Remote sensing data needs

Filling data gaps to advance blue carbon/coastal wetland management

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and
Marine Resource Management Program,
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Oregon State University
Corvallis, Oregon, USA

Oregon blue carbon data & approaches paper

Included a GHG inventory of Oregon's coastal wetlands and forested tidal wetlands

- Demonstrated that there is sufficient science and methodologies (national, IPCC) to account for blue carbon in GHG inventories
- Inventory showed that **Oregon's coastal wetlands are a net carbon sink**
- Provided the **scientific basis for including blue carbon in climate mitigation policy efforts** related to carbon sequestration & storage.

Provided policy-focused recommendations:

- Avoid further loss of coastal wetlands
- Plan for future SLR by protecting migration zones
- Look for high leverage restoration opportunities e.g., forested tidal wetlands, marginalized lands

INCORPORATING COASTAL BLUE CARBON DATA AND APPROACHES IN OREGON'S FIRST GENERATION NATURAL AND WORKING LANDS PROPOSAL

South Slough, Oregon (Photo courtesy of Craig Cornu)

White paper submitted to the Oregon Global Warming Commission
July 2021

PEW
silvestrum CLIMATE ASSOCIATES
PNW Blue Carbon Working Group
OREGON Coastal Management Program
OREGON Department of Land Conservation & Development

Hot topics across states

- Need for mapping & change over time data
- How to understand and manage sea level rise impacts on coastal landscapes
  - Fate of carbon
  - "Good adaptation strategy is a good carbon strategy"
- Accounting for multiple benefits: carbon, flood mitigation, biodiversity, water quality
- What about other carbon sinks – kelp, peatlands, etc.?

Nationwide data gaps with remote sensing potential

Map blue carbon resources (especially shrub and forested tidal wetlands)

Map potential restoration sites (diked/disconnected sites); assess restoration effectiveness

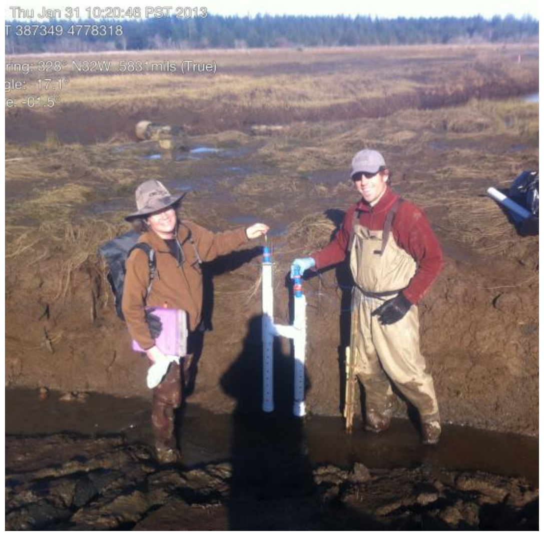

Photo: M. Ewald

Map salinity: temporal variability, existing conditions, projections

Recent progress with remote sensing

Map blue carbon resources (especially forested and shrub tidal wetlands)

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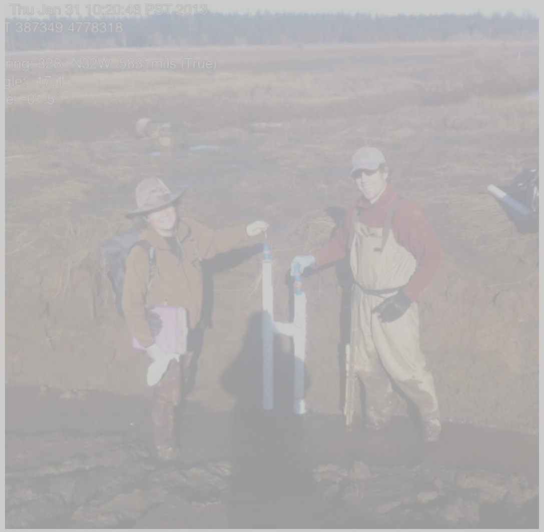


Map salinity: temporal variability, existing conditions, projections

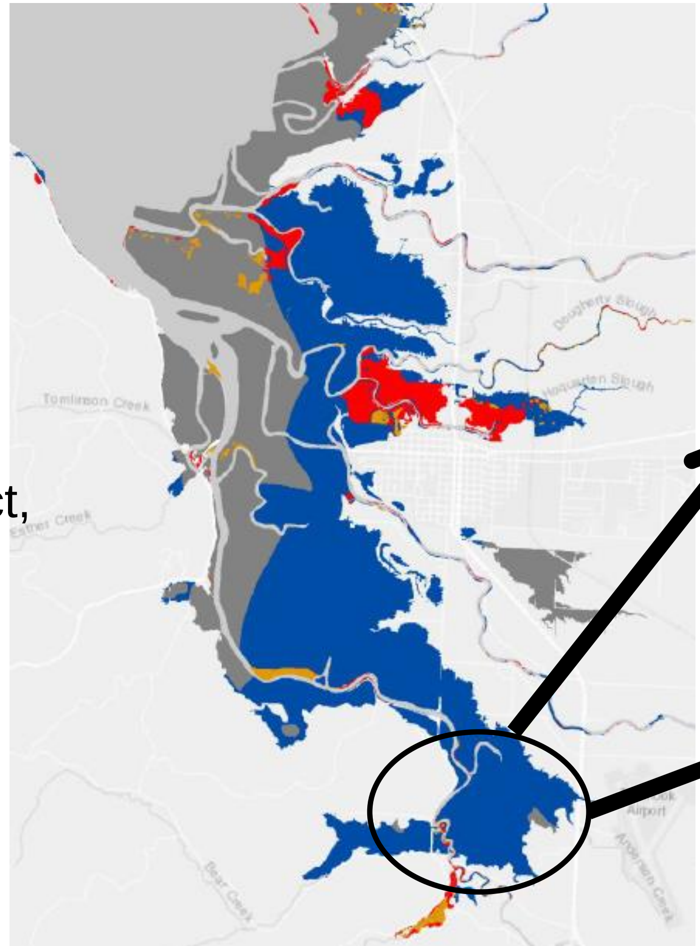
How do we map blue carbon resources?

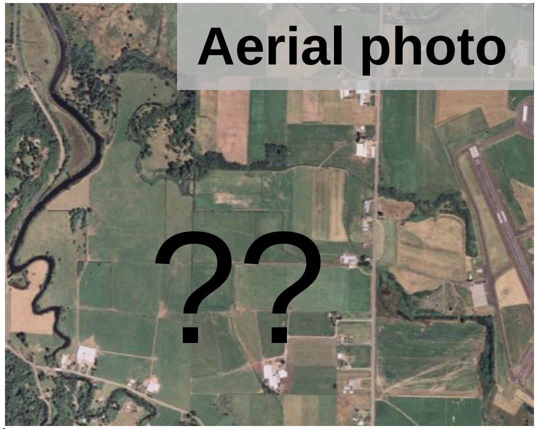
- Map all tidal wetlands:
    - Ocean to head of tide
    - Freshwater tidal zone included
    - Definition: tidal inundation at least 1X/year
    - All vegetation types included (mudflat, eelgrass, marsh, shrub, forested)
- Include all diked former tidal wetlands (restoration opportunities)

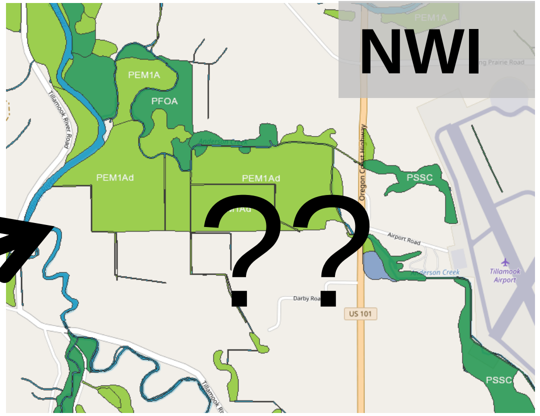
Motivation for recent mapping work

Tidal marsh is visually distinct, mapped accurately in NWI*

Tidal swamp is much less visually distinct, often not mapped in NWI*







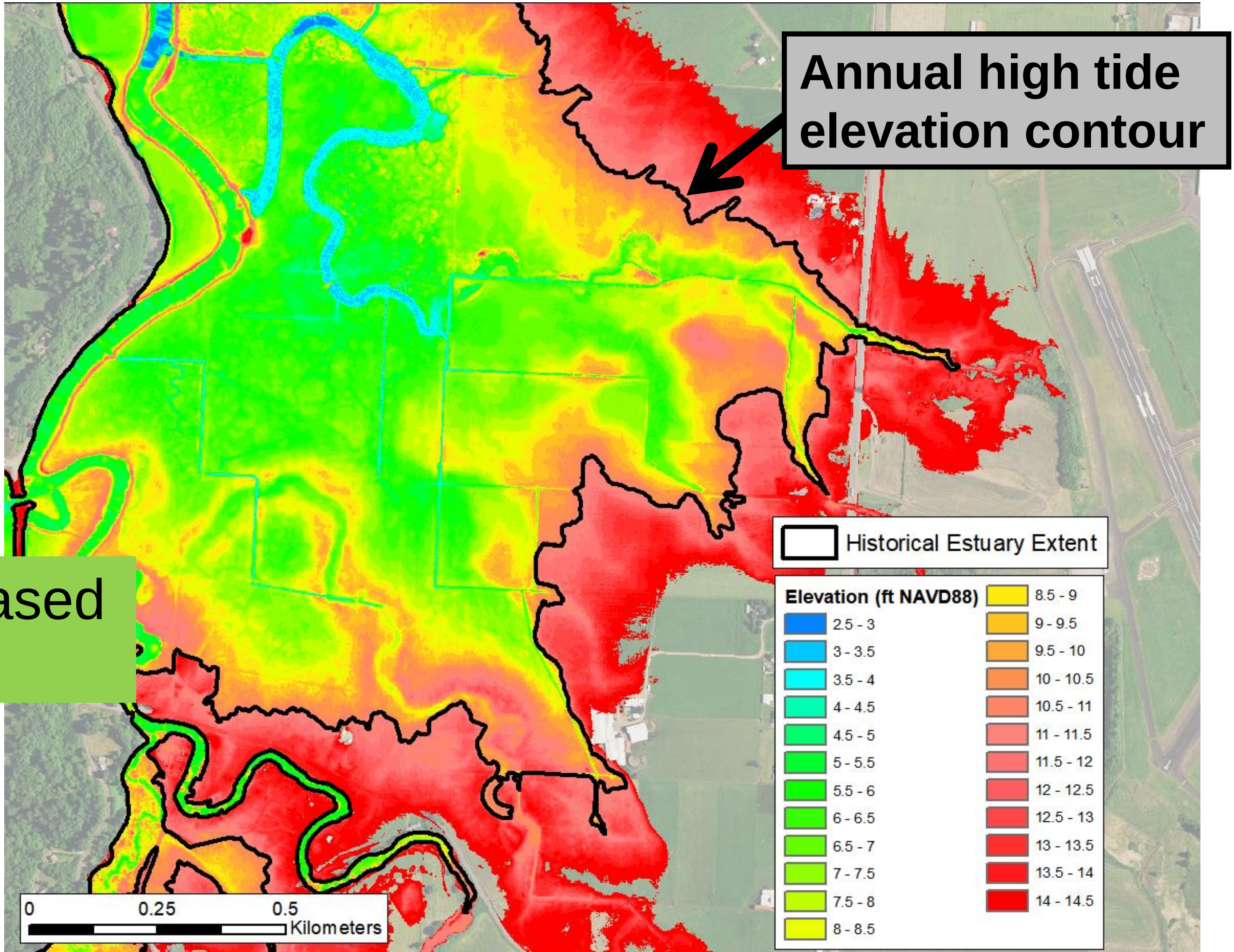
Diked former tidal wetlands: often not mapped in NWI

* NWI = National Wetlands Inventory

Mapping blue carbon resources: Remote sensing success

Our methods:

Combine LiDAR elevation data and NOAA water level data to map the full estuary extent



"EBEEM": the elevation-based estuary extent model

PMEP

PLOS ONE

RESEARCH ARTICLE

Insights into estuary habitat loss in the western United States using a new method for mapping maximum extent of tidal wetlands

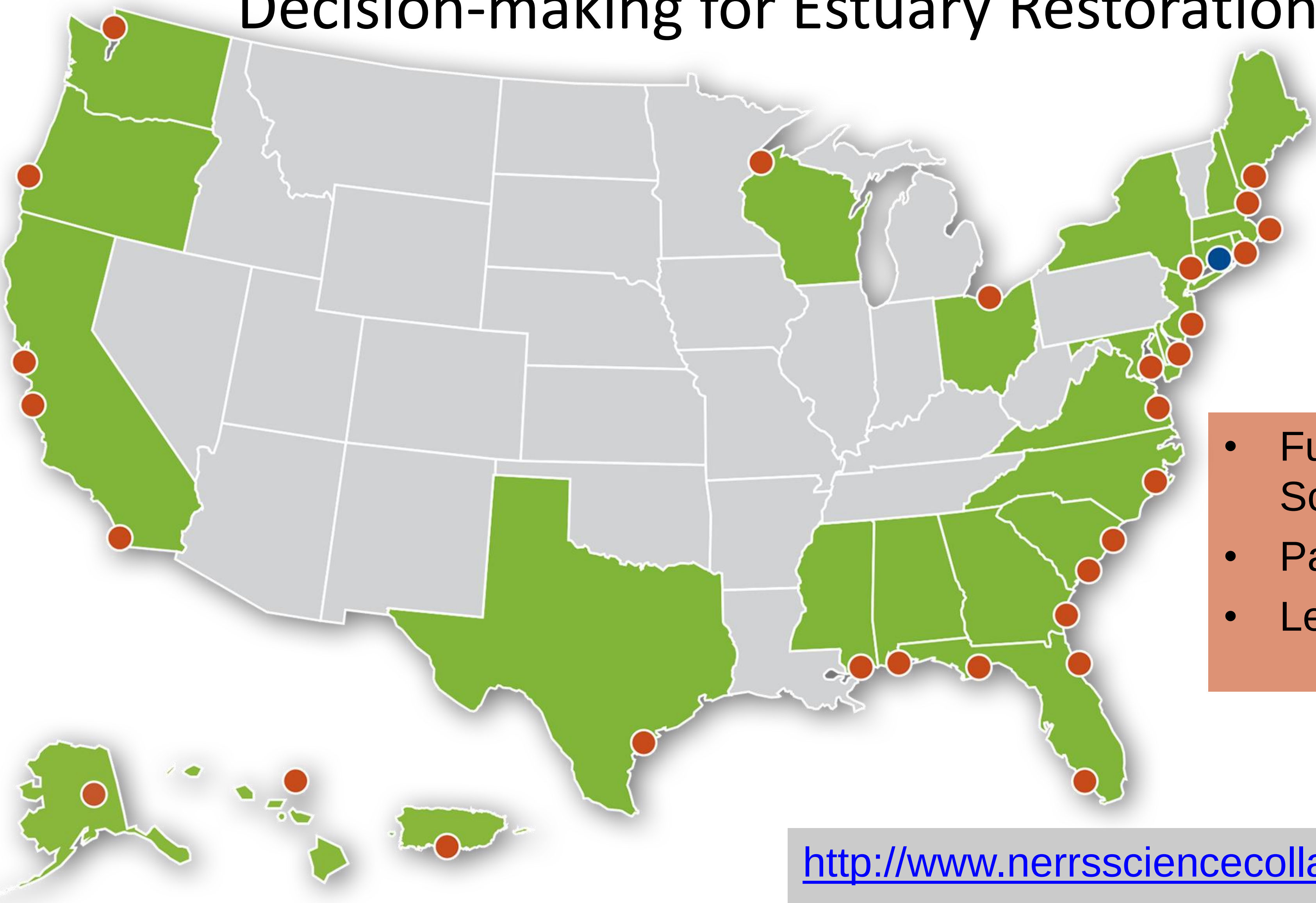
Laura S. Brophy[1], Correigh M. Greene[2*], Van C. Hare[3], Brett Holycross[3], Andy Lanier[4], Walter N. Heady[5], Kevin O'Connor[6], Hiroo Imaki[7], Tanya Haddad[4], Randy Dana[4]

Published 2019: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0218558

PMEP

Current nationwide mapping effort:

History and Topography to Improve Decision-making for Estuary Restoration (HiTIDER)



- Funded by the NERRS Science Collaborative
- Participating: All 30 NERRs,
- Lead: Elkhorn Slough NERR

http://www.nerrssciencecollaborative.org/project/Wasson20

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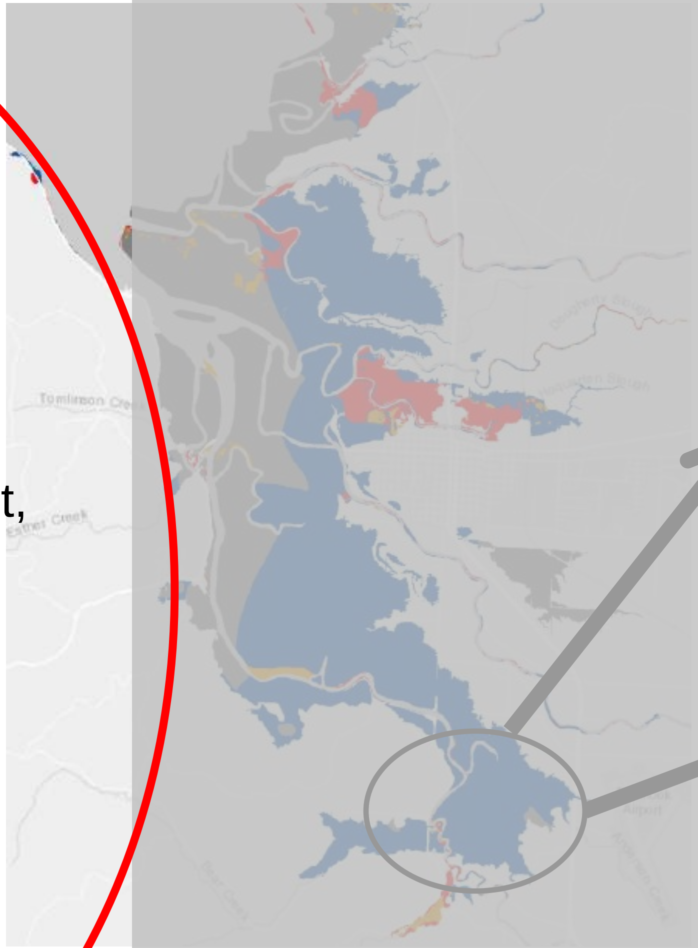

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EBEEM vs NWI, Apalachicola River estuary, FL

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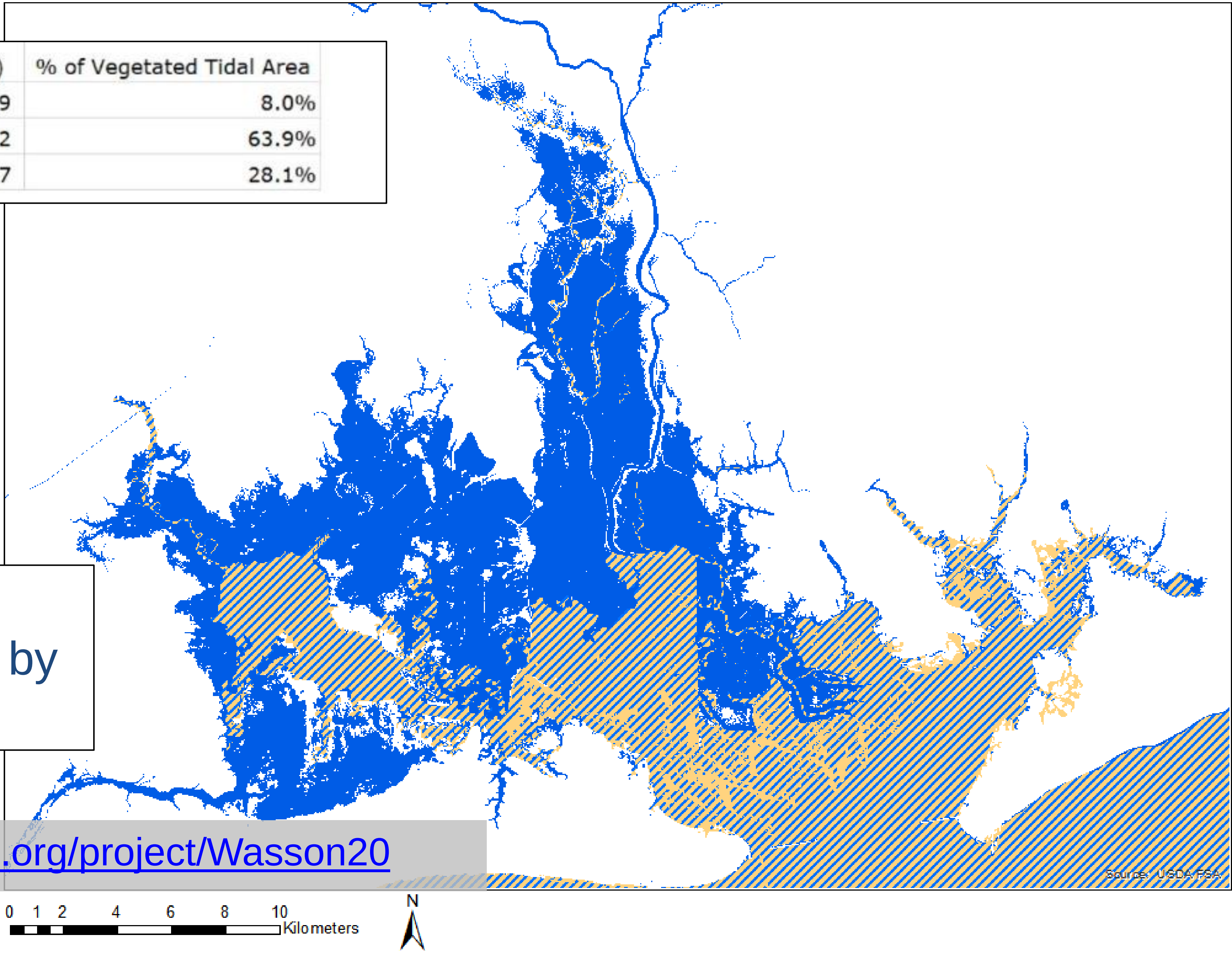

~ 23,000 ha of forested tidal wetlands identified by EBEEM but not by NWI

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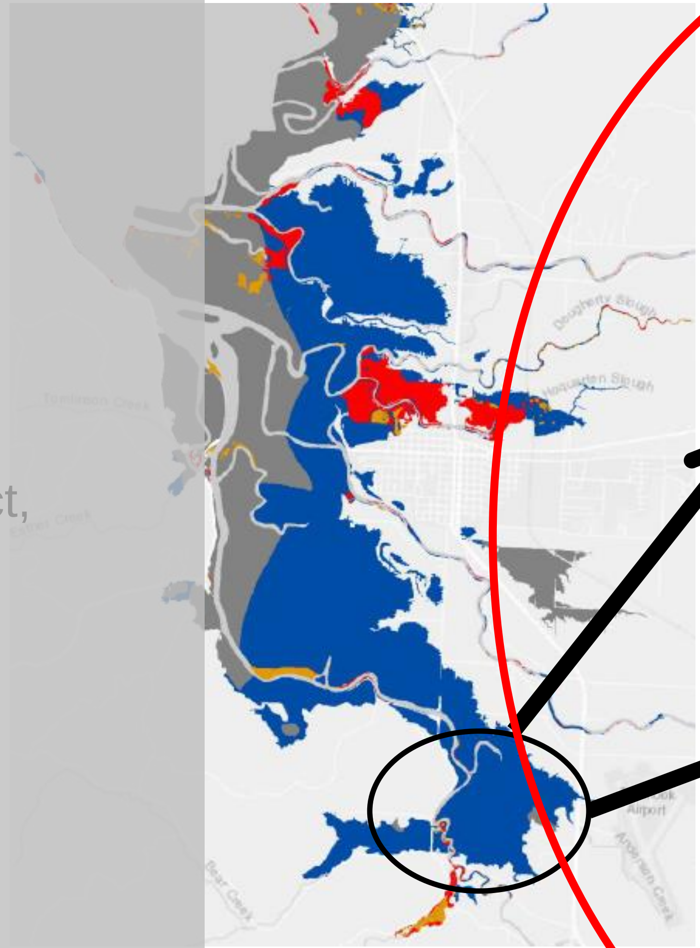

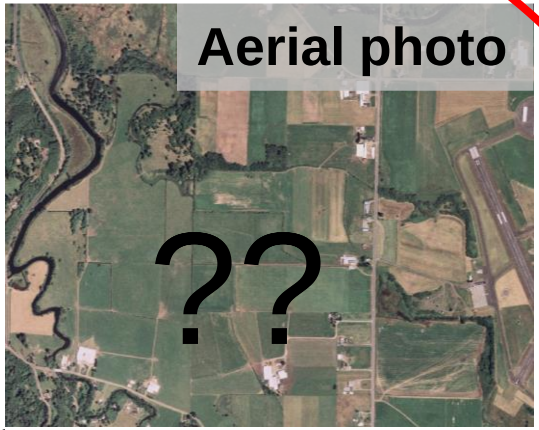

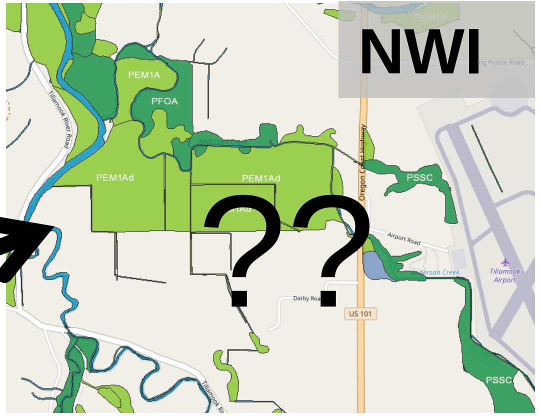

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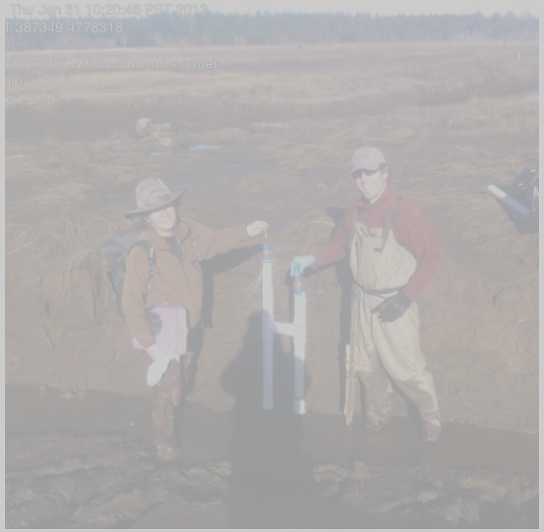
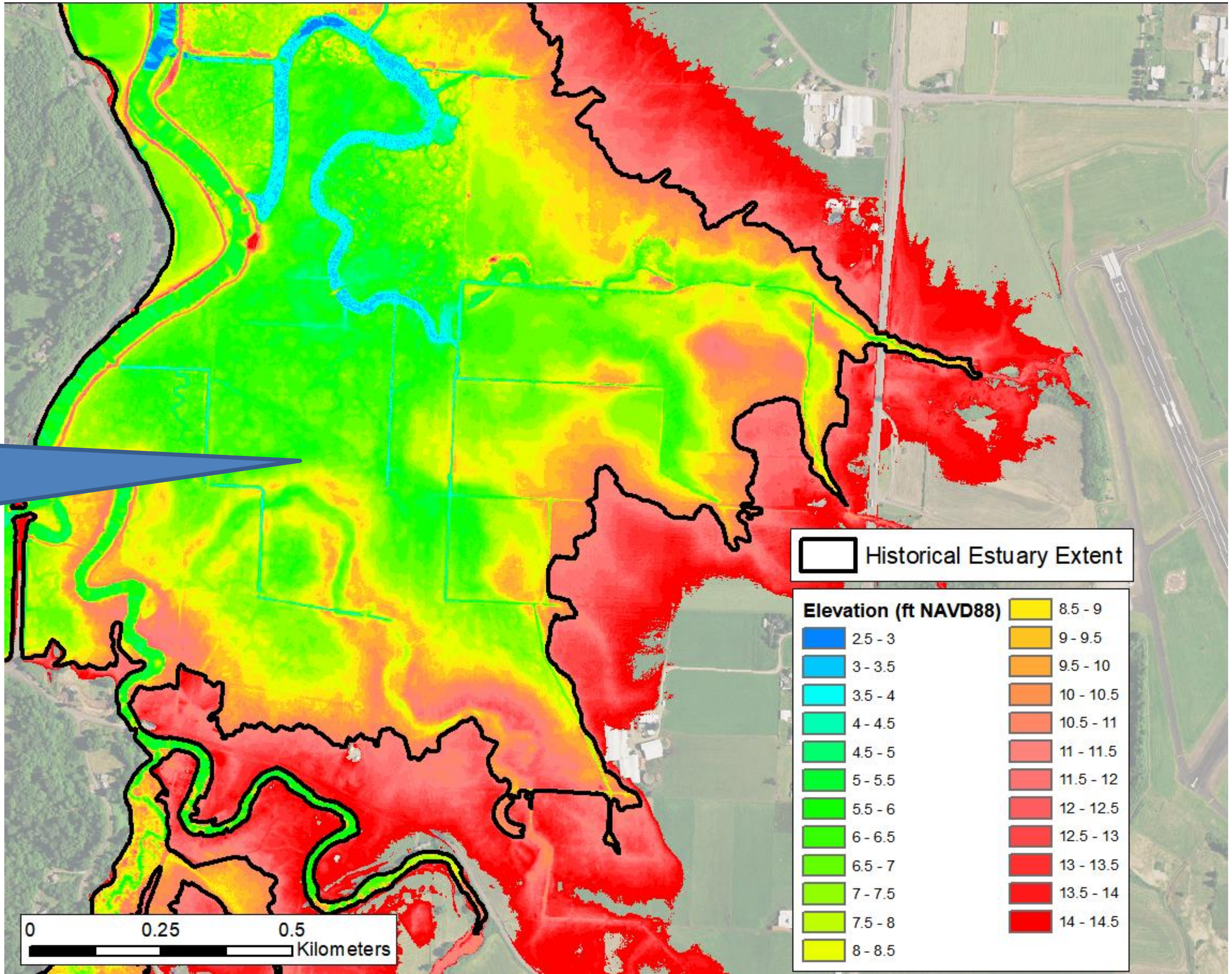


Map salinity: temporal variability, existing conditions, projections

Remote sensing potential applications

Diked/disconnected areas within the estuary boundary...
but where?



Barriers to Tidal Connectivity Symposium & Workshop

October 28 & 29, 2020

Barriers to Tidal Connectivity Symposium & Workshop

October 28 & 29, 2020

Session 5: Next Steps

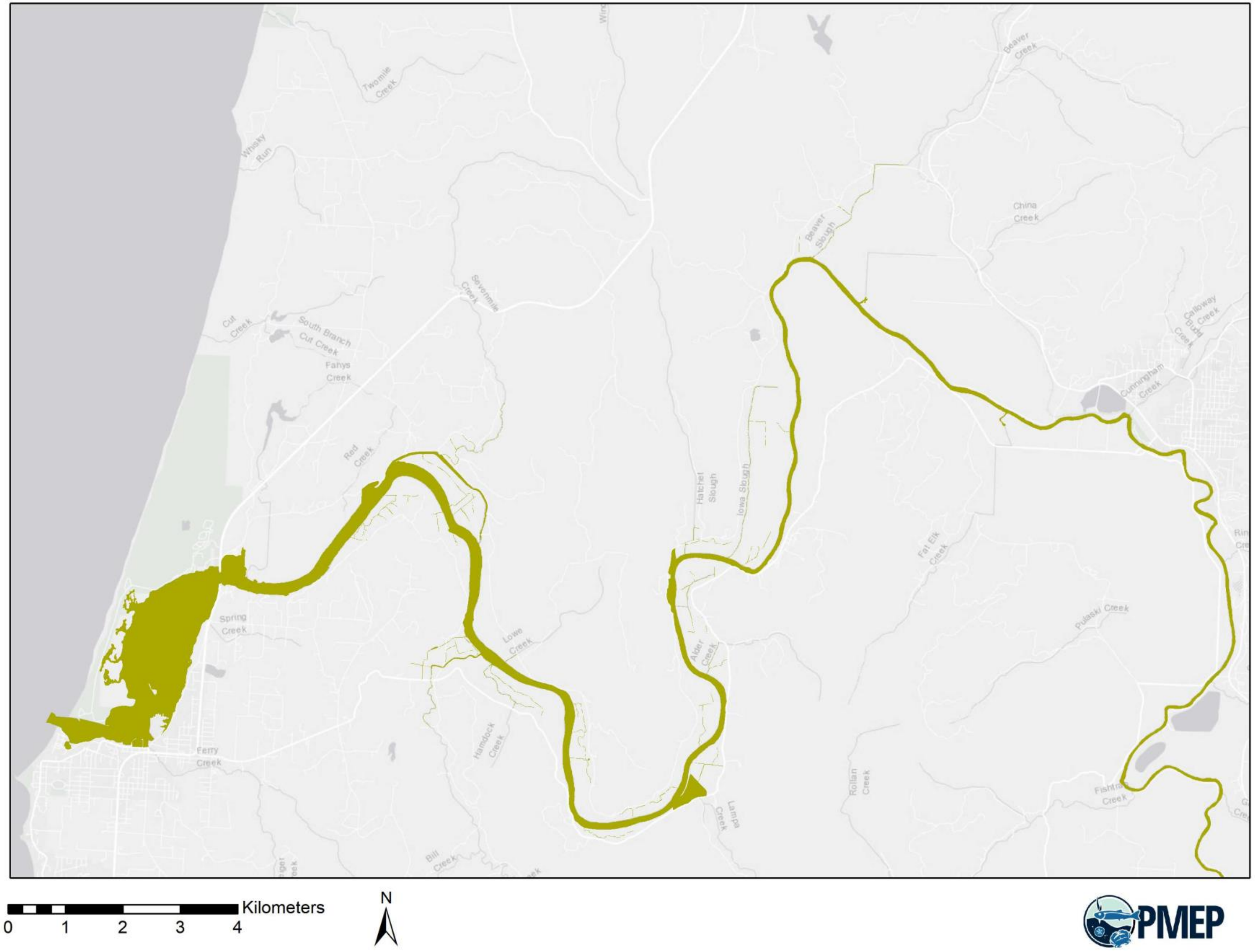
Collaborative FHP Actions Identified at the Workshop

Science Gaps

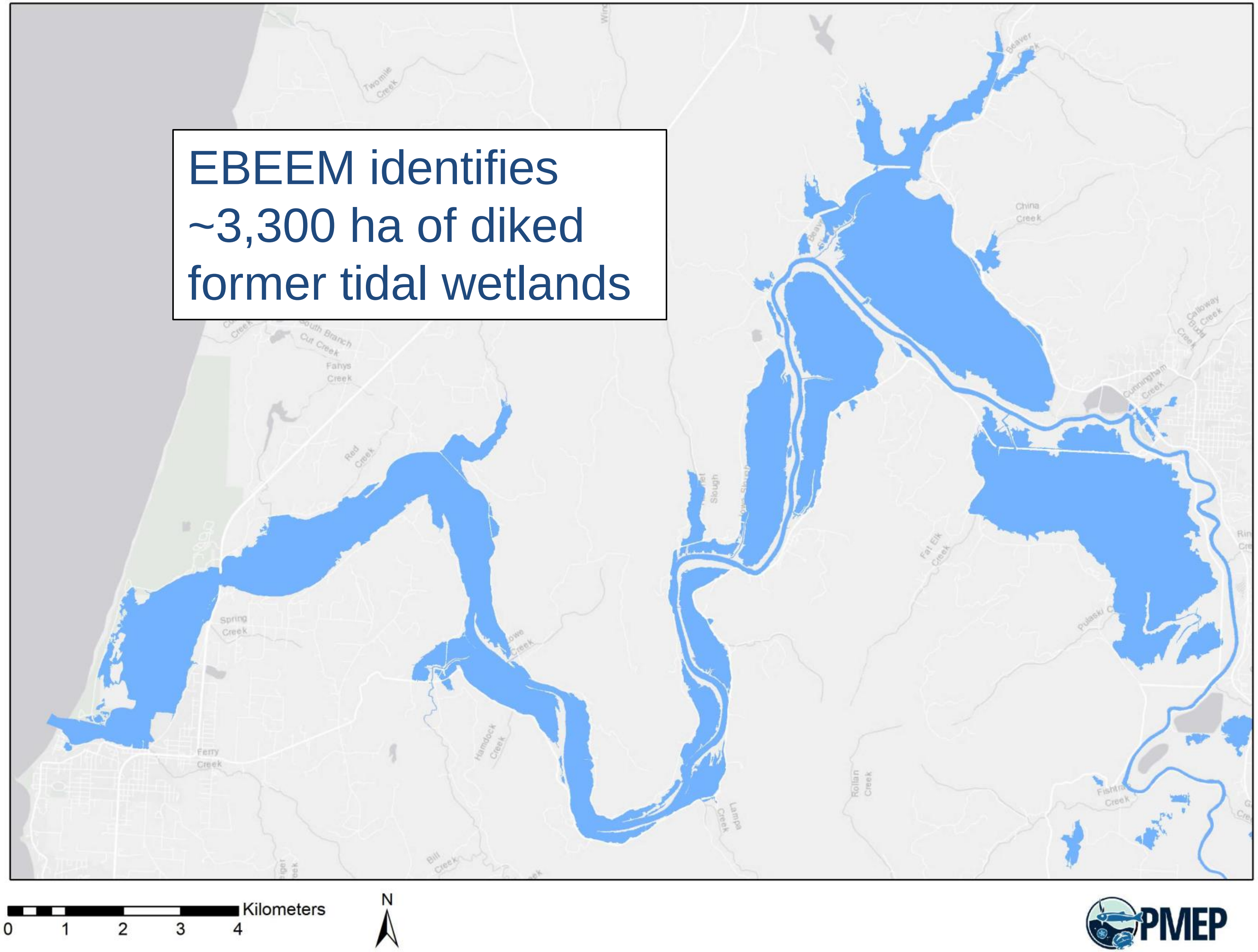
- Understanding spatial extent of barriers impacts
  - Test remote sensing methods to map & quantify tidal connectivity.
  - Identifying areas that are disconnected due to tidal barriers (by habitat type)
- Passage science
  - Passage behavior and efficiency for PL and WRL for all life stages through all types of tidal barriers.
  - Swimming performance criteria for all aquatic species.

⋮

NWI tidal wetlands, Coquille River Estuary, OR



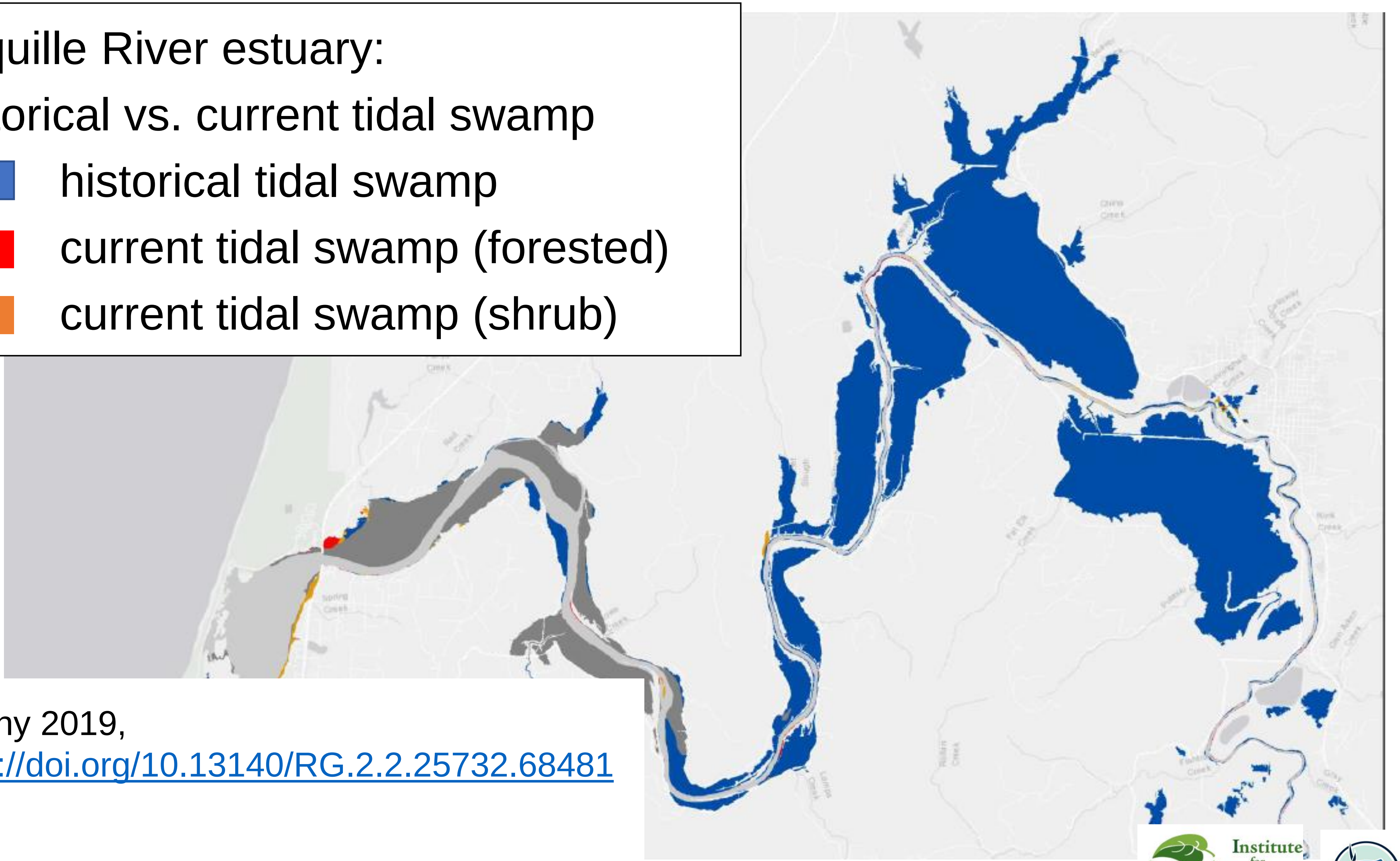
EBEEM Estuary Extent, Coquille River Estuary, OR



Coquille River estuary:

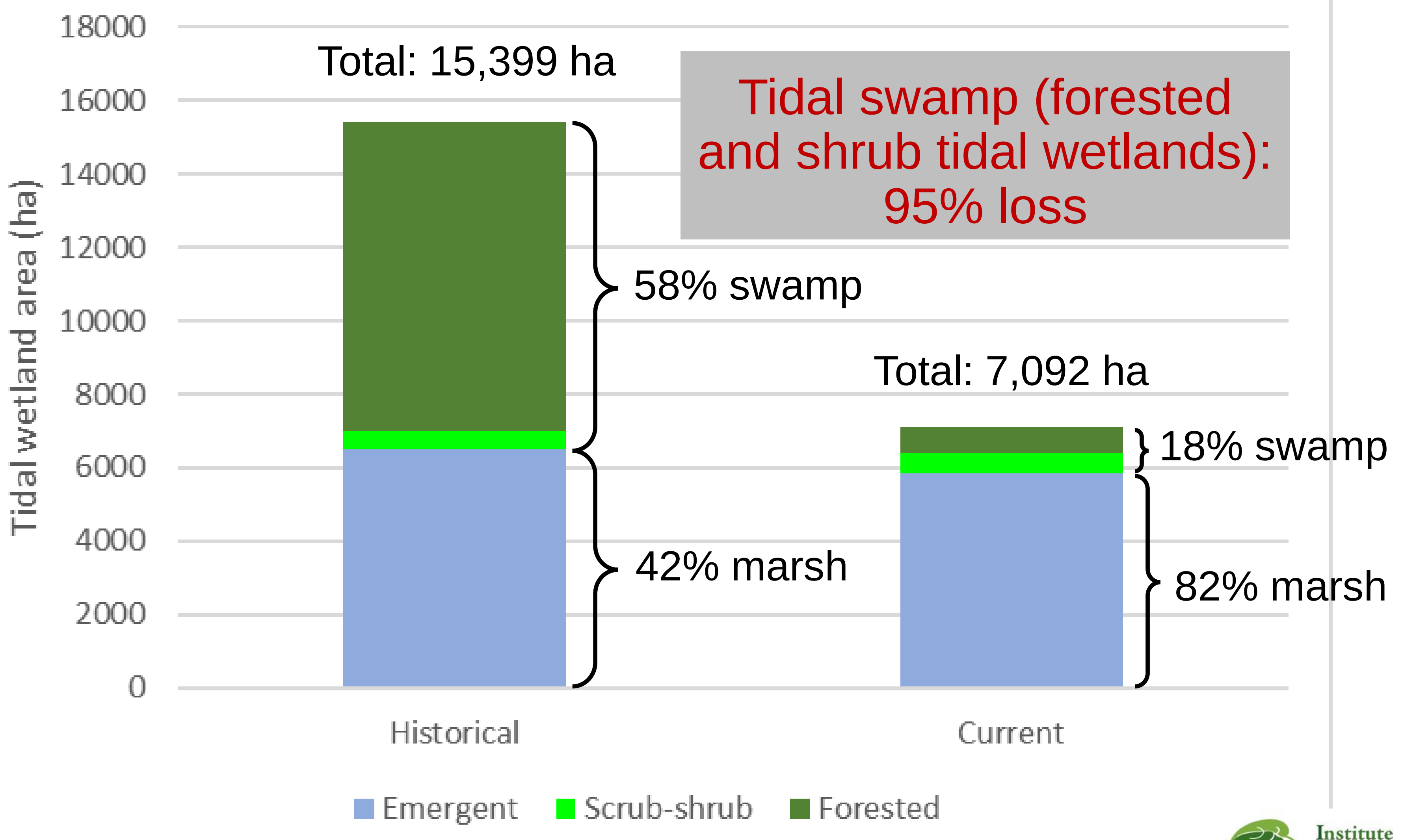
Historical vs. current tidal swamp

- historical tidal swamp
- current tidal swamp (forested)
- current tidal swamp (shrub)



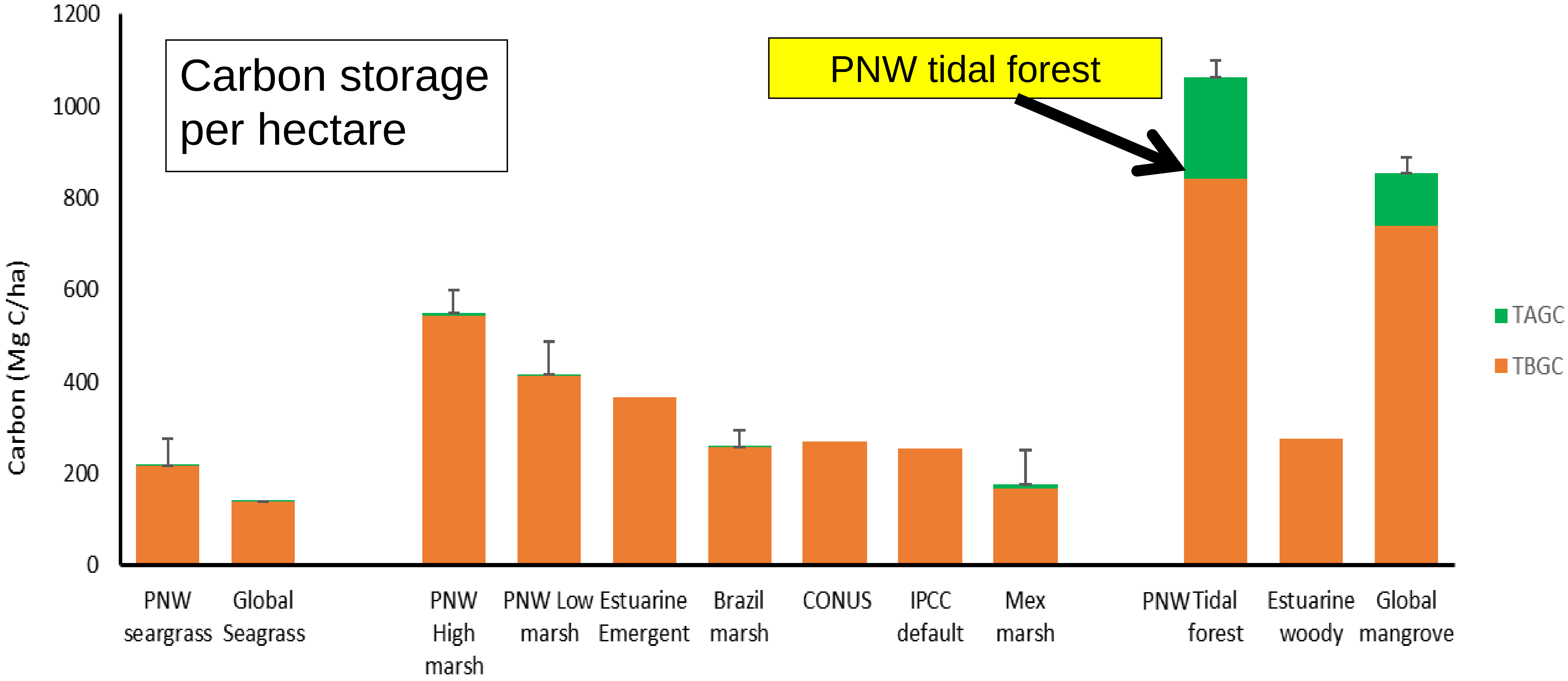
Brophy 2019,
https://doi.org/10.13140/RG.2.2.25732.68481

Oregon outer coast tidal wetlands, then (1800s) and now



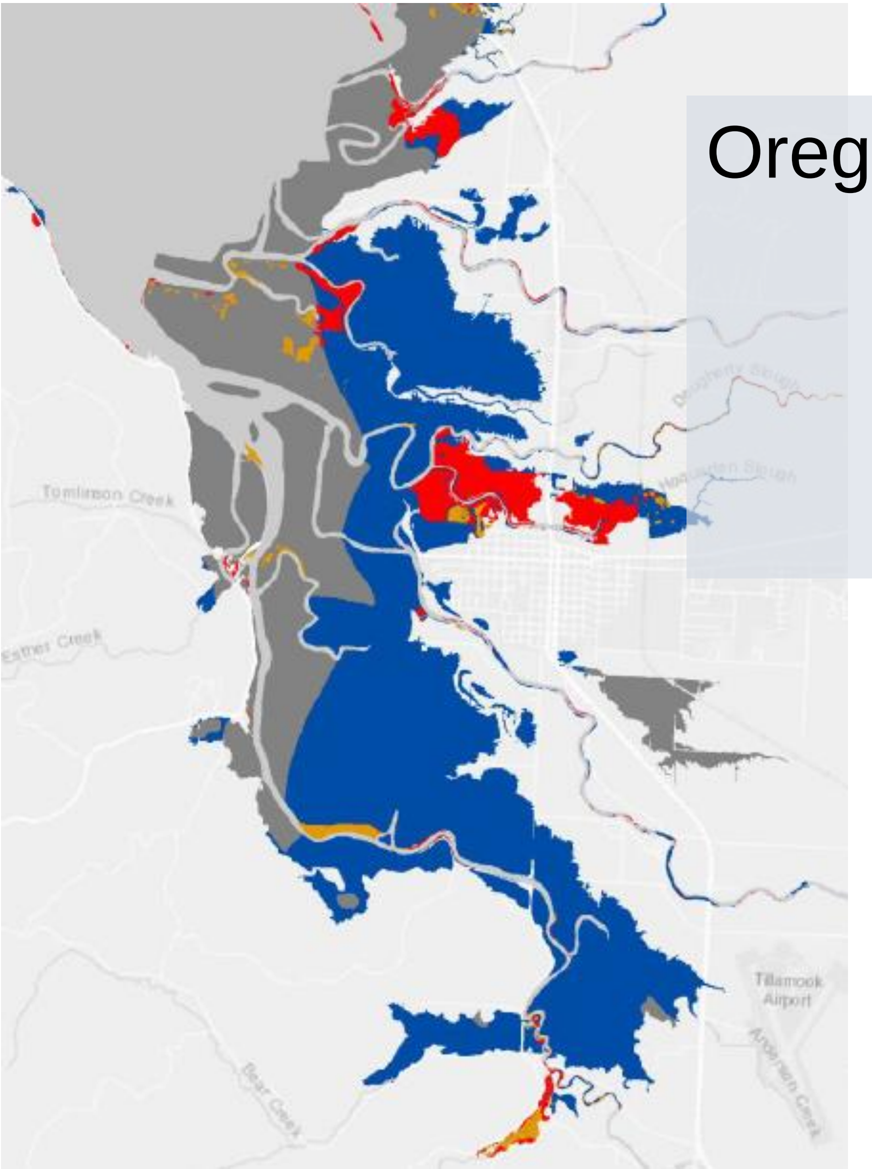
Brophy 2019, https://doi.org/10.13140/RG.2.2.25732.68481

Tidal swamps store a LOT of carbon, both below and aboveground



Source: Kauffman et al. 2020, https://doi.org/10.1111/gcb.15248

How did we determine wetland loss?

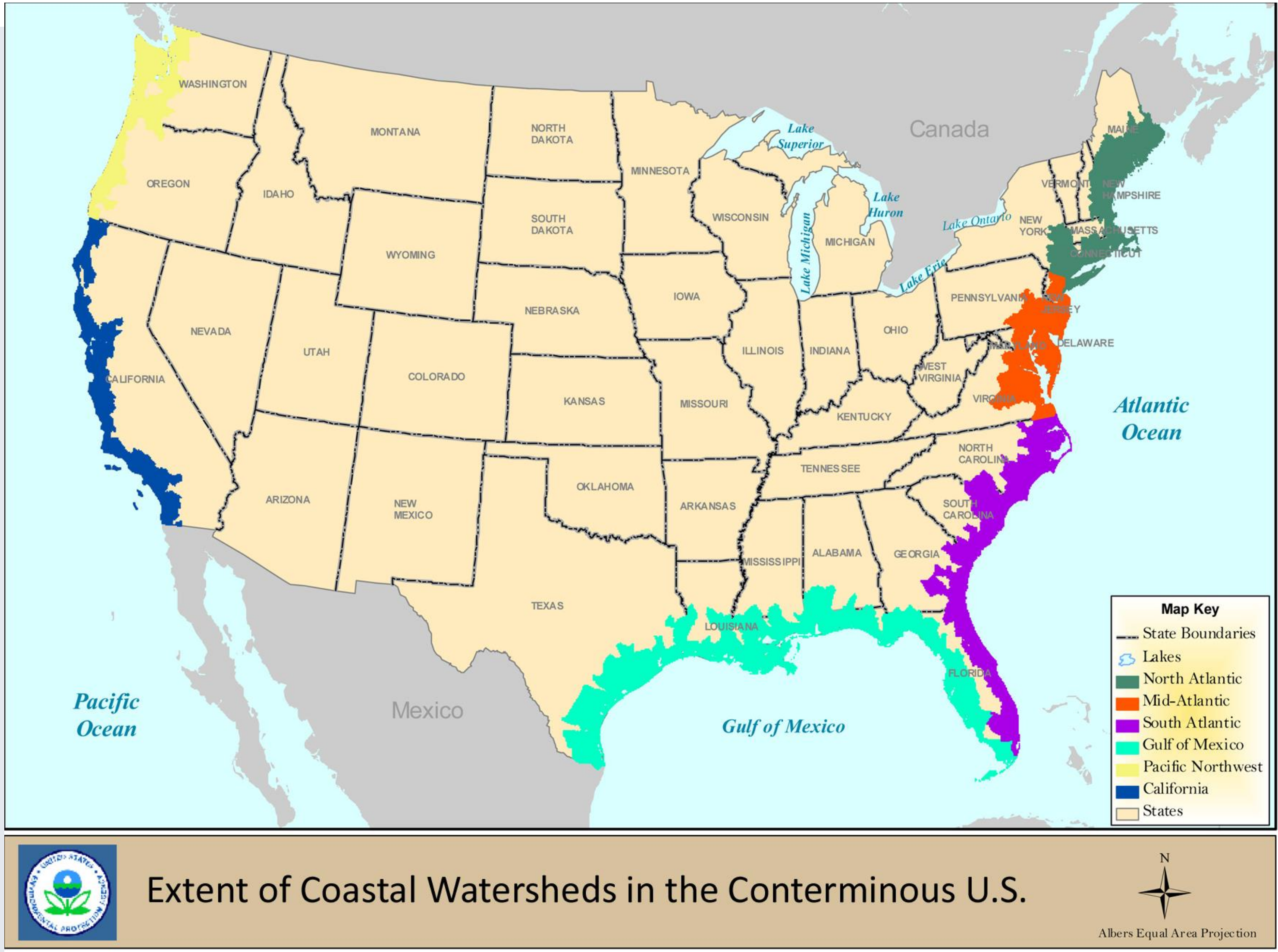


Oregon, Washington studies: Direct loss assessment

- Direct mapping of diked/disconnected areas
- Topographic analysis, expert input, hand digitization
- High-resolution, accurate enough for local planning
- Not replicable or scalable, not easily updated

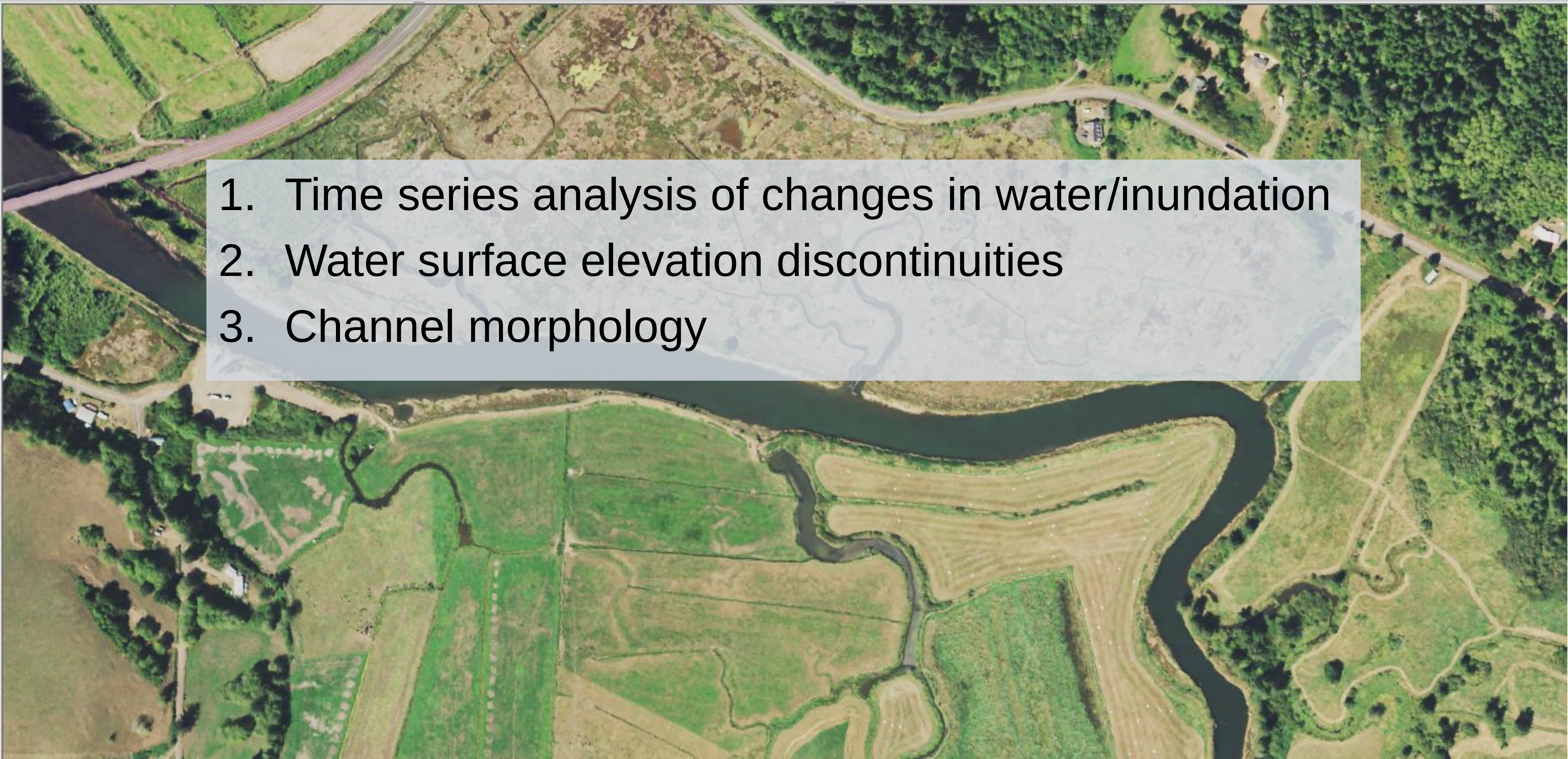
How could remote sensing improve maps of tidal connectivity?

- Improved consistency, comprehensiveness, replicability, scalability
- Goal: High-resolution, consistent data for use in regional and national assessments
- Goal: Updatable maps
- Goal: Quantify degree of connectivity



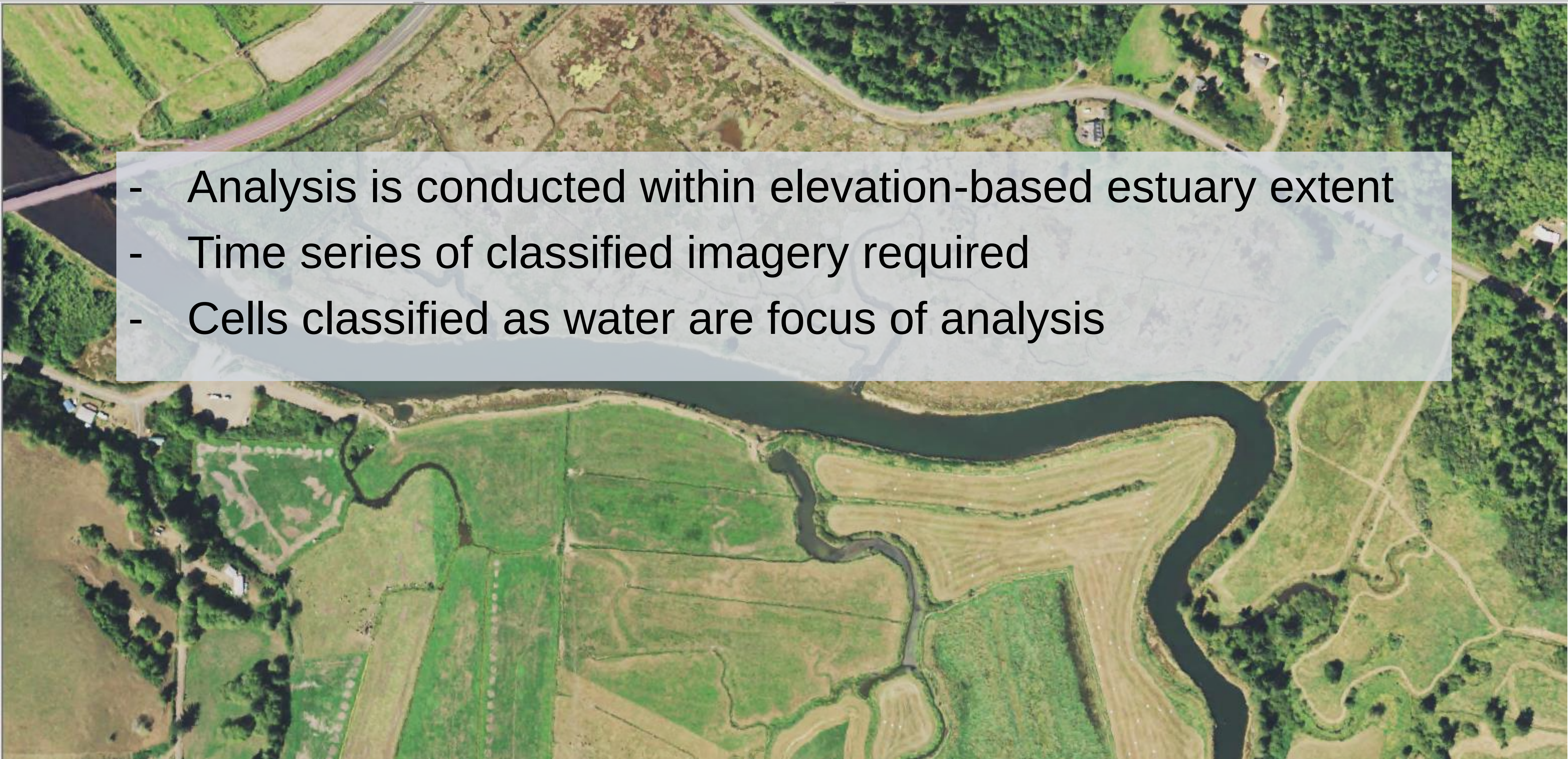
Source: https://www.epa.gov/wetlands/about-coastal-wetlands

Potential remote sensing approaches to tidal connectivity



1. Time series analysis of changes in water/inundation
2. Water surface elevation discontinuities
3. Channel morphology

Potential remote sensing approaches:
1. Time series analysis of changes in water/inundation



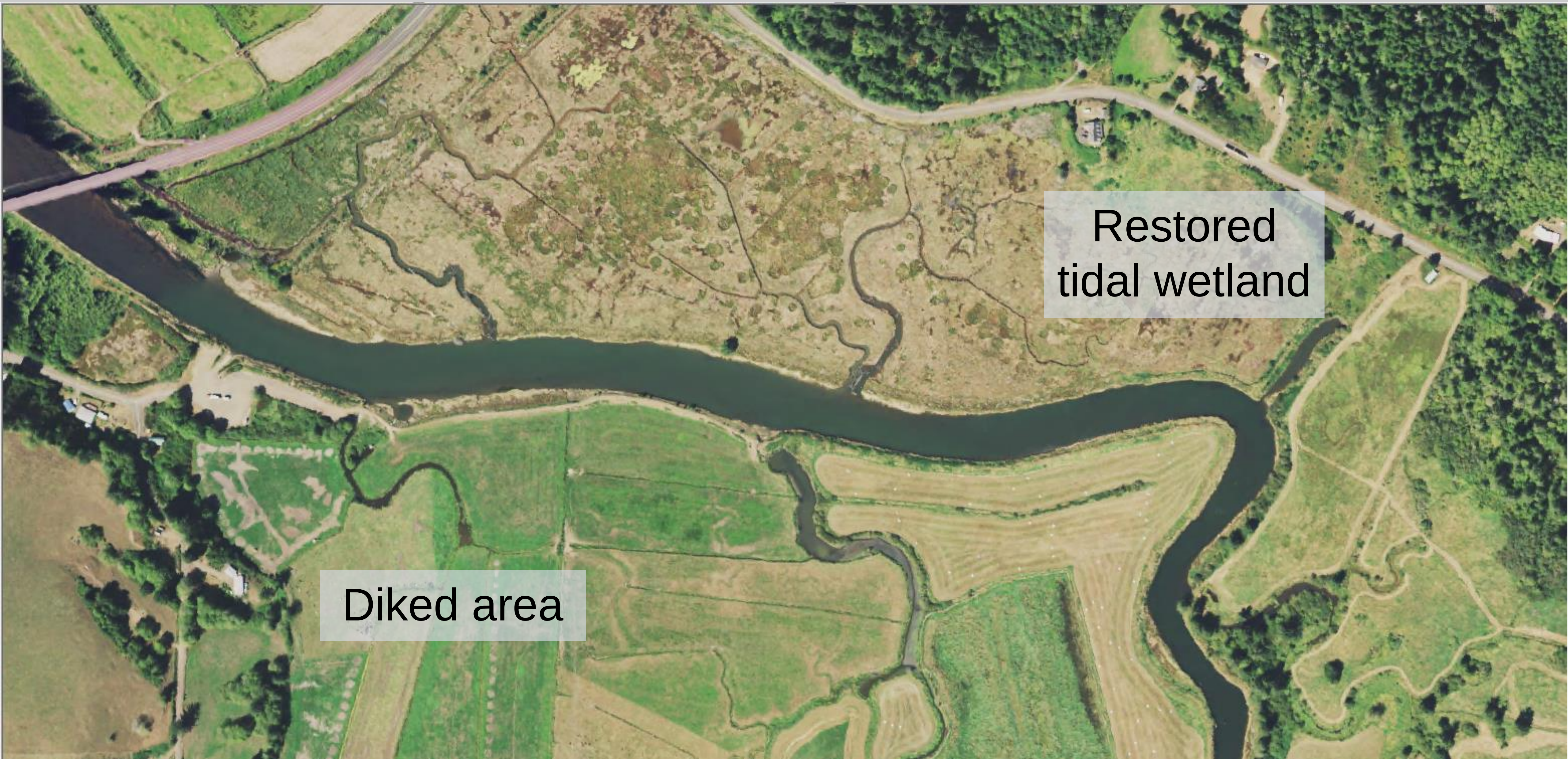
- Analysis is conducted within elevation-based estuary extent
- Time series of classified imagery required
- Cells classified as water are focus of analysis

Potential remote sensing approaches:
1. Time series analysis of changes in water/inundation

- Tidal wetlands:
  - Cells classified as water/inundation “blink” on and off
  - Periodicity matches tidal signal
- Diked/disconnected former tidal wetlands:
  - Cells classified as water are more static
  - Changes to water extent/distribution would not match known tidal periodicity

- Example: “Tidal surface water index” method developed and tested by Holmquist et al. (funding from NASA CMS and NOAA grant NA16NMF4630103)
- Degree of connectivity is theoretically classifiable

Potential remote sensing approaches:
1. Time series analysis of changes in water/inundation



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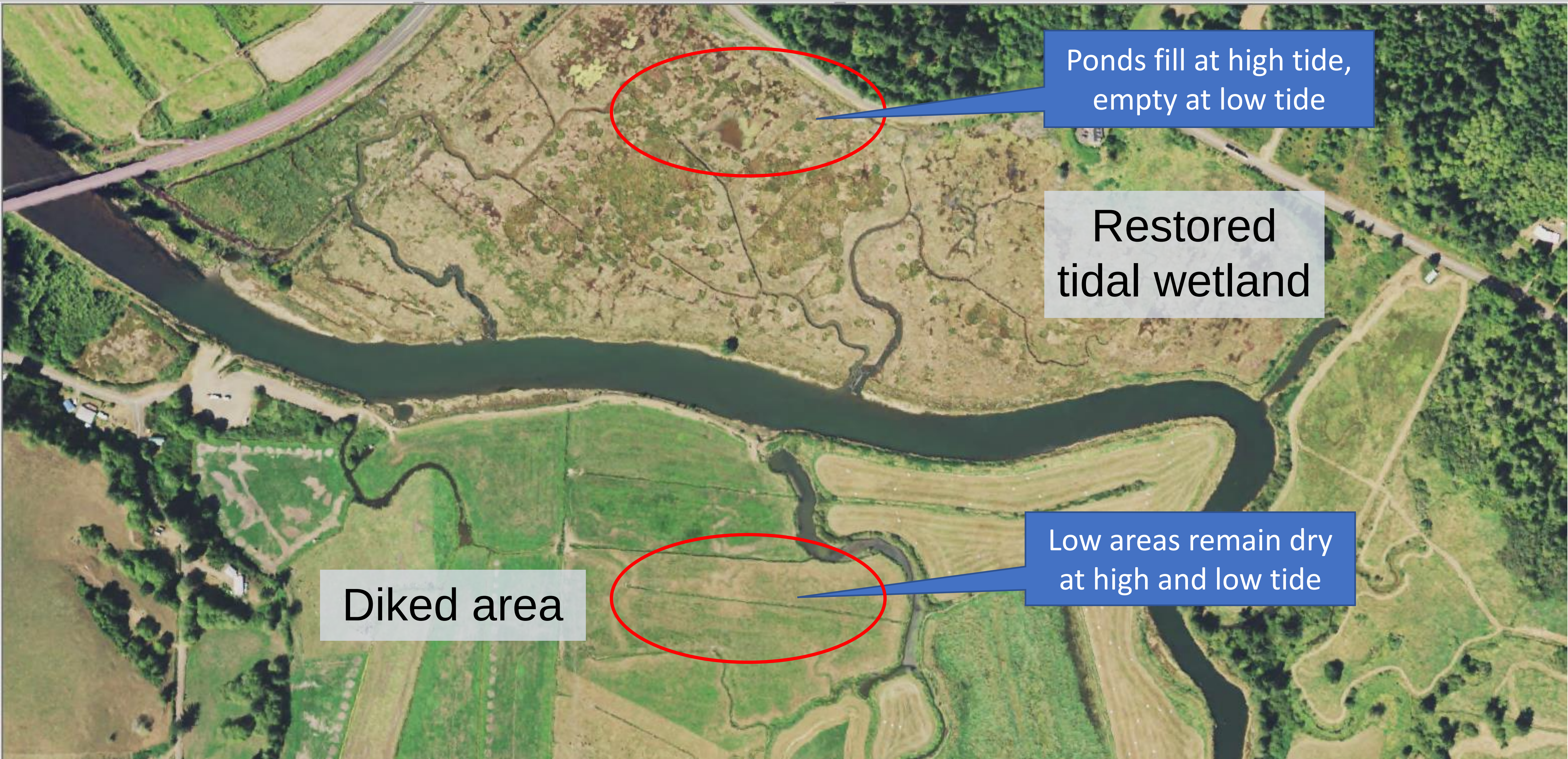

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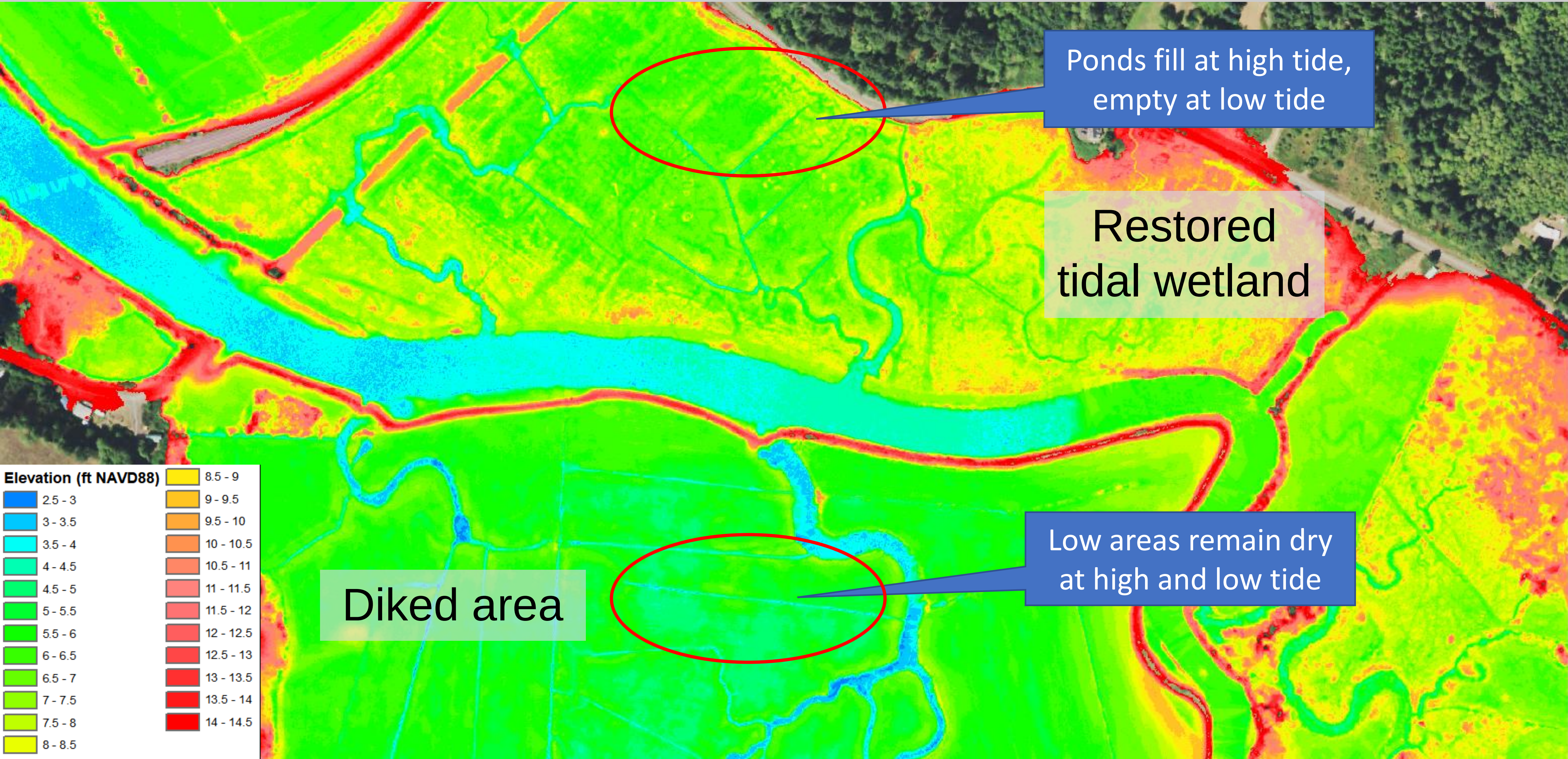

Potential remote sensing approaches:
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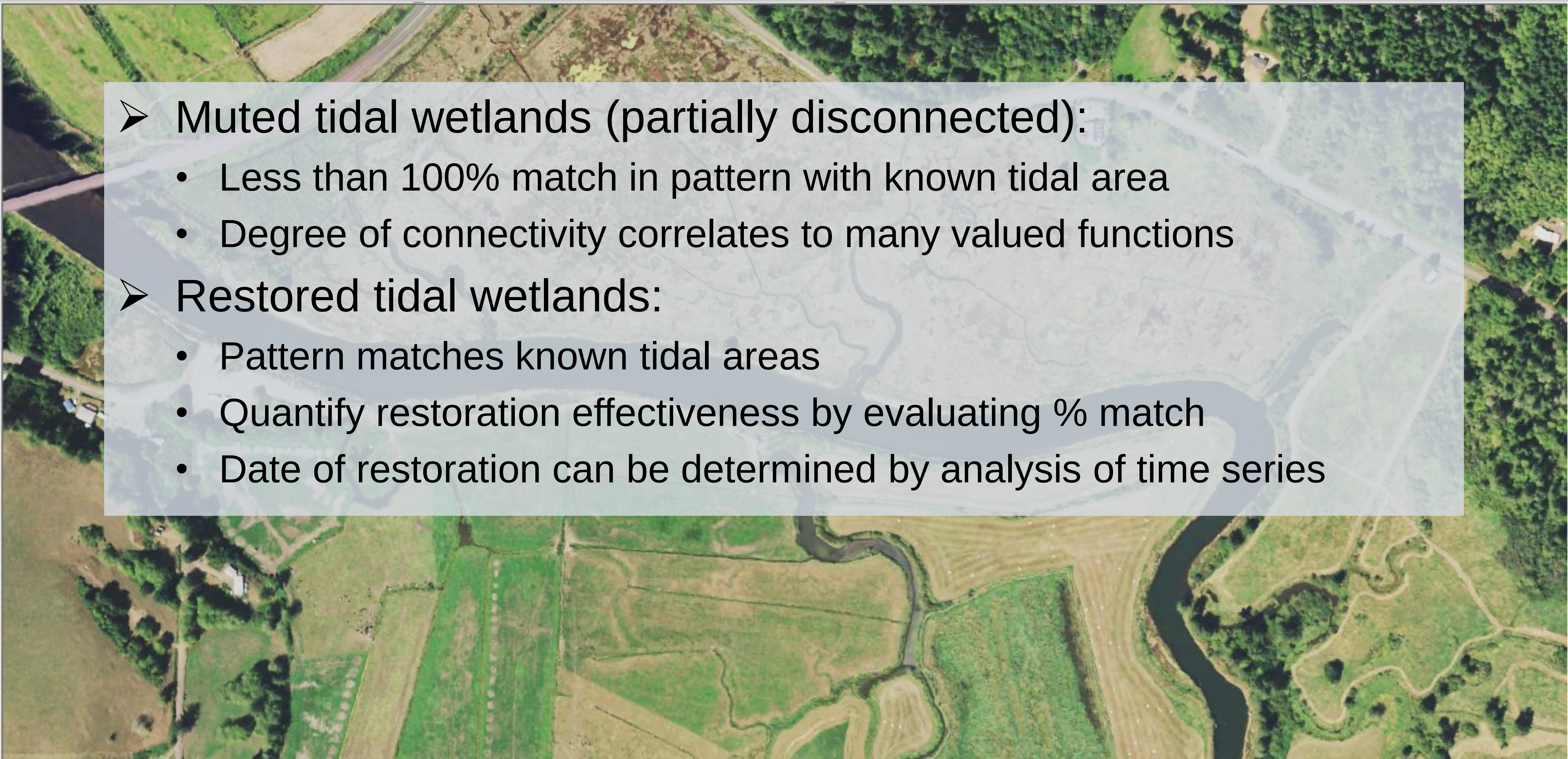
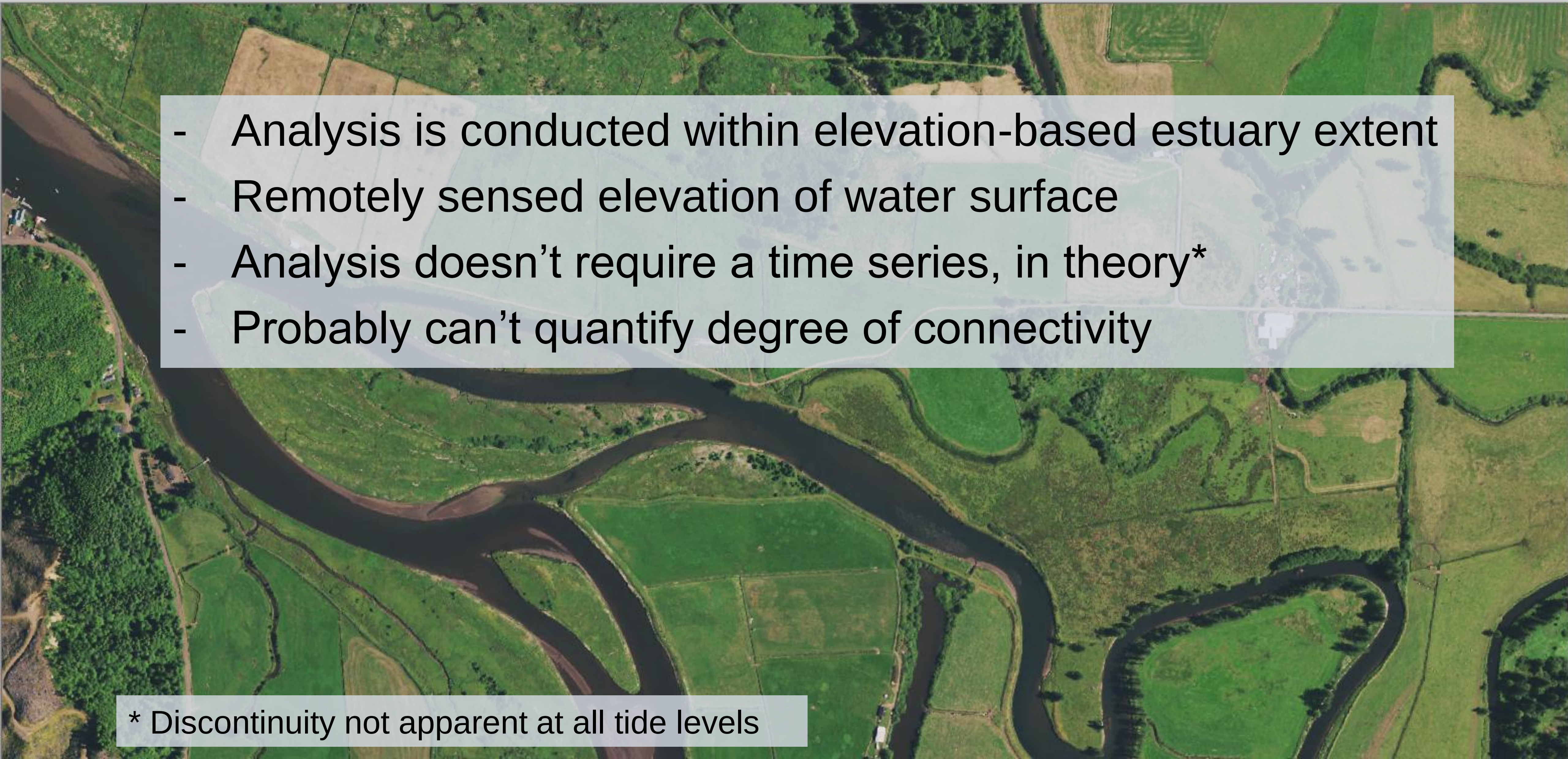


- Muted tidal wetlands (partially disconnected):
  - Less than 100% match in pattern with known tidal area
  - Degree of connectivity correlates to many valued functions
- Restored tidal wetlands:
  - Pattern matches known tidal areas
  - Quantify restoration effectiveness by evaluating % match
  - Date of restoration can be determined by analysis of time series

Potential remote sensing approaches:
2. Water surface elevation discontinuities

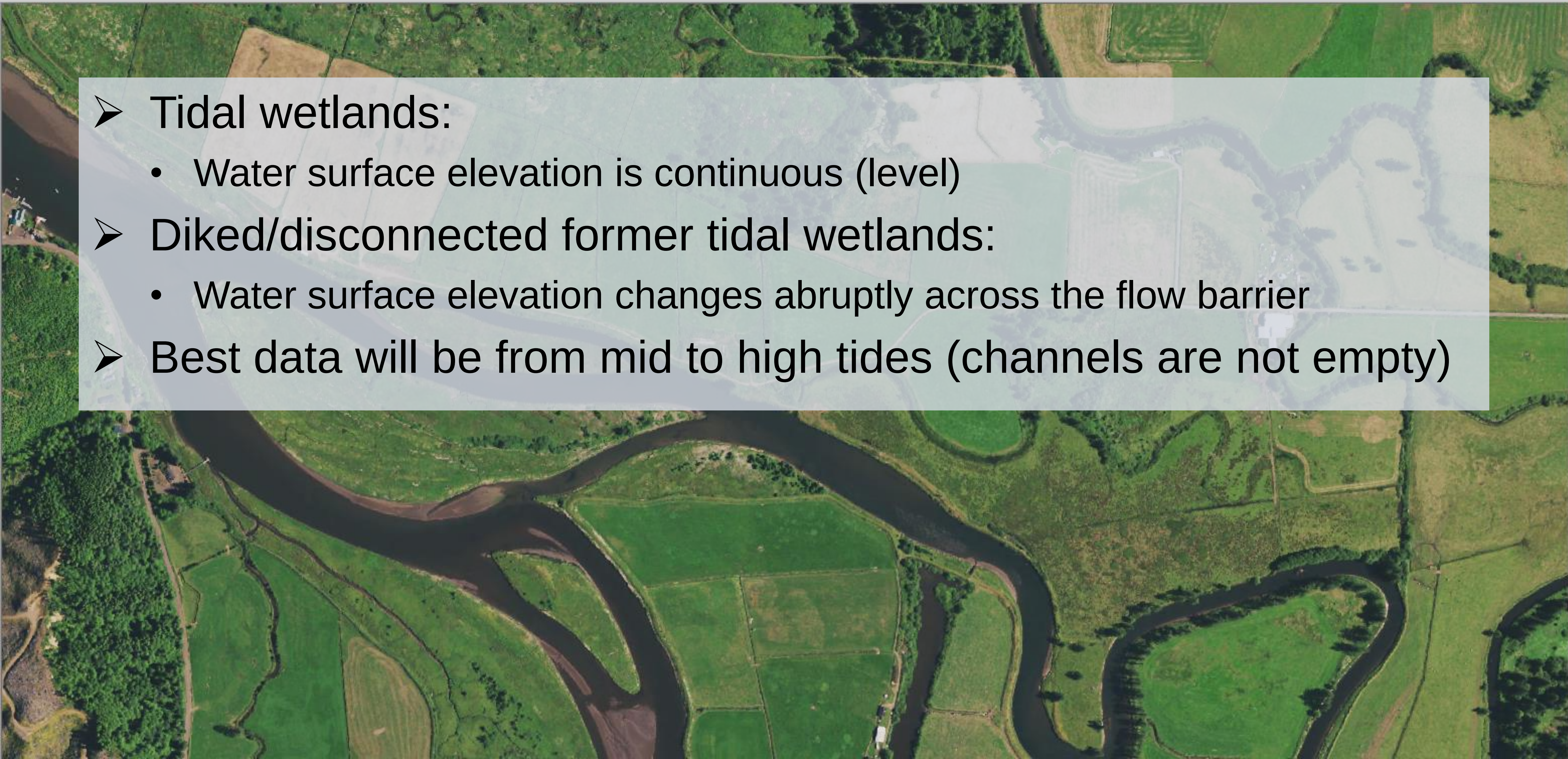


- Analysis is conducted within elevation-based estuary extent
- Remotely sensed elevation of water surface
- Analysis doesn’t require a time series, in theory*
- Probably can’t quantify degree of connectivity

* Discontinuity not apparent at all tide levels

Potential remote sensing approaches:
2. Water surface elevation discontinuities

- Tidal wetlands:
  - Water surface elevation is continuous (level)
- Diked/disconnected former tidal wetlands:
  - Water surface elevation changes abruptly across the flow barrier
- Best data will be from mid to high tides (channels are not empty)



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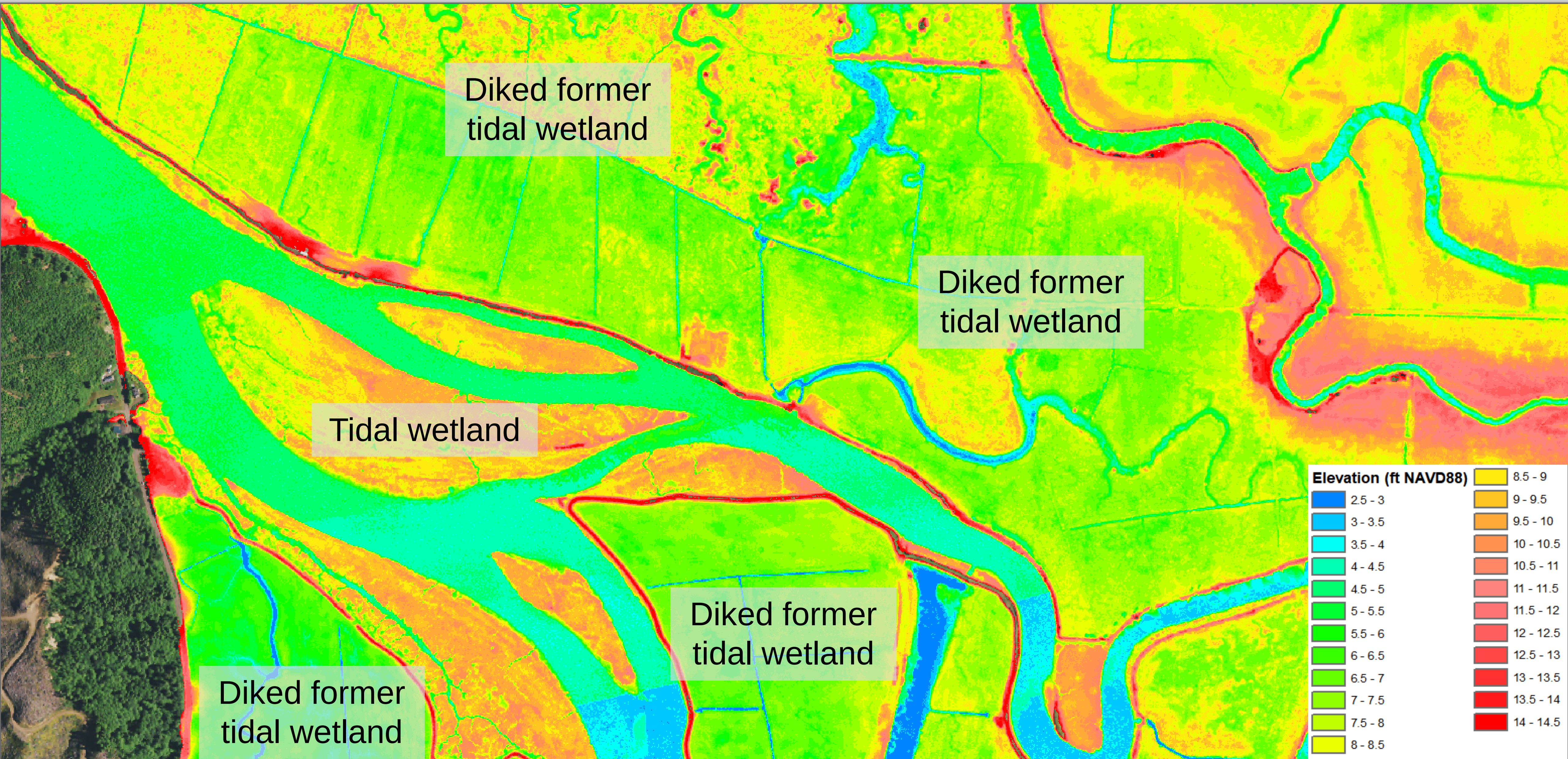

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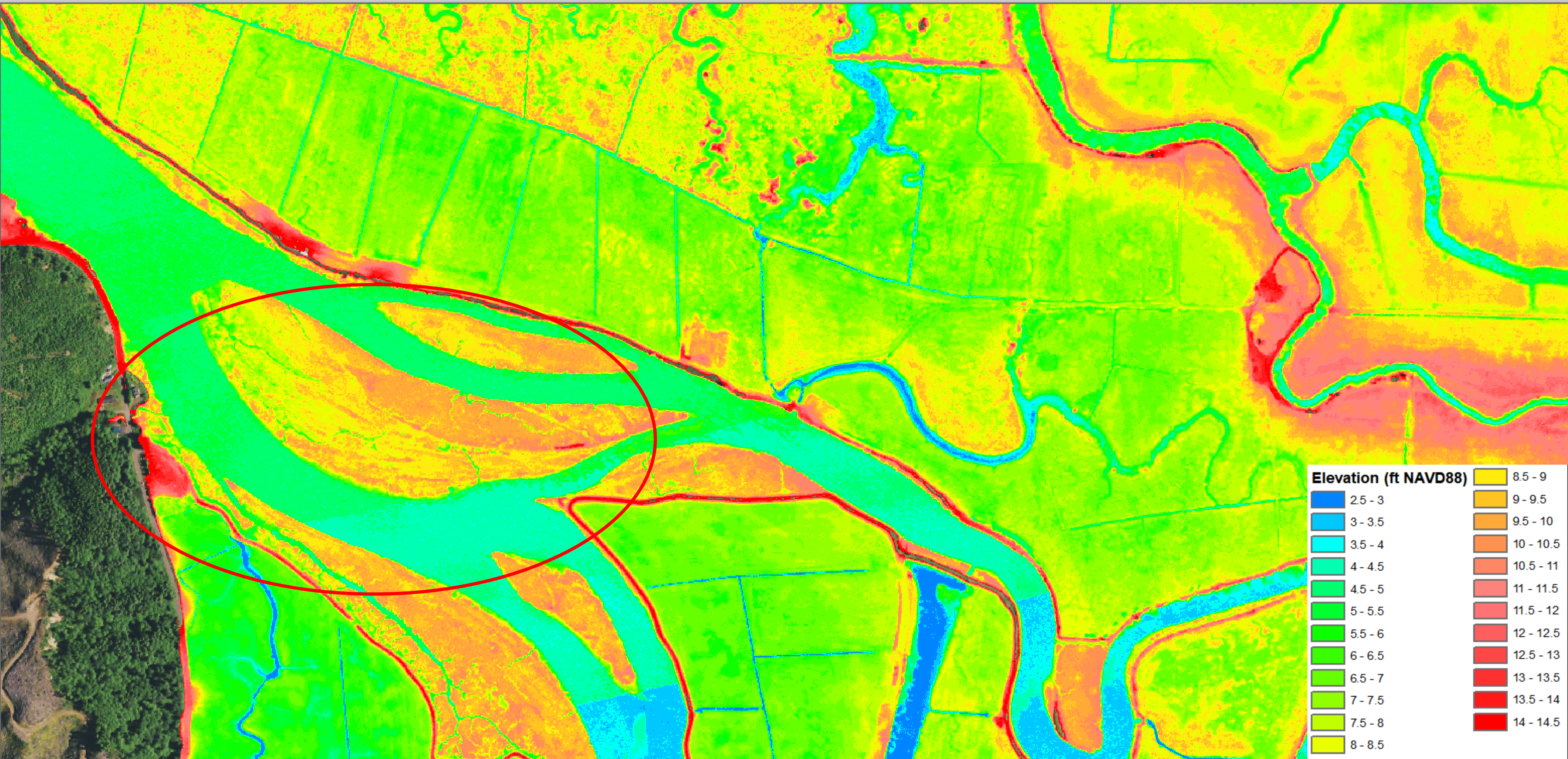

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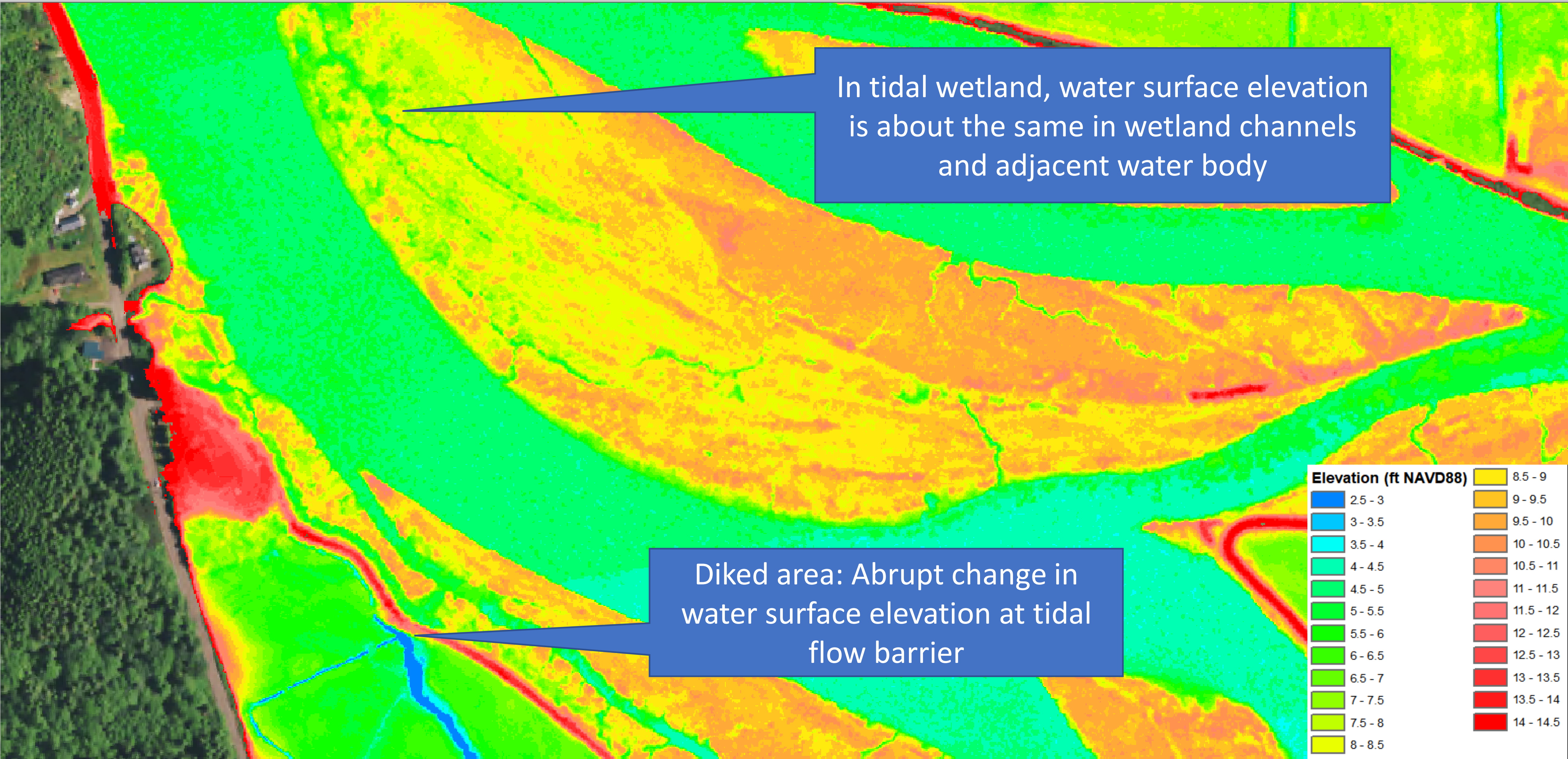
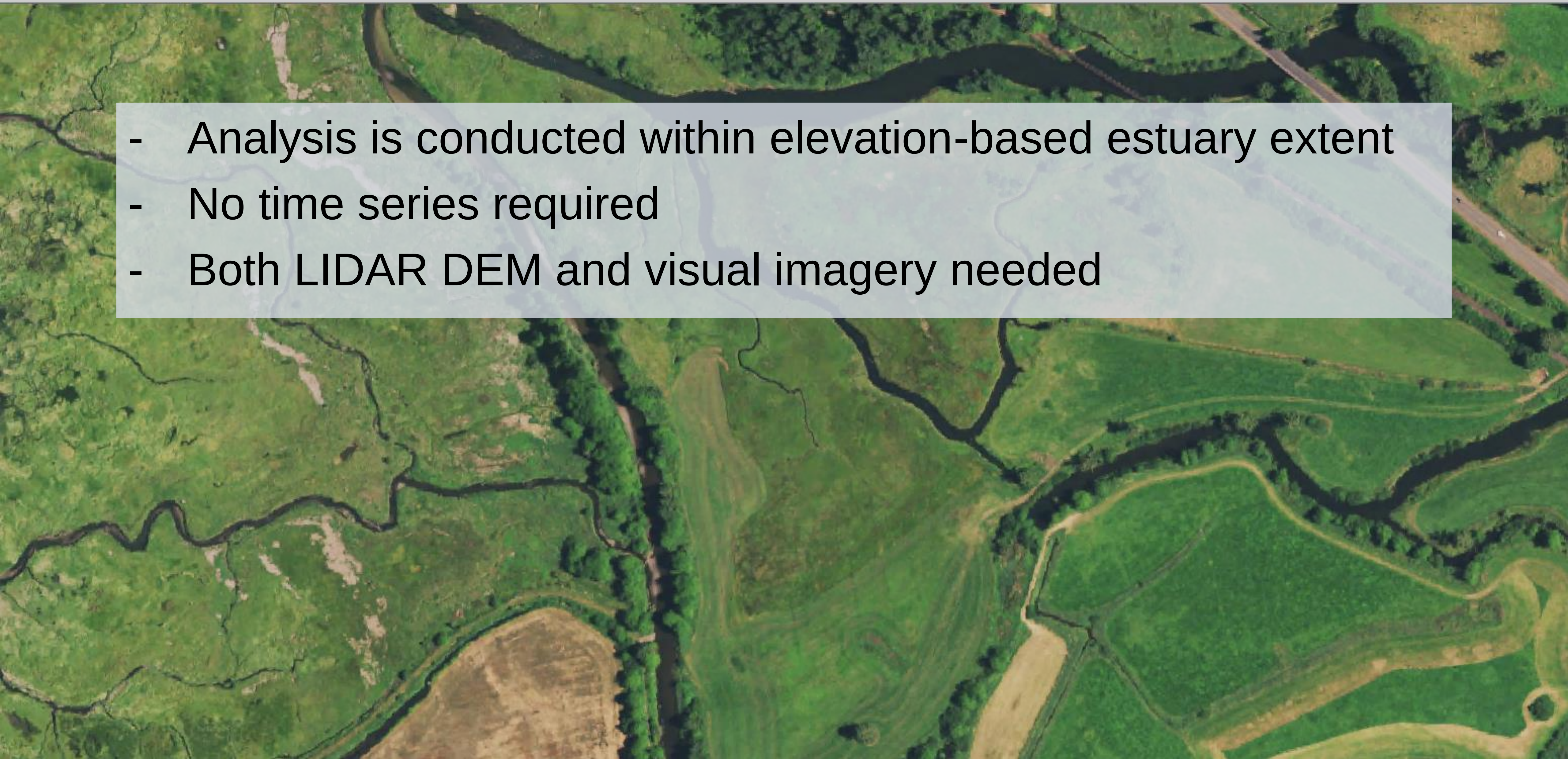


Potential remote sensing approaches:
3. Channel morphology

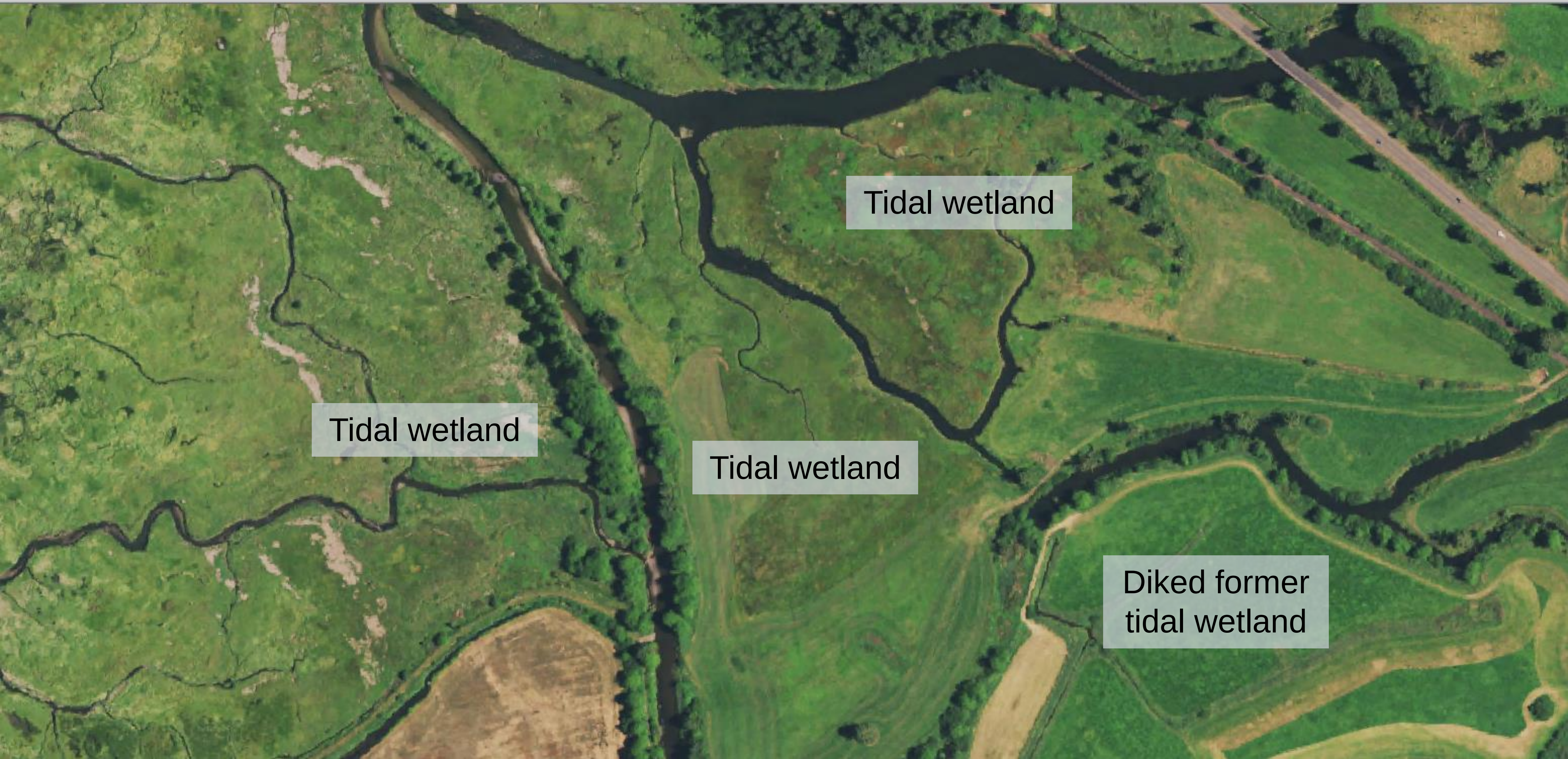


- Analysis is conducted within elevation-based estuary extent
- No time series required
- Both LIDAR DEM and visual imagery needed

Potential remote sensing approaches:
3. Channel morphology

- **Tidal wetlands:**
  - Channel width tapers gradually
  - Channels are sinuous, curving
- **Diked/disconnected or altered former tidal wetlands:**
  - Channels are often straight (ditched)
  - Channels have sudden width discontinuities, turbulence pools, etc. associated with the flow barrier (LIDAR)

Potential remote sensing approaches:
3. Channel morphology



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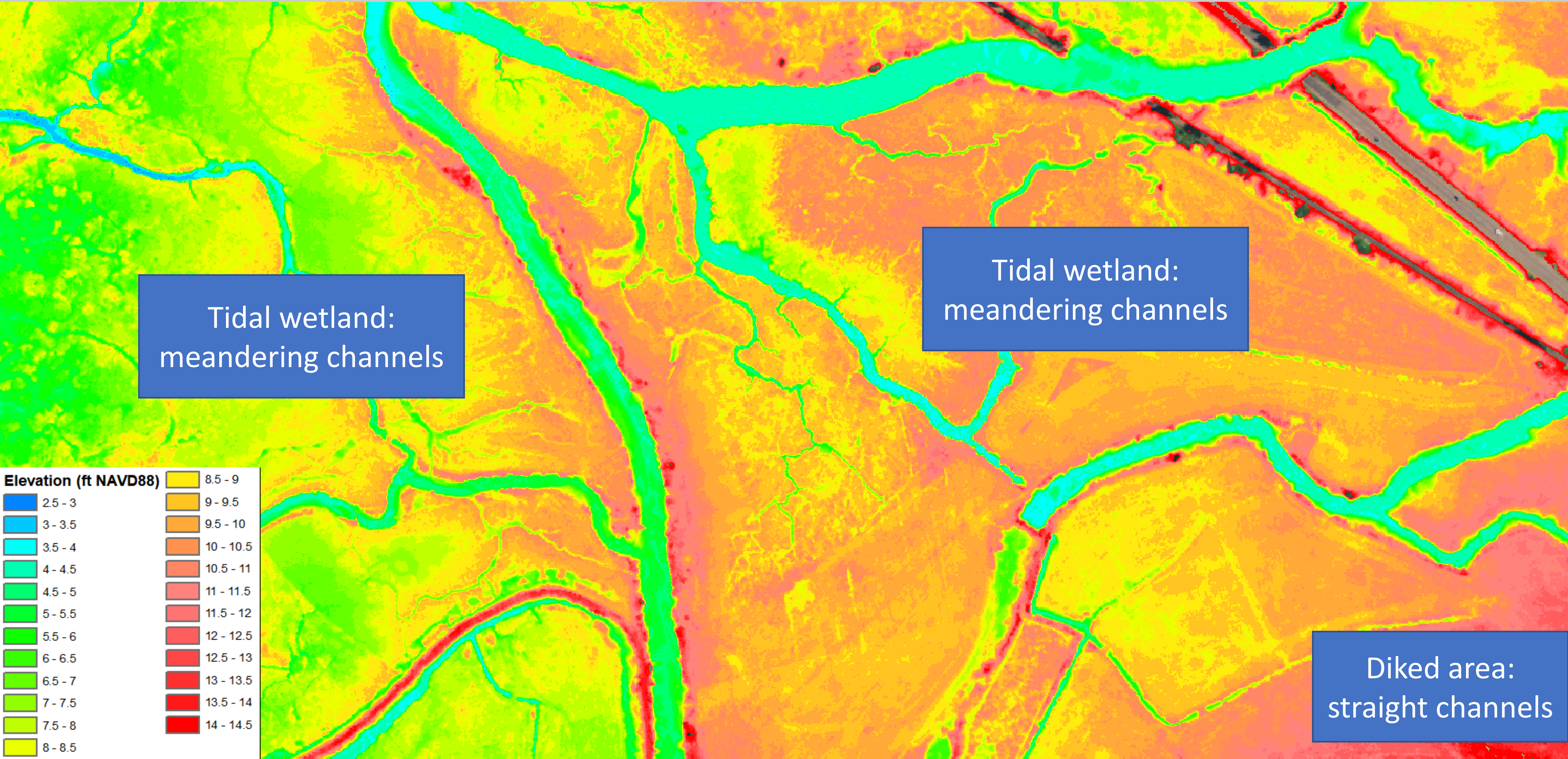

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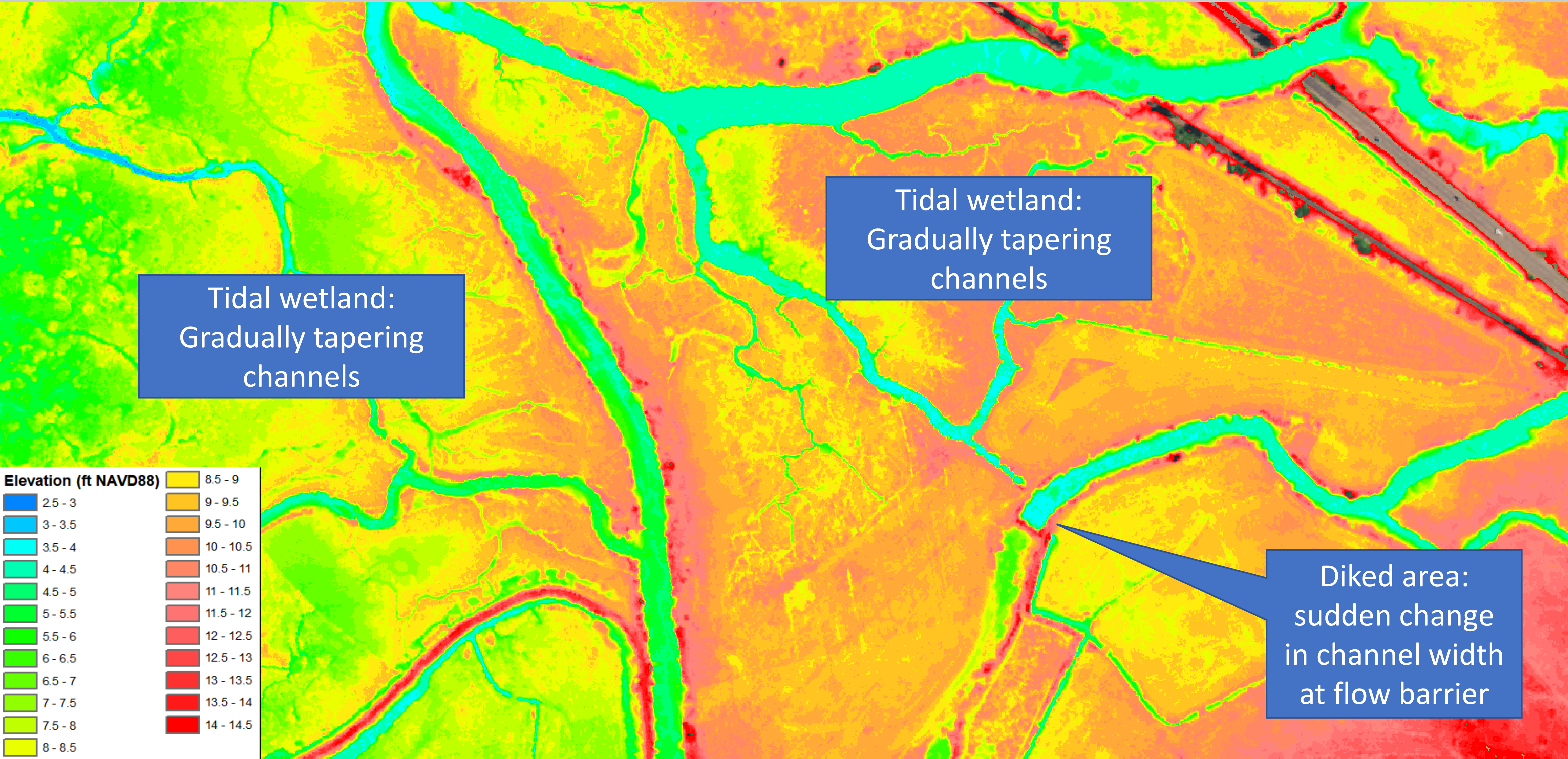
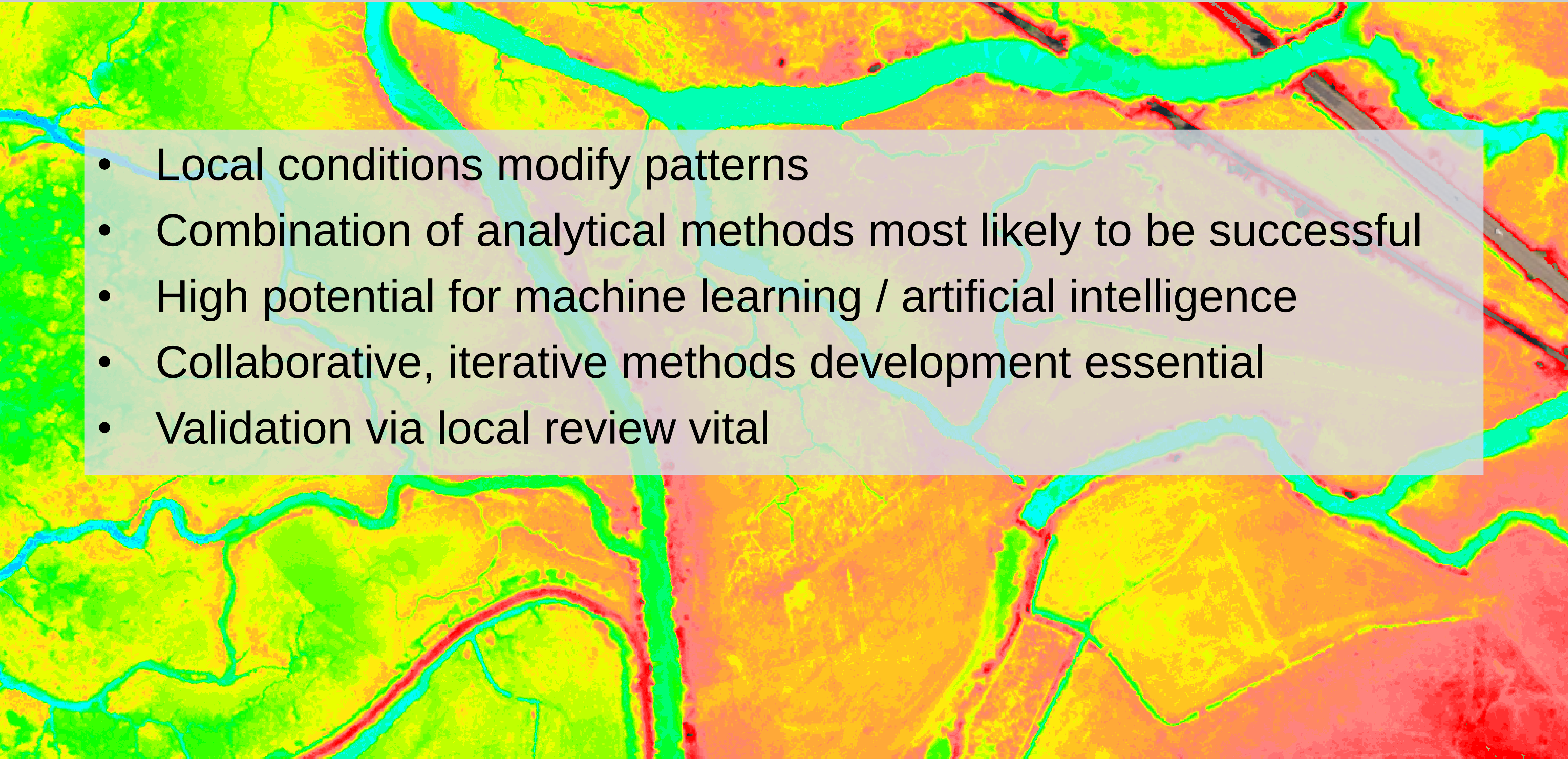


Potential remote sensing approaches: Integration



- Local conditions modify patterns
- Combination of analytical methods most likely to be successful
- High potential for machine learning / artificial intelligence
- Collaborative, iterative methods development essential
- Validation via local review vital

EBEEM vs NWI, Apalachicola River estuary, FL

Tidal Extent by Data Source	Area (ha)	% of Vegetated Tidal Area
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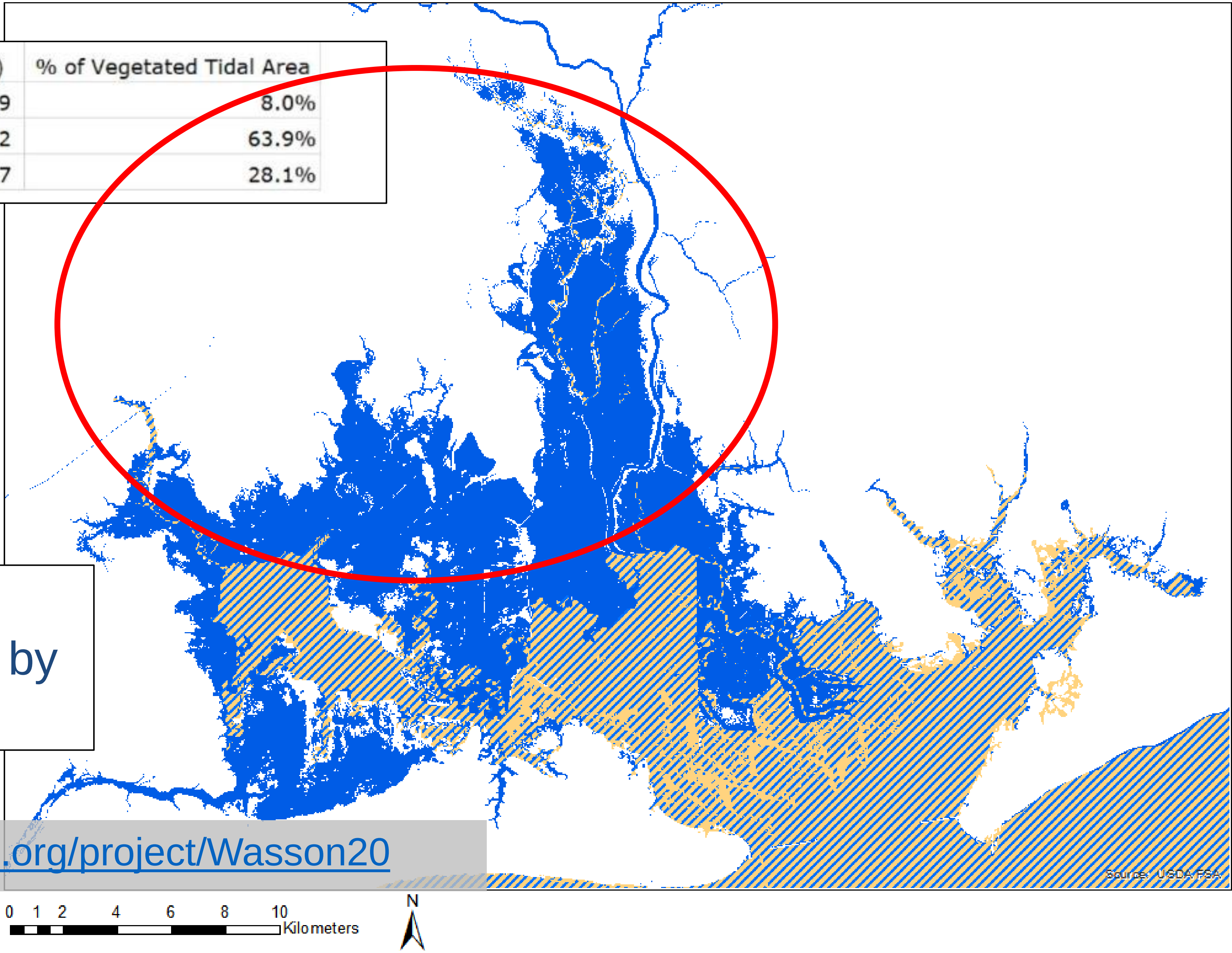

~ 23,000 ha of forested tidal wetlands identified by EBEEM but not by NWI

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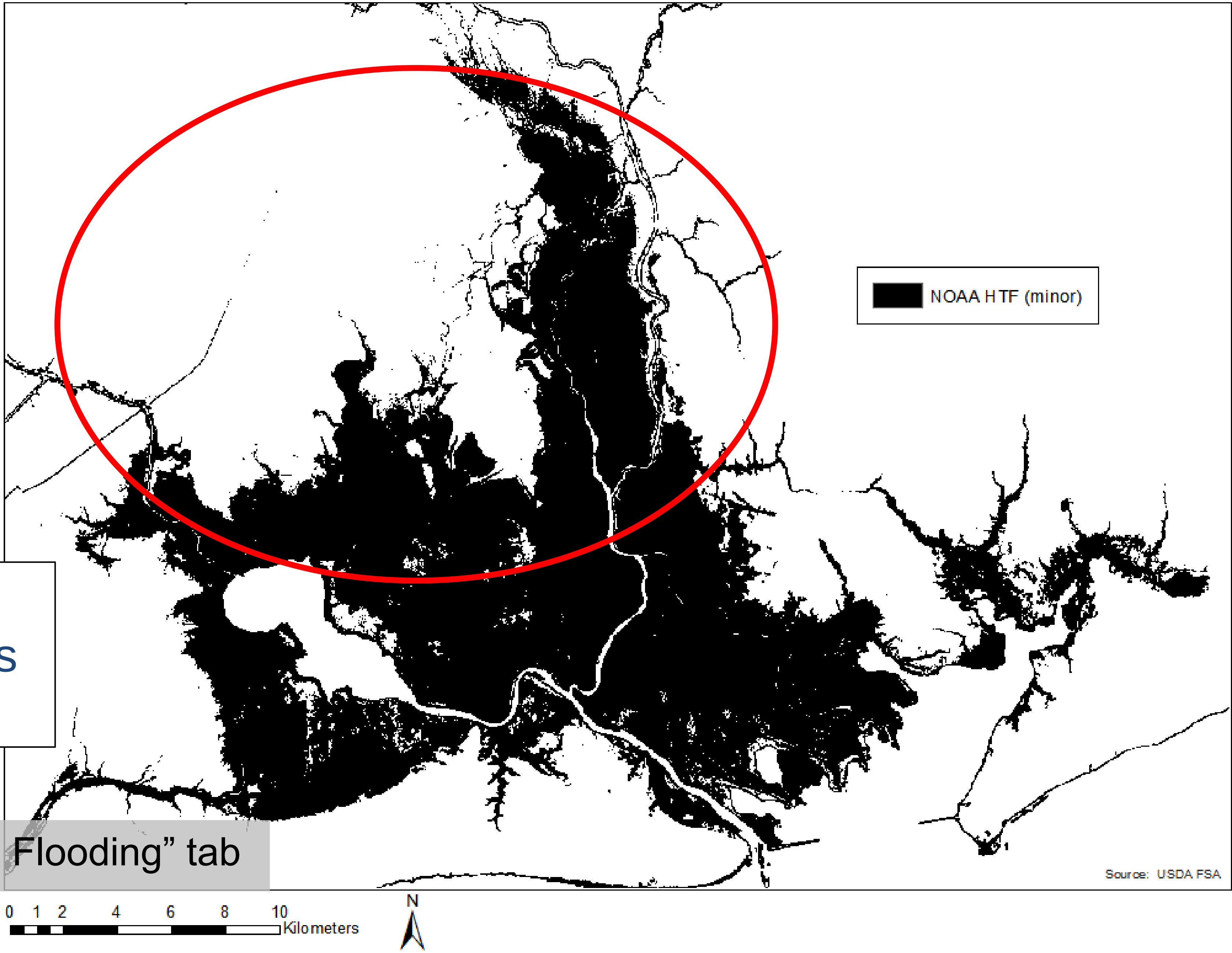
EBEEM vs NOAA High Tide Flooding (minor), Apalachicola



NOAA High Tide Flooding (minor) aligns closely with EBEEM

https://coast.noaa.gov/slr/ “High Tide Flooding” tab

Remote sensing potential applications

Map blue carbon resources (especially shrub and forested tidal wetlands)

Map potential restoration sites (diked/disconnected sites); assess restoration effectiveness

Map salinity: temporal variability, existing conditions, projections

Salinity data gap: Importance

Key driver for multiple tidal wetland functions, e.g.:

- Greenhouse gas flux and climate forcing
- Landscape distribution of tidal marsh vs. tidal forest
- Restoration site selection for marsh vs. swamp
- Wildlife support (e.g. salt adjustment for juvenile salmon)

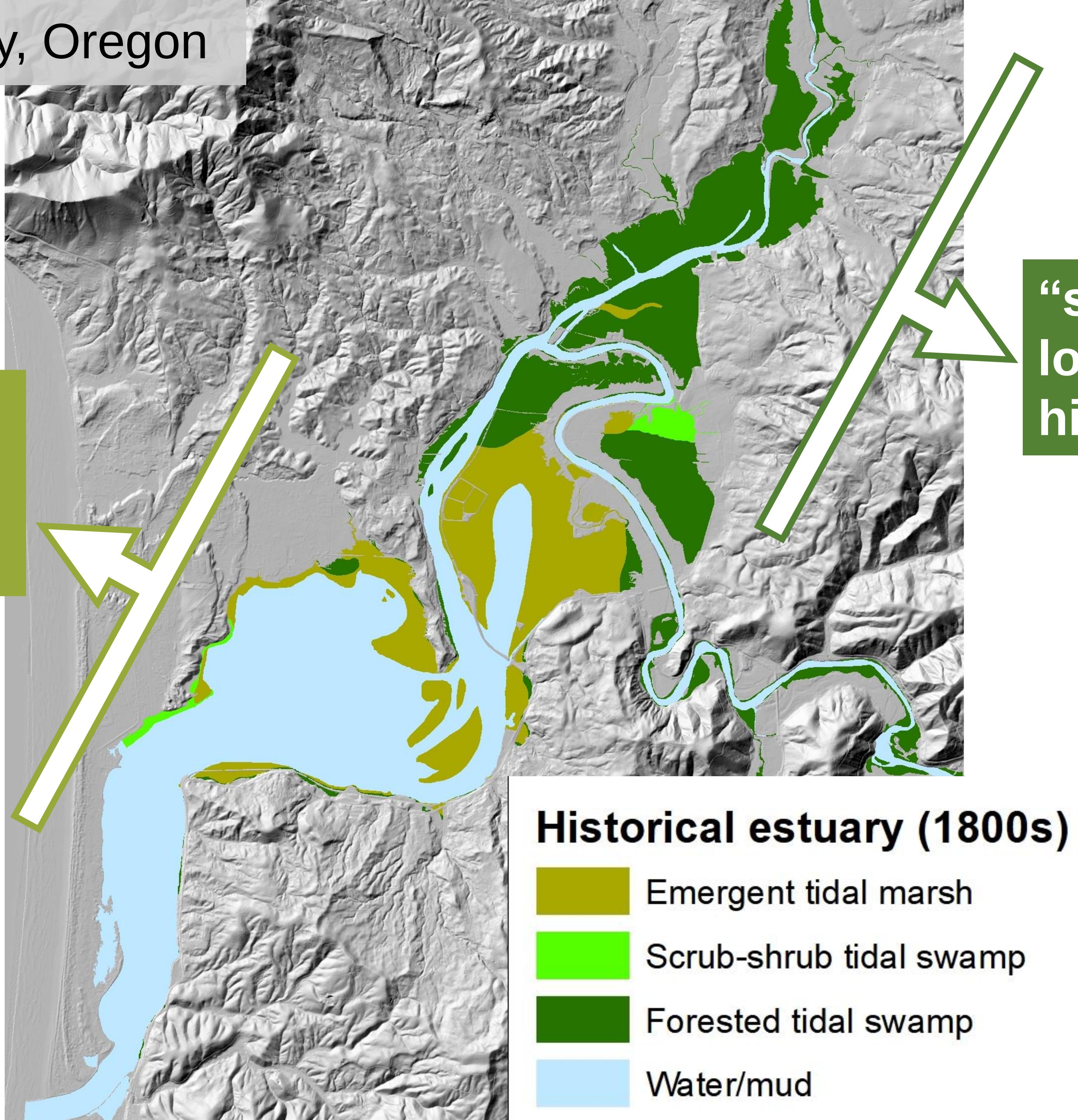
Critical to human activities:

- Drinking water
- Agriculture

Nehalem River estuary, Oregon

“marsh zone”:

higher salinity,
lower elevations



“swamp zone”:
lower salinity,
higher elevations

Nehalem River estuary, Oregon

But... where can we restore tidal swamp today?

Salinity maps are needed to guide restoration.

Institute for Applied Ecology

Salinity data gap: Challenges

Field monitoring:

- Data collection is labor-intensive
- Sensors susceptible to biofouling
- Temporal and spatial variation on multiple gradients:
  - Spatial: Lower, middle, & upper estuary; within-site gradients
  - Temporal: Daily tide cycle, neap/spring, seasonal

Modeling:

- Hydrodynamic modeling is expensive
- Difficult to parameterize
- Potential for reduced empirical model

Salinity data gap: Remote sensing approaches

Vegetation proxy:

- Primarily useful for well-studied tidal marsh
- Inadequate data for forested tidal wetlands
- Limited ability to address temporal, spatial variability

Direct remote sensing:

- Help determine thresholds for priority ecosystems
- Supports restoration planning, vulnerability assessment
- Makes no assumptions
- Can measure temporal variability, supporting GHG flux models
- Challenges: Resolution, accuracy

GIScience & Remote Sensing ›
Volume 60, 2023 - Issue 1

Review

Remote sensing of sea surface salinity: challenges and research directions

Young Jun Kim, Daehyeon Han, Eunna Jang, Jungho Im & Taejun Sung

Article: 2166377 | Received 24 Oct 2022, Accepted 03 Jan 2023, Published online: 17 Jan 2023

Download citation https://doi.org/10.1080/15481603.2023.2166377 Check for updates

"... the operational retrieval of SSS via satellite remote sensing still faces significant challenges."

Young et al. 2023

Thank you!

Laura Brophy
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and
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College of Earth, Ocean and Atmospheric Sci.
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