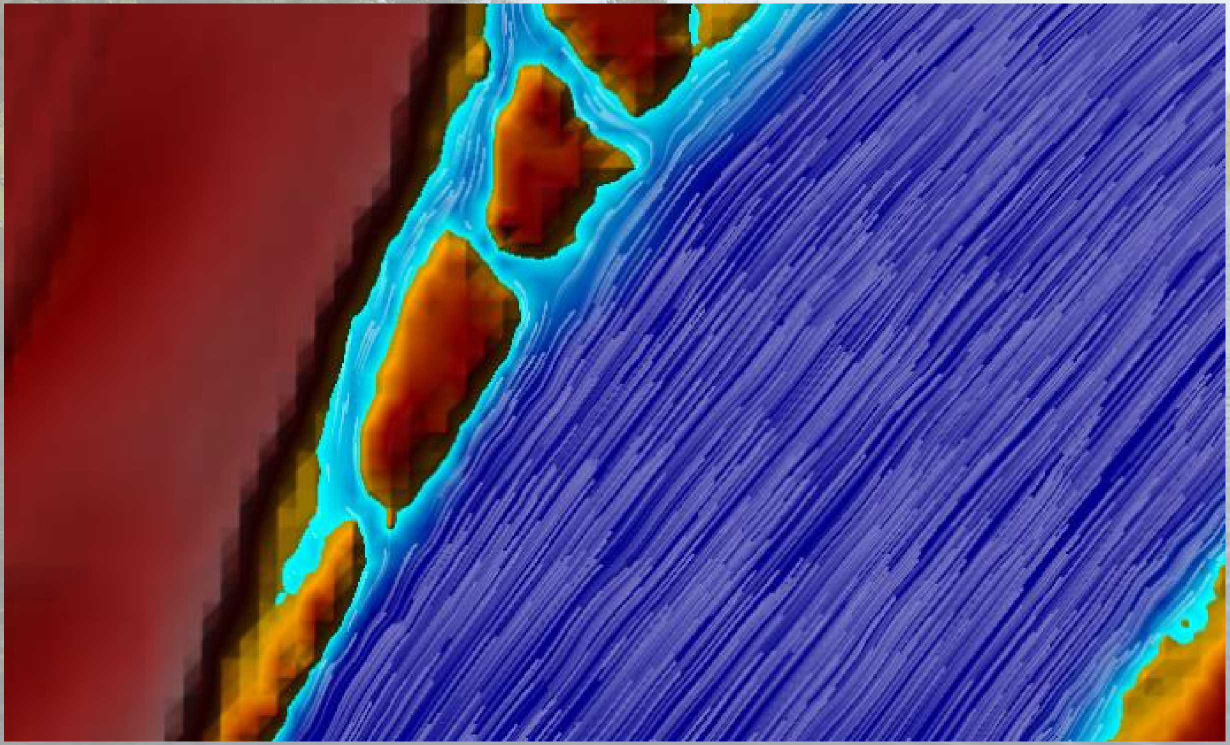
Hydraulic Modeling to Inform Flow Management and Habitat Quantity

USGS Oregon Water Science Center
James White, Rose Wallick, Gabriel Gordon, Brandon Overstreet
USGS/Oregon State University
Jim Peterson, Jessica Pease



USGS

Many people involved and contributing to study

USGS ORWSC: Laurel Stratton-Garvin, Stewart Rounds, Adam Stonewall, Greg Lind

Oregon State University: Tyrell DeWeber

USACE: Rich Piaskowski, Jacob Mcdonald, Greg Taylor, Jeff Balantine, Norman Buccola

NOAA Fisheries: Anne Mullan, Diana Dishman

ODFW: Luke Whitman, Brian Bangs

USGS WFRC: Toby Kock, Russ Perry, Gabe Hansen

Funding provided by US Army Corps of Engineers

Overview

- Background of Willamette River and flow management
- Development of hydraulic model
  - Building a seamless topo-bathymetric DEM
- Development of habitat model
- Preliminary results of habitat modeling
  - Insights to flow-habitat relations and applications
- Next Steps

Background

- 13 USACE flood-control dams in USACE Willamette Valley project
  - Finite amount of stored water
  - Uncertainty in best approach to release stored water
    - Higher Spring flows to aid downstream migration?
    - High, sustained summer flows to manage temperature?
    - Short-duration, higher summer flow to mitigate heat waves?

- 2008 Biological Opinion for USACE's Willamette Valley Project established flow objectives but recommended additional research, monitoring and evaluation to aid in future refinement.

- USGS hydraulic modeling is part of larger effort developing relationships between flow, temperature, physical habitat, and survival to develop real-time flow management tools

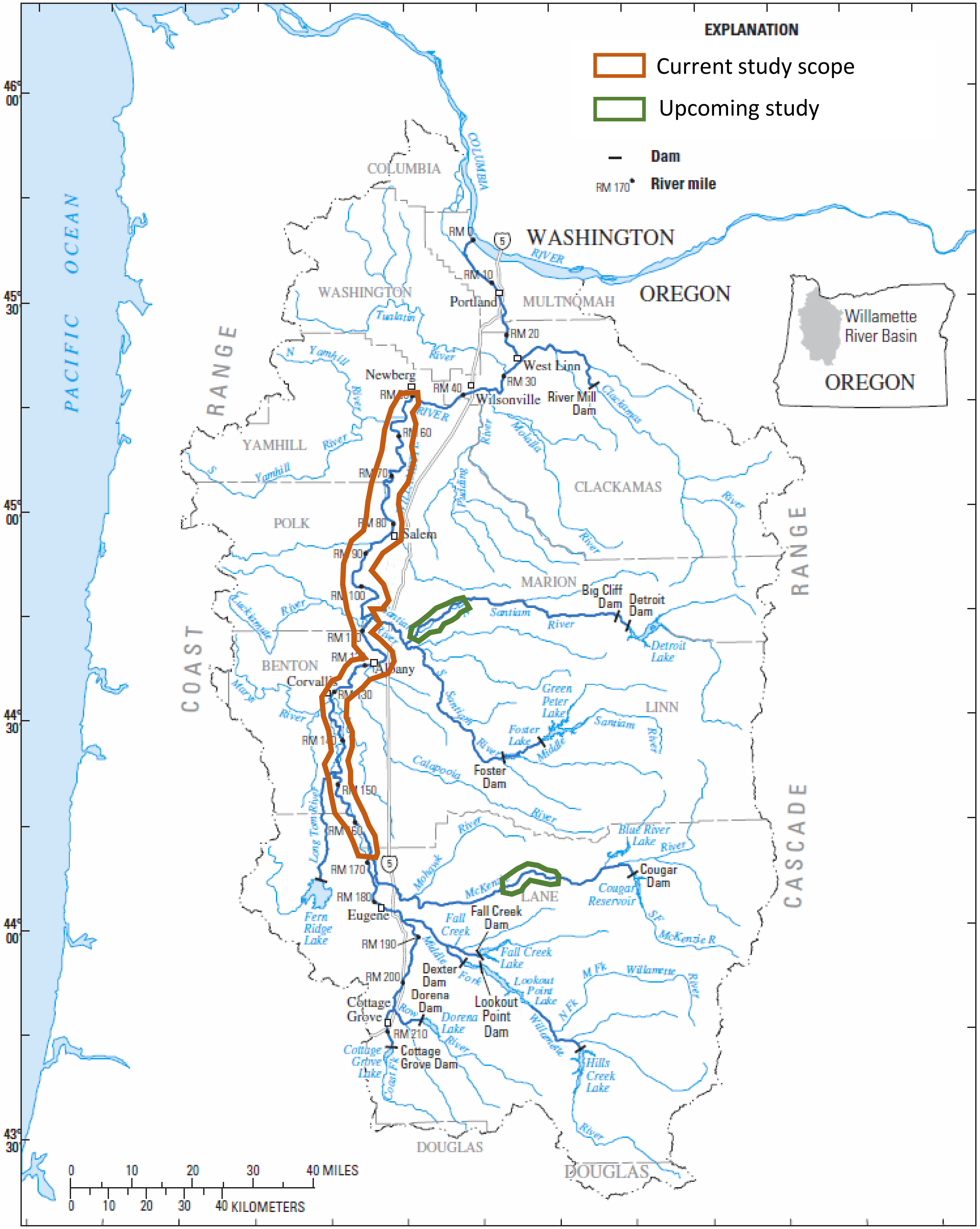
USGS

Mainstem Willamette River Flow Objectives

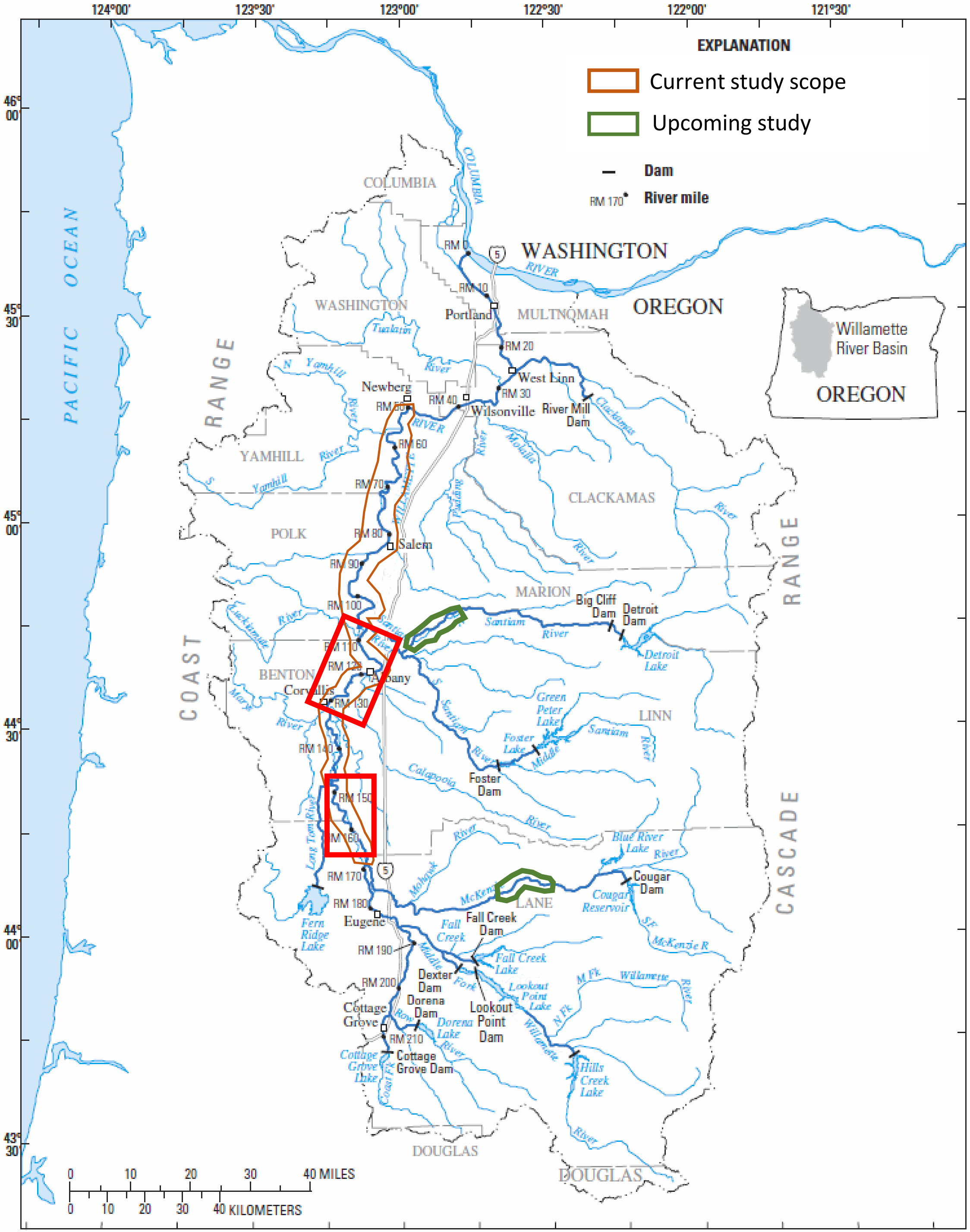
Source: Table 2-8 from Biological Opinion for USACE's Willamette Valley Project, NOAA Fisheries, 2008

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

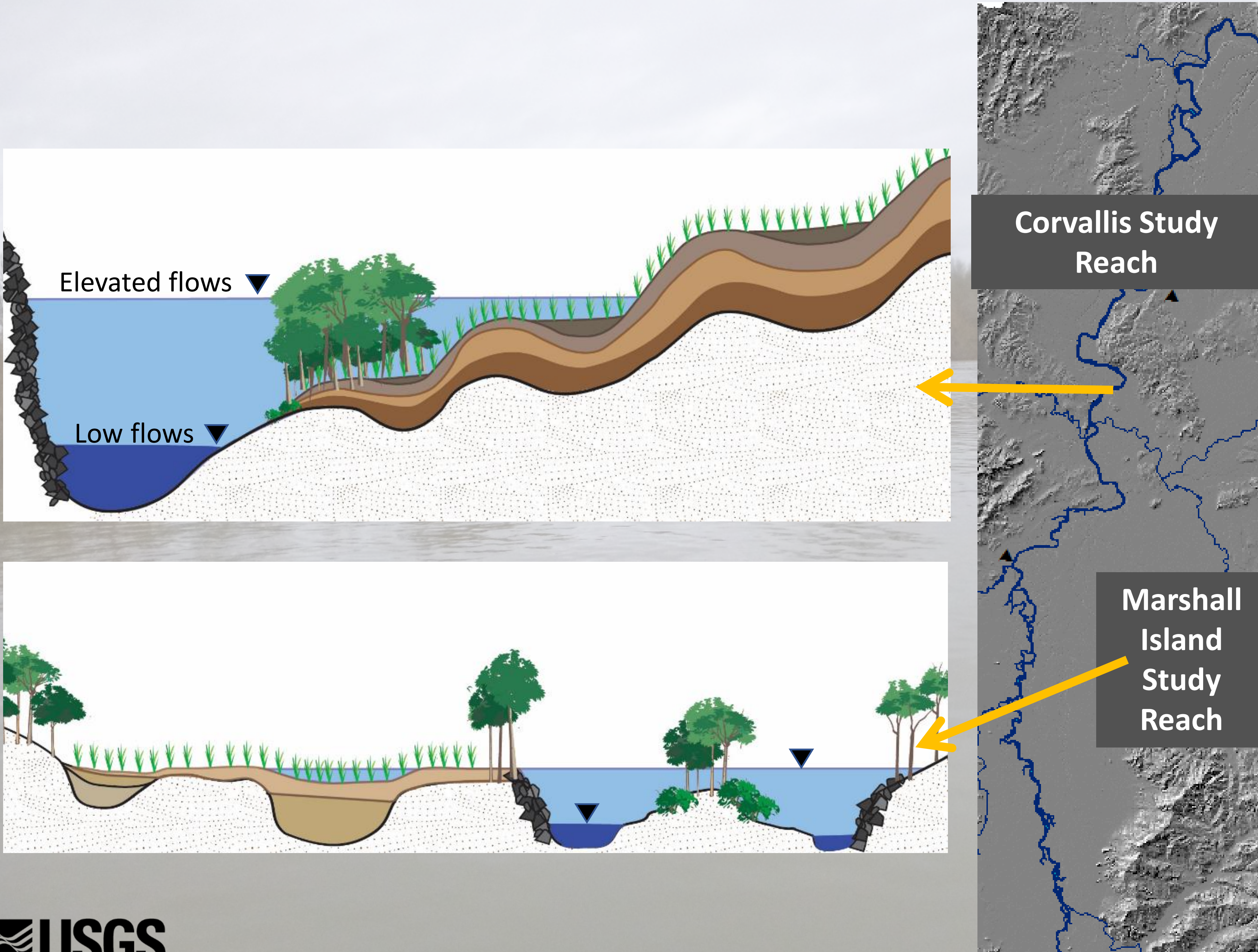
USGS


EXPLANATION
Current study scope
Upcoming study
Dam
River mile
WASHINGTON
OREGON
Willamette River Basin
OREGON
PACIFIC OCEAN
COAST RANGE
CASCADE RANGE
COLUMBIA
WASHINGTON
MULTNOMAH
YAMHILL
POLK
CLACKAMAS
MARION
BENTON
LINN
LANE
DOUGLAS
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 Lake
Lookout Point Dam
Cottage Grove Dam
Cottage Grove Lake
Hills Creek Lake
Fern Ridge Lake
0 10 20 30 40 MILES
0 10 20 30 40 KILOMETERS

USGS

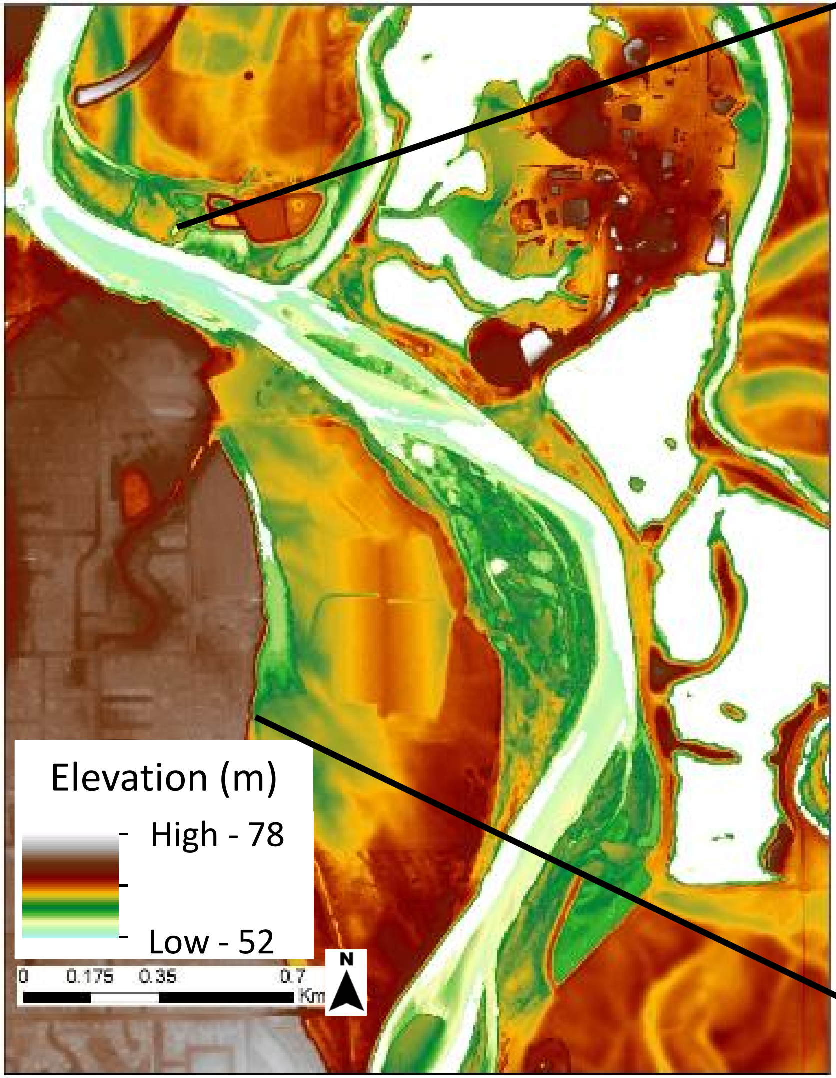


EXPLANATION
Current study scope
Upcoming study
Dam
RM 170 River mile
124°00'
123°30'
123°00'
122°30'
122°00'
121°30'
46° 00'
45° 30'
45° 00'
44° 30'
44° 00'
43° 30'
PACIFIC OCEAN
COAST RANGE
CASCADE RANGE
WASHINGTON
OREGON
COLUMBIA RIVER
COLUMBIA
WASHINGTON
MULTNOMAH
YAMHILL
POLK
CLACKAMAS
MARION
BENTON
LINN
LANE
DOUGLAS
Willamette River Basin
OREGON
Portland
West Linn
Wilsonville
Newberg
Salem
Albany
Corvallis
Eugene
Cottage Grove
RM 0
RM 10
RM 20
RM 30
RM 40
RM 50
RM 60
RM 70
RM 80
RM 90
RM 100
RM 110
RM 120
RM 130
RM 140
RM 150
RM 160
RM 170
RM 180
RM 190
RM 200
RM 210
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
Tualatin River
Yamhill River
Santiam River
Calapooia River
McKenzie River
Mohawk River
Long Tom River
Clackamas River
Molalla River
Pudding River
Luckiamute River
Marys River
0 10 20 30 40 MILES
0 10 20 30 40 KILOMETERS

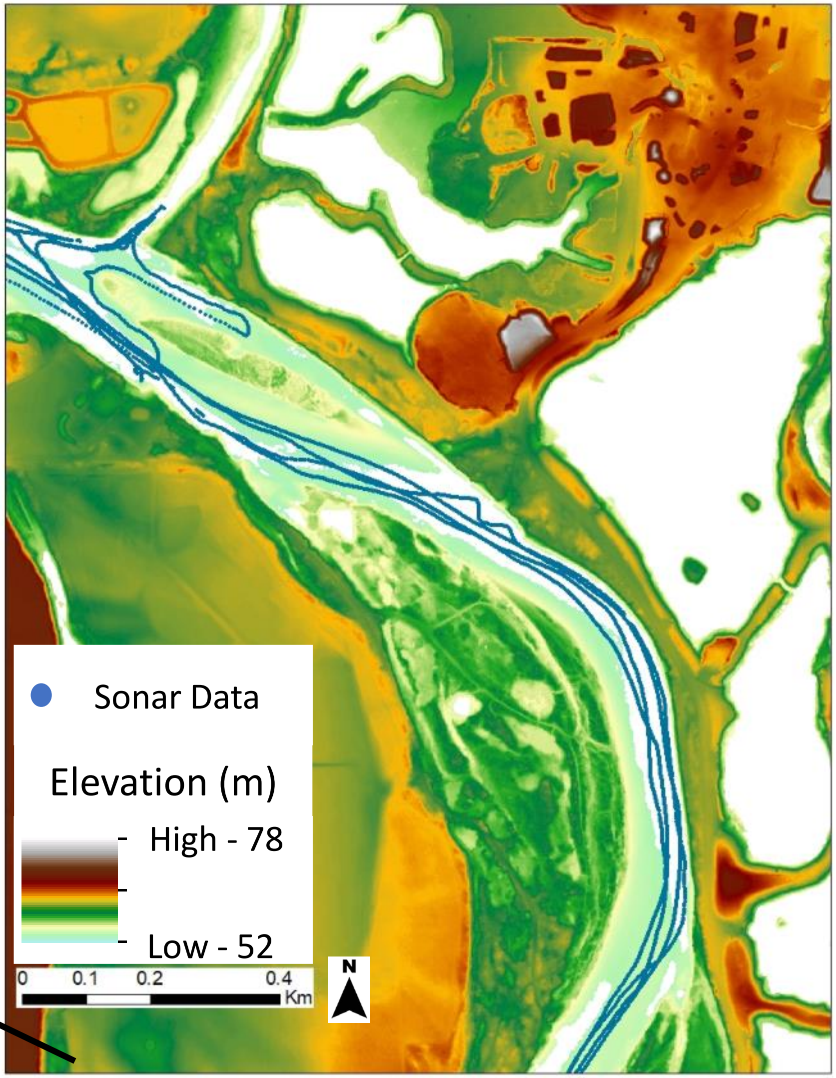

Elevated flows
Low flows
Corvallis Study Reach
Marshall Island Study Reach

USGS

Building blocks of hydraulic model



2017 topo-bathymetric lidar



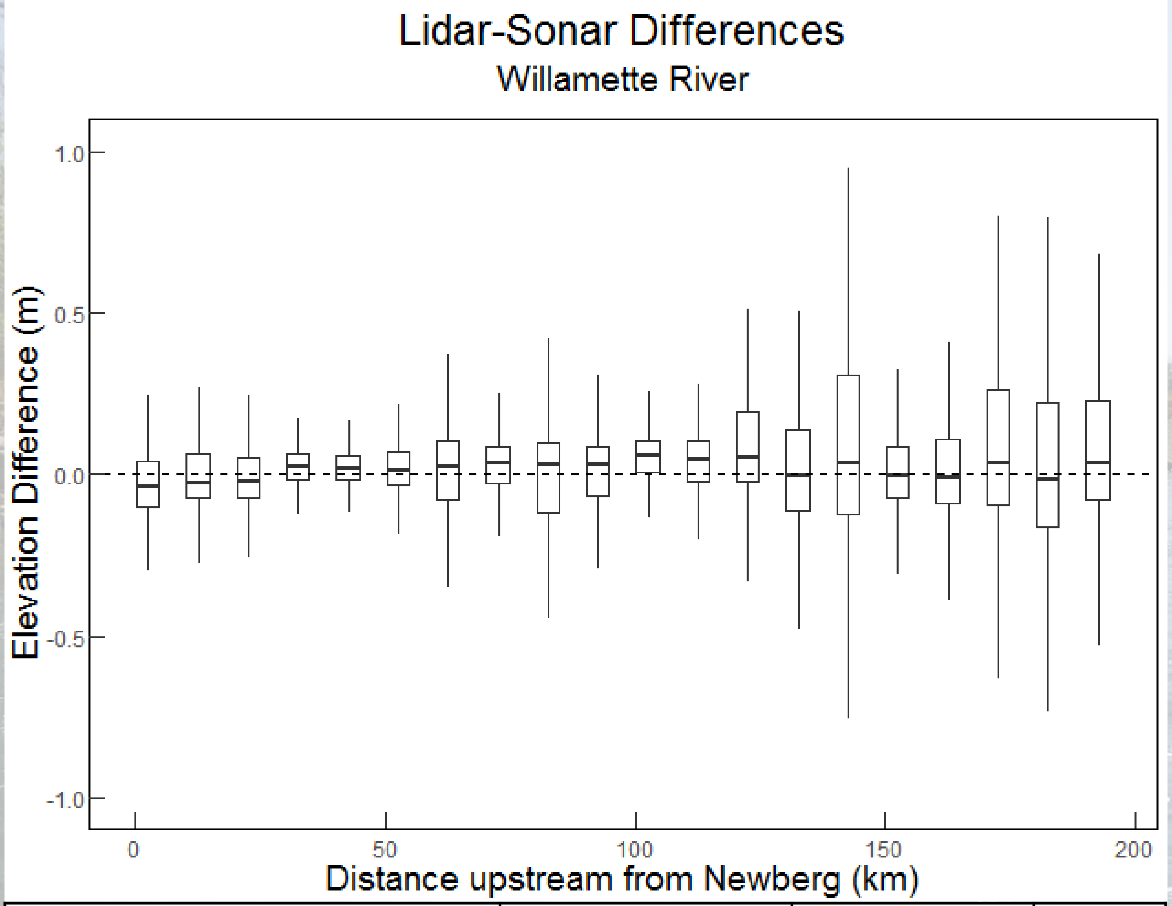
2015-2018 sonar

Data source: QSI, 2017

USGS

Preliminary Results – subject to revision

Fusing lidar and sonar data

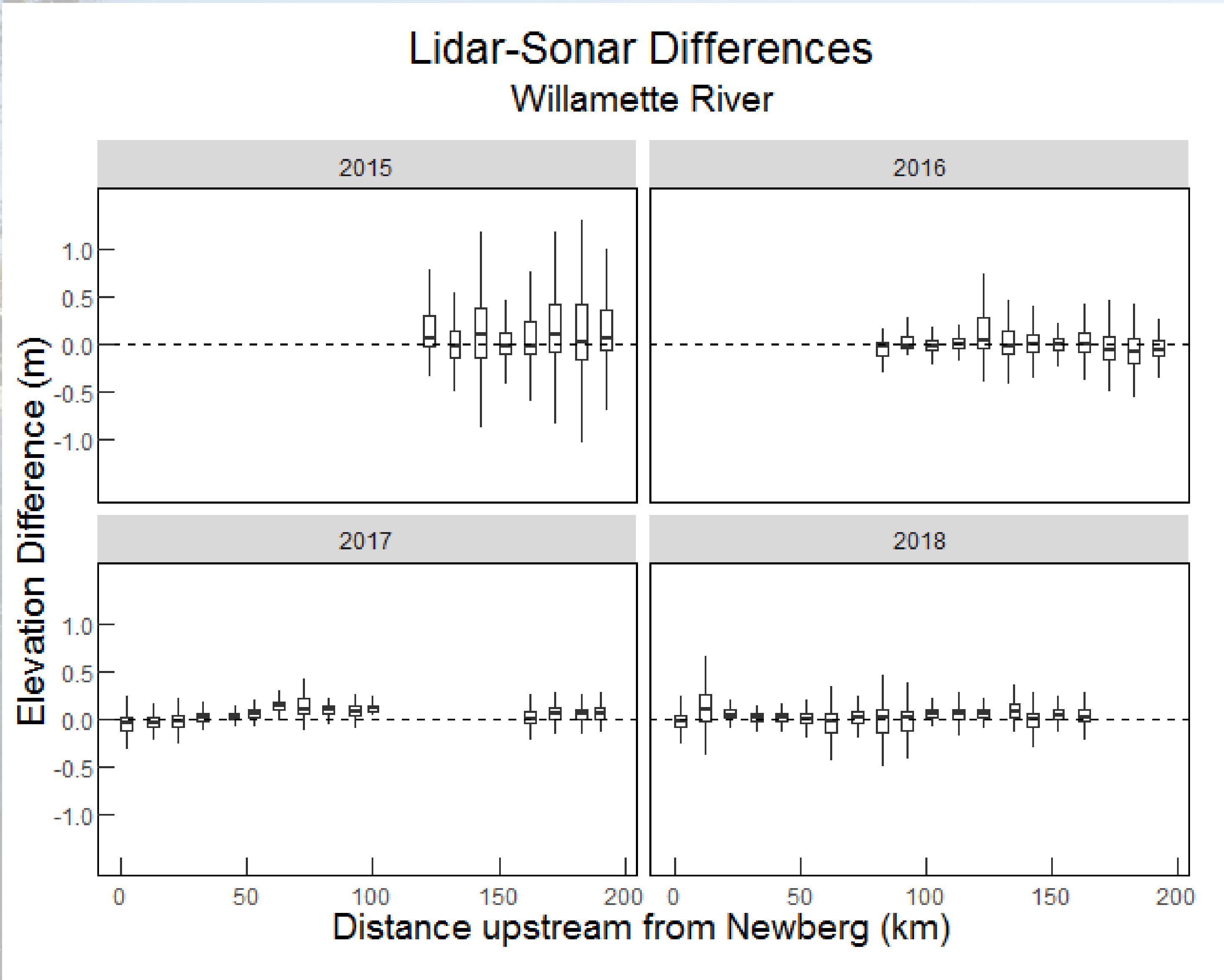


Performance Metric	Value (all data)	Value (2017 & 2018 data)	Unit
Mean Absolute Error	-0.22	0.02	m
Percent Bias	-26	-0.04	%
Root Mean Square Error	0.62	0.21	m
Standard Deviation	0.58	0.21	m
Median	-0.04	-0.03	m

USGS

Preliminary Results – subject to revision

Fusing lidar and sonar data



Preliminary Results – subject to revision

Fusing lidar and sonar data

Approach

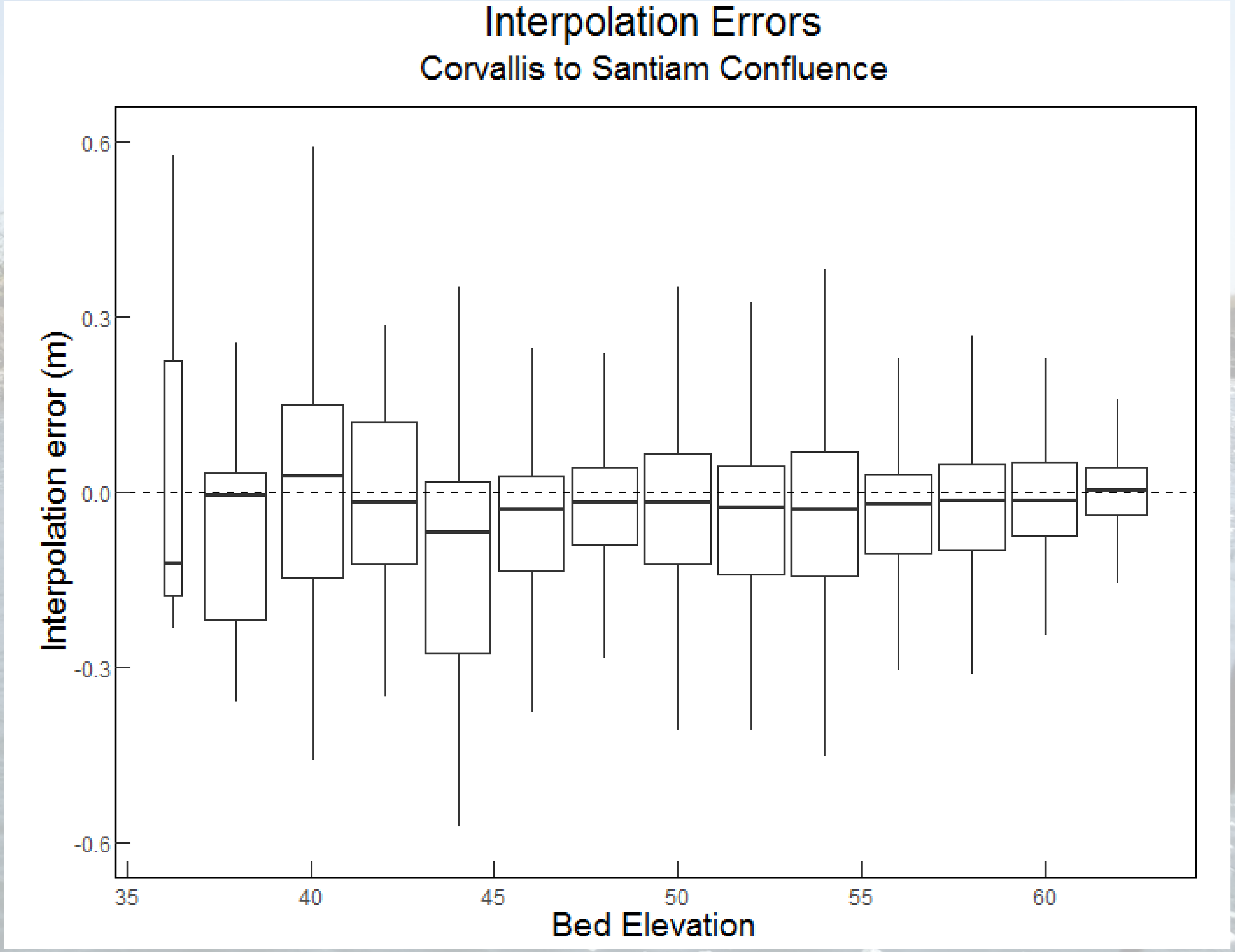
Withheld 10% of sonar-data to validate interpolation

Combined sonar and lidar data via Triangular Irregular Network (TIN)

Edited TIN to correct obvious interpolation errors

Rasterized TIN via a nearest neighbors approach

Compared raster (bathymetric) surface to withheld points for validation



Preliminary Results – subject to revision

Fusing lidar and sonar data

<u>Approach</u>

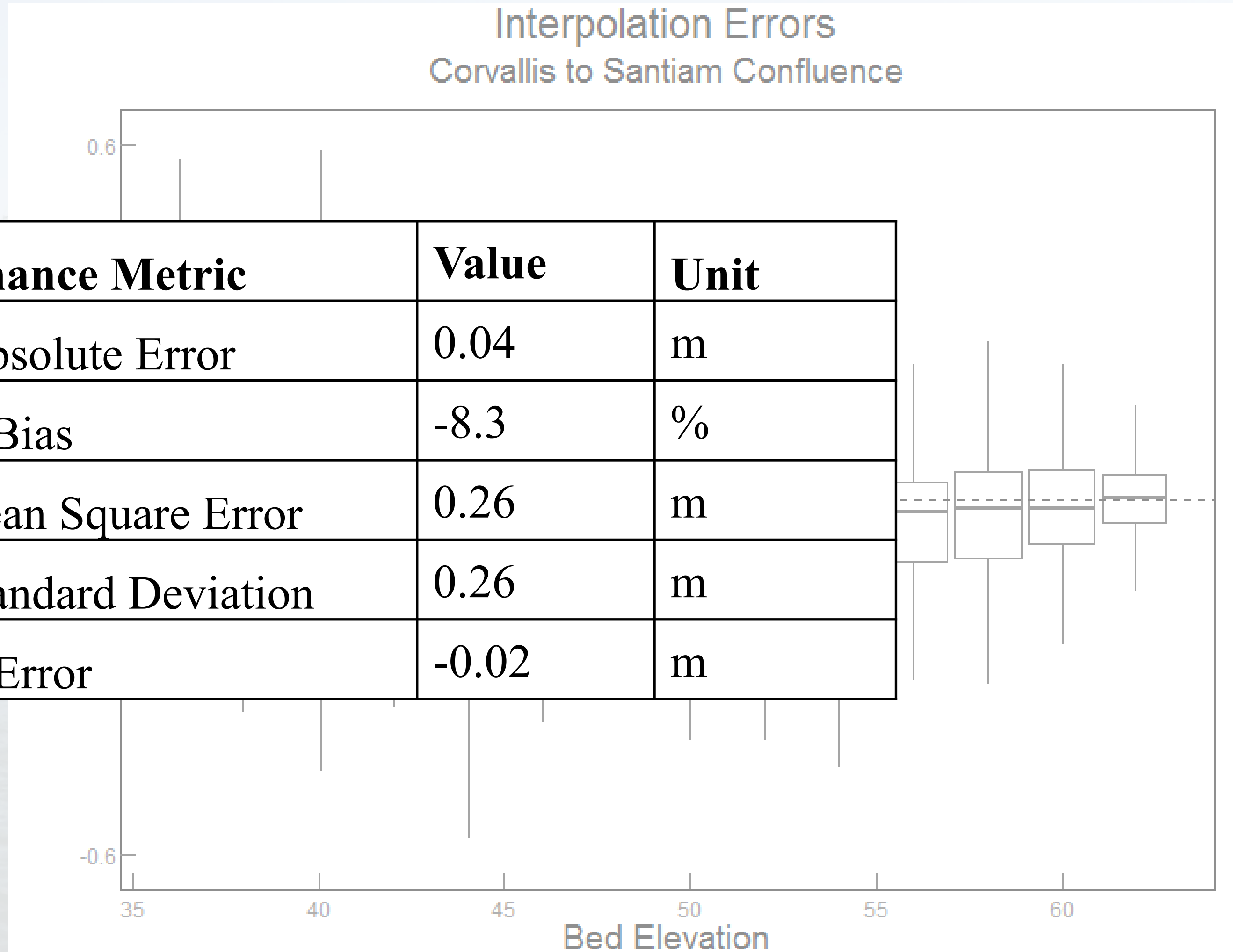
Withheld 10% of sonar-data to validate interpolation

Combined sonar and data via Triangular Ir Network (TIN)

Edited TIN to correct interpolation errors

Rasterized TIN via a neighbors approach

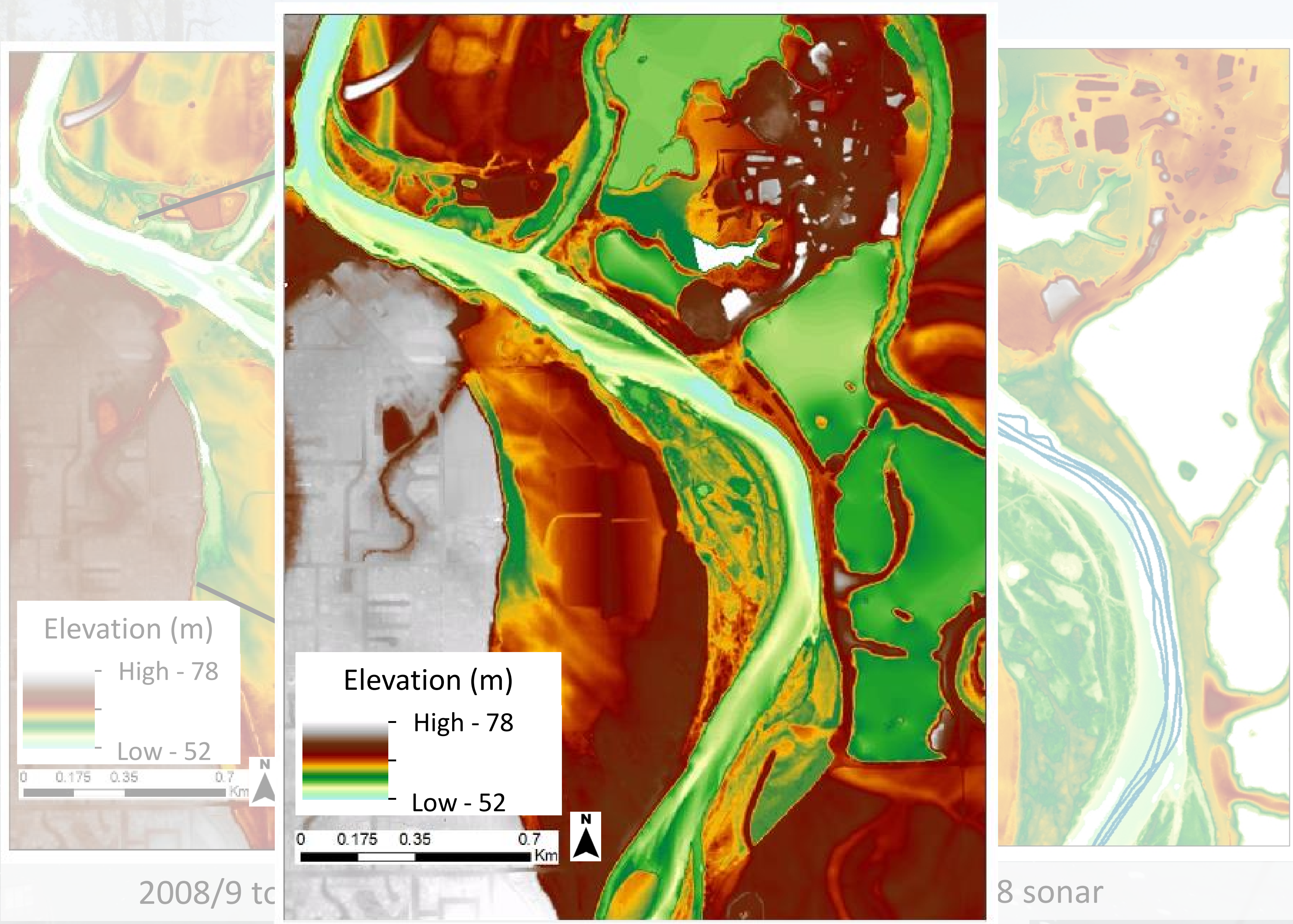
Compared raster (bathymetric) surface to withheld points for validation



Performance Metric	Value	Unit
Mean Absolute Error	0.04	m
Percent Bias	-8.3	%
Root Mean Square Error	0.26	m
Error Standard Deviation	0.26	m
Median Error	-0.02	m

USGS

Building blocks of hydraulic model



2008/9 to

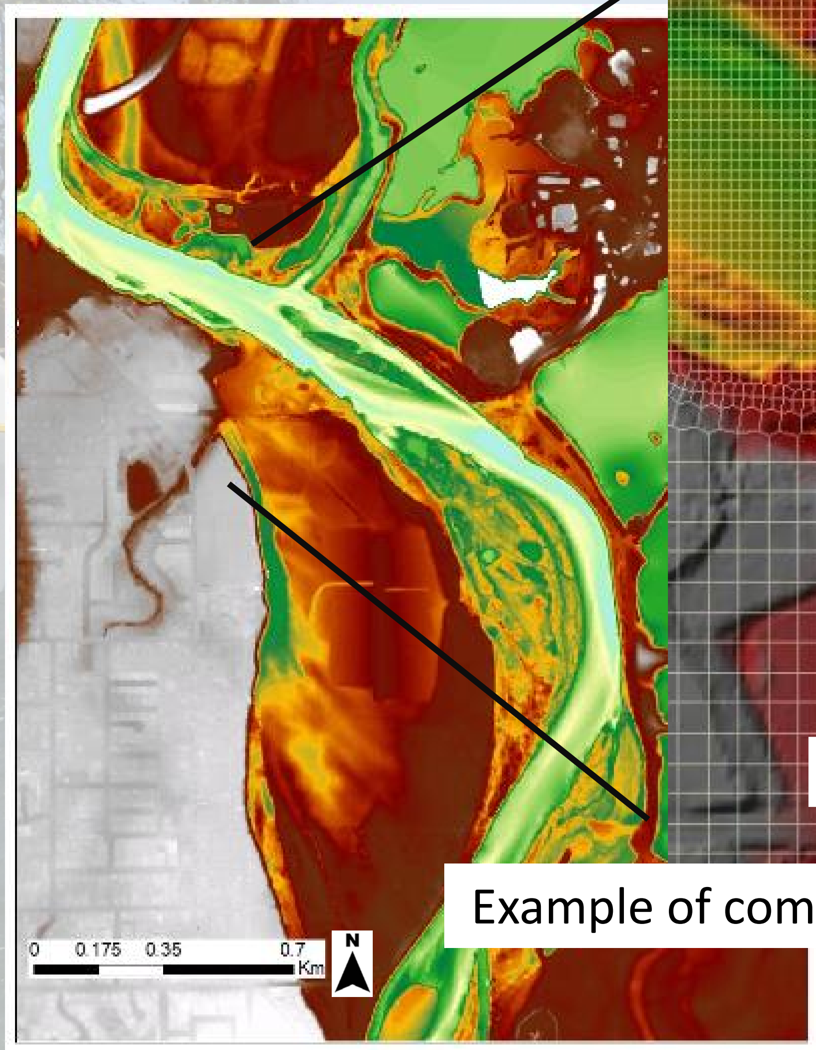
8 sonar

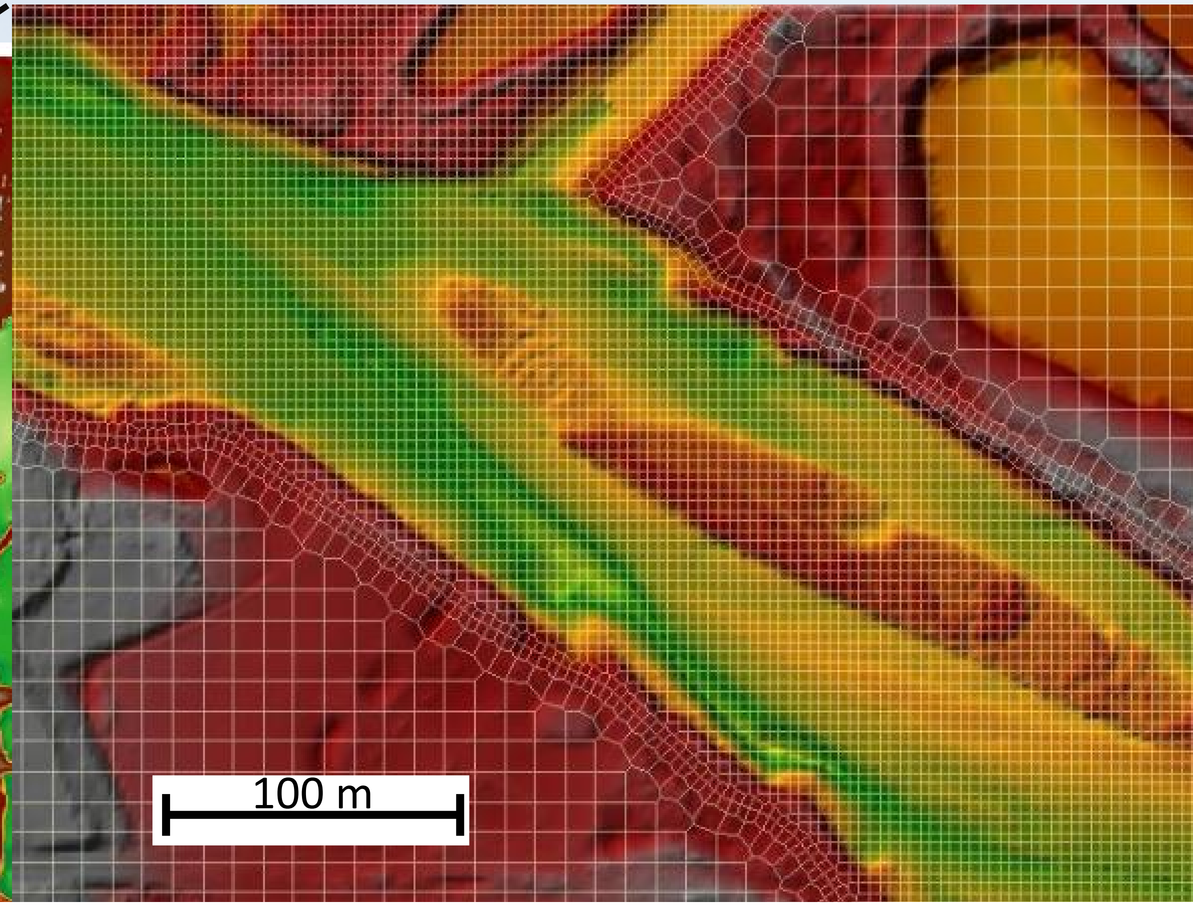
Seamless bathymetry/topography

Data source: QSI, 2017

Preliminary Results – subject to revision

Building blocks of hydraulic model

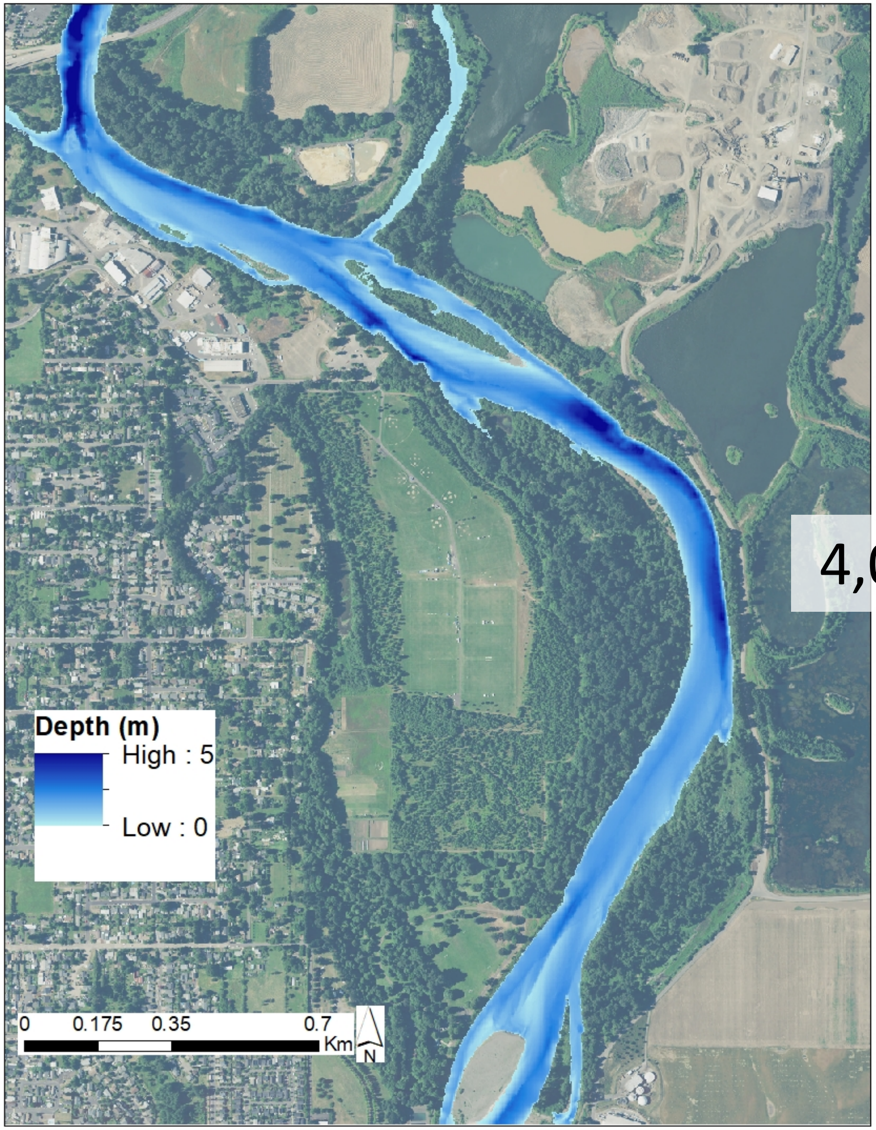




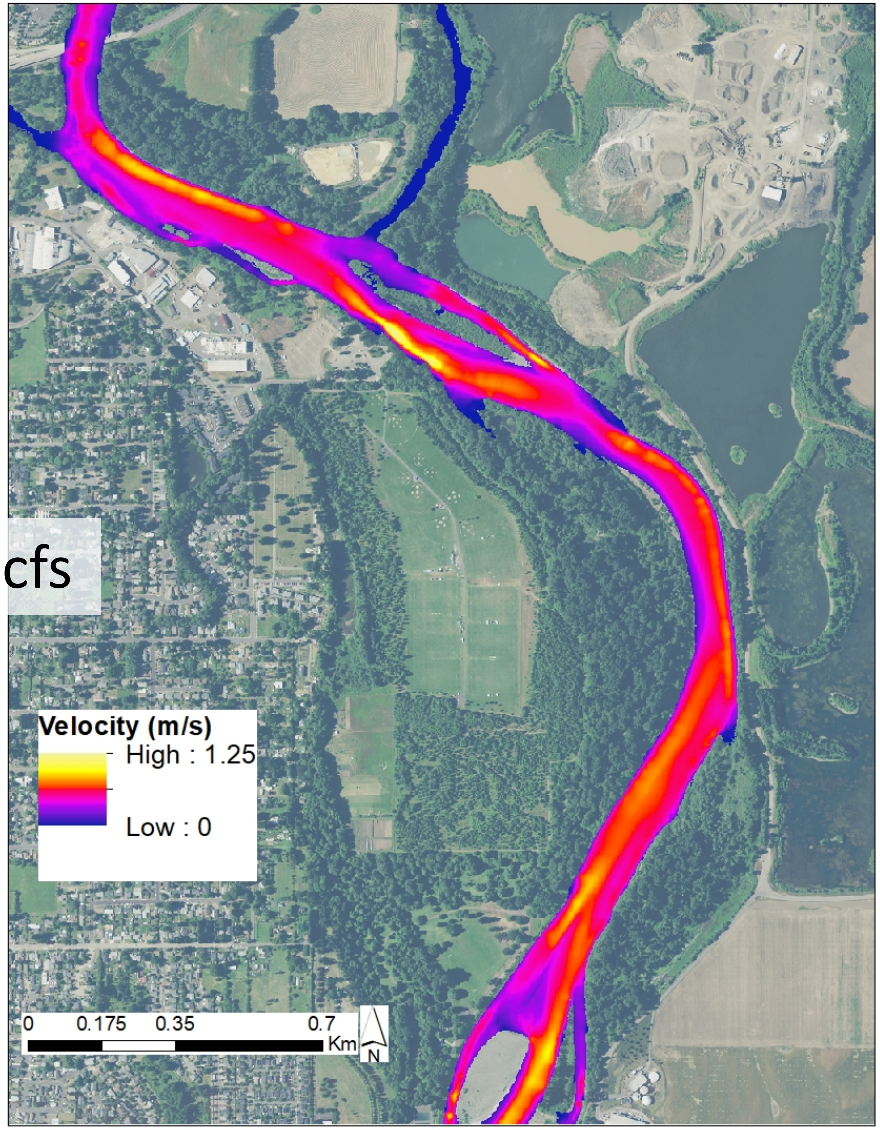
Example of computational mesh for two-dimensional hydraulics

Model platform: HEC-RAS 5.0.6

Hydraulic model outputs



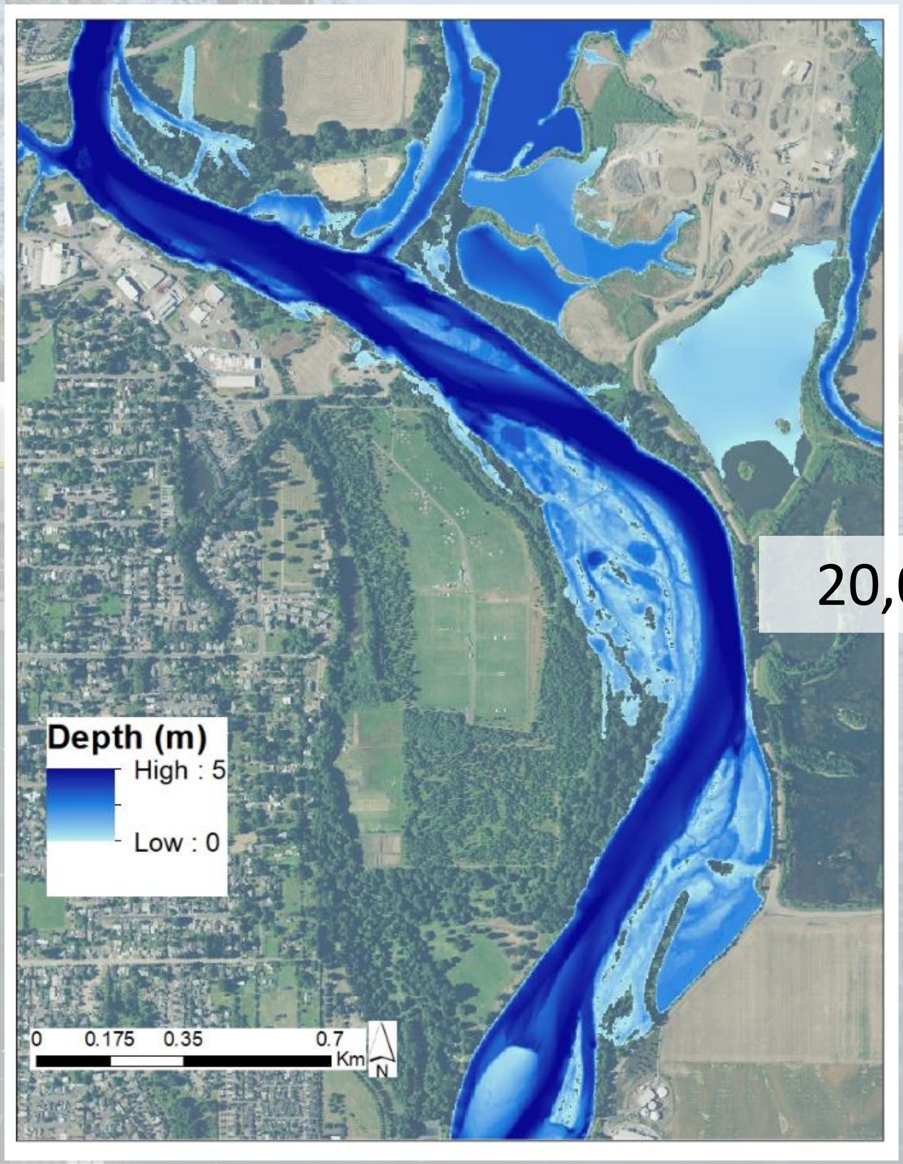
4,000 cfs



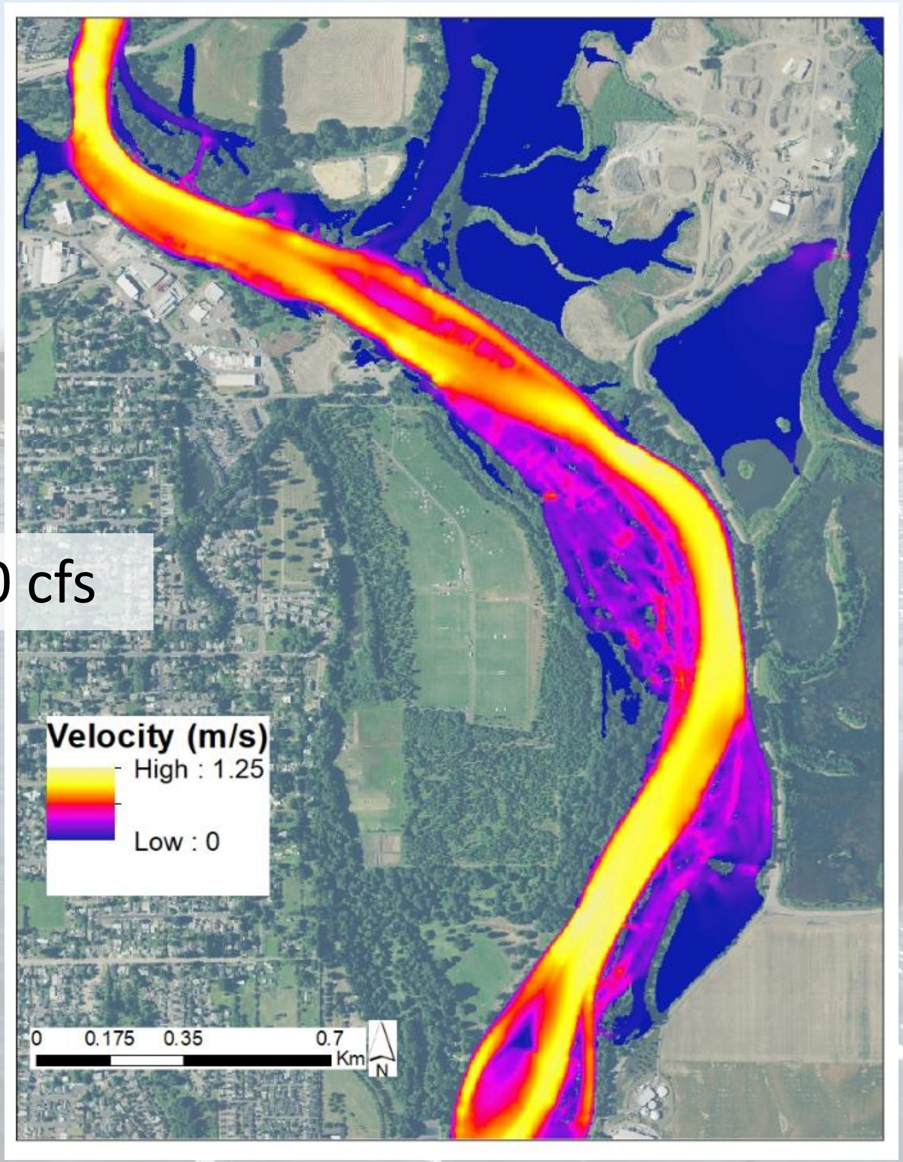
USGS

Preliminary Results – subject to revision

Hydraulic model outputs



20,000 cfs



USGS

Preliminary Results – subject to revision

Defining "useable" rearing habitat

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

USGS

Defining “useable” rearing habitat

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

Species	Size Class	Criteria	Narrow	Median	Broad
Chinook salmon	Presmolt (>60mm)	Depth (m)	0.05-0.7	0.15-3.5	0.15-Inf
		Velocity (m/s)	0-0.38	0-0.5	0-0.91
		Bed Slope (degrees)	<40	<55	Any
Chinook salmon	Fry (<60mm)	Depth (m)	0.05-0.6	0.05-1.1	0.05-1.5
		Velocity (m/s)	0-0.15	0-0.4	0-.45
		Bed Slope (degrees)	<40	<55	Any
Steelhead	Presmolt (>60mm)	Depth (m)	0.15-1	0.15-1	0.15-Inf
		Velocity (m/s)	0-0.53	0-1	0-1.1
		Bed Slope			

Data source: (Peterson and others, in progress)

2 species X 2 sizes X 4 habitat definitions X 100+ miles of river = LOTS of data to churn through and summarize

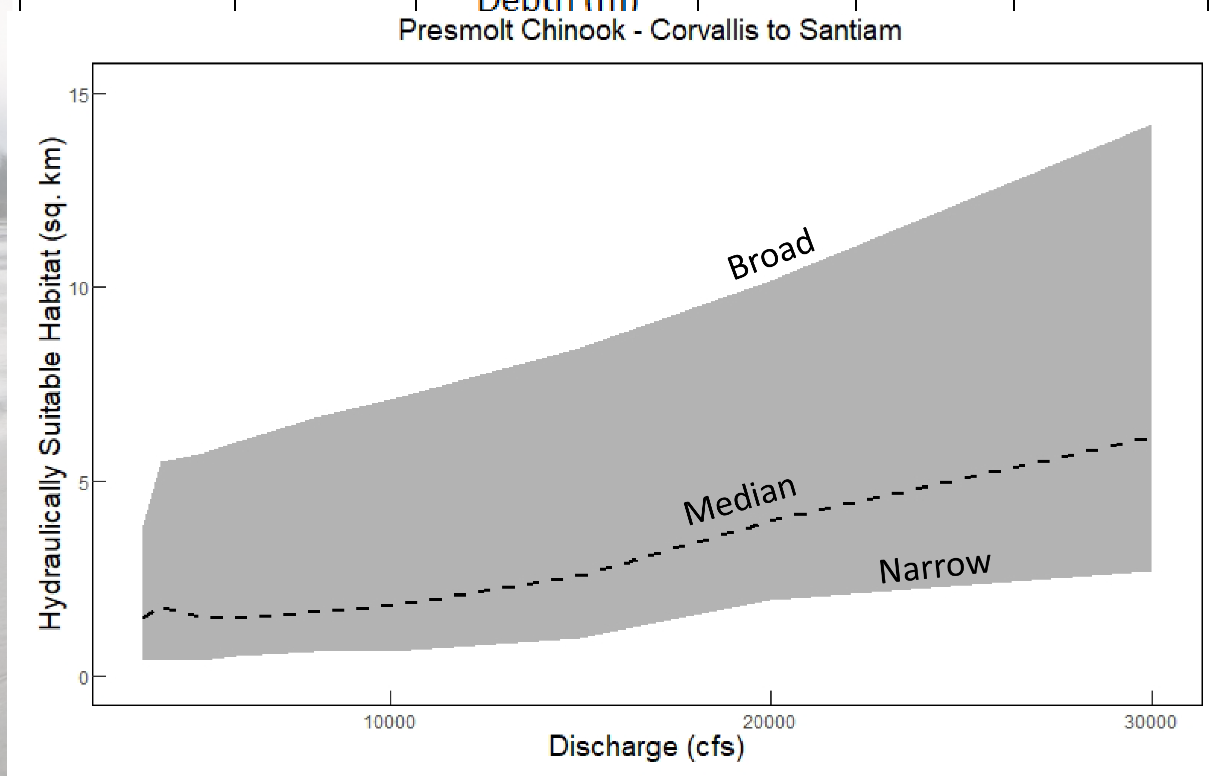
USGS

Defining "useable" rearing habitat

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

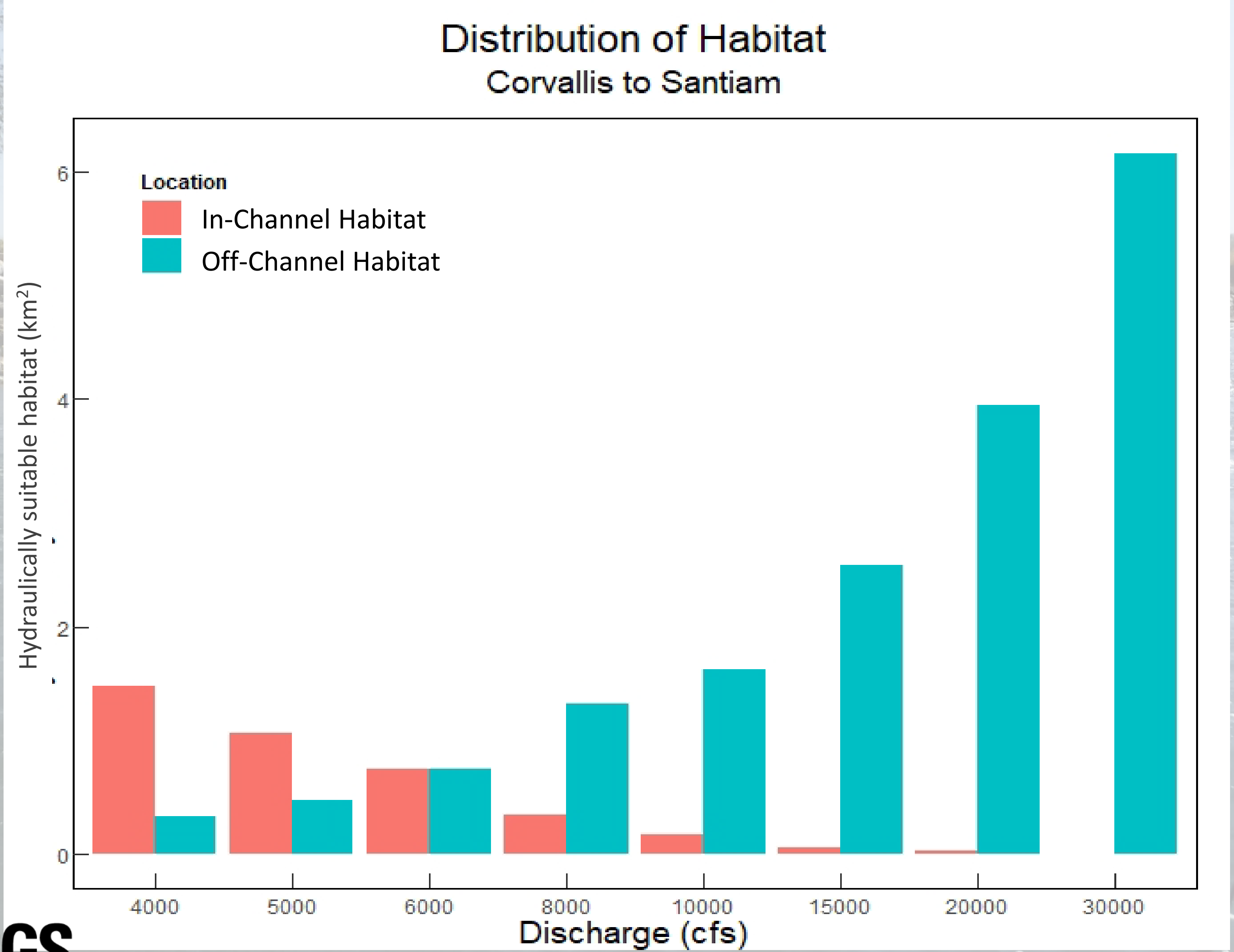
Species	Size Class	Criteria	Narrow	Median	Broad
Chinook salmon	Presmolt (>60mm)	Depth (m)	0.05-0.7	0.15-3.5	0.15-Inf
		Velocity (m/s)	0-0.38	0-0.5	0-0.91
		Bed Slope (degrees)	<40	<55	Any
		Depth (m)	0.05-0.6	0.05-1.1	0.05-1.5

Data source: (Peterson and others, in progress)



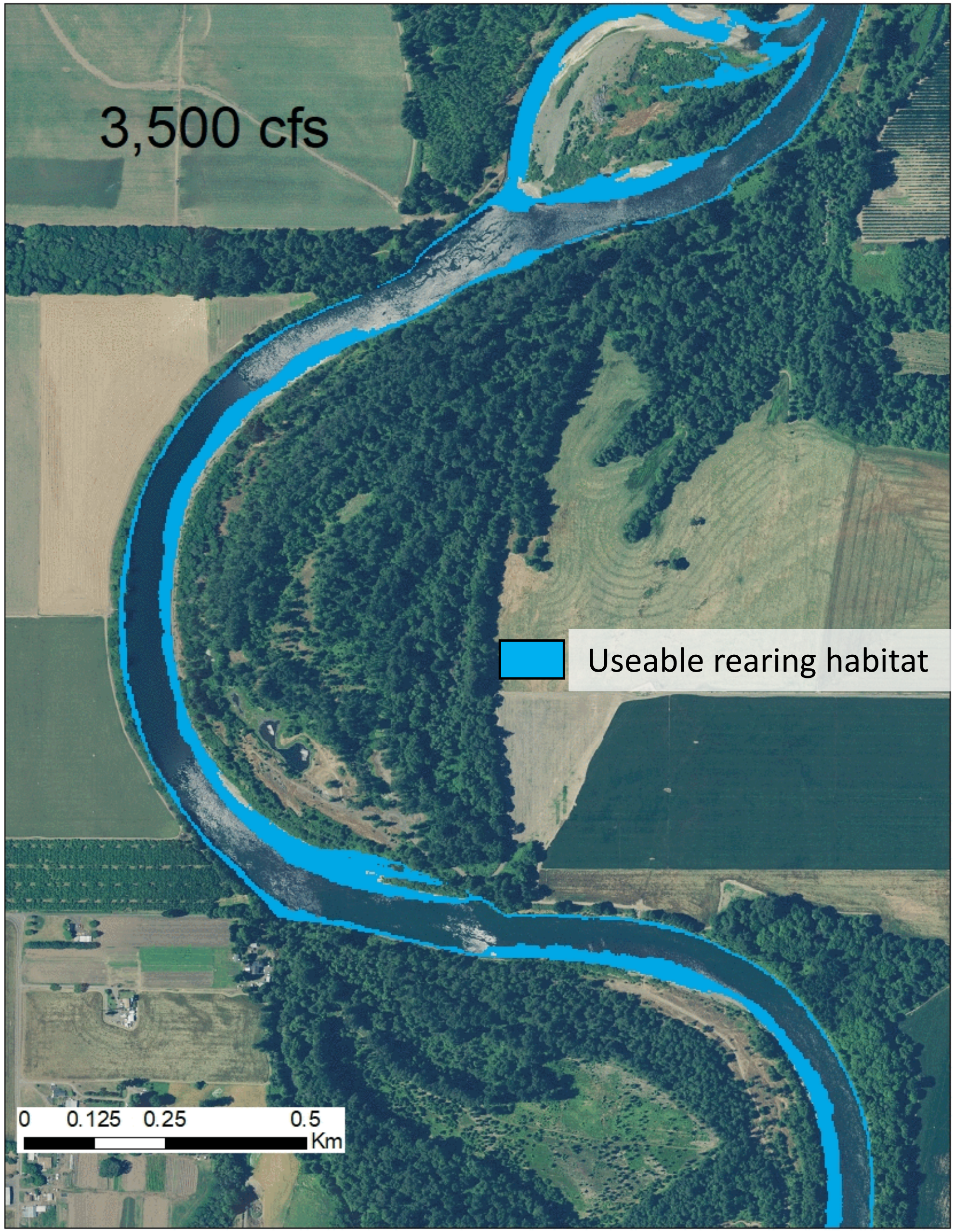
USGS

Comparing habitat availability in main channel and off-channel areas for different flows



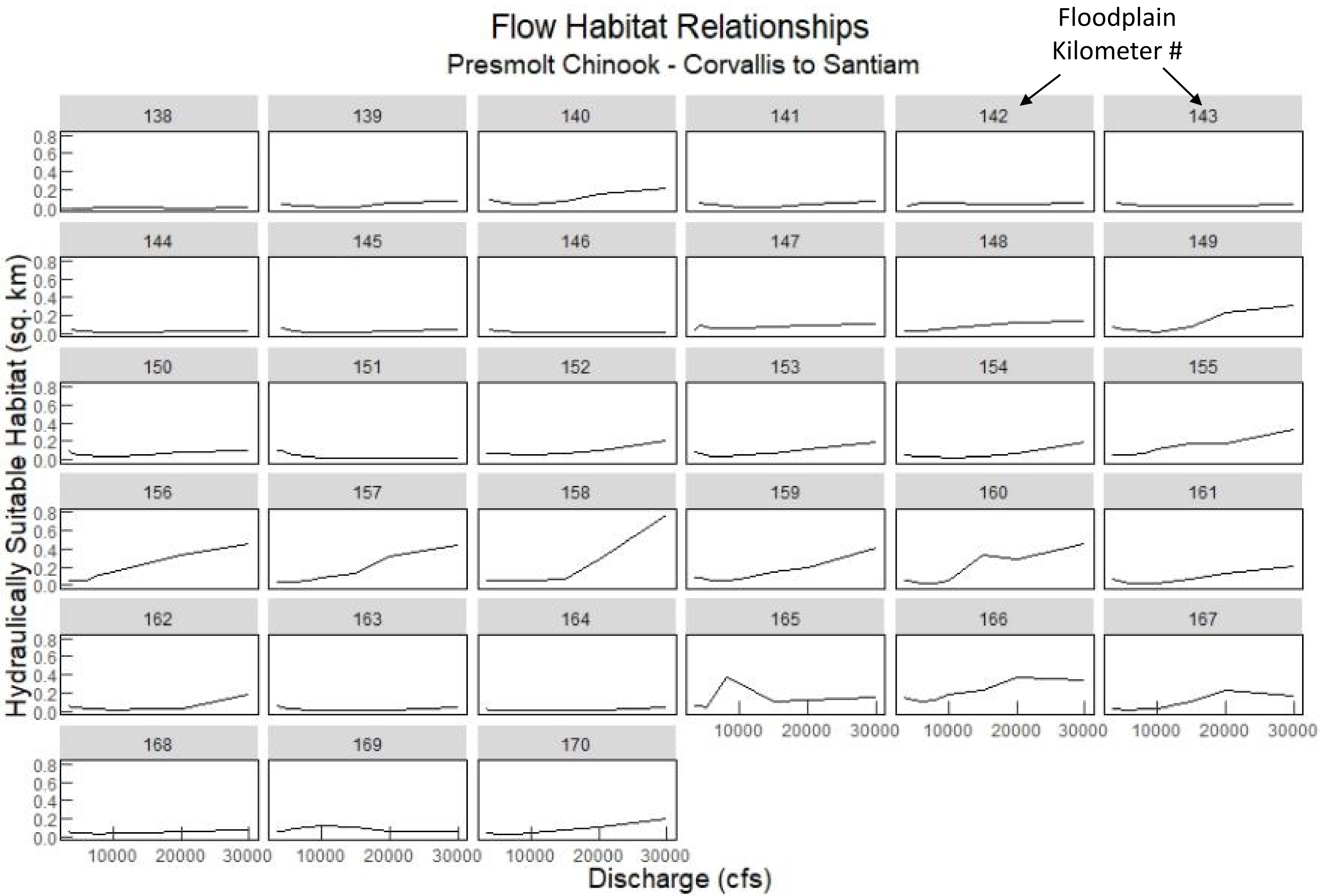
USGS

Preliminary Results – subject to revision



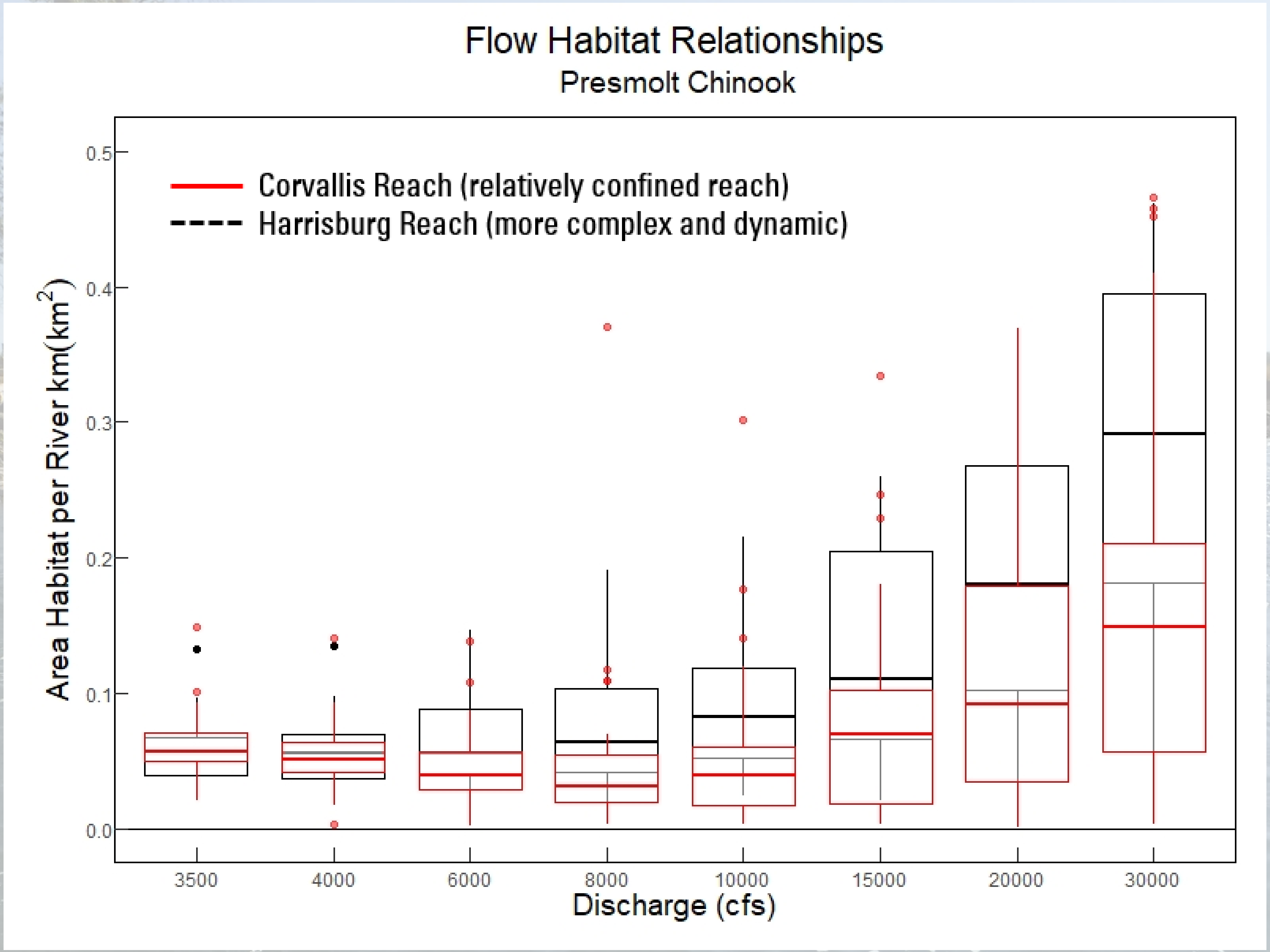
USGS

Preliminary Results – subject to revision



USGS

Preliminary Results – subject to revision



USGS

Preliminary Results – subject to revision

Preliminary results from hydraulic and habitat analysis

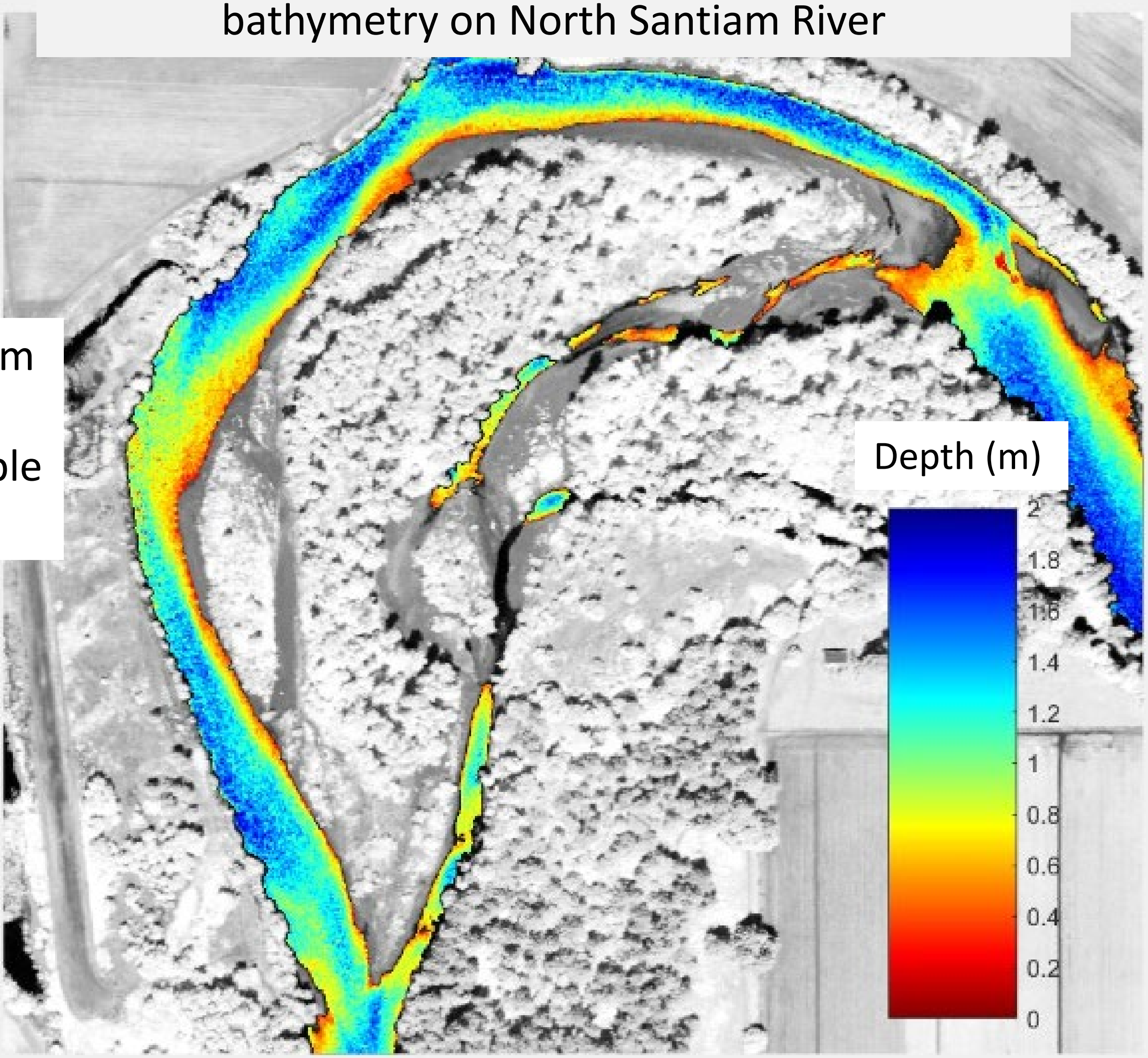
- Rearing habitat availability for spring Chinook varies substantially along Willamette River reflecting variation in channel morphology
- Increased discharge does not necessarily result in more physical rearing habitat
  - Sensitivity between flow and habitat availability varies spatially
  - During low flows, more flow may result in a reduction in physical habitat in certain reaches
- Sensitivity to habitat criteria varies spatially and for different lifestages
  - Highlights the importance of sensitivity analysis

Next Steps

Expanding into North Santiam and McKenzie Rivers

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

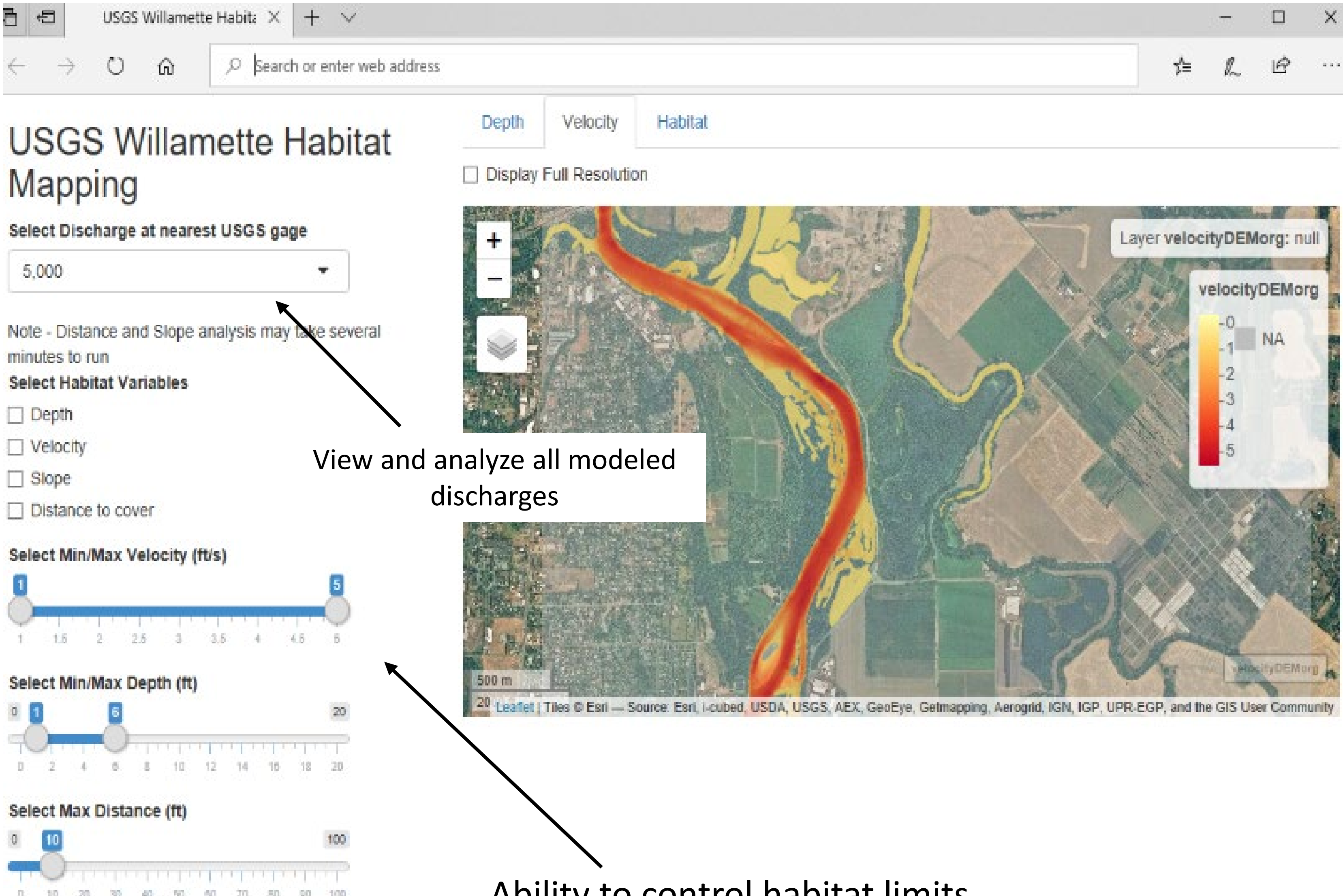
Bathymetry is derived from spectral and hydraulic analysis of publicly available imagery (NAIP)



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

Bathymetry

- Sonar point cloud (anticipated release: Spring, 2019)
- Fused lidar/sonar DEM (anticipated release: Fall, 2019)

Hydraulic models

- Development/calibration continuing through Summer 2019
  - Anticipated release: Fall/Winter, 2019

Habitat models

- Preliminary results to be included in growth, survival, and movement models under development
- Anticipated release: Fall/Winter 2019

Tributary bathymetry and models

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

Questions

jameswhite@usgs.gov

Many thanks to…..

USGS ORWSC: Laurel Stratton-Garvin, Stewart Rounds, Adam Stonewall, Greg Lind

Oregon State University: Tyrell DeWeber

USACE: Rich Piaskowski, Jacob Mcdonald, Greg Taylor, Jeff Balantine, Norman Buccola

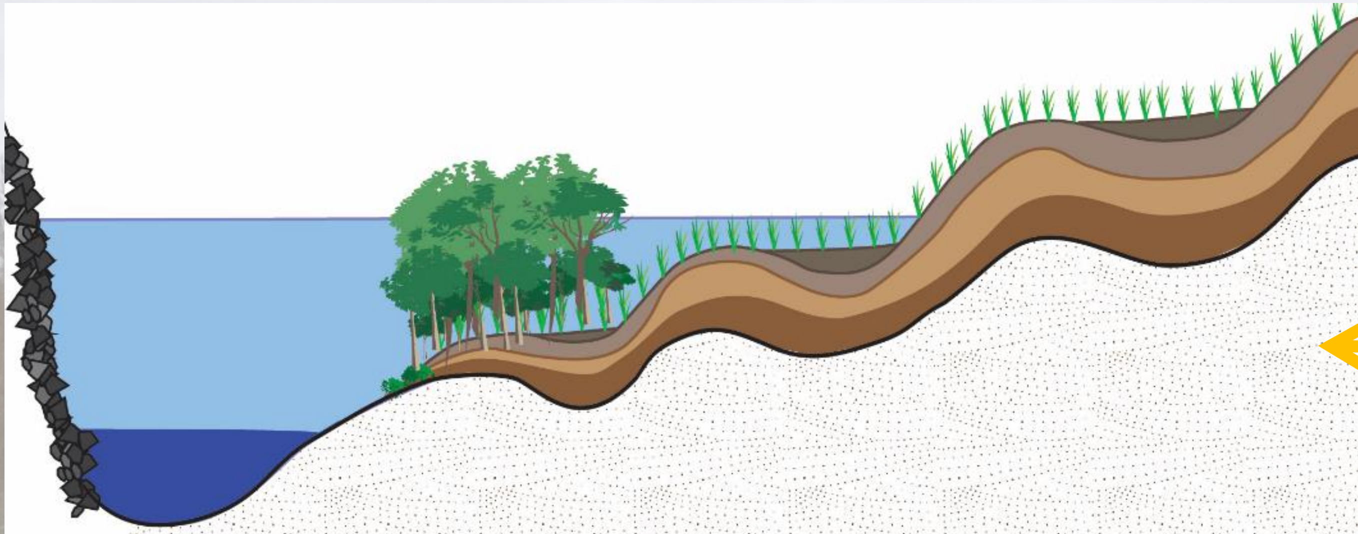
NOAA Fisheries: Anne Mullan, Diana Dishman

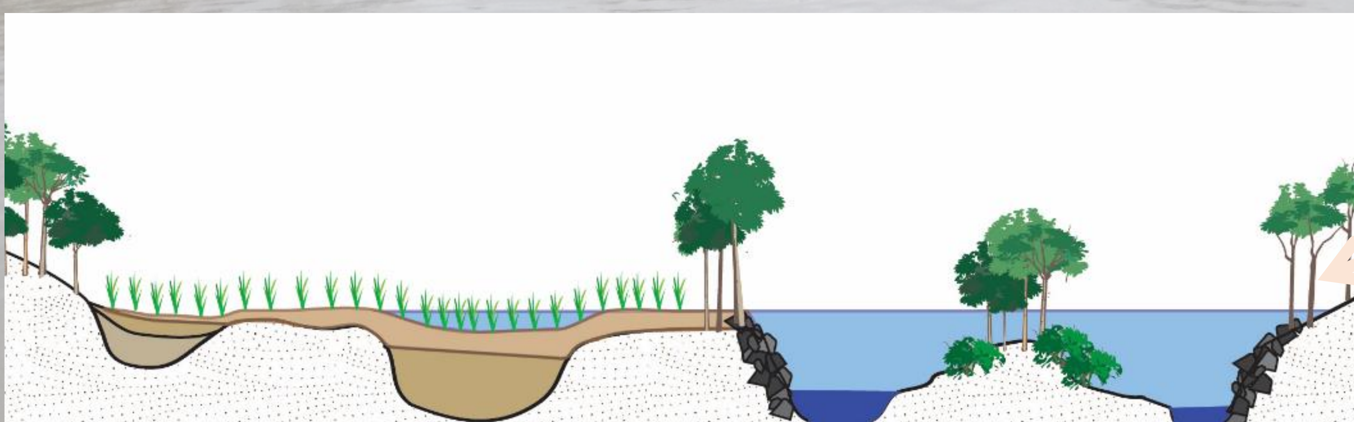
ODFW: Luke Whitman, Brian Bangs

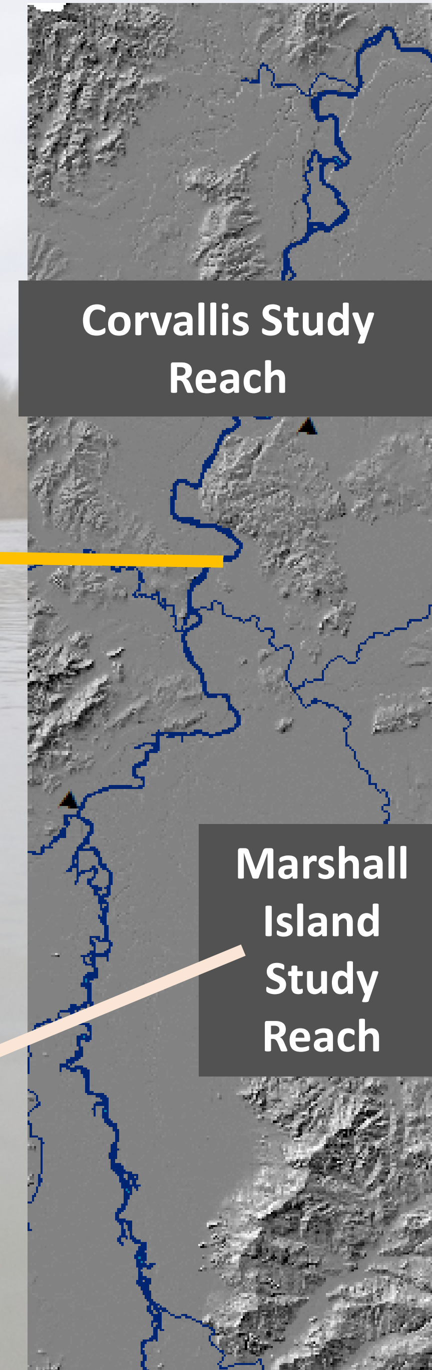
USGS WFRC: Toby Kock, Russ Perry, Gabe Hansen

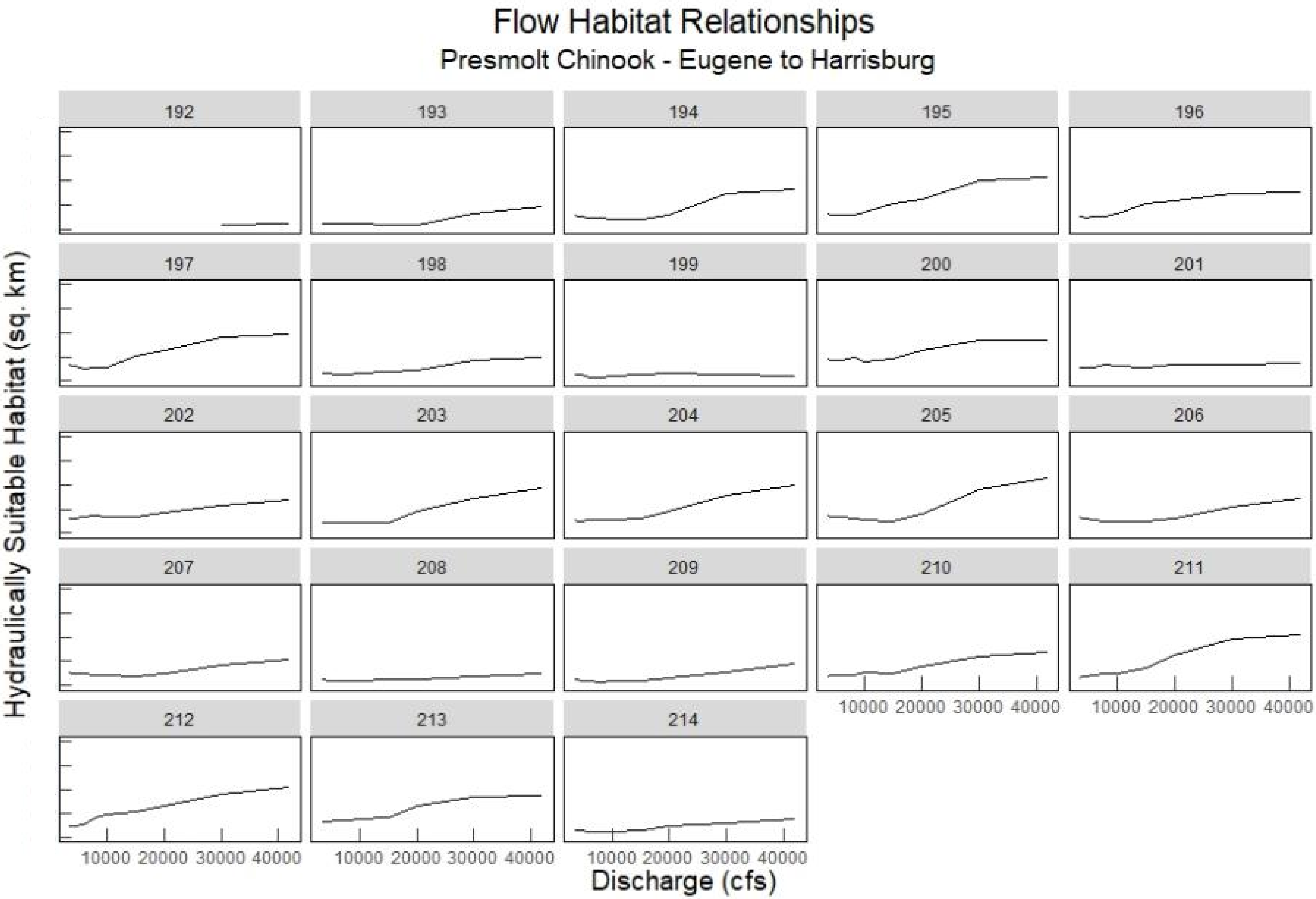
Funding provided by US Army Corps of Engineers

EXTRA SLIDES



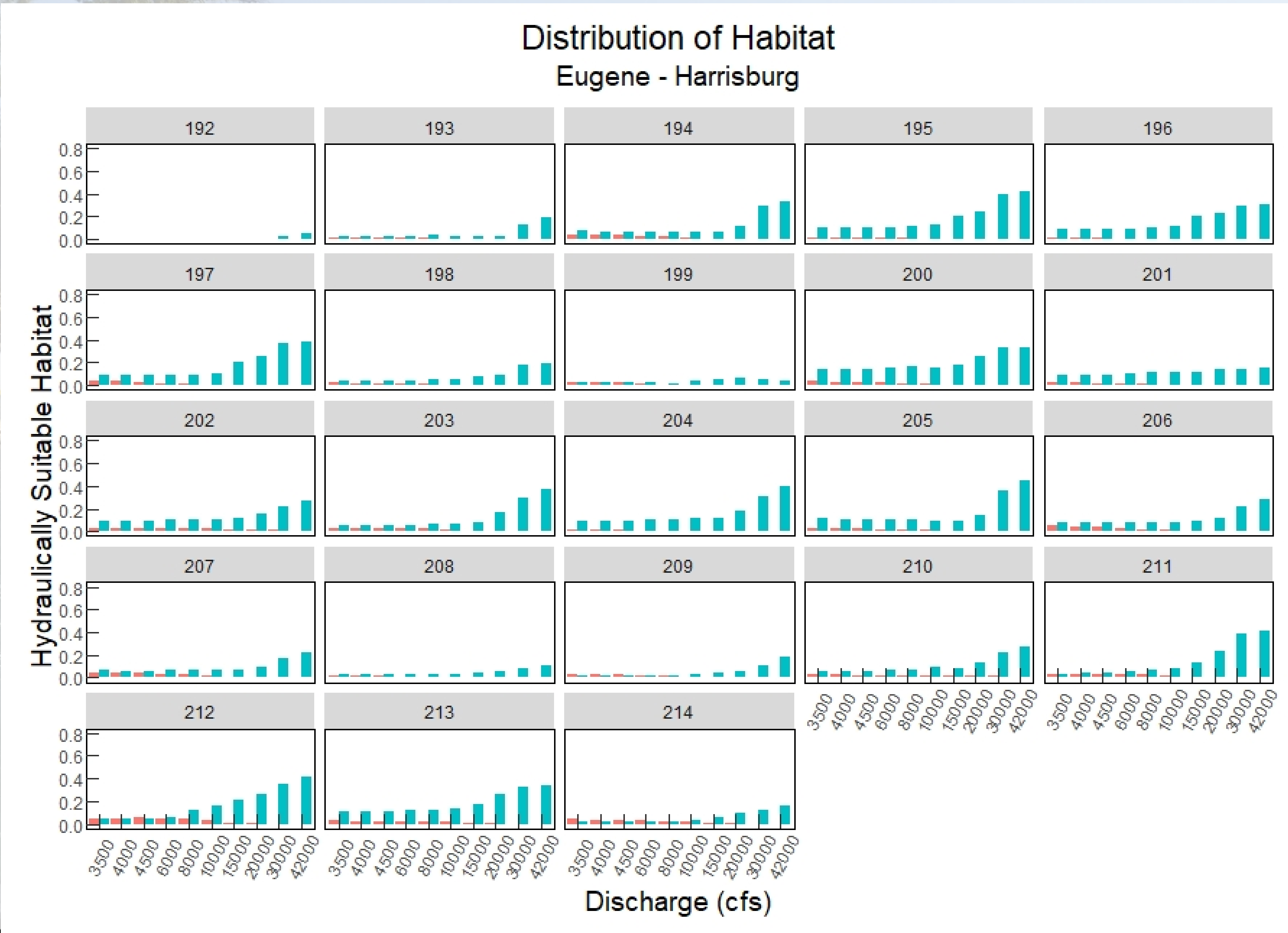



Corvallis Study Reach
Marshall Island Study Reach

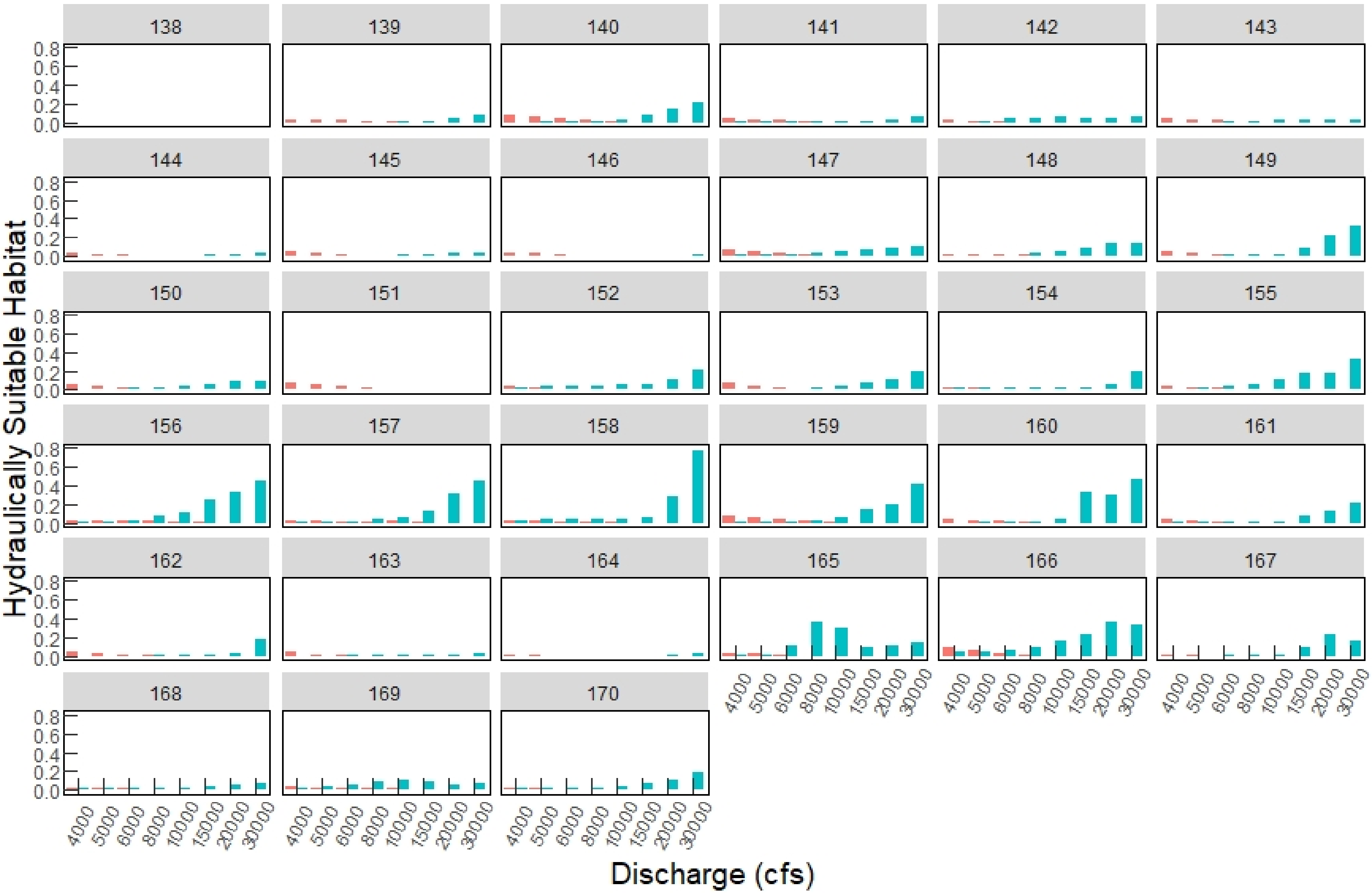


USGS

Preliminary Results – subject to revision


Distribution of Habitat
Eugene - Harrisburg
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
Hydraulically Suitable Habitat
0.0
0.2
0.4
0.6
0.8
3500
4000
4500
6000
8000
10000
15000
20000
30000
42000
Discharge (cfs)

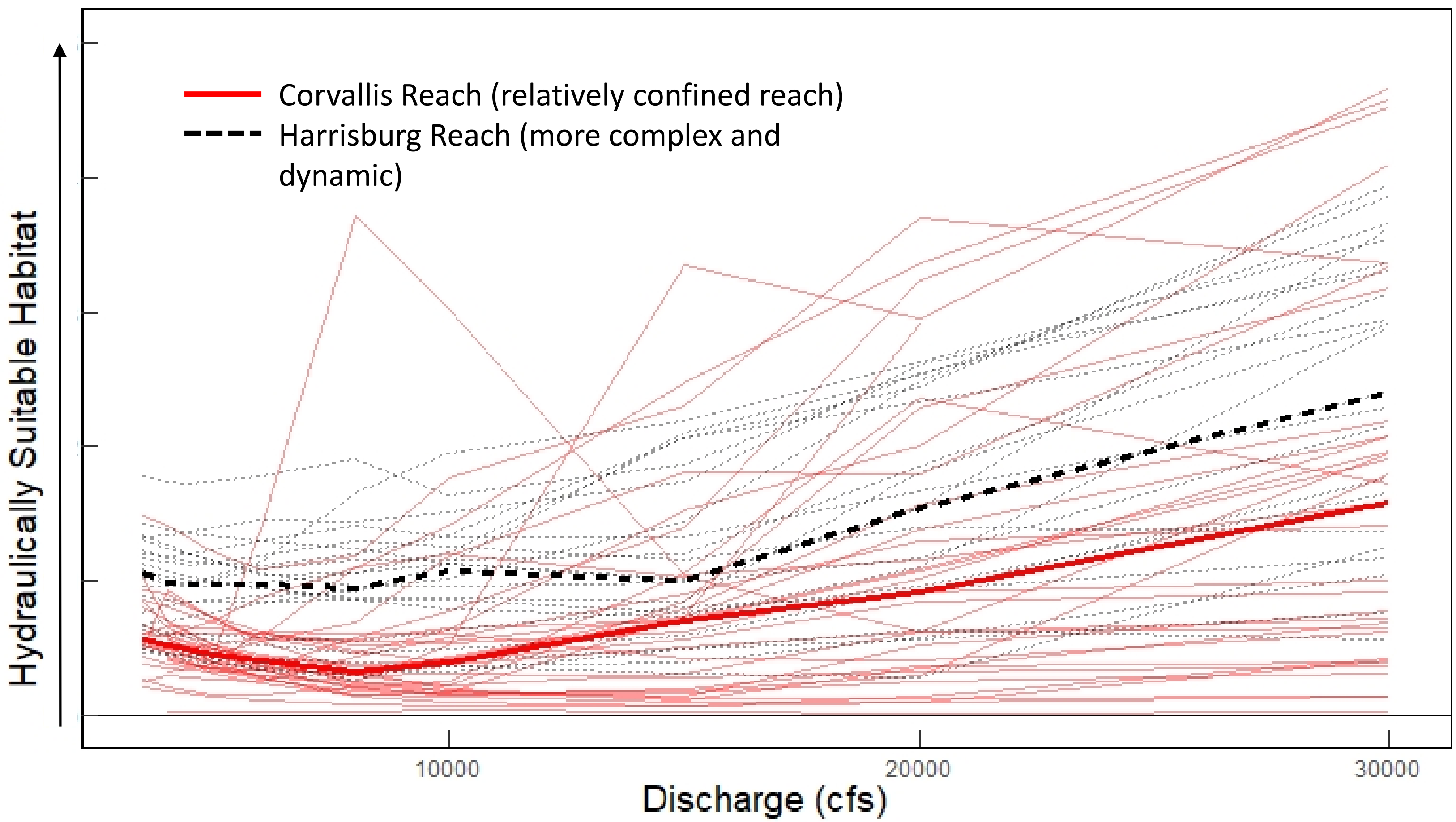
Distribution of Habitat



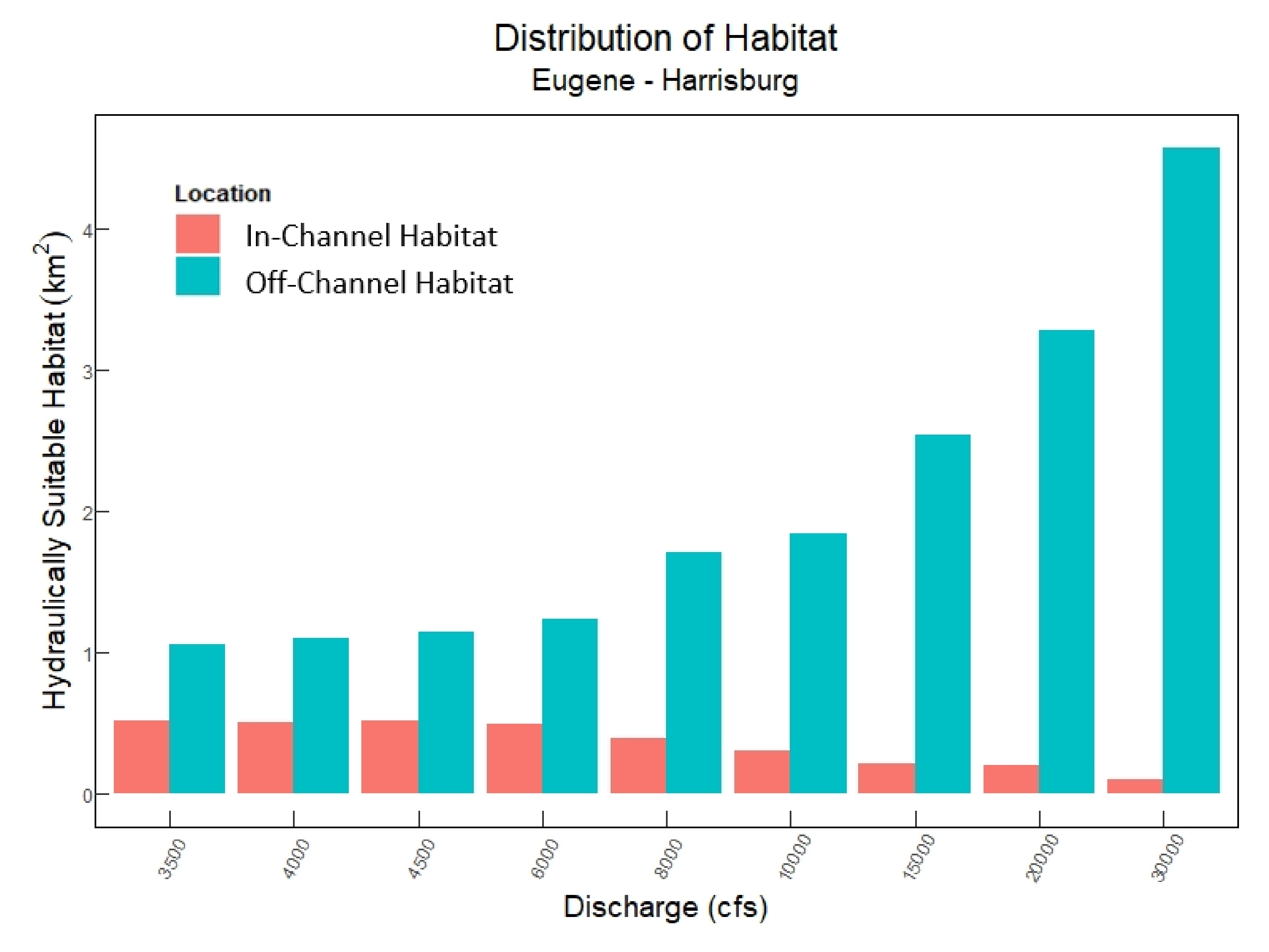
Preliminary Results – subject to revision

Flow Habitat Relationships

Presmolt Chinook - All



Comparing habitat availability in main channel and off-channel areas for different flows



USGS

Preliminary Results – subject to revision

Approach

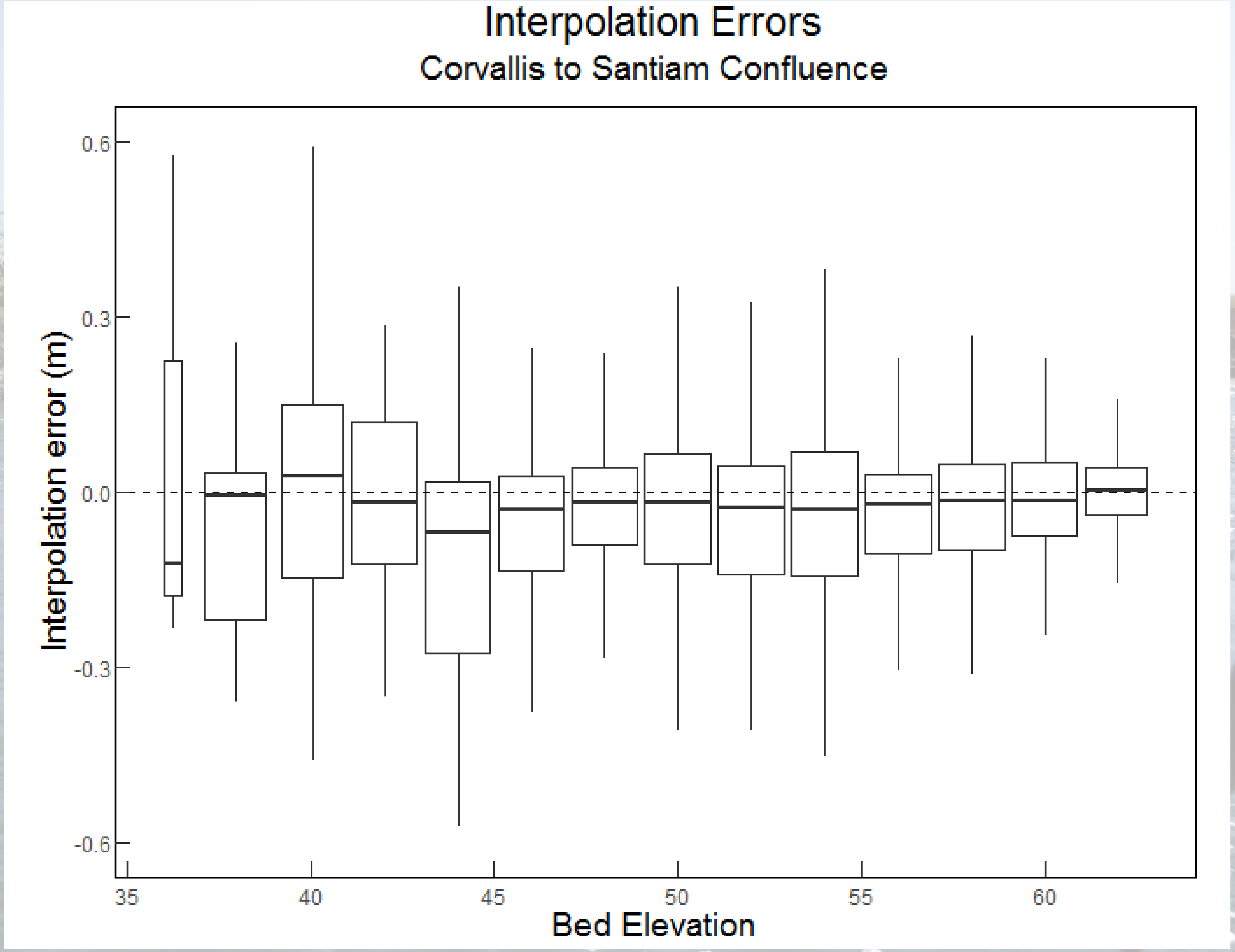
Withheld 10% of sonar-data to validate interpolation

Combined sonar and lidar data via Triangular Irregular Network (TIN)

Edited TIN to correct obvious interpolation errors

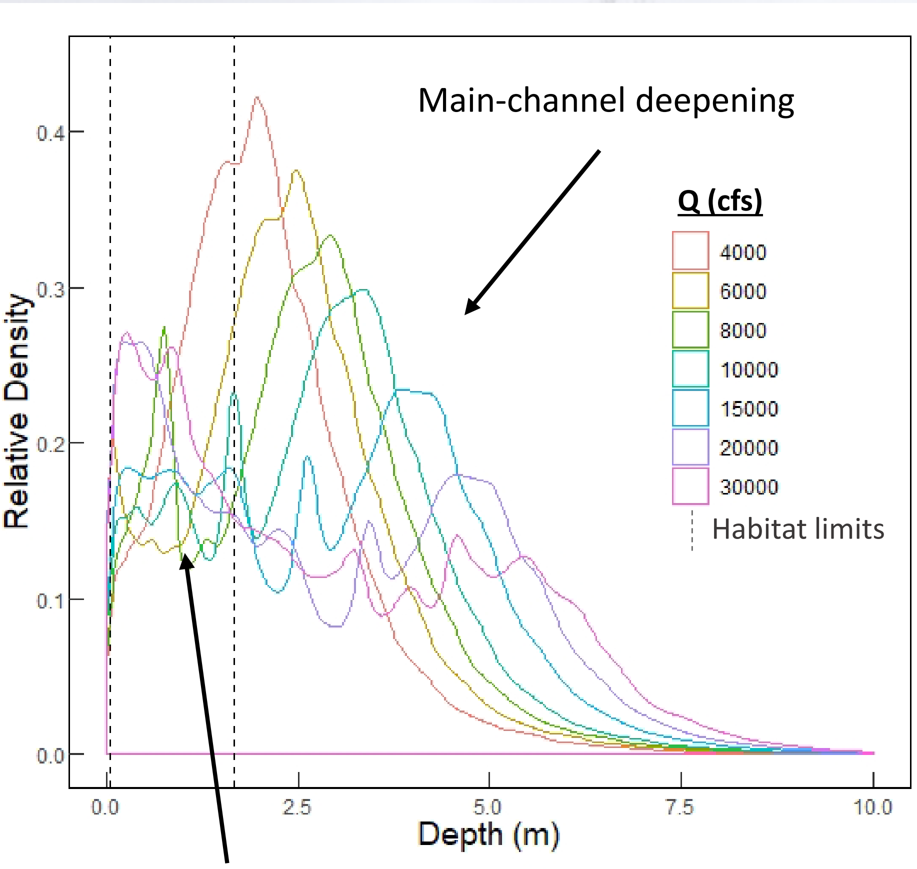
Rasterized TIN via a nearest neighbors approach

Compared raster (bathymetric) surface to withheld points for validation



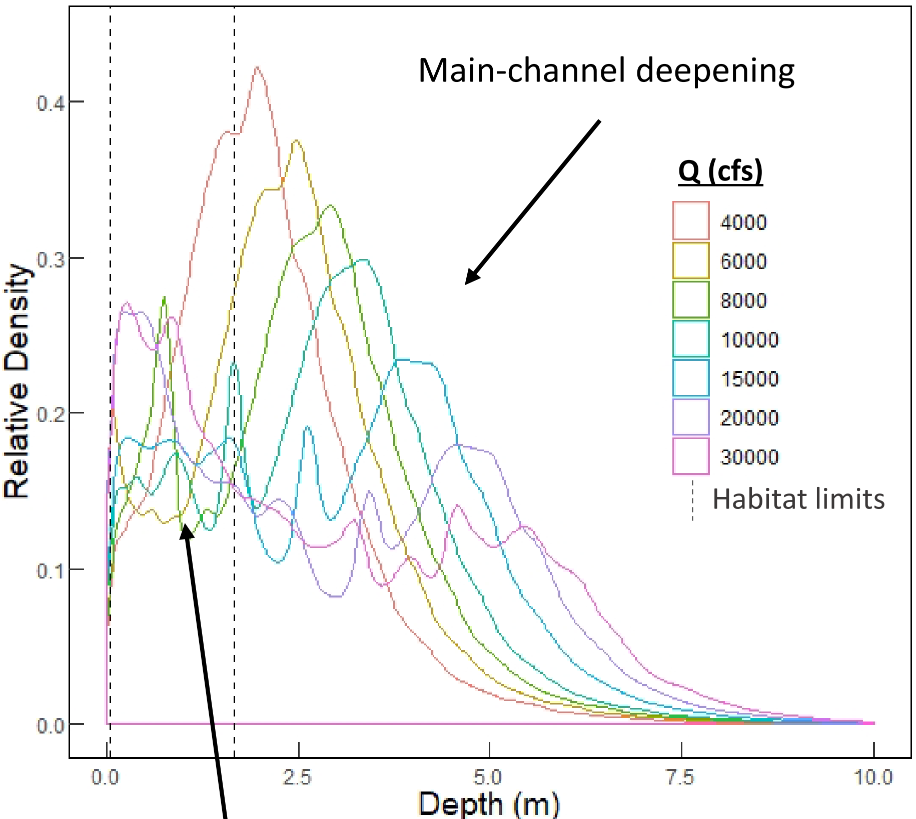
USGS

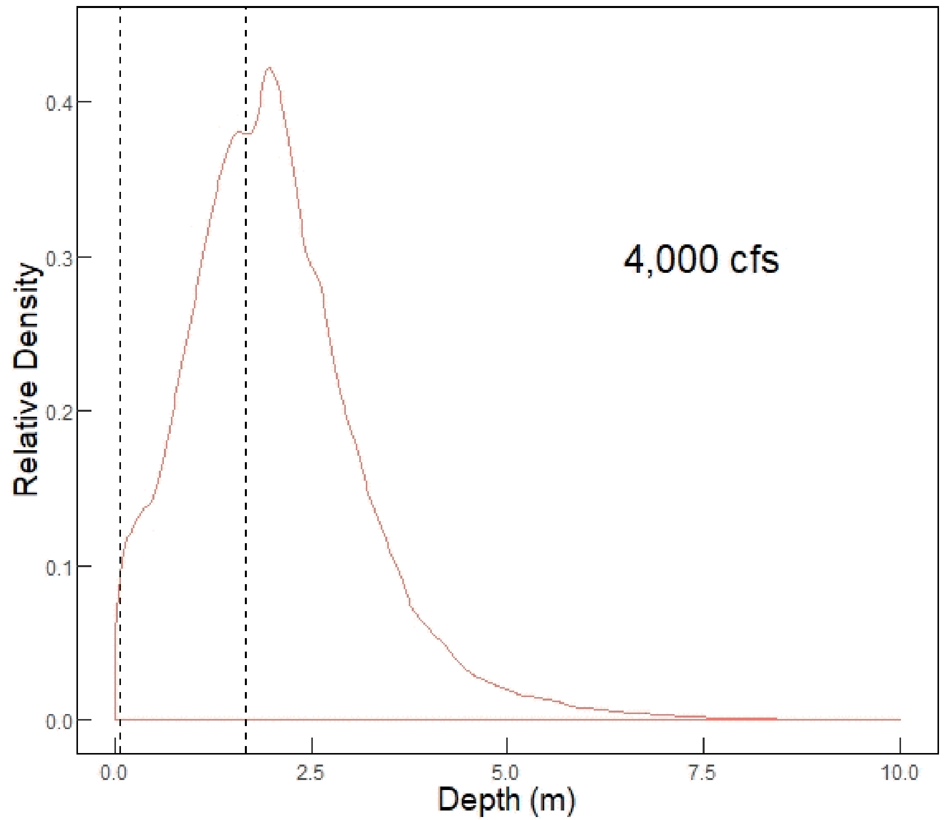
Preliminary Results – subject to revision



Increasing off-channel (shallow) inundation and depth diversity

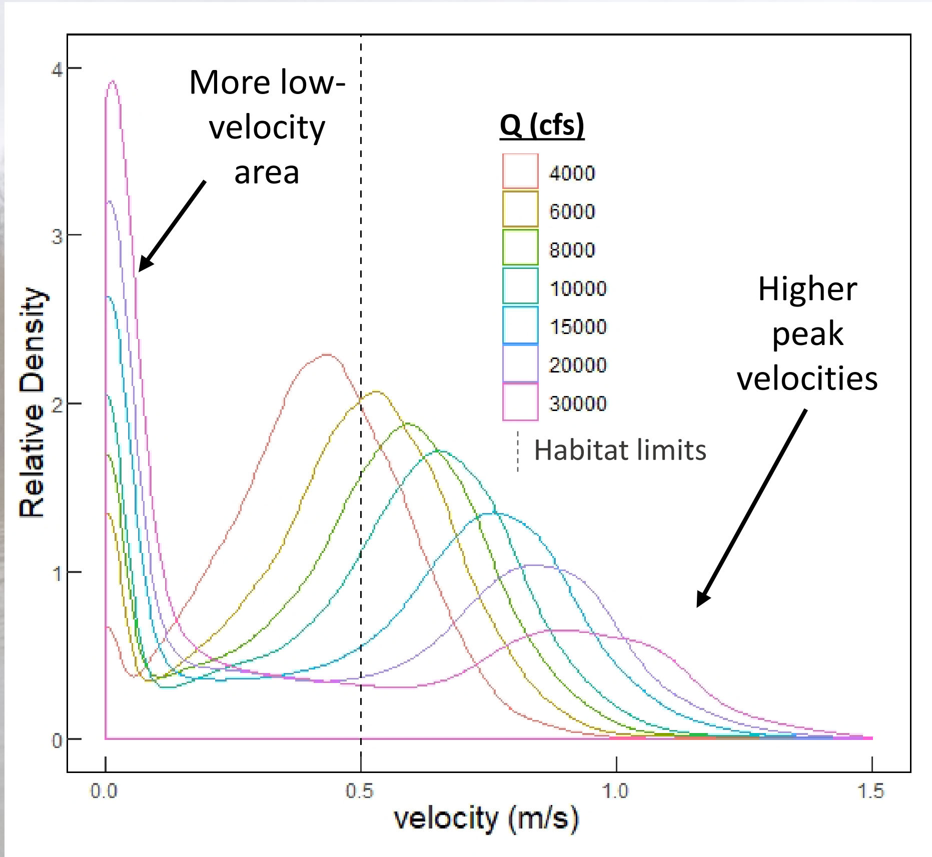
USGS



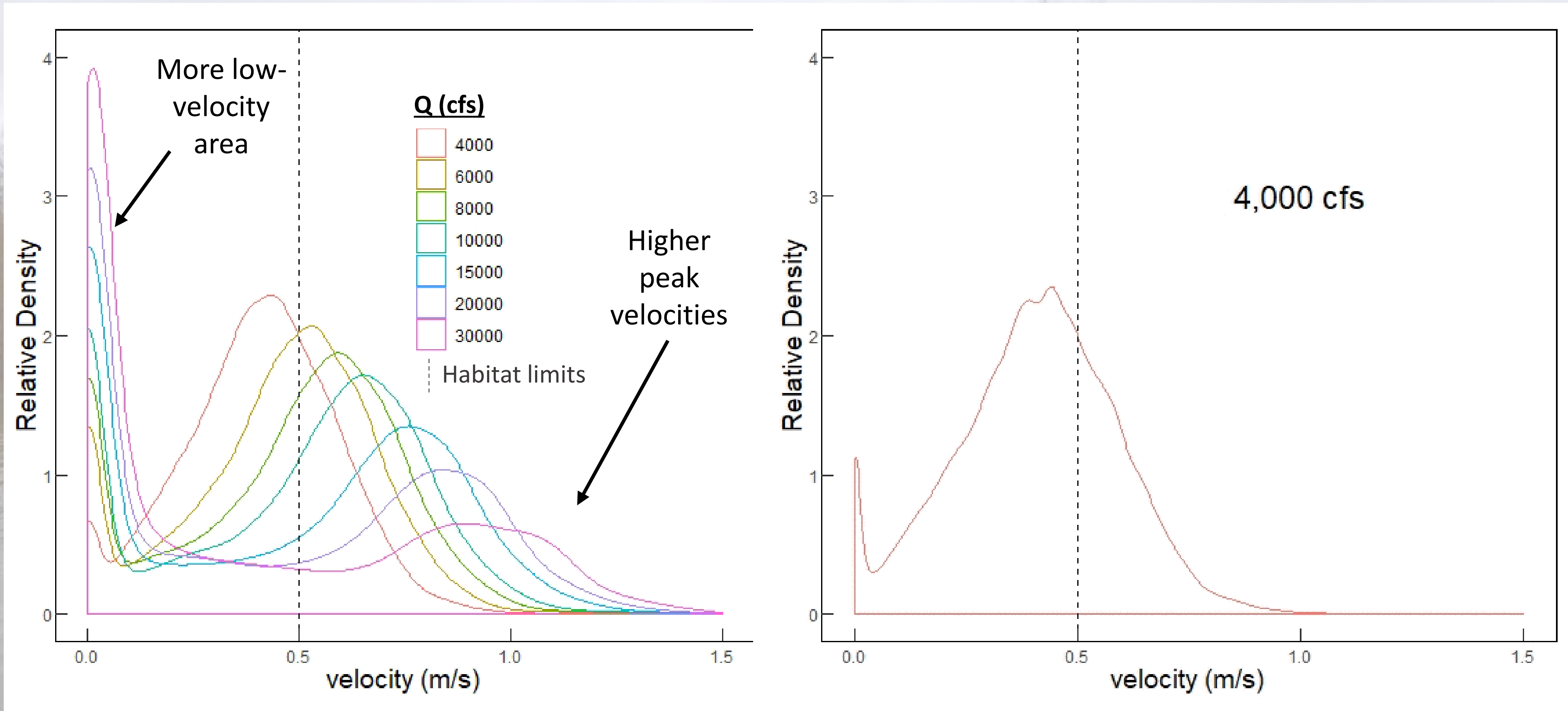


Increasing off-channel (shallow)
inundation and depth diversity

Preliminary Results – subject to revision

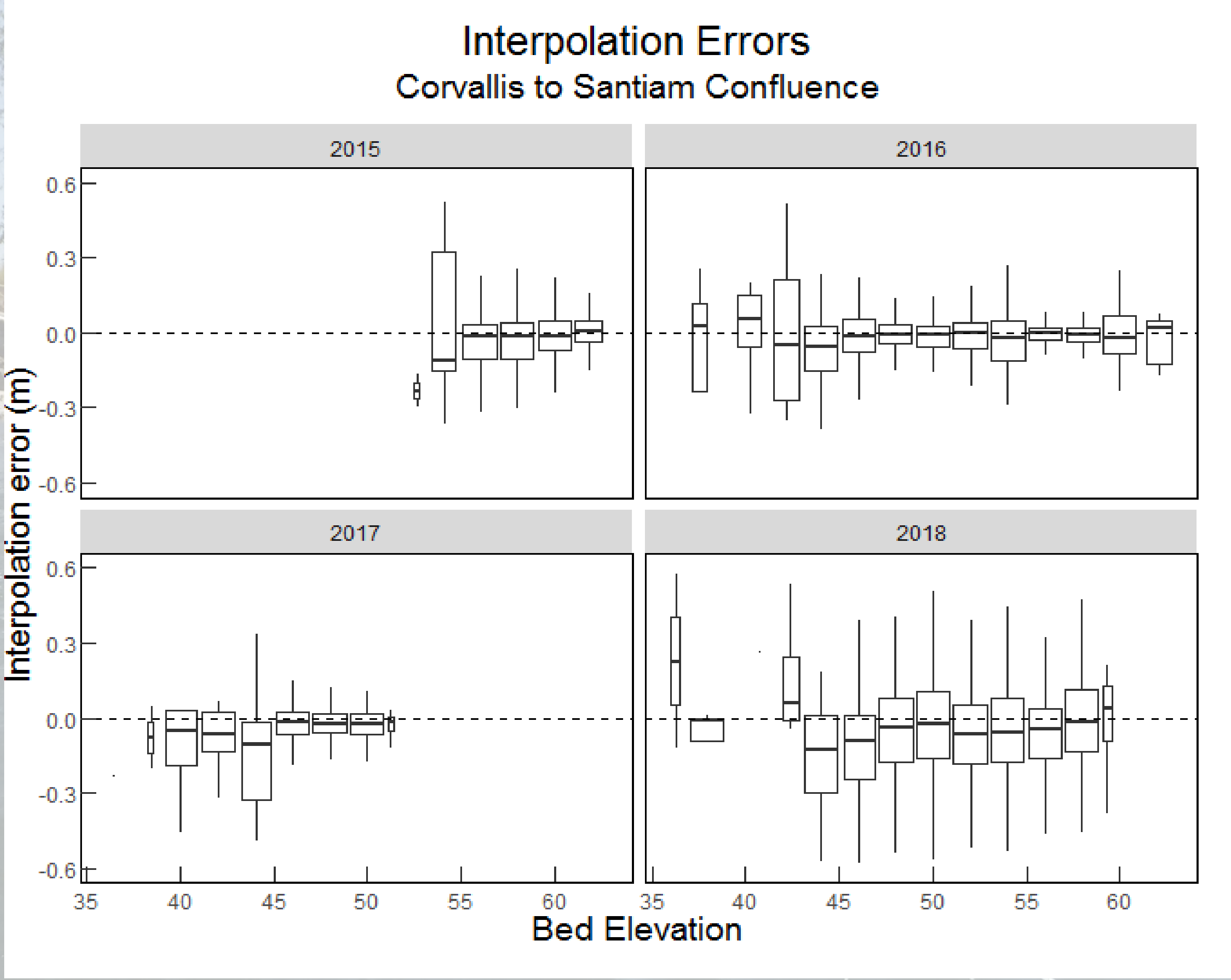


Preliminary Results – subject to revision


More low-velocity area
Q (cfs)
4000
6000
8000
10000
15000
20000
30000
Habitat limits
Higher peak velocities
Relative Density
velocity (m/s)
4,000 cfs
Relative Density
velocity (m/s)

USGS

Fusing lidar and sonar data



USGS