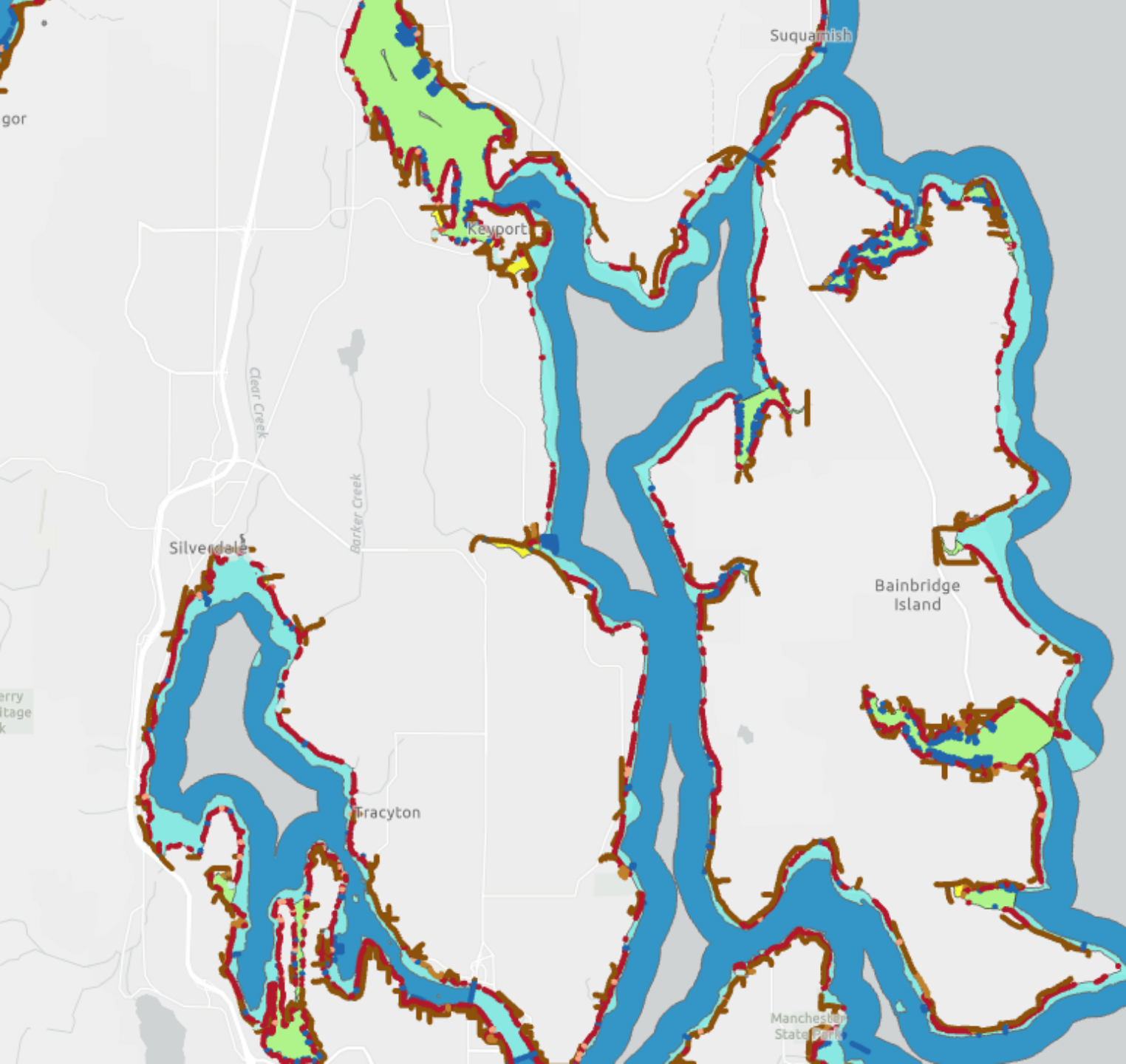


These slides have been updated after we determined the tidal restriction datasets for the Large River Deltas and Nearshore were in different coordinate reference systems, resulting in different units (meters and feet) for the features' lengths. This resulted in the tidal restriction lengths in the Large River Deltas dataset being under-represented in some of the figures we presented in our ESRP webinar in July 24, 2025.

Slides 22, 23, and 25 were updated with corrected values.

A map of Puget Sound and its tributaries, including the Skagit, Snohomish, and Kitsap rivers. The map is overlaid with a complex network of colored lines (red, blue, green, yellow) representing tidal restrictions and tidally influenced areas. Labels on the map include 'Suquamish', 'Keyport', 'Silverdale', 'Bainbridge Island', 'Tracyton', 'Manchester State Park', 'Clear Creek', and 'Barker Creek'.

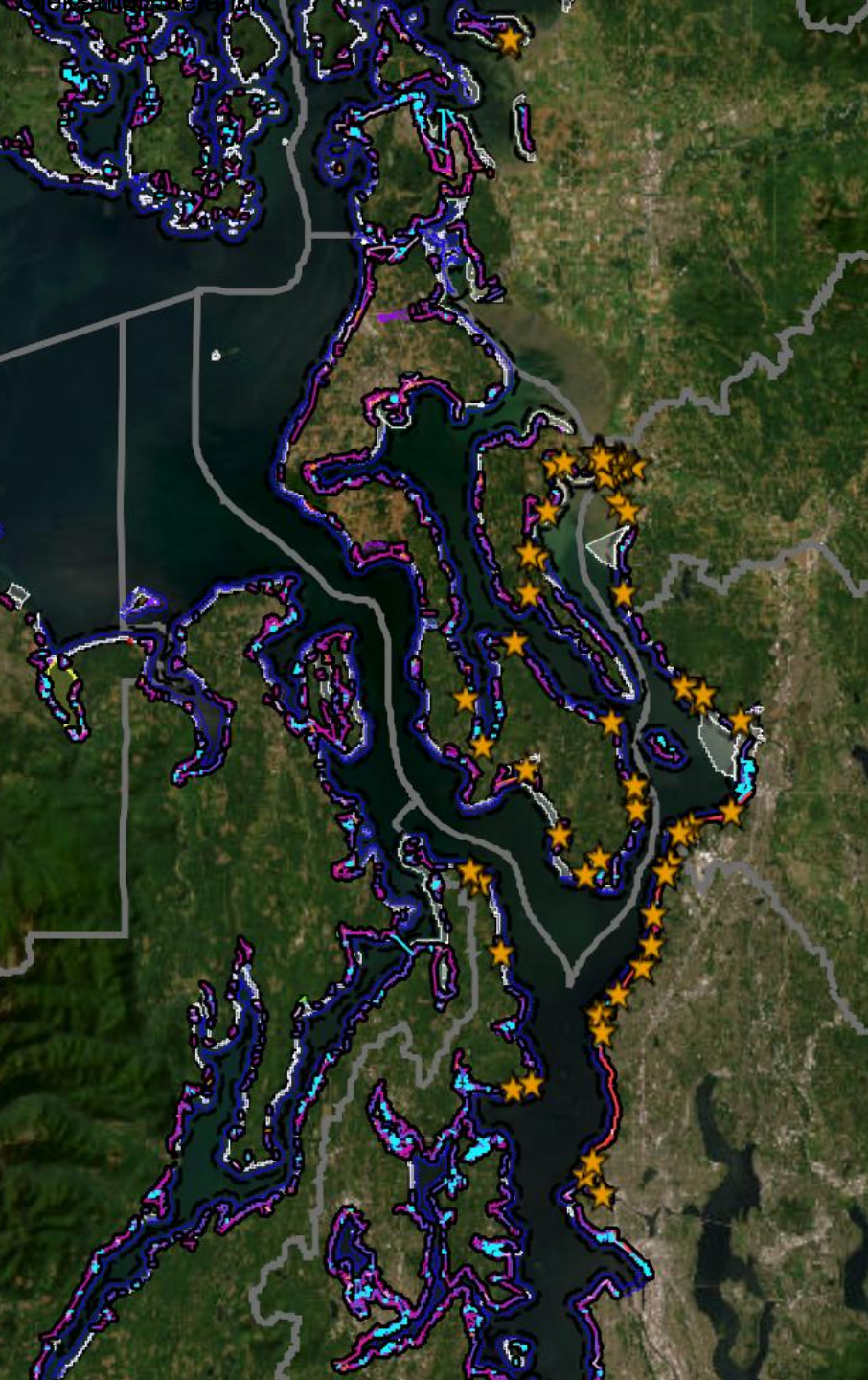
Mapping Tidal Restrictions & Tidally Influenced Extent in Puget Sound

Jason Hall, Melinda Paulus, Kai Ross

Cramer Fish Sciences

Tish Conway-Cranos (WDFW) , Jen Burke (PSP)

ESRP 20-1941 Webinar – July 24, 2025



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- Technical Advisory Group, Project Partners, and Regional Reviewers:
 - **Tish Conway-Cranos (WDFW/ESRP)**
 - **Jennifer Burke (PSP)**
 - Kay Caromile (RCO)
 - **Oleksandr Stefankiv (ECY)**
 - Mary Ramirez (King County DNR)
 - Rachel Bouchillon (WDFW)
 - **Ryan Gatchell (WDFW)**
 - **Analiese Burns (City of Bellingham)**
 - **Emily Howe (TNC)**
 - **Jessica Cote (BCE)**
 - Tim Beechie (NOAA)
 - Hannah Liss (PSP)
 - Catherine Buchalski Smith (WDFW)
 - Roger Peters (USFWS)
 - Correigh Greene (NOAA)
 - Annelise Del Rio (PSP)
 - Nathalie Hamel
 - Megan Wilson (PSP)
 - **Todd Zackey (Tulalip Tribes)**
 - **Laura Brophy (Institute for Applied Ecology)**
 - Dorris Small
 - Dawn Spilsbury
 - Josh Chamberlin (NOAA)
- All the folks that reviewed the dataset– ***THANK YOU!***

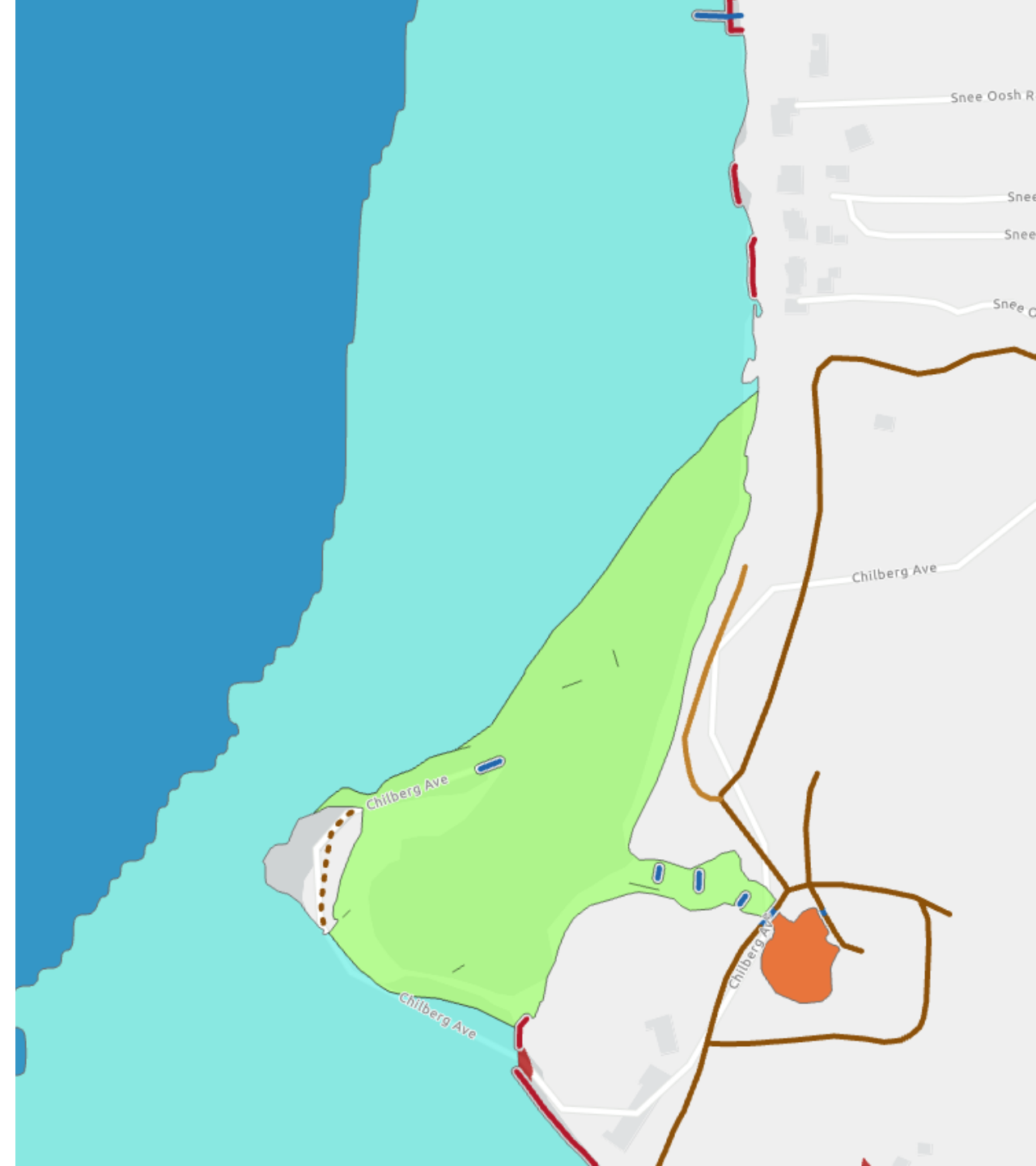


WASHINGTON STATE
Recreation and
Conservation Office



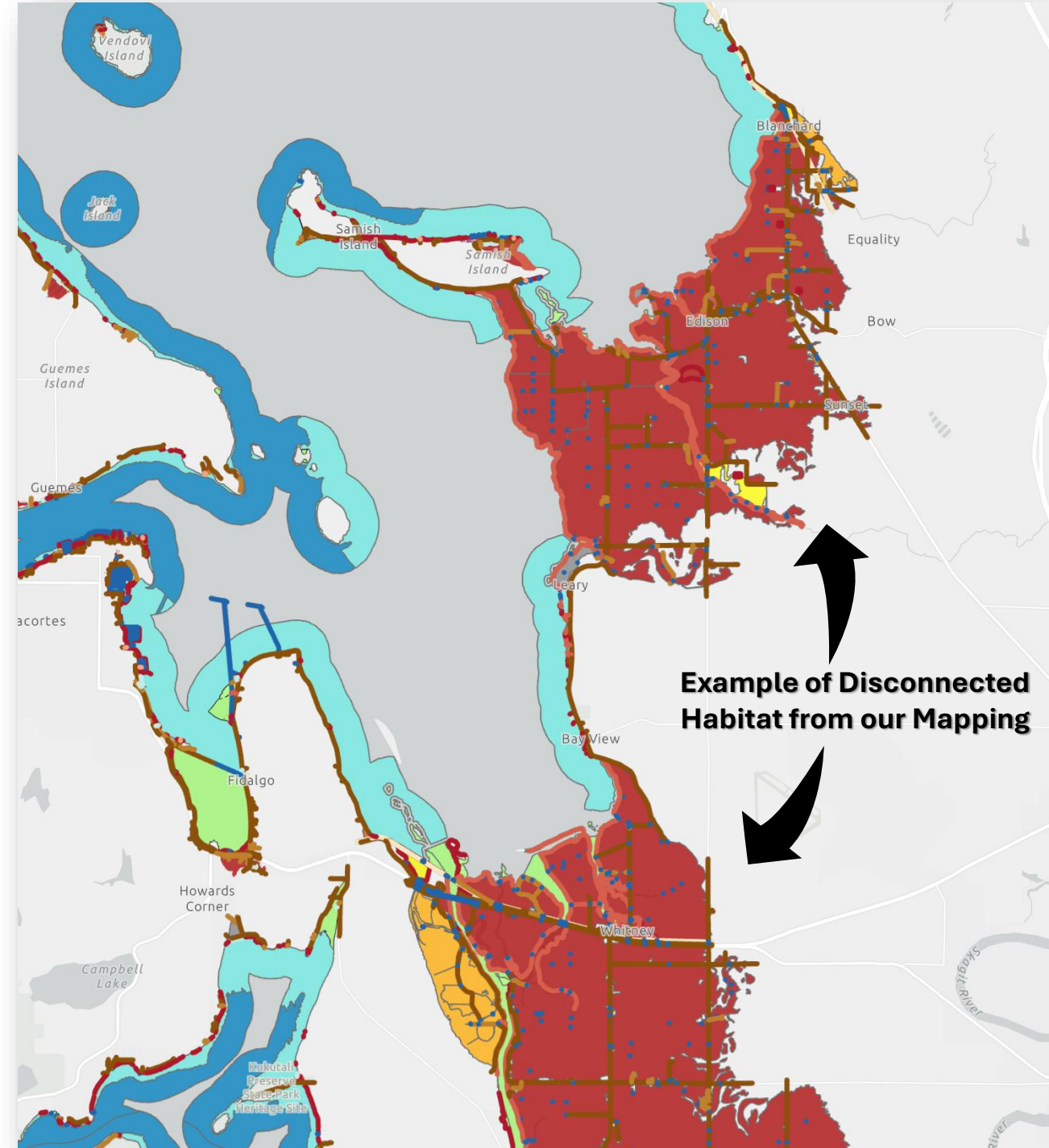
Outline

- Background and objectives
- Methods & Approach
- Results
- Applications & Next Steps



Background

- Significant loss of tidally influenced habitats in Puget Sound
- Connectivity a central issue – tidal restriction features
- Restoration a priority for Chinook recovery



What are tidal restrictions?



Tidal restrictions: *Man-made features that disrupt tidal and floodplain functions & processes as well as biotic movement*

Levees / Dikes



Roads / Railways



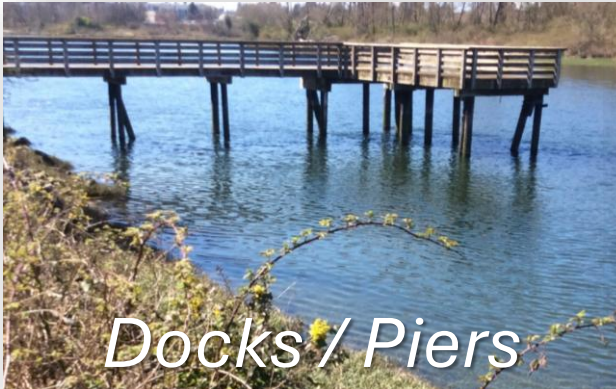
Fill



Armor



Docks / Piers



Bridges



Culverts



Tide Gates



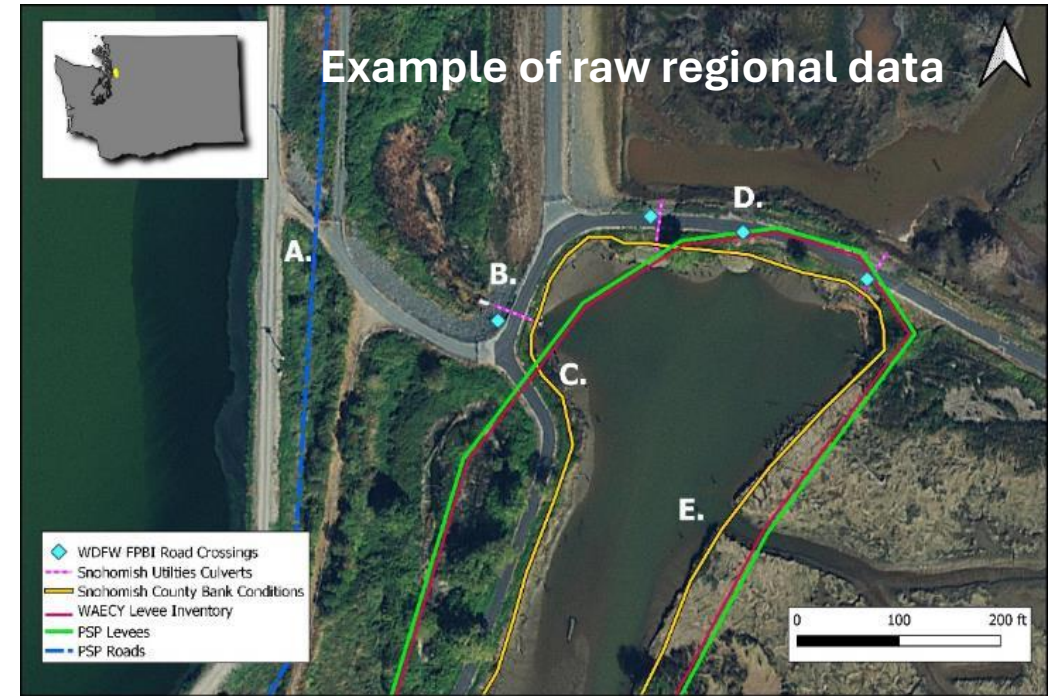
The Problem

Many data sets exist but...

- *Outdated/incomplete*
- *Different accuracy/resolution*
- *Varying attributes/applications*
- *Not in central location or standardized format*

Need consistent regional data

- *Habitat status and trends monitoring and reporting*
- *Identify and prioritize restoration opportunities*
- *Inform restoration and recovery planning*

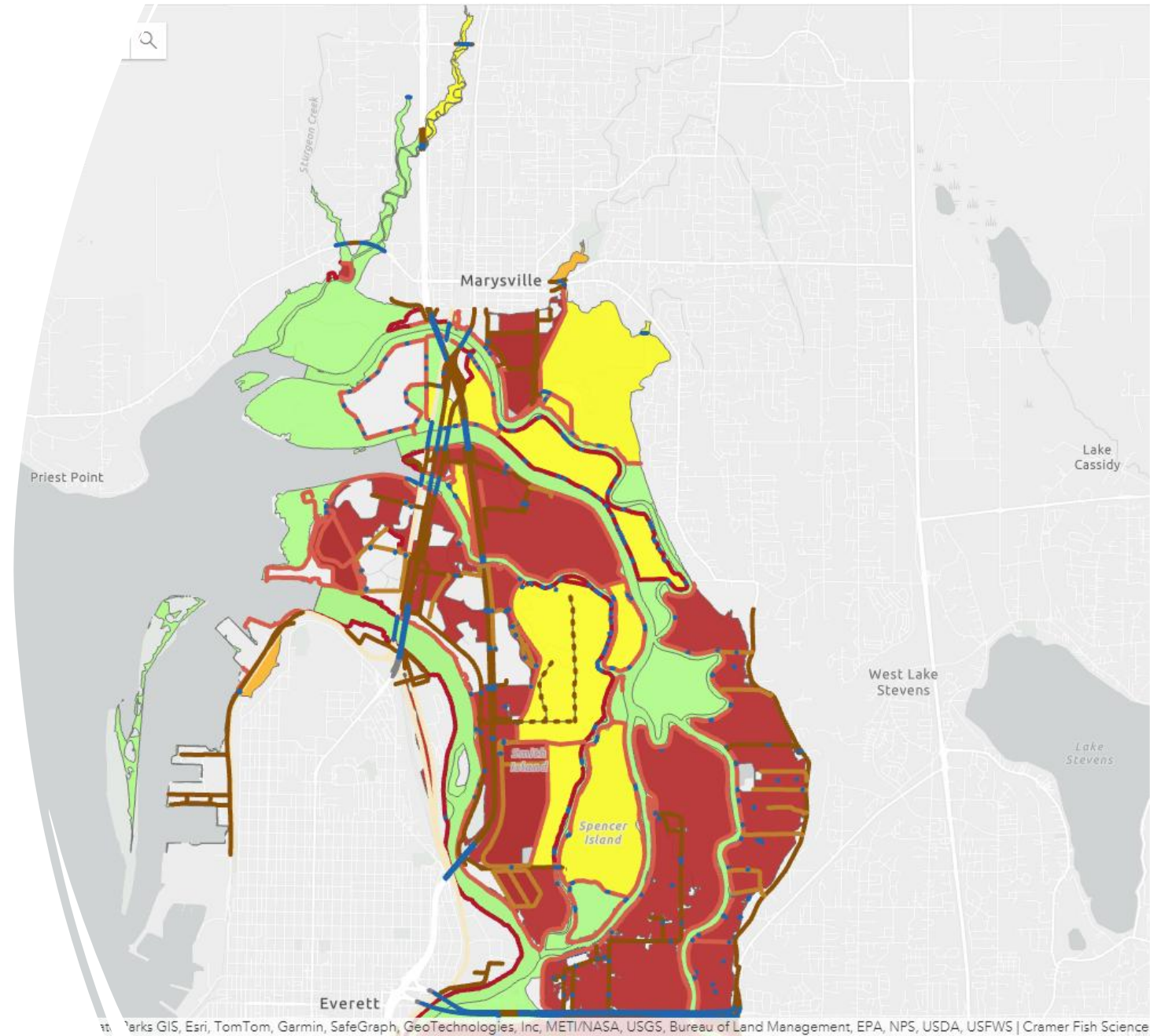


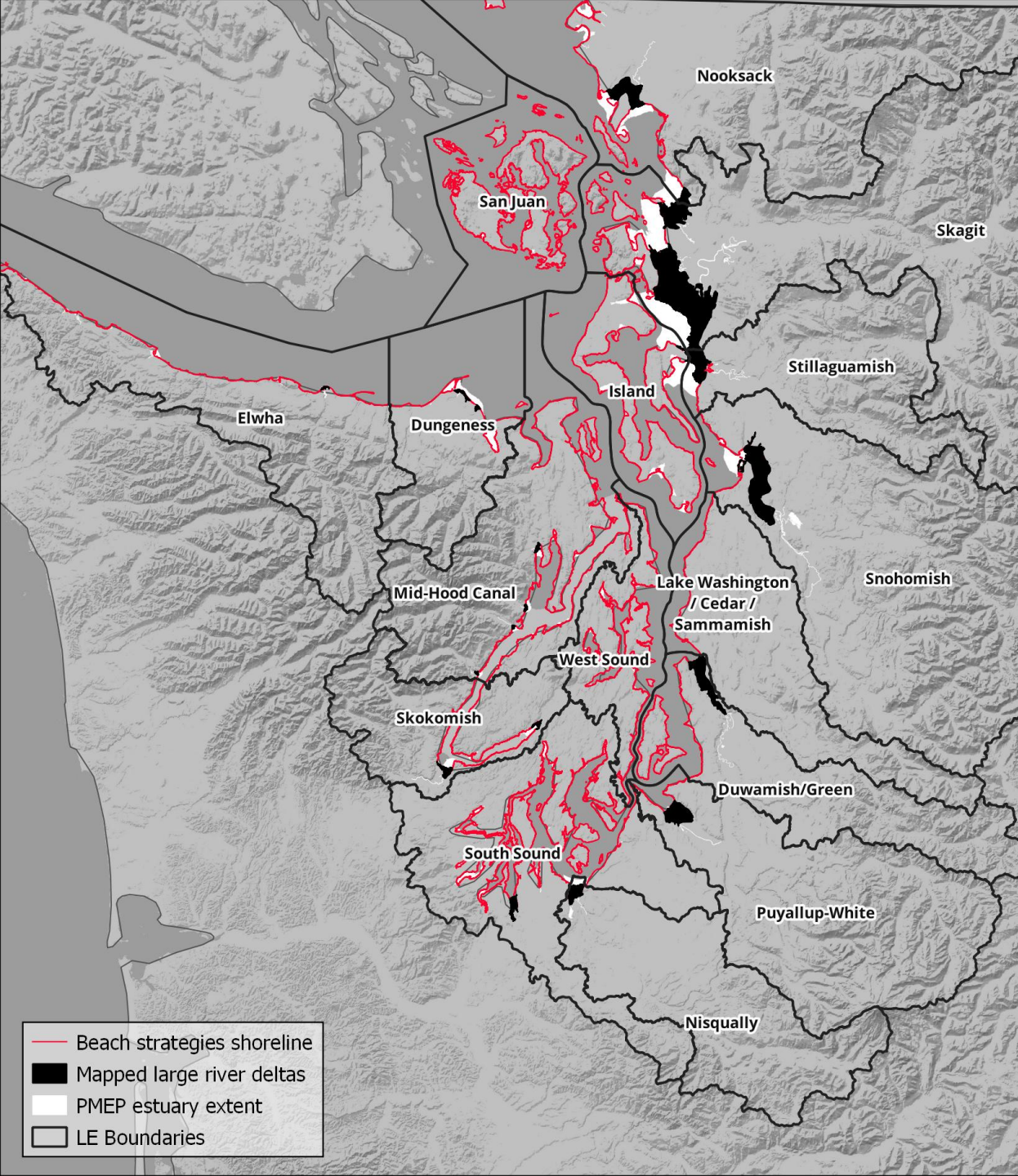
Examples of agencies that can utilize consistent regional scale data



The Approach

- PS deltas mapped as part of previous ESRP Learning Project (18-2250)
- Developed standardized spatial database and remote sensing-based approach
- Mapped tidal restrictions and tidally influenced habitats and published data
- Applying the same approach to map the rest of the Puget Sound shoreline for this project (20-1941)





Project Goals & Objectives

- Map rest of Puget Sound shoreline
- Combine with PS delta data
- Create consistent regional scale spatial database of:
 - *Tidal restriction features*
 - *Tidally influenced habitats*
- Publish data to WDFW Webmap
- Readily accessible data to support regional recover planning and reporting

Methods & Approach



Data compilation and standardized database



Remote sensing and digitizing tidal restriction features



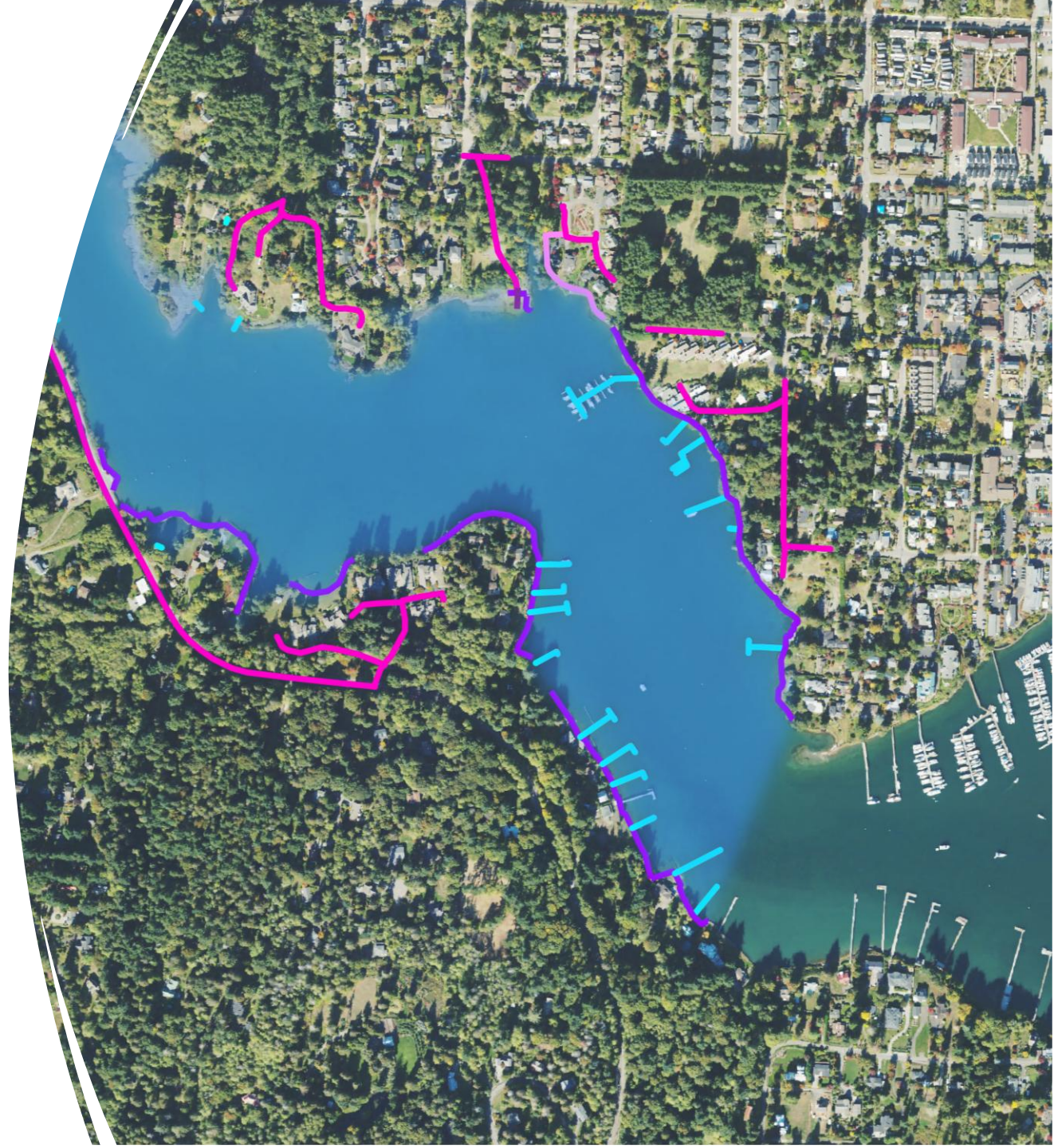
Delineating and classifying tidally influenced extent



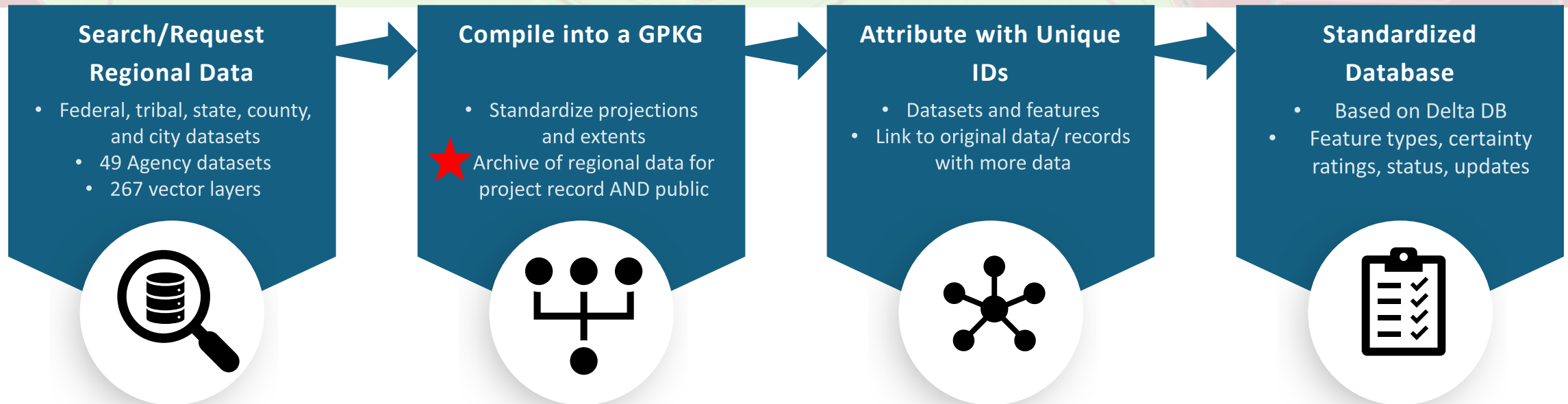
Regional review



Data sharing

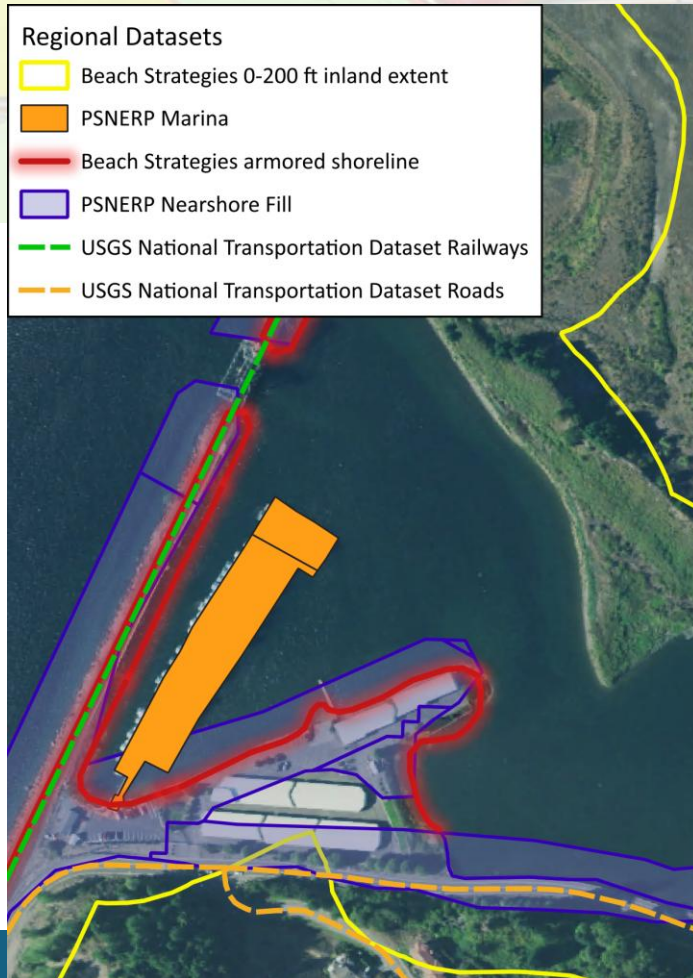


Data compilation and standardized database

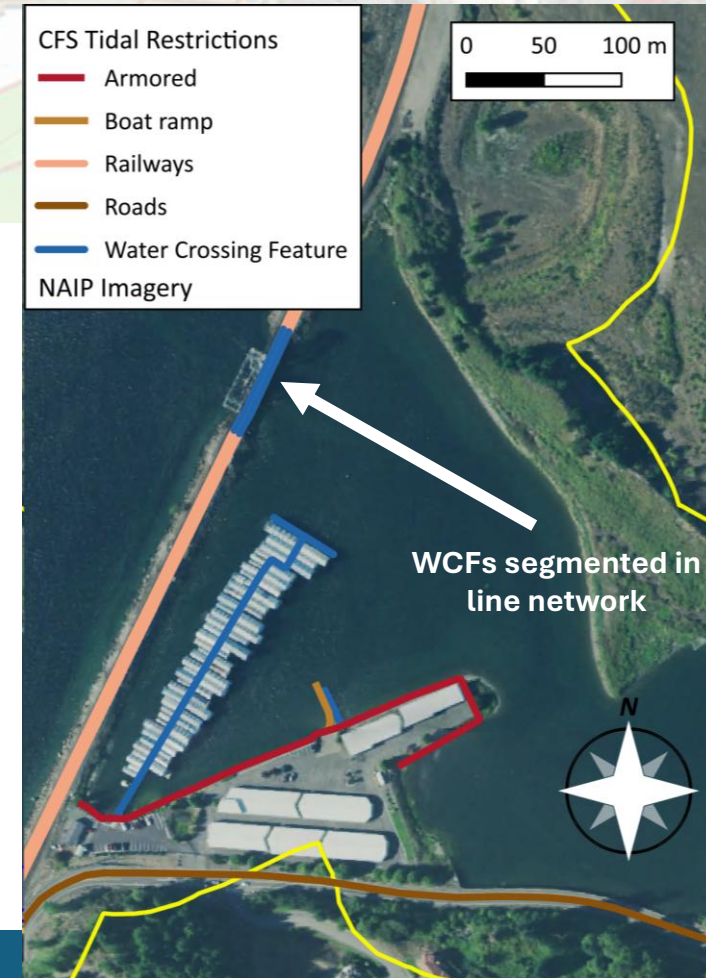


Remote sensing and digitizing tidal restrictions

Raw regional data

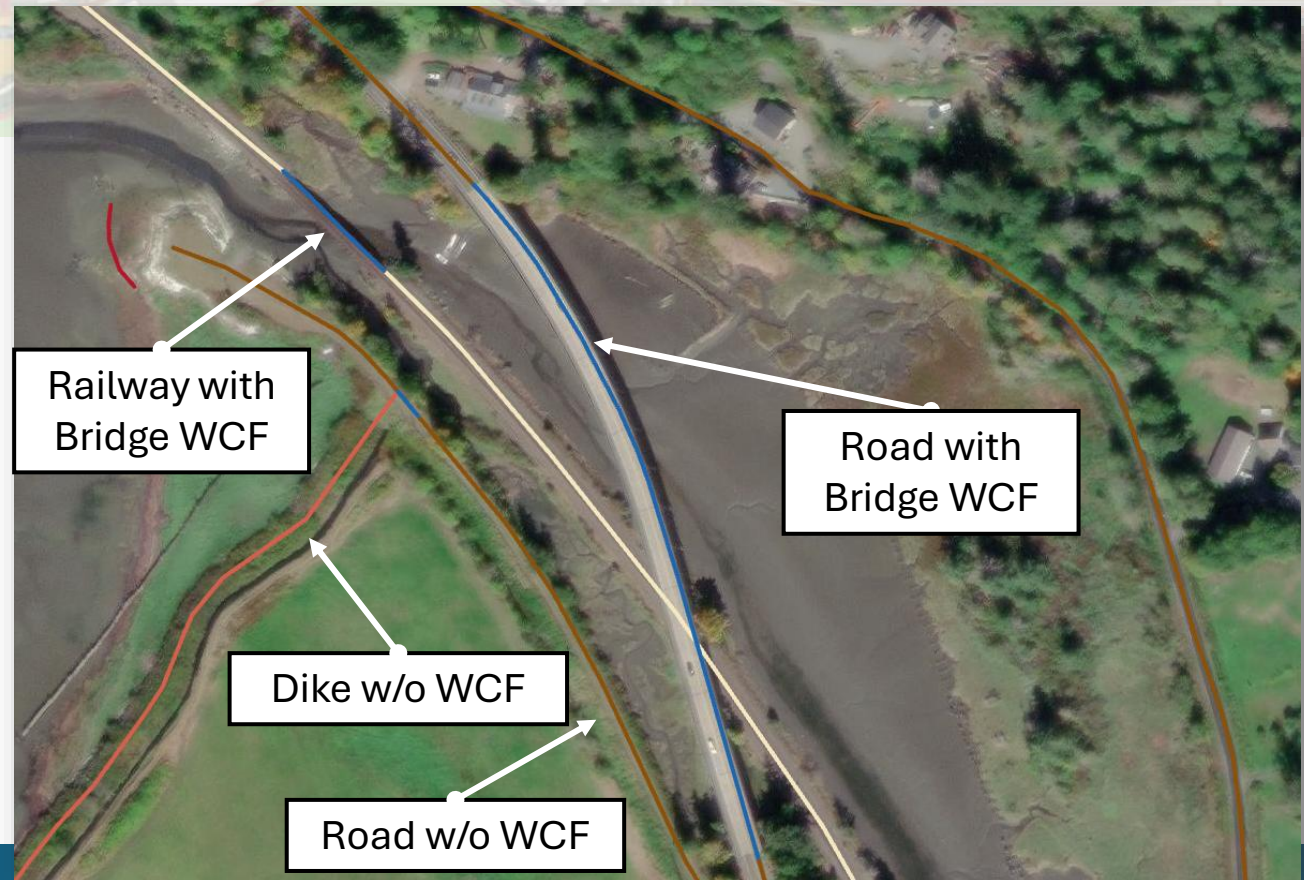


Final data



Tidal restriction feature type classifications

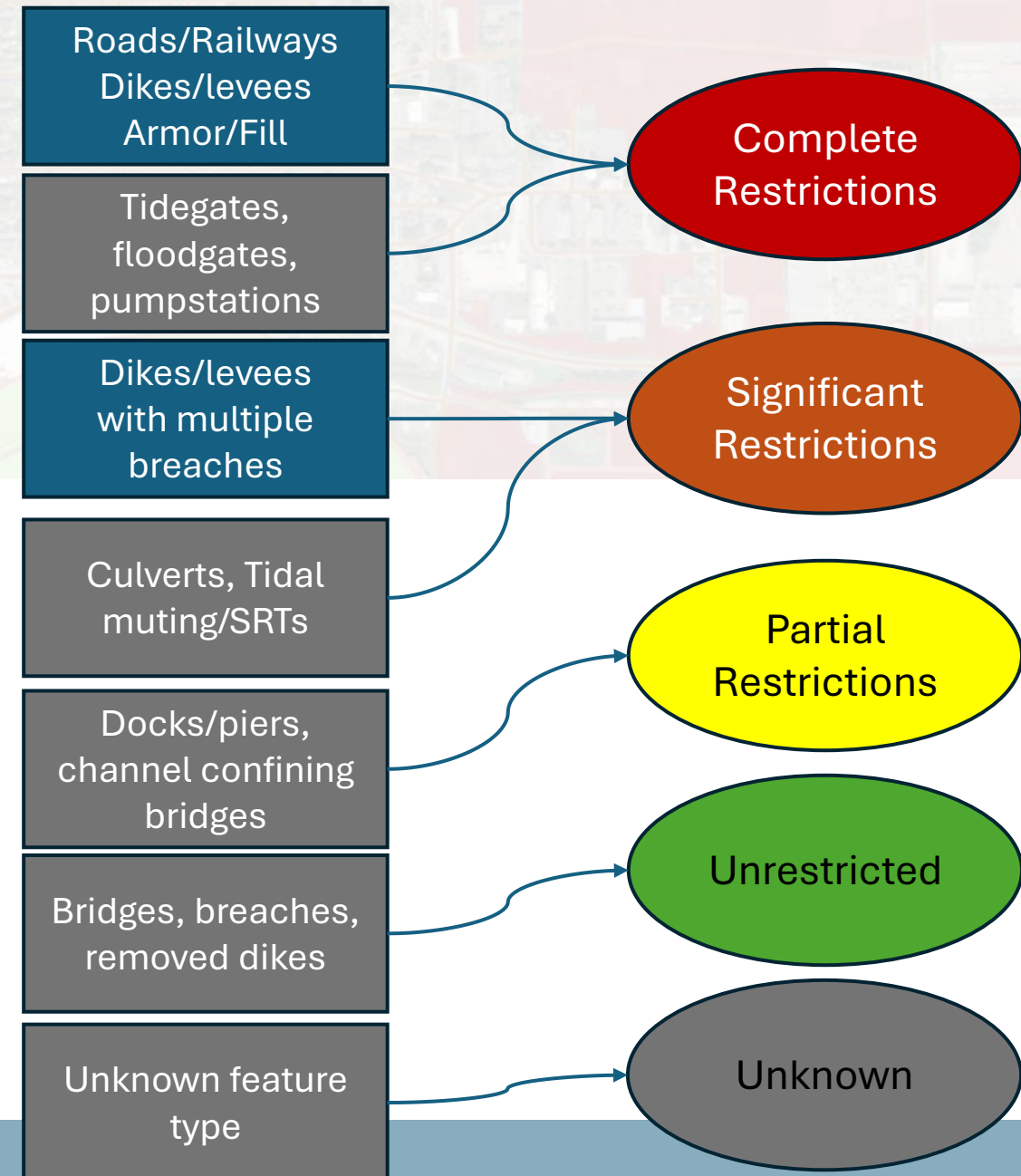
1. Two-tiered classification:
 - *Primary feature type*
 - *Water Crossing Feature (WCF)*
2. Use feature type from regional data if available - OR
3. Determine from aerial imagery if possible (some easier than others)
4. Otherwise classified as unknown and flagged for review



Tidal restriction connectivity ratings

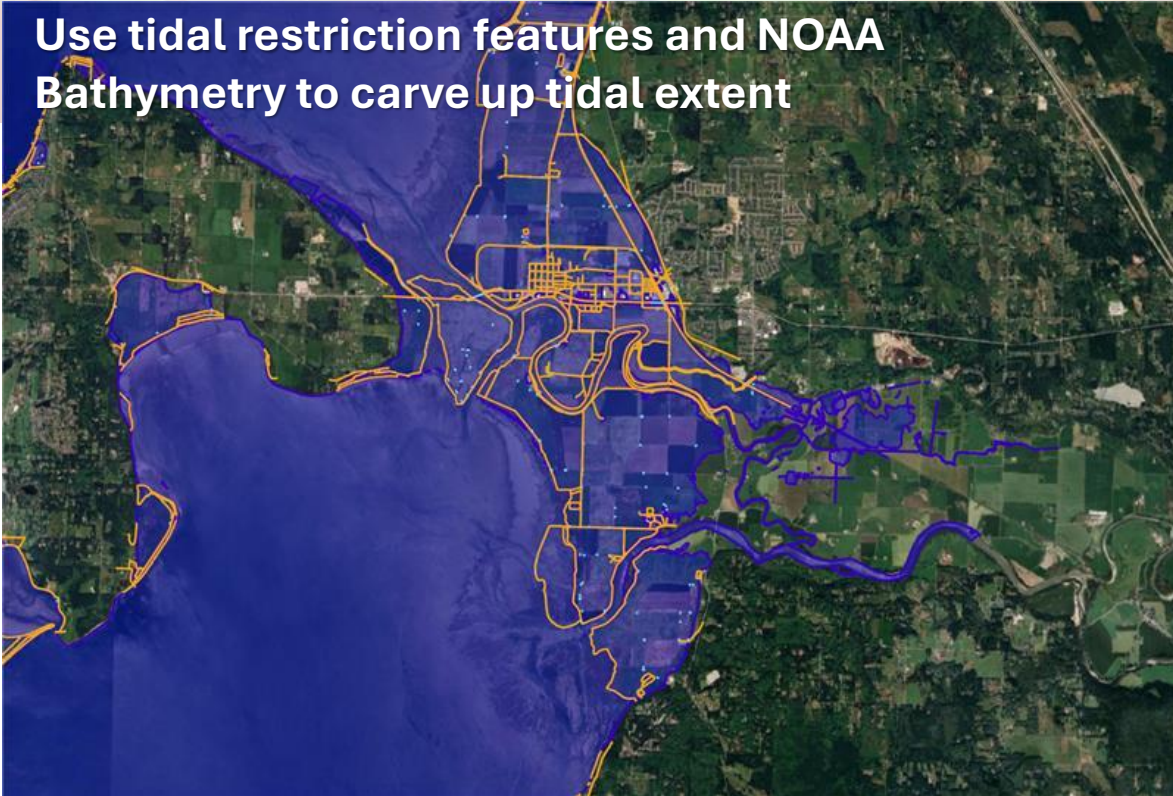
1. Rule-based classification system based on feature type and remote sensing
2. Includes feature status, certainty rating, and update fields
 - *Supports trends/change analysis*
 - *Identify features for review / validation*

Simplified rule-based classification system used to classify tidal connectivity impacts



Delineating and classifying tidally influenced extent

Use tidal restriction features and NOAA Bathymetry to carve up tidal extent

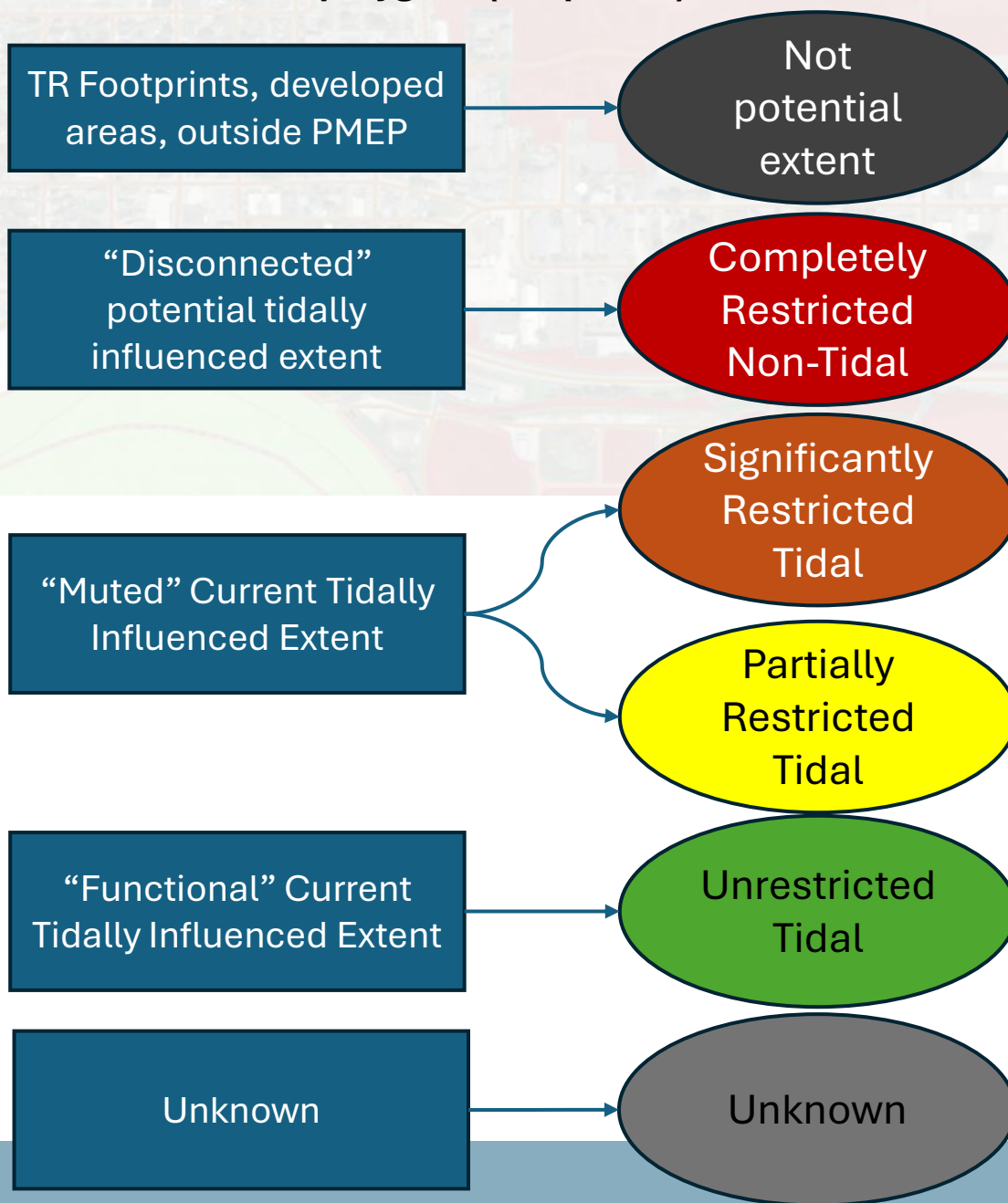


- PMEP tidal exceedance and 1,000-ft buffer NGF Shoreline to define seaward extent
- **Removed** tidal restriction feature footprints and developed areas from potential extent
- “Carved up” polygons with TR restriction polyline network
- Classify connectivity ratings based on tidal restriction features and landscape position

Tidal extent connectivity ratings

1. Considered:
 1. *TR features that surround the polygon*
 2. *TR features seaward or downstream of polygon (uses most severe rating)*
2. Includes certainty ratings to support review and validation
3. And update fields for status and trends

Connectivity ratings used for tidally influenced extent polygons (simplified)

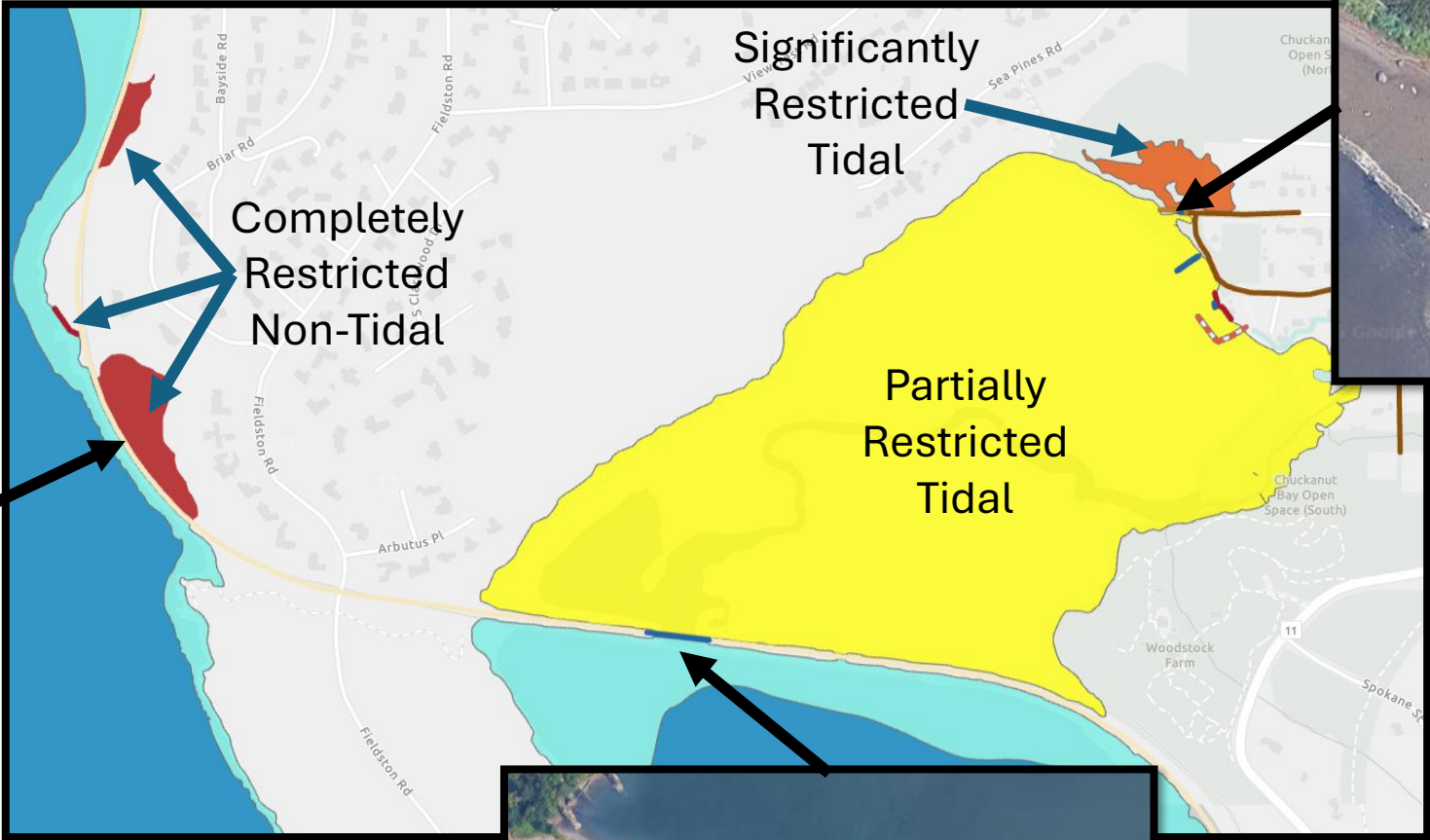


Example: Chuckanut Pocket Estuary

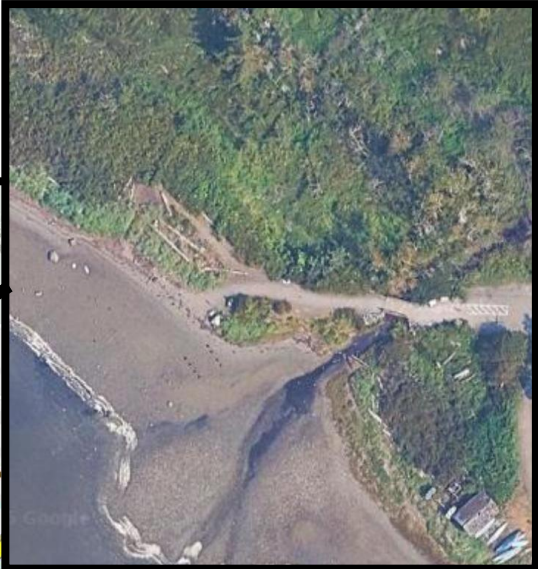
Culvert WCF in regional data
classified as a Significant Restriction



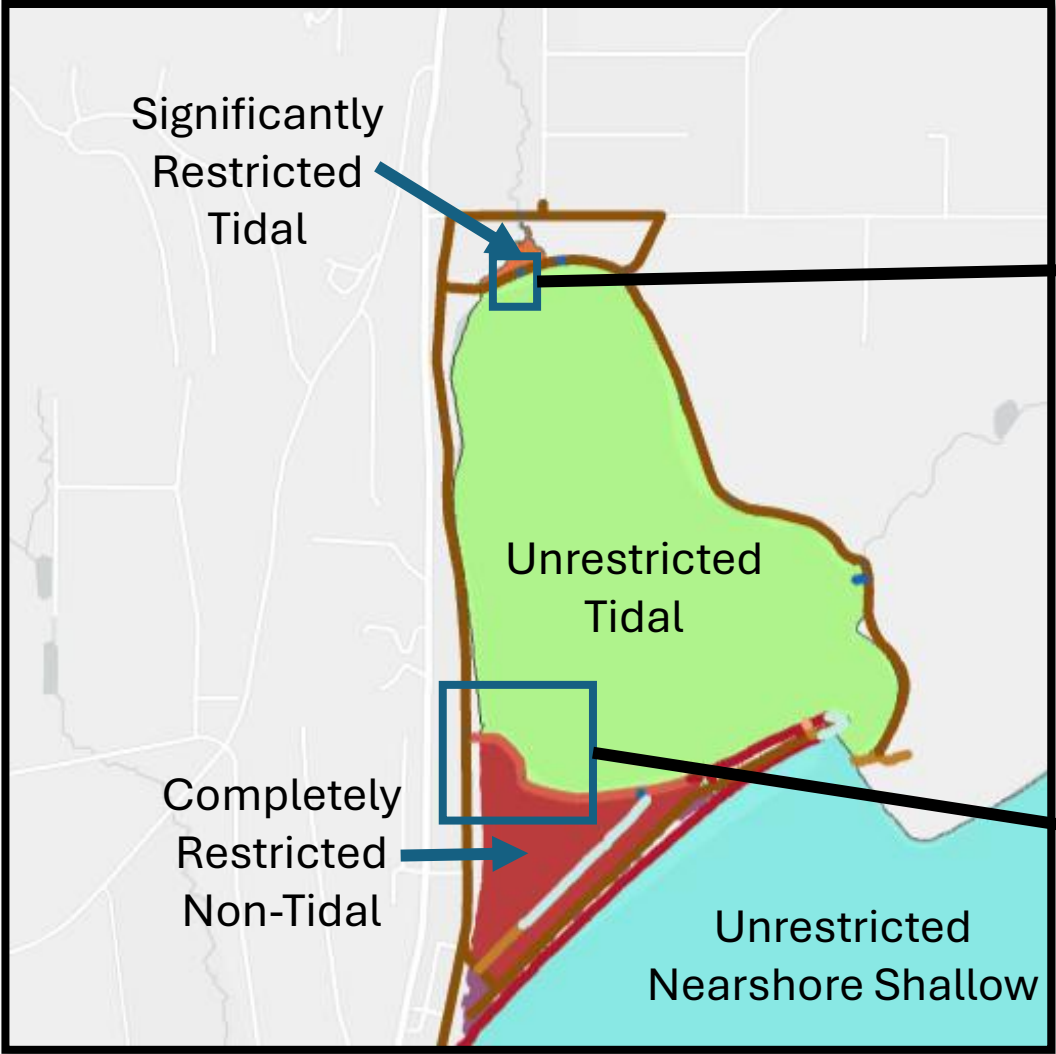
Railway without a known/visible WCF, completely disconnecting area within PMEP extent



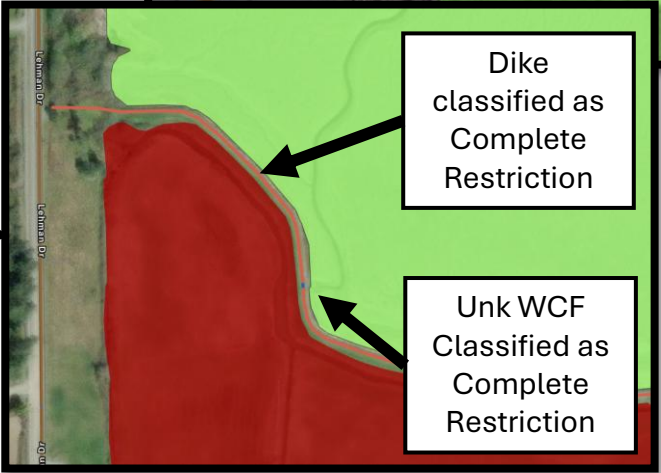
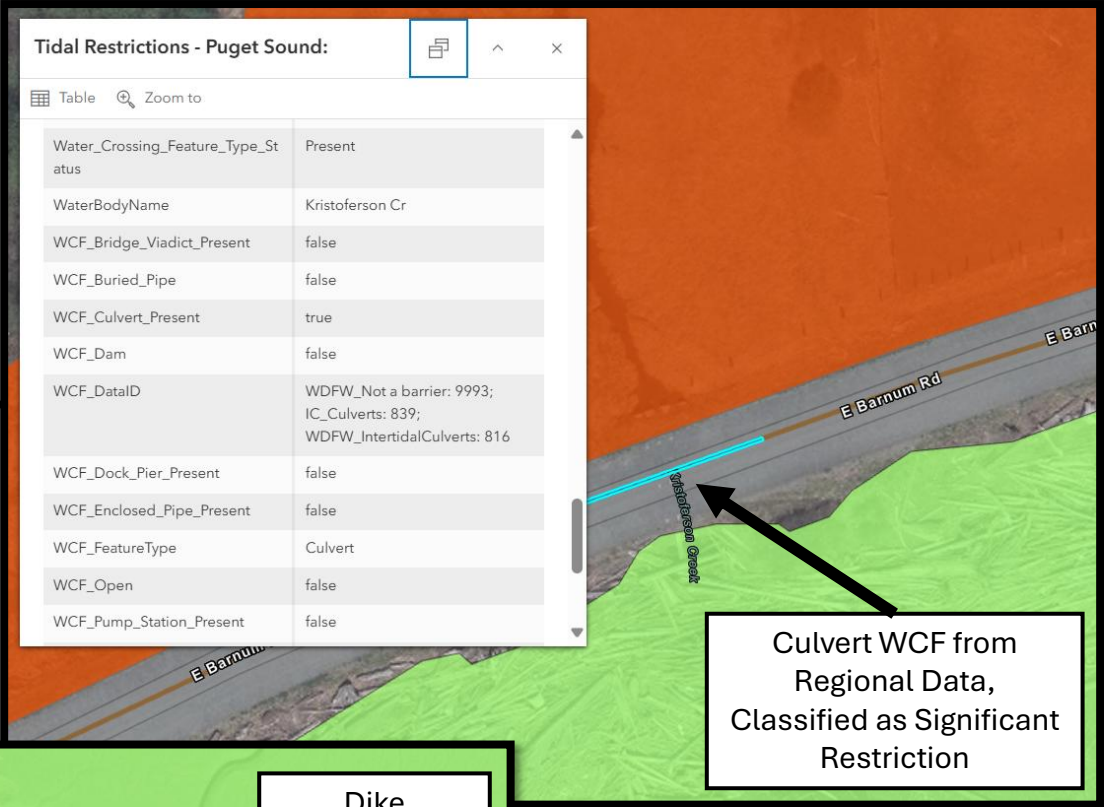
Bridge WCF classified as a Partial Restriction



Example: Triangle Cove

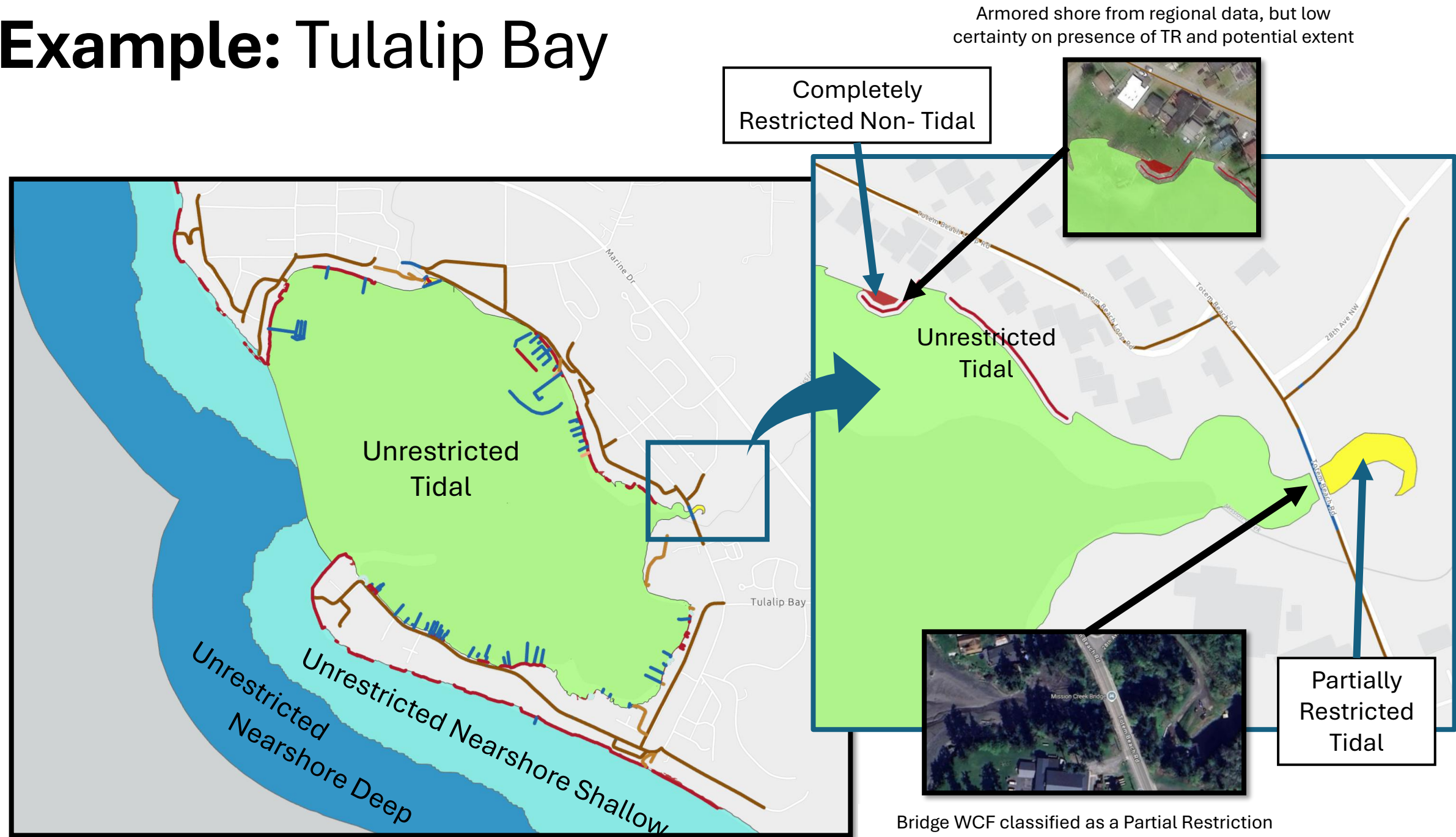


Area within PMEP extent but impacted by complete restrictions (road) with a significant tidal restriction WCF (culvert)



Area within PMEP extent but disconnected by complete tidal restriction features

Example: Tulalip Bay



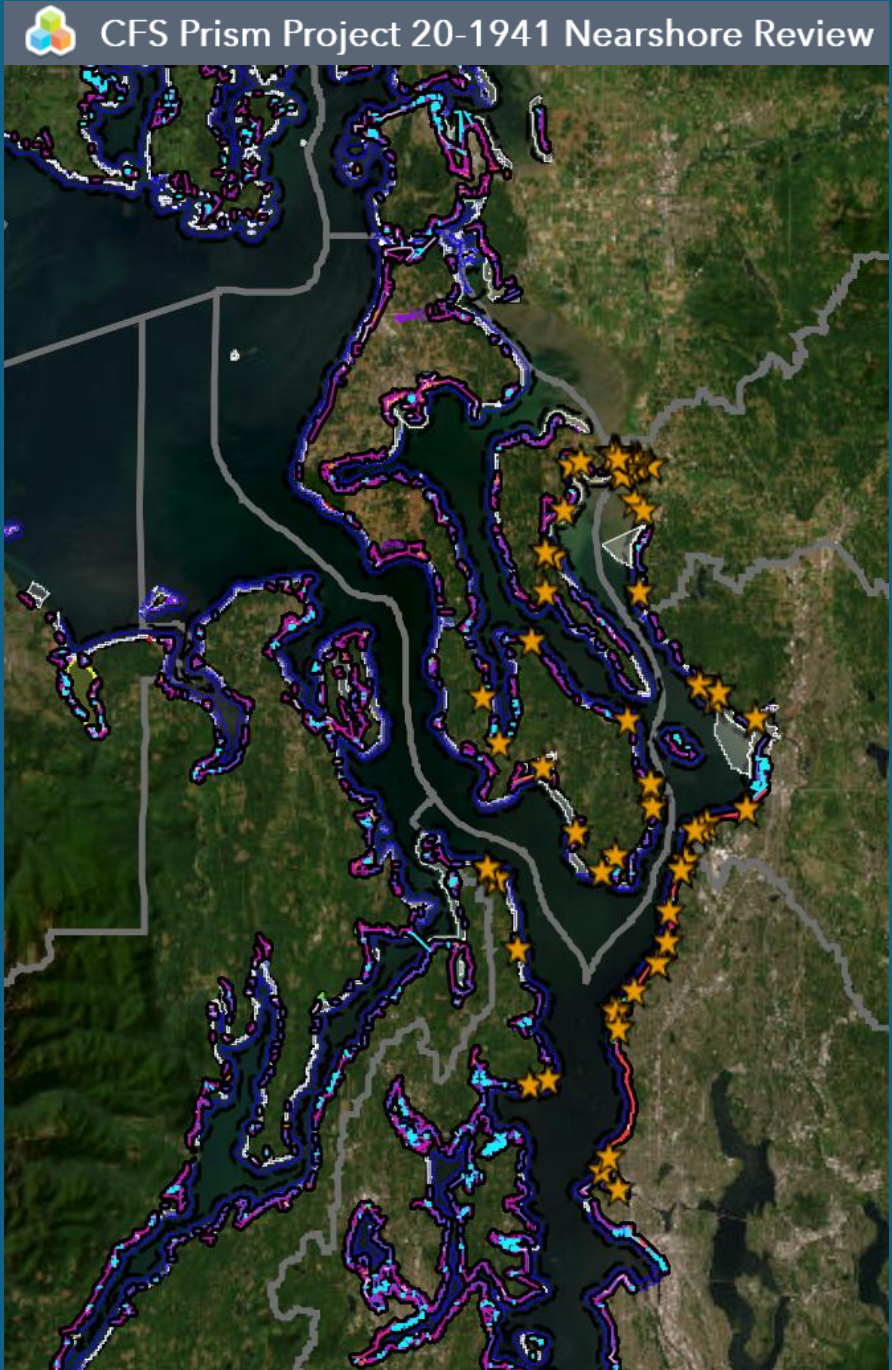
Regional Review

Regional Review

- Feedback received from federal, tribal, state, and county agencies +TAG and partners
- 97 comments received

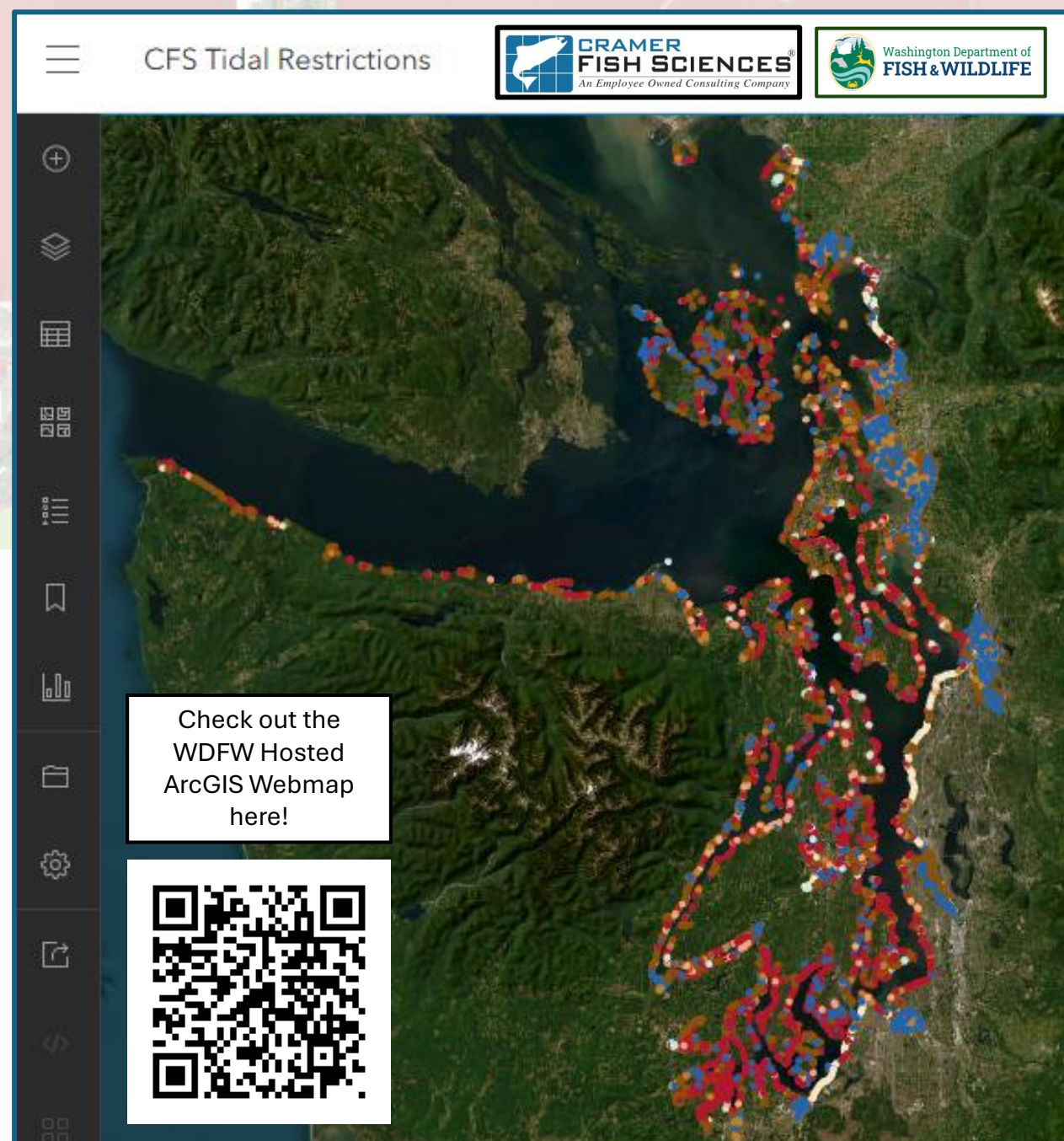


1. Leveraged local area knowledge to review features and classifications – no field validation this phase
2. WDFW hosted webmap with respondents asked to provide feedback on:
 - *Feature type, presence/absence, missing features, connectivity*
 - *Focus on familiar areas and features flagged as unknowns or with low certainty ratings*
3. Feedback used to update the database – and dropping attempted geomorphic habitat classification schema!



Data Sharing

1. Published spatial data in collaboration with WDFW – readily accessible to public, comanagers, and practitioners!
2. Combines data from this phase with the large river delta dataset
3. Consistent regional scale spatial data products for tidal restriction features and tidally influenced extent



Results



Regional patterns of tidal restrictions
and tidally influenced extent



Regional review



Webmap and data sharing





PUGET SOUND TIDAL RESTRICTIONS

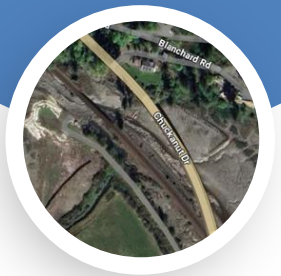
3,150 km

TR features mapped along Puget Sound shoreline:
(+2,011 km with Deltas)



50%

TR feature length were roads:
32% armor/fill, 10% docks/piers,
and 6% railways



86%

TR feature length classified as
completely restricting tidal
connectivity



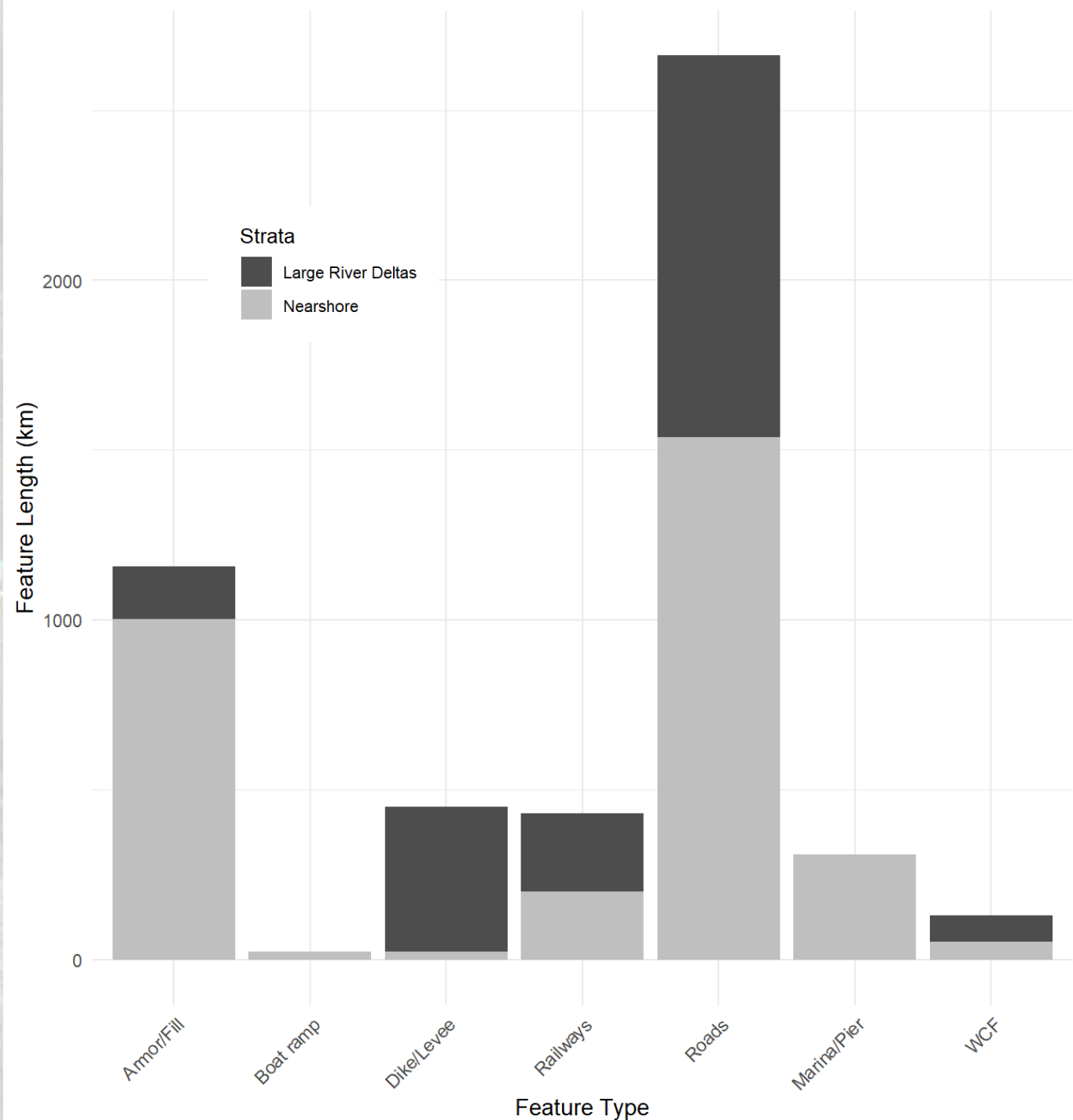
8,256

WCFs mapped:
363 km by length
7.8% not previously mapped

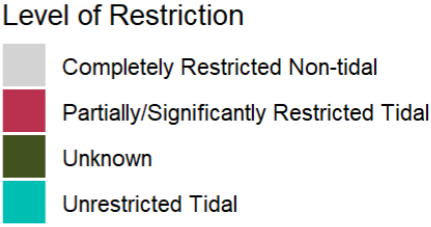
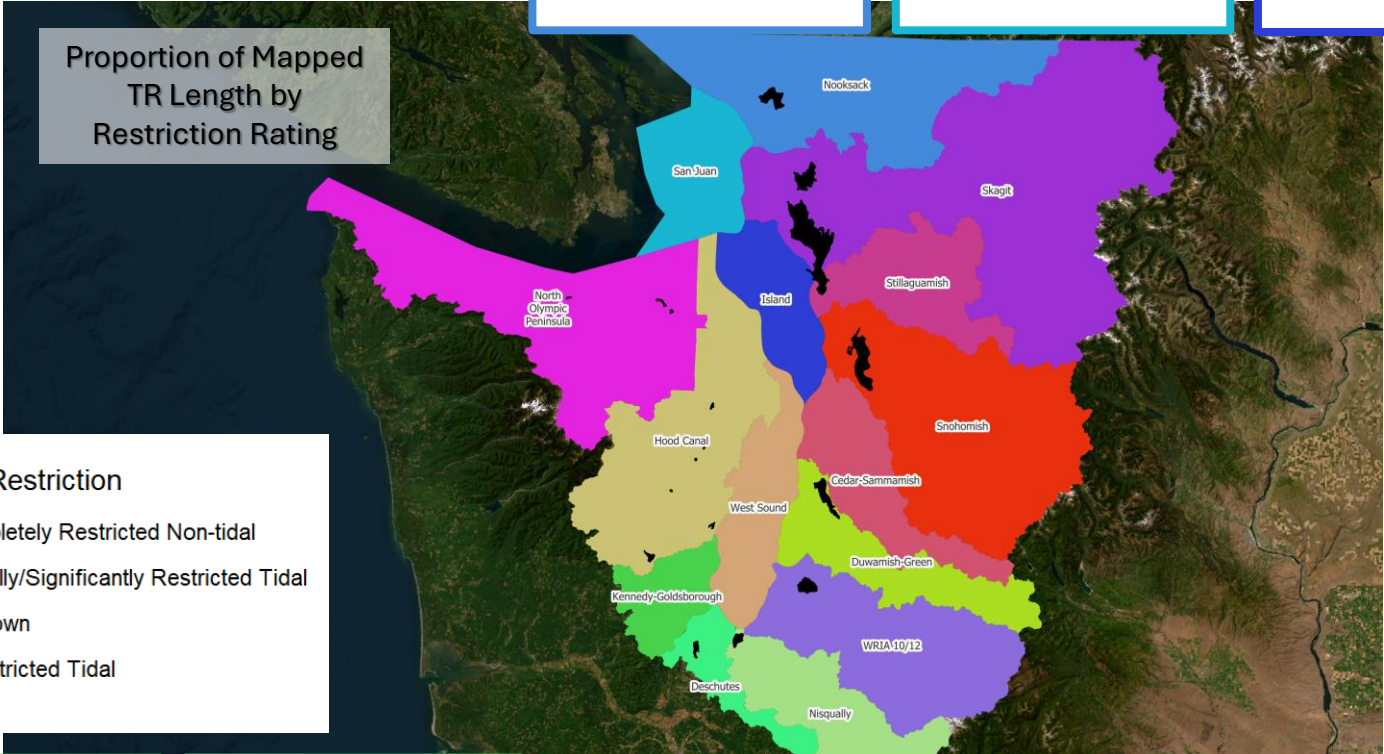
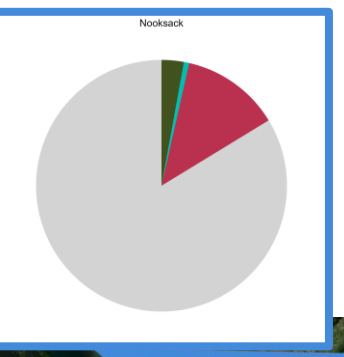
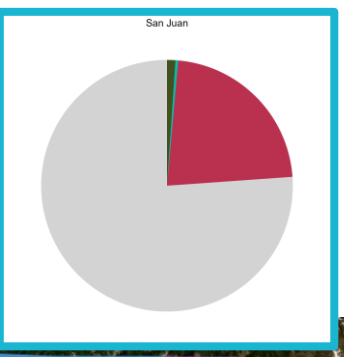
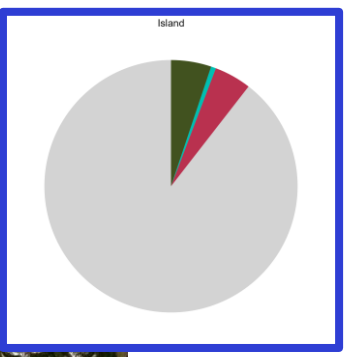
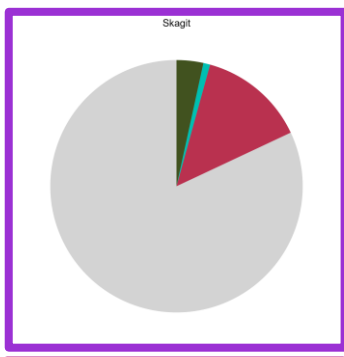
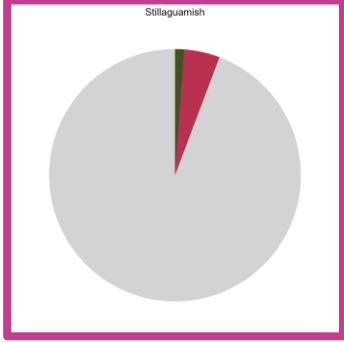
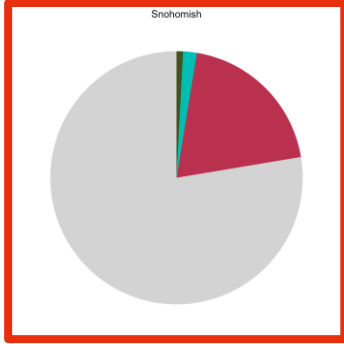
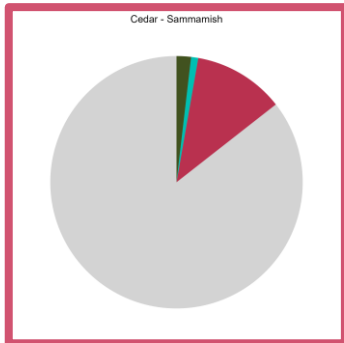
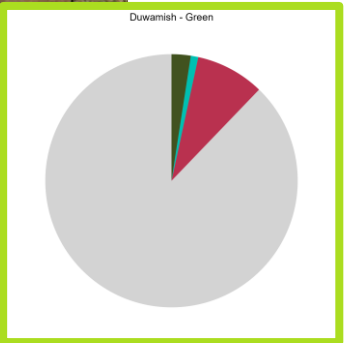
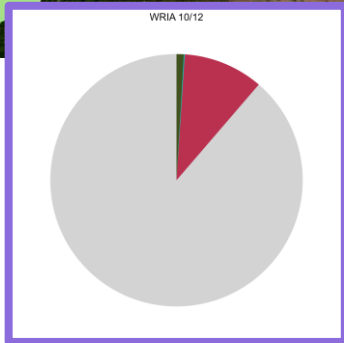
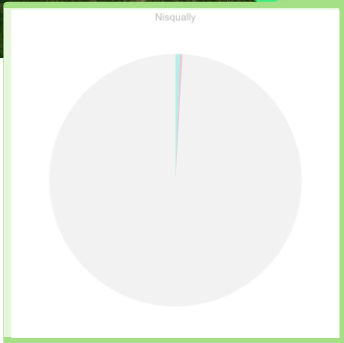
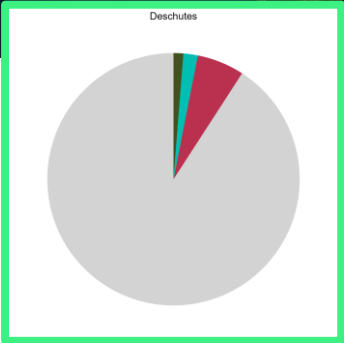
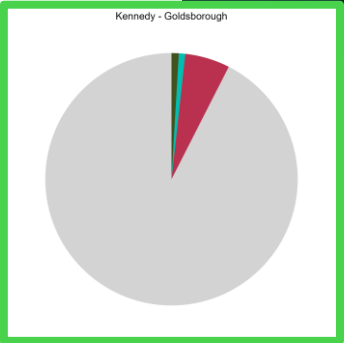
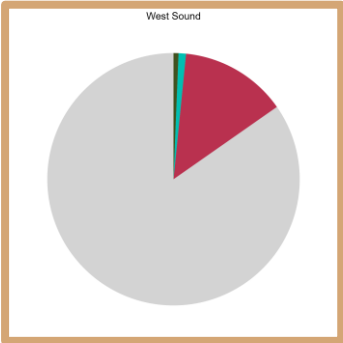
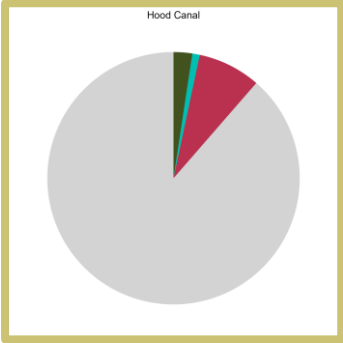
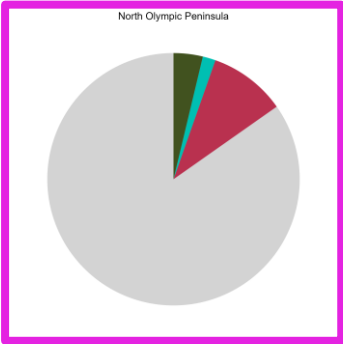


Tidal Restriction Feature Types

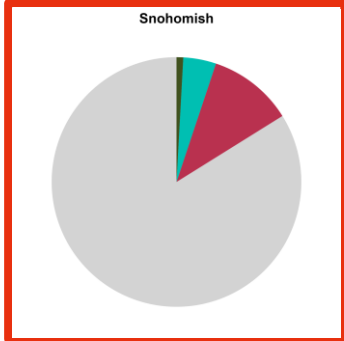
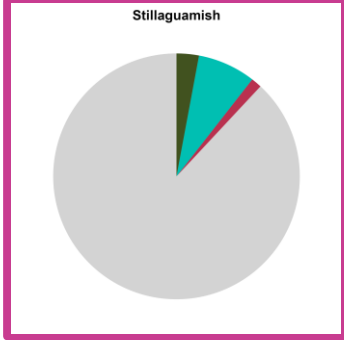
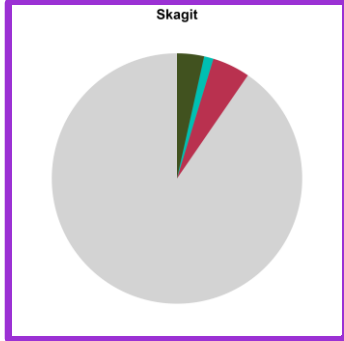
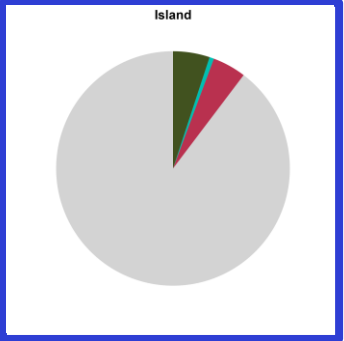
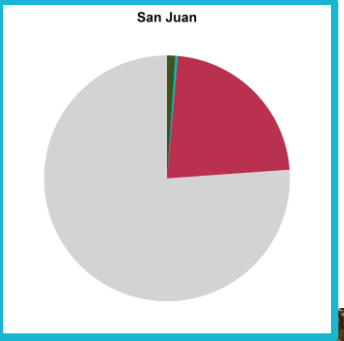
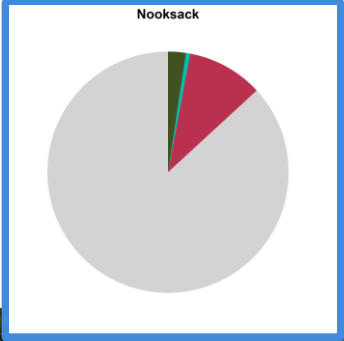
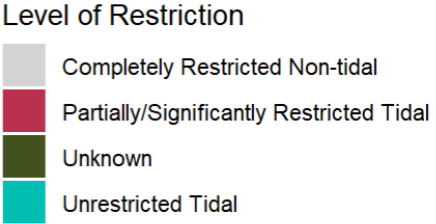
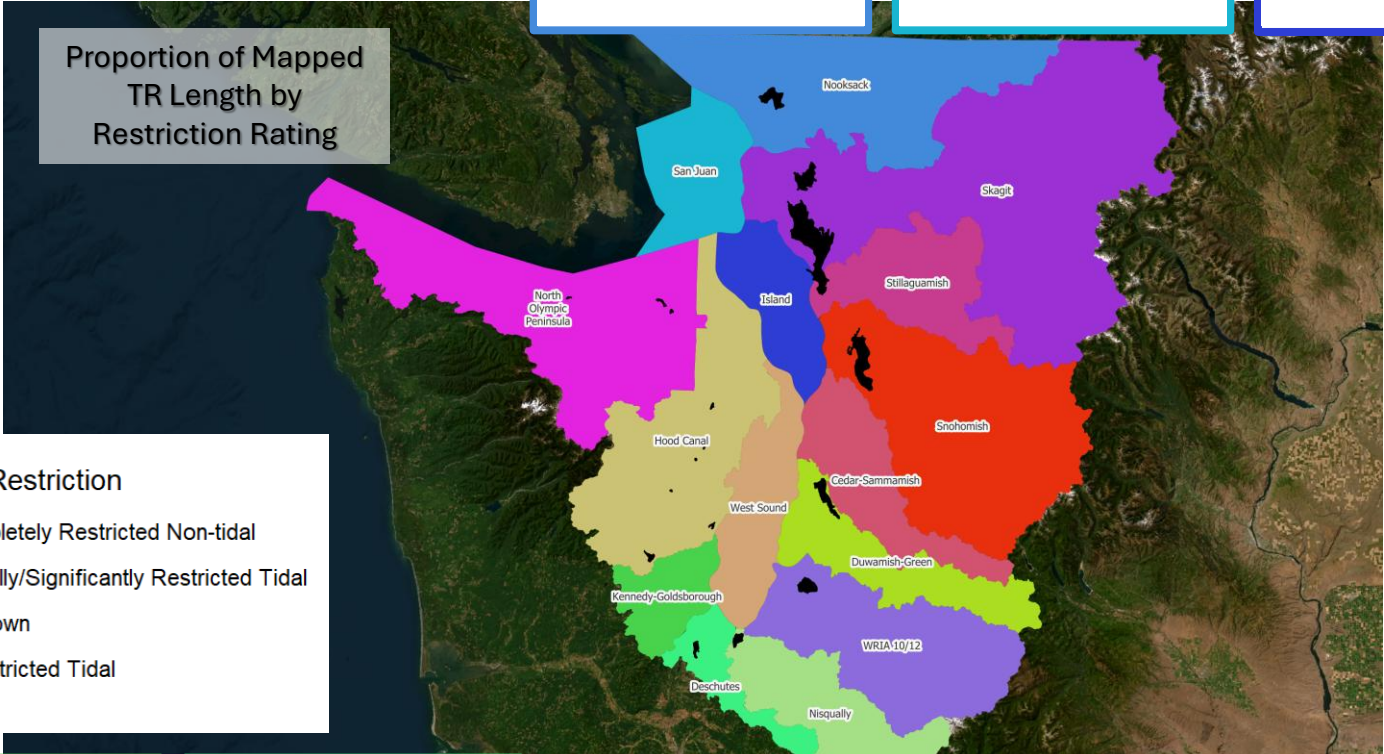
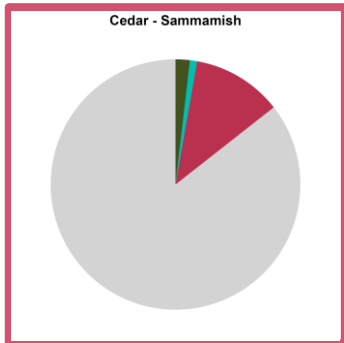
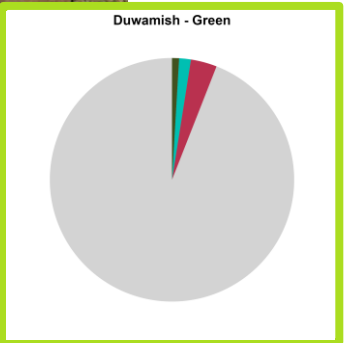
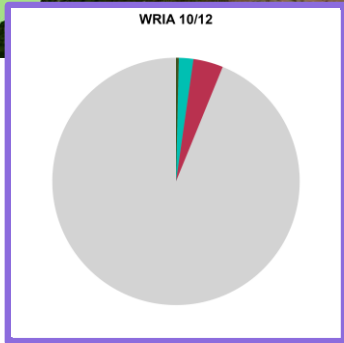
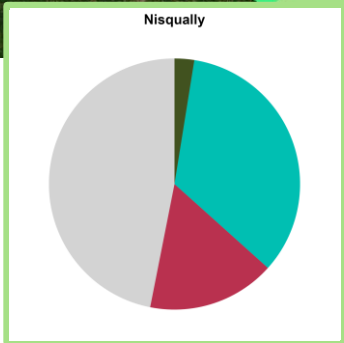
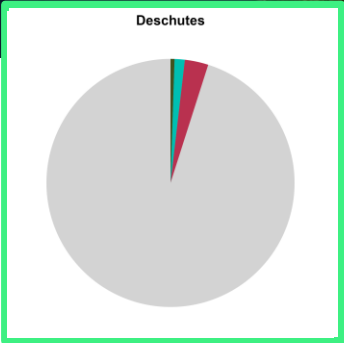
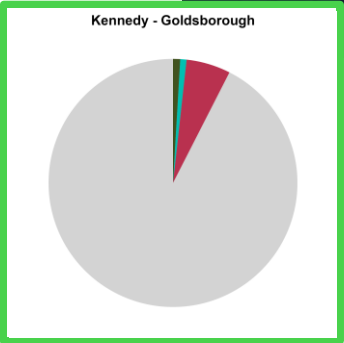
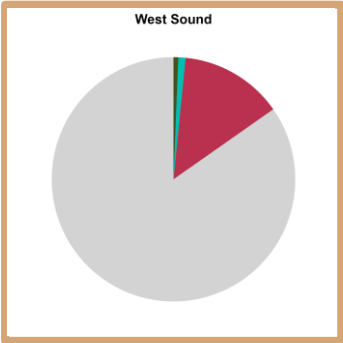
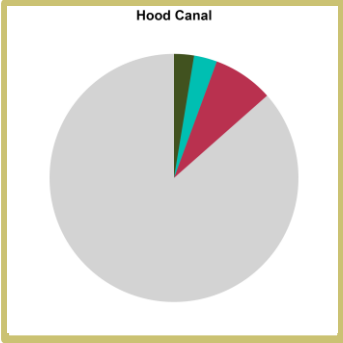
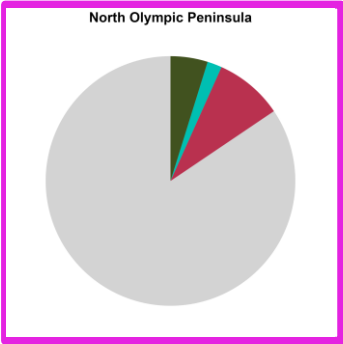
- Mapped 3,150 km of TR features along PS shoreline
- 5,160 km total with Deltas
- Mostly roads in both deltas and along shoreline
- Comparatively few dikes/levees in nearshore compared to deltas



Tidal Restrictions from Nearshore



Tidal Restrictions across Puget Sound



PUGET SOUND TIDALLY INFLUENCED EXTENT

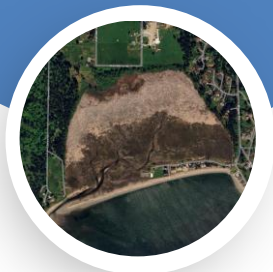
12,680 ha

Potential tidally influence habitat mapped
(+39,571 ha with Deltas)
(+161,470 ha Nearshore)



85%

Area tidally connected:
80% Unrestricted tidal and
5% Partially/Significantly restricted tidal



11%

Of area classified as non-tidally connected (Completely restricted non-tidal)



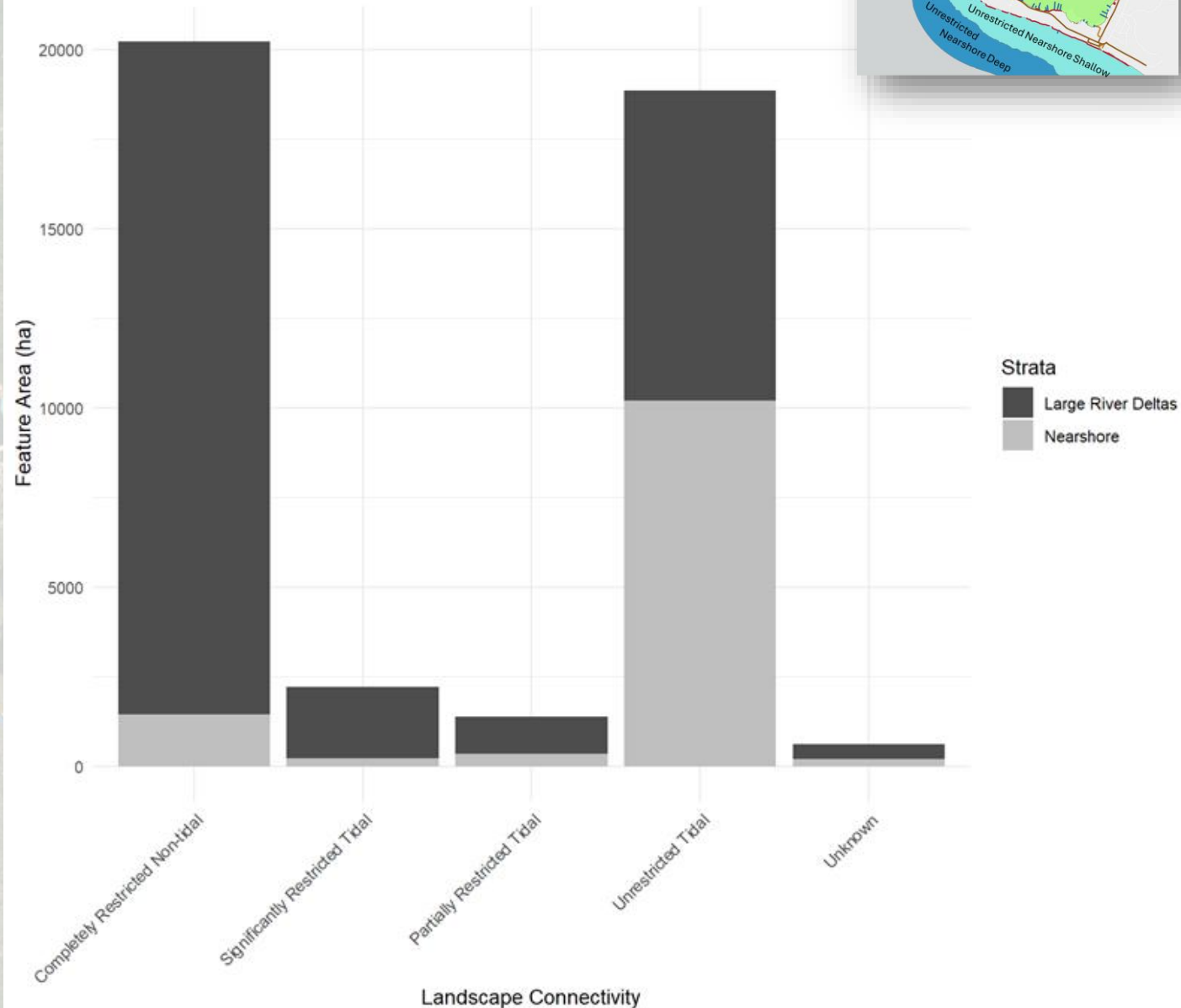
209 ha

Classified as Unknown Connectivity

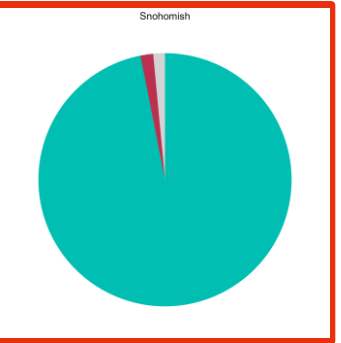
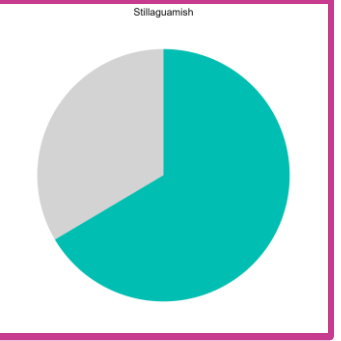
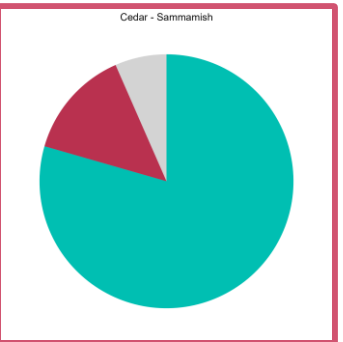
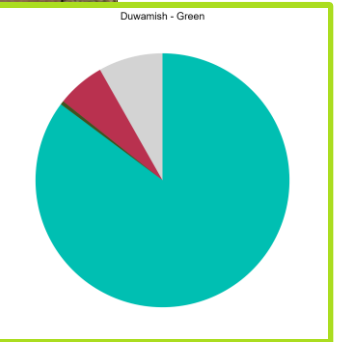
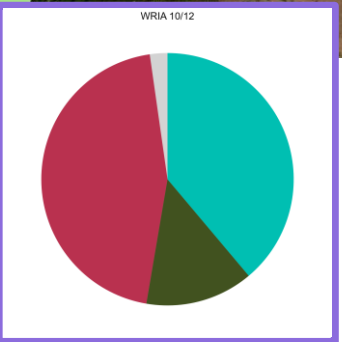
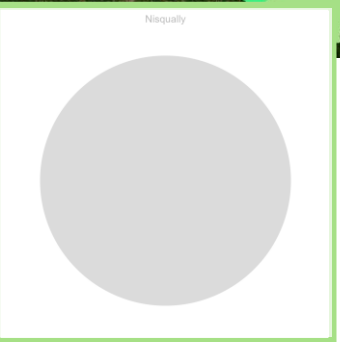
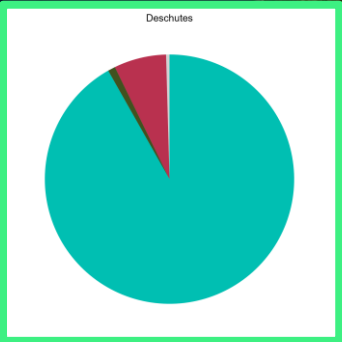
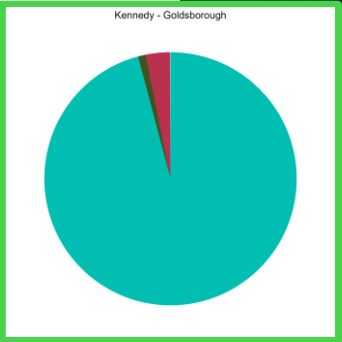
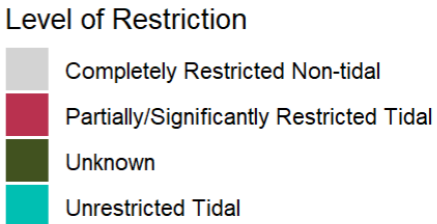
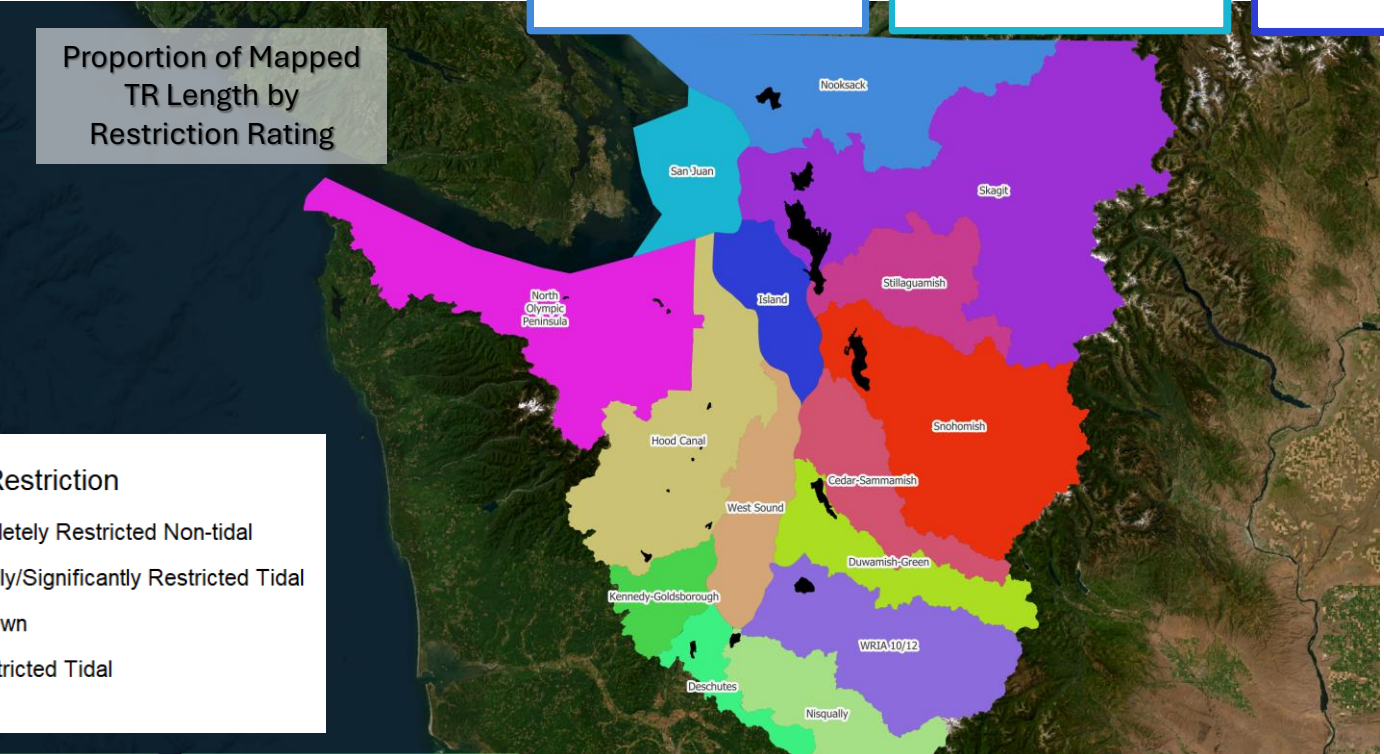
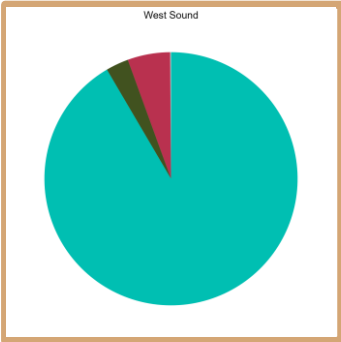
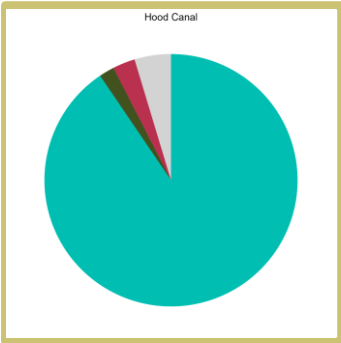
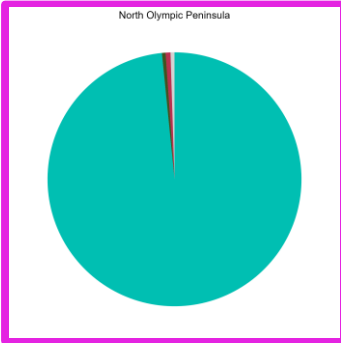
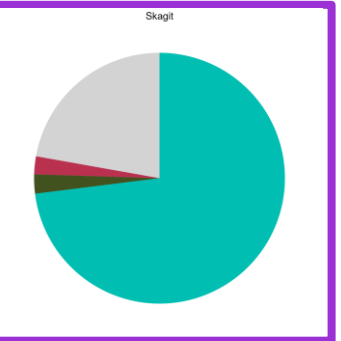
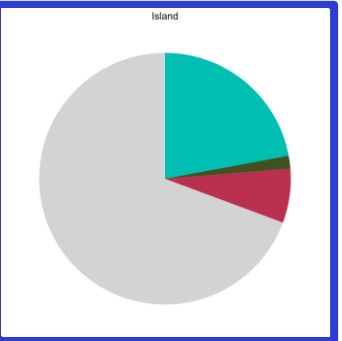
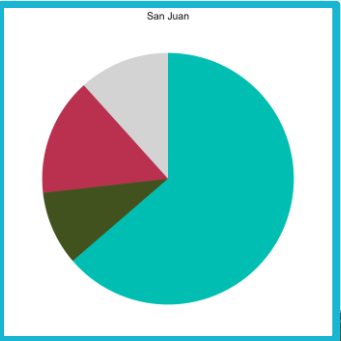
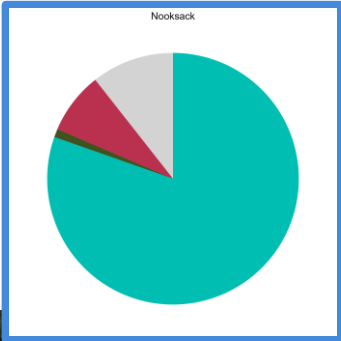


Tidally Influenced Extent

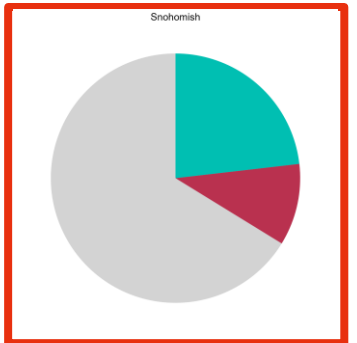
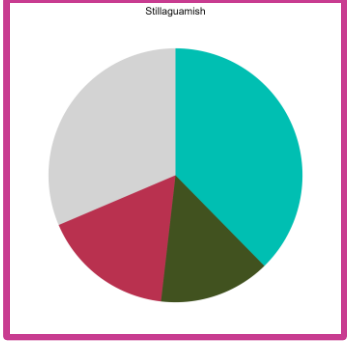
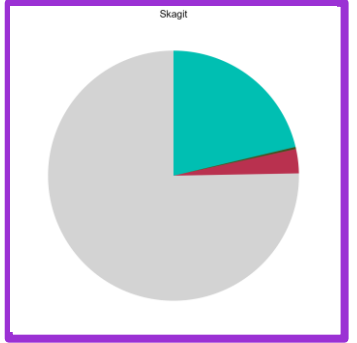
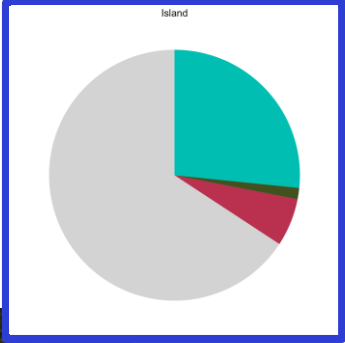
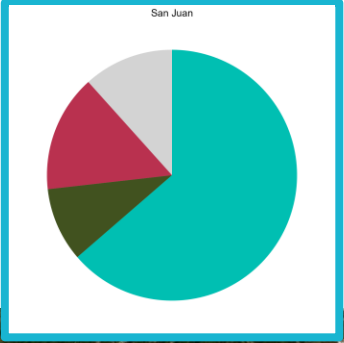
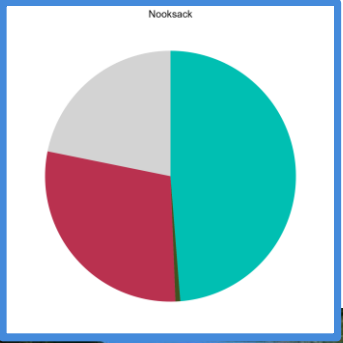
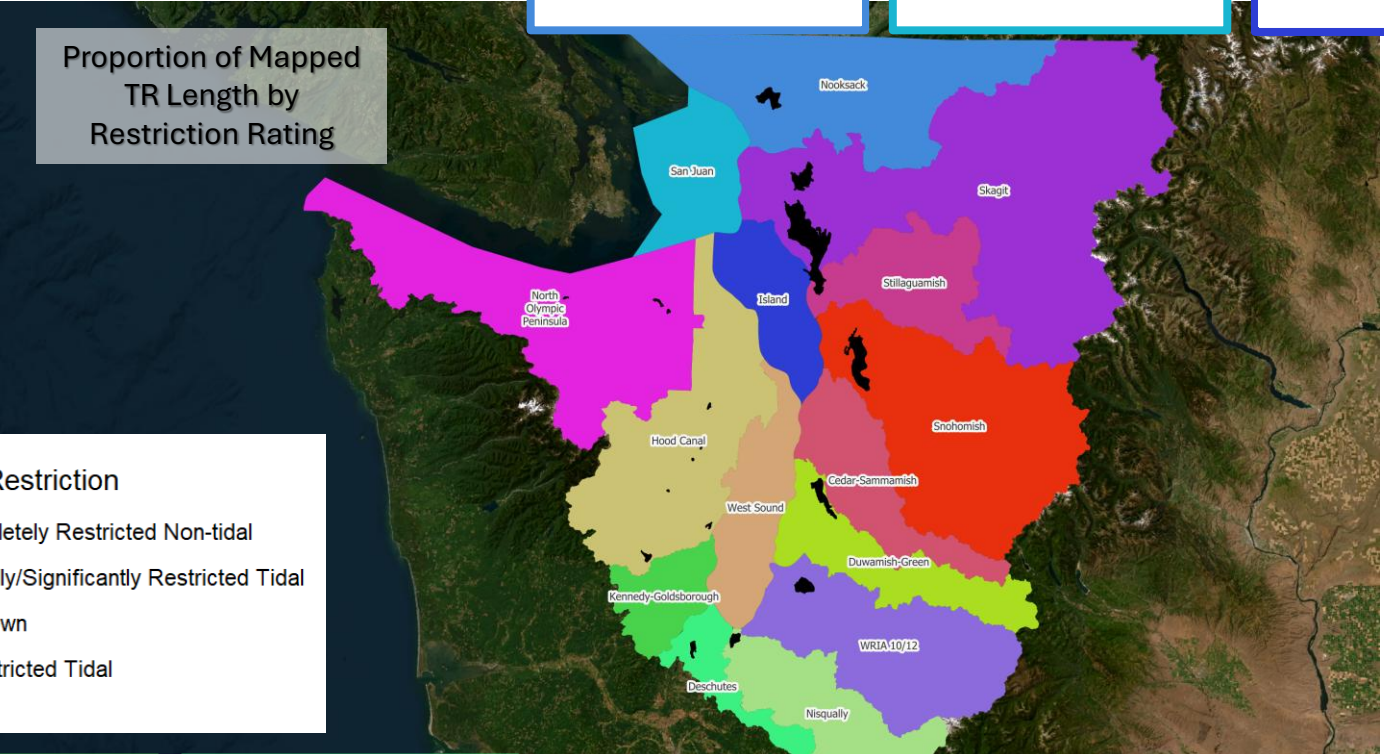
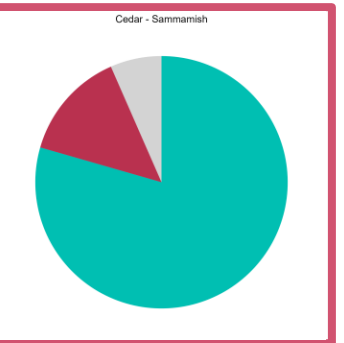
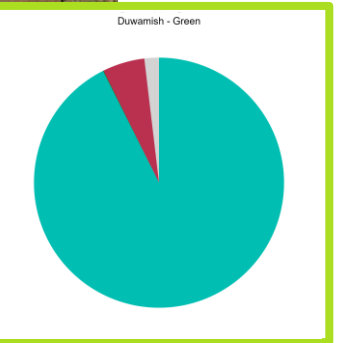
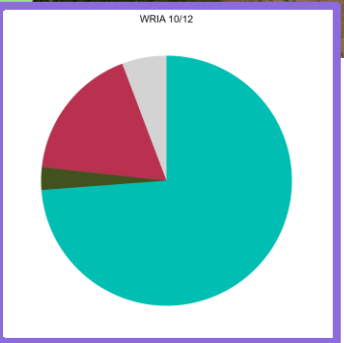
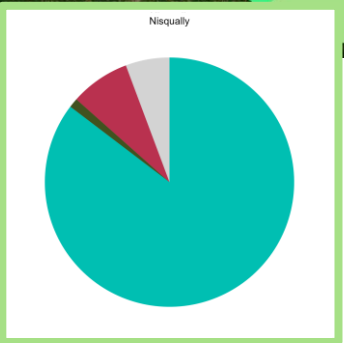
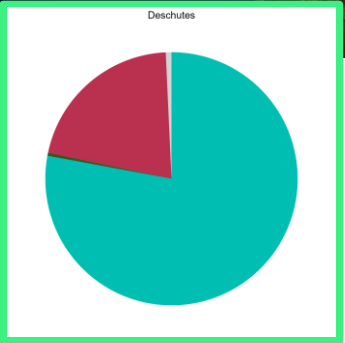
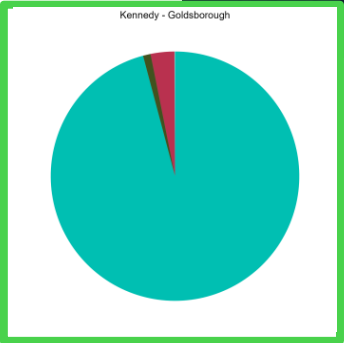
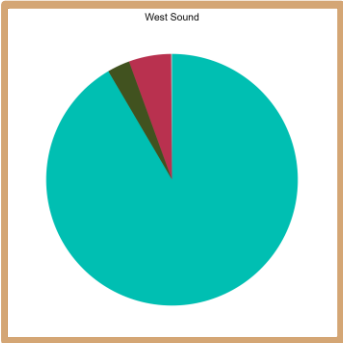
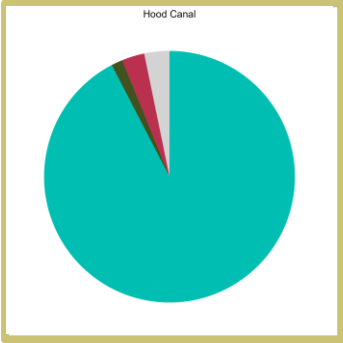
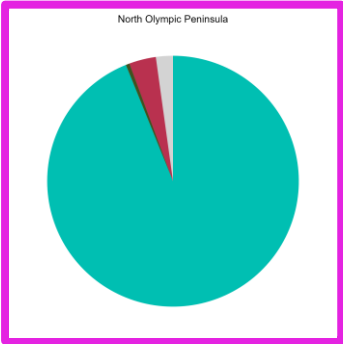
- 12,680 ha of potential tidally influenced habitat mapped
 - *Additional 161,470 ha mapped as nearshore deep / shallow*
- 52,251 ha total with Deltas
- Mostly unrestricted along shoreline
- Deltas mostly completely restricted non-tidal



Tidally Influenced Extent from Nearshore



Tidally Influenced Extent across Puget Sound



REGIONAL REVIEW

97 Comments

- Federal, tribal, state, county, and TAG participation
- Extended review period and hosted meetings to review data



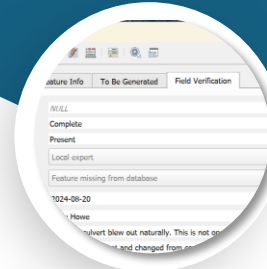
Missing Features Added

- Reviewer comments identified 22 missing features that were added



Feature Types and Connectivity Updated

- 27 TR features updated
- 14 tidally influenced polygons updated



Continued Review Needed

- 2% of TR features classified with unknown connectivity
- 209 ha of unknown connectivity tidal extent



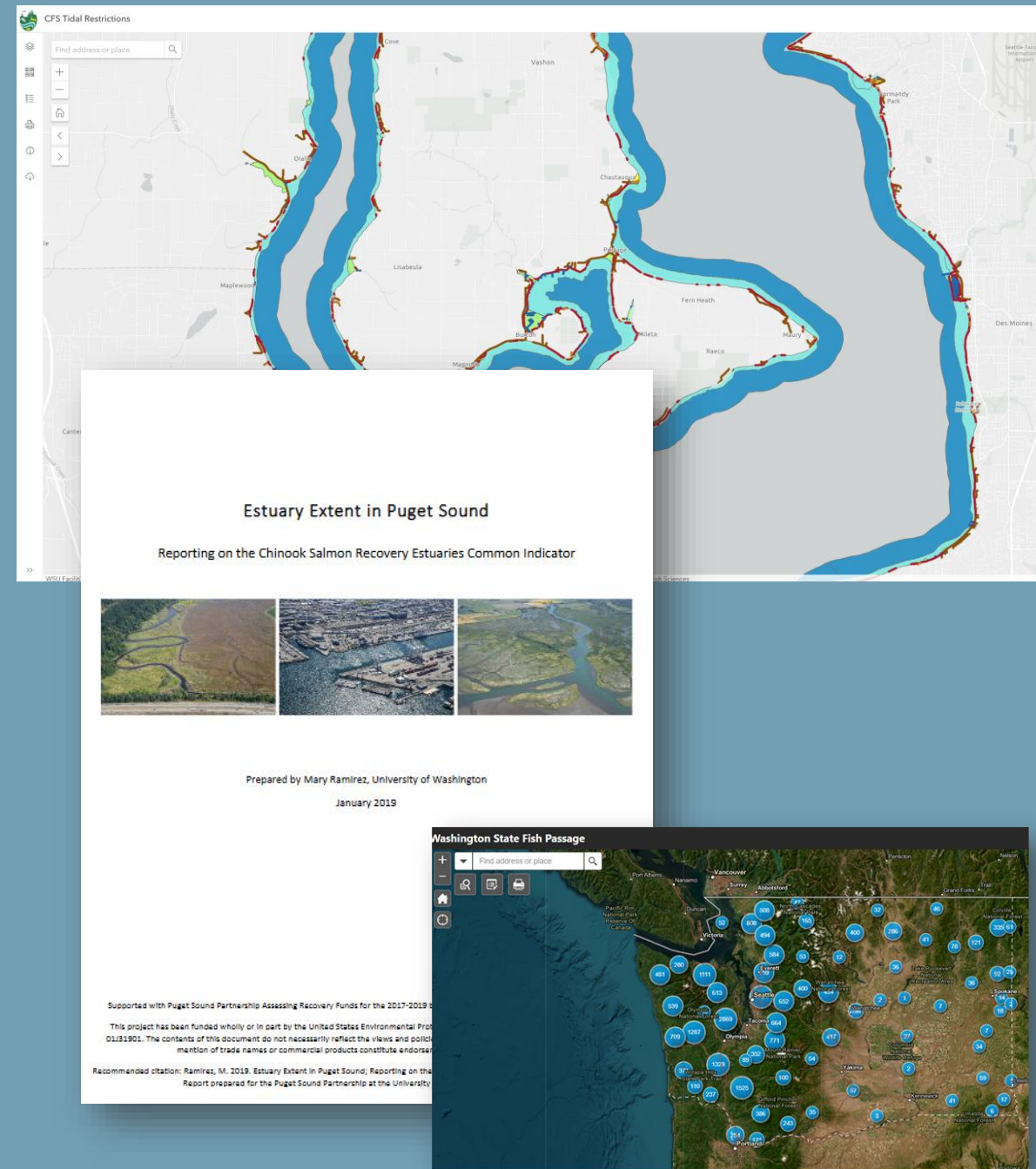
Applications:



Habitat status and trends reporting



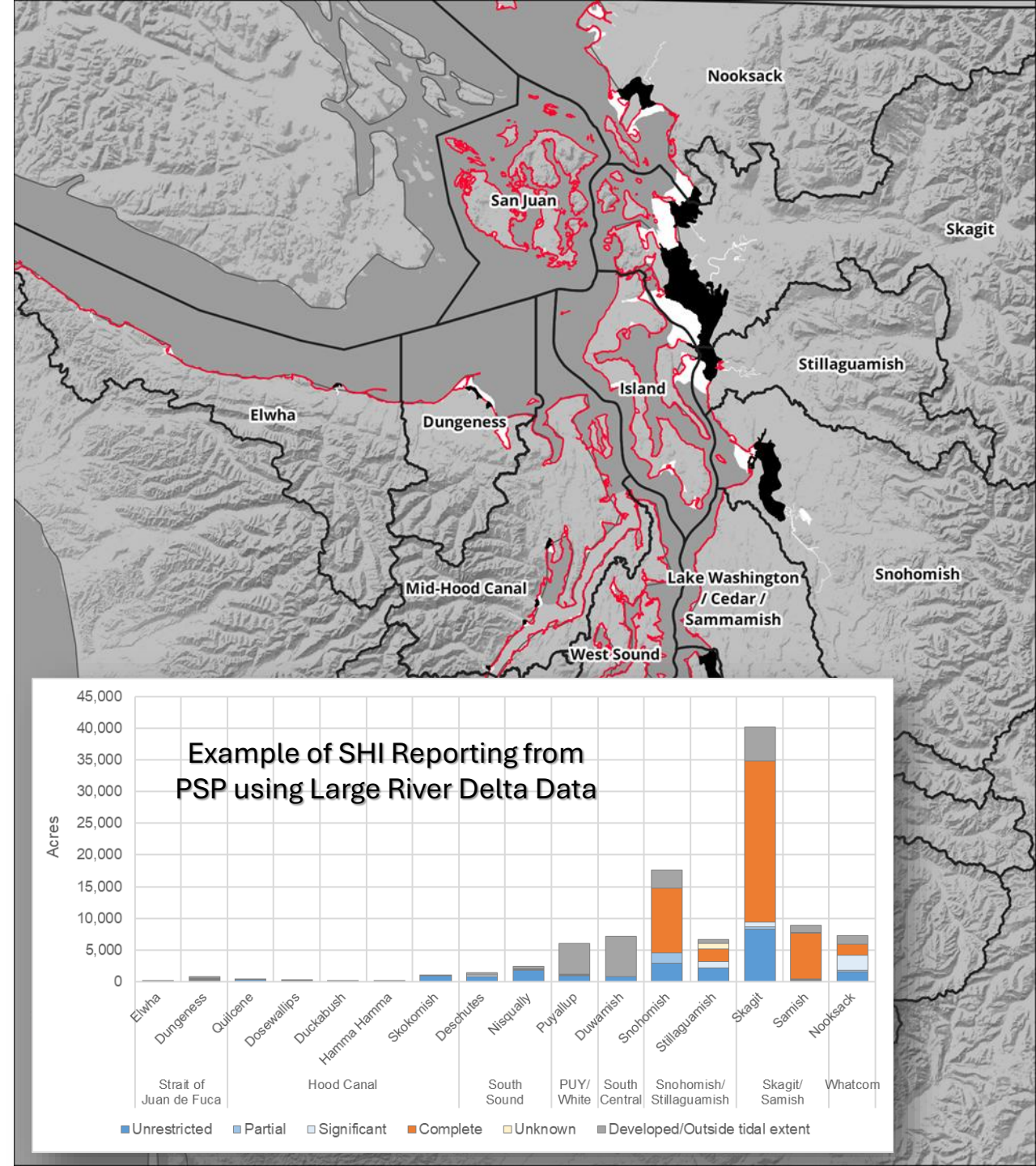
Identify and prioritize restoration opportunities



Habitat status and trends reporting

Consistent regional scale spatial data supports reporting at multiple scales

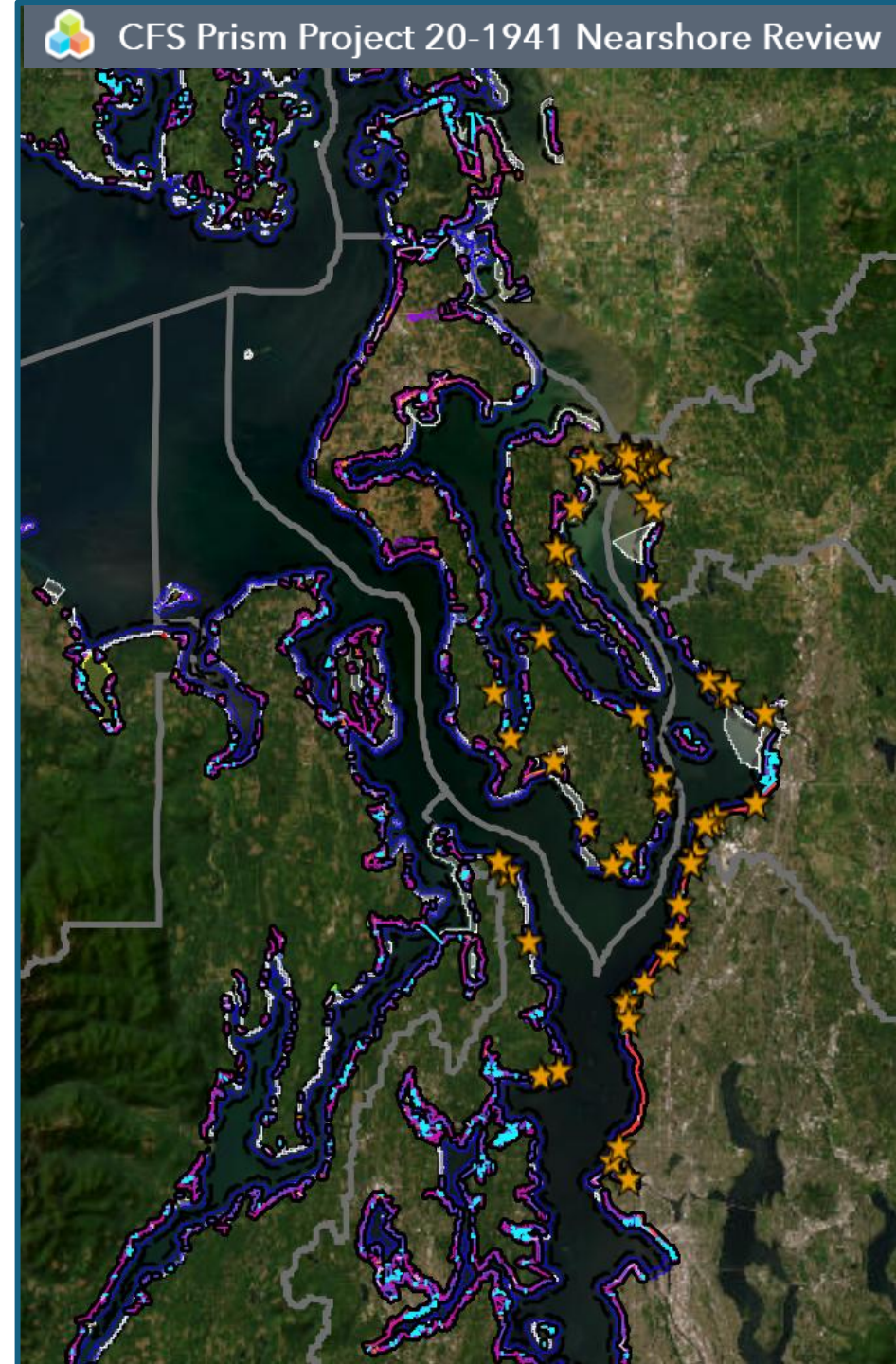
- Spatial data can be summarized by lead entity areas, watersheds, drift cells, etc.
- Metrics directly linked to regional HS&T programs
- Can develop widgets to support reporting



Habitat status and trends reporting

Can be updated with continued regional review / validation

- Improve accuracy / completeness
- Features flagged with low certainty or as unknowns
- Fields to track updates
- Can be supported by Webmap tools

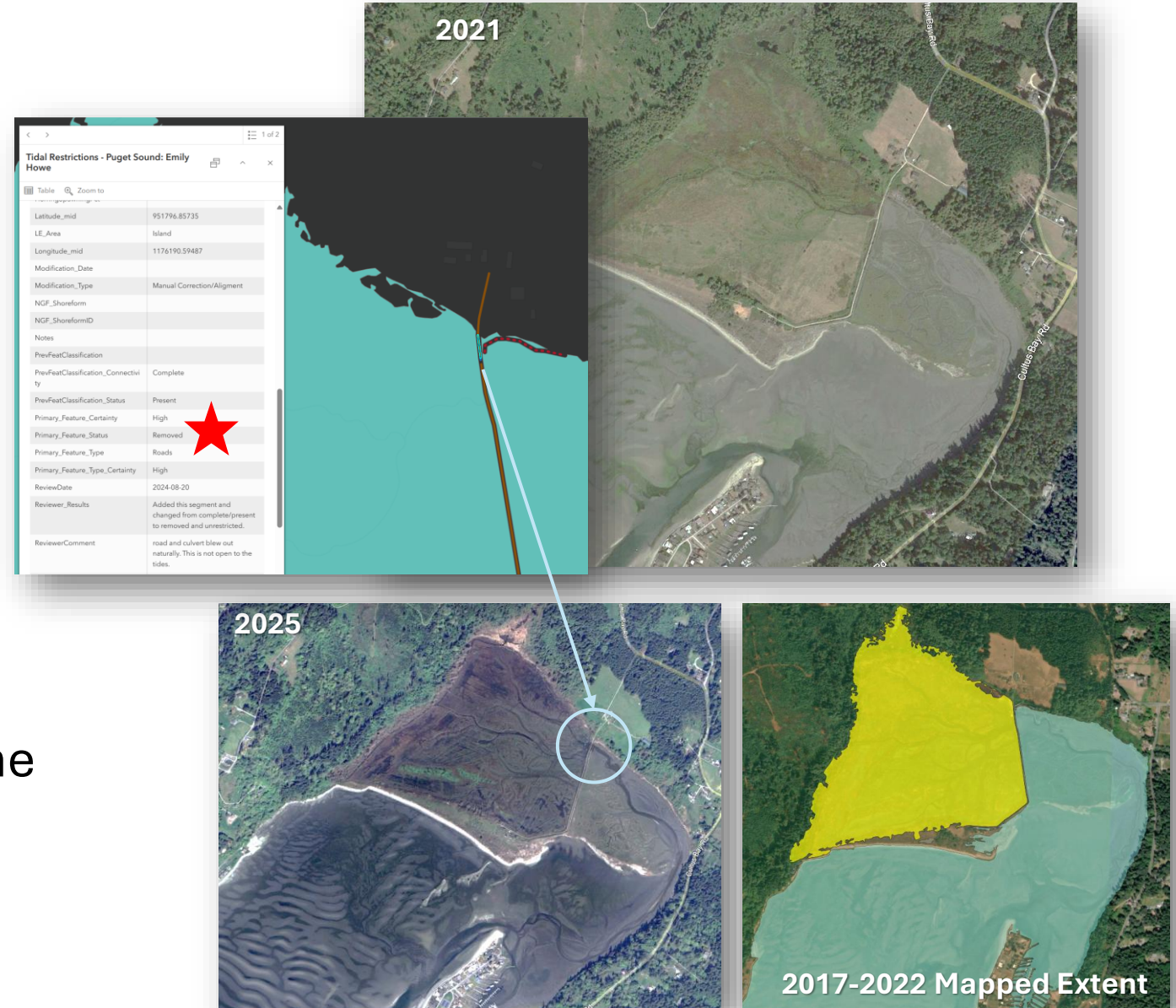


Habitat status and trends reporting

Can be updated over time to evaluate trends and progress towards recovery

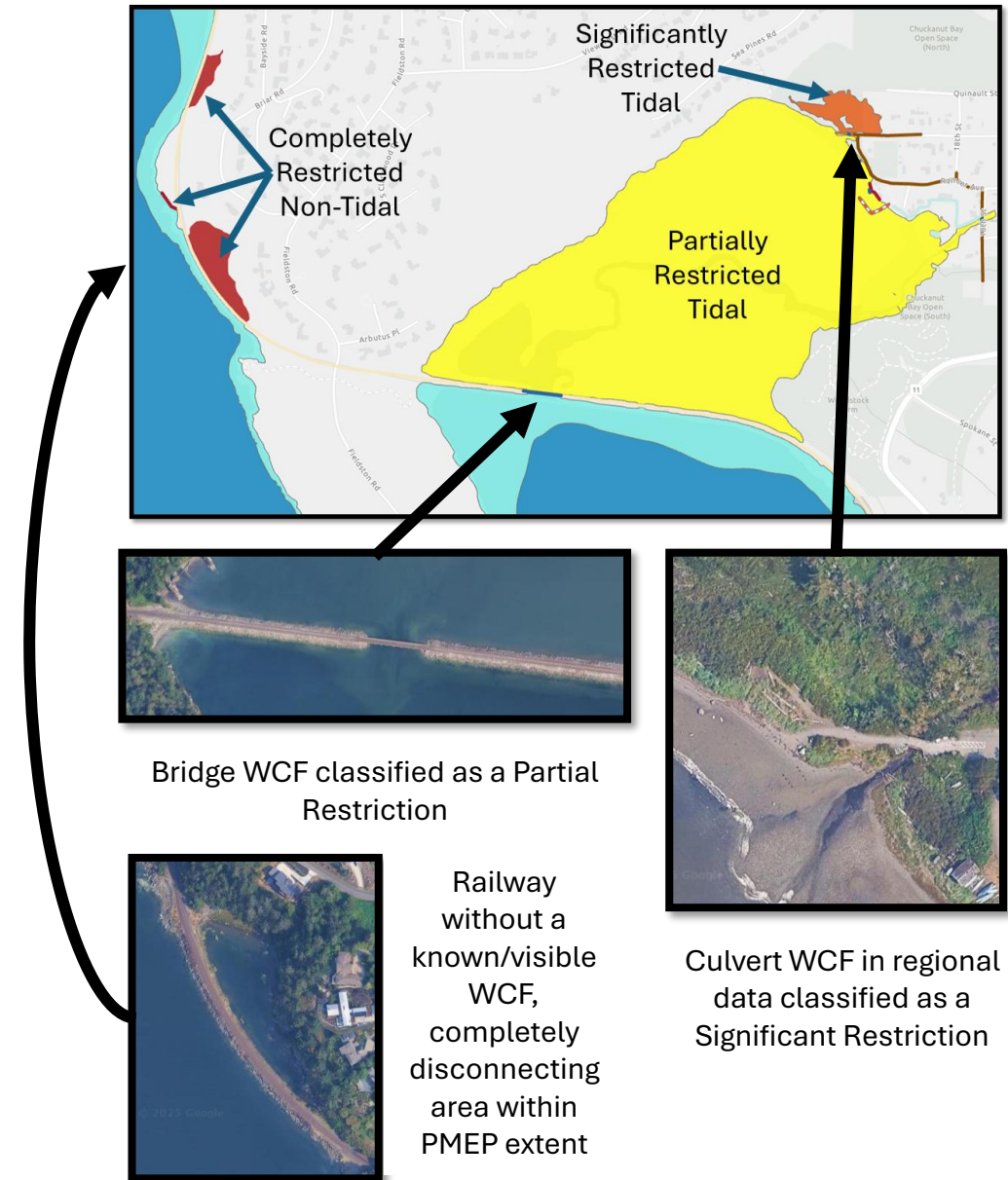
- Implementation of restoration
- Natural Change
- Development / loss
- Fields to track changes over time
- Status fields allow retention of removed features

Example of change with restoration in Cultus Bay, Whidbey Island



Identify and prioritize restoration opportunities

- Spatial data can be used to identify and prioritize restoration opportunities
- Filter by regions, connectivity rating, feature types...
- Identify potential tidally influenced extent and the TR features that affect connectivity
- Identify areas where tidal connectivity is muted and the TR features that
- Consider other spatial data like ownership, drift cells, etc. to help with prioritization
- Build tools / widgets to support identification and periodization of restoration opportunities?



Next Steps:



Developing reporting tools



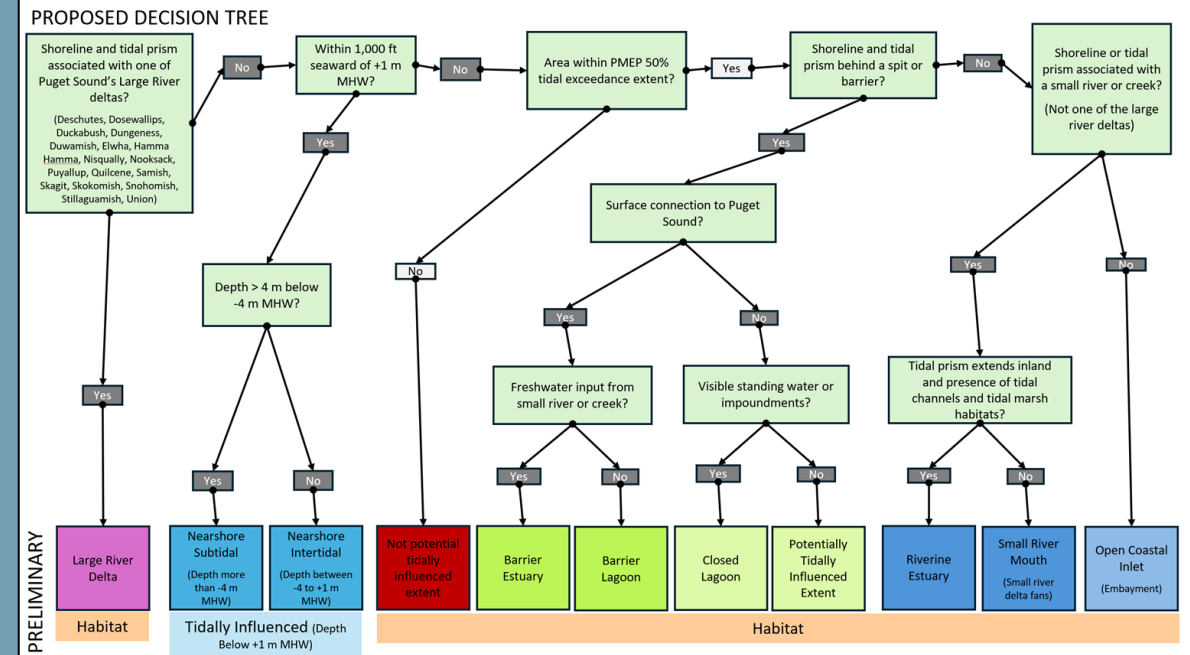
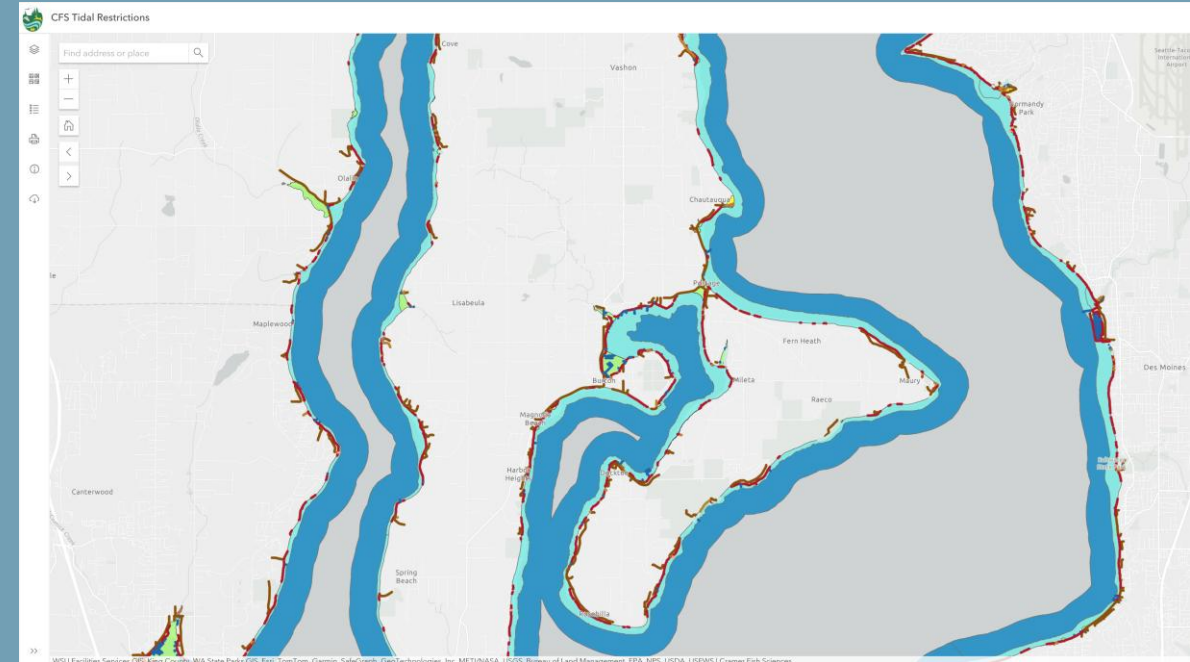
Develop guidance for updating and maintaining the database



Integrate datasets into ongoing regional efforts

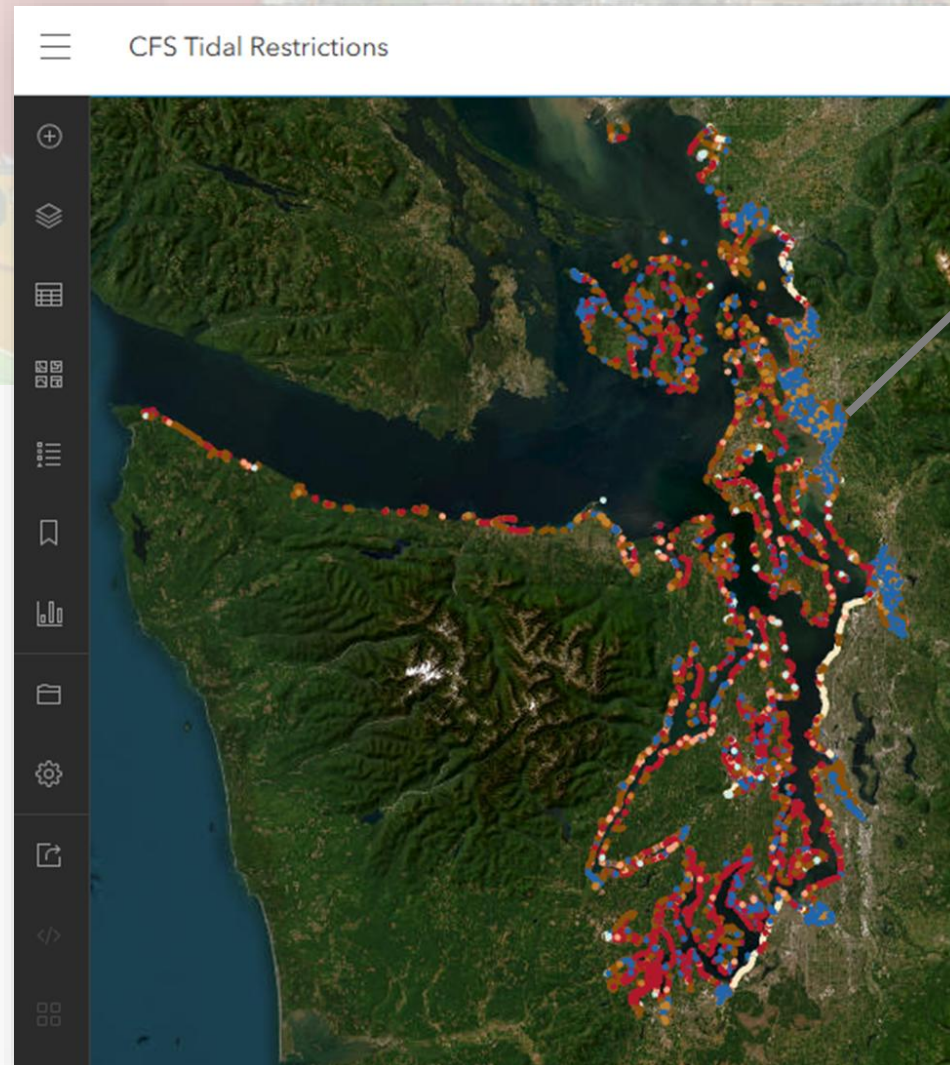


Add more components, attributes, and tools



Developing reporting tools

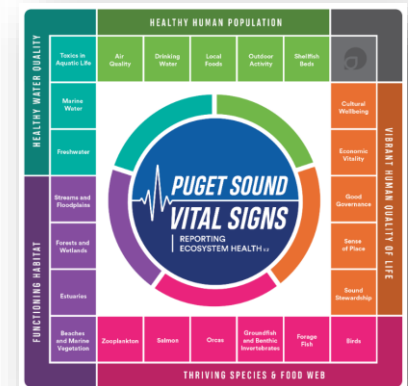
- Develop reporting tools with Webmap
- Summary tables / graphics
- Support filtering and regional HS&T programs
- Improve data use and access
- Also support restoration planning and prioritization?



Habitat Status and Trends
Reporting Graphics and Tables



Support Regional Recovery
Programs



Guidance for maintaining database

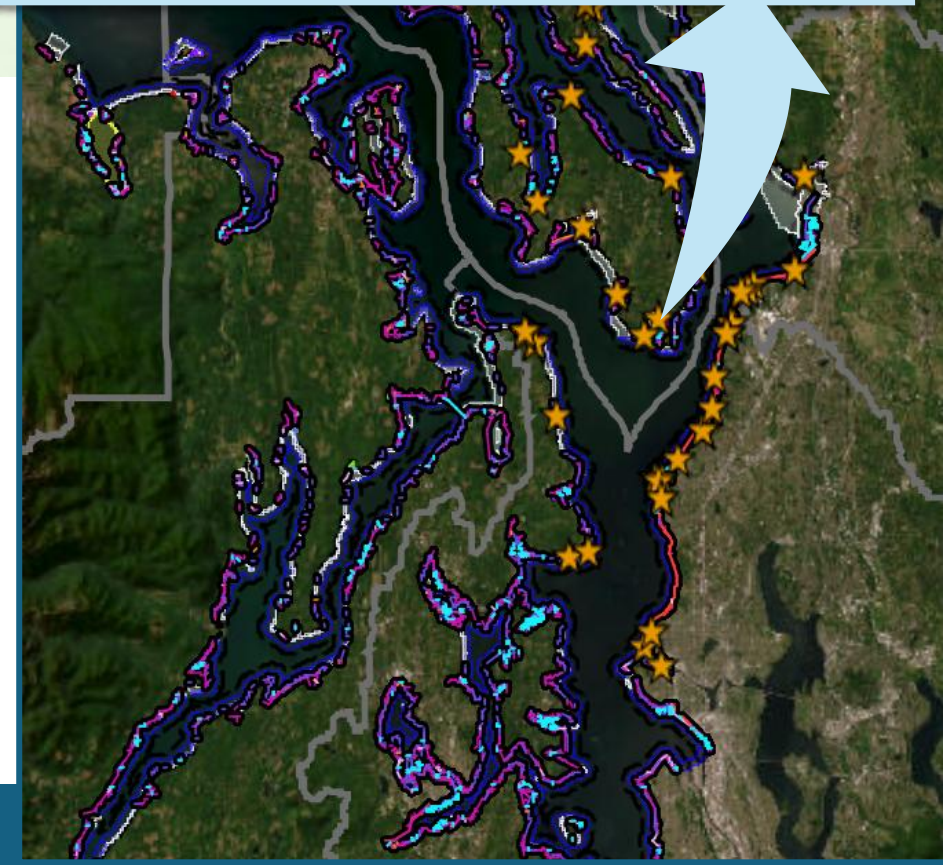
26148, Filtered: 26148, Selected: 1

Example reviewer's comment

General	Water Crossing Feature	Feature Info	To Be Generated	Field Verification
PrevFeatClassification		NULL		
PrevFeatClassification_Connectivity		Complete		
PrevFeatClassification_Status		Present		
Verification_Method		Local expert		
Verification_Category		Feature missing from database		
ReviewDate		2024-08-20		
ReviewerName		Emily Howe		
ReviewerComment		road and culvert blew out naturally. This is not open to the tides.		
Reviewer_Results		Added this segment and changed from complete/present to removed and unrestricted.		



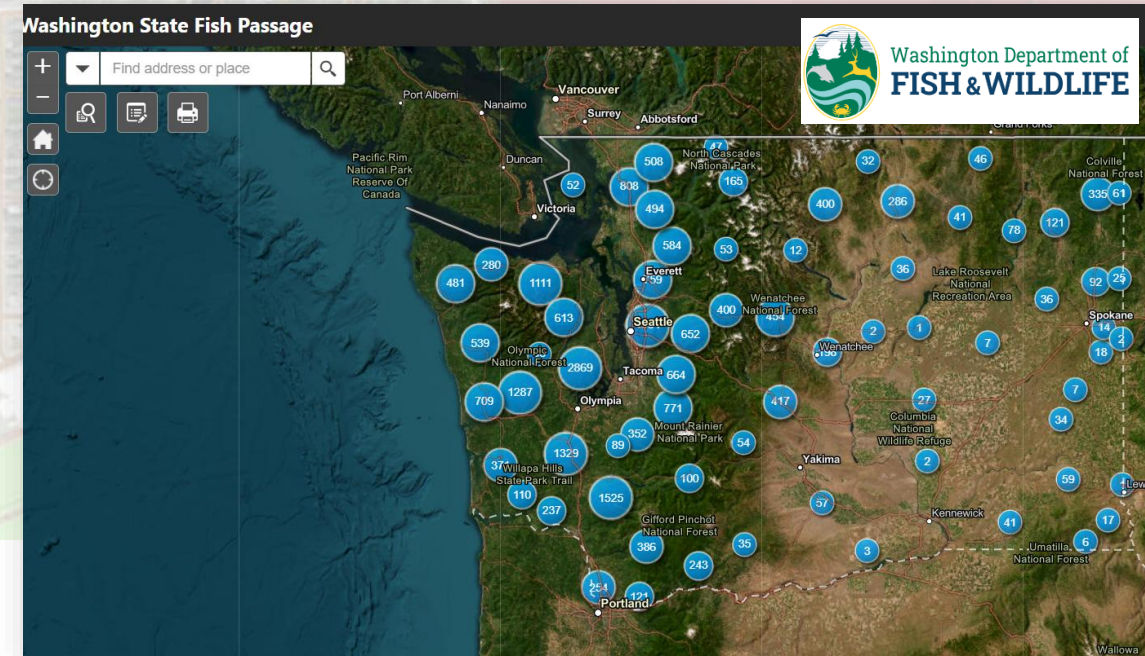
- These types of datasets are always “out of date” by the time you are done....
- Working with PSP to develop guidance on how to maintain and update the database
- Continued regional review / validation - how to collect feedback (WDFW Webmap?)
- Update with newer imagery and as restoration is implemented
- How often to make updates and PSP leads updates?



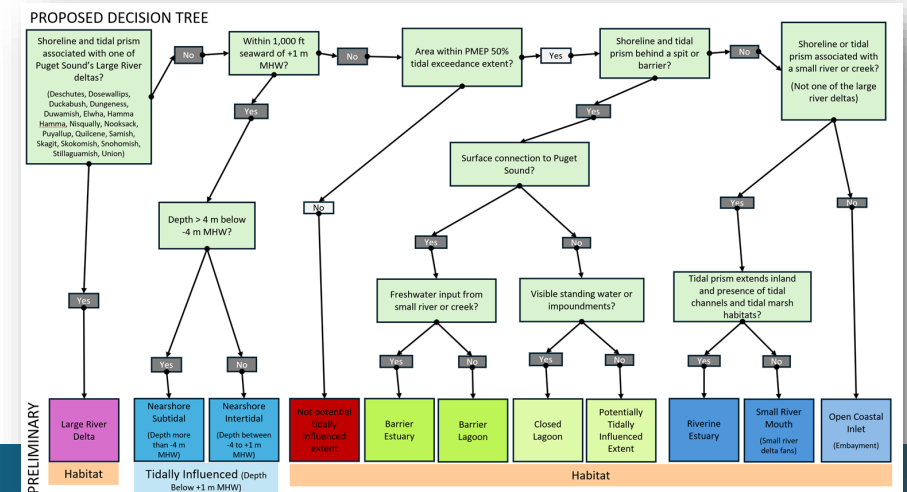
Integrate with regional efforts and datasets

- Integration with HS&T programs
- Update spatial inventory of WCFs in FPDSI
- Update PMEP tidal exceedance extents
- Integrate with other workgroups:
 - *PSEMP Spatial Data Group*
 - *ESRP Embayment Strategies Team*
 - *ESRP Automated Landscape Connectivity Team*

WDFW Fish Passage and Diversion Screening Inventory



Preliminary DRAFT geomorphic habitat classification being developed in collaboration with the ESRP Embayment Strategies





Adding more components, attributes, and tools



Add networking to tidal restriction polygons to support dynamic updates with restoration or scenarios



Add elevation to tidal restriction polyline and tidal extent polygon data – refine classifications

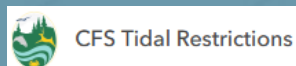


Add biotic and/or geomorphic habitat classifications to tidal extent polygons





Check out the
WFDW Hosted
ArcGIS Map



<https://geodataservices.wdfw.wa.gov/hp/tidal-restrictions/>

Questions?

Email us:

Jason.Hall@fishsciences.net

Melinda.Paulus@fishsciences.net



Thank you!