Mapping Wetlands and Beaver Activity across Colorado and the Colorado River Basin using Machine Learning

Sarah Marshall, Matt Lythe, Dan Bull, Marinus Boon

Colorado Natural Heritage Program

Lynker Analytics

Lynker

Colorado Watershed Assembly
www.coloradowater.org

Overview

Why?

- Track **wetland change** - droughts, beaver activity, restoration, policy change, etc.
- Better mapping for the most **dynamic wetlands**
- Mapping wetlands across large geographic scales is expensive and time-consuming

Objective

- Track **extent of vegetated wetlands, open water, and beaver- influenced wetlands** over time using **repeatable** and **low-cost** Machine Learning (ML) techniques

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Study Area: Colorado River Basin (U.S.

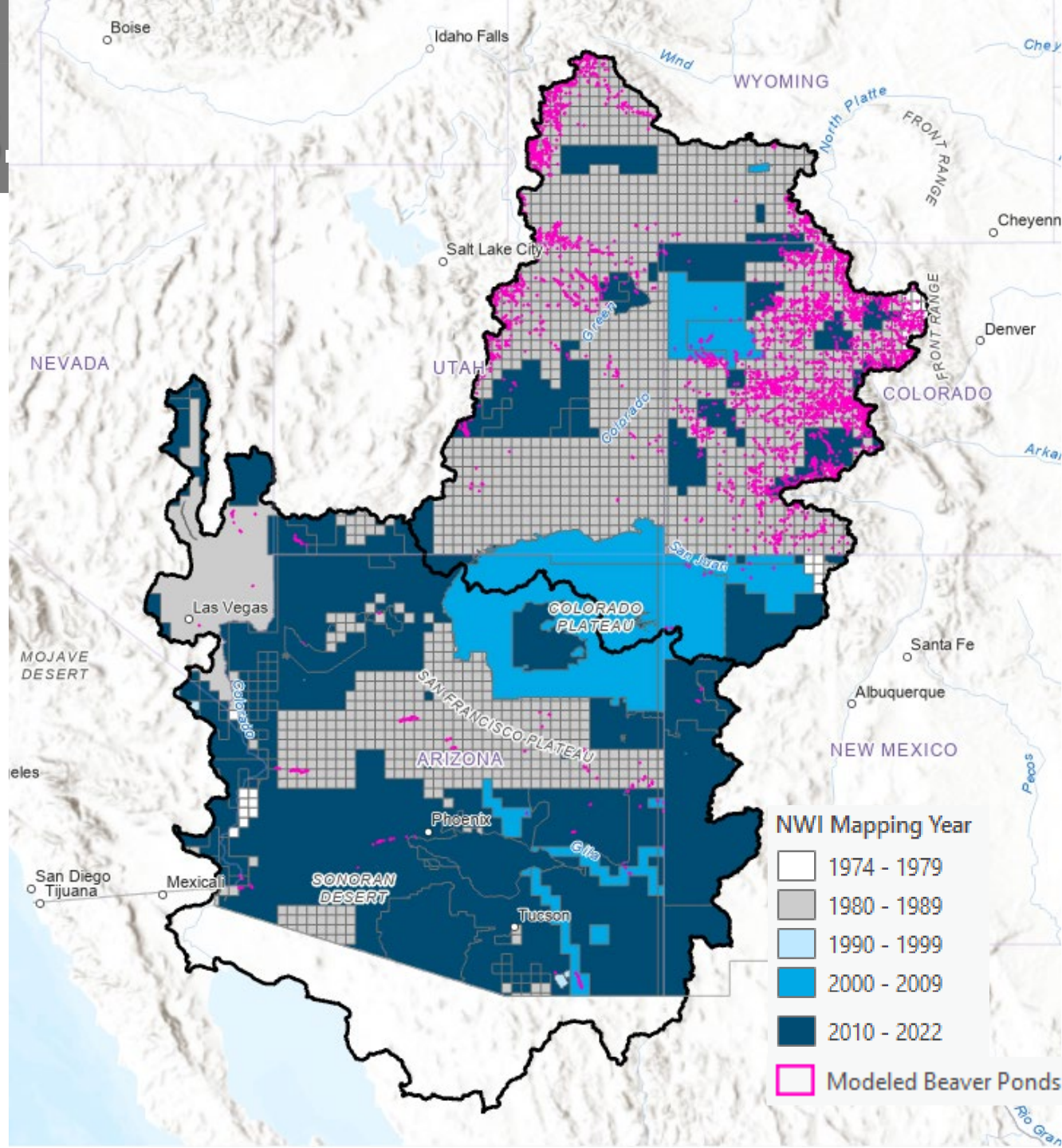
Model Extent: U.S. portion of CRB

Four Level 1 Ecoregions

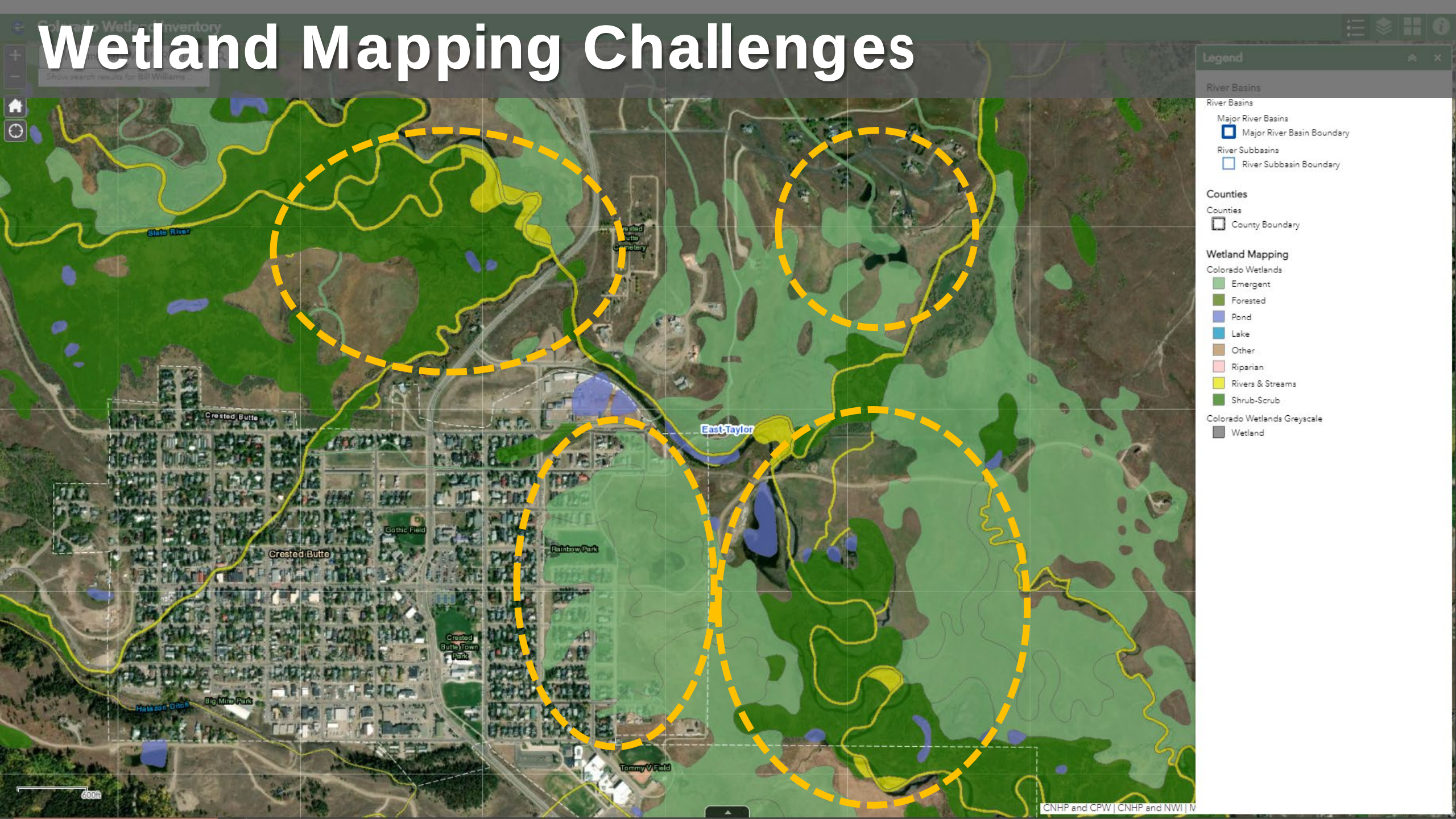
Seven states

Training: 24 NAIP tiles (>300 mi^2)

Time Period: 2012-2020 v1; through 2022 for v2



Wetland Mapping Challenges



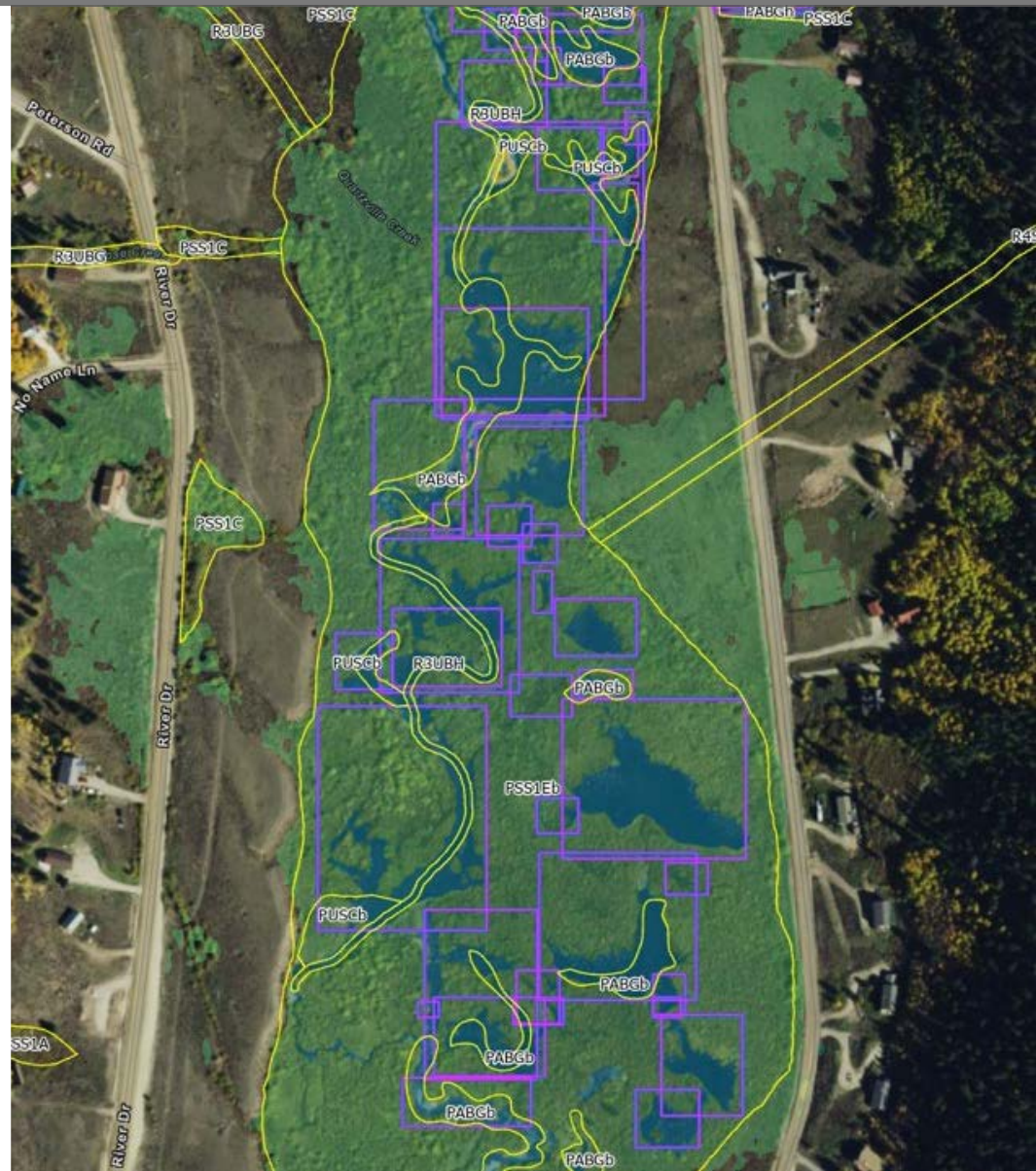
Desired Modeling Outcomes

Three Models

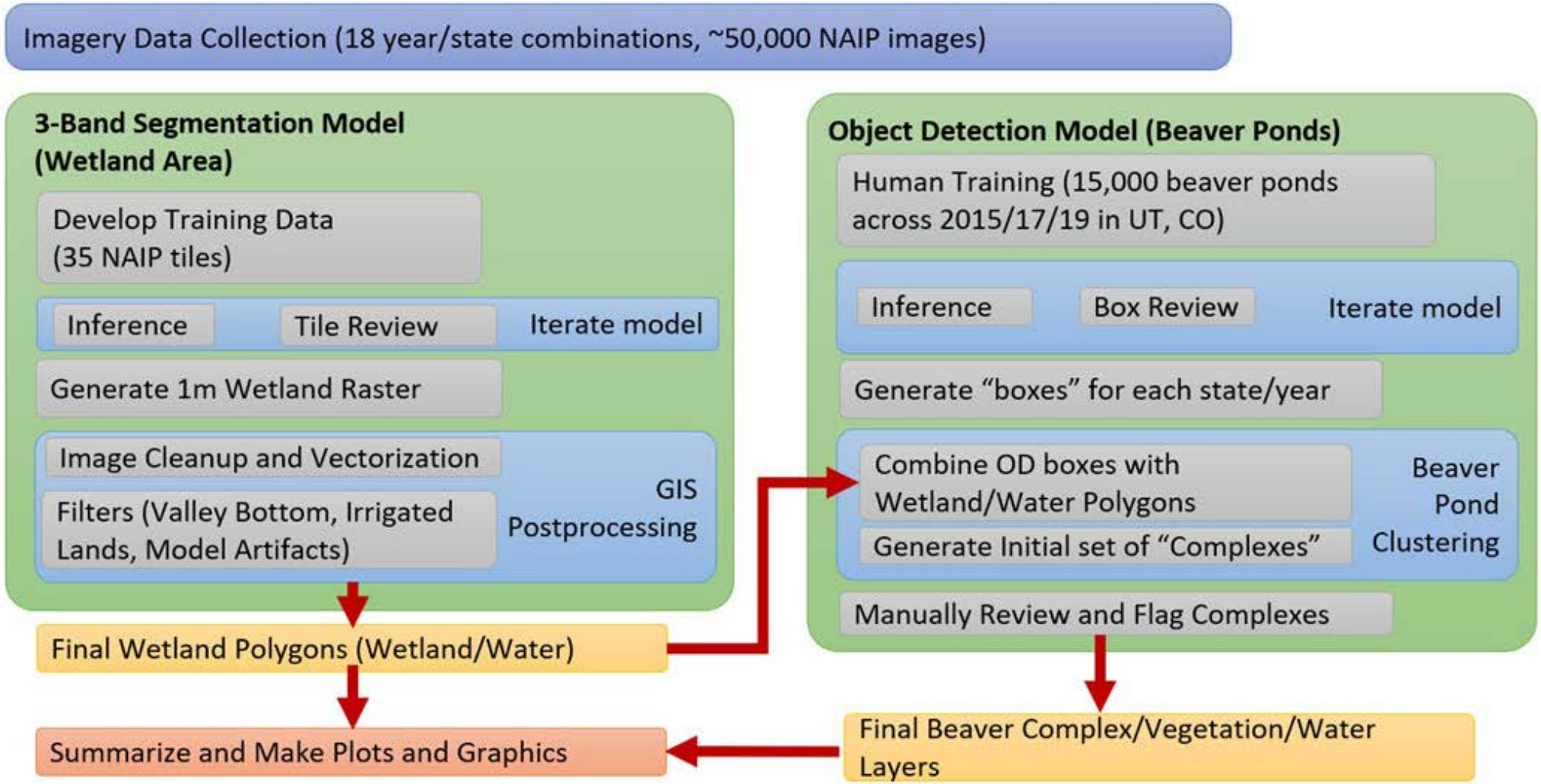
1. Define and classify vegetated wetlands
2. Map standing and flowing water (lakes, ponds, rivers, etc.)
3. Identify distinct beaver ponds

Final Result

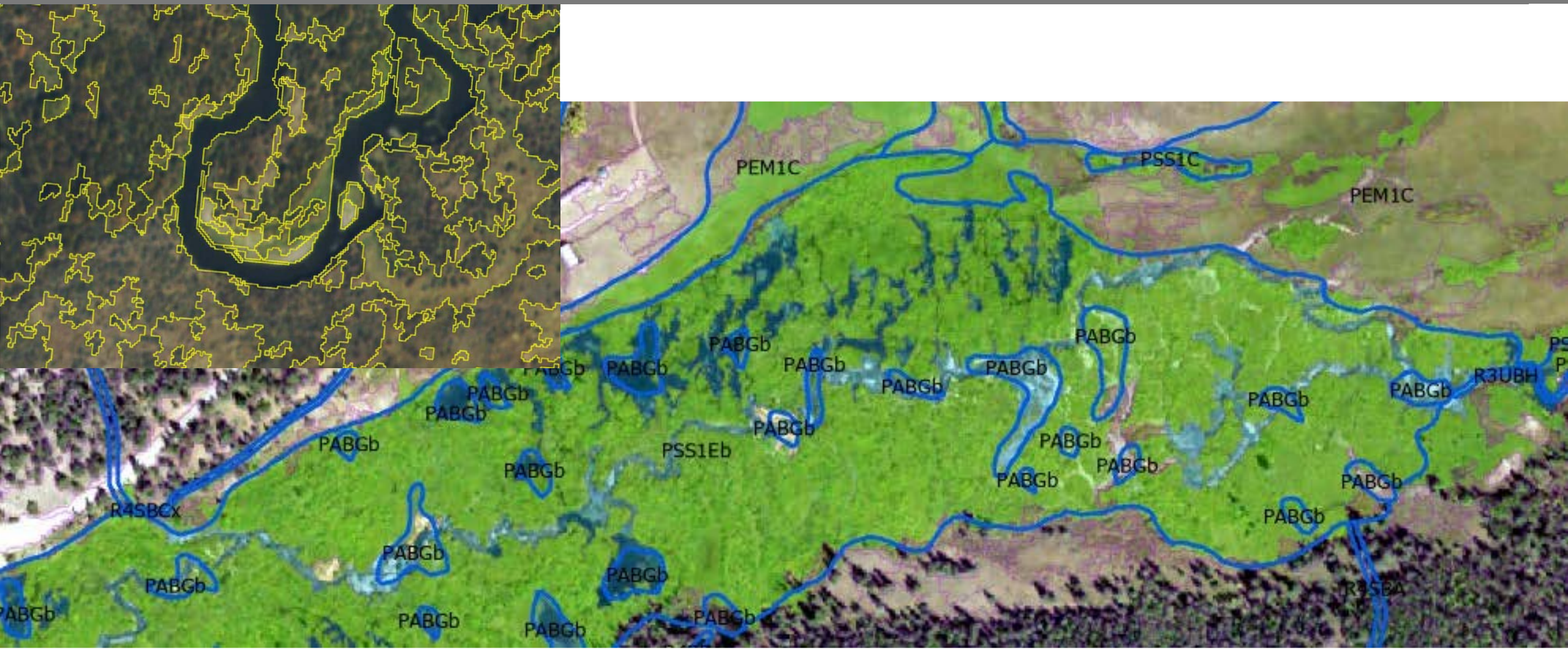
1. Map with averaged vegetated wetland footprint for the last 5-10 years
2. Water mapped for each NAIP year
3. Beaver ponds for each NAIP year



Methods


Imagery Data Collection (18 year/state combinations, ~50,000 NAIP images)
3-Band Segmentation Model (Wetland Area)
Develop Training Data (35 NAIP tiles)
Inference
Tile Review
Iterate model
Generate 1m Wetland Raster
Image Cleanup and Vectorization
Filters (Valley Bottom, Irrigated Lands, Model Artifacts)
GIS Postprocessing
Final Wetland Polygons (Wetland/Water)
Summarize and Make Plots and Graphics
Object Detection Model (Beaver Ponds)
Human Training (15,000 beaver ponds across 2015/17/19 in UT, CO)
Inference
Box Review
Iterate model
Generate "boxes" for each state/year
Combine OD boxes with Wetland/Water Polygons
Generate Initial set of "Complexes"
Beaver Pond Clustering
Manually Review and Flag Complexes
Final Beaver Complex/Vegetation/Water Layers

Segmentation Training and Early Performance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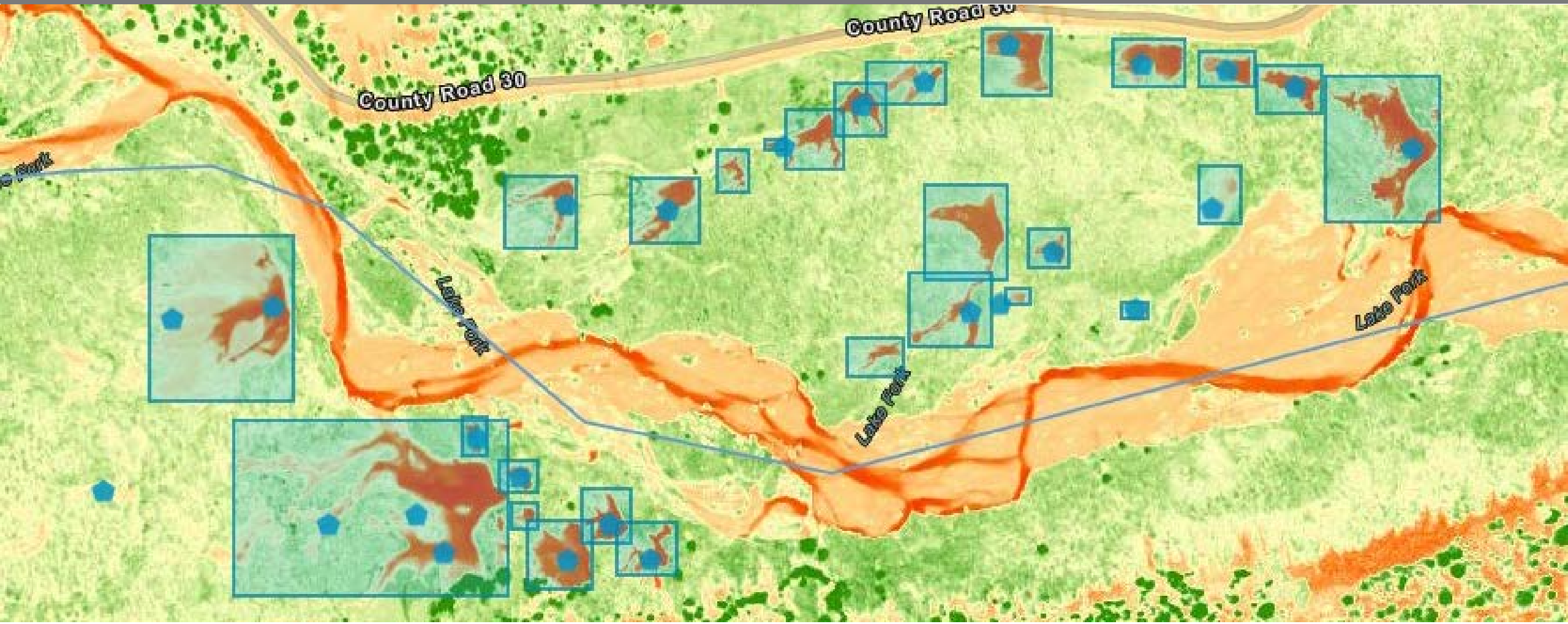
Beaver Pond Model Training



Challenges and Limitations

- **NAIP Data Variations -**
  - Large differences between years/states → comparing inference results between years showed larger variation than expected.
    - Corrected with a histogram match
      - Still challenges with snow, variation in brightness, blurred portions of imagery, etc.

- **Seasonal variations** due to NAIP flight timing
  - Early season images (e.g., June) compared with later season images (e.g., October) mean that some of the change detected will be season differences rather than year-to-year variation.

- **Imagery Resolution**
  - Earlier imagery (pre-2017) was 1-m resolution; later imagery was 0.6-m.
  - Results from later imagery showed better detail.

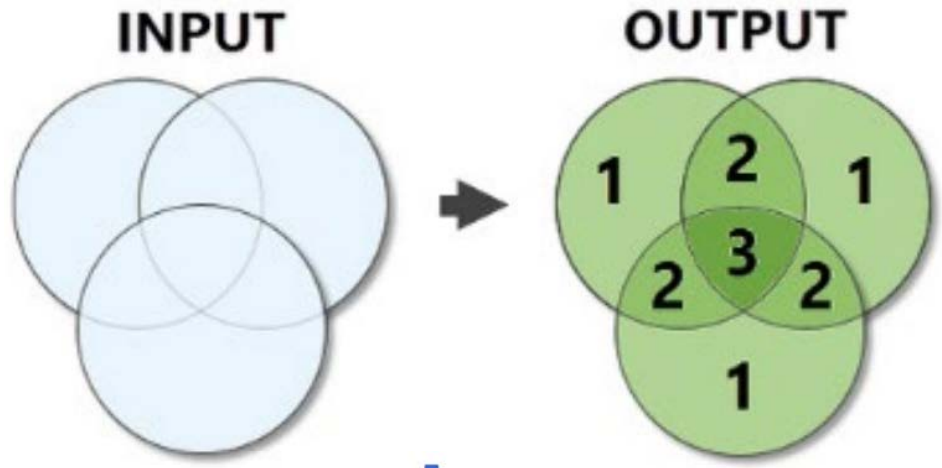
Bringing it All Together...

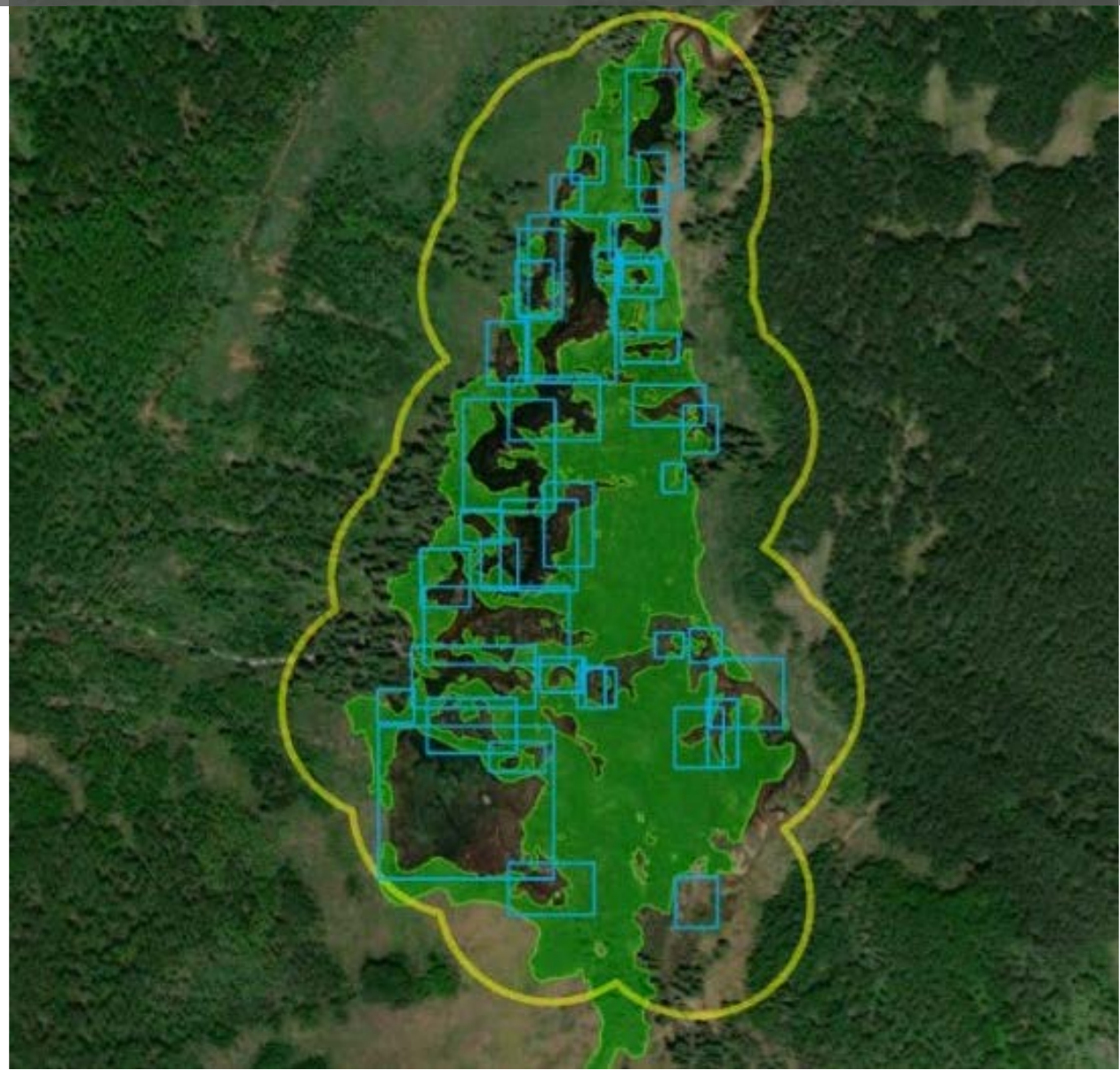
GIS Post Processing

- Raster data cleaning and vectorization
- Valley-bottom buffer filtering process
- Size thresholding
- False positive removal via intersection

Beaver activity areas

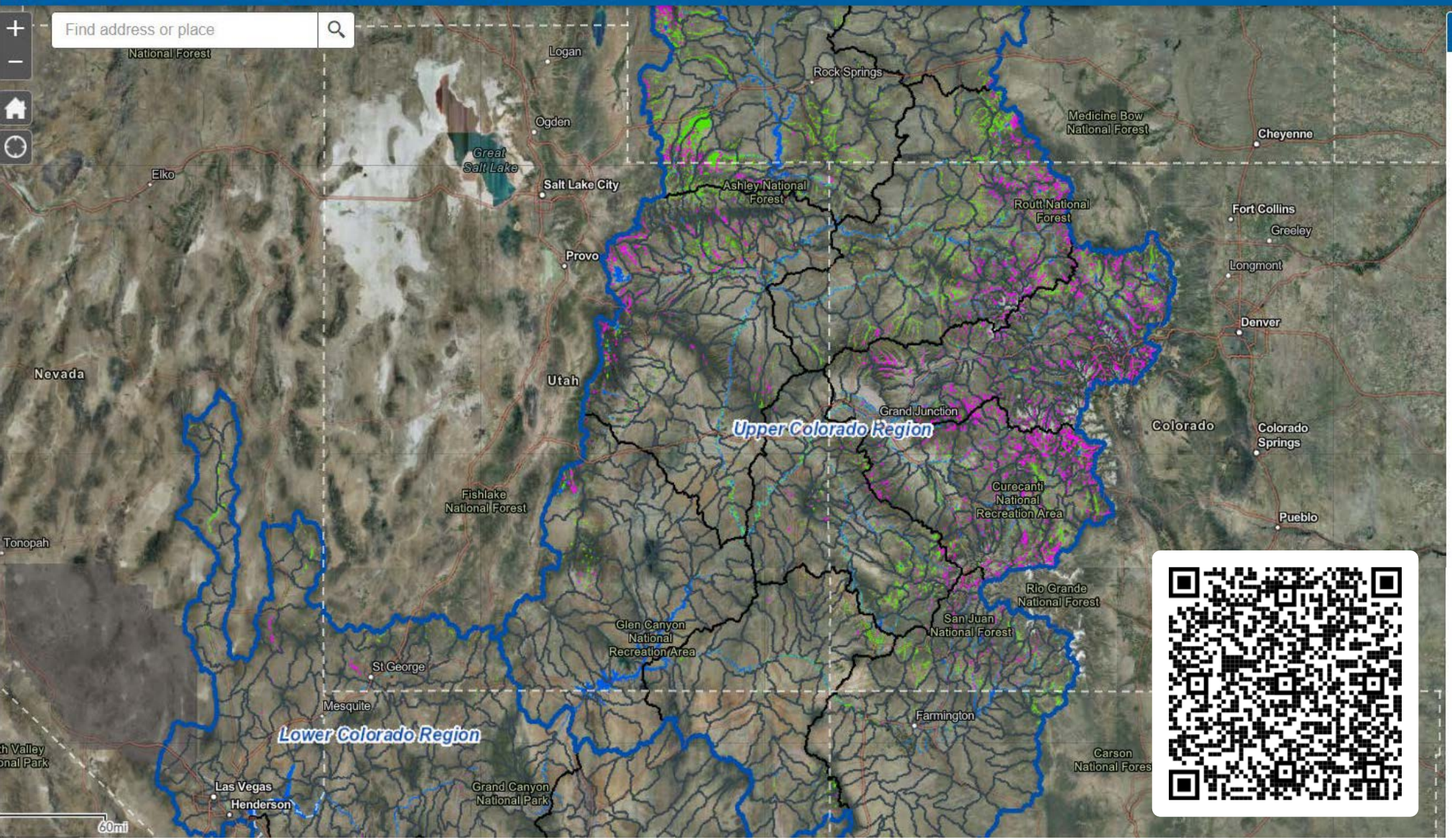
Decision by quorum





Colorado River Basin Dynamic Wetland Mapper

More Project Information



About

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The Colorado River Basin Dynamic Wetland Mapper is intended to assist watershed managers, planners, and restoration practitioners explore modeled wetland and open water areas, along with recent beaver activity and potential beaver habitat suitability across the basin for riverscape restoration.

The mapper displays several modeled datasets depicting wetlands, open water, beaver activity areas (complexes), and summary information by HUC10 watershed across the entire Colorado River basin within the United States. Use the controls in the upper right to toggle between the Legend, Layer List and Base Maps.

Mapping was produced by Lynker and CNHP (2022) with funding from the Walton Family Foundation. The supporting segmentation and object detection machine learning models were developed by Lynker using wetland and beaver pond training data and technical guidance from CNHP. Model inputs included National Agricultural Imagery Program (NAIP) aerial imagery composites for three periods: 2012-2013, 2016-2017, and 2018-2020, and used a quorum approach to define final mapped vegetated and open water areas as meeting those criteria in at least 2/3 modeled time periods.

Watershed units (2-, 8-, and 10-) from the Watershed Boundary Dataset (WBD; USGS) are included in the mapper to support watershed-scale restoration and

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Results: Model Accuracy

Segmentation Model

Intersection over Union (IoU) Analysis

tile	year	wetland	water	shoreline	Multiclass F1 (no shoreline)
3710718_se	2017	0.627	0.793	0.175	0.710
3810601_sw	2017	0.821	0.873	0.076	0.845
3910737_se	2019	0.486	0.634	0.008	0.552
4210913_se	2012	0.619	0.900	0.013	0.764
4211014_nw	2012	0.972	0.796	0.057	0.899
All test		0.775	0.859	0.062	**0.815**

F1 score of 0.815 suggests that model is generally doing well across the study area, particularly where wetlands are more abundant.

Object Detection Model

Twenty (HUC10) watersheds randomly selected for validation

State	True Positive	False Positive	False Negative	F1
CO	382	161	432	0.56
UT	350	239	435	0.50
WY	198	93	168	0.60
AZ	28	37	12	0.53
NM	1	2	93	0.020
Total	959	532	1140	**0.53**

The **model performed well in identifying beaver ponds** within wetlands where there was a **characteristic shape** and a **strong water signature**.

Model not ready for use without human review and integration with segmentation model.

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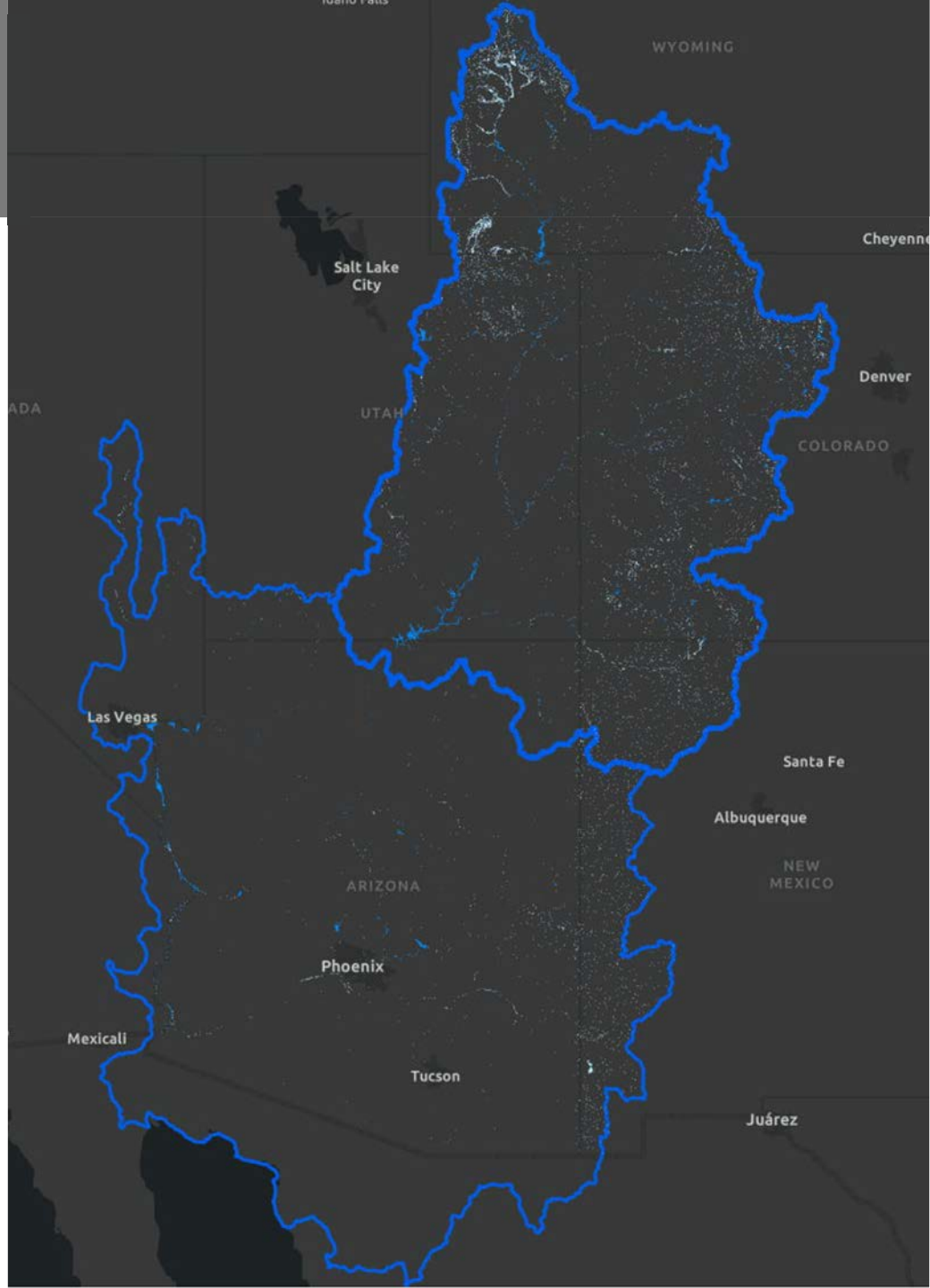
Modeled Wetland Acreage

Total **vegetated wetland area**: **954,104 acres**

Total **open water area**: **605,455 acres** (*196,586 acres excluding lakes >200 acres*)

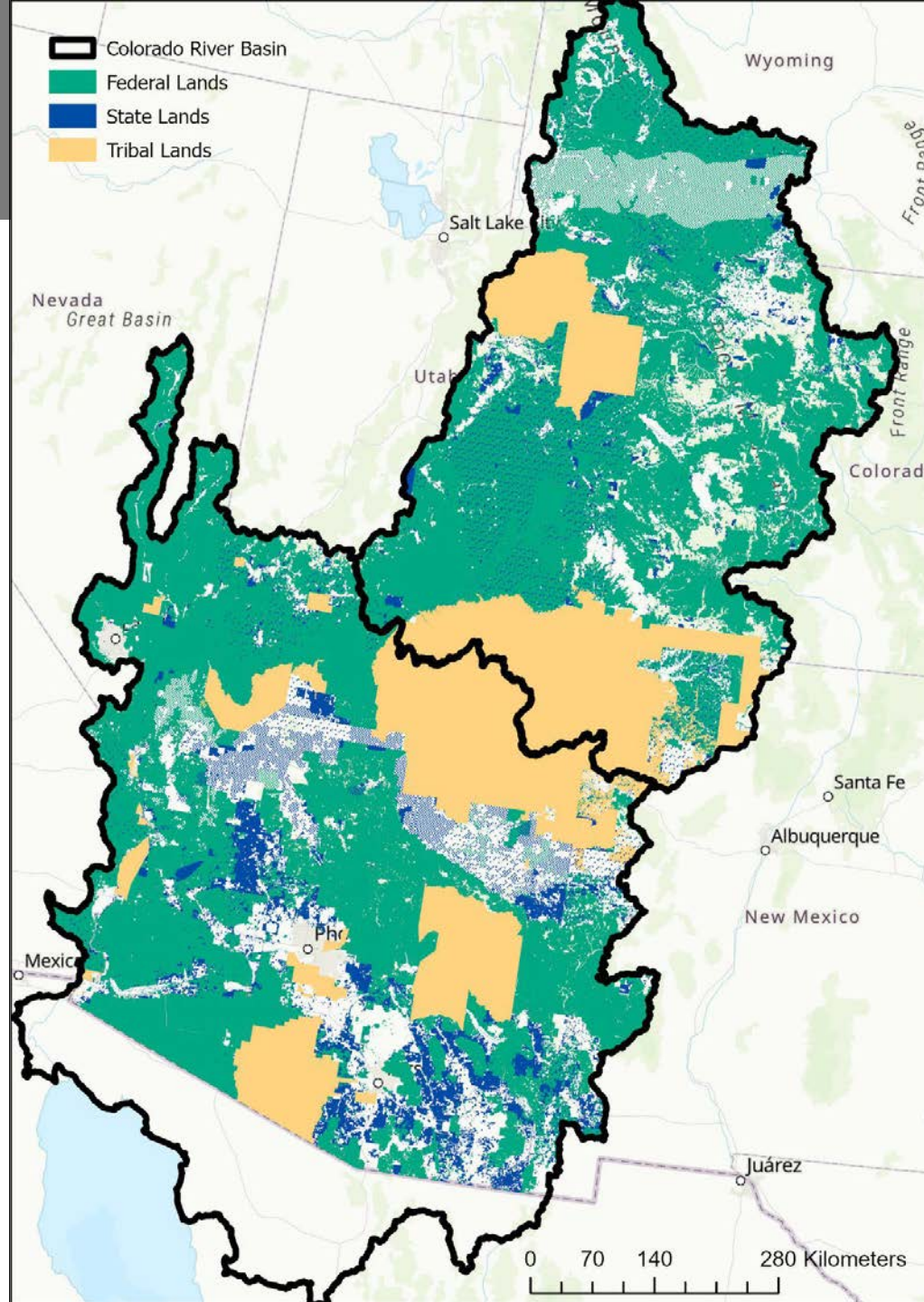
State	Wetland Area (acres)	Open Water Area (acres)	Combined Area (acres)	Combined NWI Wetland Area (acres)
Colorado	342,376	109,003	451,379	**456,257**
Wyoming	336,436	85,560	**421,996**	386,195
Utah	136,277	175,963	312,240	**355,229**
Arizona	94,079	131,732	225,811	**375,289**
Nevada	10,479	73,358	83,837	**127,644**
New Mexico	29,433	15,200	**44,633**	42,656
California	5,024	14,639	19,663	**31,495**
Total	**954,104**	**605,455**	**1,559,559**	**1,774,765**



Wetland Area by Ownership

Land Ownership/ Management	Open Water Area (acres)	% of Total Area	Wetland Area (acres)	% of Total Area	Beaver Pond Area (acres)	% of Total Area	Pond Count (2018-2020)	% of Total Ponds
Entire Basin								
Federal	469,547	**77.6**	363,895	38.1	3,887	**74.1**	30,658	**75.1**
State	41,922	6.9	46,633	4.9	280	5.3	1,433	3.5
Tribal	30,948	5.1	99,164	10.4	229	4.4	1,757	4.3
Private and Other	63,038	10.4	444,412	**46.6**	846	16.1	6,986	17.1
Total	605,455	100.0	954,104	100.0	5,242	100.0	40,834	100.0

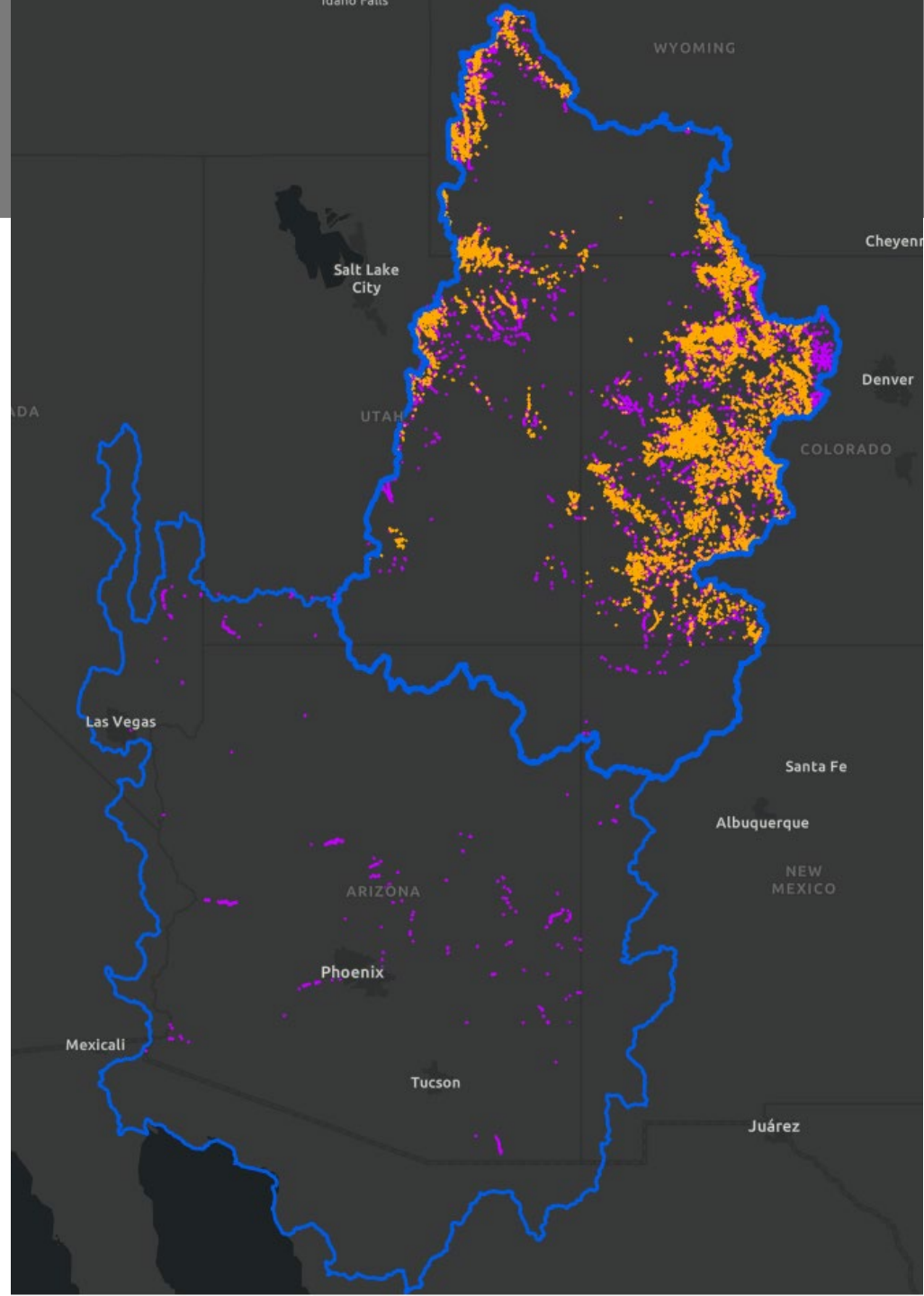
More open water and beaver activity on federal land; vegetated wetlands on private/other land



Beaver Activity

- **40,834** beaver ponds (~**5,242 acres**) in 2018/2019/2020
- **5,626** verified beaver activity areas (complexes)
- No NWI beaver wetlands in AZ, NM, or NV within the basin
- Expansion of mapped beaver areas in upper basin (CO, WY, UT)

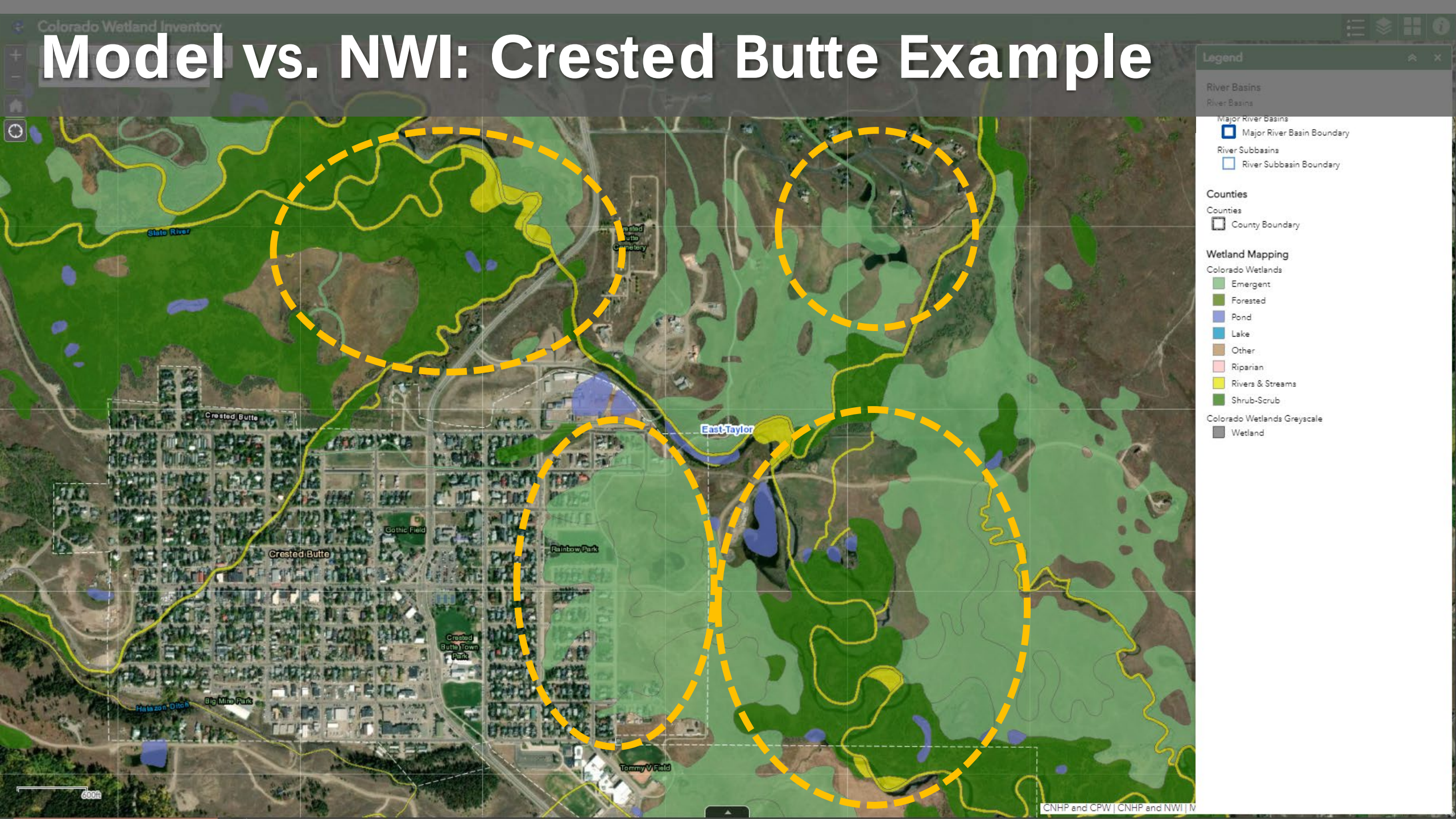
State	Verified Activity Areas	Ponds in Activity Areas
Colorado	**3,487**	**27,191**
Wyoming	1,179	6,779
Utah	737	5,210
Arizona	182	1,470
New Mexico	23	110
Nevada	17	72
California	1	2
Total	**5,626**	**40,834**



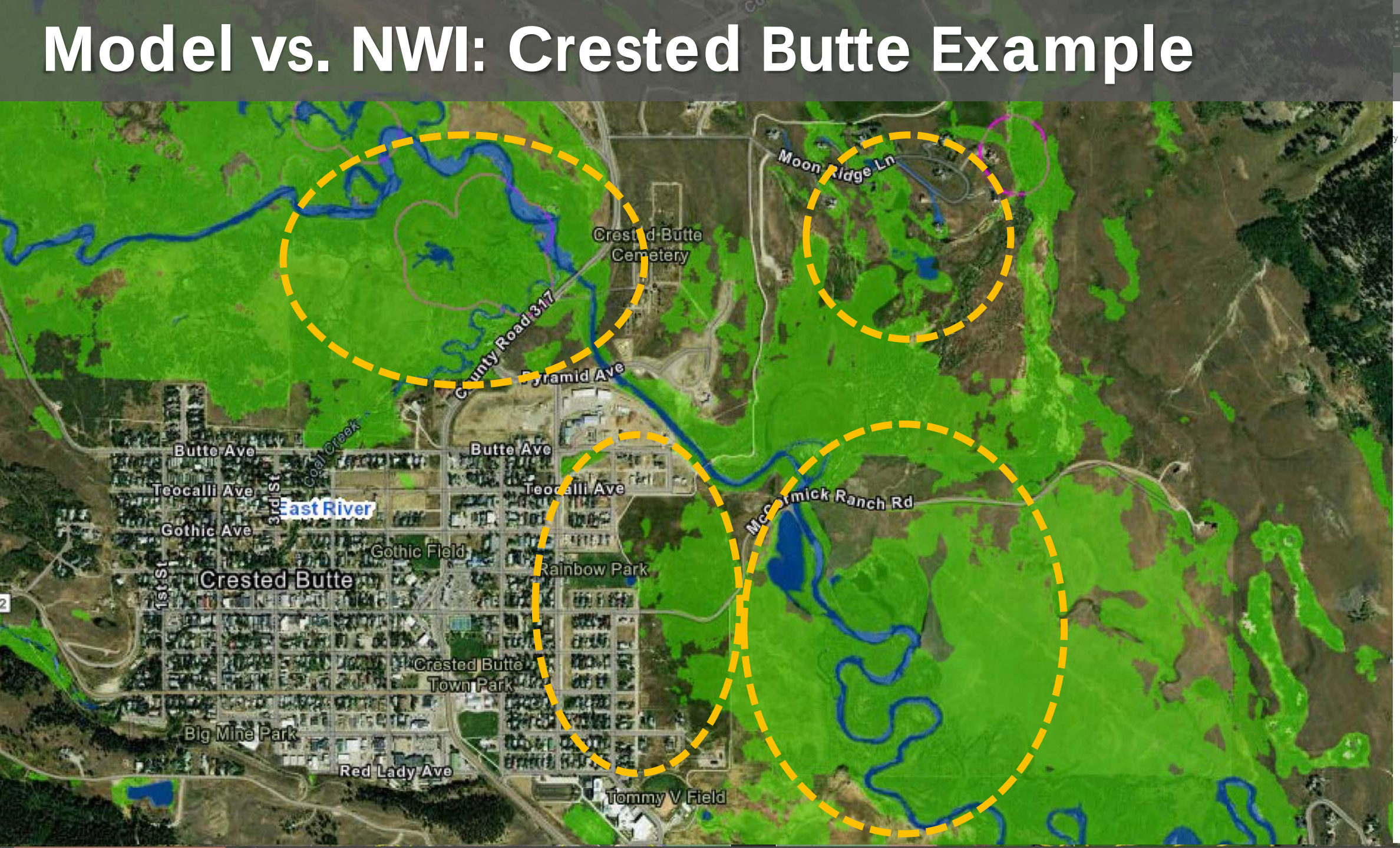
Colorado Beaver Stats (2019)

- **3,487 verified beaver complexes**
- **27,191 modeled ponds** within verified complexes
- 89% of model-identified ponds in a verified beaver complex
- **Mean**: 7.5 ponds/complex
- **Median**: 4 ponds/complex
- **Max**: 139 ponds/complex

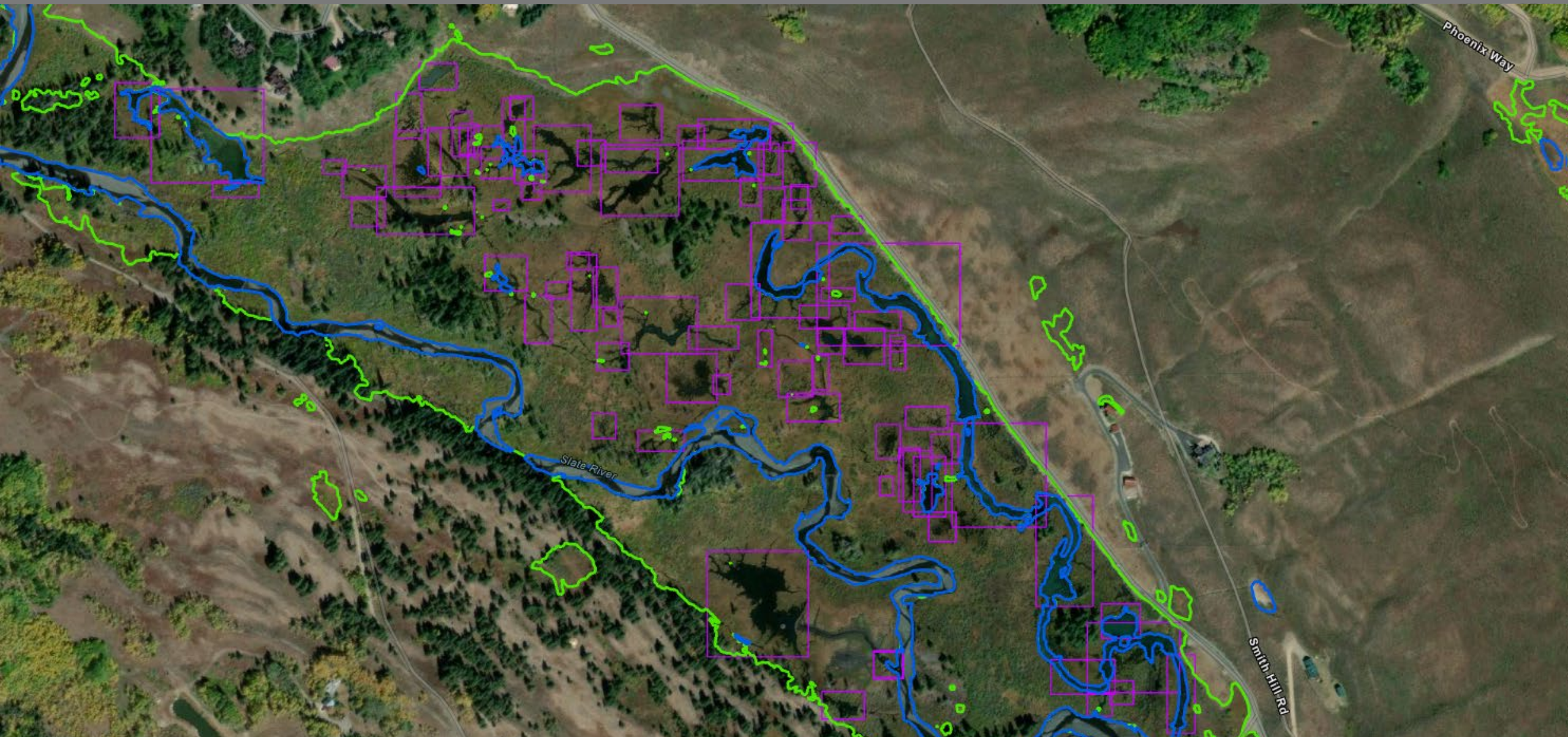
Model vs. NWI: Crested Butte Example



Model vs. NWI: Crested Butte Example

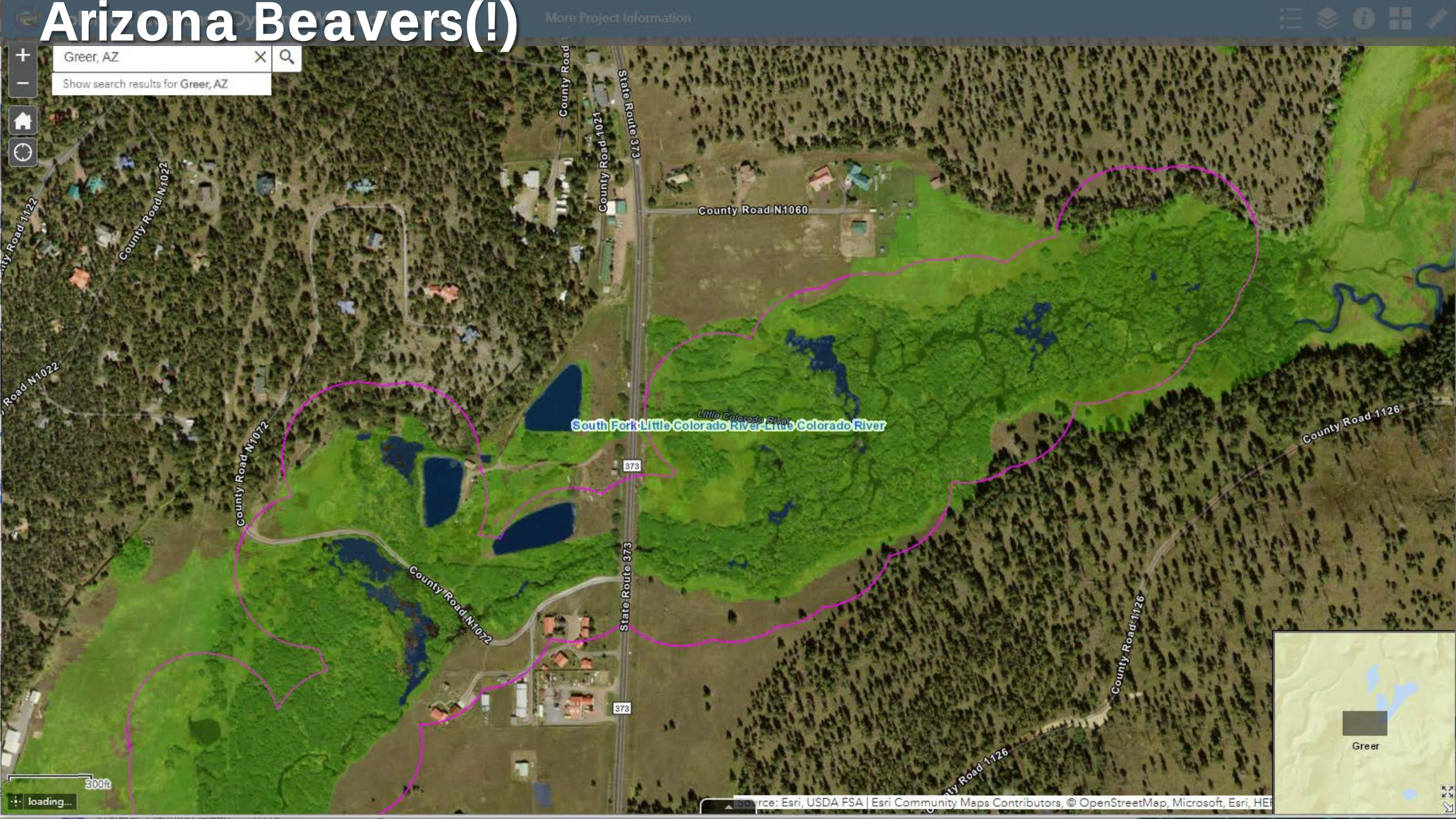


Slate River, Upstream of Crested Butte

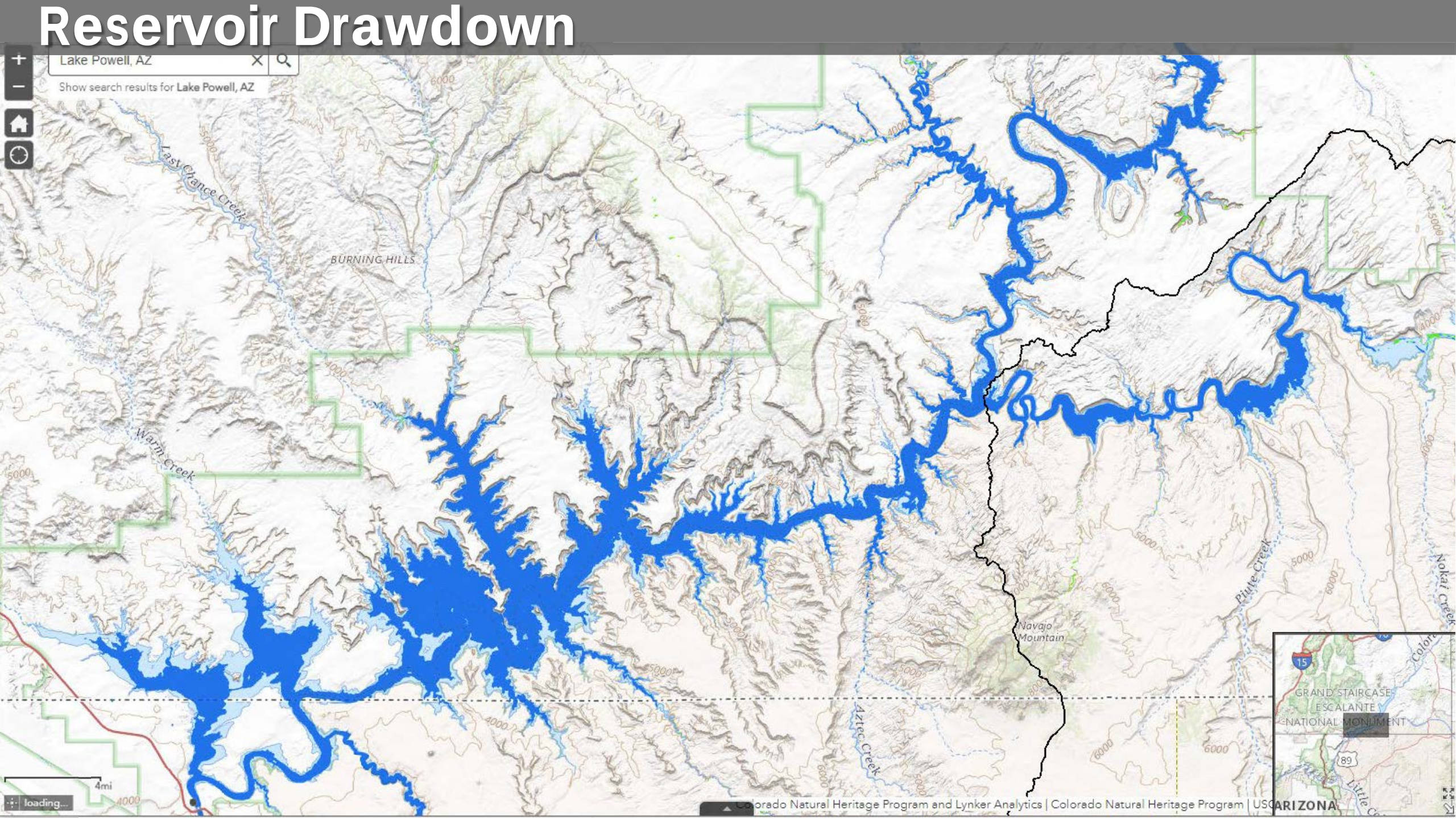


Utah NWI Comparison

Arizona Beavers(!)



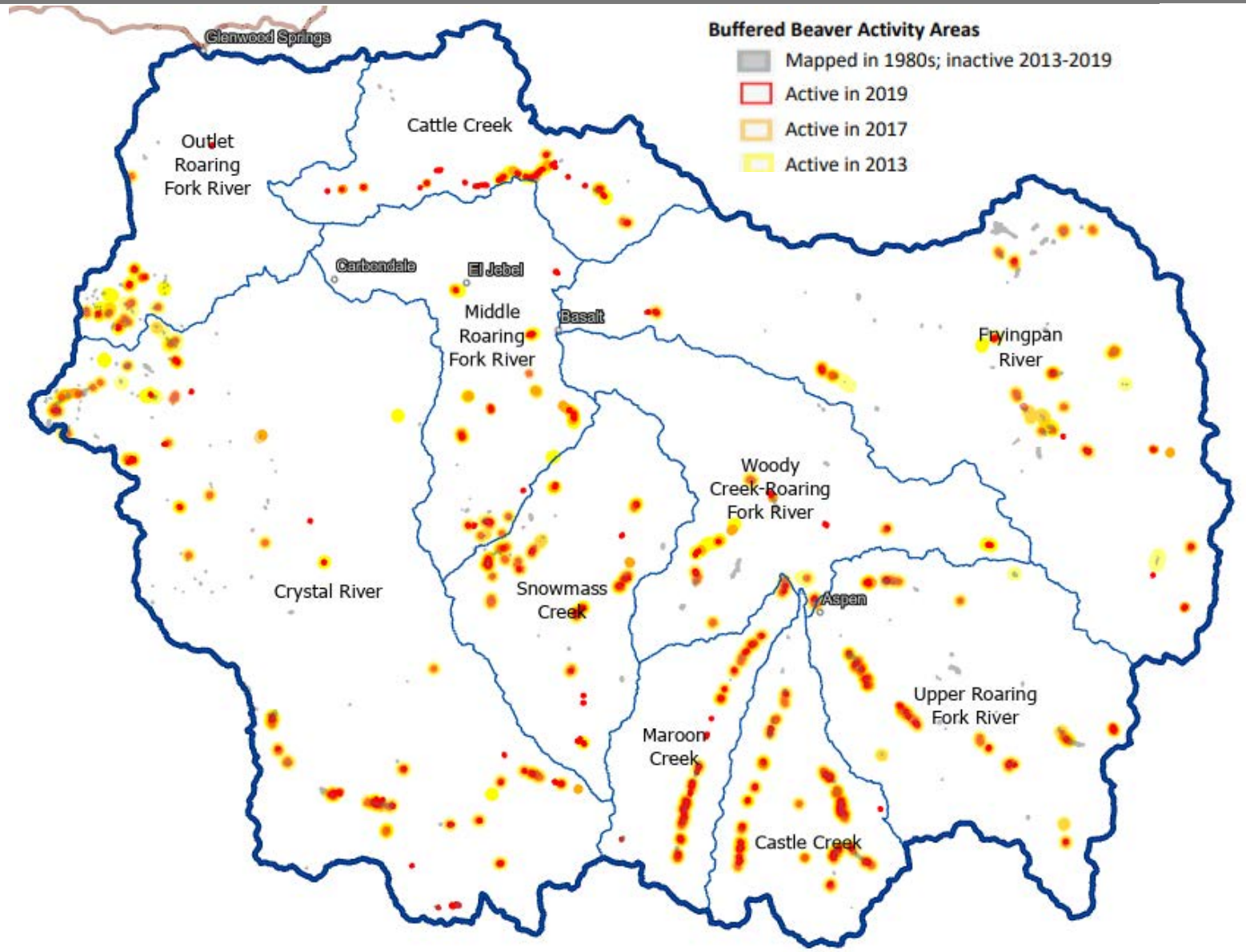
Reservoir Drawdown



Early Applications: Beaver Activity Over Time

Beaver “hotspot” mapping

- 1980s NWI vs. newer beaver activity
- Potential **restoration** and coexistence areas
- Helpful for looking at **beaver wetland functions**
  - Habitat
  - Sediment capture
  - Fire
  - Drought resilience



Ongoing Work

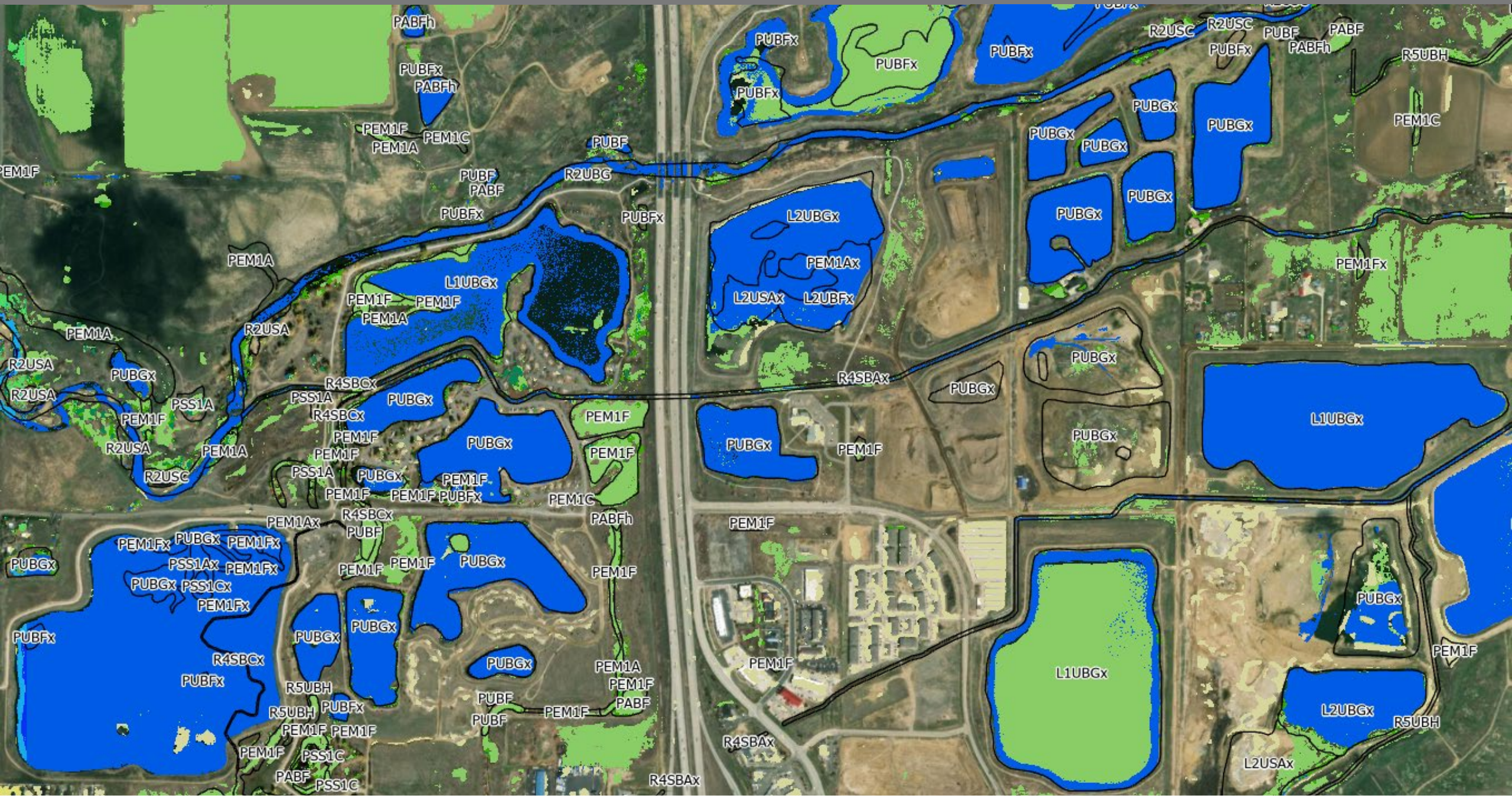
- Expand models → all Colorado (2013-2021)
  - 40 training areas across CO
  - Add wetland classes (SS, EM, etc.)
- Run newer models for CO River basin through 2022 NAIP year
- Improve **water** class
- Add **topographic data** (LiDAR)
  - Probability of wetland occurrence
  - Valley bottoms
  - Depressions
- **Improve beaver pond detection** model
  - Fewer missed ponds

Slate River, CO Example from Previous Model...

New Models with Wetland Classes + 2013-2021 Water

New Models vs. NWI

New Models in Eastern Colorado



Thank You!

Sarah Marshall

Sarah.Marshall@colostate.edu

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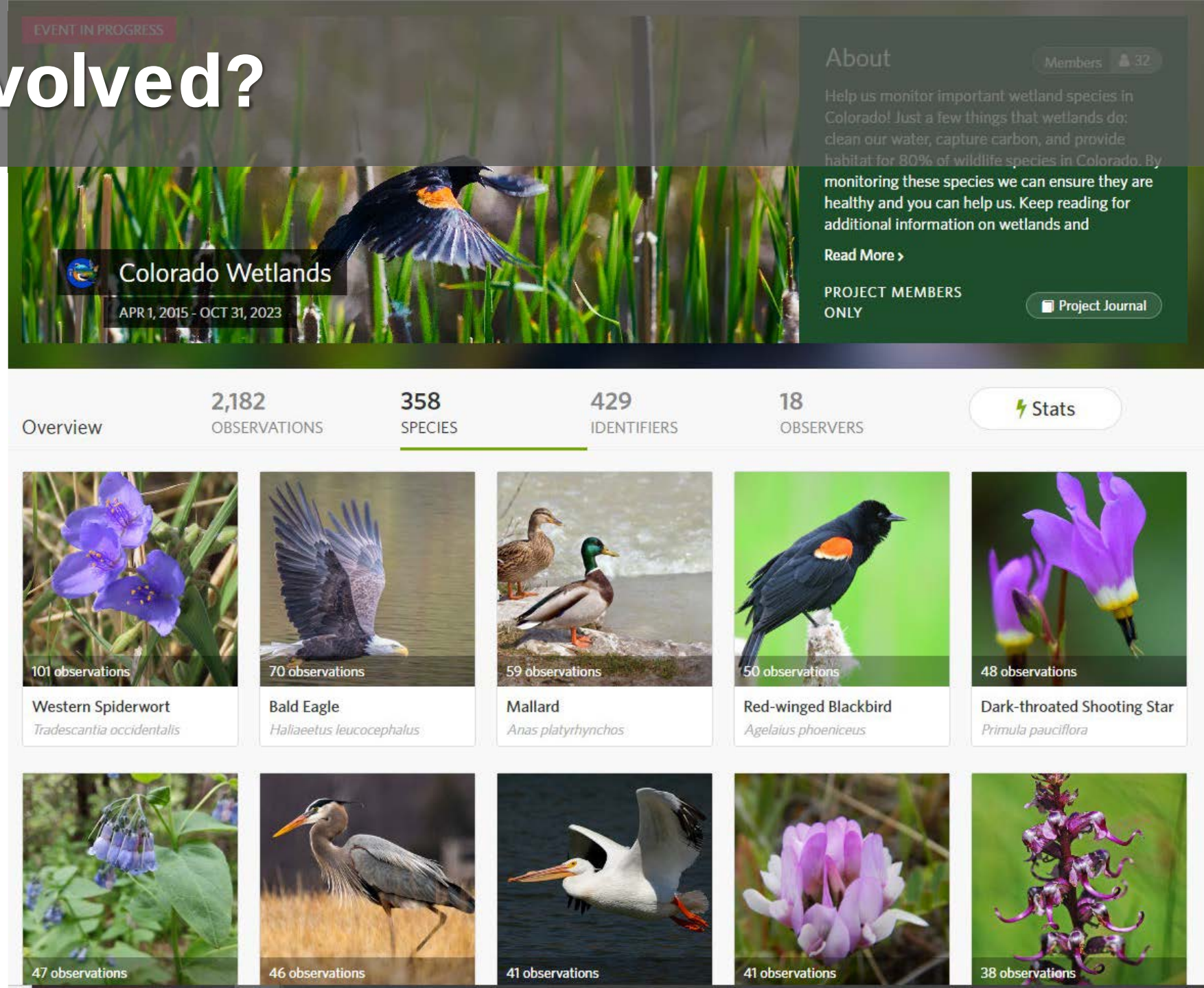
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