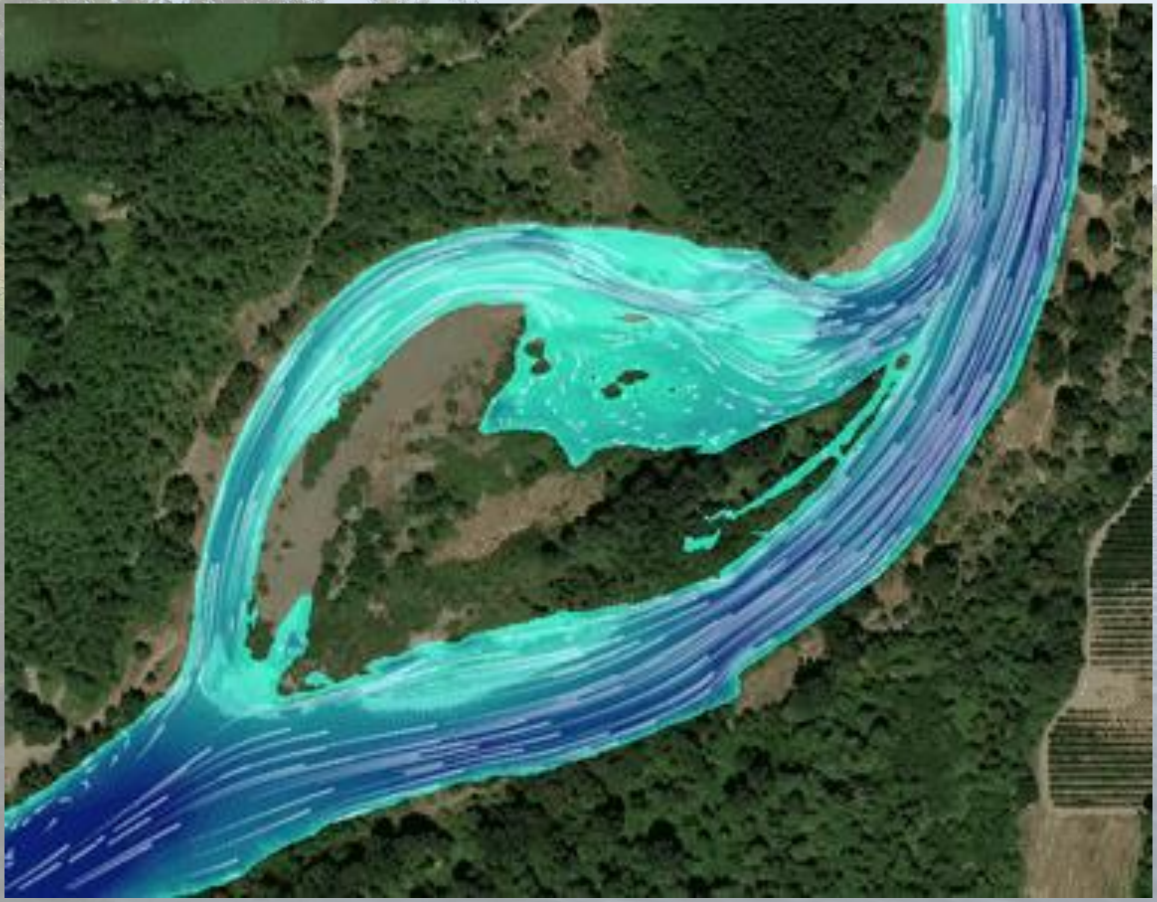
Where, When, and How Much Salmonid Habitat is Available on the Willamette River?

James White, Rose Wallick, Laurel Stratton, Brandon Overstreet, Gabriel Gordon

January 15, 2020



USGS

Many people involved and contributing to study

USGS ORWSC: Stewart Rounds, Adam Stonewall, Greg Lind, Mackenzie Keith, Krista Jones

USACE: Rich Piaskowski, Jacob Macdonald, Greg Taylor, Jeff Balantine, Norman Buccola, Paul Sclafani

Oregon State University: Jim Peterson, Jessica Pease, Tyrell DeWeber

USGS WFRC: Toby Kock, Russ Perry, Gabriel Hansen

NOAA Fisheries: Anne Mullan, Diana Dishman

ODFW: Luke Whitman, Brian Bangs

USGS

Funding provided by US Army Corps of Engineers

Overview

- Willamette River
  - Geomorphology, hydrology, and flow management

- Quantifying habitat:
  - Flow-management decisions
    - What is the relationship between streamflow and juvenile salmonid habitat?

  - Restoration planning and prioritization
    - Where and when is habitat limiting?

  - Status and trends of habitat over time
    - What is the trajectory of habitat availability?

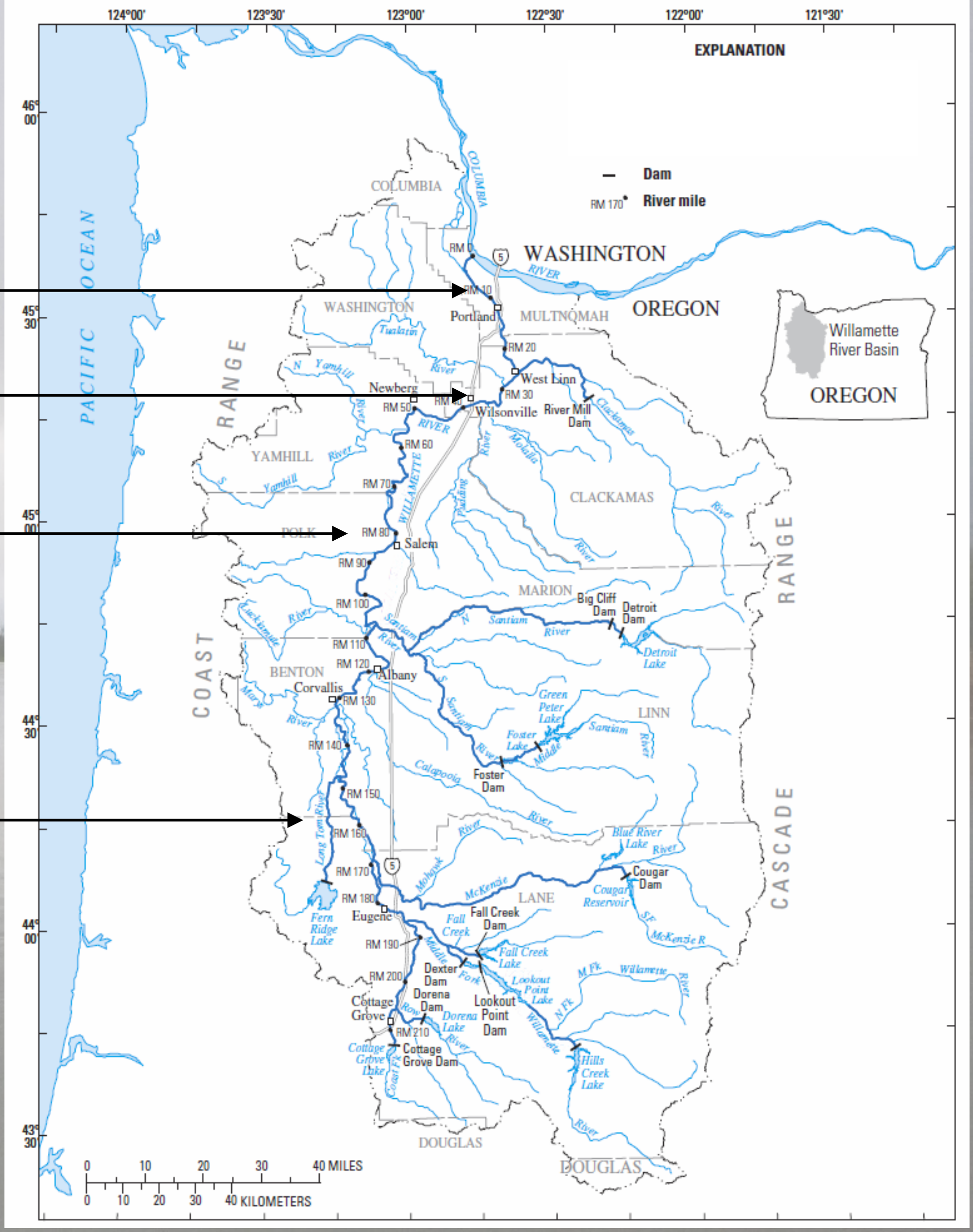
Willamette River – four rivers in one valley

Lower Willamette

Newberg Pool

Middle Willamette

Upper Willamette



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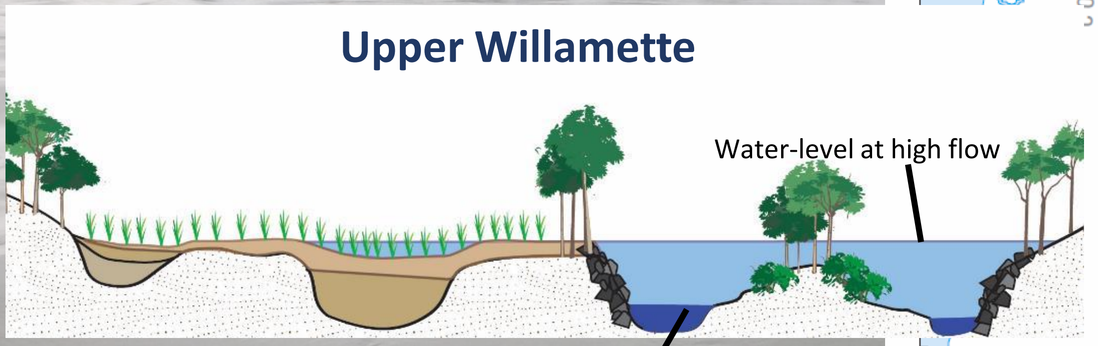
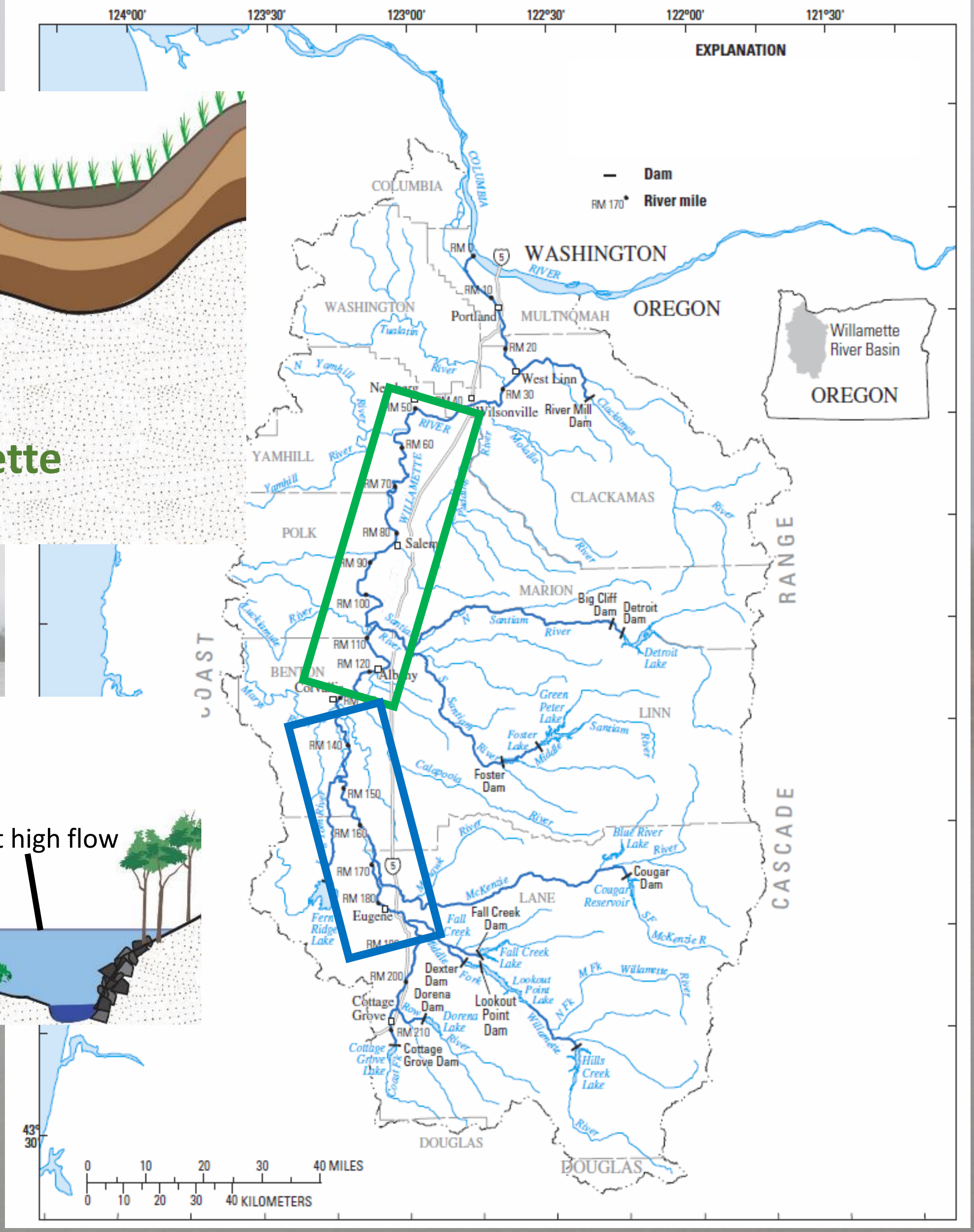
Willamette River – four rivers in one valley





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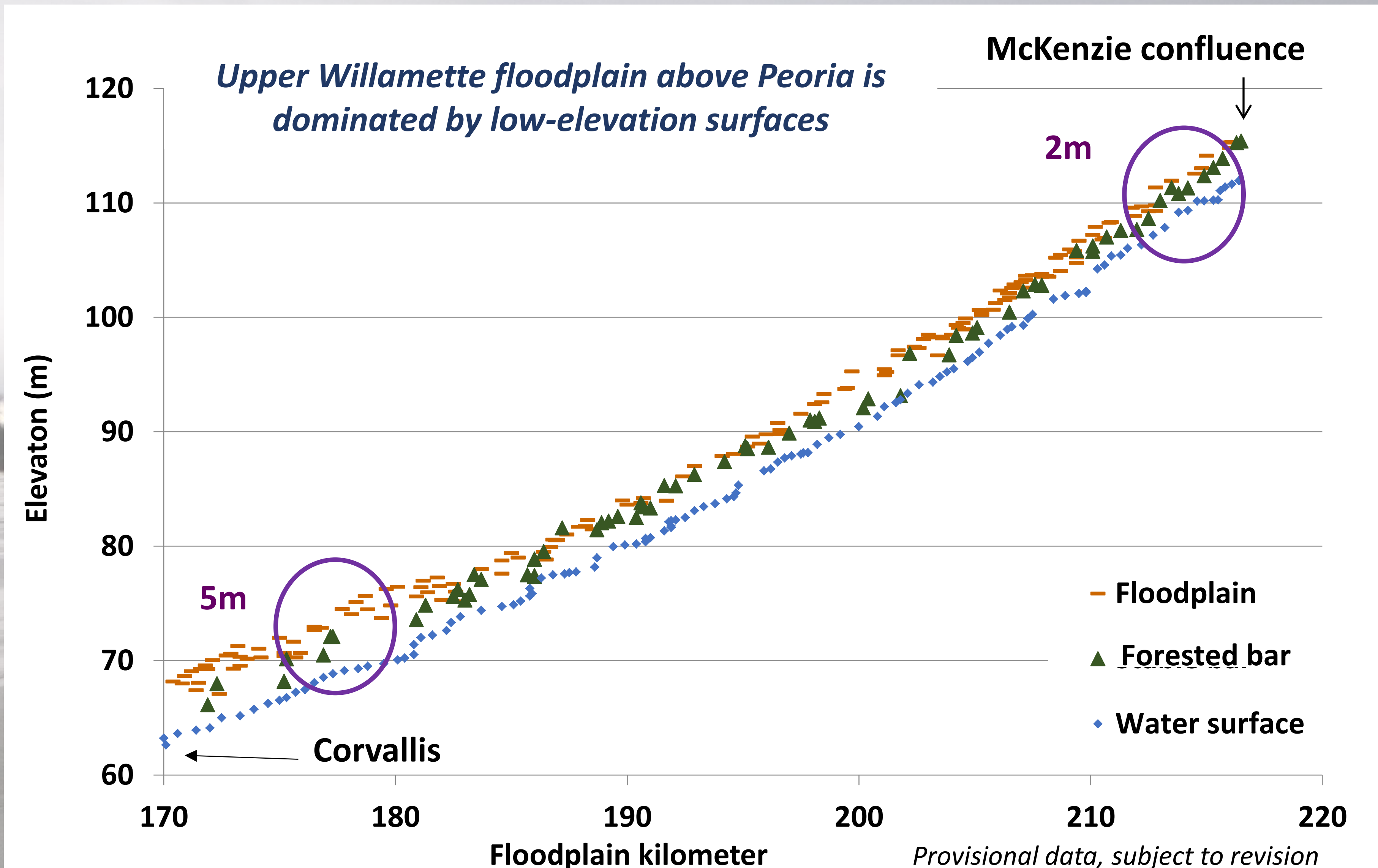
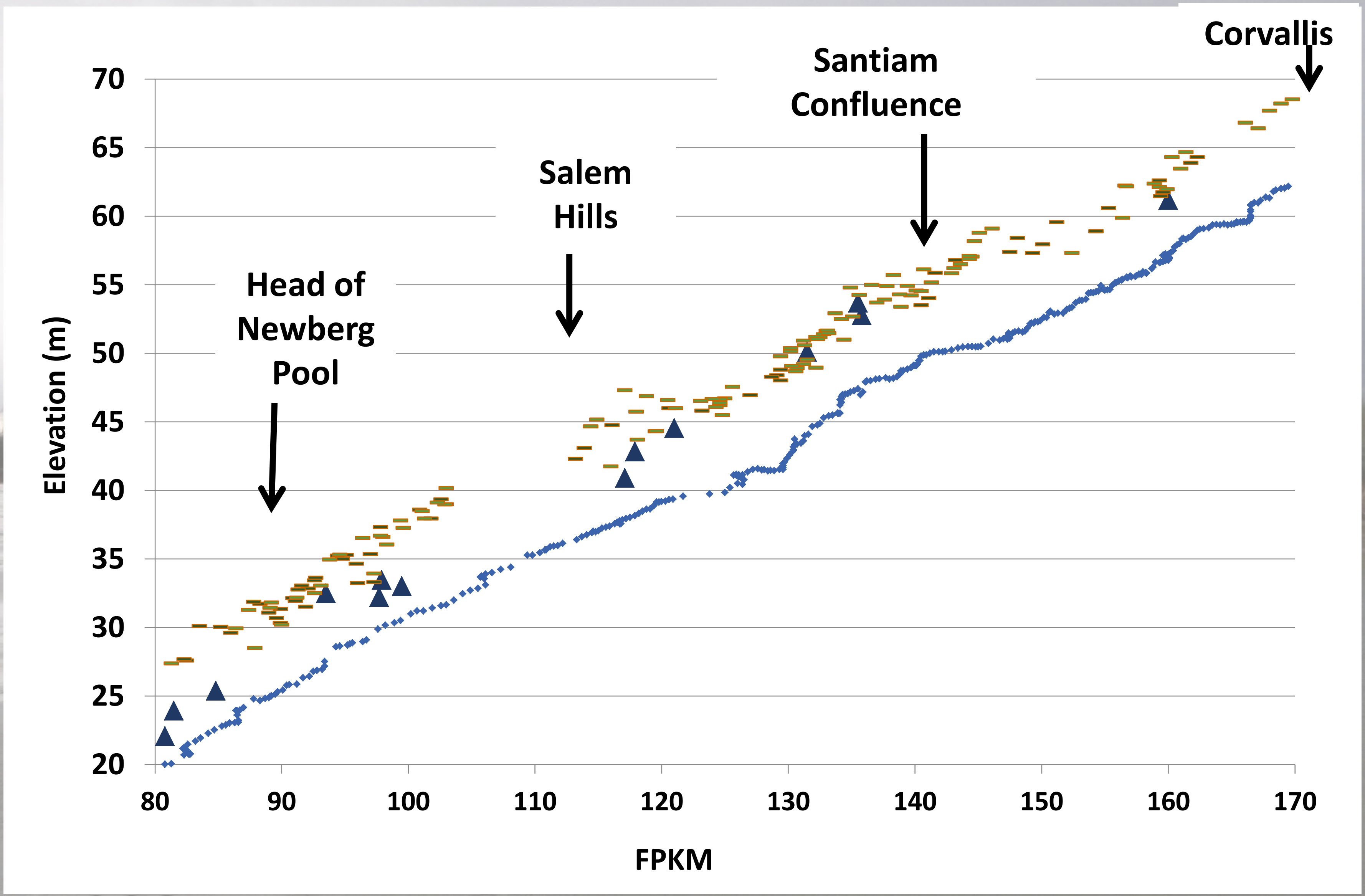
Long Profile of Upper Willamette



Long Profile of Middle Willamette



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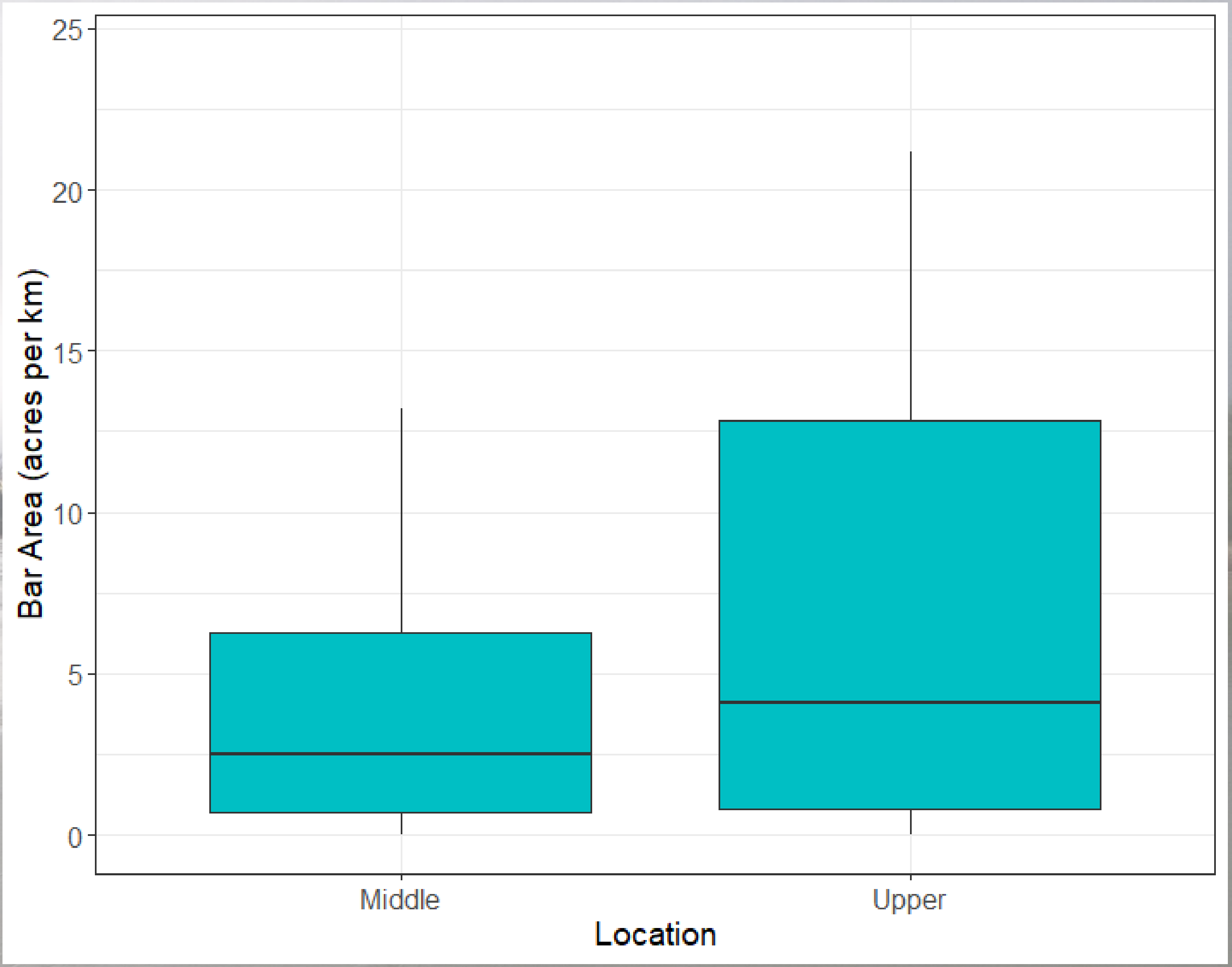
Bar Distribution 2016



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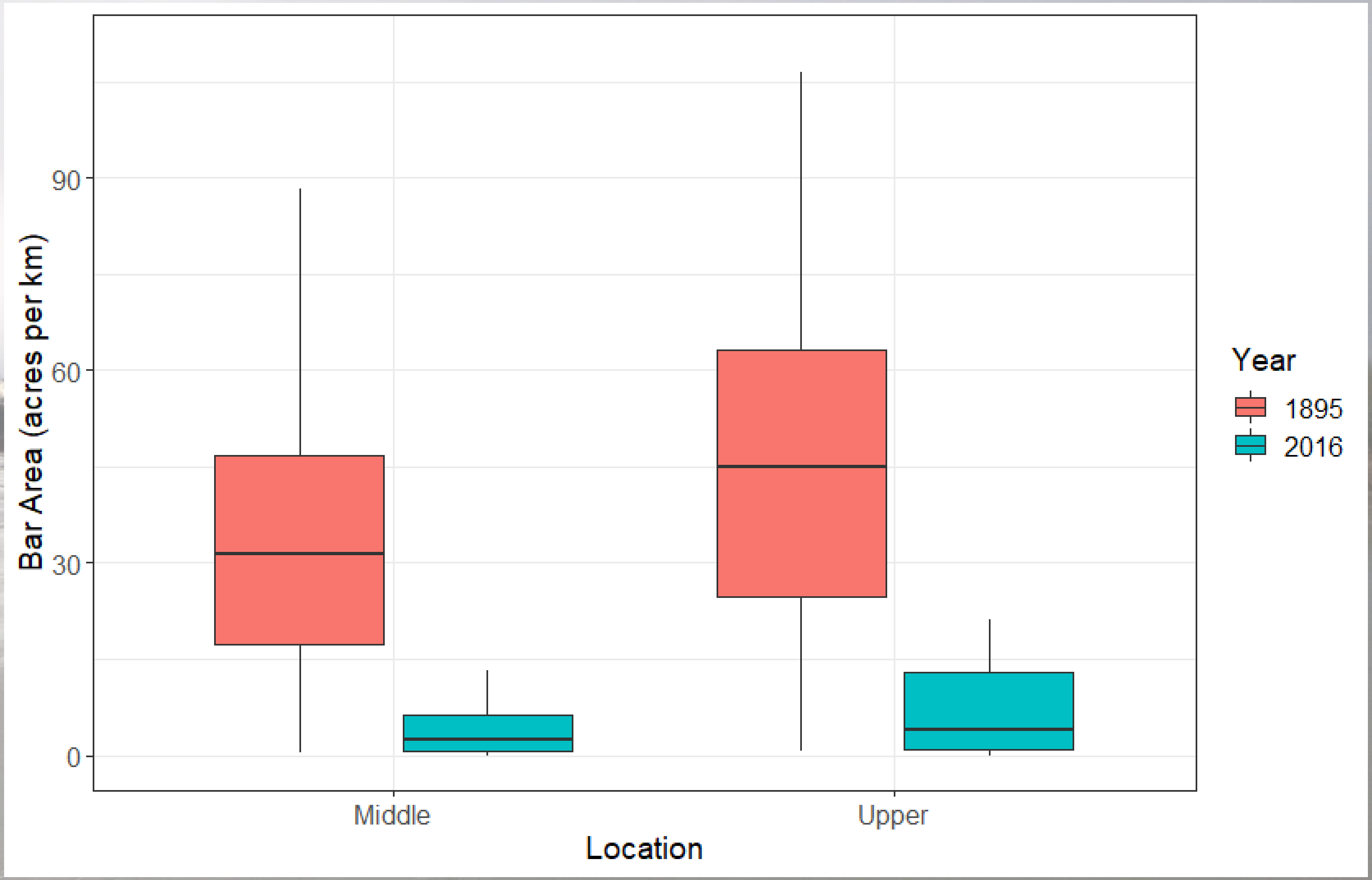
Change in gravel bars 1895-2016

~85% reduction in bare bars in Willamette River above Newberg



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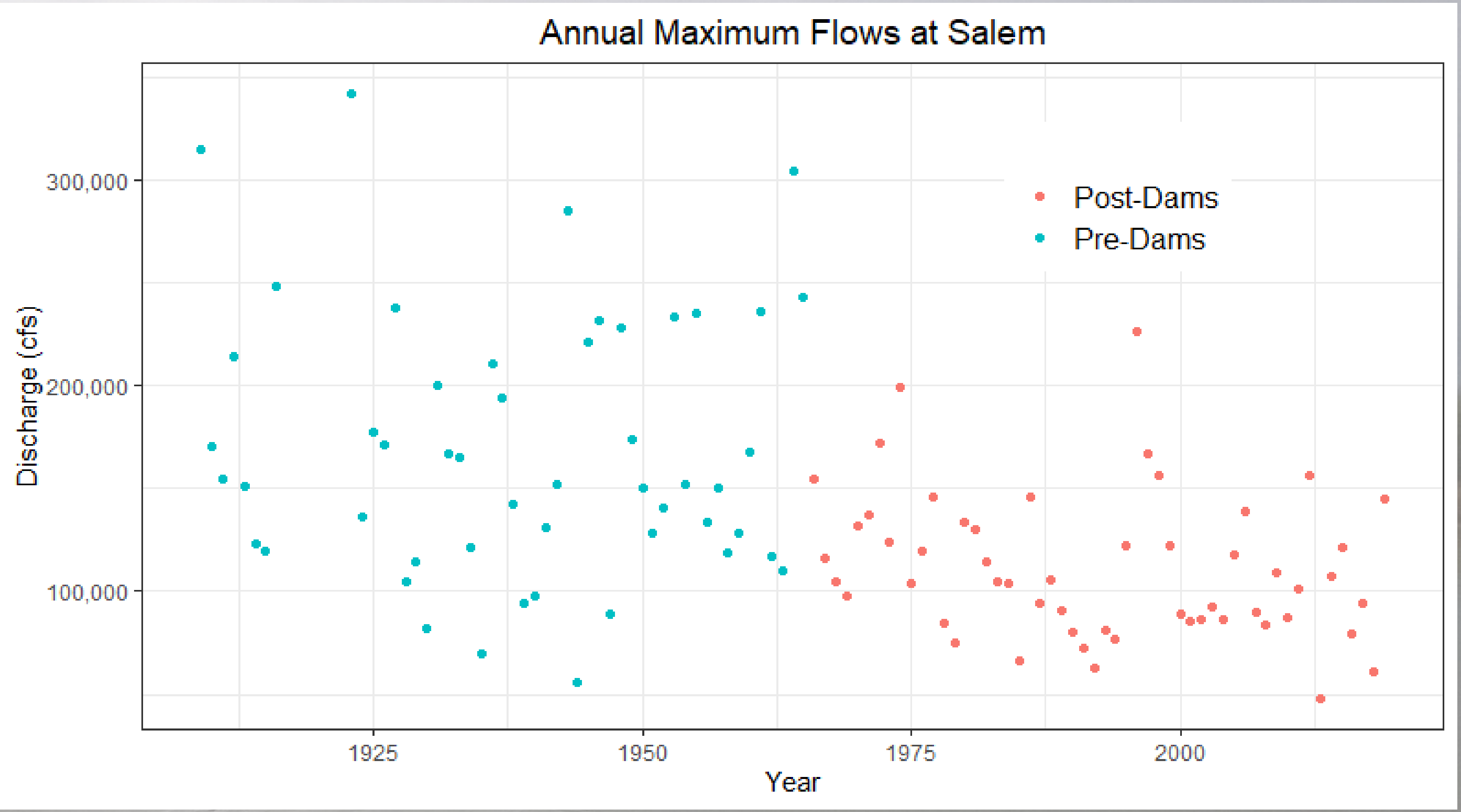
Willamette River
Peak Flows 1895 - 2019



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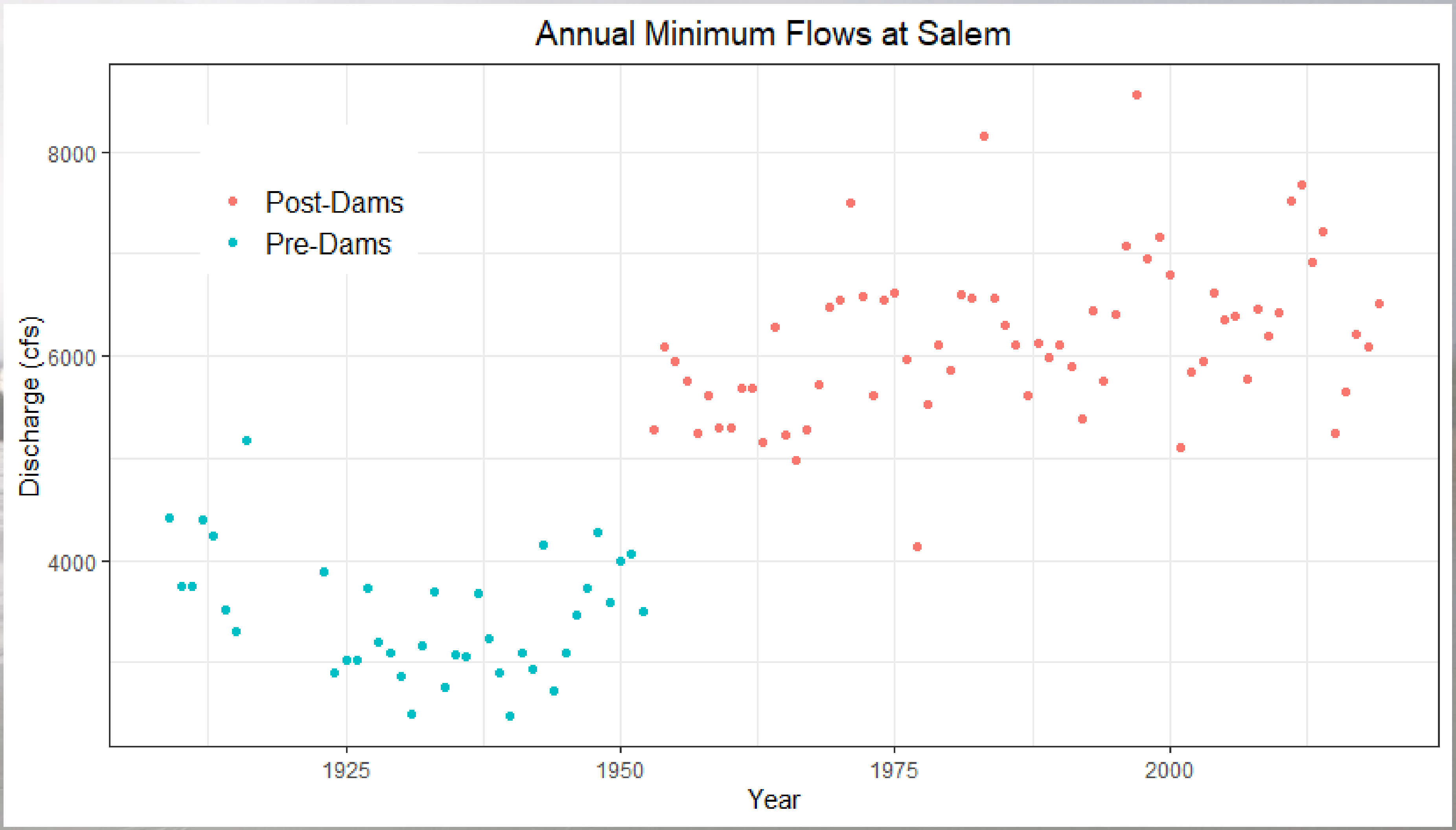
Willamette River
Annual Minimum Flows 1895 - 2019



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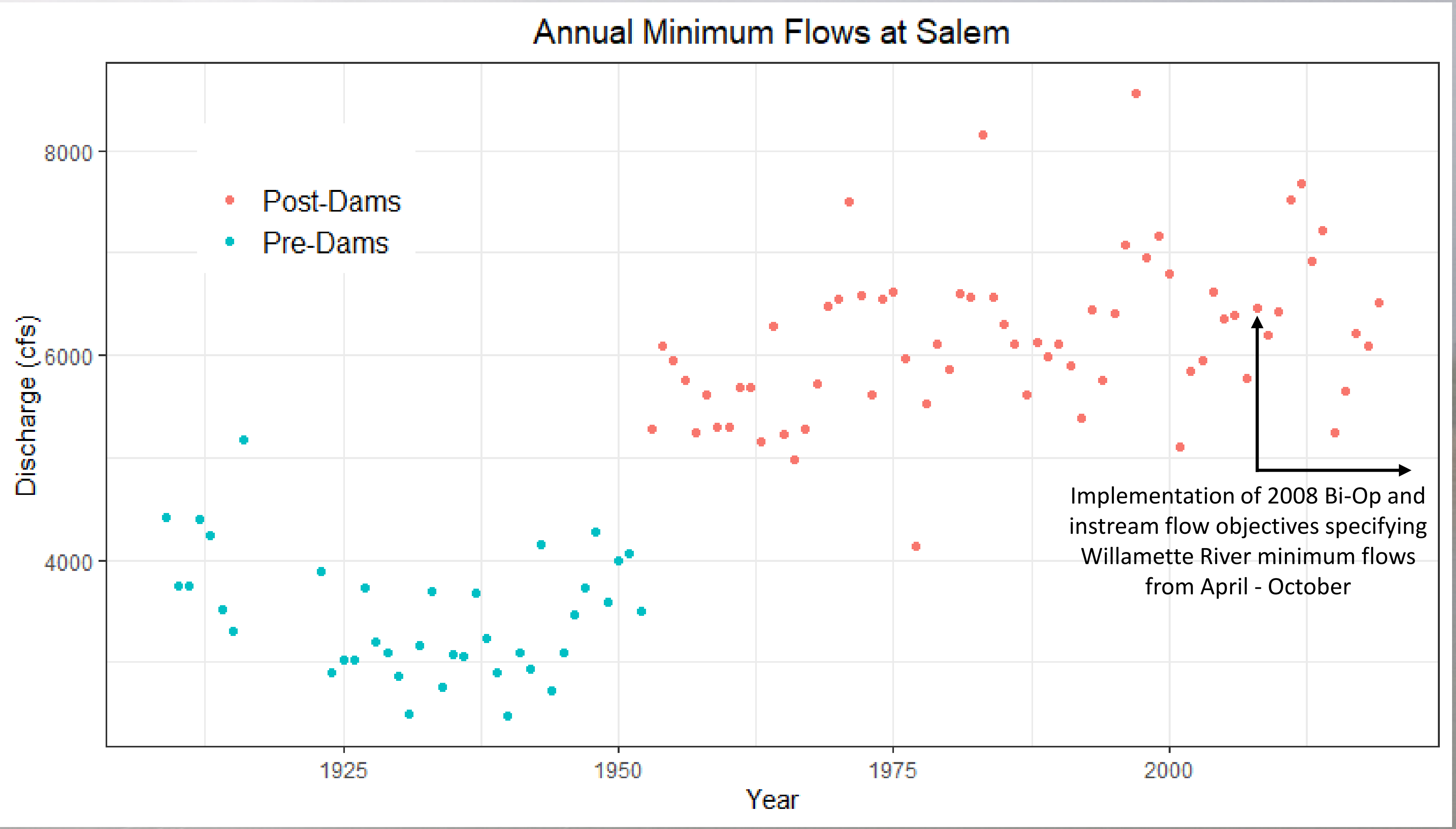
Willamette River

Annual Minimum Flows 1895 - 2019



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The Need to Quantify Habitat

- Flow-management decisions
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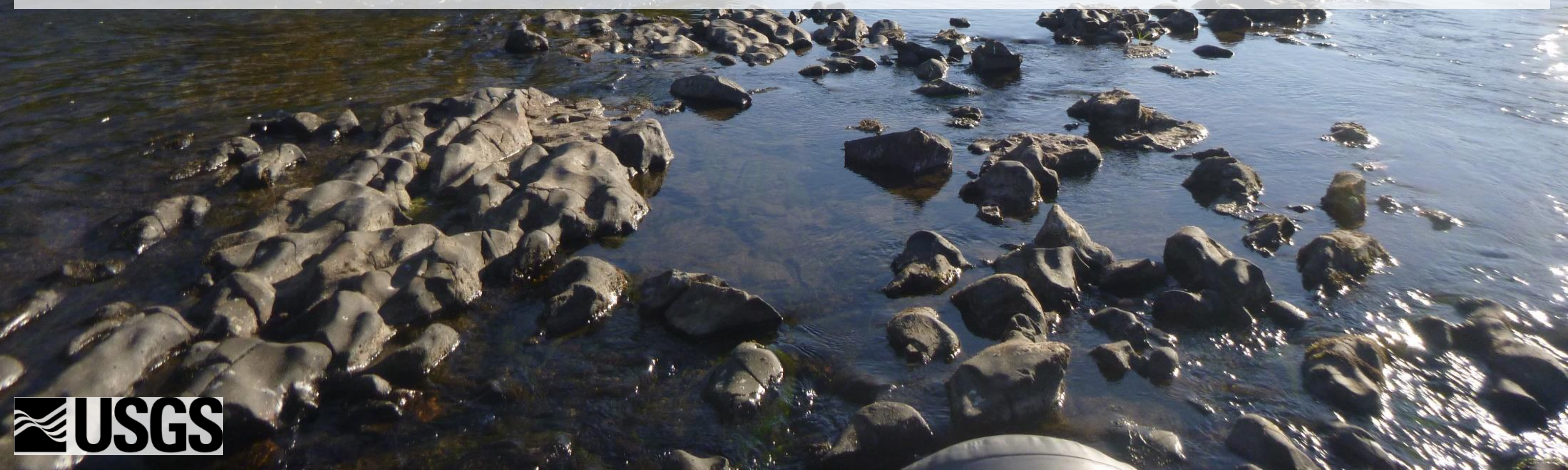
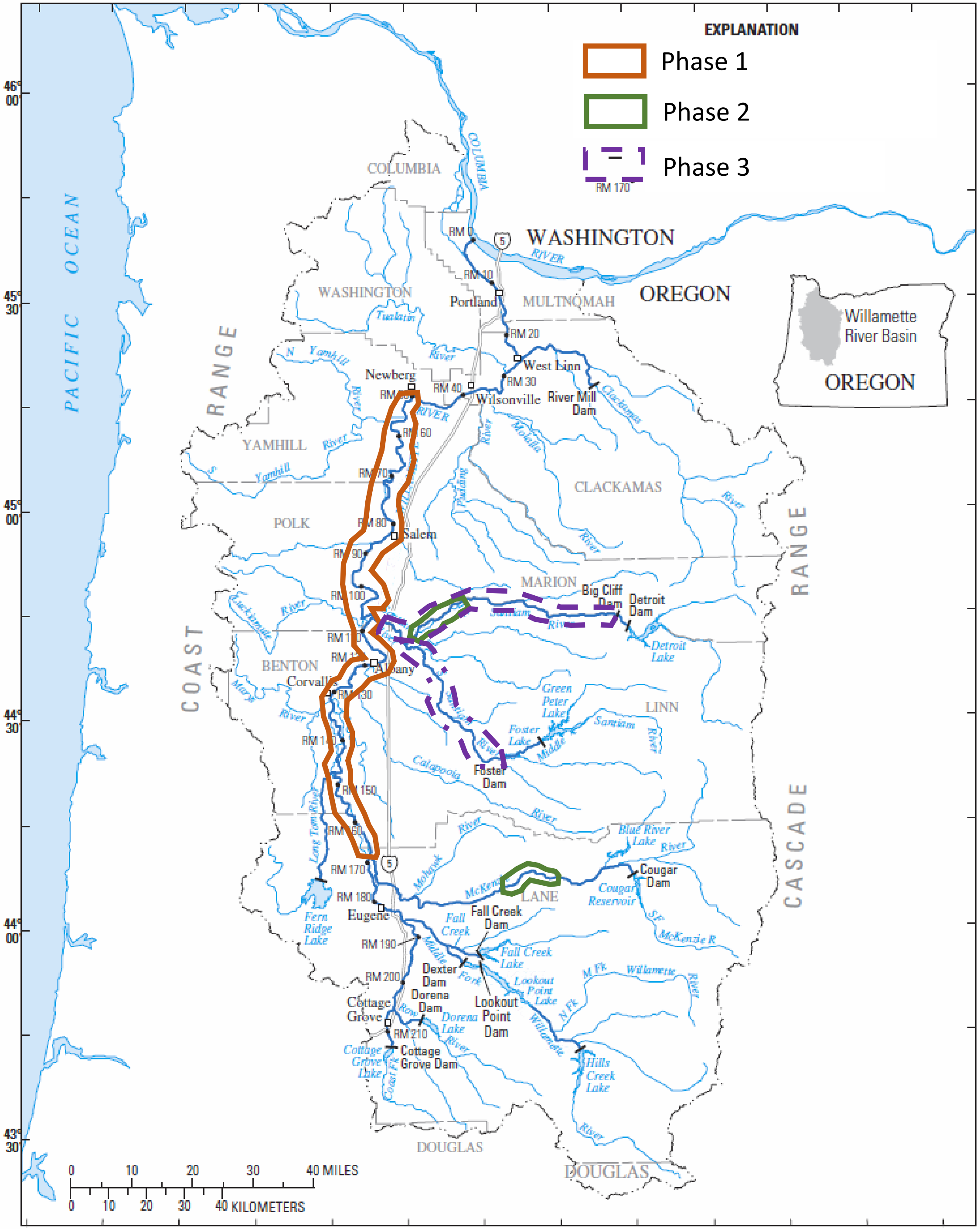
- Where and when is habitat limiting?
- Status and trends of habitat over time
  - What is the trajectory of habitat?




EXPLANATION
Phase 1
Phase 2
Phase 3
124°00'
123°30'
123°00'
122°30'
122°00'
121°30'
PACIFIC OCEAN
COAST RANGE
CASCADE RANGE
WASHINGTON
OREGON
Willamette River Basin
OREGON
COLUMBIA RIVER
COLUMBIA
WASHINGTON
MULTNOMAH
YAMHILL
POLK
CLACKAMAS
MARION
BENTON
LINN
LANE
DOUGLAS
Portland
West Linn
Wilsonville
Newberg
Salem
Albany
Corvallis
Eugene
Cottage Grove
River Mill Dam
Big Cliff Dam
Detroit Dam
Detroit Lake
Green Peter Lake
Foster Lake
Foster Dam
Blue River Lake
Cougar Dam
Cougar Reservoir
Fall Creek Dam
Fall Creek Lake
Dexter Dam
Dorena Dam
Dorena Lake
Lookout Point Dam
Lookout Point Lake
Cottage Grove Dam
Cottage Grove Lake
Hills Creek Lake
Fern Ridge Lake
RM 0
RM 10
RM 20
RM 30
RM 40
RM 60
RM 70
RM 80
RM 90
RM 100
RM 130
RM 150
RM 170
RM 180
RM 190
RM 200
RM 210
0 10 20 30 40 MILES
0 10 20 30 40 KILOMETERS

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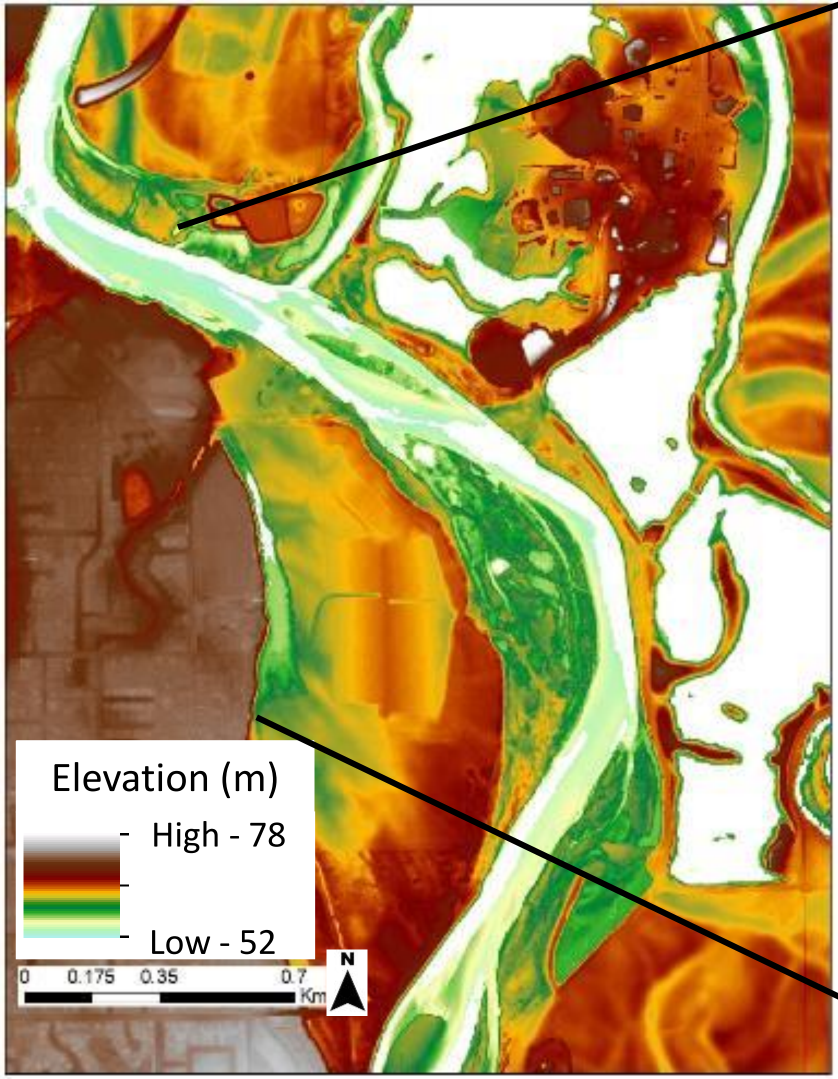
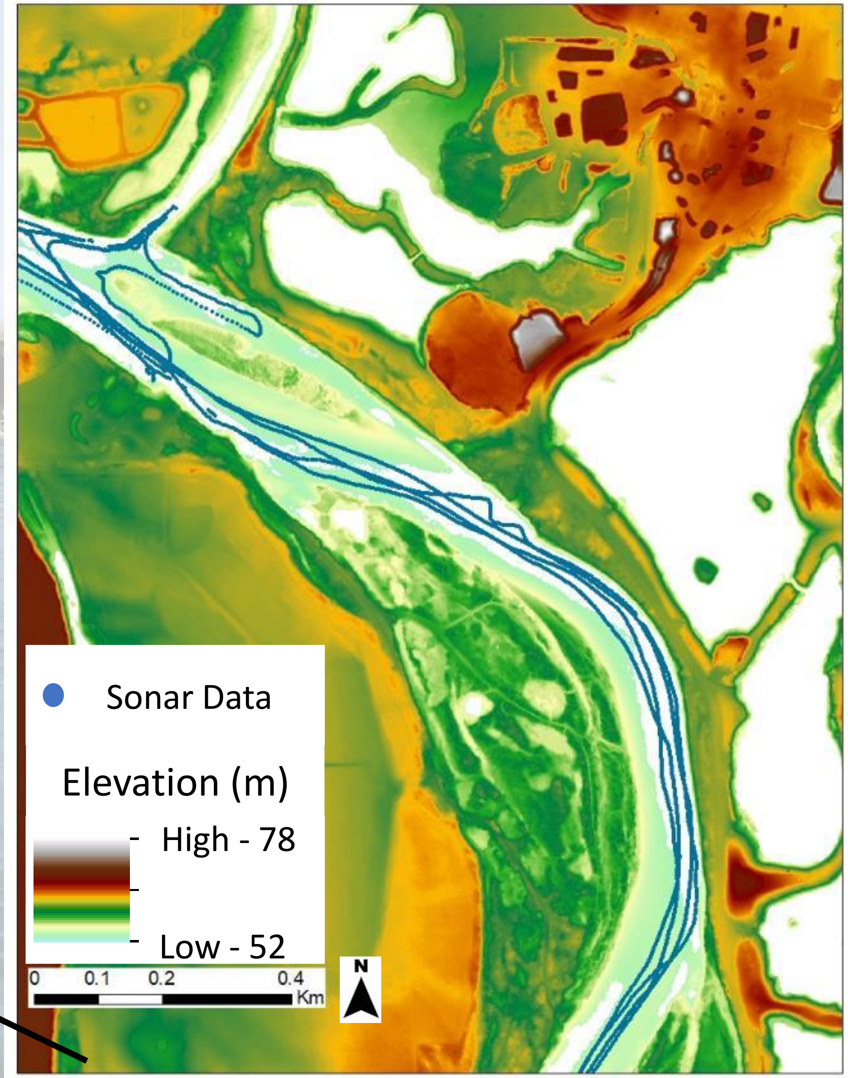
Building blocks of hydraulic model



2017 topo-bathymetric lidar



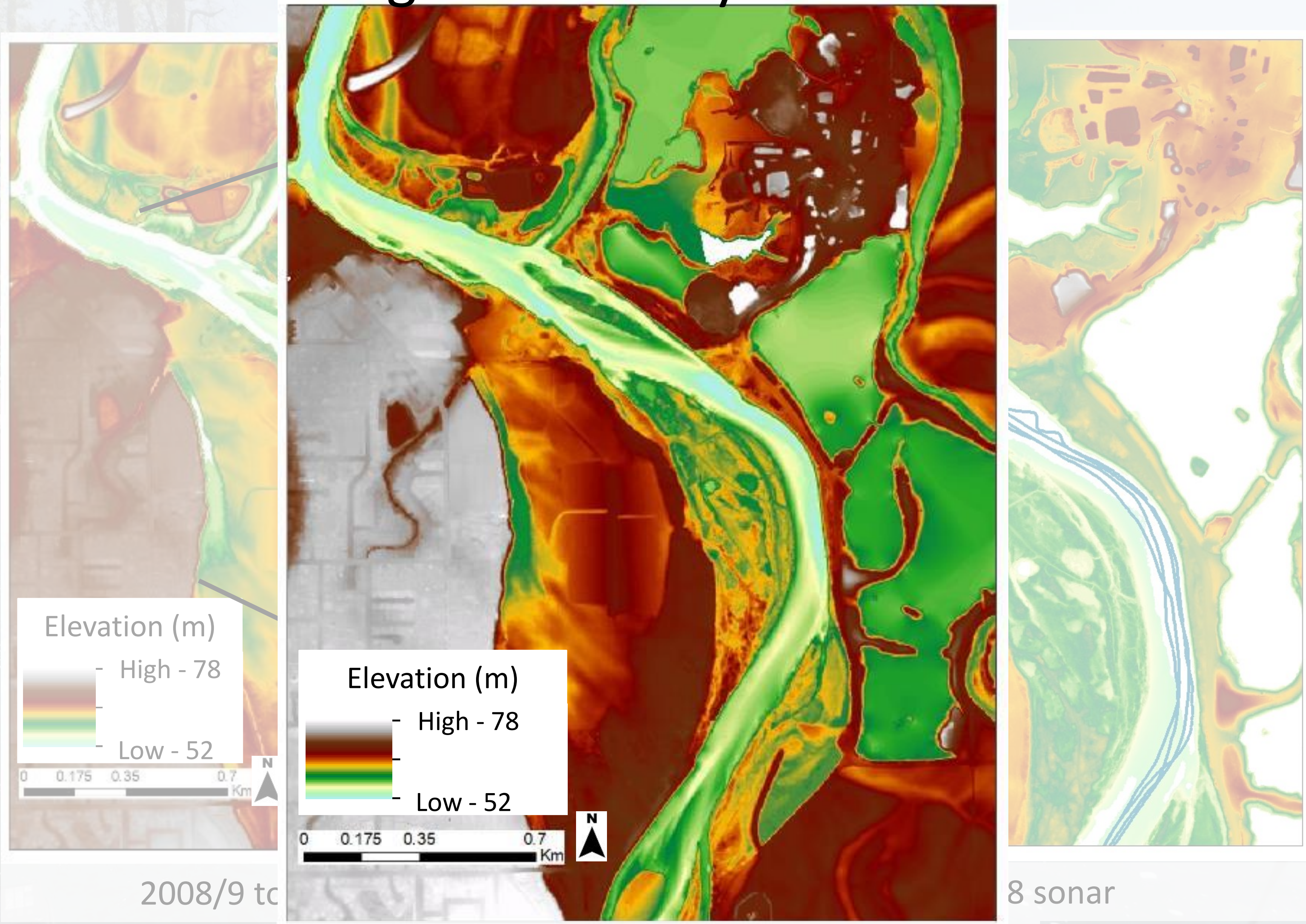
2015-2018 sonar

Data source: QSI, 2017

USGS

Preliminary Results – subject to revision

Building blocks of hydraulic model



Seamless bathymetry/topography

Data source: QSI, 2017

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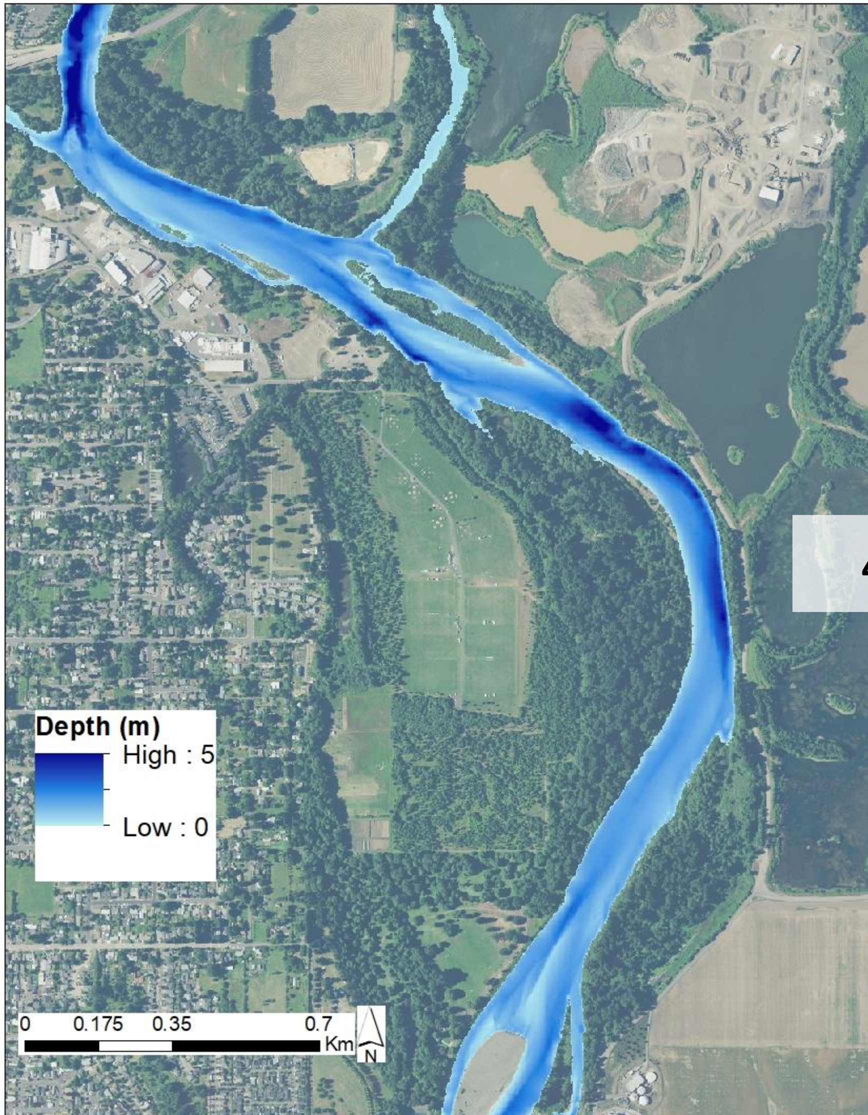
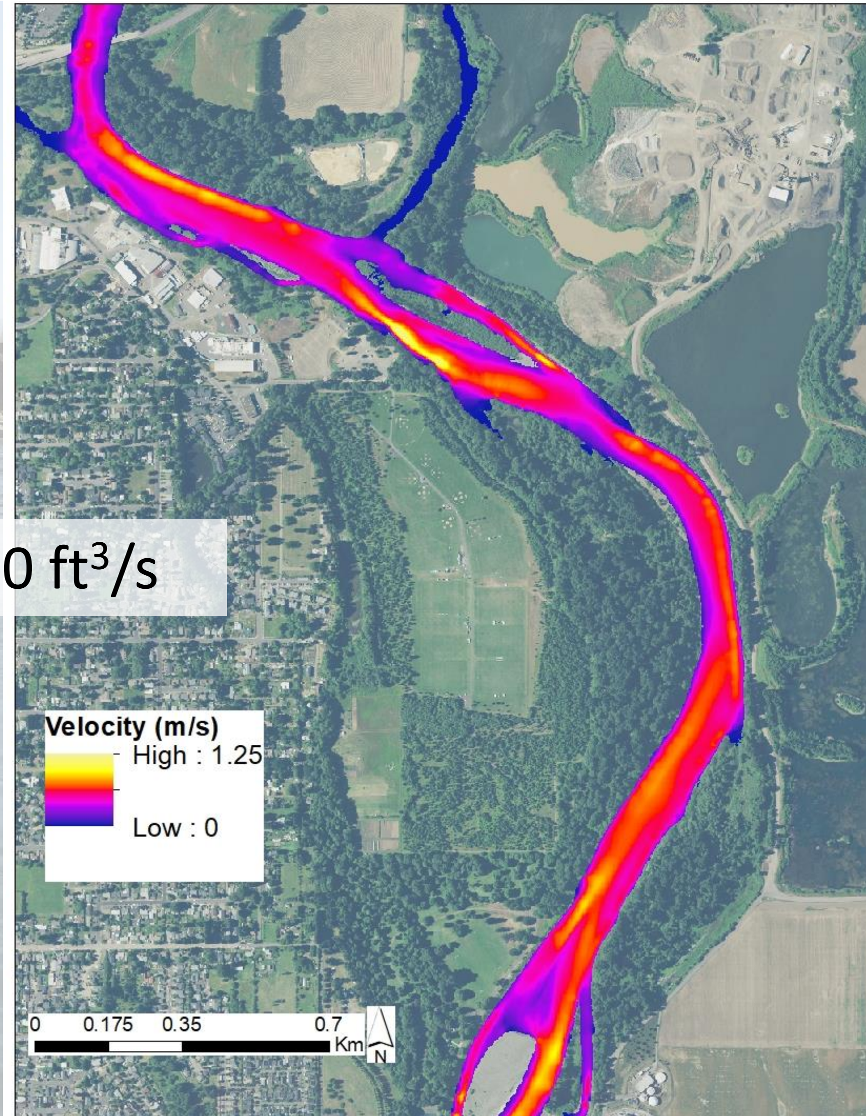
Preliminary Results – subject to revision

Hydraulic model outputs



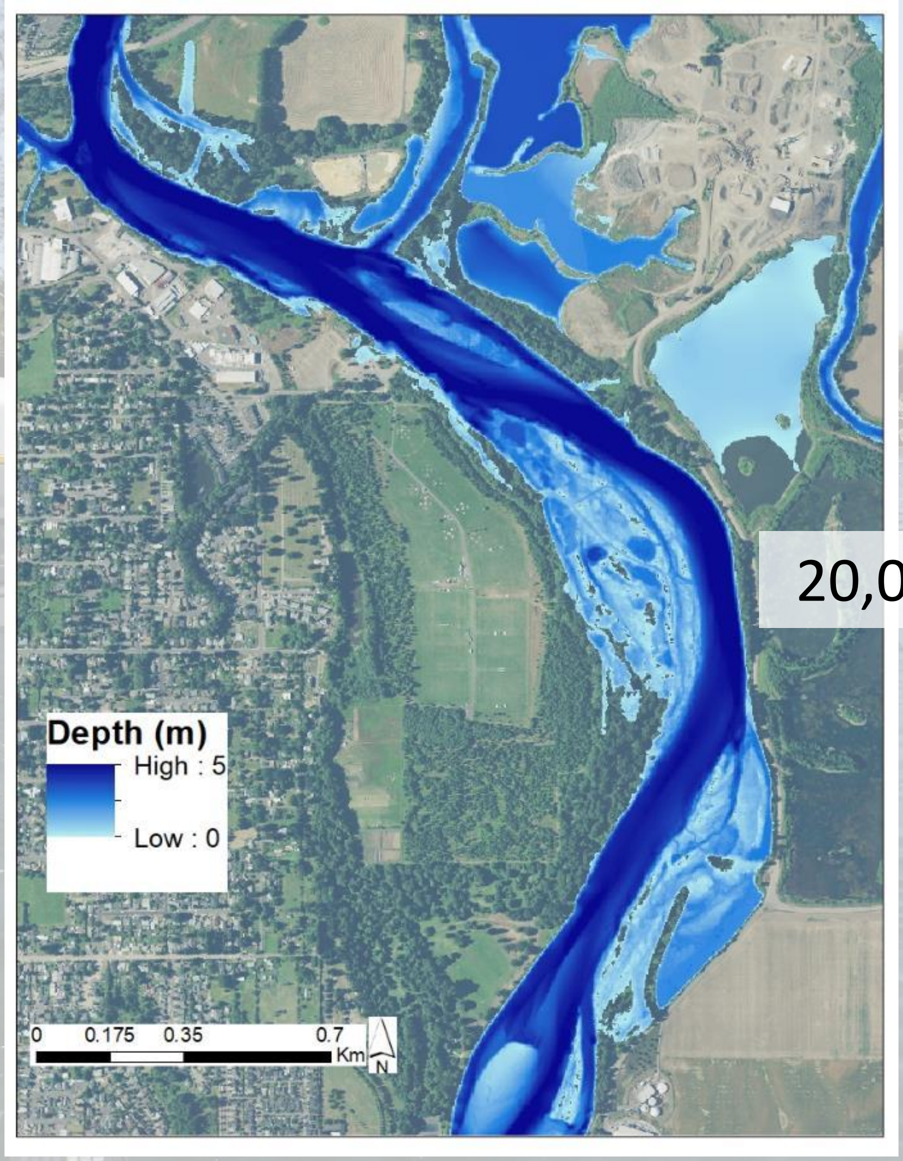
4,000 ft^3/s



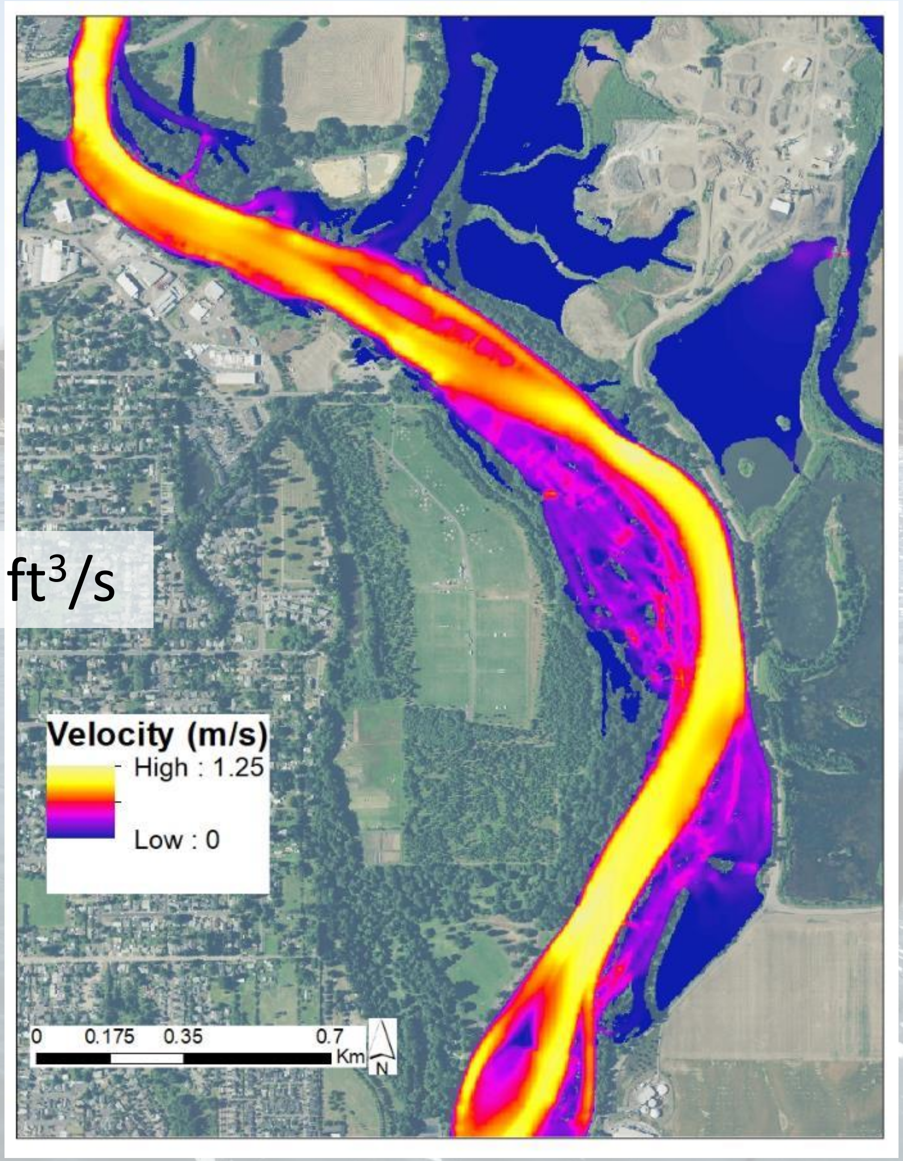
USGS

Preliminary Results – subject to revision

Hydraulic model outputs



20,000 ft^3/s



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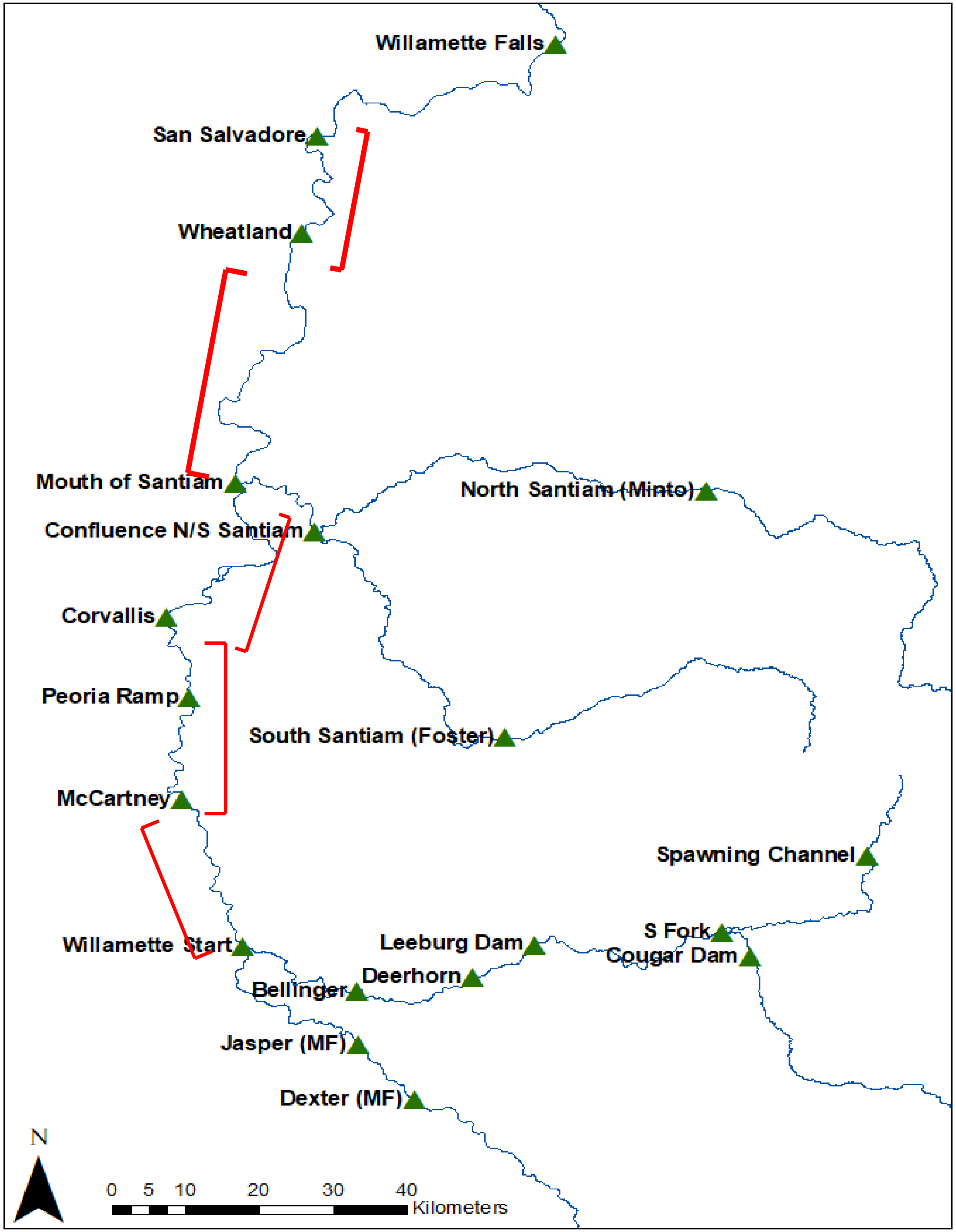
Preliminary Results – subject to revision

Hydraulic Model Reaches



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Defining “useable” rearing habitat

Fish habitat = f(depth, velocity, cover, bed- slope, temperature, predation, food, DO….)

USGS

Defining "useable" rearing habitat

Fish habitat = f(depth, velocity, cover, slope, temperature, predation, DO, food…)

Species	Size Class	Criteria	Narrow	Median	Broad
Chinook salmon	**Pre-smolt (>60mm)**	Depth (ft)	0.15-2.25	0.15-3.5	0.15-Inf
		Velocity (ft/s)	0-1.25	0-1.63	0-3
		Bed Slope	<0.4	<0.55	Any
Chinook salmon	**Fry (<60mm)**	Depth (ft)	0.15-2.0	0.15-3.5	0.15-5
		Velocity (ft/s)	0-0.5	0-1.25	0-1.5
		Bed Slope	<0.4	<0.55	Any
Steelhead	**Pre-smolt (>60mm)**	Depth (ft)	0.15-1	0.15-1	0.15-Inf
		Velocity (ft/s)	0-1.75	0-3.25	0-3.5
		Bed Slope	NA	NA	NA
Steelhead	**Fry (<60mm)**	Depth (ft)	0.25-1.25	0.25-2	0.25-5
		Velocity (ft/s)	0-0.5	0-1.25	0-2
		Bed Slope	NA	NA	NA

Photo: NOAA

Photo: ODFW

USGS

Habitat criteria source: Peterson and others, 2019

Defining "useable" rearing habitat

Fish habitat = f(depth, velocity, cover, bed- slope, temperature, predation, food, DO....)

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		Velocity (ft/s)	0-1.25	0-1.63	0-3
		Bed Slope	<0.4	<0.55	Any
Chinoo salmo					0.15-5
					0-1.5
					Any
Steelhe					0.15-Inf
					0-3.5
					NA
Steelhe					0.25-5
					0-2
					NA

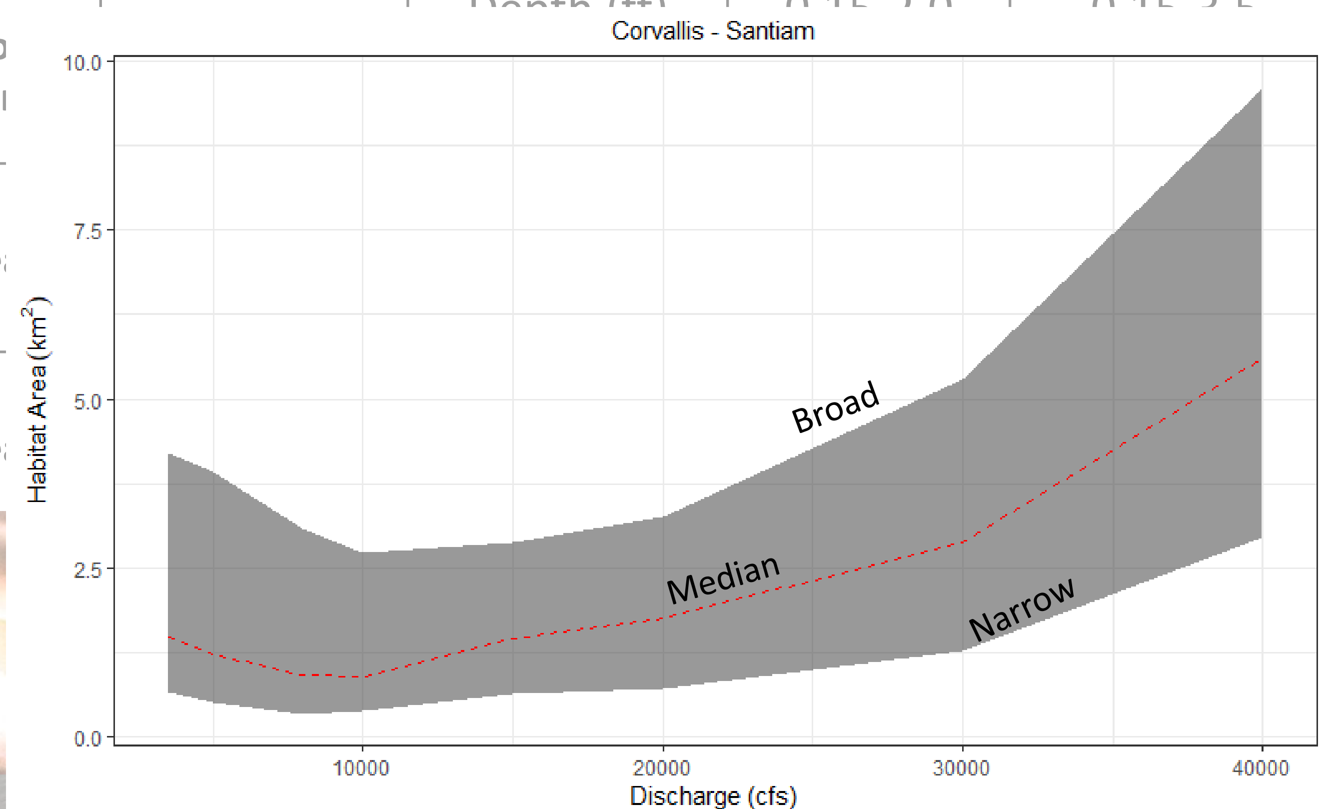
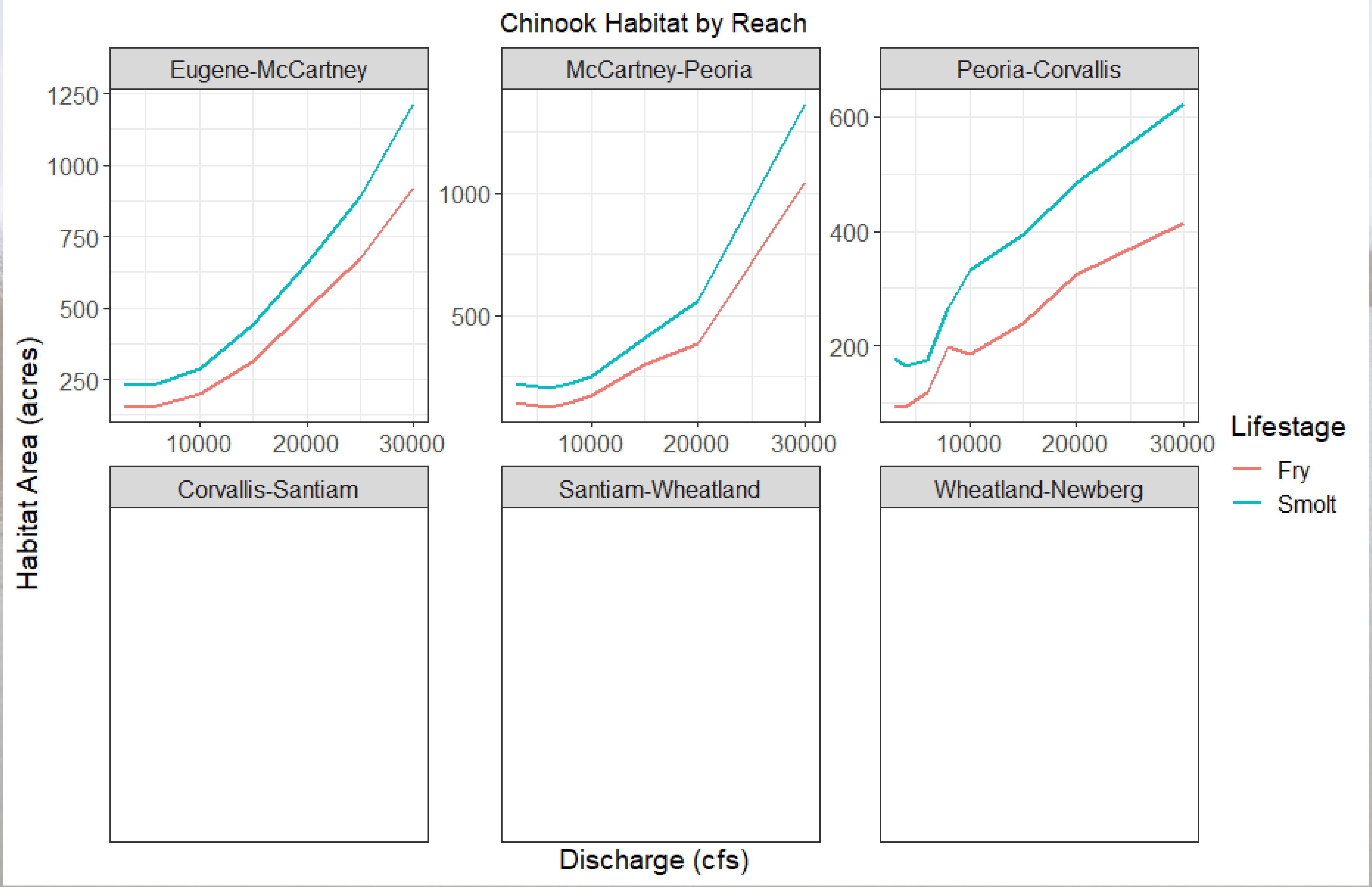


Photo: ODFW

Habitat criteria source: Peterson and others, 2019

Habitat Model Results



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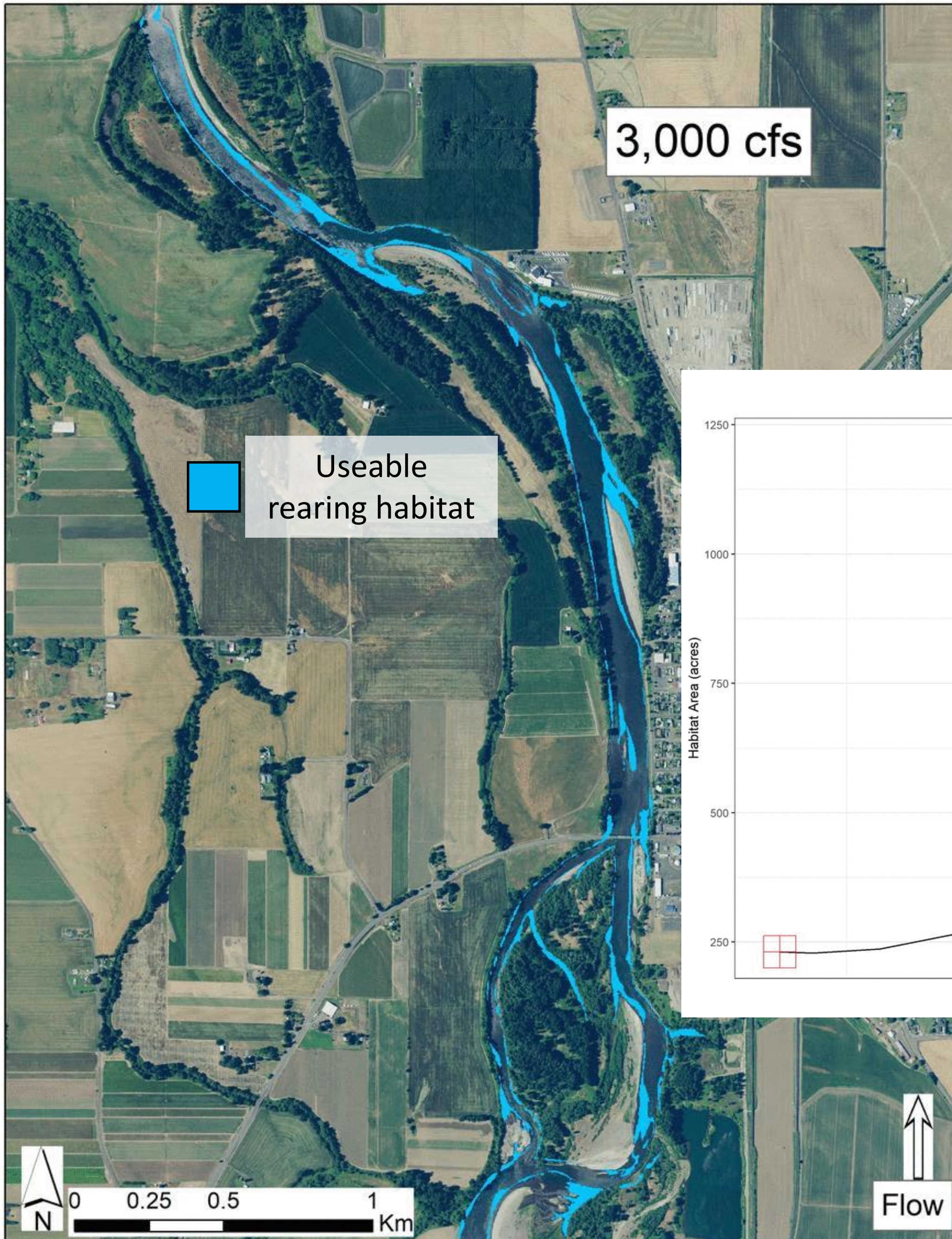
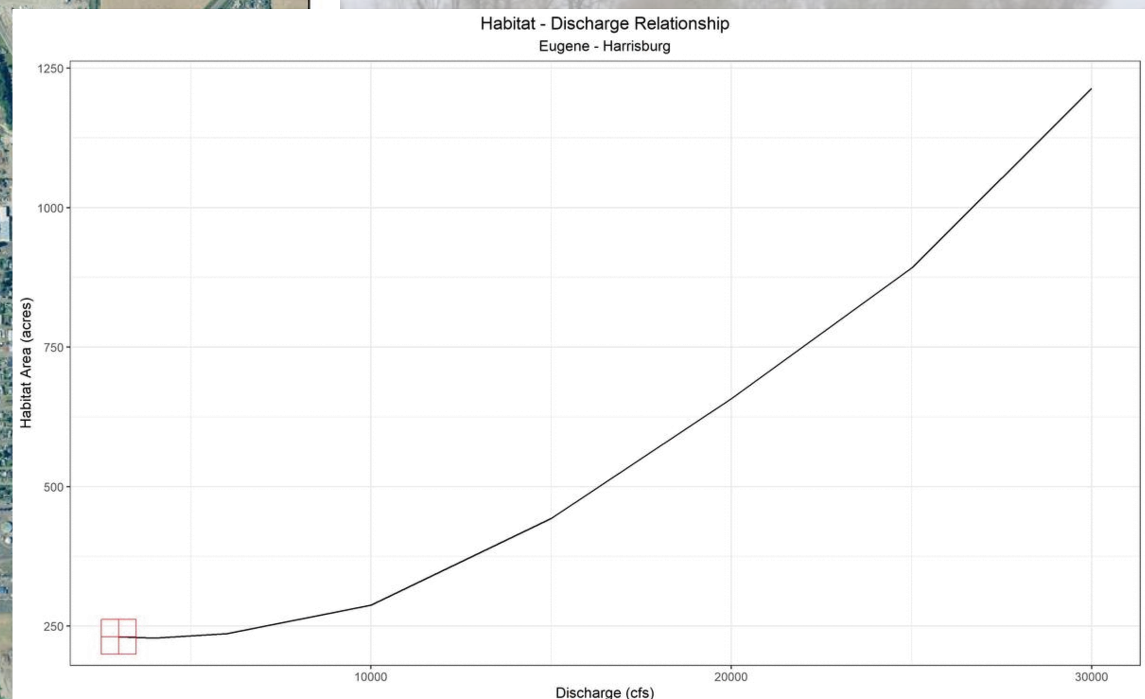
Preliminary Results – subject to revision

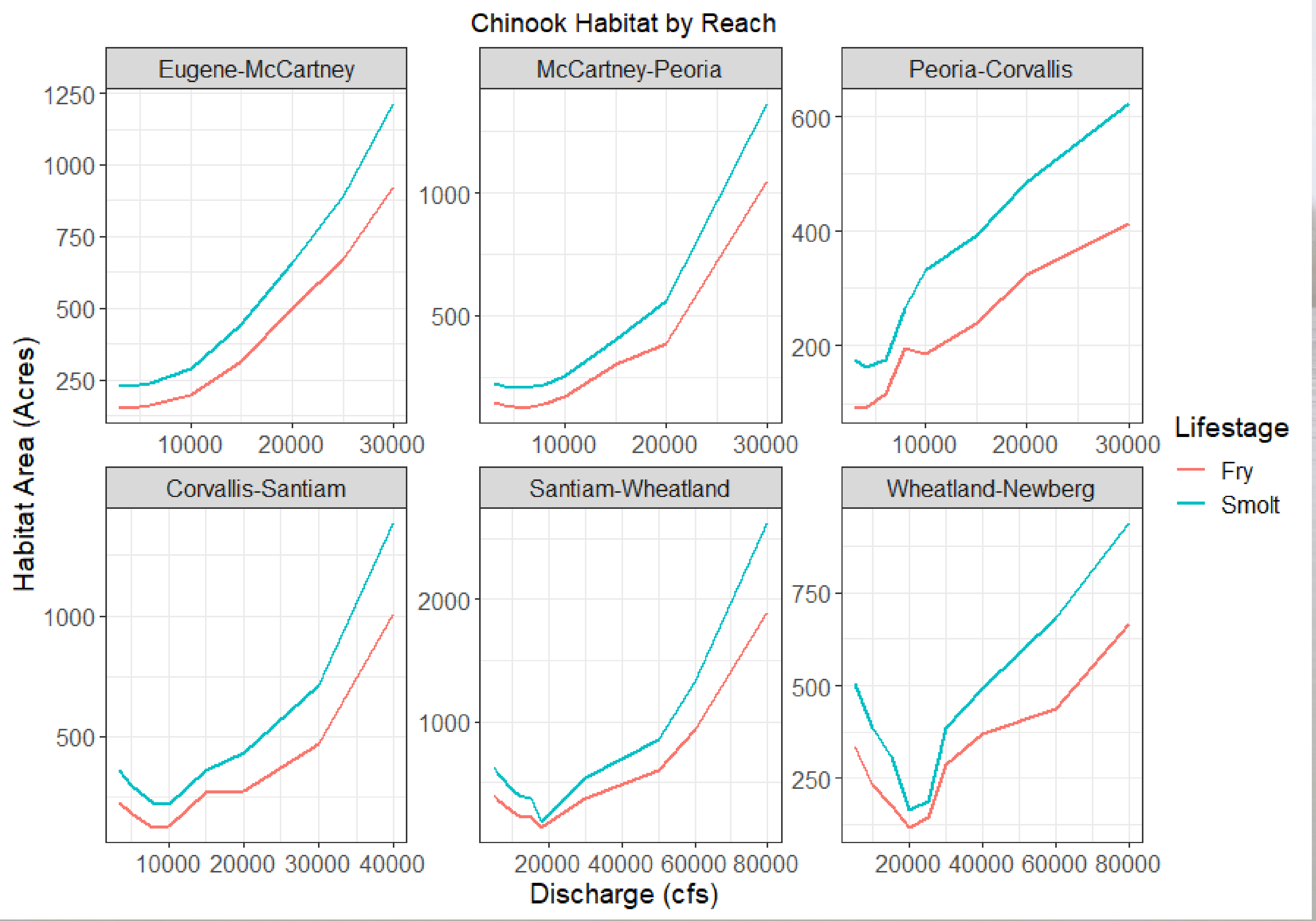
Upper Willamette: multi-channel, low elevation floodplain, lots of active gravel bars





Preliminary Results – subject to revision

Habitat Model Results



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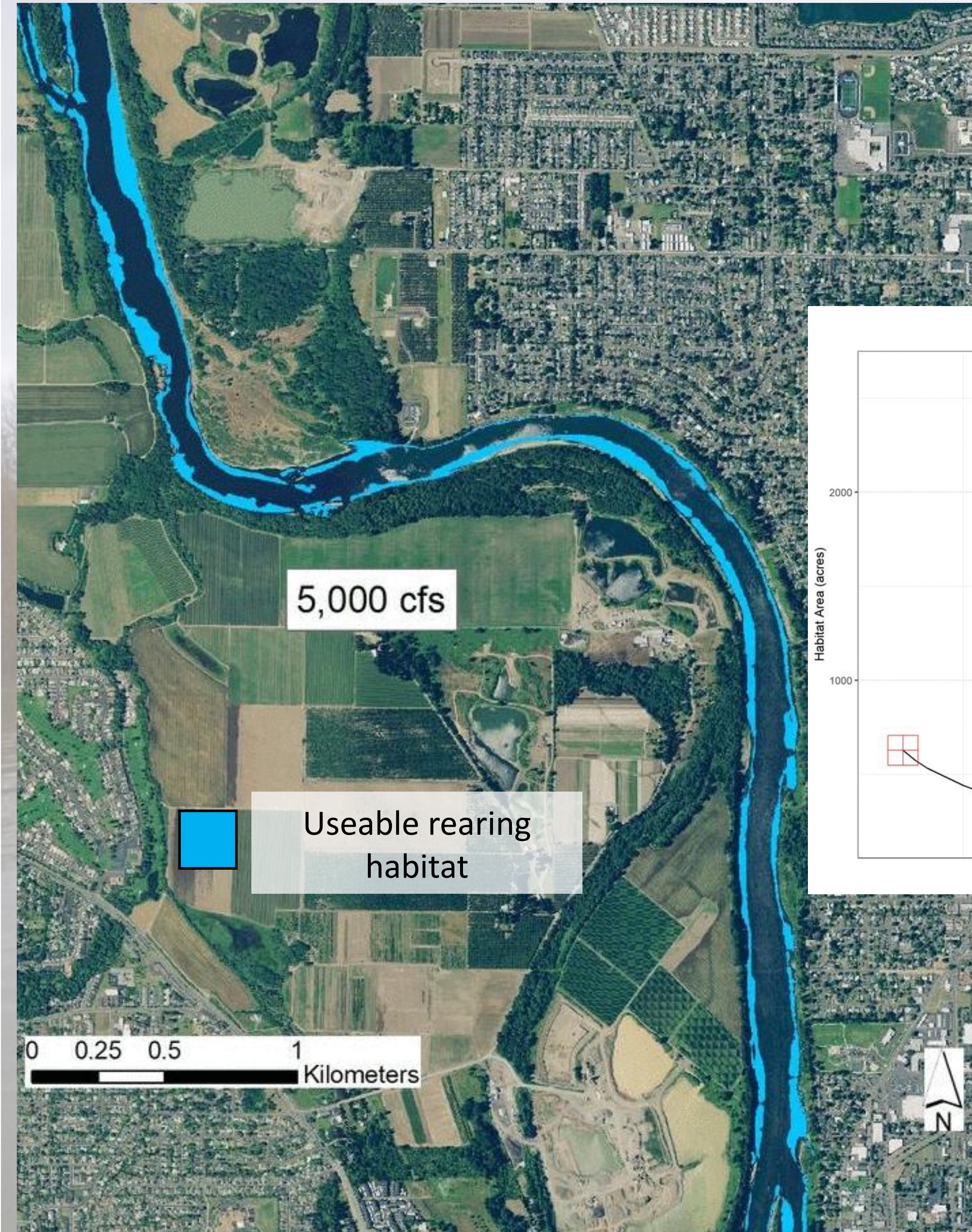
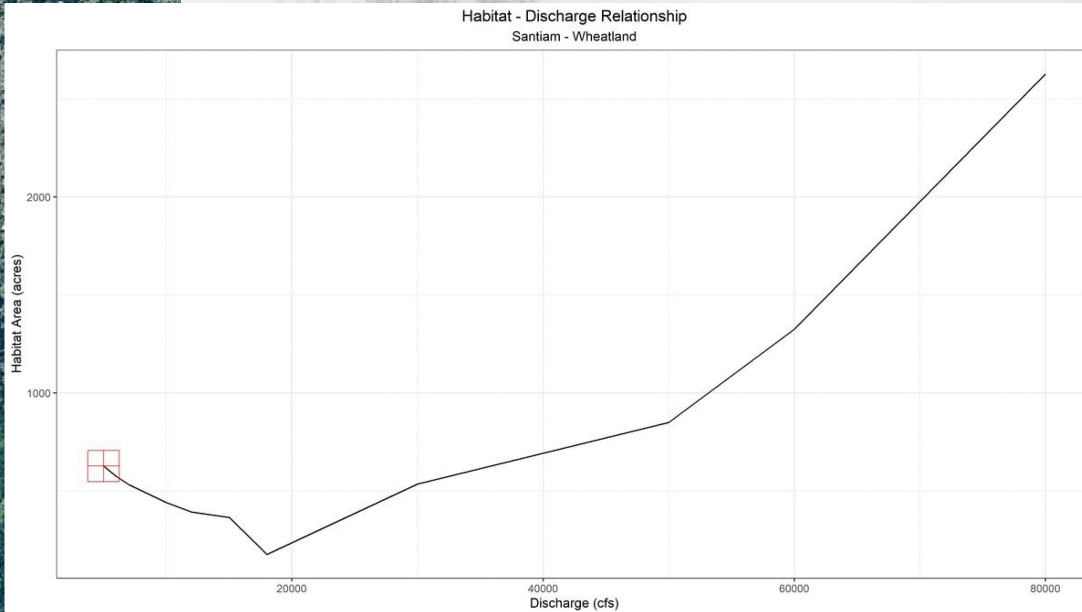
Preliminary Results – subject to revision





Preliminary Results – subject to revision

The Need to Quantify Habitat

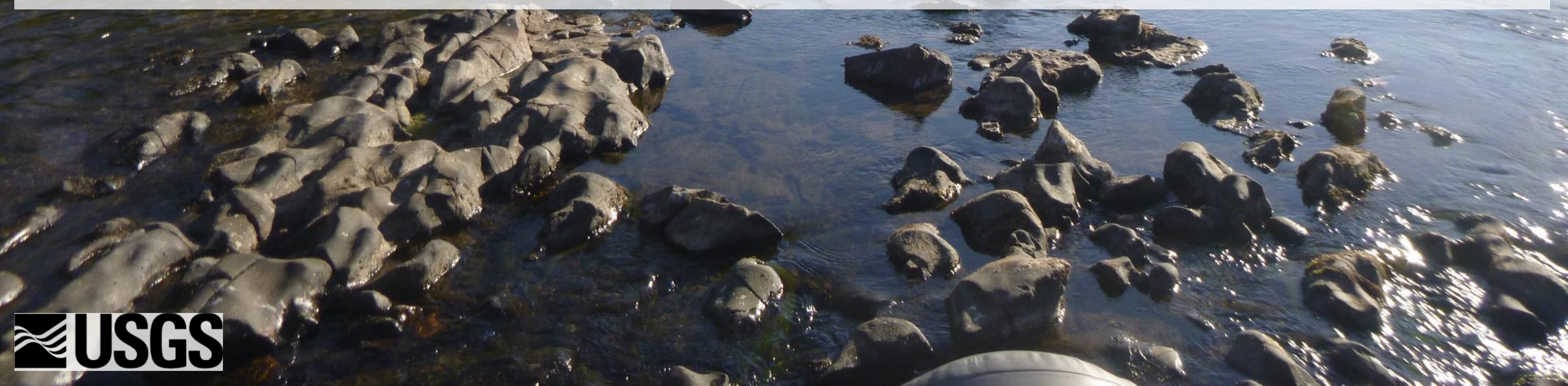
- Flow-management decisions
  - What is relationship between streamflow and juvenile salmonid habitat?

Key findings:

- Greatest amount of habitat is at high flows
- Habitat availability varies but is largely driven by geomorphic setting and flows
  - Reaches with more confined and single threaded channel:
    - At moderate flows, habitat area decreases with increasing flow
    - At high flows, habitat area increases with flow
  - Reaches with less confined and multi-threaded channels:
    - For all flows, habitat area generally increases with flow

The Need to Quantify Habitat

- Flow-management decisions
  - What is relationship between streamflow and juvenile salmonid habitat?
- Where and when is habitat limiting?
- Status and trends of habitat over time
  - What is the trajectory of habitat?
  - Are we making progress towards restoration goals?



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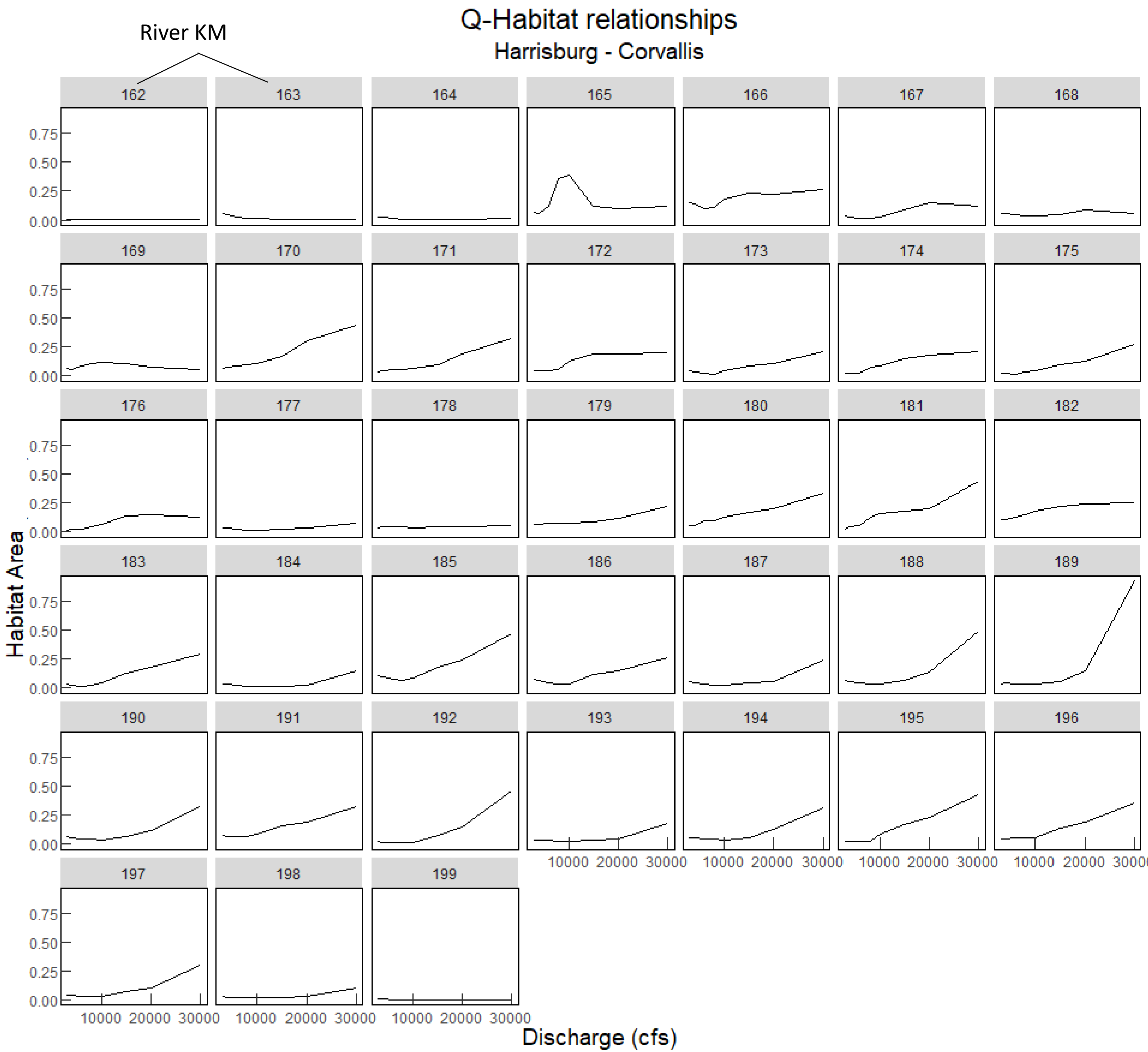
Q-Habitat relationships
Harrisburg - Corvallis
River KM
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Habitat Area
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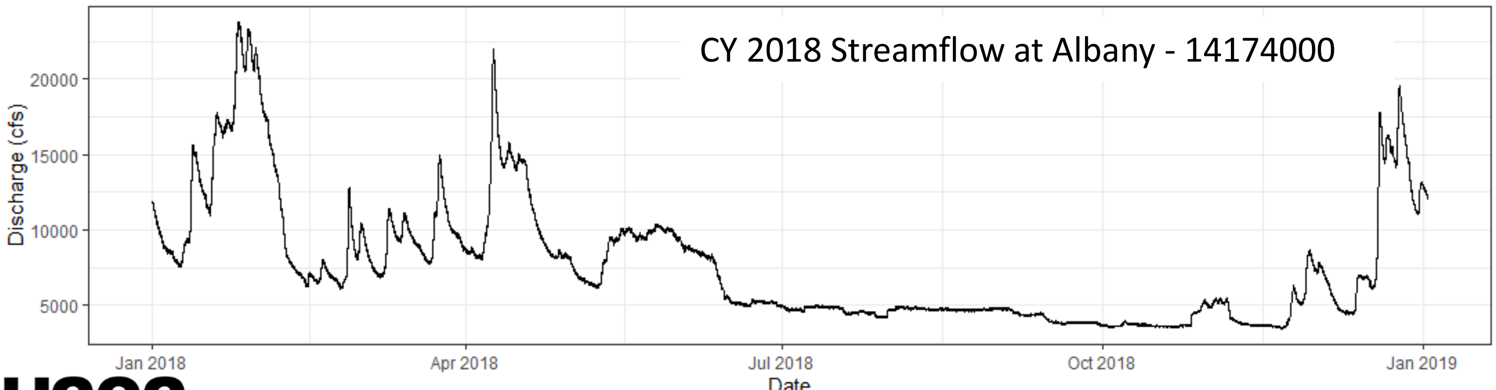
0.25
0.50
0.75
10000
20000
30000
Discharge (cfs)

:o revision



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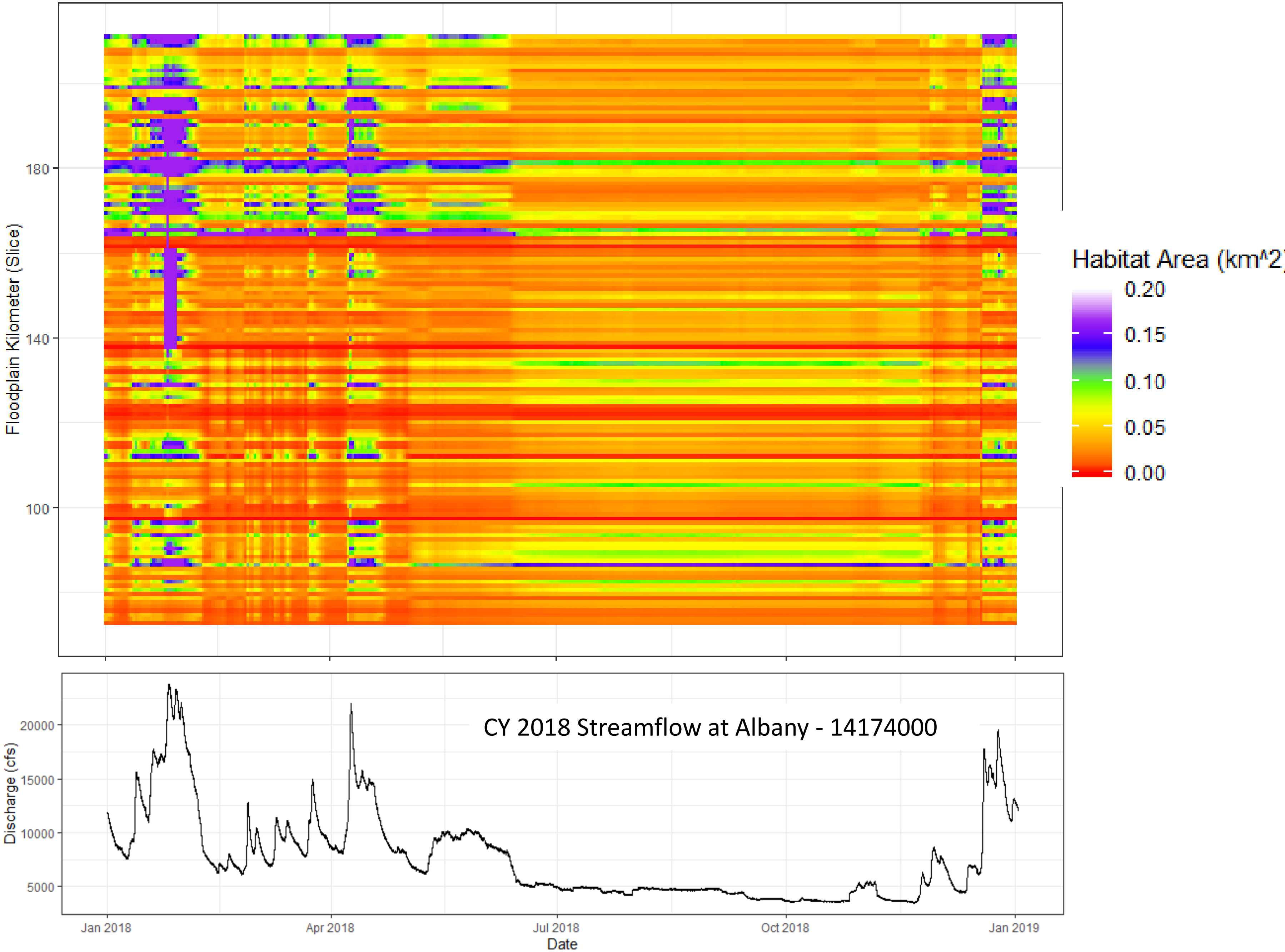
Preliminary Results – subject to revision



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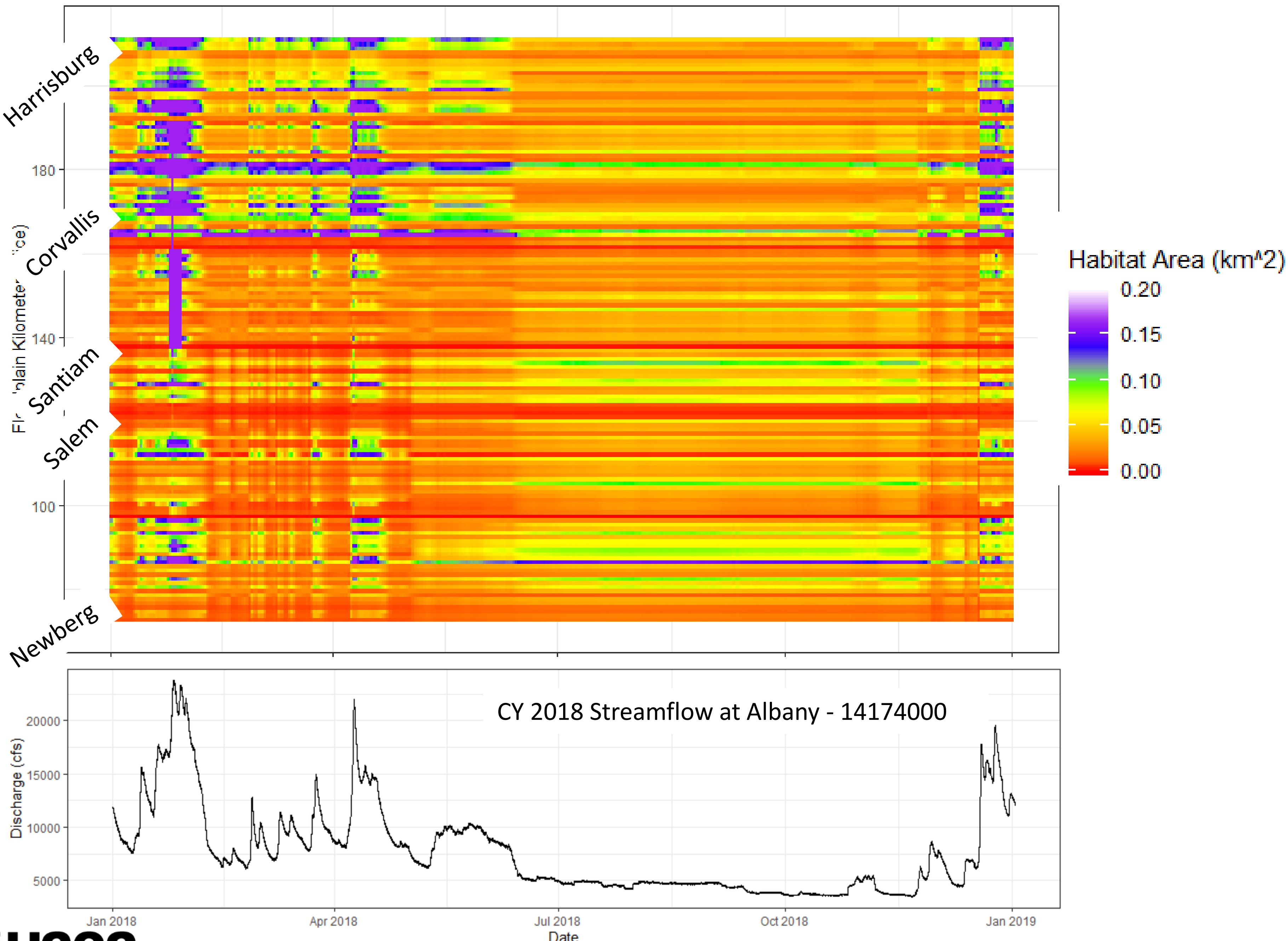

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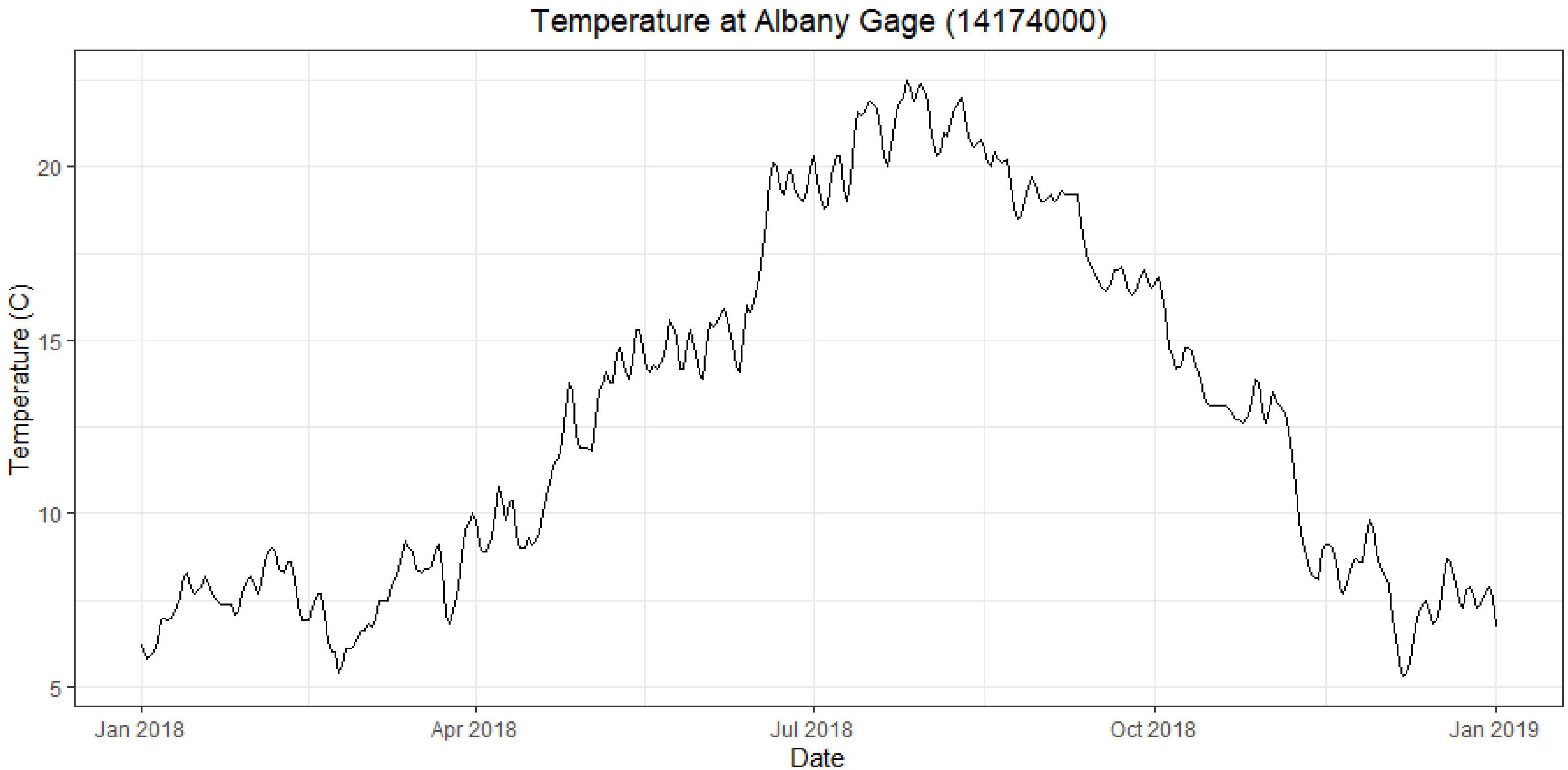

		Water temperature, °C		
Species	**Life-stage**	**Narrow**	**Median**	**Broad**
Spring Chinook salmon	**Adult migration/holding**	8–12	3–17	3–20
	Spawning	6–13	4–14	4–16
	Incubation	6–10	4–12	2–14
	Rearing	10–15	4–19	4–22
Literature sources – McCullough 1999; U.S. EPA 2003; Carter 2005, 2008; Kubo 2017				

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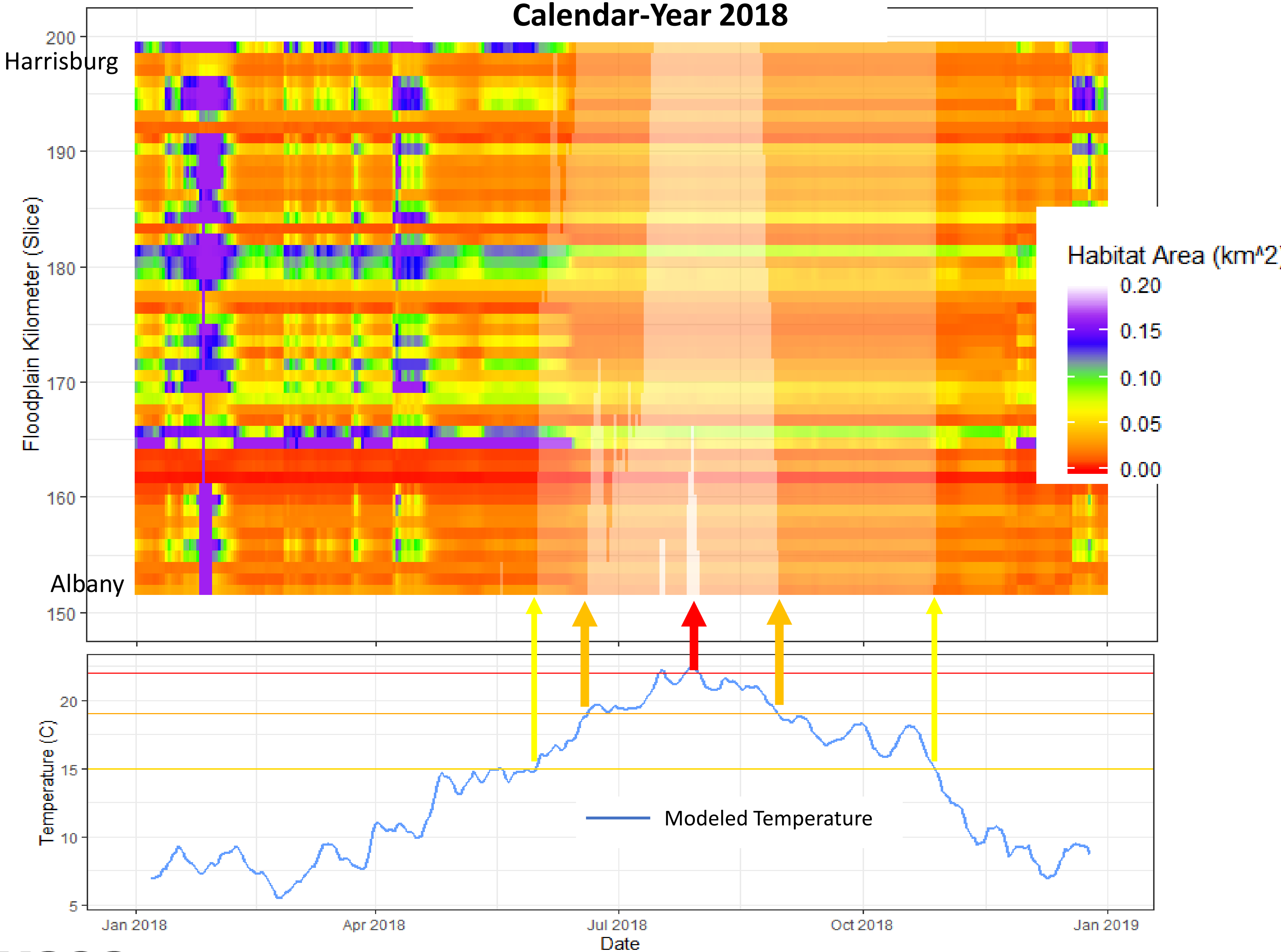
Preliminary Results – subject to revision

Calendar-Year 2018



Temperature model results from Laurel Stratton and Stewart Rounds

Preliminary Results – subject to revision

The Need to Quantify Habitat

- Flow-management decisions
  - What is relationship between streamflow and juvenile salmonid habitat?

- Where and when is habitat limiting?

Key findings:

- Spatial patterns of habitat availability are highly variable:
  - Short river segments can account for much of reach-aggregated habitat area
- Reach-scale patterns of habitat limitations vary seasonally
  - Upper Willamette has more habitat area in winter but less in summer, compared to Middle Willamette

The Need to Quantify Habitat

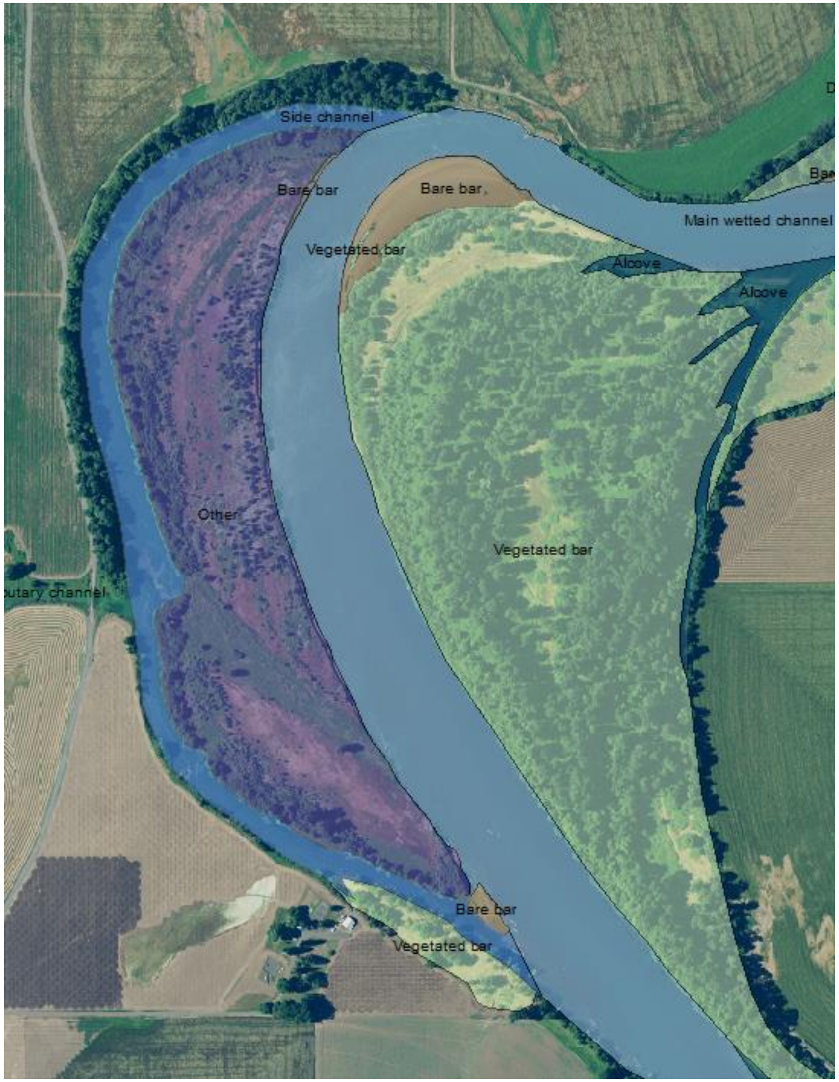
- Flow-management decisions
  - What is relationship between streamflow and juvenile salmonid habitat?

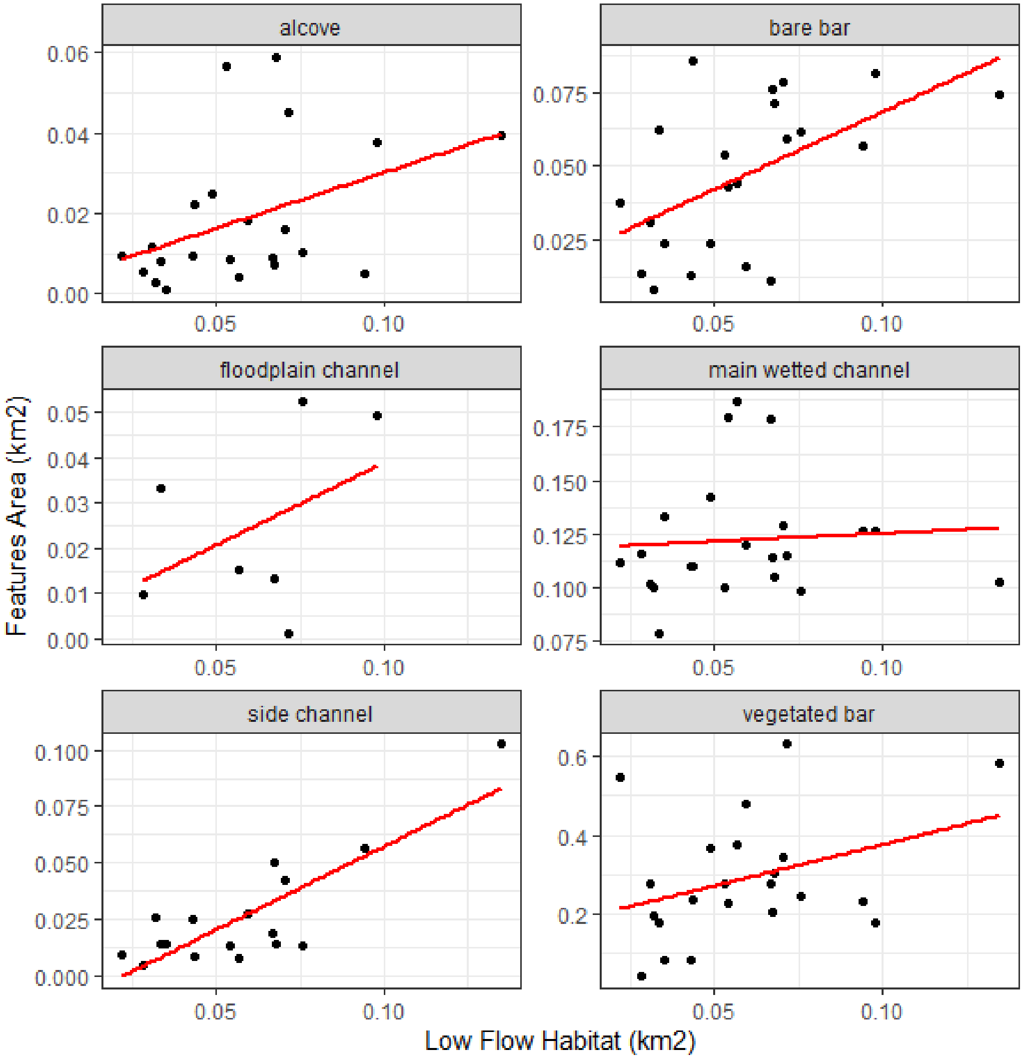
- Where and when is habitat limiting?

- Status and trends of habitat availability over time
  - What is the trajectory of habitat availability?
  - Are we making progress towards restoration goals?

How can we affordably track changes in habitat?

Where and how to leverage remote sensing and machine learning?





Preliminary Results – subject to revision

The Need to Quantify Habitat

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  - What is relationship between streamflow and juvenile salmonid habitat?
- Where and when is habitat limiting?
- Status and trends of habitat availability over time
  - What is the trajectory of habitat availability?
  - Are we making progress towards restoration goals?

Key findings:
Habitat variation can likely be explained in large part by river and geomorphic characteristics

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Tying it together

Take home points

- Least amount of habitat exists at low to medium flows throughout the Willamette River
- Higher flows has most habitat, but is inundated a few weeks a year
  - Highest flows (e.g. 1+ year RI) may be inundated a few days a year or less

- Habitat and its response to streamflow varies spatially
  - Large-scale trends explained by geomorphology
  - At smaller scales, considerable variation exists
    - Model results highlight areas that can be preserved for high quality habitat, or identify reaches lacking in habitat

- Where summer habitat exists, it is likely to be warm and potentially unusable
  - Eventual goal to combine results with cold-water refugia work

- Habitat results are a snapshot in time
  - Detailed results will change over time, but trends likely to remain the same
  - Upper Willamette likely to change faster than lower Willamette
  - Detailed habitat modeling impractical to conduct frequently, but coarser quantification possible with aerial photos

- Larger life-cycling model work may help evaluate fish-response to increased habitat
  - This would be at reach (30-50km) scale

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Questions from us

Most work has been done to better understand how flow-management affects habitat

- Results provide insights into river dynamics and distributions of habitat

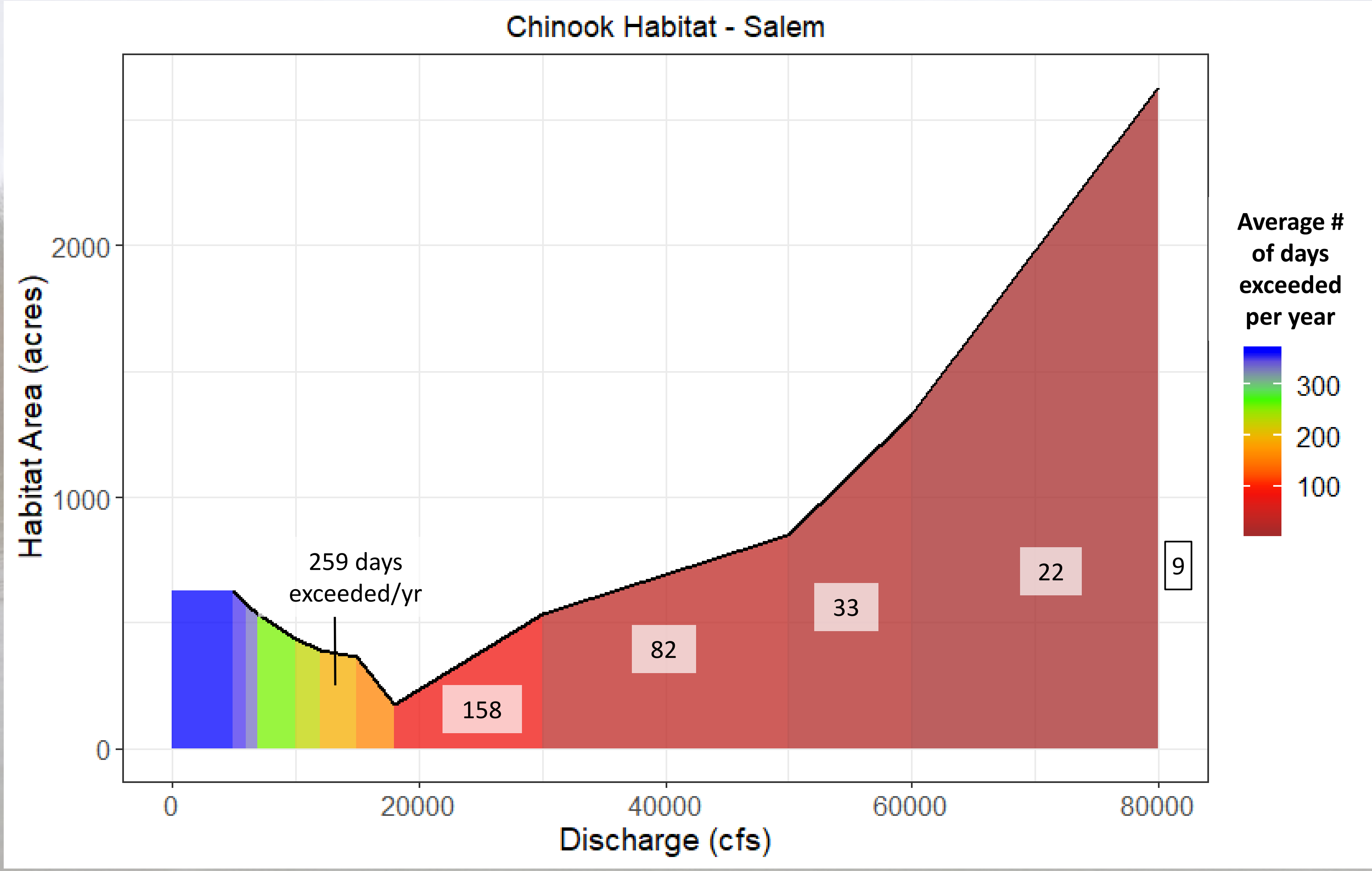
How can this be more useful for:

- Restoration planning?
  - Hydraulic model availability?
  - Identifying/prioritizing reaches?
  - Inundation extents at various streamflows
- Restoration monitoring?
  - Area habitat created?
  - Days inundated?
- What other information would be helpful?

Questions

jameswhite@usgs.gov

EXTRA SLIDES



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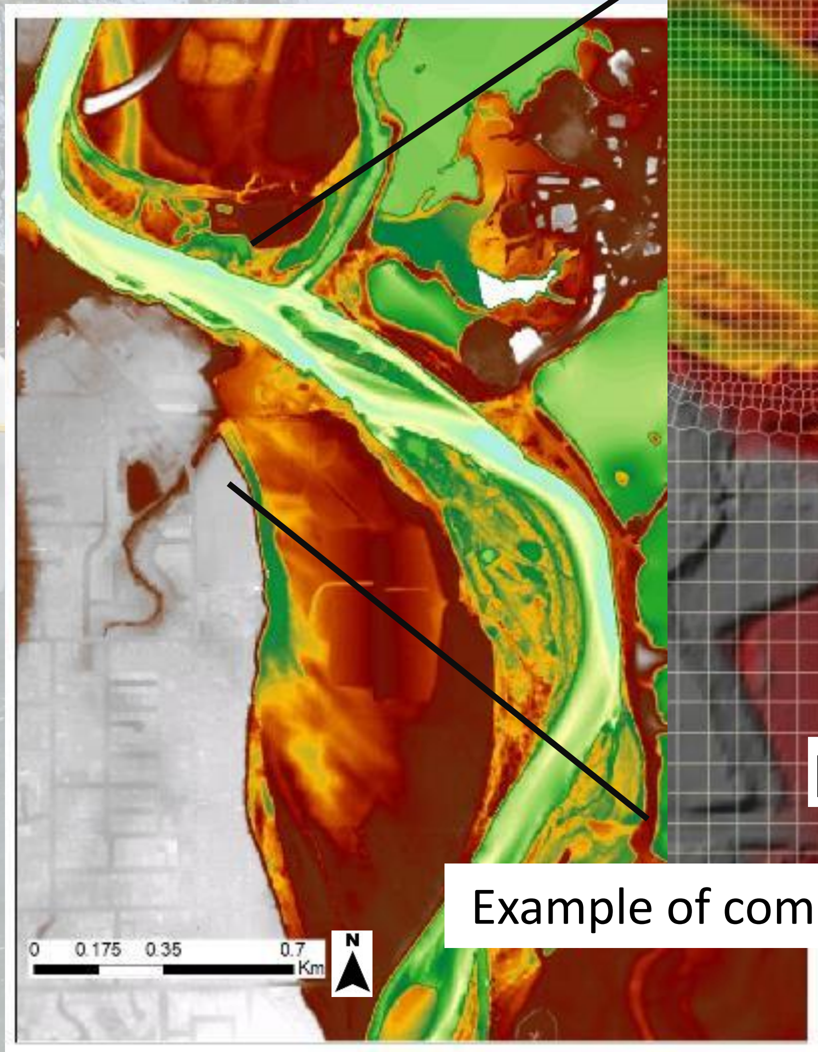
Preliminary Results – subject to revision

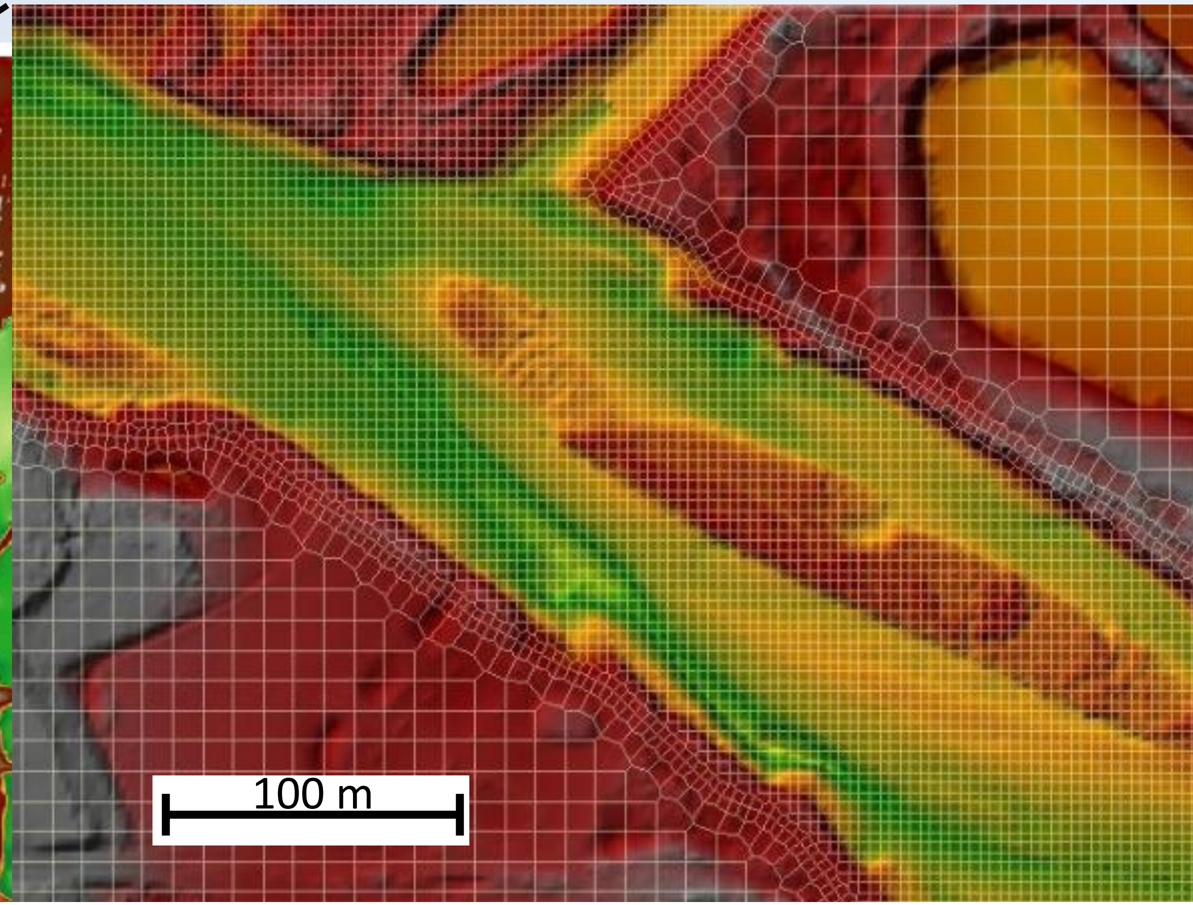
Willamette River Flow Objectives

Source: Table 2-8 from Biological Opinion for USACE's Willamette Valley Project, NOAA Fisheries, 2008

Time Period	7-Day Moving Average[1] Minimum Flow at Salem (cfs)	Instantaneous Minimum Flow at Salem (cfs)	Minimum Flow at Albany (cfs) [2]
April 1 - 30	17,800	14,300	---
May 1 - 31	15,000	12,000	---
June 1 - 15	13,000	10,500	4,500
June 16 - 30	8,700	7,000	4,500
July 1 - 31	---	6,000	4,500
August 1 - 15	---	6,000	5,000
August 16 - 31	---	6,500	5,000
September 1 - 30	---	7,000	5,000
October 1 - 31	---	7,000	5,000

Building blocks of hydraulic model





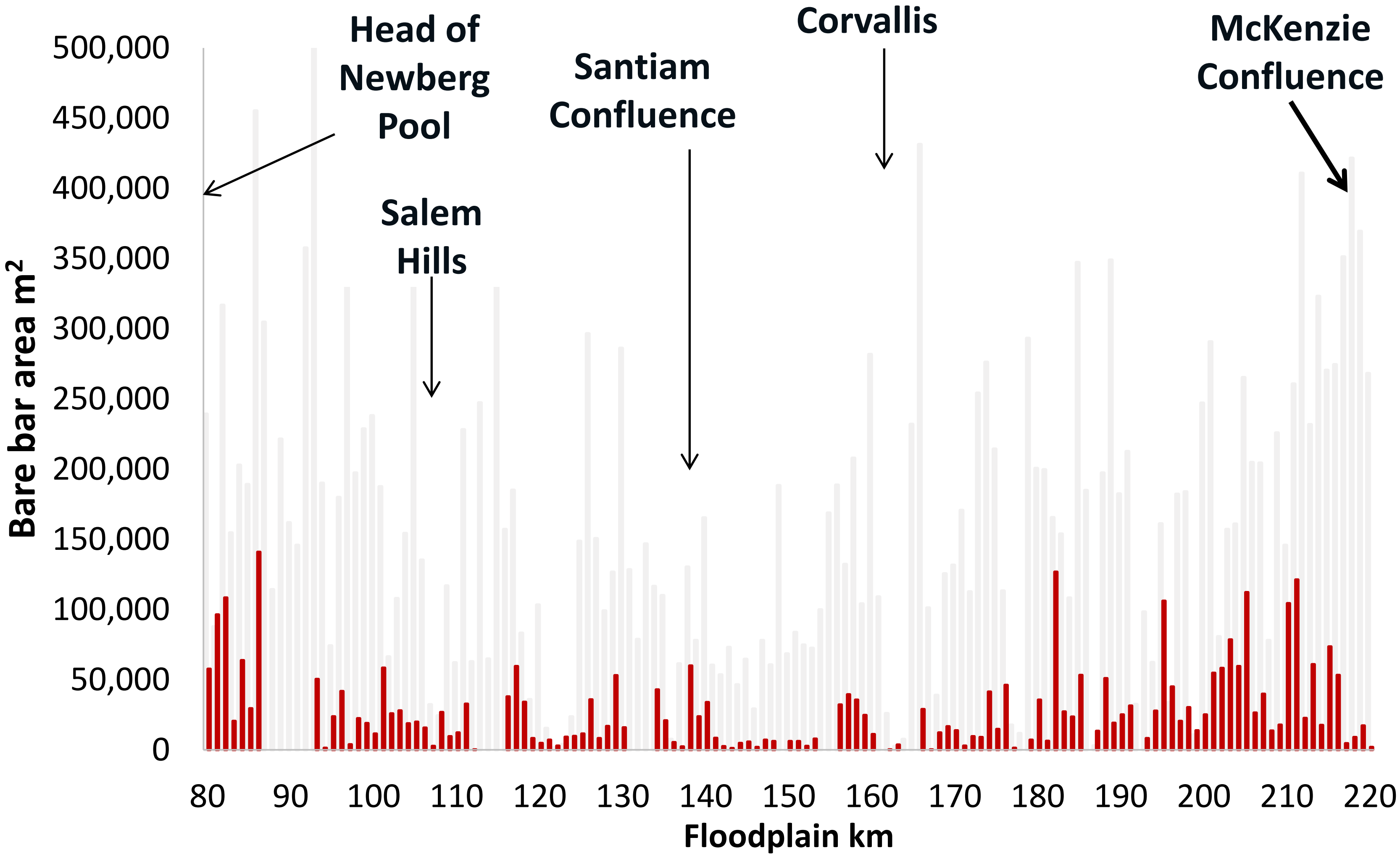
Example of computational mesh for two-dimensional hydraulics

Model platform: HEC-RAS 5.0.6

Change in gravel bars 1895-2008

~85% reduction in bare bars in *Willamette River above Newberg*

1895 bars mapped from USACE navigational surveys; 2008 bars mapped from LiDAR. Provisional data, subject to revision.



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Alternative approaches to bathymetry

What about places where topo-bathymetric lidar isn't available?

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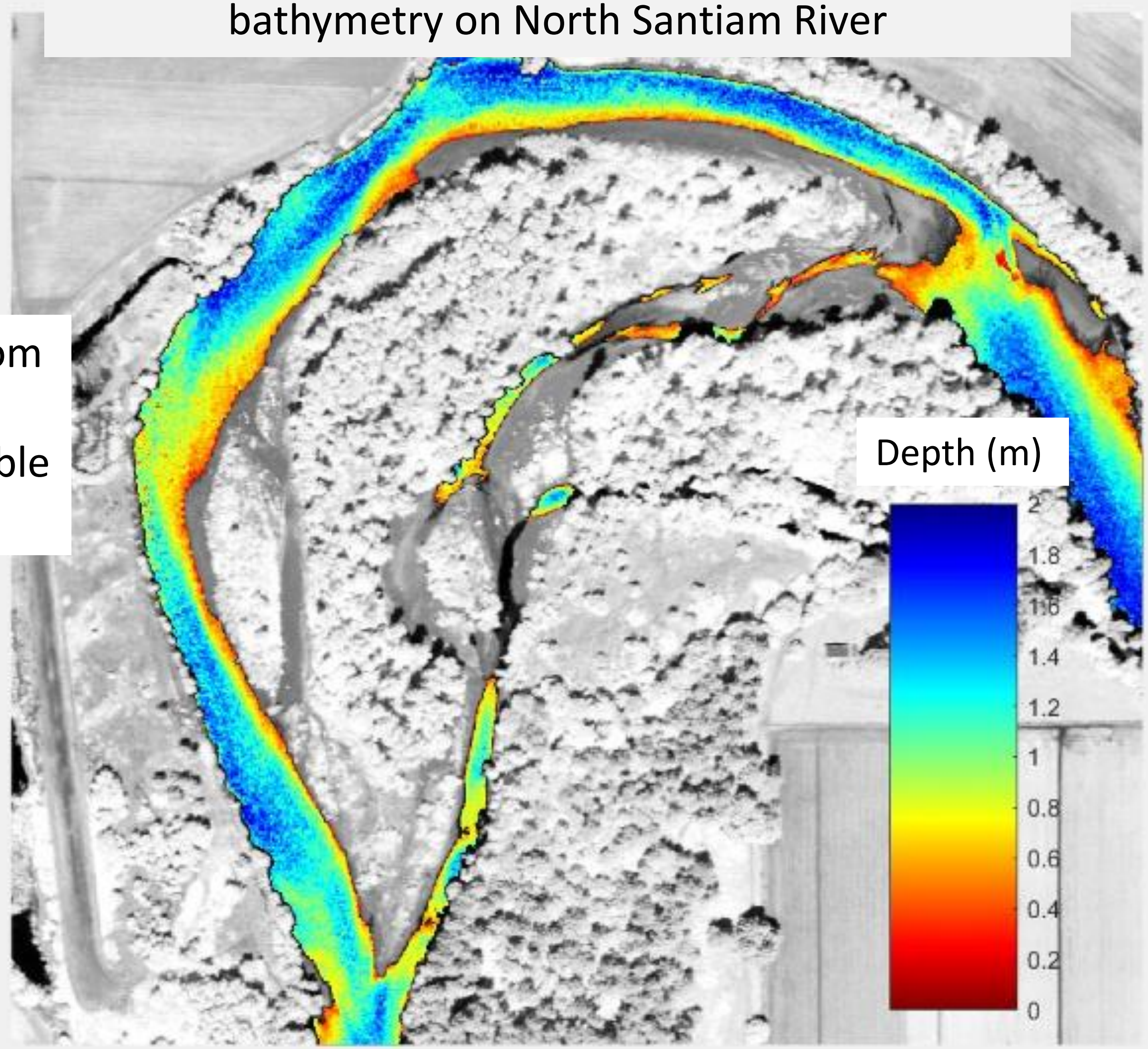
Preliminary Results – subject to revision

Alternative approaches to bathymetry

Example of preliminary image (RBG) derived bathymetry on North Santiam River



Bathymetry is derived from spectral and hydraulic analysis of publicly available imagery (NAIP)

USGS

Preliminary Results – subject to revision

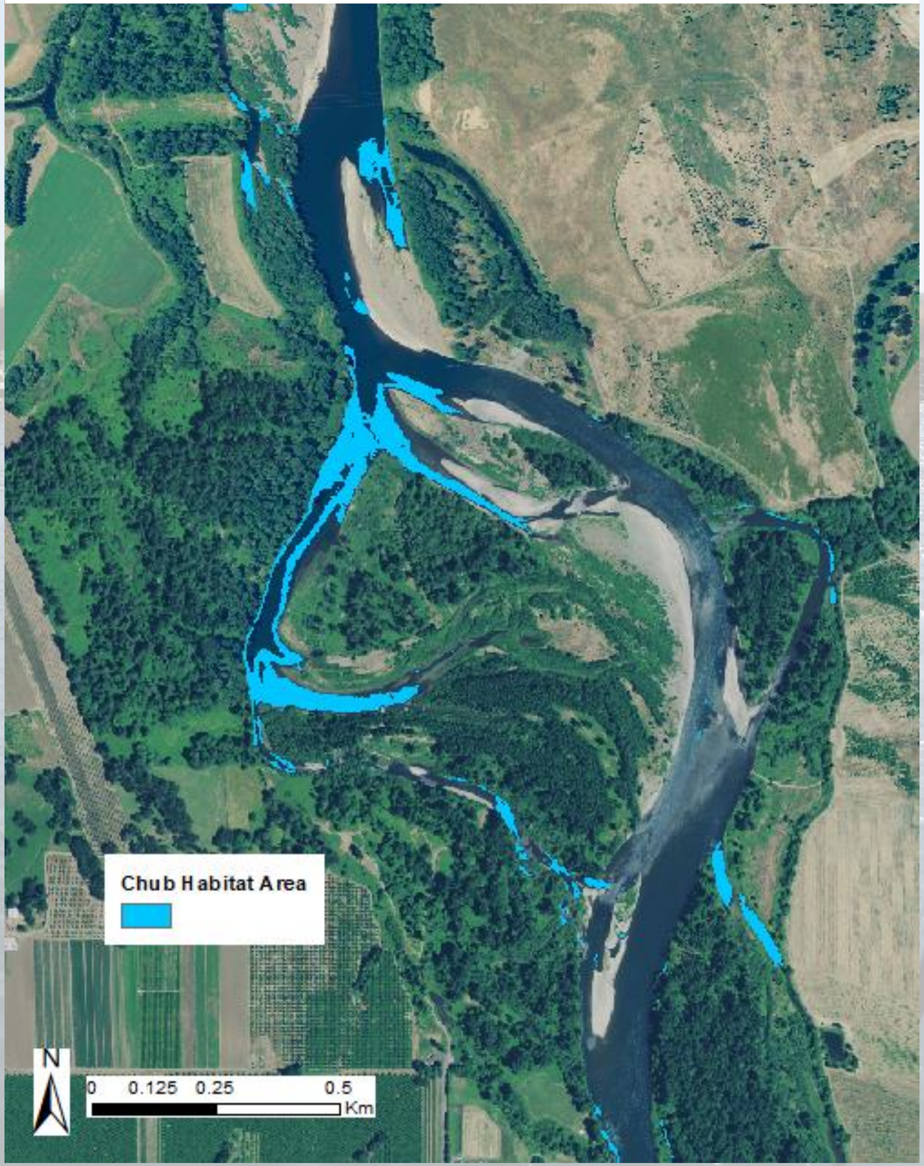
Modeling other species and interactions

Photo: Jeremy Monroe, Freshwater Illustrated

Oregon Chub habitat preferences:
- Depth: 0.5 m – 2.0 m
- Velocity: <0.1 m/s
- Reaches with upstream connections in winter

Habitat criteria provided by Brian Bangs, ODFW

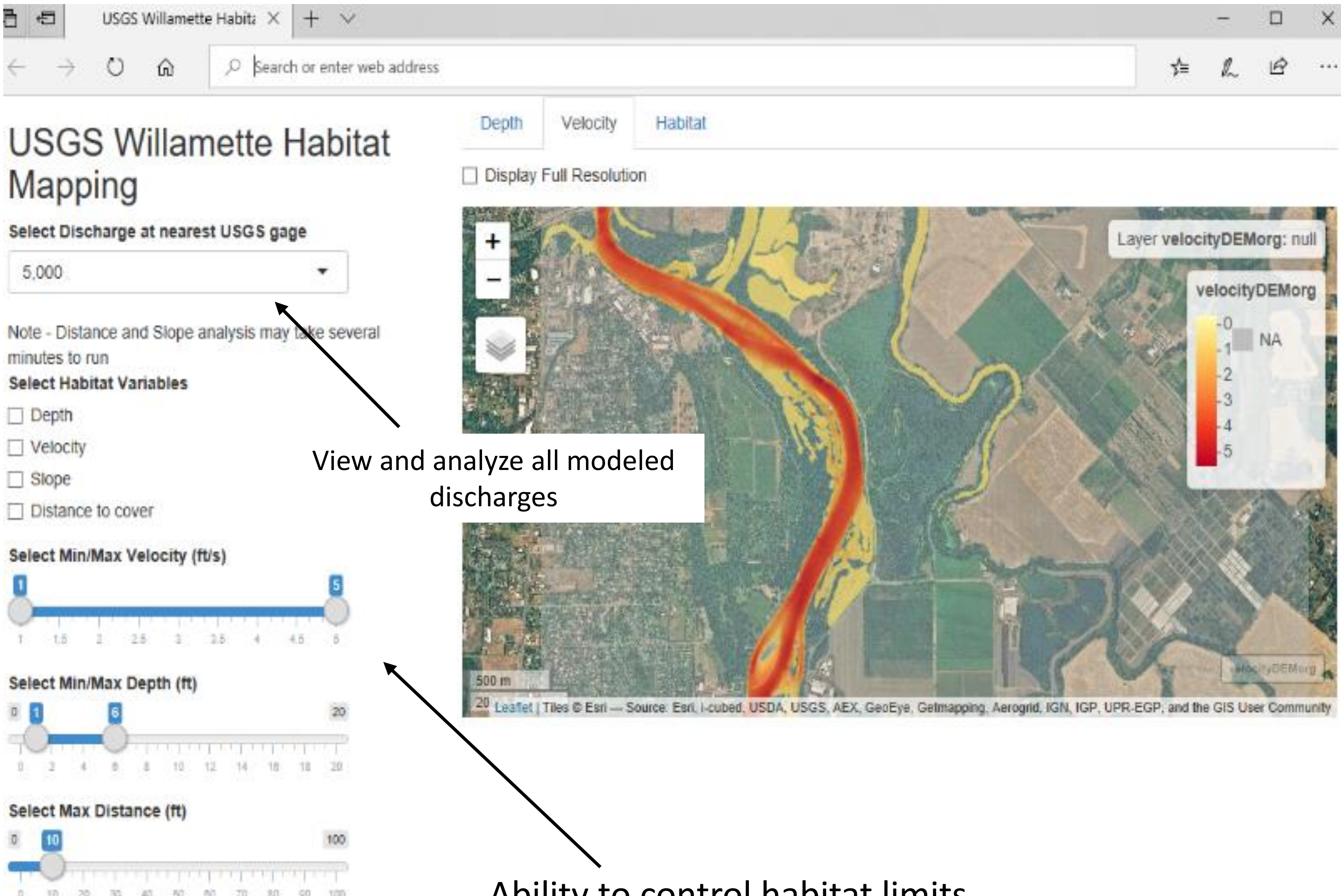
Upper Willamette River near Green Island



Preliminary Results – subject to revision

Potential tools to support flow management and habitat restoration

Example Shiny Application where user can define habitat criteria and view maps of habitat availability



View and analyze all modeled discharges

Ability to control habitat limits

USGS

Anticipated products and timelines

<u>Bathymetry</u>

- Sonar point cloud published – www.sciencebase.gov → search "Willamette River Bathymetry"……. or just email me
- Fused lidar/sonar DEM (anticipated release: Spring, 2020)

<u>Hydraulic models</u>

- Calibration continuing through Fall 2019
  - Anticipated release: Spring, 2020

<u>Habitat models</u>

- Preliminary results included in growth, survival, and movement models under development by OSU – expected release Spring 2020

<u>Tributary bathymetry and models</u>

- Under development (anticipated release: Summer/Fall 2020)

<u>Flow-management and analysis tools</u>

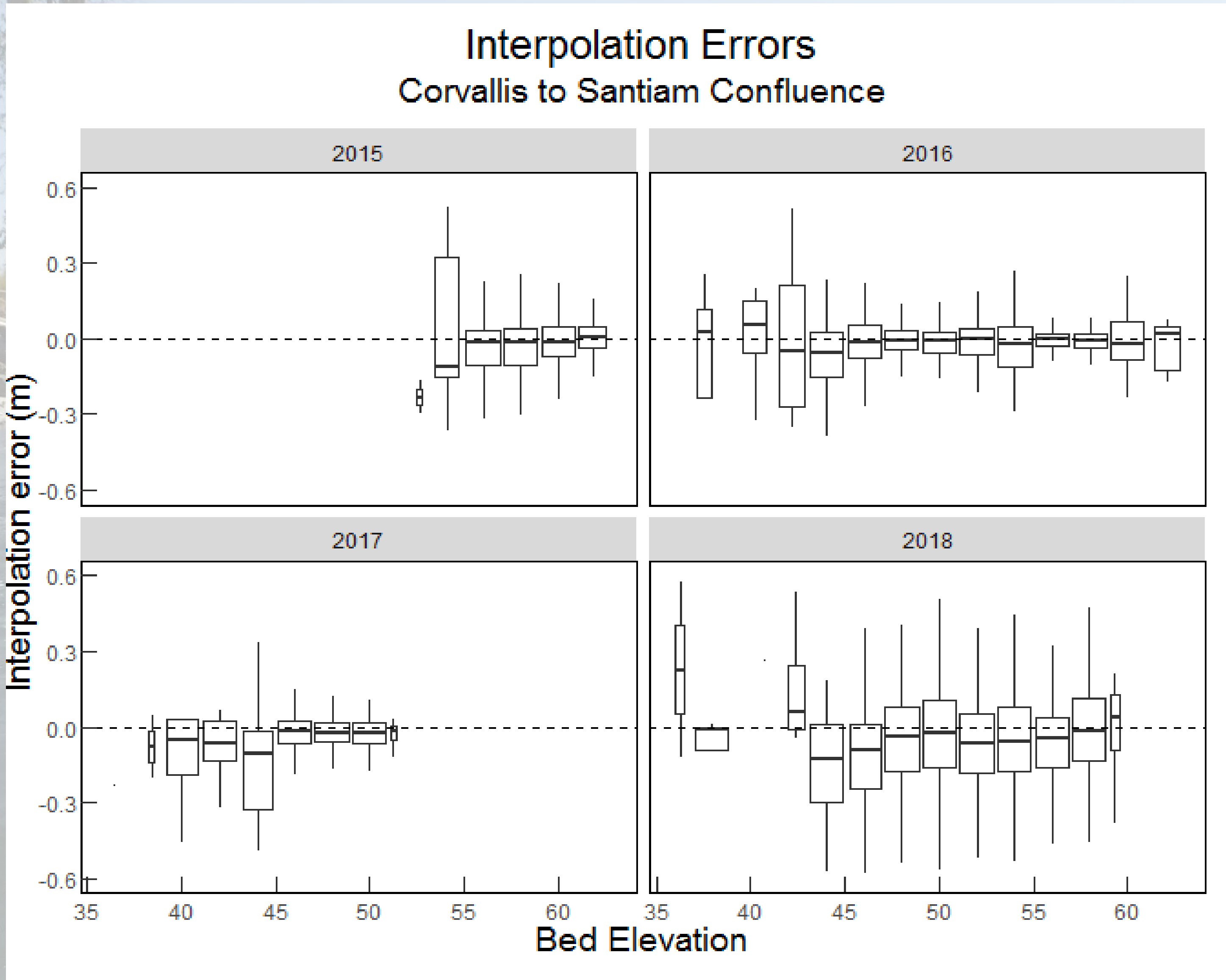
- Under development – soliciting input from broader community – Summer 2020?

Hydraulic model outputs

Percentile	Salem	Albany	Harrisburg
(%)	(ft^3/s)		
1	5,517	3,875	3,457
5	6,369	4,427	4,010
10	6,811	4,777	4,495
90	49,031	27,951	21,374
95	64,610	36,995	28,570
99	93,355	54,281	41,470

Source: Peterson and others, 2018

Fusing lidar and sonar data



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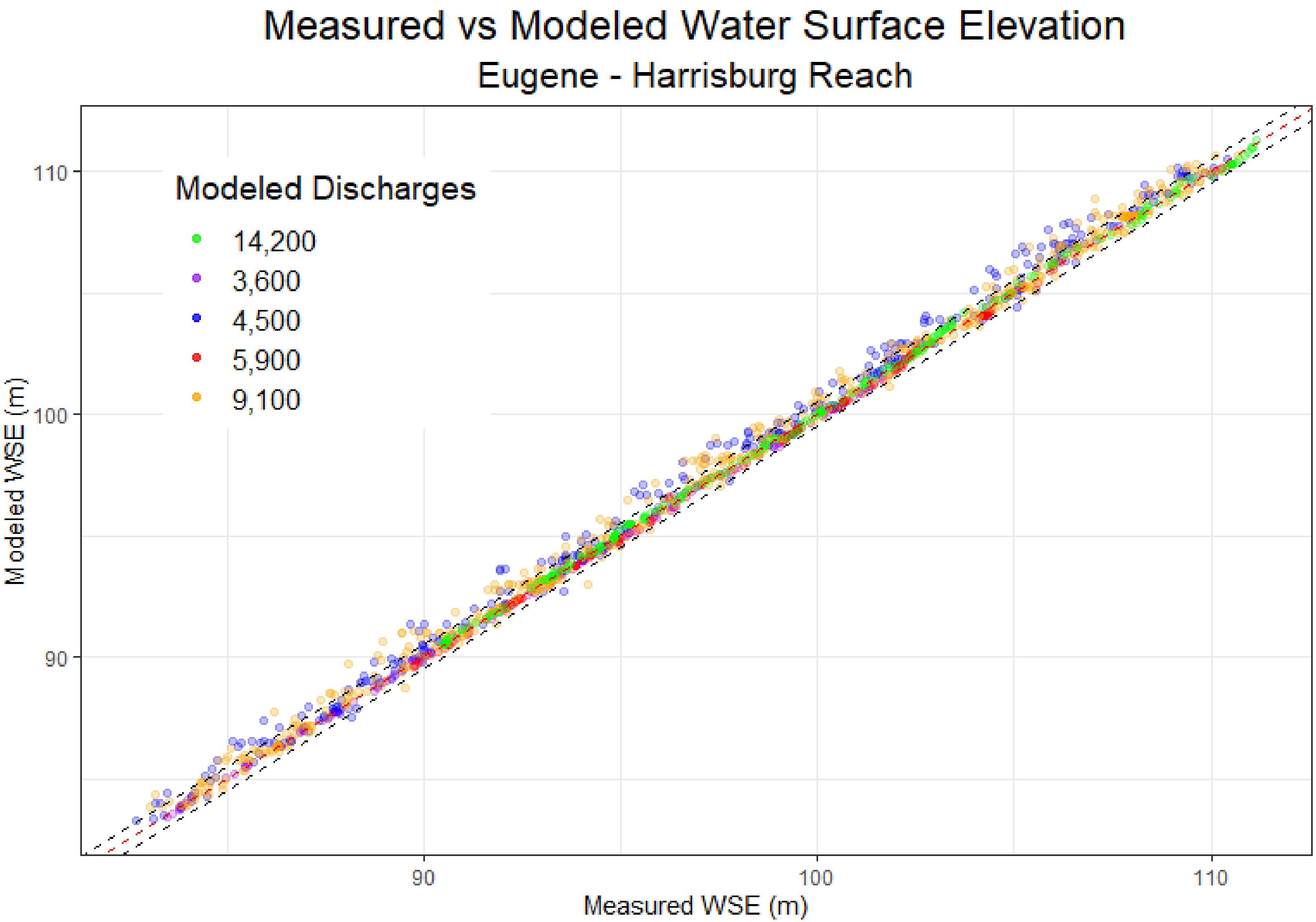
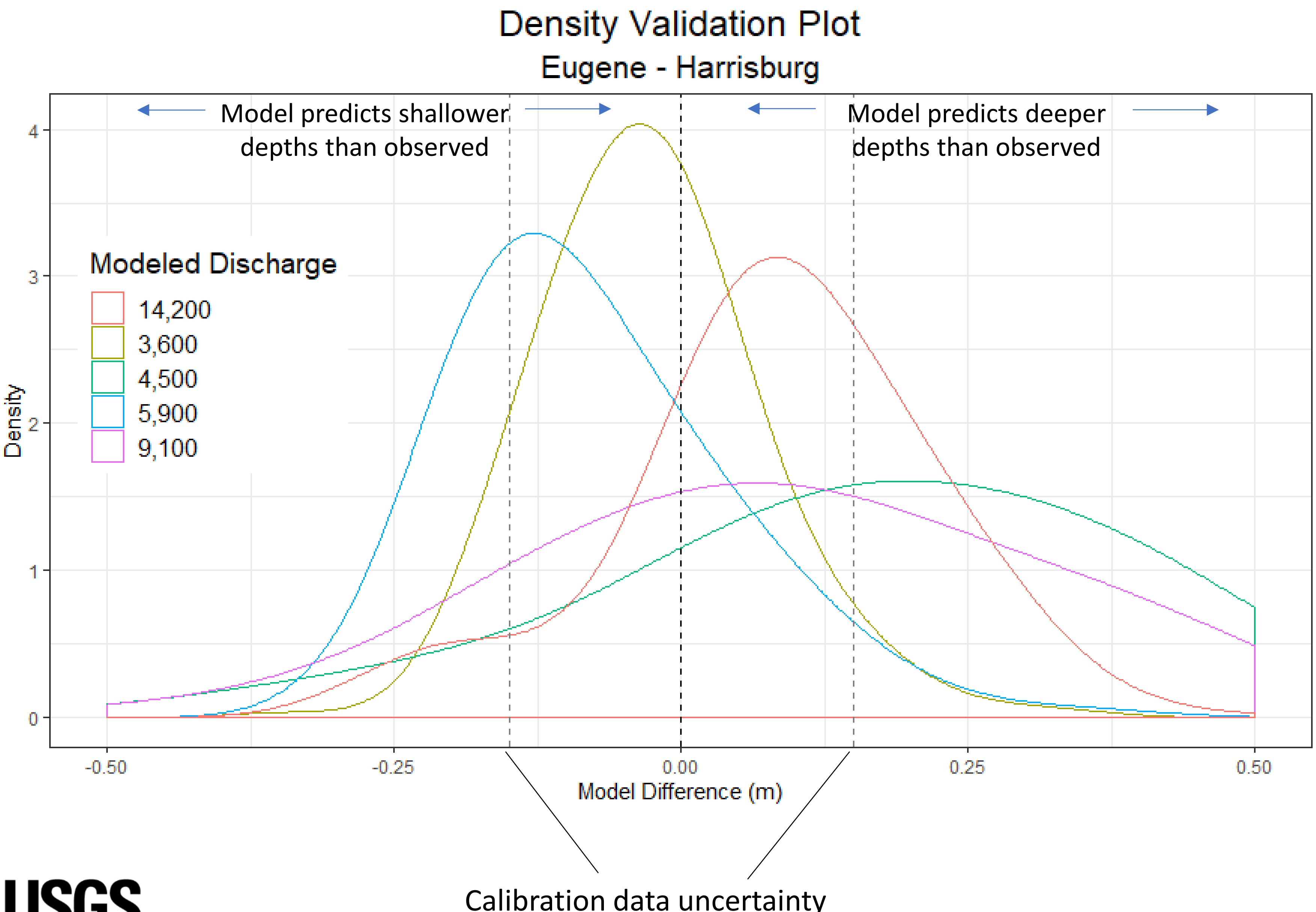
Quantifying Uncertainty in Model Results



Preliminary Results – subject to revision

Quantifying Uncertainty in Model Results



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Preliminary Results – subject to revision