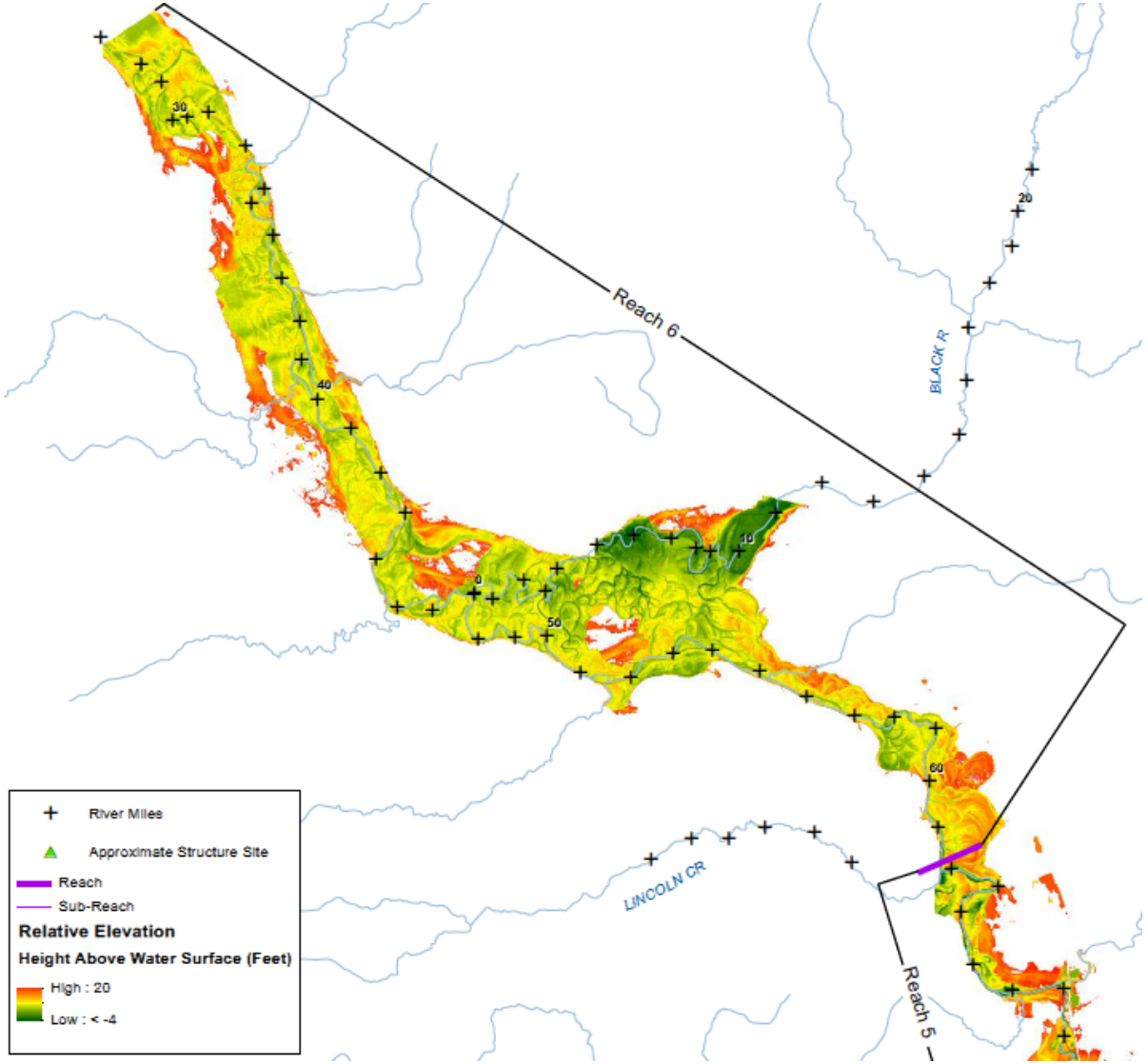
Geomorphology Considerations

- Project operation could affect:
  - Peak flows (sediment transport)
  - Sediment input (reservoir storage, change in bank erosion)
  - Large woody debris input/transport
- Potential Key Geomorphology/Habitat Effects
  - Substrate (spawning gravel, interstitial rearing, etc.)
  - Channel forming processes (meander rate, LWD input, holding pools, etc.)
  - Floodplain and off-channel connectivity

Geomorphic Reaches and Sub-Reaches



Geomorphic Reaches and Sub-Reaches



Channel Migration

- Small amounts of channel migration occur during small (2-year recurrence) peak flows ~10,000 cfs at Doty
- Major channel change takes place in response to large woody debris loading (e.g., 2007)
- Reduction in peak flows under with-Project scenarios would likely result in narrower active channel and somewhat less channel migration

Large Woody Debris

- Existing low levels of large woody debris
- Large woody debris would be trapped in either reservoir
- Interruption/reduction of large woody debris transport with reservoir
- Management plan – likely transport wood around structure, place in downstream channel
- Less input of large woody debris if less bank erosion between dam and RM 70

Reservoir Sediment and Debris Loading

- Long term operations/maintenance concern
- Multi-Purpose
  - All bedload, 86-93% of suspended load (42 acre-ft/yr)
- Flood Retention Only
  - 25-50% of bedload (4.3-8.7 acre-ft/yr)
- Larger amounts of woody debris expected during floods with 10-25 year recurrence interval
- 2007 flood event (extreme flood)
  - 2,000-3,000 acre-ft of coarse sediment
  - 230 acre-ft of woody debris

Geomorphic Effects on Aquatic Habitat

Reach 1 – Reservoir

Variable	Flood Retention Only	Multi-Purpose
Substrate/Spawning Gravel	Finer substrate/ transient delta	Inundated
Channel Width/Depth	Likely wider/ shallower wetted channel	Inundated
Large Woody Debris	Wood trapped – transported around dam	Wood trapped – transported around dam
Channel Migration	n/a - confined	n/a - confined

Geomorphic Effects on Aquatic Habitat

Confined Reaches – 2A, 2C, 4A, 4C

Variable	Flood Retention Only	Multi-Purpose
Substrate/Spawning Gravel	Minor changes	Erosion/ coarsening
Channel Width/Depth	Minor changes	Possible narrower channel
Large Woody Debris	Likely less LWD	Likely less LWD
Channel Migration	n/a - confined	n/a - confined

Geomorphic Effects on Aquatic Habitat

Unconfined Reaches – 2B, 3, 4B

Variable	Flood Retention Only	Multi-Purpose
Substrate/Spawning Gravel	2B - Continued aggradation/fining 3 - Minor changes 4B – Possible coarsening	Erosion/ coarsening
Channel Width/Depth	Minor changes	Possible narrower channel
Large Woody Debris	Likely less LWD	Likely less LWD
Channel Migration	Likely less channel migration	Likely less channel migration

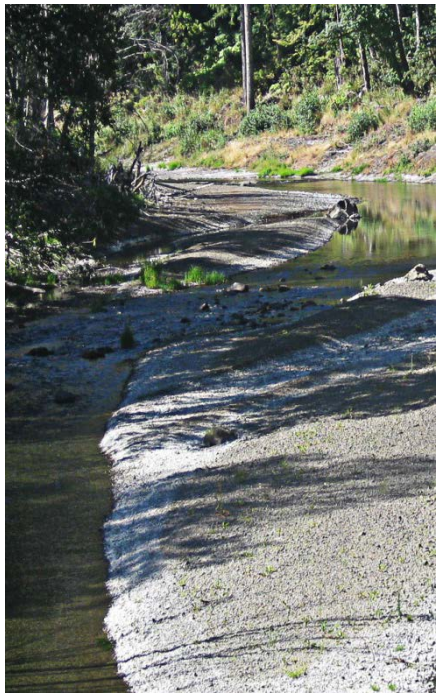
Geomorphic Effects on Aquatic Habitat

Reaches 5, 6 – Downstream of RM 75

- Limited changes – bedrock control re-sets bedload transport
- Tributary input of water/wood sediment mute effects of flood control facilities

Geotechnical

Shannon & Wilson

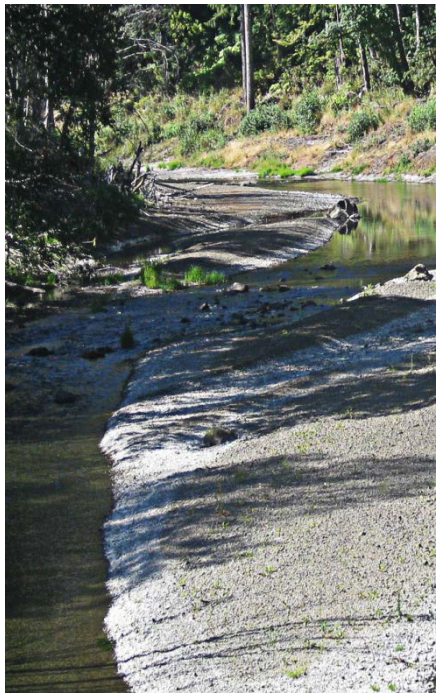


Geotechnical

- A review of the source of dam materials was performed to refine construction cost estimates
- Materials for an earth/rock fill dam are available in the proposed reservoir area, sand and gravel suitable for drainage/filter layers are available within 40 miles.
- Concrete aggregate for an RCC dam is available in existing quarries within 25 miles.
- The estimated costs for RCC material was substantially lowered, lowering the overall construction cost of FRO-RCC and MP-RCC alternatives.

Water Quality

Anchor QEA, Stillwater Sciences



Historical Water Quality Issues in the Chehalis Basin

- Chehalis River above Newaukum River confluence
  - Temperature
  - Fecal coliforms
- Centralia Reach
  - Dissolved oxygen (DO)
  - Biological Oxygen Demand (BOD)
  - Ammonia-N
- Black River
  - Total phosphorus
  - DO
  - Fecal coliform

Water Quality Study Objectives

- Provide an evaluation of baseline water quality in the Chehalis River
- Provide a dataset for model calibration
  - Refine existing water quality models or
  - Develop new/improved models
  - Address data gaps identified in the 2012 fish study
- Data collection only during this phase

Water Quality Study Design

- Continuous temperature monitoring
  - 12 locations overall
  - Covers mainstem Chehalis River and major tributaries
- Synoptic low-flow water quality surveys
  - Three surveys, 15 locations during each survey
  - Designed to measure nutrient and BOD loads
- Diurnal surveys at select locations
  - Characterizes daily fluctuations in temperature, DO and pH
- Depth profiles of water quality parameters at select locations

Water Quality Study Design (continued)

- Boat survey in Centralia reach
  - Historically problematic reach with thermal stratification and low DO in summer
  - Characterization of the DO and temperature regime
- Winter water quality sampling at Pe Ell
  - To develop boundary conditions for reservoir model
- Groundwater temperature surveys
  - To provide an estimate of temperature mitigation in gaining reaches
  - Focus primarily on mainstem reach above Newaukum River confluence

Other Program Elements to Support Water Quality Modeling

- Riparian shade surveys
  - Review of existing LiDAR data to identify vegetation type and density
  - Field surveys in May 2014 to ground truth (using hemi-view) vegetation type and canopy density classifications
  - Assessments will provide inputs needed for temperature modeling
- Adding meteorological sensors to rain gage on Chehalis River near Thrash Creek
  - Will provide wind speed and direction, dew point temperature and incident solar radiation
  - Data available to public through early warning system website
- FLIR Systems thermal imaging

Temperature Summary

- Upper reaches consistently showed exceedances over criterion
  - Temperature at tributary mouths also warm
  - Data indicates that thermal refuge available to aquatic species is limited in the upper watershed
  - Riparian study indicates only limited shading available in upper reaches (consistent with Ecology's TMDL which calls for more shading)
- Conditions in fall generally below applicable criterion
- Thermal stratification observed in Centralia Reach

Exceedances in Other Parameters

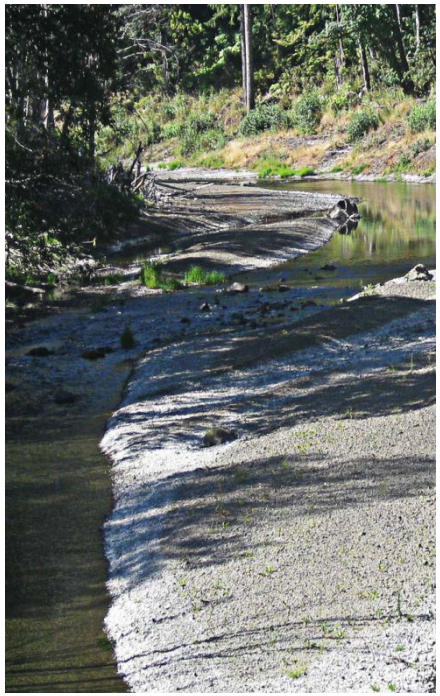
- DO potentially problematic in upper reaches in summer
  - Evidence of (attached) algal activity
  - pH swings correspond to DO swings, but no excursions noted during study
- DO very low in lower waters of stratified portions of Centralia Reach
  - Particularly from River Miles 68 to 70
  - SOD is likely cause
  - pH also affected in bottom waters, likely from sediment redox activity
- No excursions in turbidity

Conclusion – Water Quality

- Water quality study has collected data consistent with the objectives
  - Establishes baseline conditions
  - Data sets for developing temperature and water quality models
- Continued data collection will help establish inter-annual trends
  - Data set collected is over 12-month period covering two summers and one winter
- Data can be used in future water quality models of Chehalis River and proposed reservoir

Environmental & Fisheries

Anchor QEA, ICF, BioAnalysts



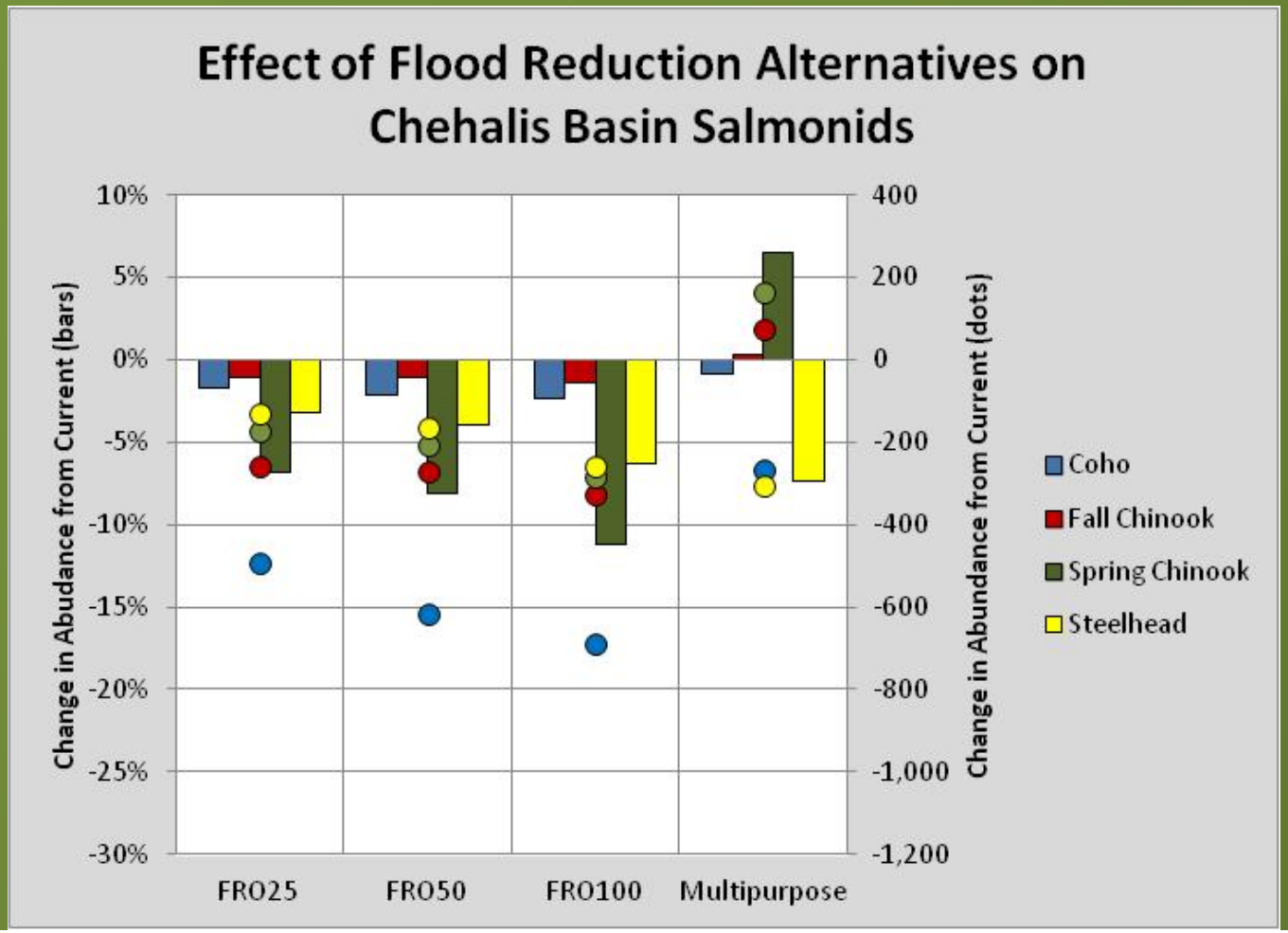
Overview of Methods - Salmon

- Scope: Upstream of and including the Wynoochee River
- EDT model: Spring- and fall-run Chinook, coho, steelhead
- Water Retention Structures
  - FRO25, FRO50, FRO100 (i.e., 25, 50 , or 100% of habitat in footprint is lost to production)
  - Multi-purpose
- Climate
  - Low and High scenarios of wetter winters, drier summers and warmer temperatures

Water Retention Structures

- FRO results:
  - Impacts ranged from -2 to -11%
  - Largest impacts on spring-run Chinook and steelhead
- MPD results:
  - Effects ranged from -7% (steelhead) to +6% (spring-run Chinook)
  - The 6% benefit is questioned by WDFW
- Assumptions:
  - MPD: Spring-run Chinook hold where they spawn and benefit from cold water releases – this would need additional study before all parties agree
  - Spring-run Chinook are currently migrating upstream and holding below the proposed dam site in order to realize the benefits of reduced temperature and higher summer flows
  - No change in baseline over time

Water Retention Structures (bars are %; dots are #'s)



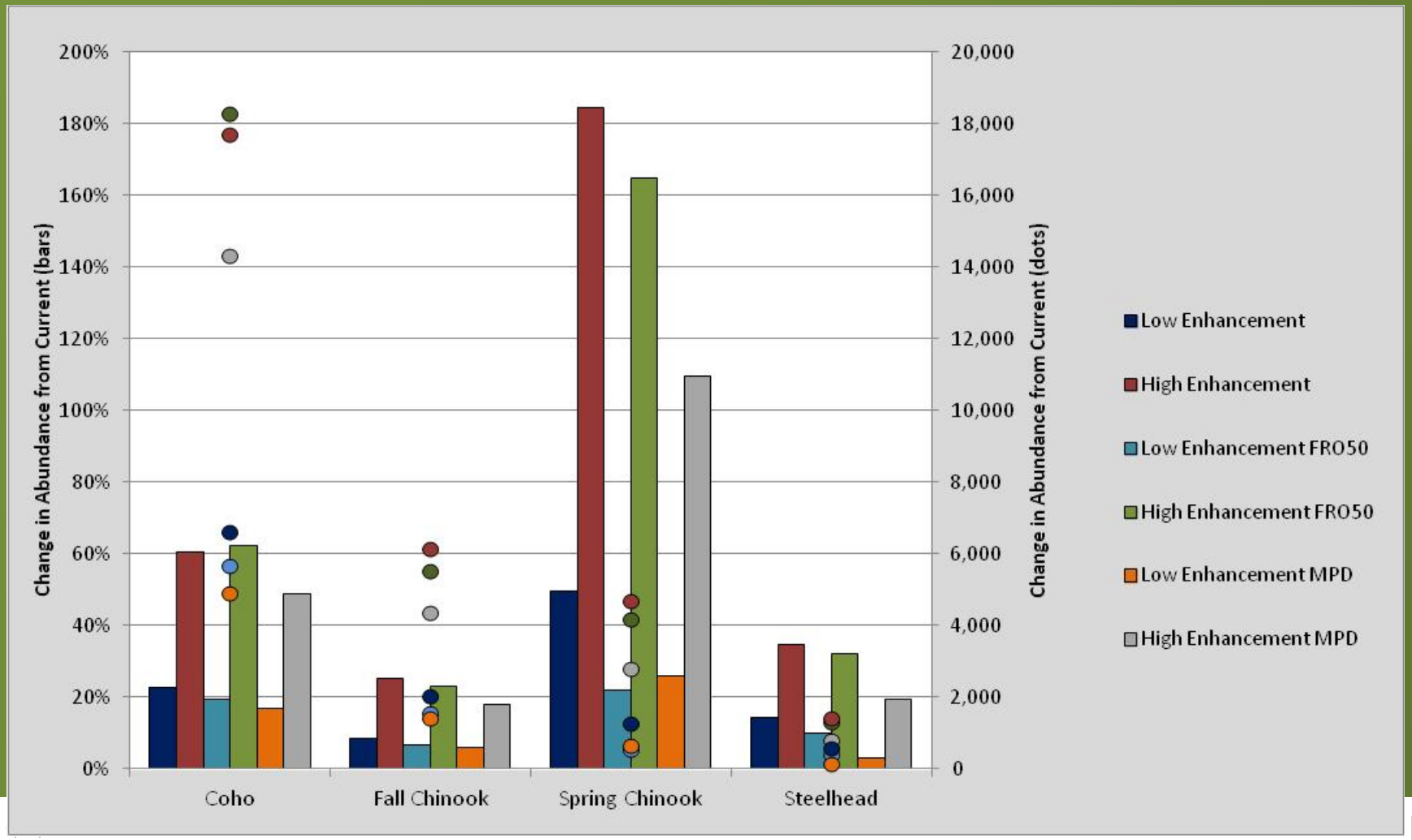
Key Findings – Salmon - Dams

- Effects of dam alternatives were generally negative
- Generally, effects of FRO > MPD (cold water releases and some reservoir rearing)
- Effects were greatest to upper populations
- At the basin scale, effects were largest on spring-run Chinook salmon and steelhead
- One exception was positive effect of MPD Alternative on spring-run Chinook salmon (due to cool water releases)
- This effect, however, is predicated on:
  - Assumption that spring-run Chinook salmon currently hold at sites near where they spawn rather than seeking cold water refugia elsewhere
  - Under this assumption, they would benefit from cold water released from a storage facility

Water Retention Structures + Habitat Enhancement

- All combinations increase fish populations
- High Enhancement + dams > Low Enhancement + dams
- Assumptions:
  - No degradation in baseline over time
  - Habitat assumption that needs to be validated
    - Functional response can be achieved and sustained; wood stays in system; culverts continue to function

Water Retention Structures + Habitat Enhancement (riparian enhancements, culvert removal) (bars %; dots #)



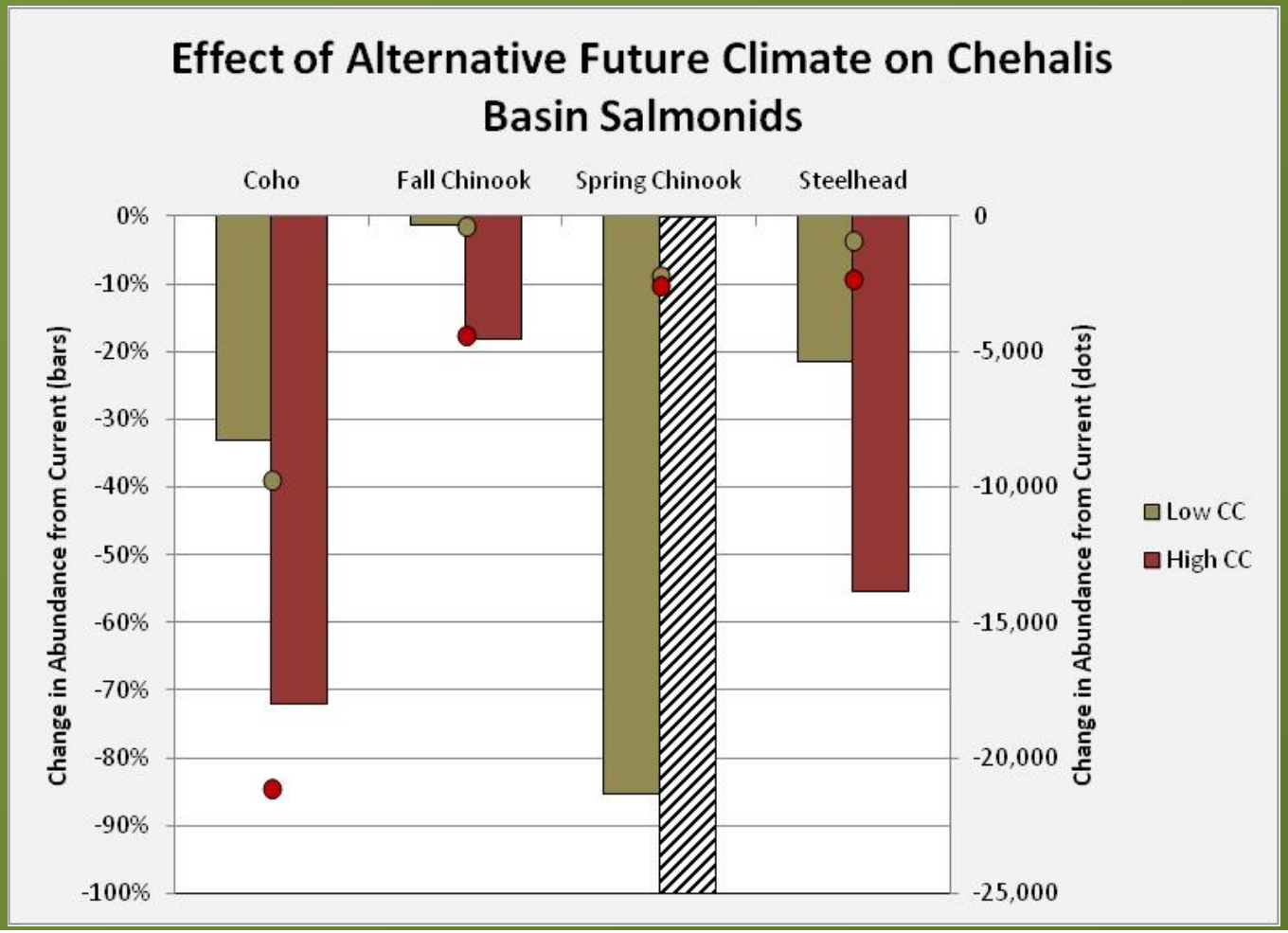
Key Findings – Salmon – Dams + Habitat Enhancement

- Results were positive for salmon and steelhead (i.e., enhancement exceeded dam effects)
- Relative benefit was strongest for spring-run Chinook salmon because some enhancement actions targeted this run
- Enhancement actions focused on other species will produce somewhat different results
- The results should be interpreted with caution because of the need to test and validate some of the key assumptions about the interactions between enhancement and dam effects

Climate

- Scenarios modeled:
  - Low and High climate (wetter winters and drier summers, warmer temperatures)
- Results:
  - Largest effect on coho and spring-run Chinook
  - Spring-run Chinook extirpated under High climate
- Assumptions:
  - No change in baseline over time other than climate

Climate (bars are %'s; dots are #'s)



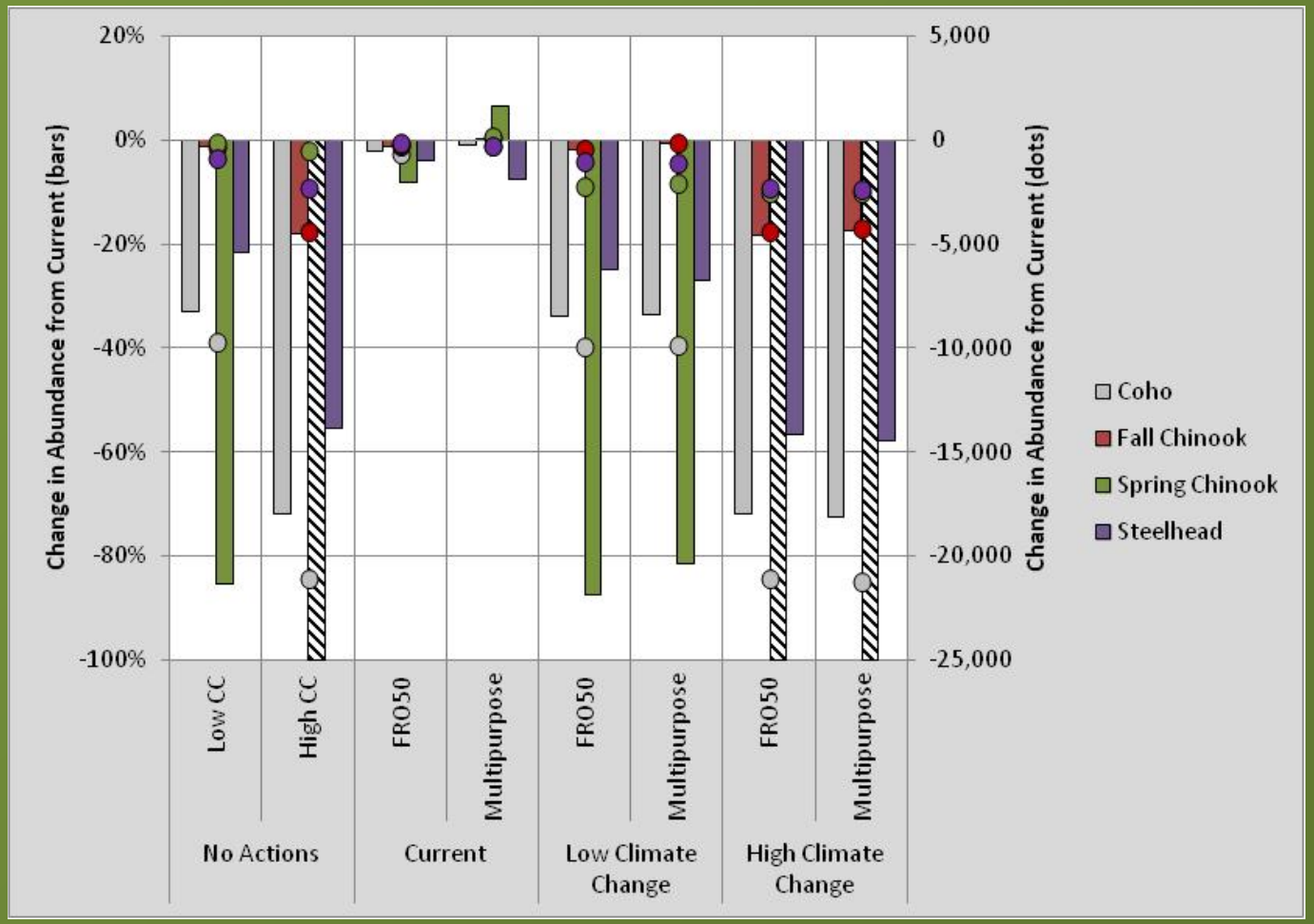
Key Findings - Salmon – Climate

- Climate change could lead to a major decline for all salmon and steelhead, and the extirpation of spring-run Chinook salmon in the basin and some populations of other species
- Given these findings, a more in-depth climate change risk assessment is warranted in any future work

Dams + Climate

- Action:
  - FRO50, MPD, Low and High climate
- Results:
  - Climate effects exceed dam effects
  - Entire basin (climate) vs. Upper basin (dams)
  - Spring-run Chinook extirpated under High climate
- Assumptions:
  - No change in baseline over time other than climate
  - Change in baseline with climate and MF60

Dams and Climate Combined (relative to current conditions; bars are %'s; dots are #'s)



Key Findings – Salmon – Dams + Climate

- Dams and climate combined have negative effects
- Climate effects exceed dam effects (scale issue)

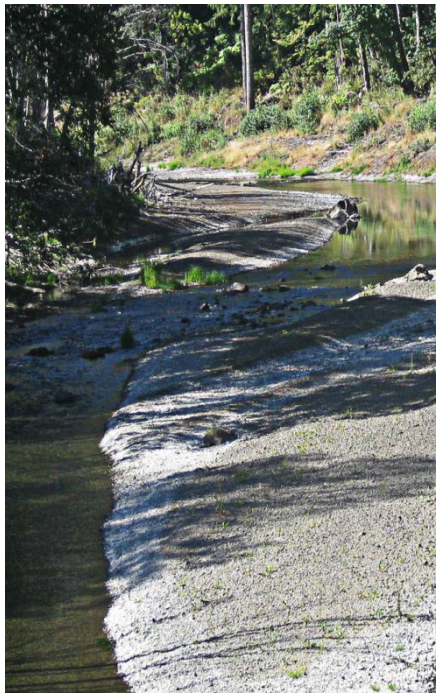
Methods: Other Fish and Non-fish Species

- Modeled habitat change and changes in species abundance
- In-channel: Changes in habitat associated with
  - Multi-purpose structure
  - Climate
- Off-Channel: Changes in floodplain inundation patterns
  - 500-, 100-, 20-, 10-, and 2-year events
  - Generic water retention structure

Key Findings: Other Fish and Non-fish Species

- In-channel:
  - Most species sustained declines in habitat with multi-purpose water retention structure
  - Pacific Lamprey responses were mixed
  - Mountain Whitefish sustained increases across all reaches
- Off-channel:
  - Marked decline in available habitat at all flood levels except the 2-year event
  - Inundation index generally decreased with distance from dam; area of inundation generally increased closer to the river mouth
  - Results did not account for predicted changes from climate change

Next Steps if Project Proceeds



Dam, Fish Passage Design

- Refine conceptual designs, including fish passage concept based upon need for CHTR for FRO
- Geotechnical investigations for foundations, landslides, materials
- Additional hydrologic modeling

Salmon

- Validate assumptions regarding salmon life histories and effects from dam
- Continue WDFW surveys and add additional to verify juvenile and adult salmon movements
- Validate dam operations assumptions regarding temp, debris, and sediment
- Validate reservoir assumptions

Other Fish and Non-fish Species

- Comprehensive surveys of species abundance and distribution, and verify life histories, habitat use, and limiting factors
- Additional studies to determine other impacts from a dam (upstream) and better habitat mapping
- Relationship between climate change and off-channel

Data Gaps – Modeling

- HEC-RAS model stability and calibration at low flow
- Water temperature modeling