Development of a Stage-Specific Floodplain Inundation Model to Predict Suitable Spawning Habitat Availability for Assessing Alligator Gar Recruitment

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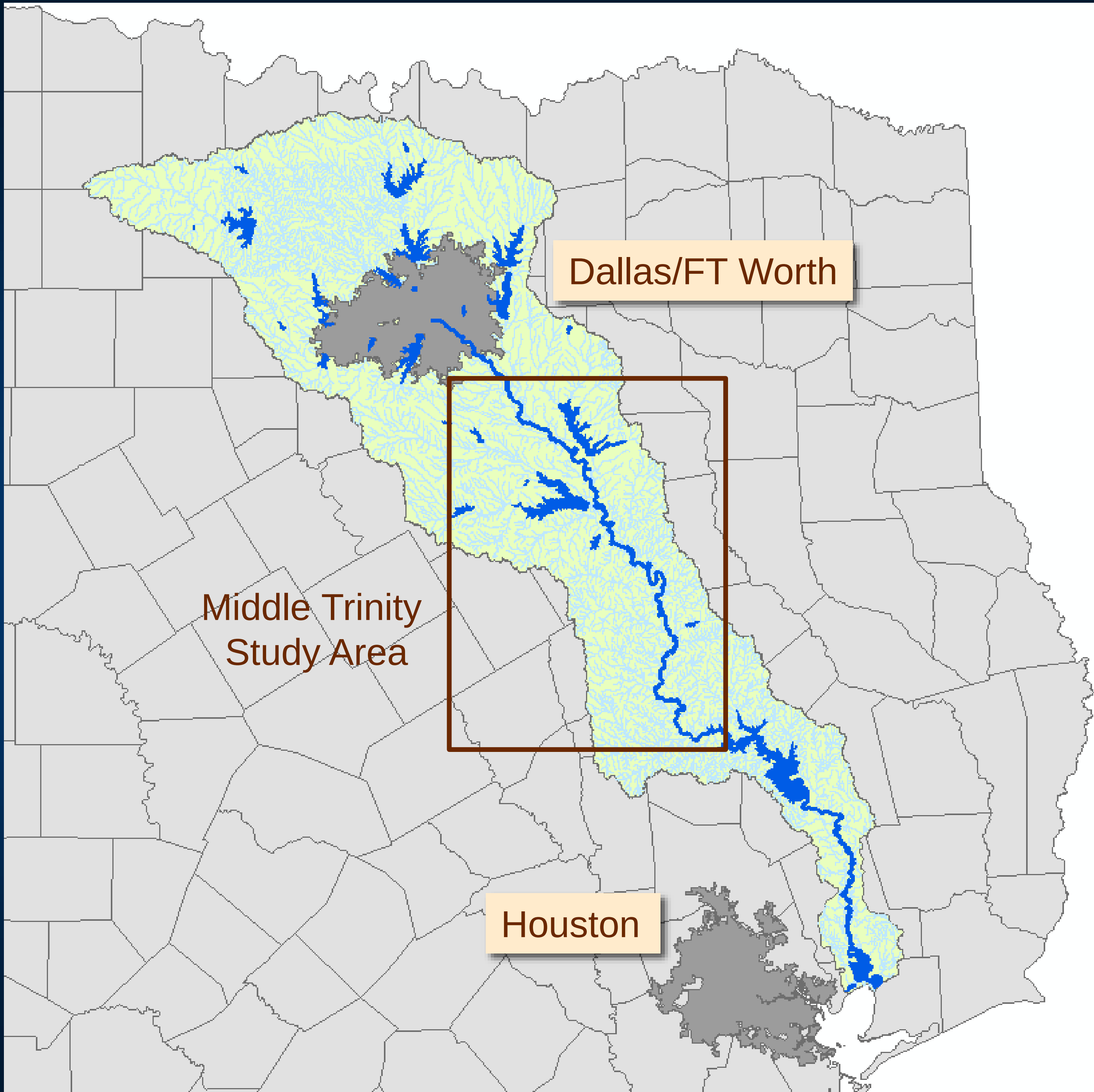
Alligator Gar

- Large floodplain river species that is dependent on floodplain connectivity for successful reproduction
- Most large floodplain rivers throughout their range have been severely altered, and from which they have been extirpated.

Floodplain Inundation Modeling

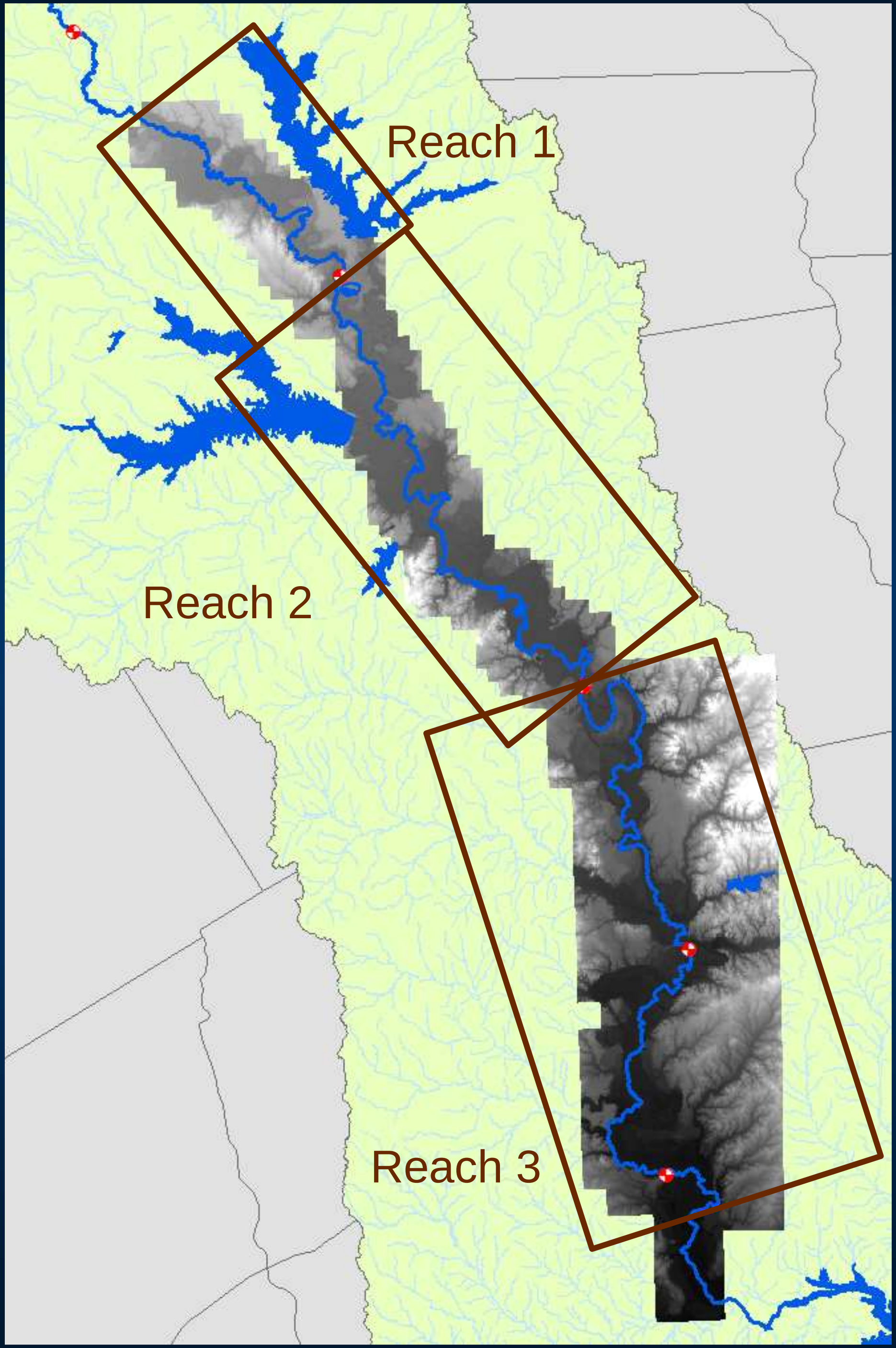
- Successful conservation of Alligator Gar depends on defining the specific characteristics of flood pulse events that lead to successful recruitment.
- The purpose of this study is to develop a river basin scale floodplain inundation model to predict Alligator Gar spawning habitat availability to assess the flood pulse characteristics that correlate with successful Alligator Gar recruitment.

Trinity River Basin



Inundation Model Development

- 1 meter DEMs (~1500 tiles)
- HEC-RAS model from Tarrant Regional Water District
- ArcMap and Erdas Imagine

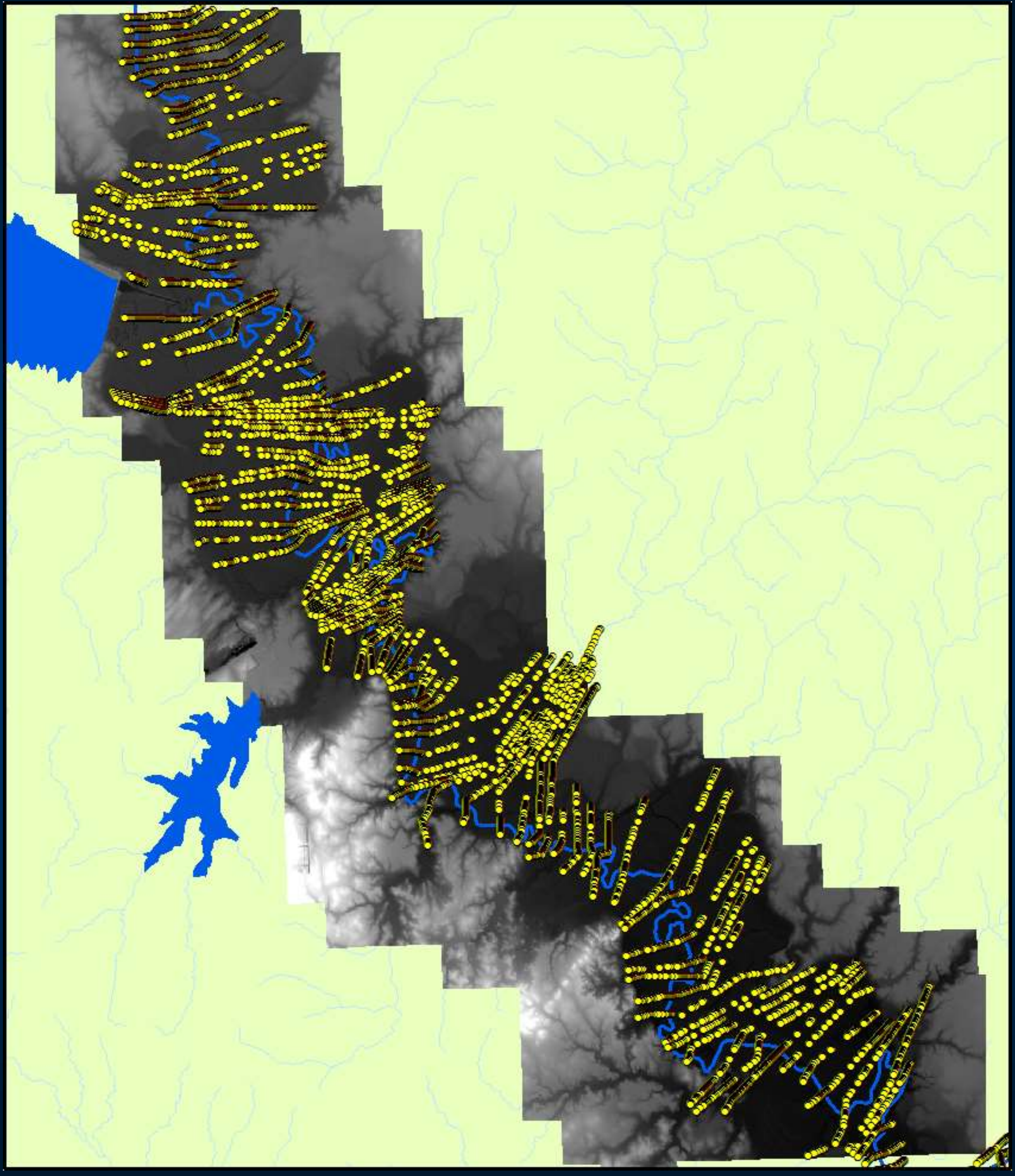


Merge DEMs into three reaches for data management purpose

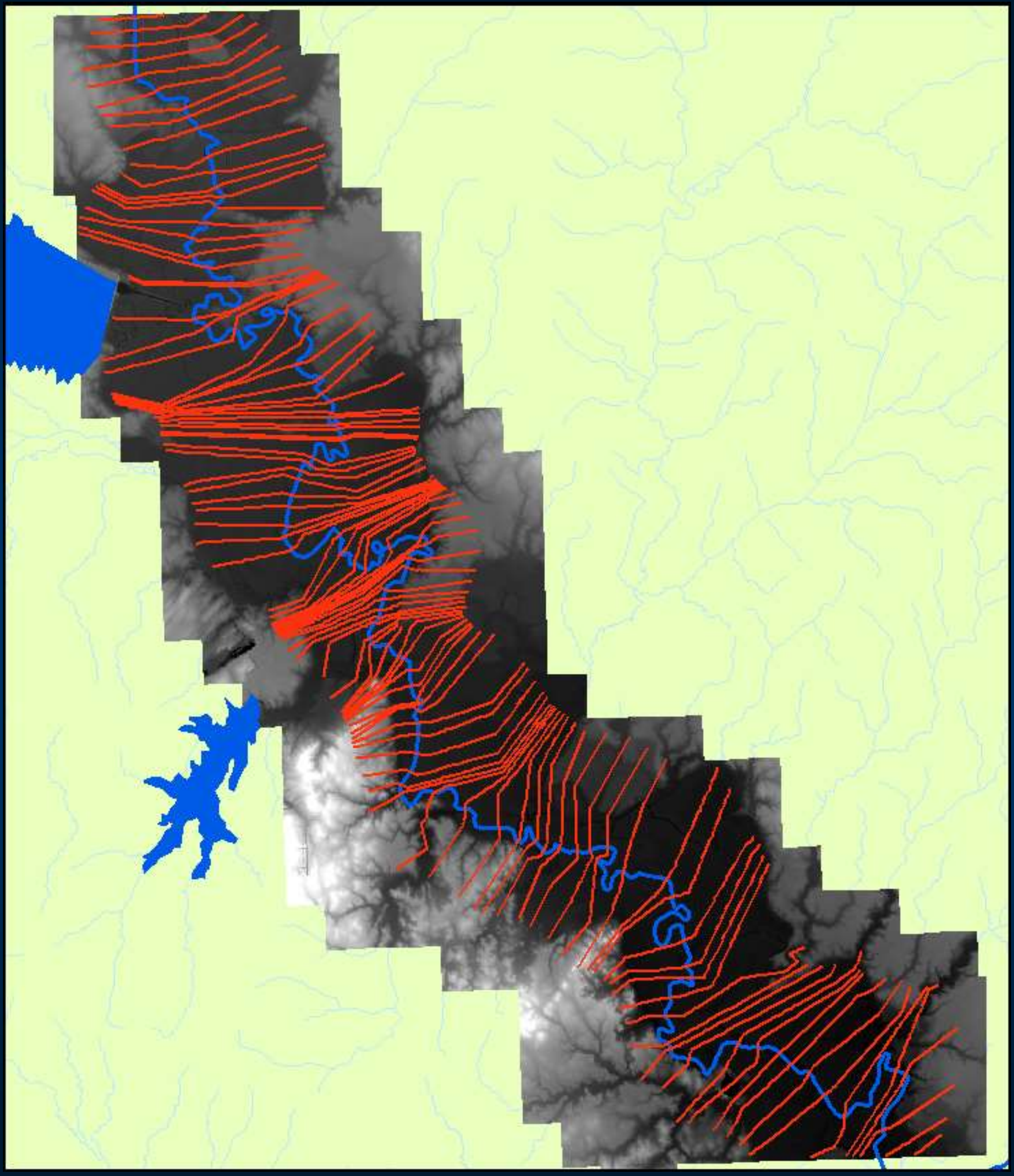
Developing Modeled Water Surfaces:

- Using HEC-RAS model developed by Tarrant Regional Water District, cross sections were produced for flows of: 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70 and 80K cfs
- Water surface elevations generated for each discharge

Reach 2
60K example



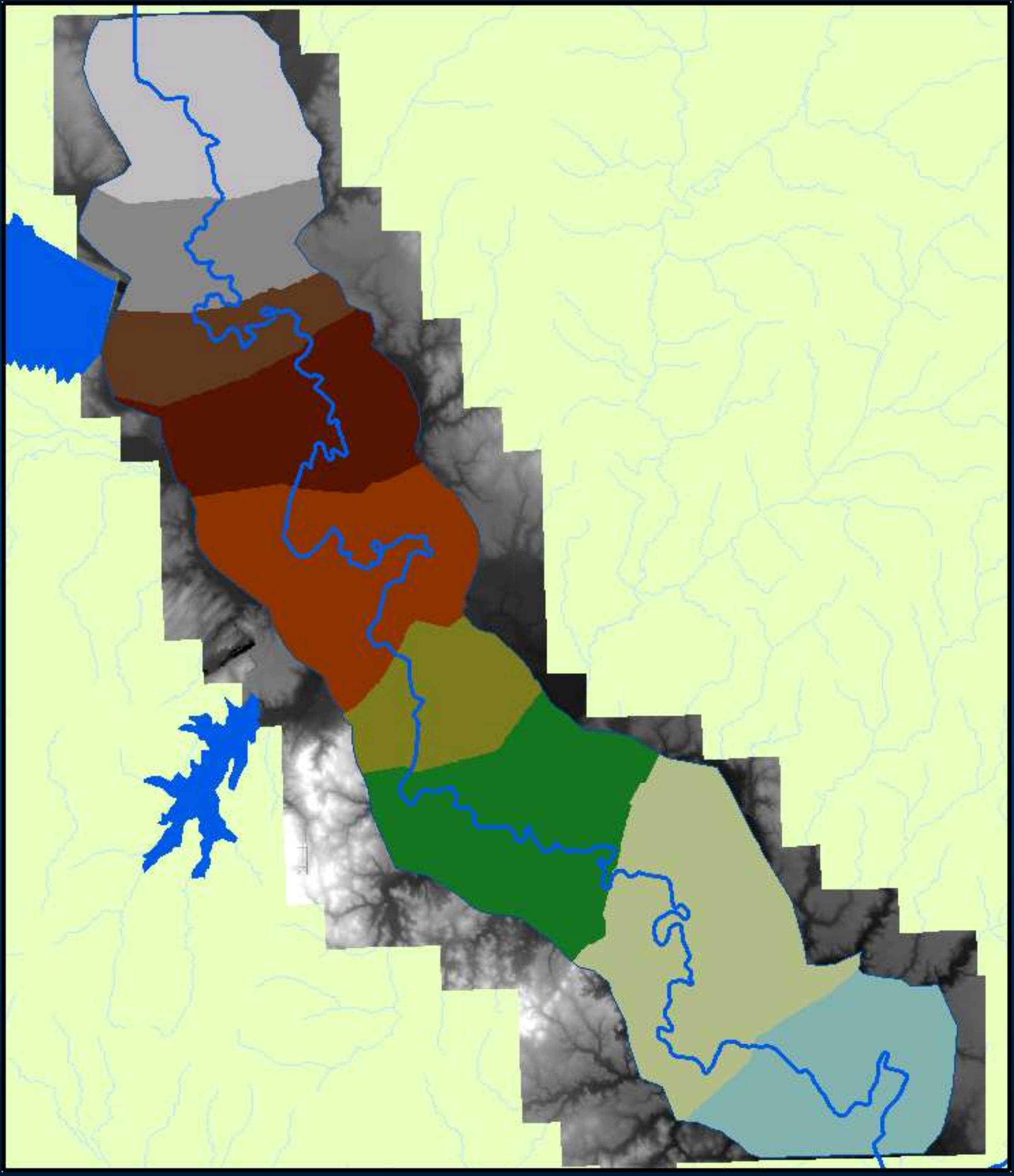
Cross section data imported from HEC RAS



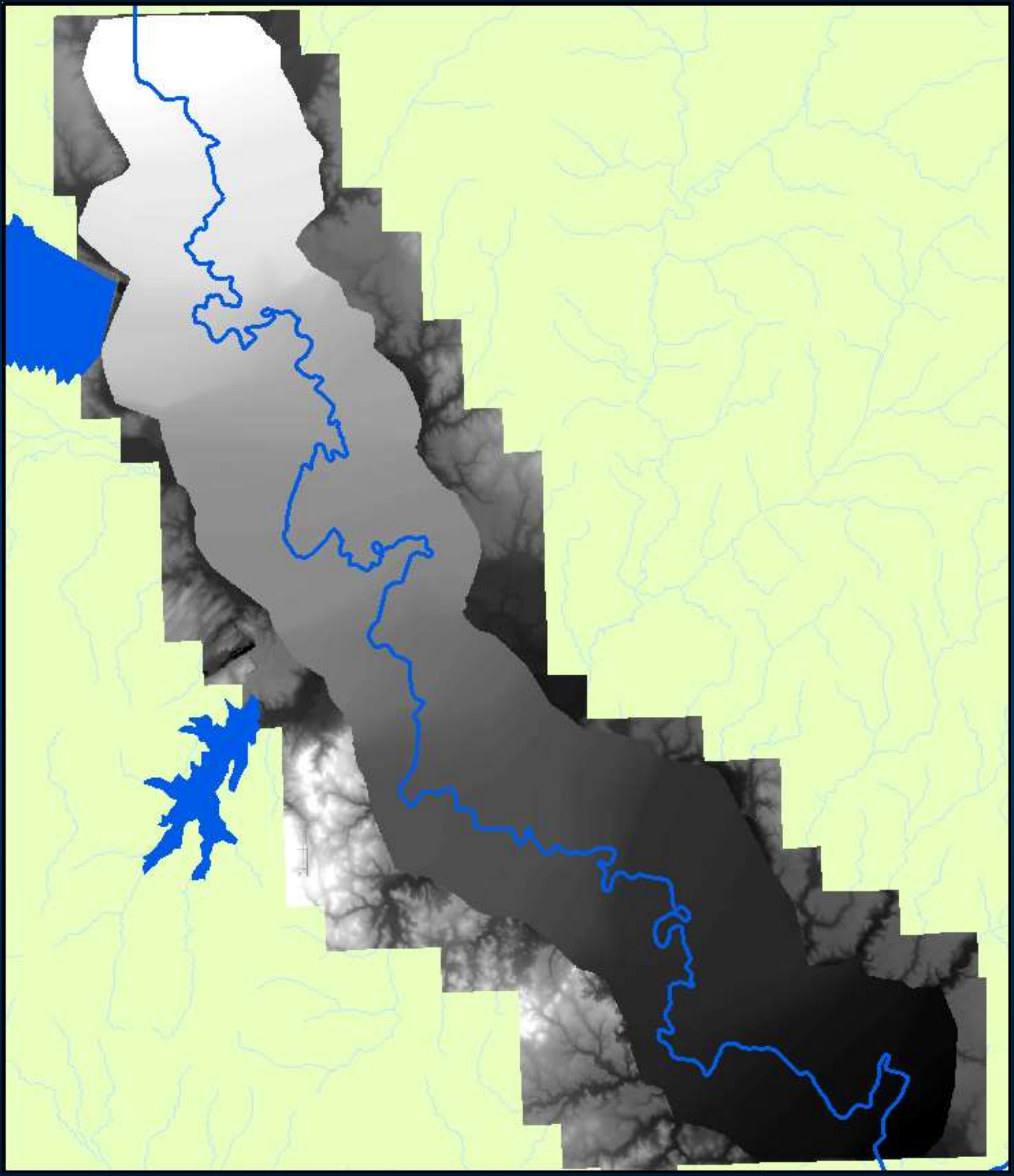
Reach 2
60K example

WSE from points spatially joined to transect lines for TIN development

Reach 2
60K example



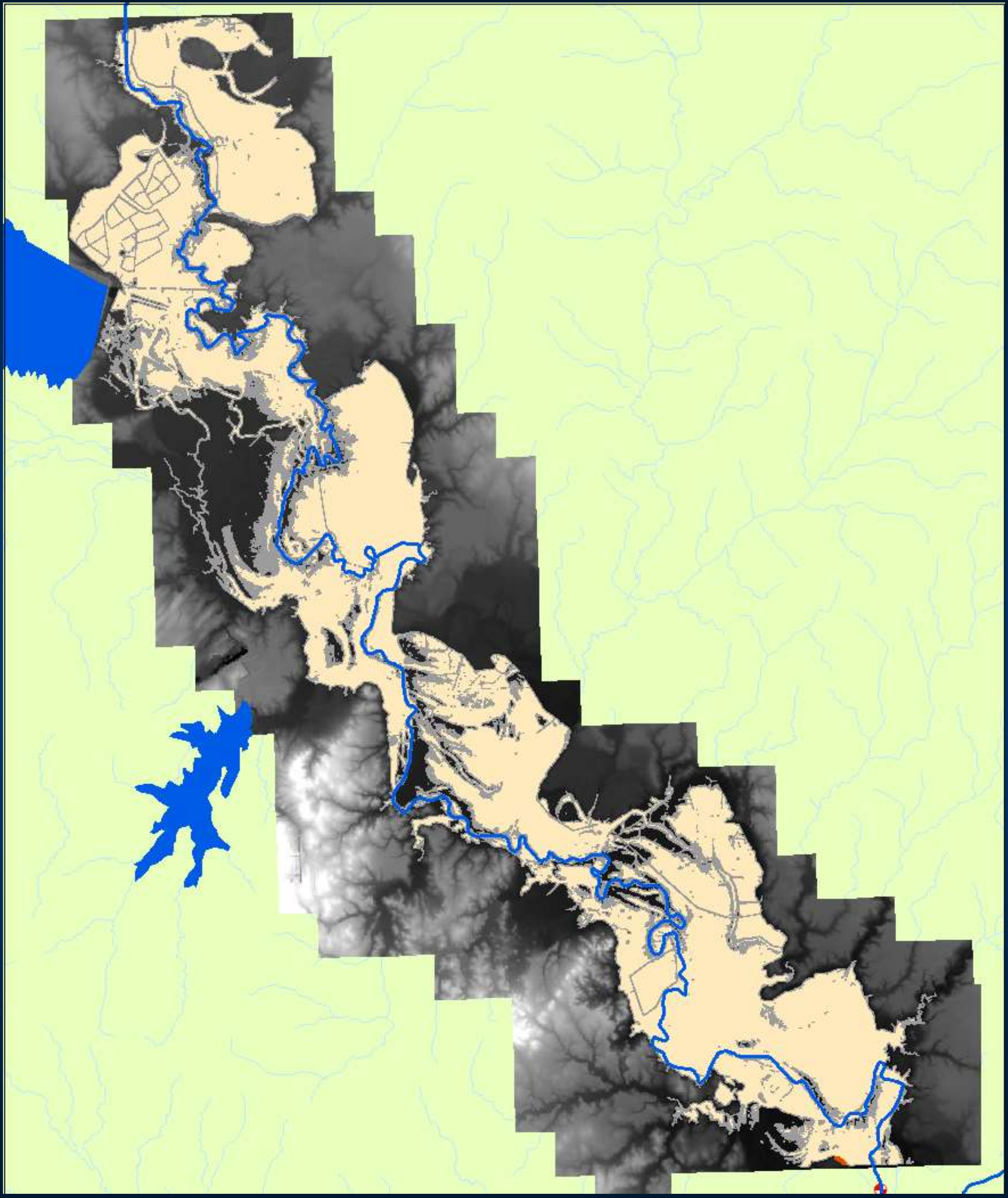
TIN generated to produce a smooth water surface and converted to raster



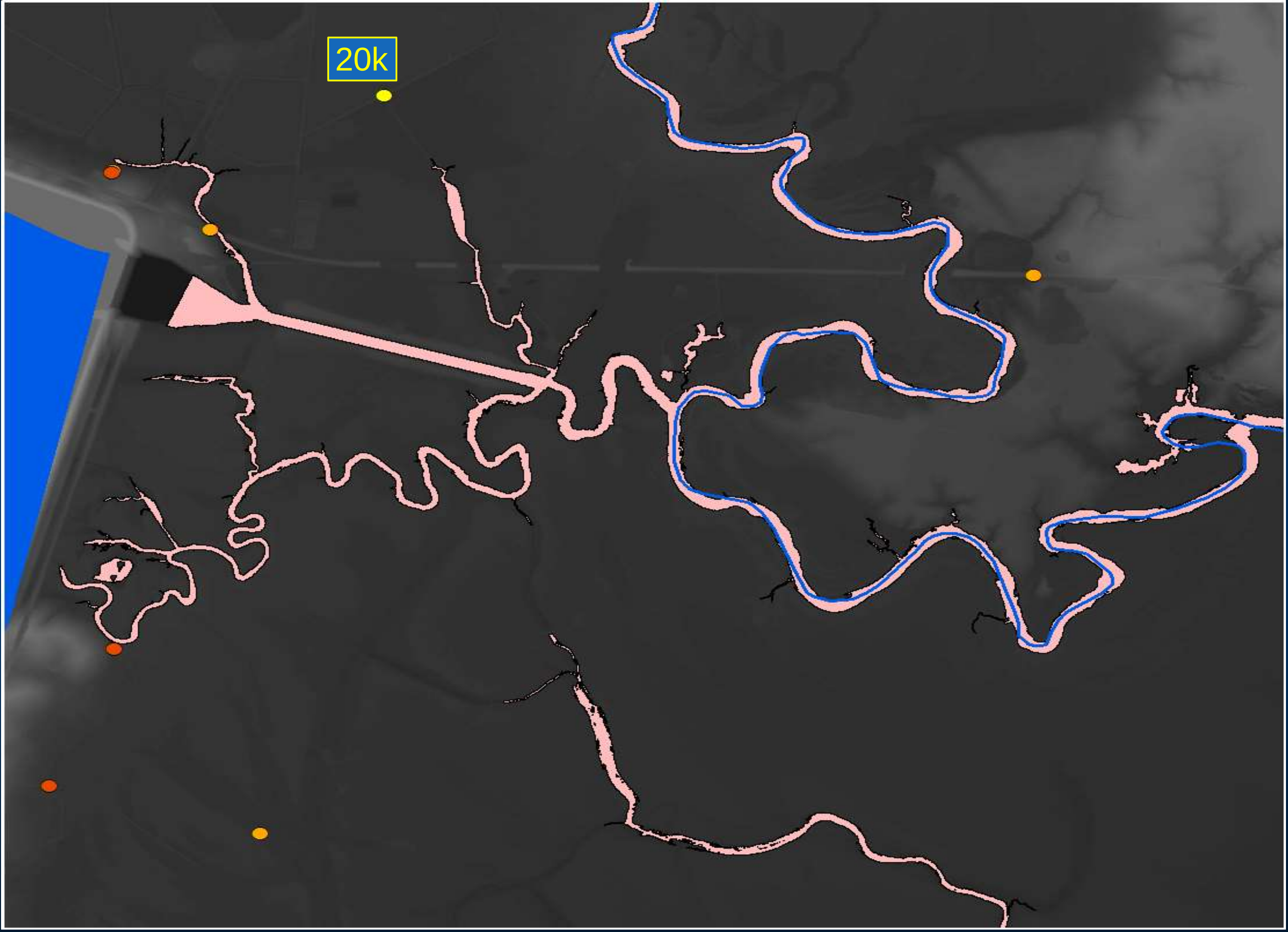
Reach 2
60K example

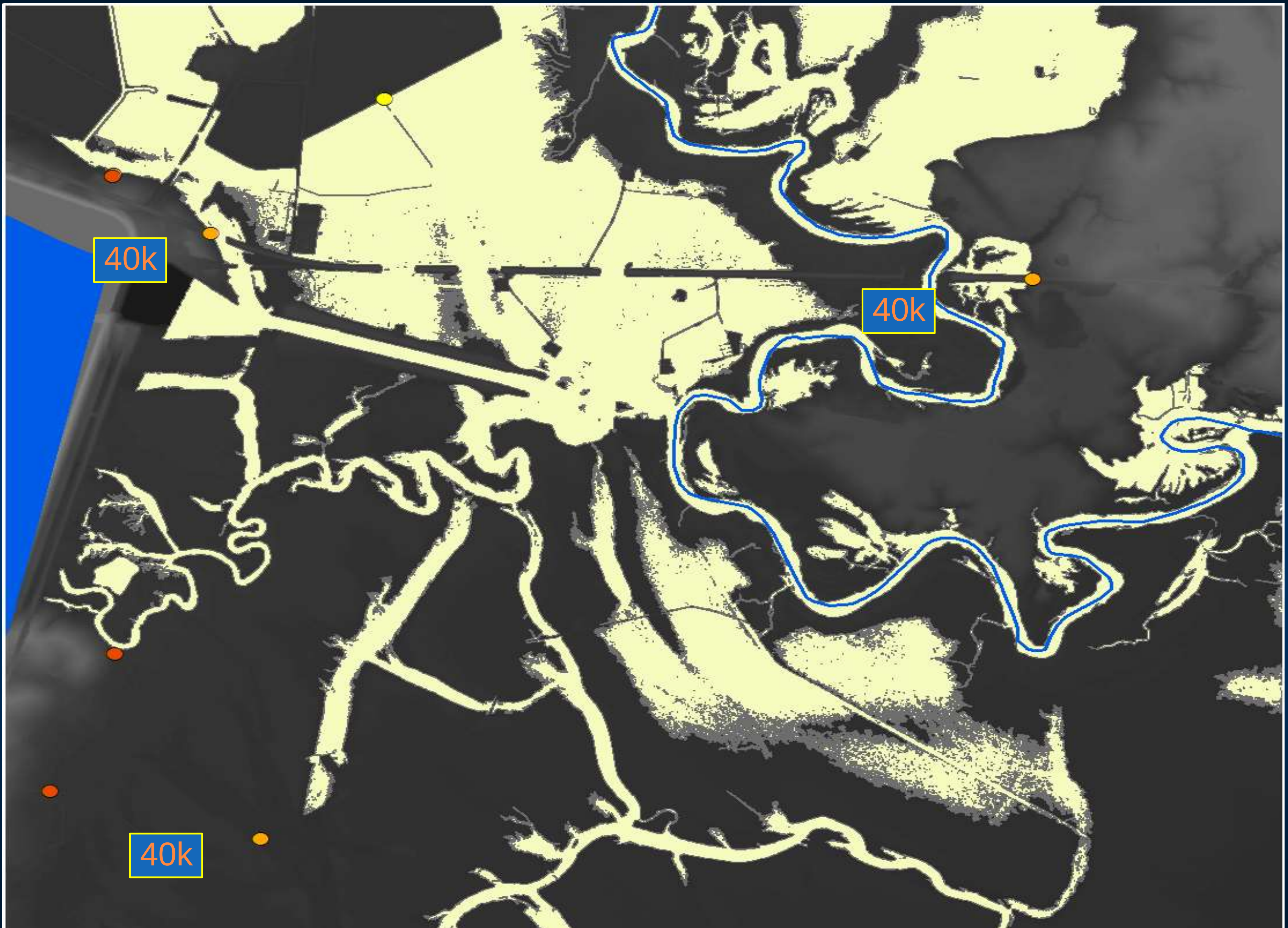
Water surface raster used to query DEMs and calculate inundation extent using ERDAS Imagine

Reach 2
60K example

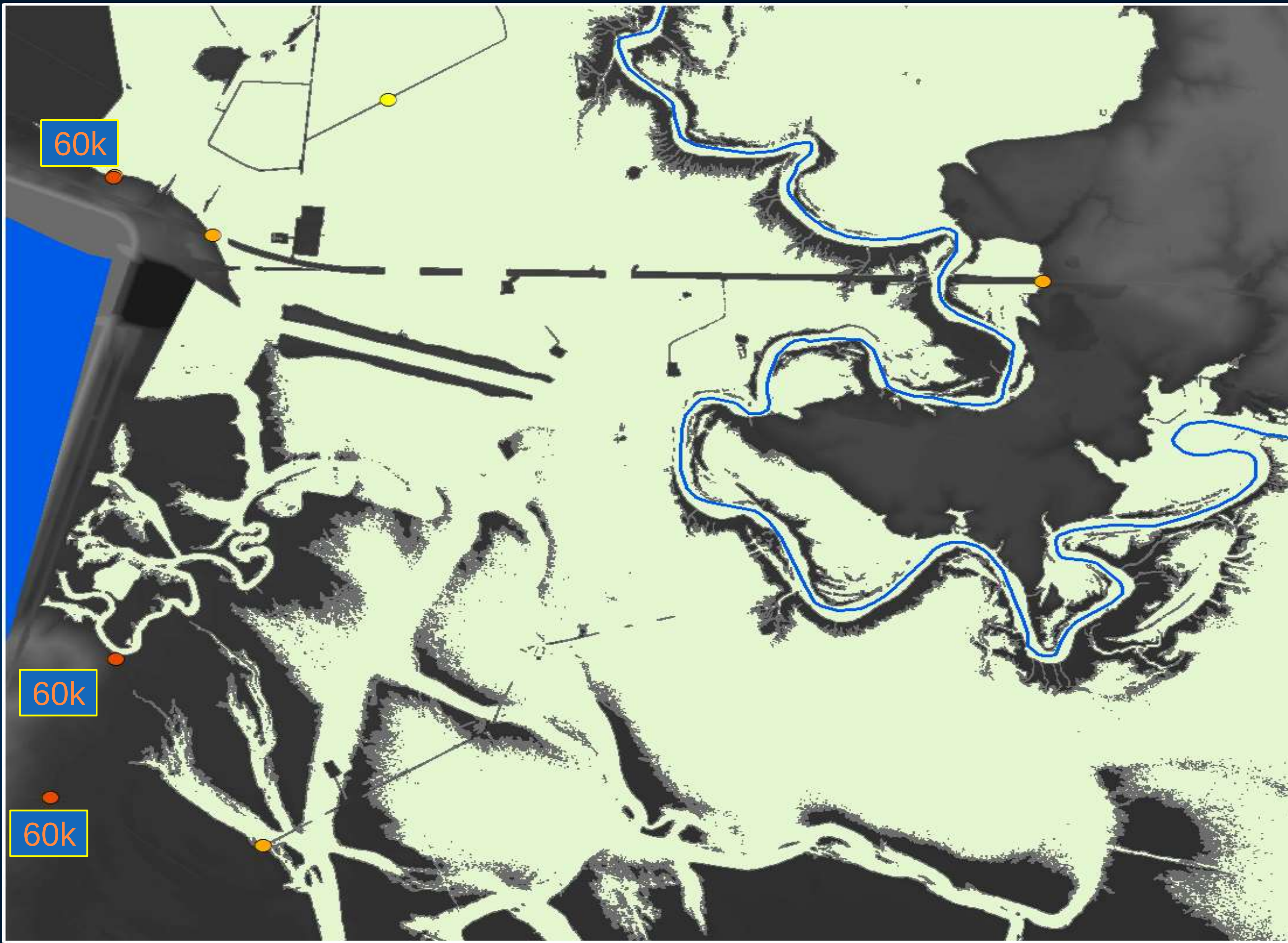


Total calculated inundated area.

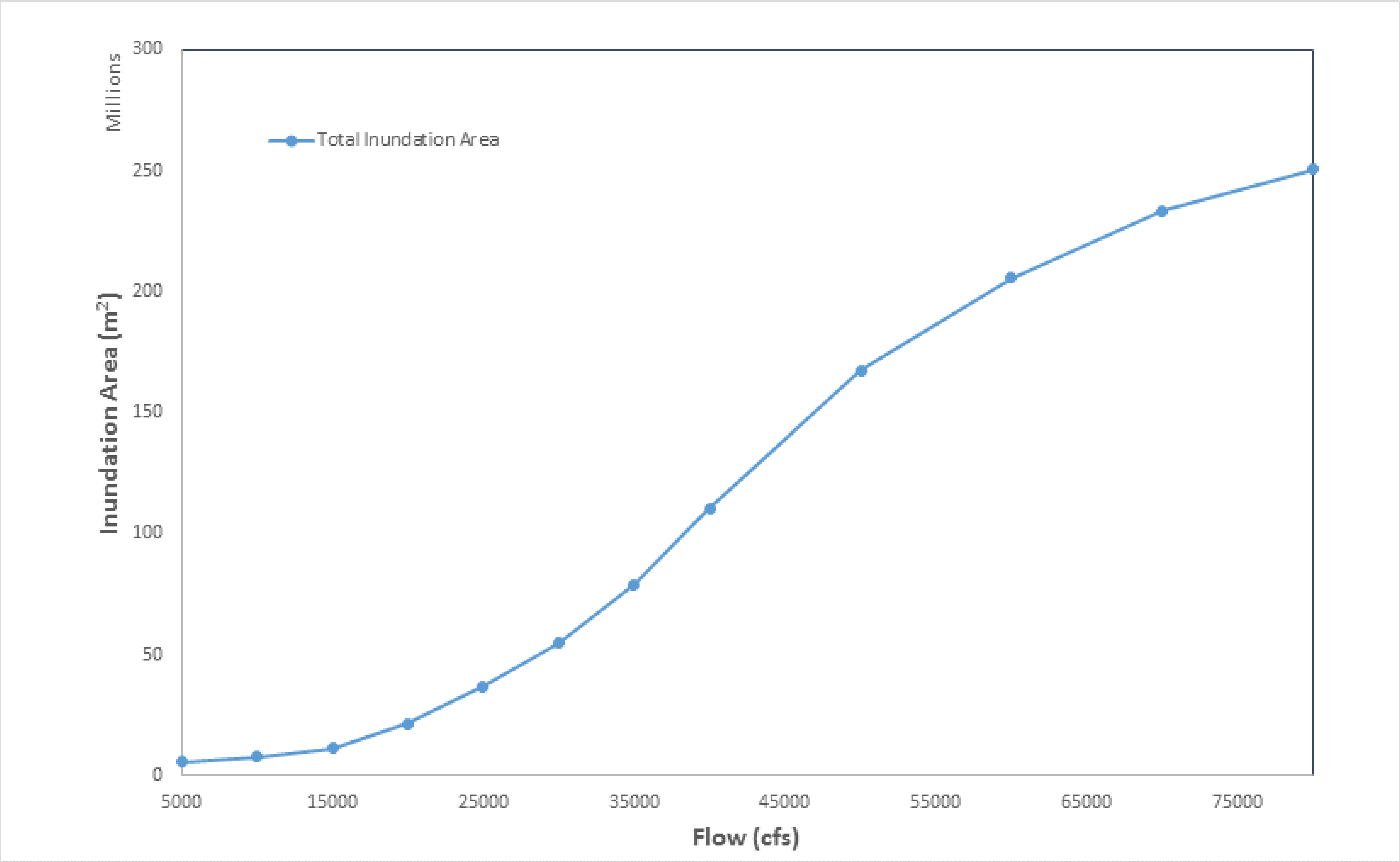

20k



40k
40k
40k


60k
60k
60k

Discharge Relationship to Area Inundated



Alligator Gar Spawning Habitat

- Previous work in LA[1] and ARK[2] show preferred habitat for spawning gar as open canopy vegetation types:
  - Examples:
    - Flooded herbaceous vegetation
    - Flooded shrubs
- Spawning typically occurs in shallow areas

[1]Allen, Y.C., Kimmel, and G.C. Constant 2014. Using remote sensing to assess alligator gar spawning habitat suitability in the lower Mississippi River. U.S. Fish and Wildlife Service. Baton Rouge Fish and Wildlife Conservation Office report.

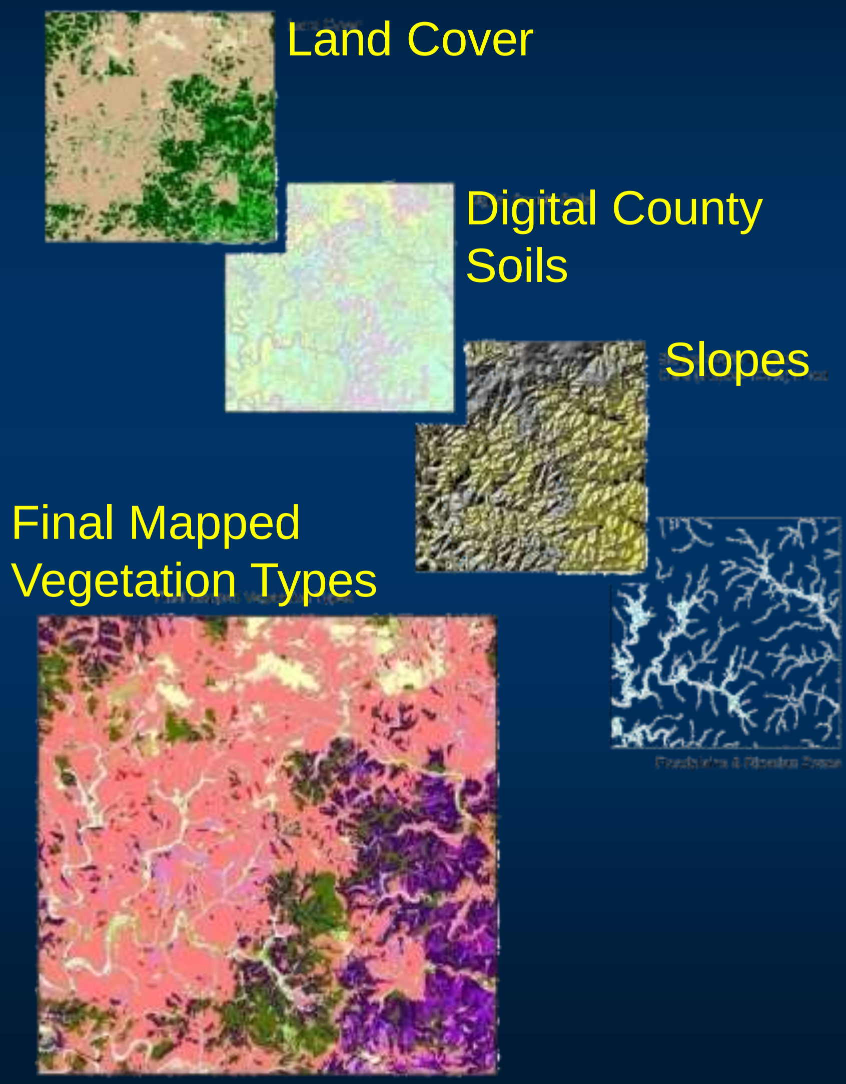
[2]Inebit, T.E. 2009. Aspects of the reproductive and juvenile ecology of Alligator Gar in the Fourche LaFave River, Arkansas. M.S. Thesis, University of Central Arkansas, Conway, Arkansas.

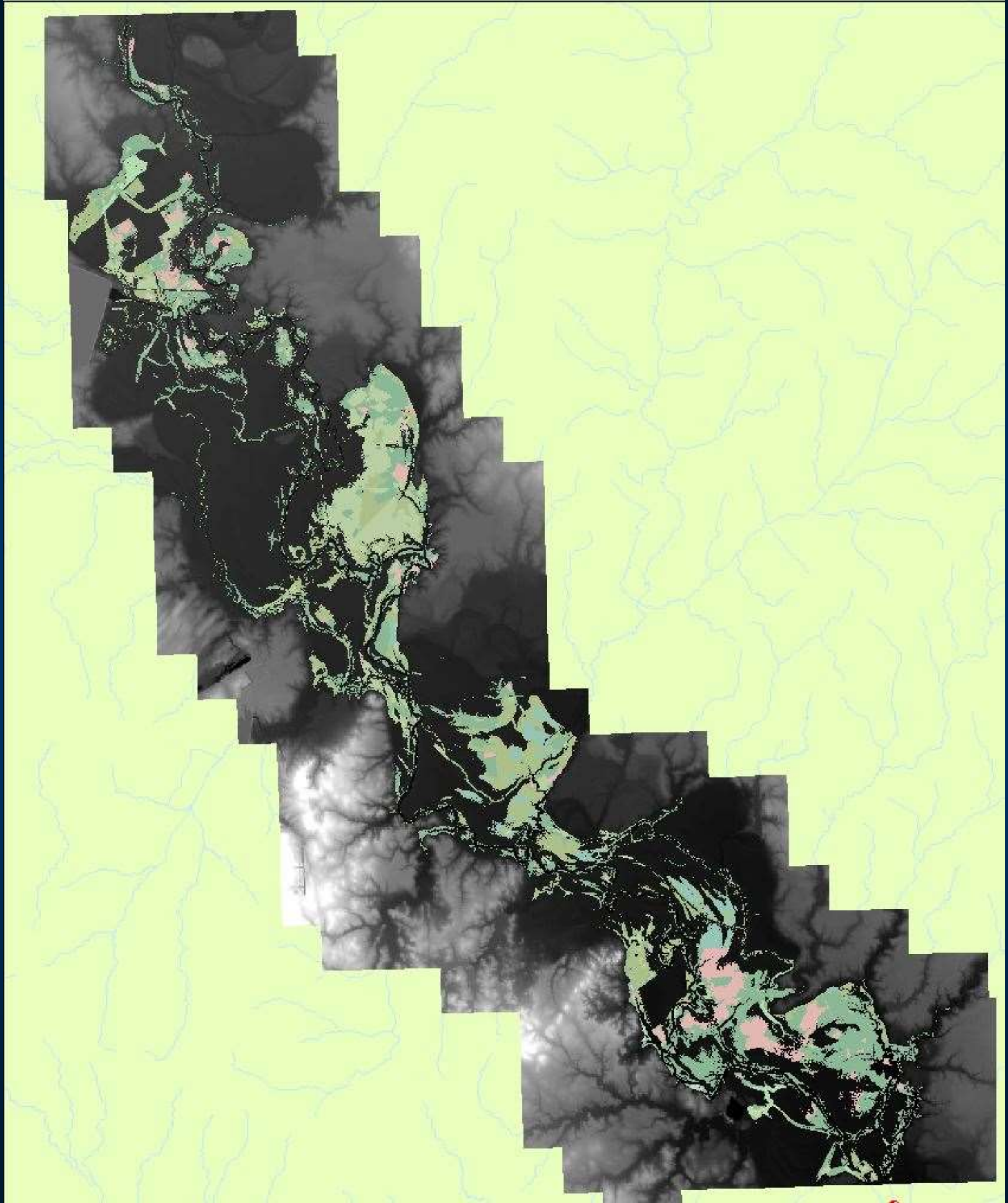
Inundated Habitat Data

- Determine types and areas of habitats being inundated
  - Vegetation classes
- Clip inundated vegetation classes to depths from 0.5-2m

Ecological Mapping Systems Data-Inputs

- Statewide **current** vegetation data
- Spatial Resolution
  - 10meters
- Thematic Resolution
  - 398 mapped habitat types
  - Abiotic variables (Enduring Features)
- Ground verified
  - >14,000 field data points
- Accuracy
  - 74% to 90%
- Anthropogenic effects
  - 19 Invasive types mapped





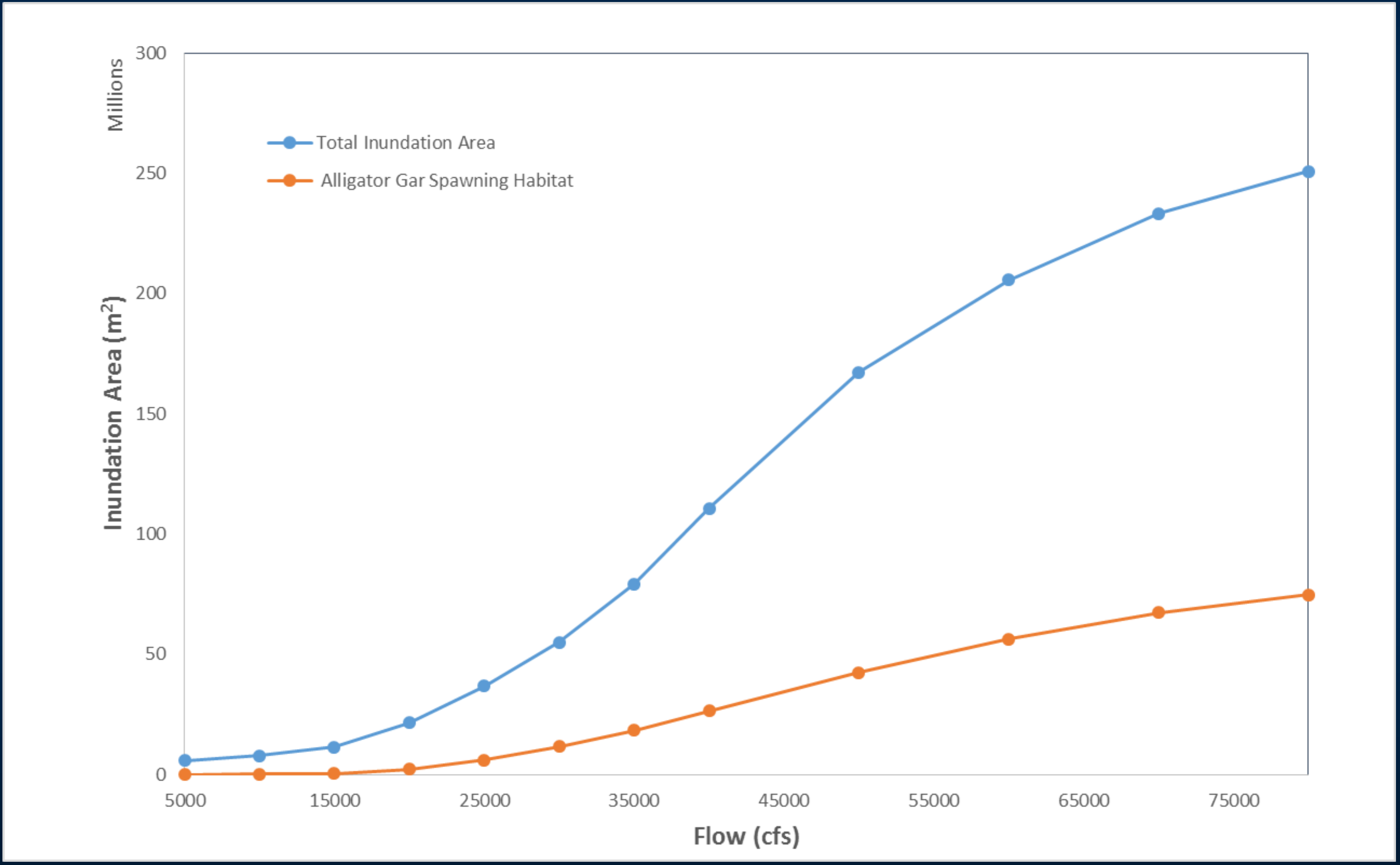
Reach 2
50K example

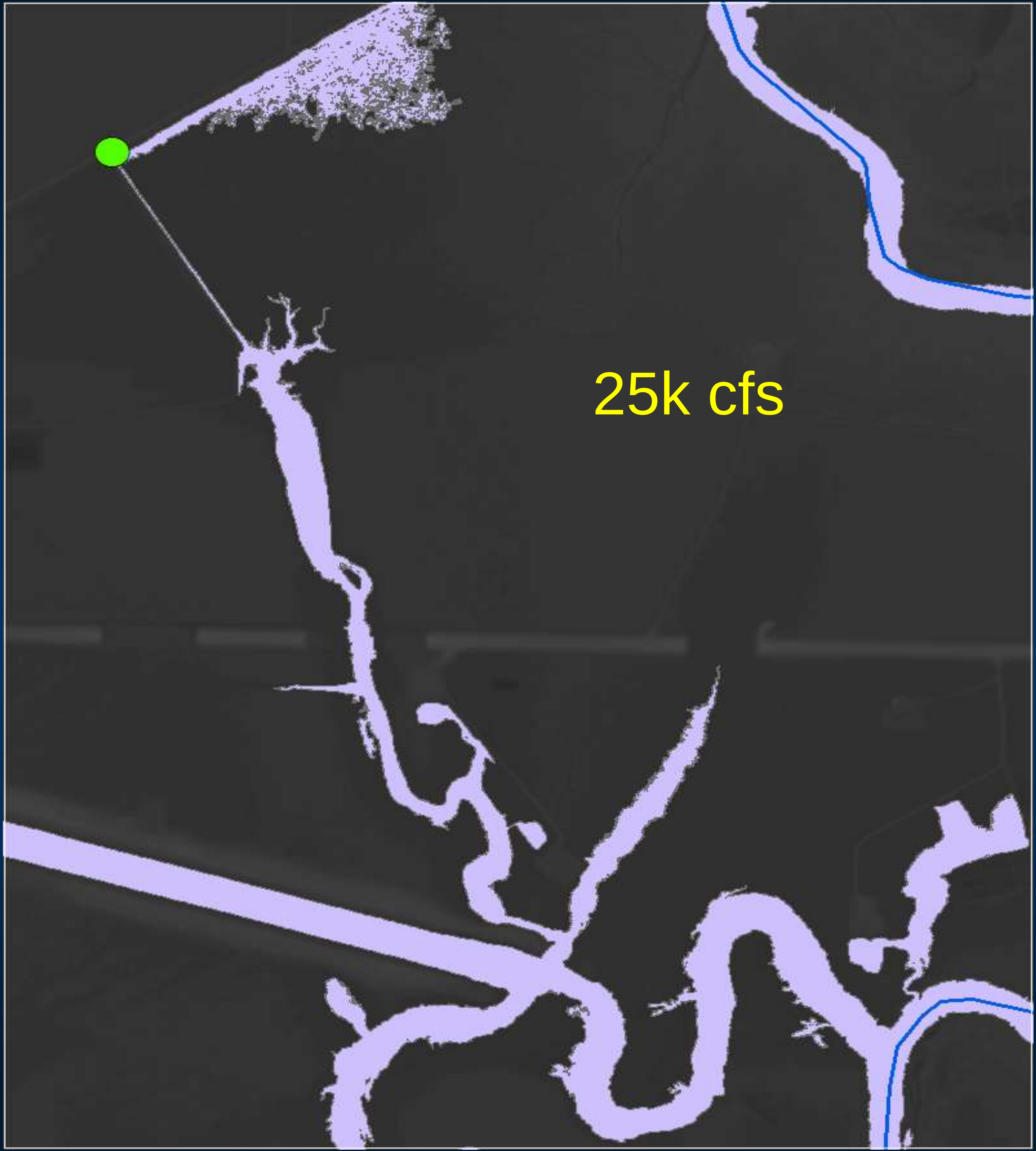
EMS clipped to spawning depth criteria

This was done for each of the target flows


Reach 2
50K example

Alligator Gar Spawning Habitat

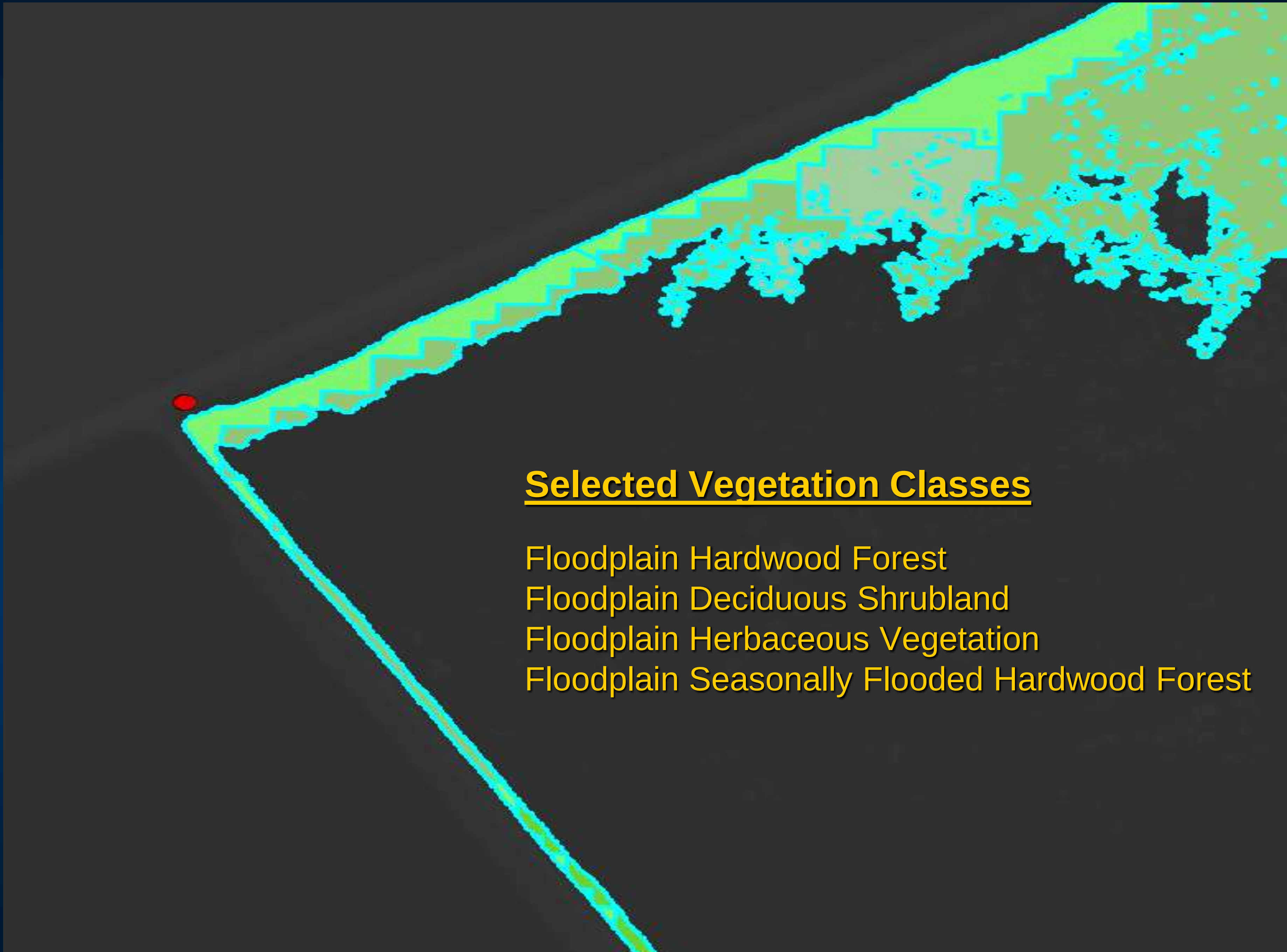




Inundation Model Validation

Richland Creek WMA

May 2015 Flood Pulse


Selected Vegetation Classes
Floodplain Hardwood Forest
Floodplain Deciduous Shrubland
Floodplain Herbaceous Vegetation
Floodplain Seasonally Flooded Hardwood Forest

Alligator Gar Recruitment Success

- Correlate hydrology (e.g. spawning habitat availability) and environmental factors with known successful year classes to determine which factors are important for successful recruitment.

Year	Obs	Exp	Deviation	Obs/Exp
1986	**2**	**1.09**	**0.91**	**1.84**
1987	**2**	**1.19**	**0.81**	**1.69**
1988	0	1.30	-1.30	0
1989	**10**	**1.42**	**8.58**	**7.06**
1990	**6**	**1.55**	**4.45**	**3.87**
1991	**6**	**1.69**	**4.31**	**3.54**
1992	1	1.85	-0.85	0.54
1993	1	2.02	-1.02	0.49
1994	**3**	**2.21**	**0.79**	**1.36**
1995	0	2.41	-2.41	0
1996	1	2.64	-1.64	0.38
1997	0	2.88	-2.88	0
1998	1	3.15	-2.15	0.32
1999	0	3.45	-3.45	0
2000	1	3.77	-2.77	0.27
2001	0	4.11	-4.11	0
2002	1	4.50	-3.50	0.22

Year	Obs	Exp	Deviation	Obs/Exp
2003	0	4.91	-4.91	0
2004	2	5.37	-3.37	0.37
2005	0	5.87	-5.87	0
2006	5	6.42	-1.42	0.78
2007	**43**	**7.01**	**35.99**	**6.13**
2008	5	7.66	-2.66	0.65
2009	5	8.37	-3.37	0.60
2010	1	9.15	-8.15	0.11

- 120 Alligator Gar
- Expected YCS was calculated from assumed constant annual recruitment and mortality rates

Buckmeier, D.L., N.G. Smith, D.J. Daugherty, and D.L. Bennett. *In Review.* Reproductive ecology of Alligator Gar: identification of environmental drivers for recruitment success.

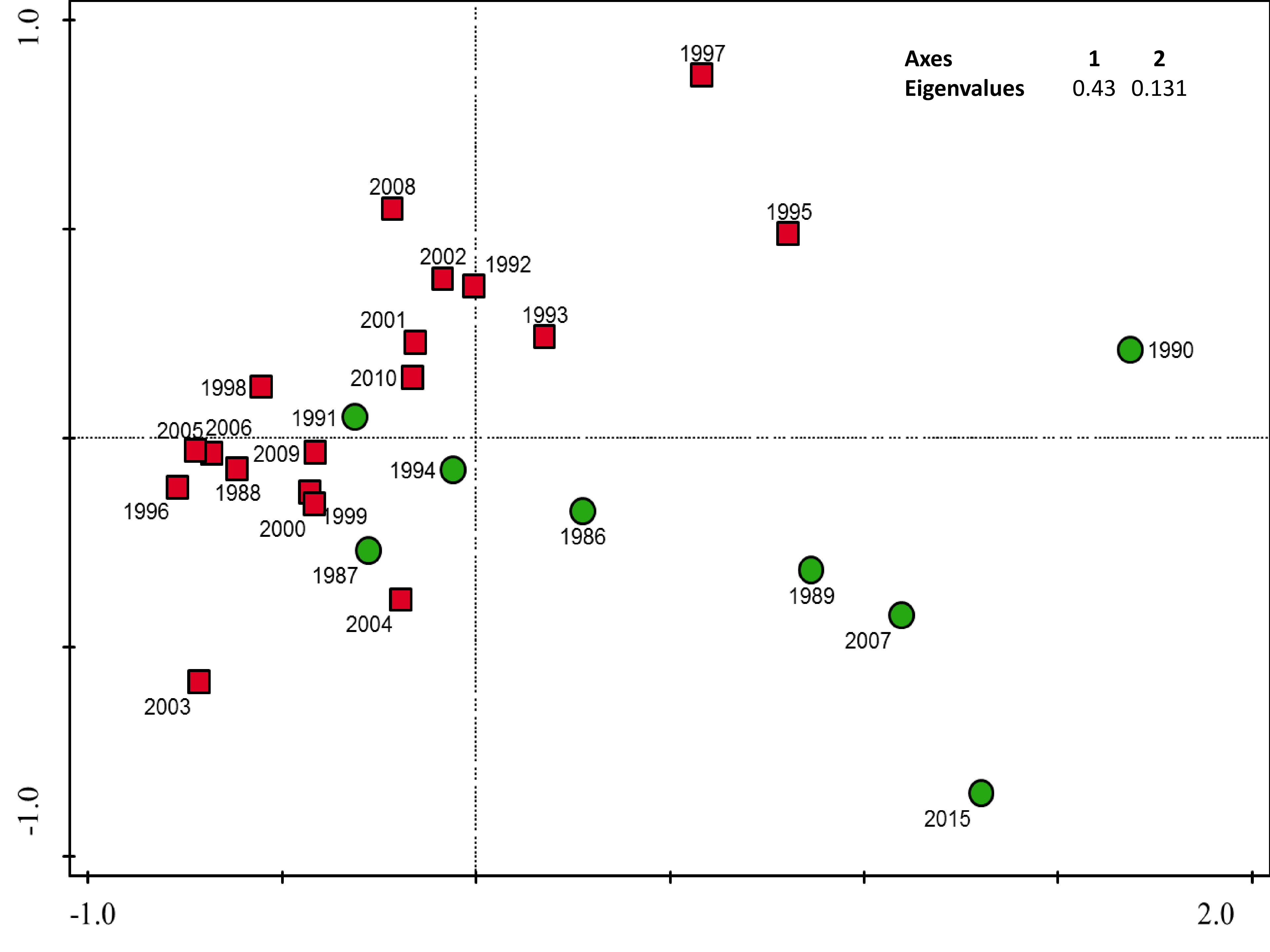
Hydrologic/Environmental Variables

- All variables assessed only during the spawning season (April-July)
- 42 total variables compiled from 1986-2010 (2015 also included)
- Temperature
  - Average Water Temp (monthly)
  - Cumulative Degree Days above 20°C (monthly)

Hydrologic/Environmental Variables

- Utilized variables derived from Indicators of Hydrologic Alteration (IHA) analysis constrained to the spawning months
  - Mean/Max monthly flows (converted to available spawning habitat)
  - Monthly pulse count and pulse duration
  - Seasonal pulse count and pulse duration

AvgT_Apr	1-day max	April_HFP#
AvgT_May	3-day max	April_HFPMaxCD
AvgT_June	7-day max	April_HFPTotalD
Avgt_July	30-day max	May_HFP#
Apr_MaxCDD	90-day max	May_HFPMaxCD
May_MaxCDD	Date max	May_HFPTotalD
June_MaxCDD	Lo pulse #	June_HFP#
July_MaxCDD	Lo pulse L	June_HFPMaxCD
April_MeanQ	Hi pulse #	June_HFPTotalD
May_MeanQ	Hi pulse L	July_HFP#
June_MeanQ	Fall rate	July_HFPMaxCD
July_MeanQ	Reversals	July_HFPTotalD
April_MeanHab	April_MaxQ	Spawn Season HFP_totalD
May_MeanHab	May_MaxQ	Spawn Season HFP MaxCD
June_MeanHab	June_MaxQ	
July_MeanHab	July_MaxQ	
1-day max Hab		
3-day max Hab		
7-day max Hab		
30-day max Hab		
90-day max Hab		
April_MaxHab		
May_MaxHab		
June_MaxHab		
July_MaxHab		


Axes 1 2
Eigenvalues 0.43 0.131
1.0
-1.0
-1.0
2.0
1997
1995
2008
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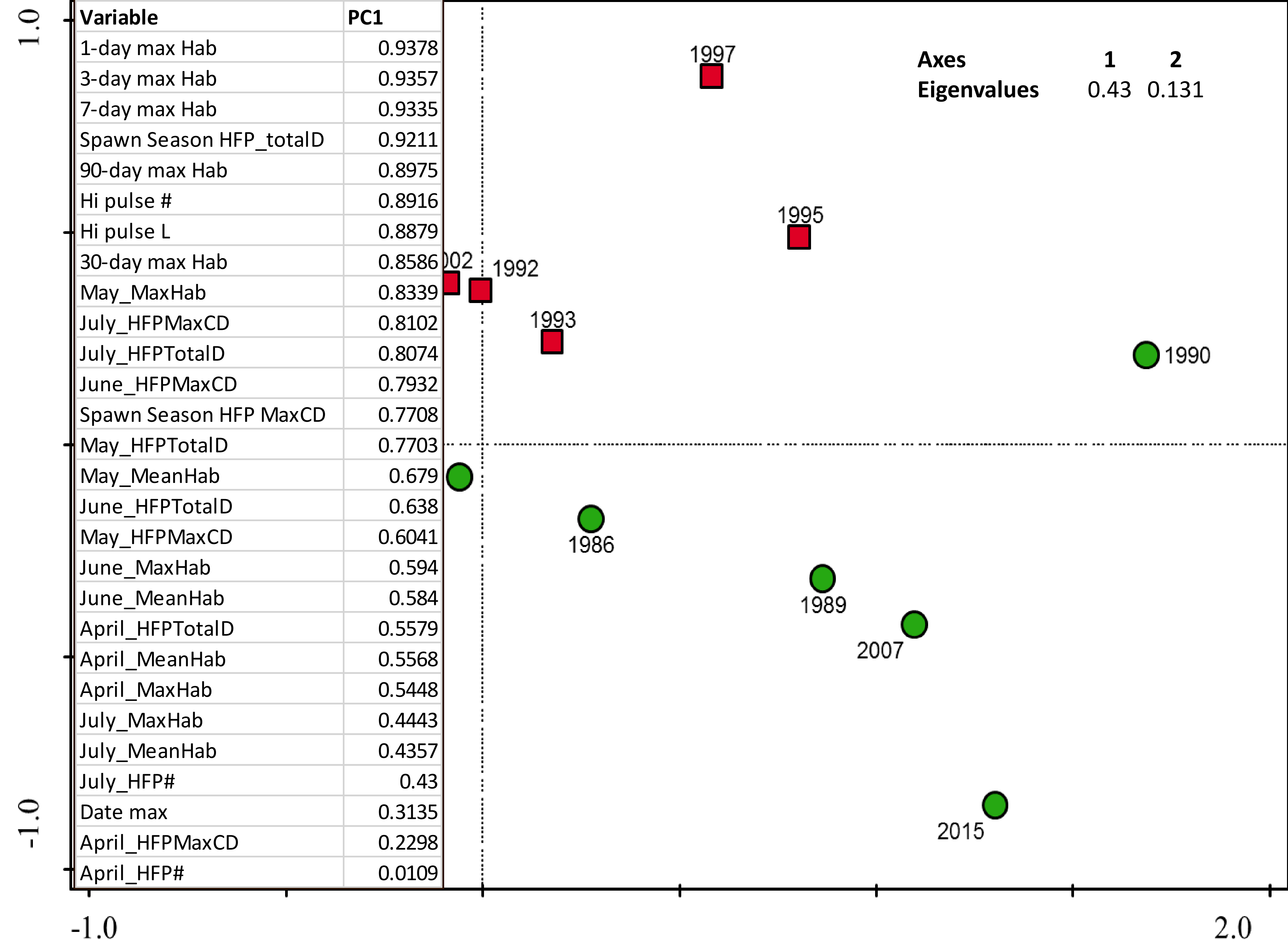
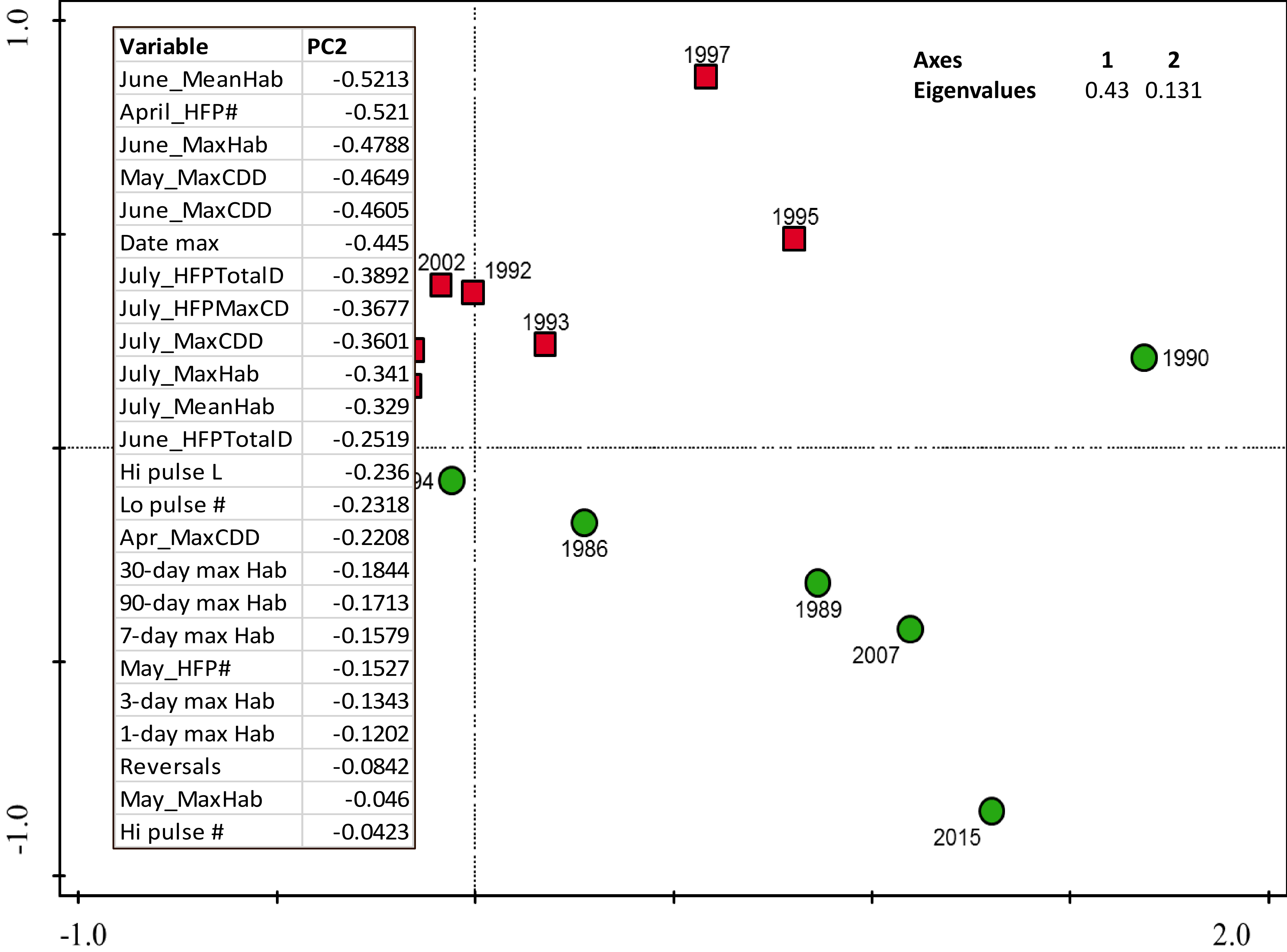
2015



Variable	PC1
1-day max Hab	0.9378
3-day max Hab	0.9357
7-day max Hab	0.9335
Spawn Season HFP_totalD	0.9211
90-day max Hab	0.8975
Hi pulse #	0.8916
Hi pulse L	0.8879
30-day max Hab	0.8586
May_MaxHab	0.8339
July_HFPMaxCD	0.8102
July_HFPTotalD	0.8074
June_HFPMaxCD	0.7932
Spawn Season HFP MaxCD	0.7708
May_HFPTotalD	0.7703
May_MeanHab	0.679
June_HFPTotalD	0.638
May_HFPMaxCD	0.6041
June_MaxHab	0.594
June_MeanHab	0.584
April_HFPTotalD	0.5579
April_MeanHab	0.5568
April_MaxHab	0.5448
July_MaxHab	0.4443
July_MeanHab	0.4357
July_HFP#	0.43
Date max	0.3135
April_HFPMaxCD	0.2298
April_HFP#	0.0109



Variable	PC2
June_MeanHab	-0.5213
April_HFP#	-0.521
June_MaxHab	-0.4788
May_MaxCDD	-0.4649
June_MaxCDD	-0.4605
Date max	-0.445
July_HFPTotalD	-0.3892
July_HFPMaxCD	-0.3677
July_MaxCDD	-0.3601
July_MaxHab	-0.341
July_MeanHab	-0.329
June_HFPTotalD	-0.2519
Hi pulse L	-0.236
Lo pulse #	-0.2318
Apr_MaxCDD	-0.2208
30-day max Hab	-0.1844
90-day max Hab	-0.1713
7-day max Hab	-0.1579
May_HFP#	-0.1527
3-day max Hab	-0.1343
1-day max Hab	-0.1202
Reversals	-0.0842
May_MaxHab	-0.046
Hi pulse #	-0.0423

Alligator Gar Recruitment Success

- Utilizing the results of the PCA analysis, 42 variables were reduced to 21 for correlation analysis.
- Spearman rank correlation analysis ran on the 21 variables and the Obs/Exp YCS values to determine the important variables that reflect strong YCS.

Alligator Gar Recruitment Success

	Spearman's Rank Corr.	p-value
30-day max Hab	**0.447**	**0.0252**
90-day max Hab	**0.414**	**0.0396**
July_HFPMaxCD	**0.407**	**0.0433**
June_MeanHab	**0.397**	**0.0487**
May_MaxHab	0.394	0.0506
Hi pulse L	0.386	0.0561
3-day max Hab	0.386	0.0561
July_HFPTotalD	0.378	0.0621
7-day max Hab	0.377	0.0627
1-day max Hab	0.357	0.0783
Spawn Season HFP_totalD	0.345	0.0905
May_HFPTotalD	0.341	0.0943
May_HFPMaxCD	0.326	0.11
Hi pulse #	0.318	0.12
Spawn Season HFP MaxCD	0.256	0.215
June_HFPMaxCD	0.212	0.305
April_MeanHab	0.111	0.592
April_HFPTotalD	0.0808	0.698
Reversals	-0.215	0.297
Fall rate	-0.34	0.0951
Lo pulse #	**-0.459**	**0.0211**

Alligator Gar Recruitment Success

Year	July_HFPMaxCD	June_MeanHab	30-day max Hab	90-day max Hab	May_MaxHab
1986	62	5,577,364	5,810,430	2,902,645	5,193,686
1989	90	10,970,836	12,135,607	6,570,011	47,887,662
1990	130	5,669,539	63,658,867	18,574,340	75,722,432
1994	10	1,528,282	5,466,580	2,120,645	8,577,706
2007	67	5,217,529	26,235,891	7,815,945	8,067,695
2015	83	36,908,278	49,939,644	14,704,057	70,517,223
Avg	74	10,978,638	27,207,836	8,781,274	35,994,401
FLOW (cfs)		24,983	39,107	24,182	51,617

Next Steps

- Assess new HEC-RAS model to develop inundated habitat criteria for all three reaches
- Correlate hydrologic indices from all three reaches to adult year class data to develop high flow pulse recommendations for recruitment
- Flow recommendations will be included in Texas Instream Flow Program instream flow study for the middle Trinity River





Questions?

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Acknowledgements

Alice Godbey – TRWD

Dr. Thom Hardy – TSU

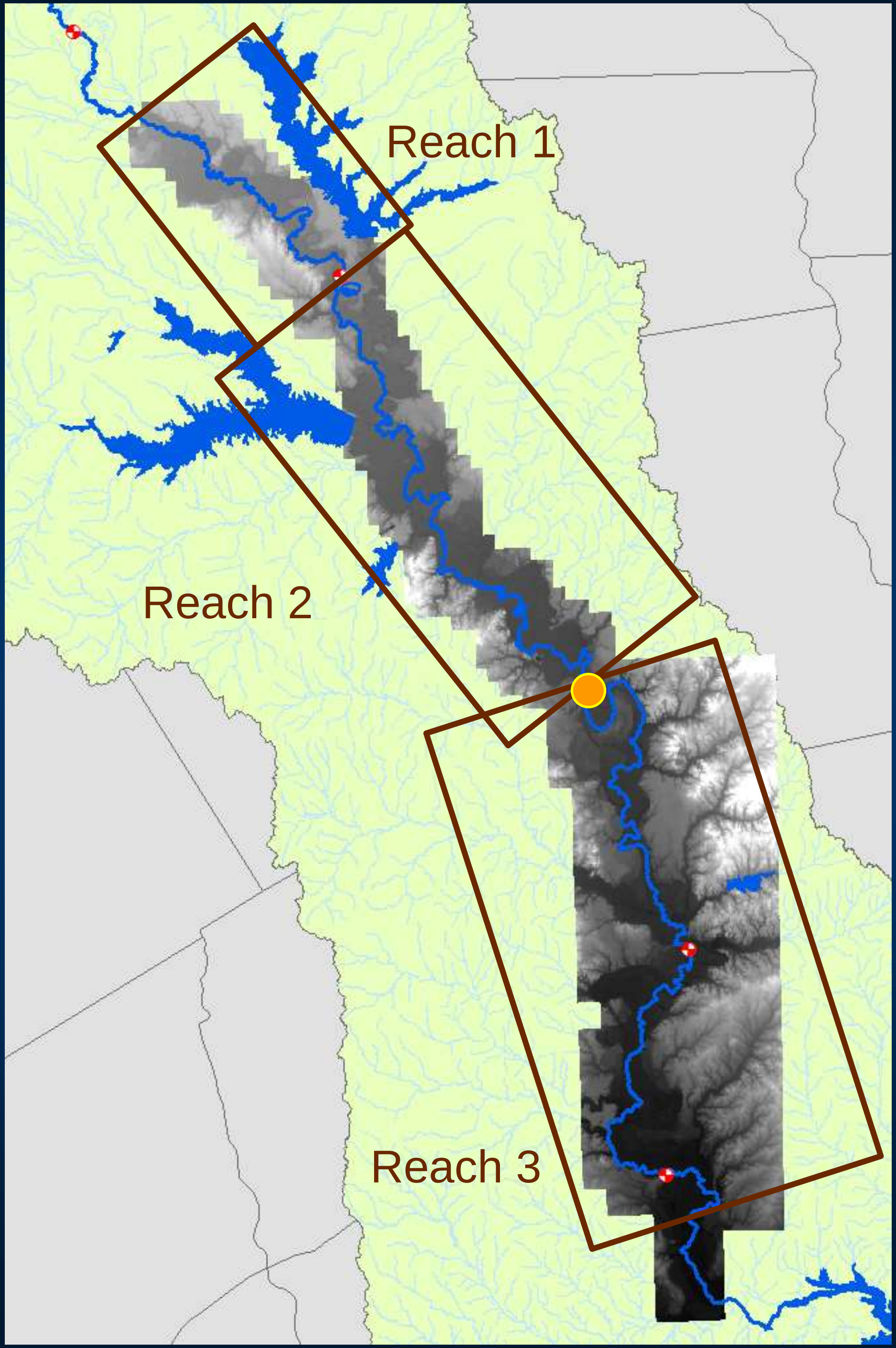
Duane German– TPWD

Dan Bennett – TPWD

Dan Daugherty – TPWD

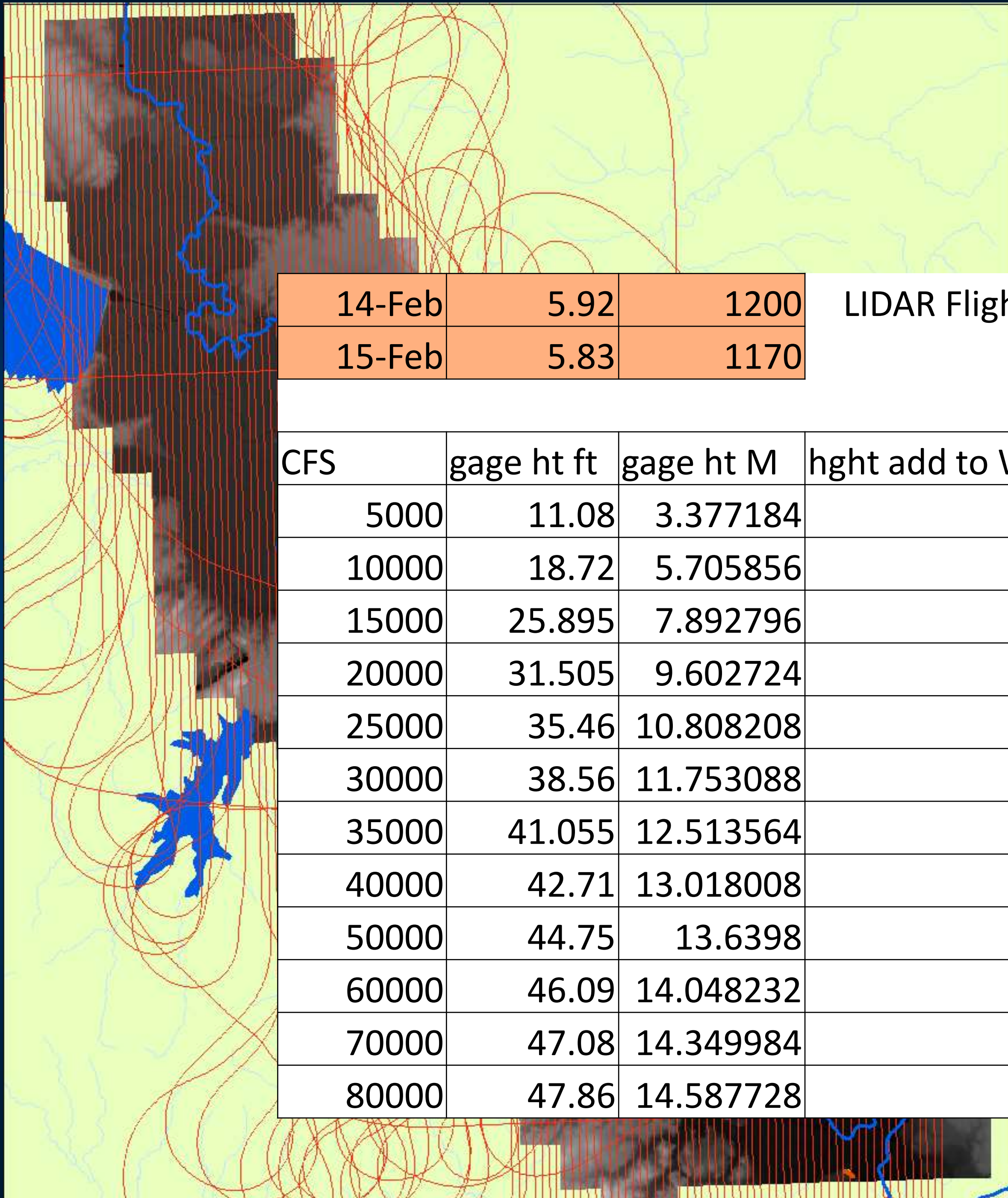
Developing Modeled Water Surfaces: Using USGS gage data

- Utilized gage at downstream extent of Reach 2
- Used USGS published rating curve
- Kept same flood flows of: 5, 10, 15, 20, 25, 30, 35, 40, 50, 60, 70 and 80k cfs
- Water surface elevations generated for each discharge



Gage at the downstream extent of Reach 2

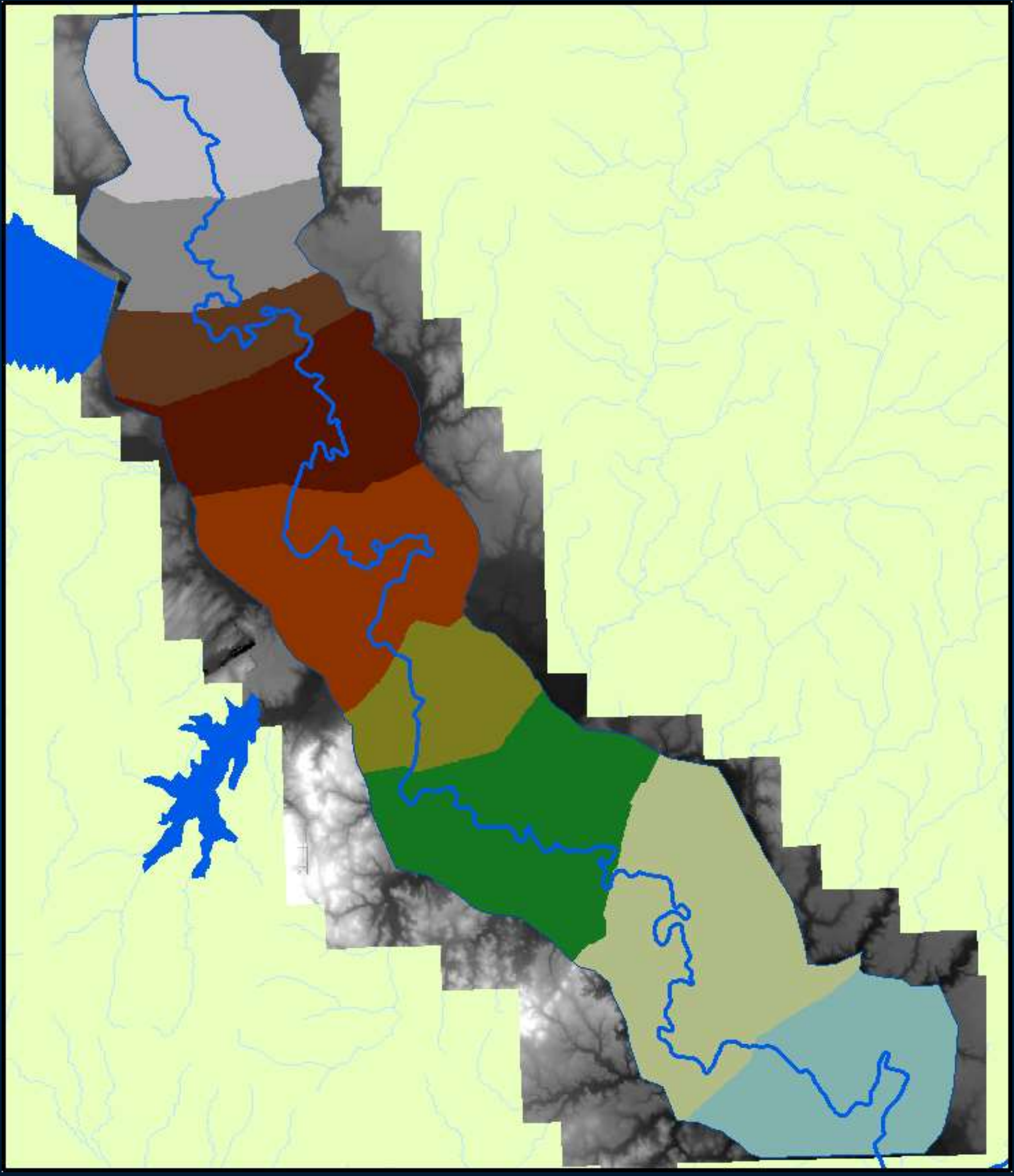
Reach 2
60k example



14-Feb	5.92	1200	LIDAR Flight Dates
15-Feb	5.83	1170	

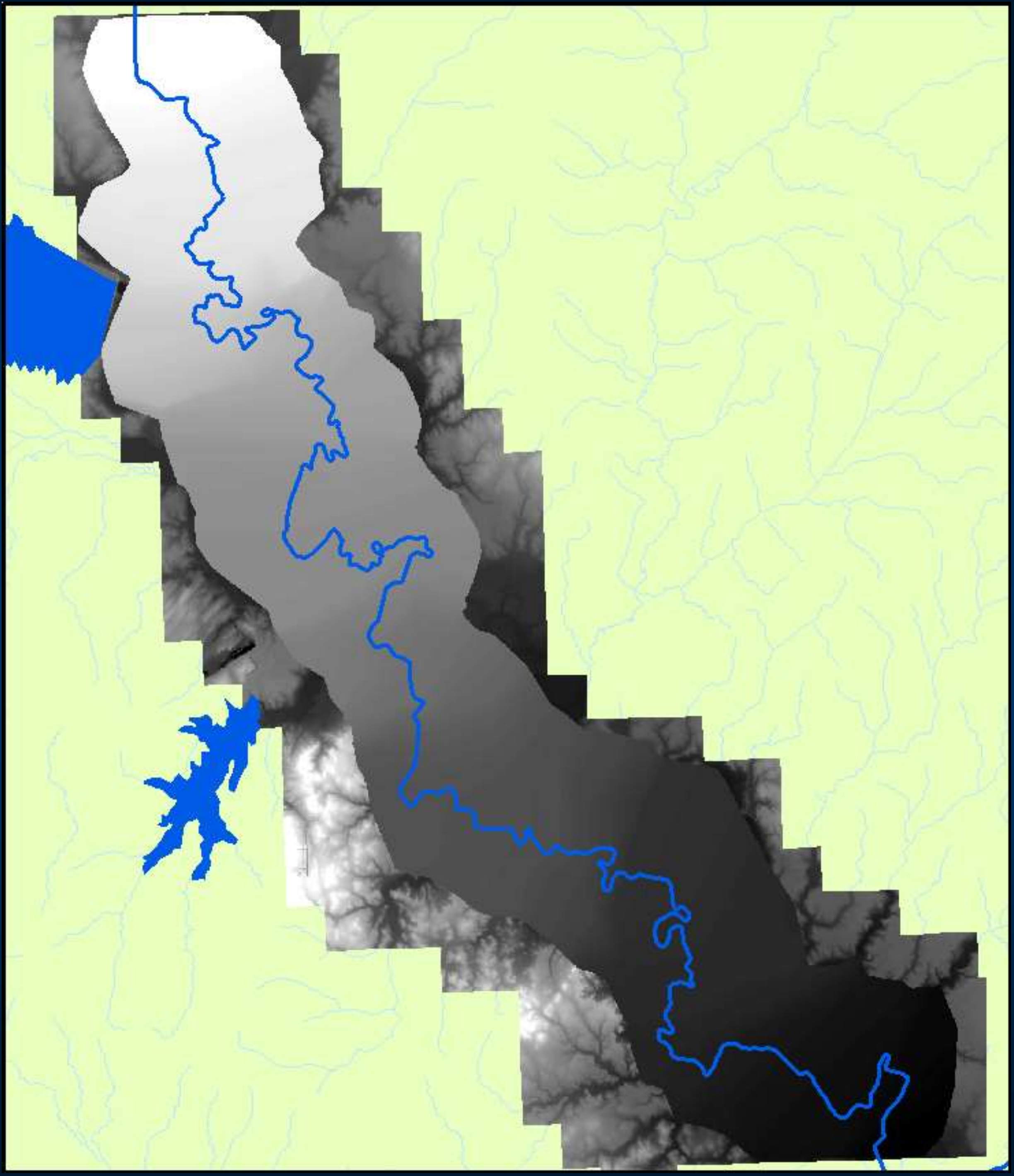
CFS	gage ht ft	gage ht M	hght add to WSE points M
5000	11.08	3.377184	1.59
10000	18.72	5.705856	3.92
15000	25.895	7.892796	6.10
20000	31.505	9.602724	7.81
25000	35.46	10.808208	9.02
30000	38.56	11.753088	9.96
35000	41.055	12.513564	10.72
40000	42.71	13.018008	11.23
50000	44.75	13.6398	11.85
60000	46.09	14.048232	12.26
70000	47.08	14.349984	12.56
80000	47.86	14.587728	12.80

LIDAR flight
s to establish
lationship
ween LIDAR
and USGS
ge heights



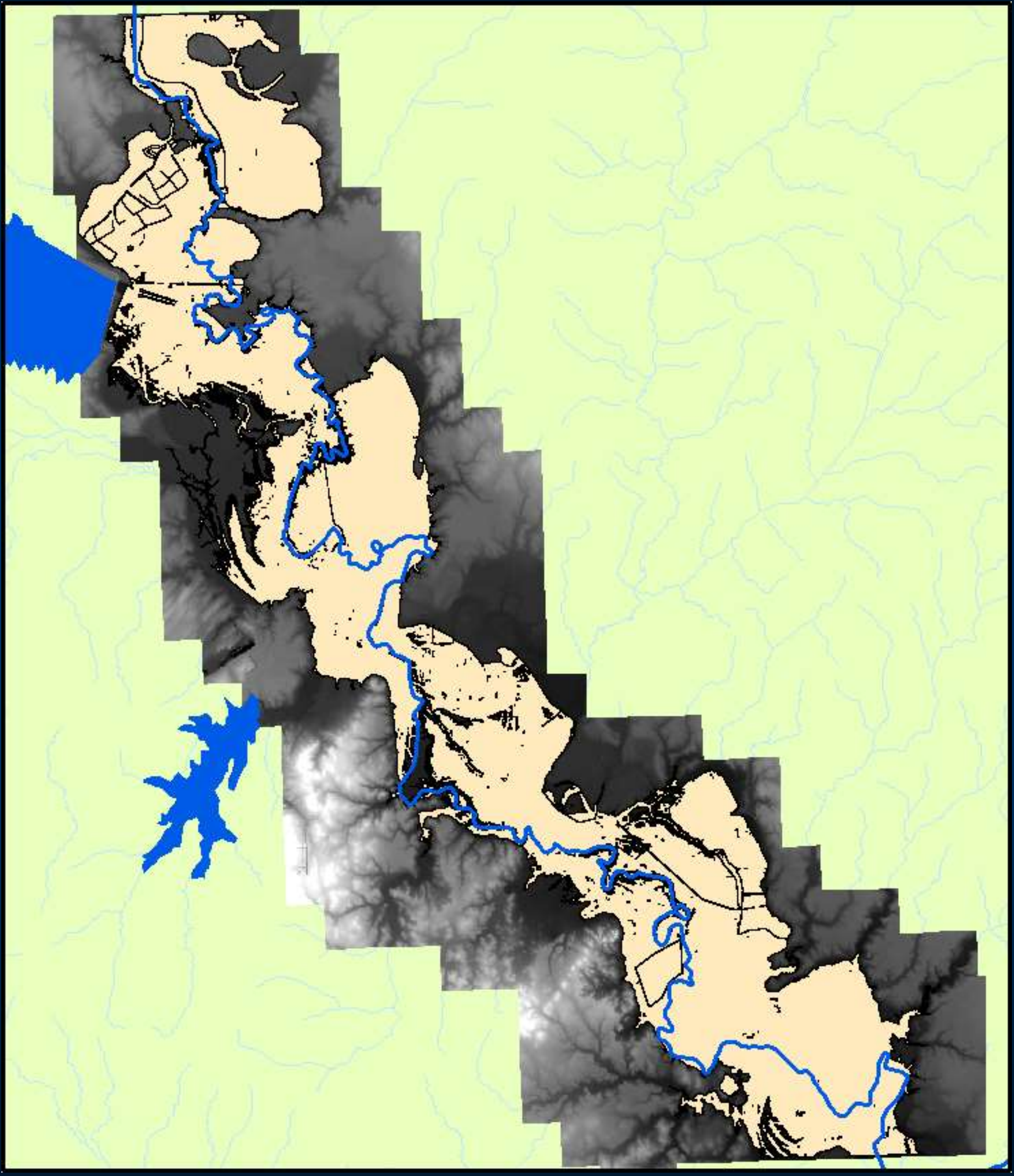
Reach 2
60k example

TIN generated to produce a smooth water surface and converted to raster



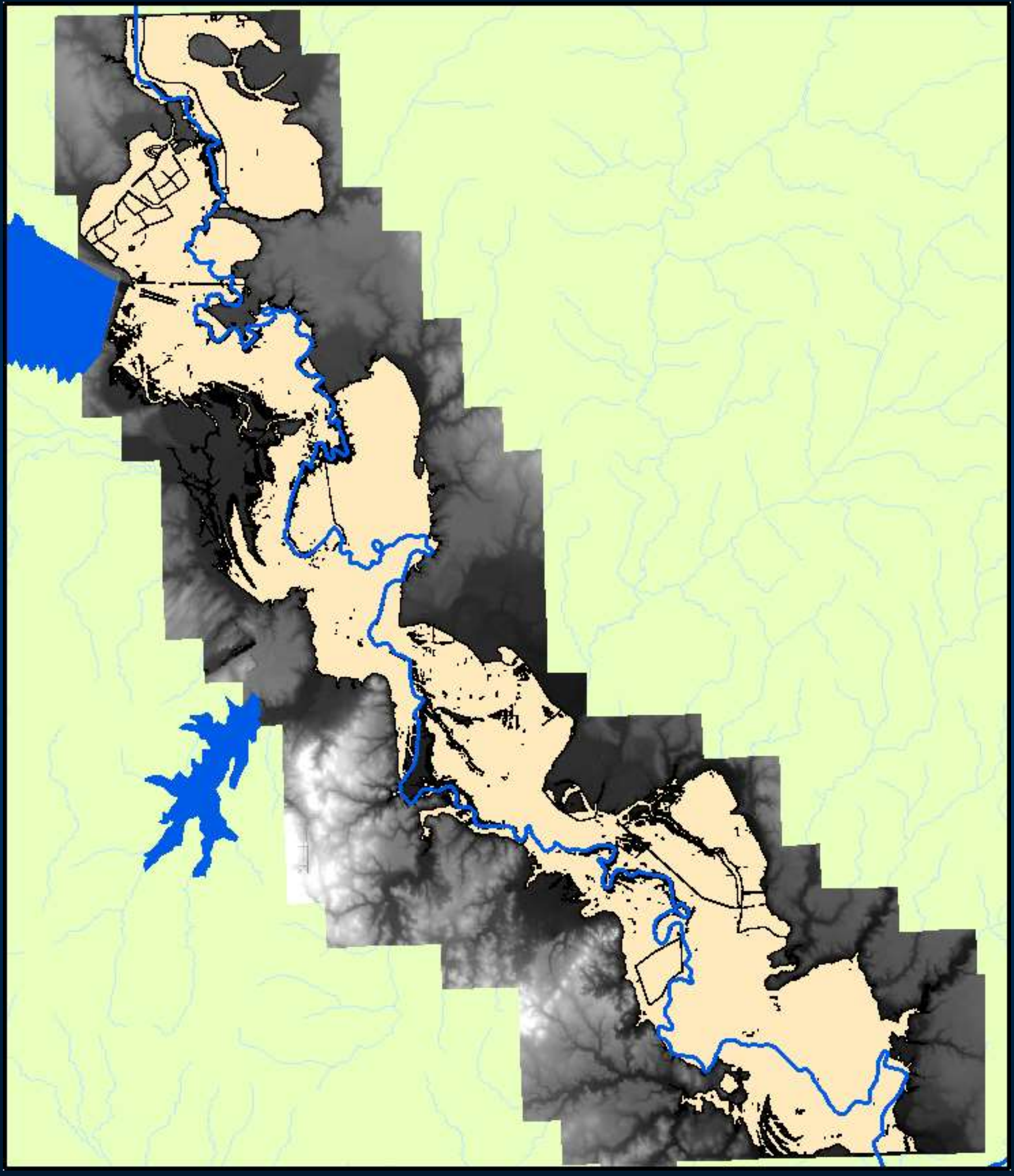
Reach 2
60k example

Water surface raster used to query DEMs and calculate inundation extent using ERDAS Imagine



Reach 2
60k example

Total calculated inundated area.

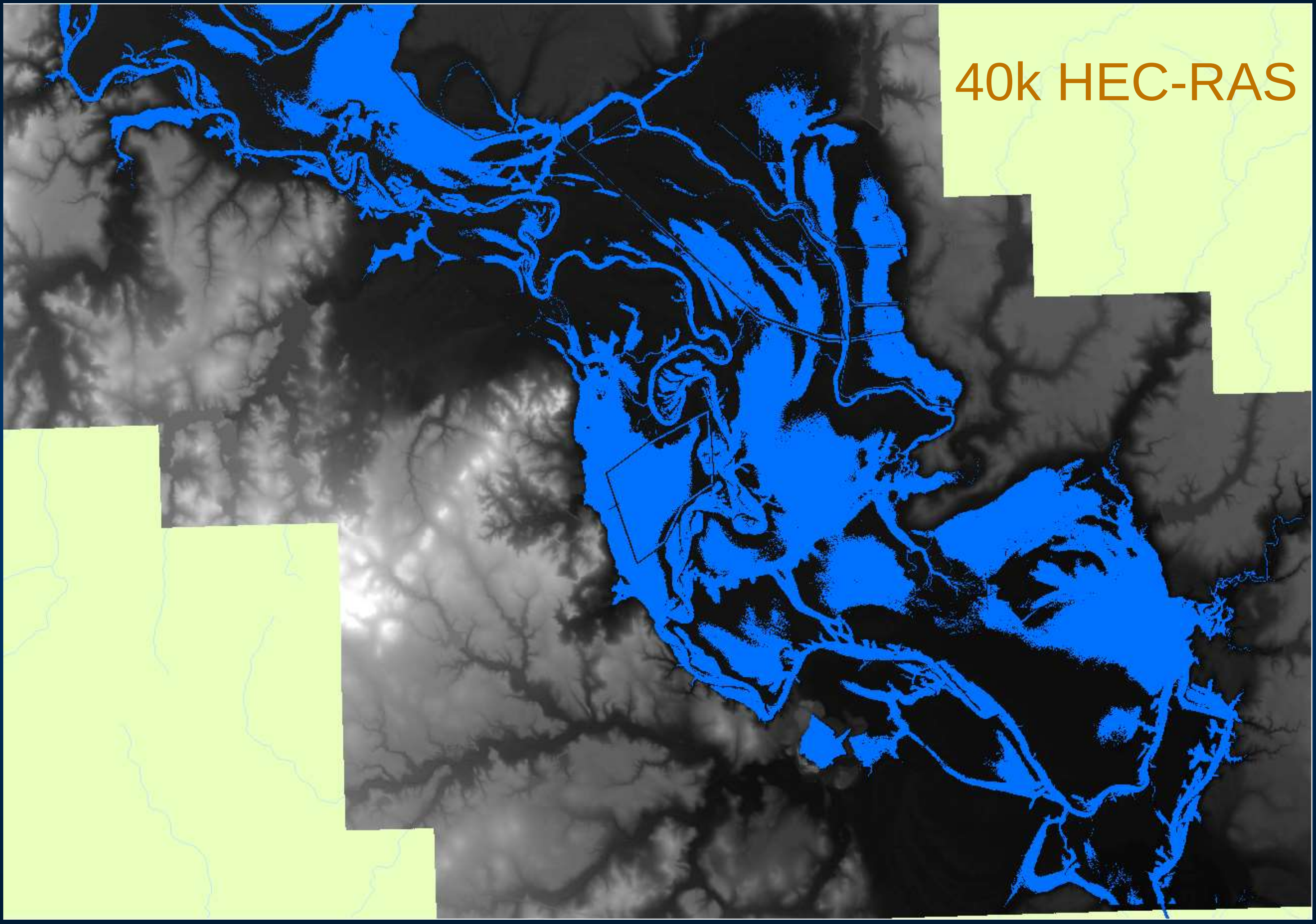


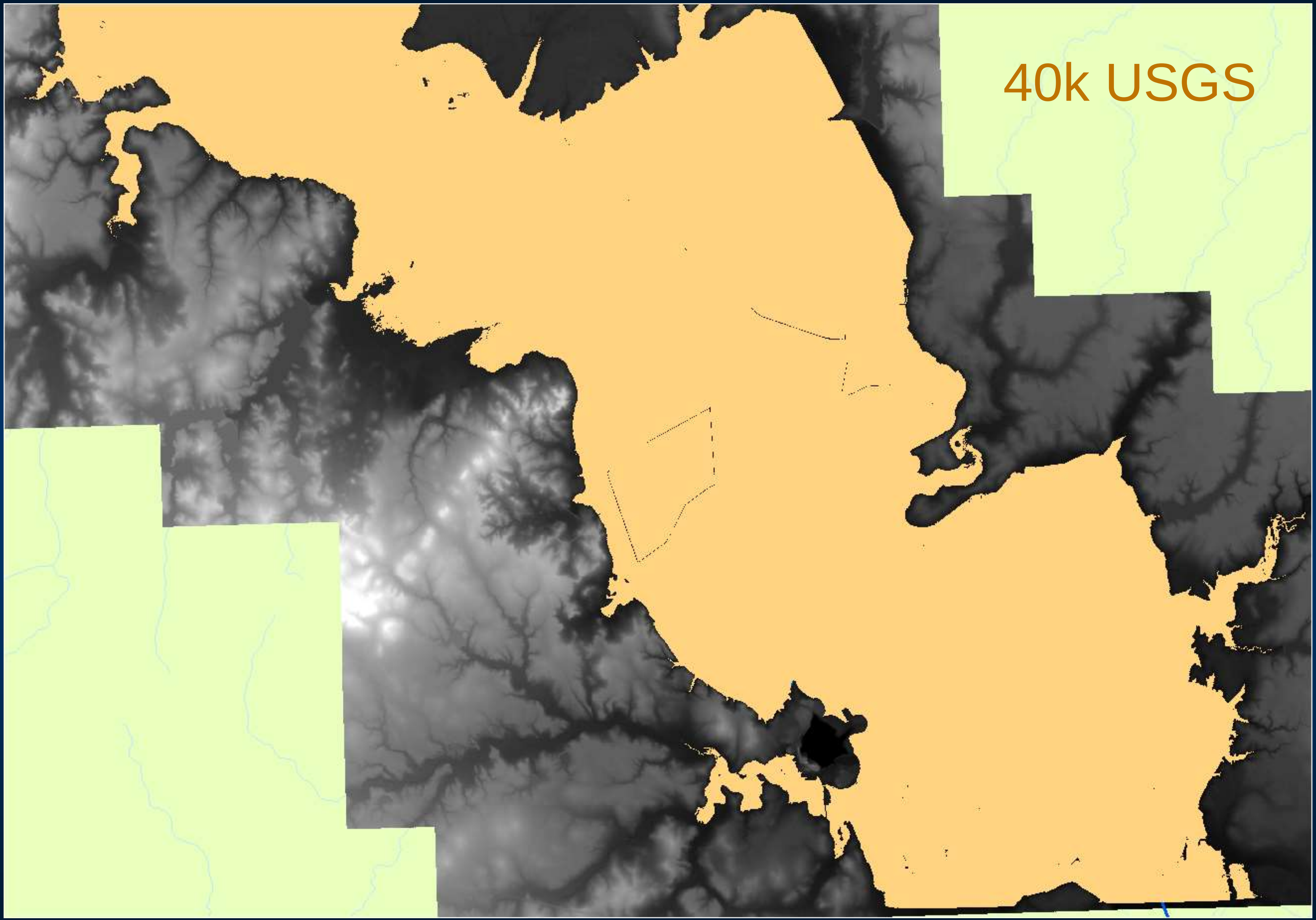
Reach 2
80K example

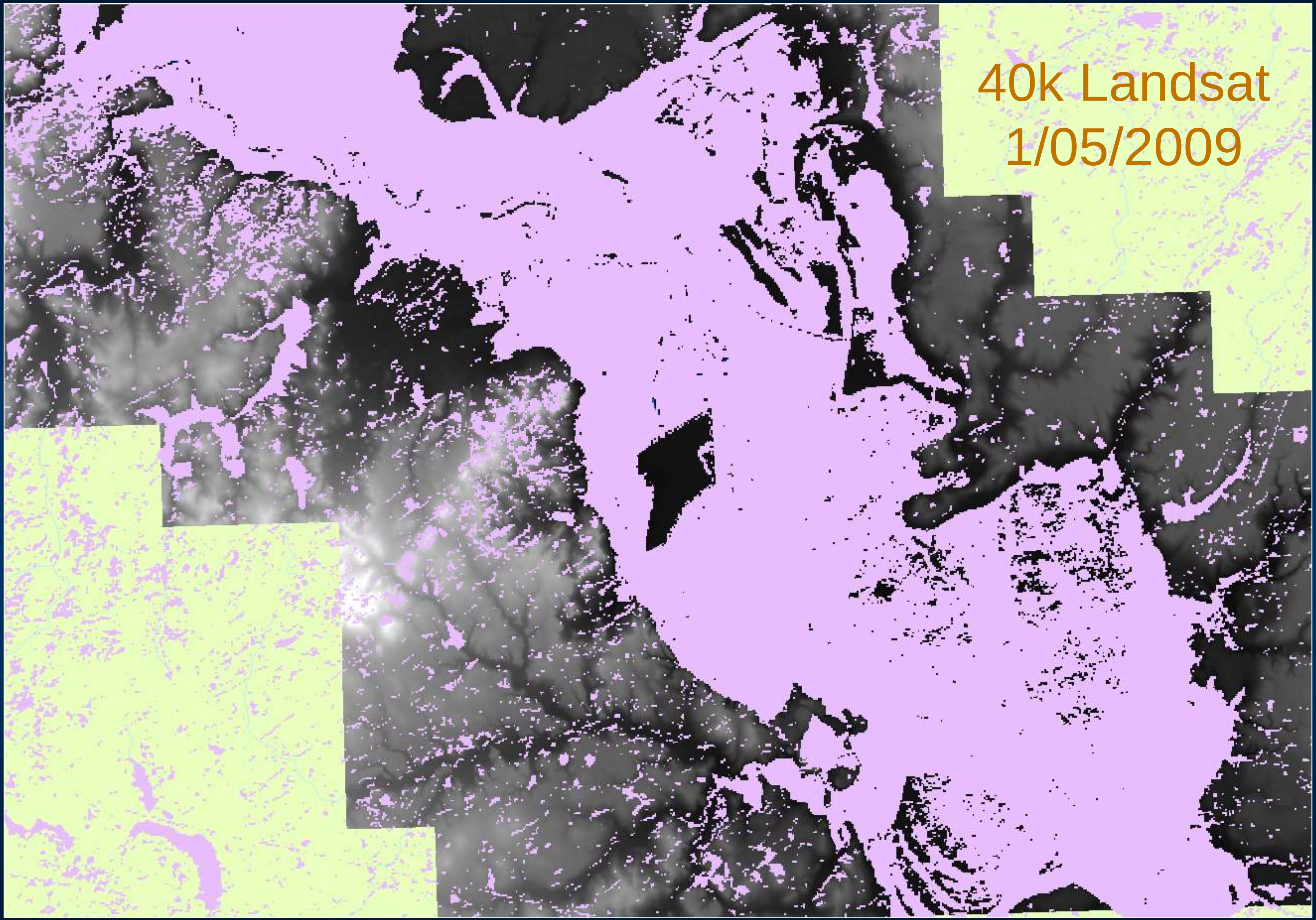
Total calculated inundated area.

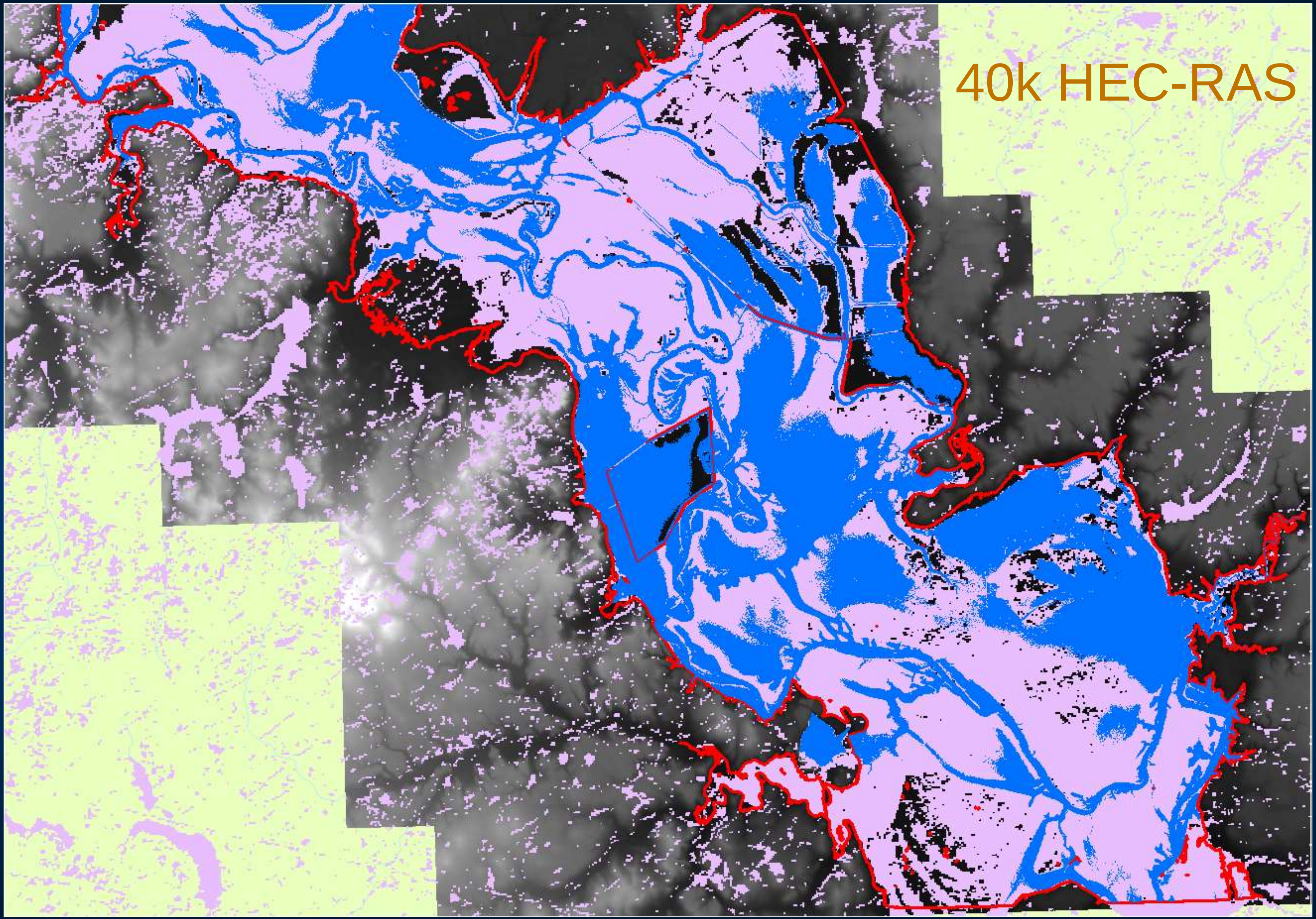
Landsat Imagery

- Using USGS gage data, searched for dates of targeted flood events
- Ran unsupervised classification on 15 classes, recoded into three classes (water, no water, and mixed)


40k HEC-RAS


40k USGS


40k Landsat
1/05/2009


40k HEC-RAS