National Aeronautics and Space Administration

Remote Sensing for Freshwater Habitats

Amber McCullum & Juan Torres-Pérez

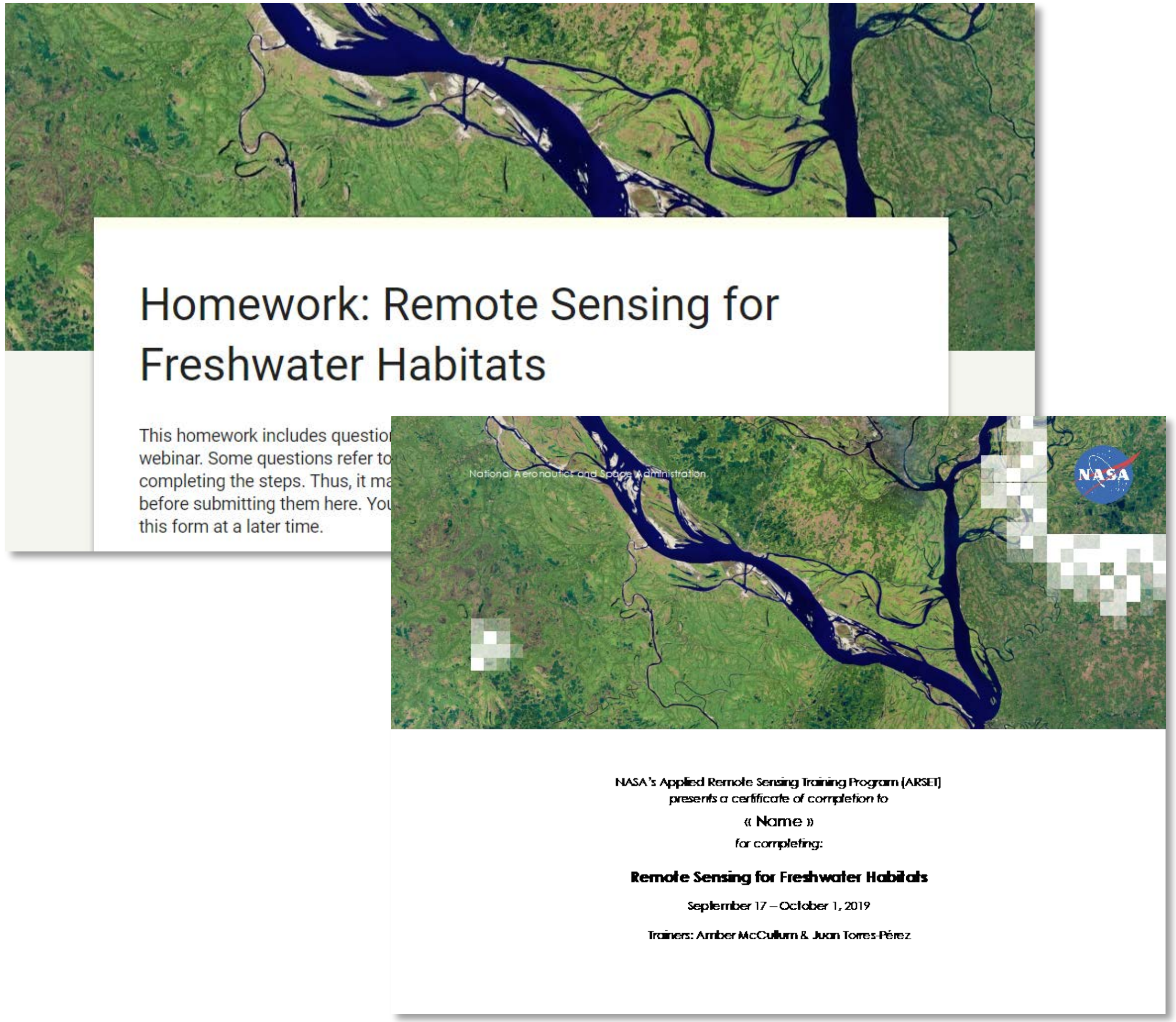
17 September – 1 October, 2019

Course Structure

- Three, 1-hour sessions on September 17, 24, and October 1
- The same content will be presented at two different times each day:
  - Session A: 10:00-11:00 EST (UTC-4)
  - Session B: 18:00-19:00 EST (UTC-4)
  - **Please only sign up for and attend one session per day**
- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
  - **https://arset.gsfc.nasa.gov/land/webinars/2019-freshwater**
- Q&A: Following each lecture and/or by email
  - amberjean.mccullum@nasa.gov
  - Or juan.l.torresperez@nasa.gov

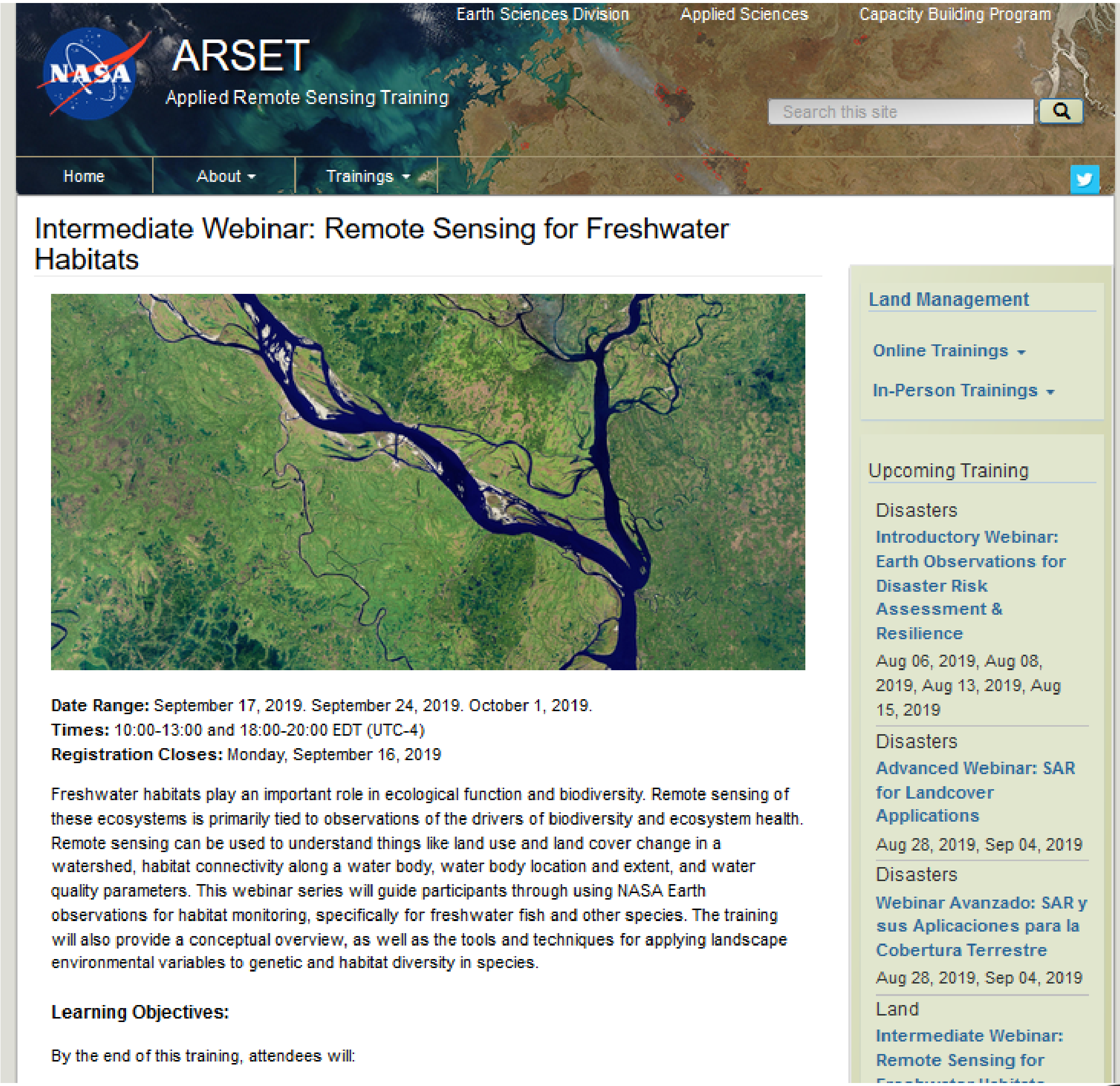
Homework and Certificates

- Homework
  - One homework assignment
  - Answers must be submitted via Google Forms
- Certificate of Completion:
  - Attend both live webinars
  - Complete the homework assignment by the deadline (access from ARSET website)
    - **HW Deadline: Tuesday Oct 15**
  - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com



Prerequisites and Course Materials

- Prerequisite
  - Please complete [Sessions 1 & 2A of Fundamentals of Remote Sensing](), or have equivalent experience
    - Attendees who do not have this knowledge may not follow the pace of the training
- Course Materials
  - Found here: https://arset.gsfc.nasa.gov/land/webinars/2019-freshwater



Course Outline

Session 1: Aquatic Remote Sensing

- Satellites and sensors
- Data limitations
- Combining multiple data types for freshwater habitat mapping
- Some case study examples

Session 2: Riverscape Analysis Project (RAP)

- Case studies
- RAP overview
- Data and analysis with RAP
- RAP demo

Session 3: Freshwater Health Index

- Freshwater health metrics overview
- FHI overview
- FHI demo

Review of Session 1

- Inland waters are important for drinking sources, ecosystem services, biodiversity, recreation, power, irrigation, etc.
- Remote Sensing can be used for assessing freshwater habitats and water quality parameters:
  - Depth, sediment size, water surface extent: LiDAR
  - Water quality (Chl-a, suspended sediments, etc.): multispectral and hyperspectral sensors (e.g. MODIS, HyspIRI)
  - River complexity: Landsat, Sentinel-2
  - And many more!

- Case study examples
  - Lake Erie Algal blooms
  - Bathymetry in Yellowstone National Park

Session 2 Agenda

- Landscape genetics
  – Ties to remote sensing data
- Case-study examples of landscape genetics assessments
- Overview of the Riverscape Analysis Project (RAP)
- Data access and analysis with RAP
- RAP Demo
- Question and Answer session

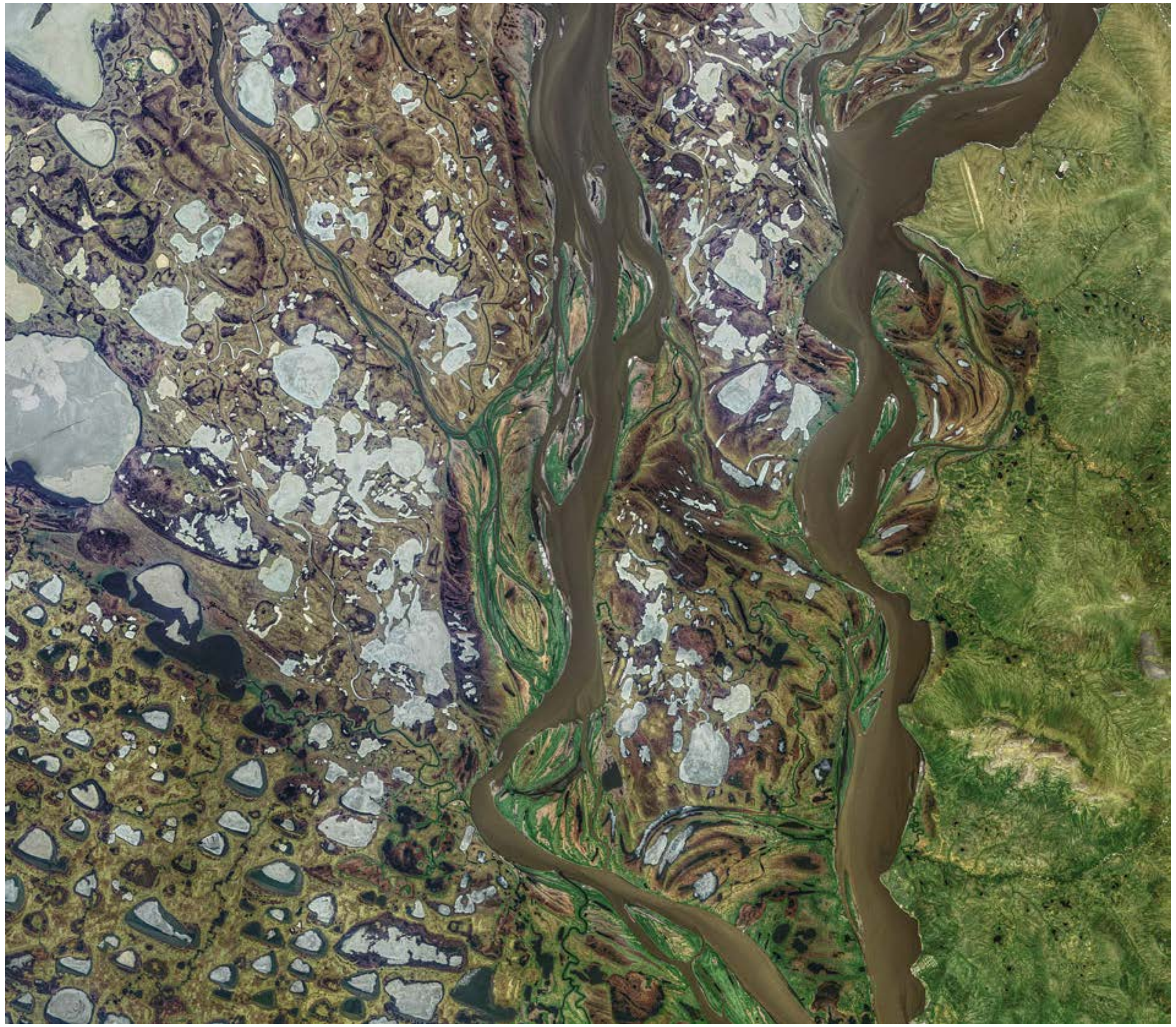


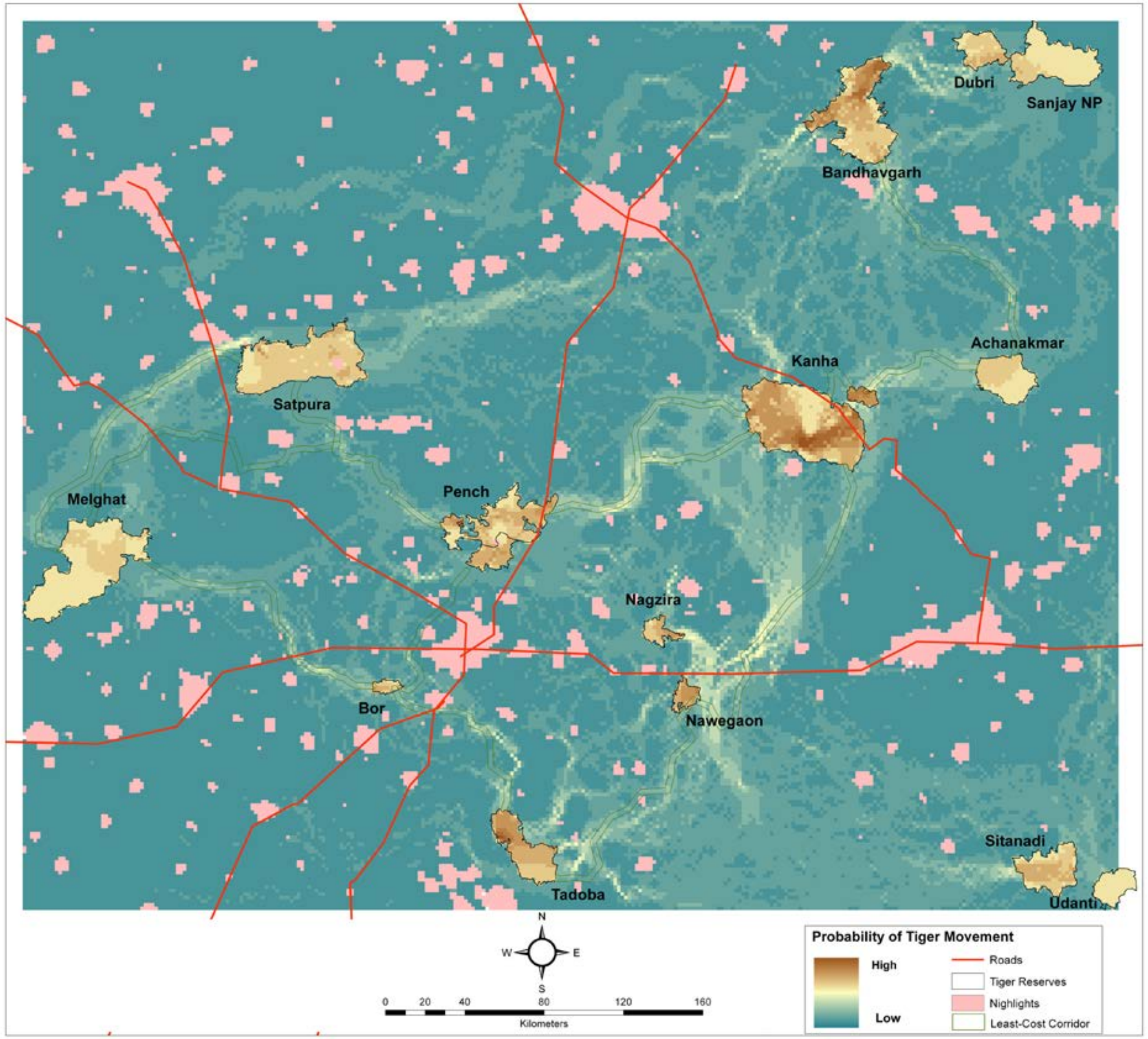
Image Credit: Earth Observatory

Landscape Genetics

Landscape Genetics

- The study of the influence of the landscape or environmental features on the genetic diversity of populations

- Combination of
  - **landscape ecology** and
  - **genetic monitoring**



Tiger movement probability in Central India. [Yumnam et al., 2014](#).

Landscape Ecology

- The study of the pattern and interaction between ecosystems within a region of interest and how these interactions affect the ecological process
  - Remote sensing and geospatial analysis have transformed the discipline
    - Land cover classification (habitat types)
    - Change detection
    - Connectivity and fragmentation
      - Corridor mapping
      - patch identification
    - Climate change assessments

Genetic Monitoring

- Study of the structure and function of chromosomes and gene expression
- Use of genetic markers to:
  - Identify and monitor individuals and populations
  - Quantify changes in population genetic metrics
    - Population size, genetic diversity, etc.
  - Detect changes in species abundance and/or diversity
- This is important for biodiversity and conservation

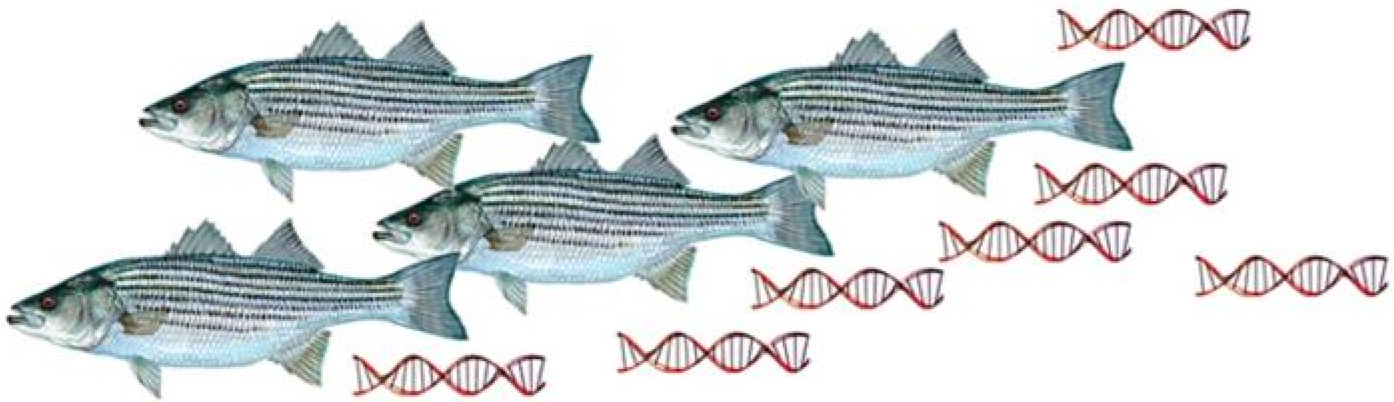
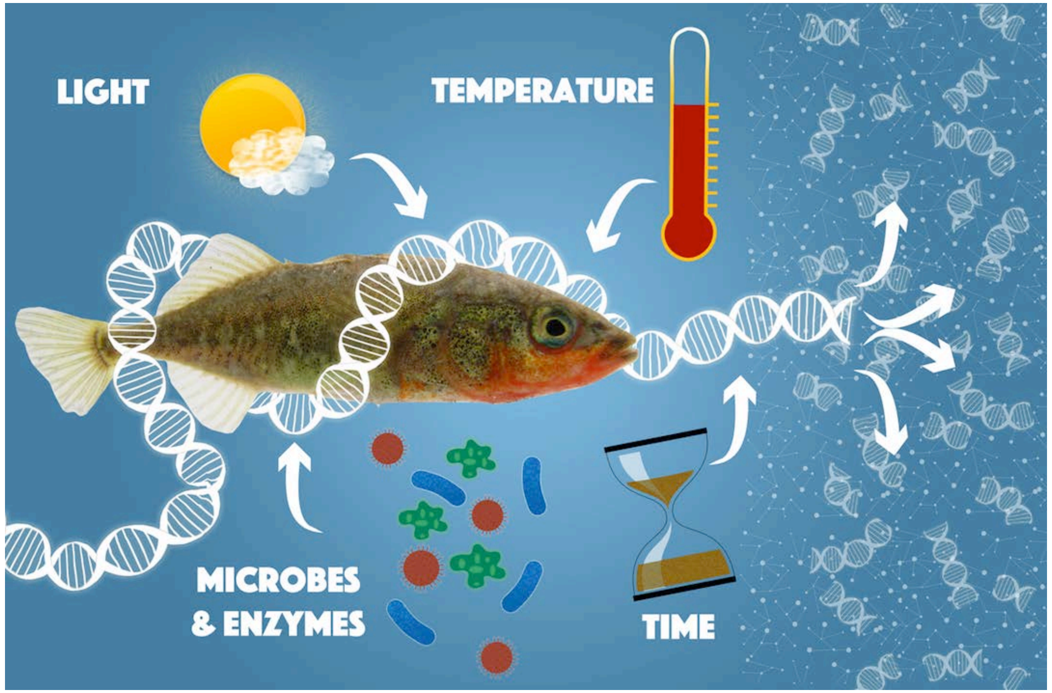


Image Credit: The Rockefeller University

Environmental DNA (eDNA)

- Genetic material obtained directly from environmental samples without any obvious signs of biological source material [1]
- Collected from soil, rocks, and the water column
- Allows for biomonitoring without collection of the living organism
  - Effective for freshwater species, including invasive species
  - Estimates presence and abundance



Please refer to last slide for reference; Image Credit: Fishbo

Environmental DNA (eDNA)

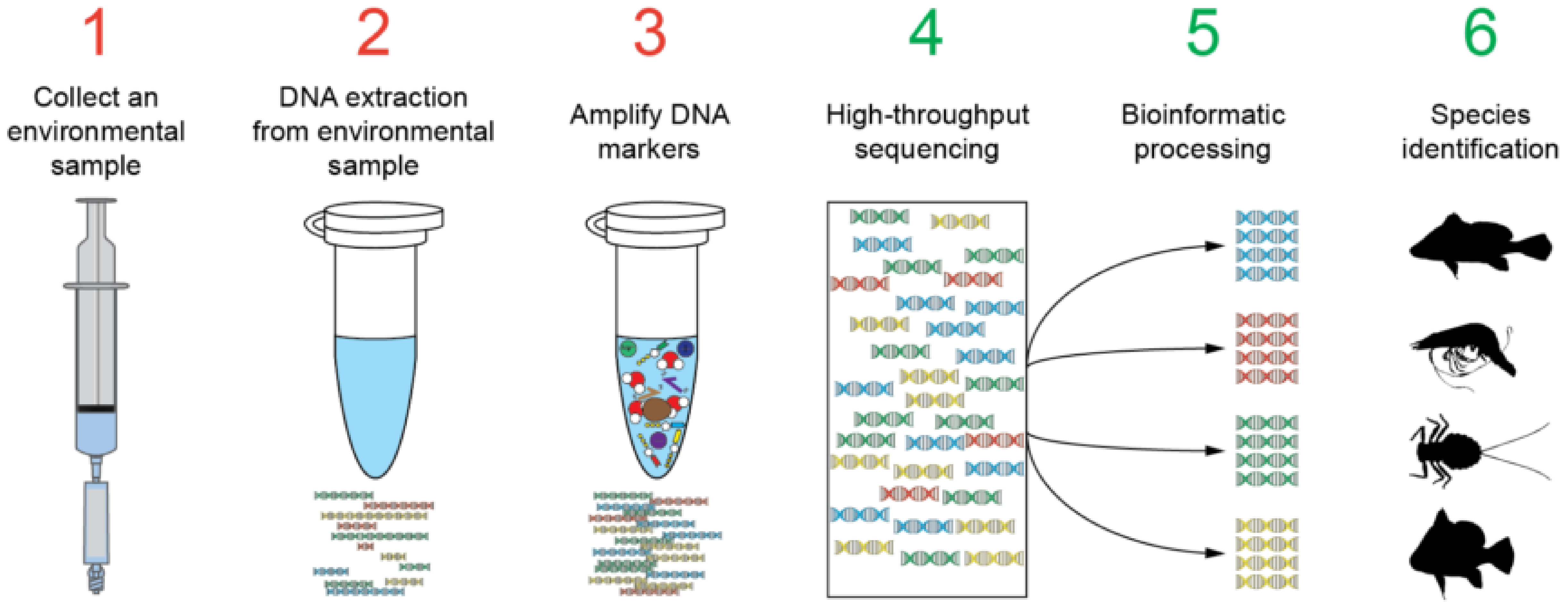


Image Credit: Nature Metrics via Sixth Researcher

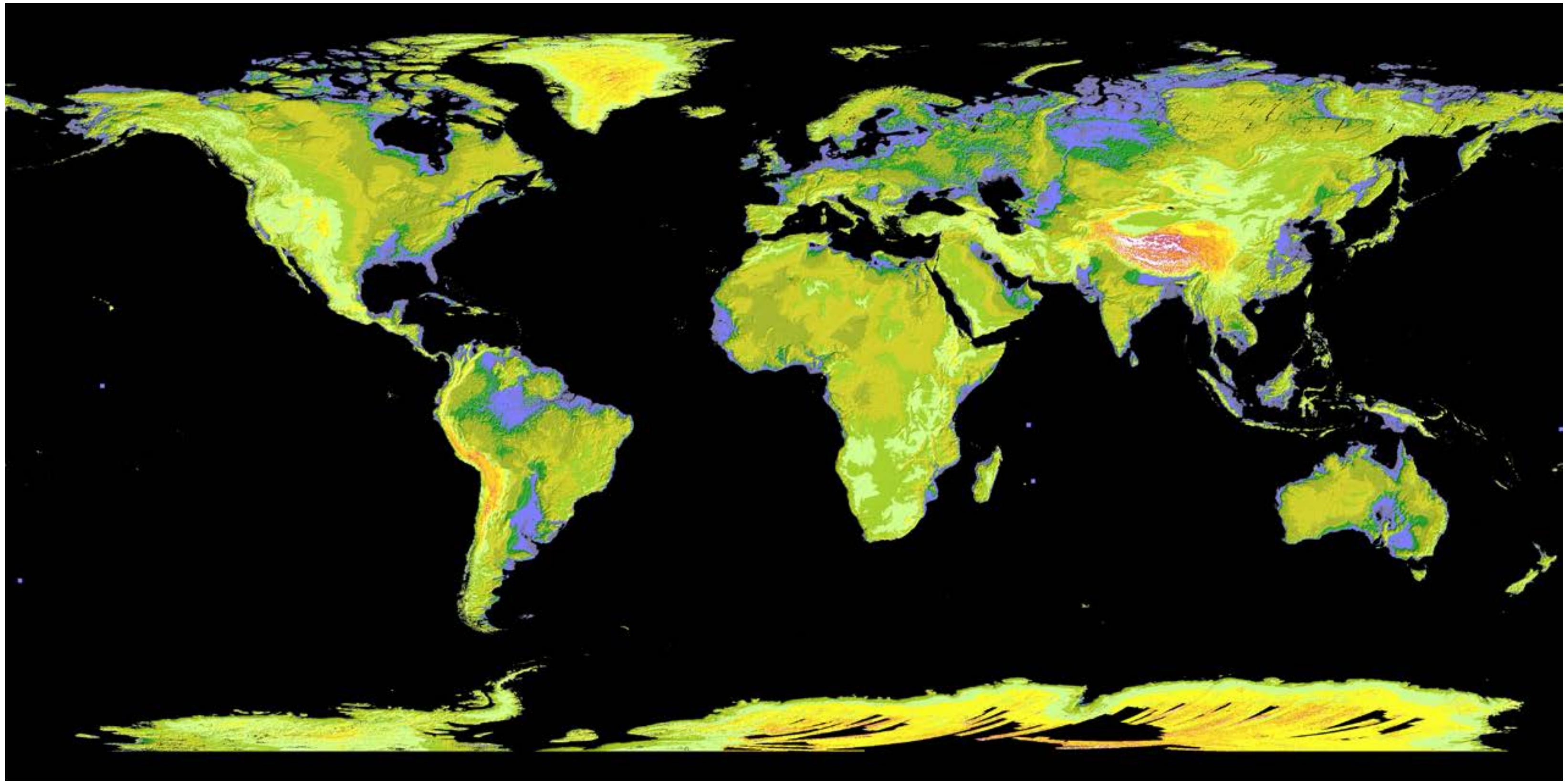
Conducting Landscape Genetics Analyses

Conducting Landscape/Riverscape Genetics Analyses

1. Data acquisition
2. Landscape/environmental variable analysis
   - Creating resistance map layers
3. Modeling movement pathways
4. Analyzing geospatial statistics, and
5. Combining this information and conducting multiple model runs to assess species movement and/or vulnerability

1. Data Acquisition

- Obtain landscape/environmental data
  - Examples:
    - Elevation
    - Habitat type
    - Snow cover
    - Road cover
    - Stream locations
    - Water quality
  - See session 1



Global digital elevation model (DEM) from NASA's ASTER sensor

Image Credit: NASA

1. Data Acquisition

- Collection of eDNA or DNA samples
  - Water samples (eDNA)
  - Fin clips or other biocollections (DNA)
- Followed by genetic analyses in lab
- Many projects have citizen science component

Researchers collecting eDNA samples for the USGS

Citizen scientists collecting fin clips of trout for the RAP project

Image Credits: (Left) USGS; (Right) University of Montana RAP

2. Landscape/Environmental Variable Analysis

- Combine weighted, individual landscape features into a resistance surface or map
- **Resistance Map**: A hypothesis of species dispersal based on weighted landscape variables suspected to be important to gene flow
  - Multiple grids representing all the landscape variables that fit into your model
    - Continuous or classified data

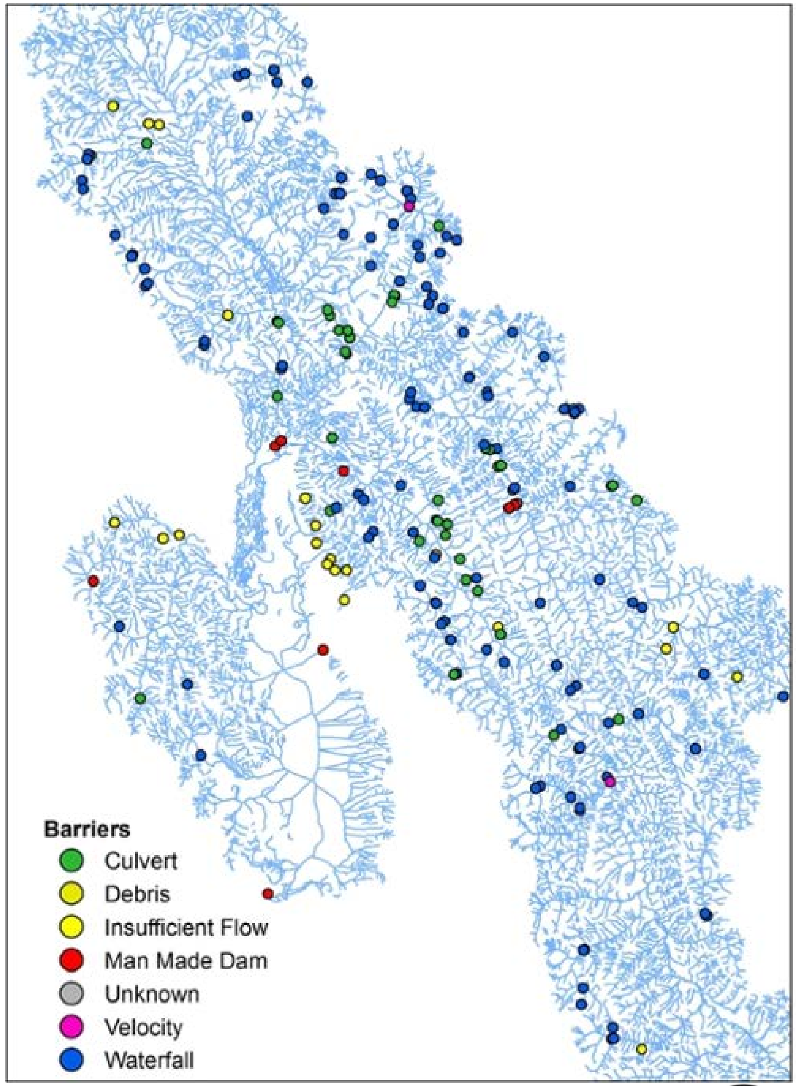


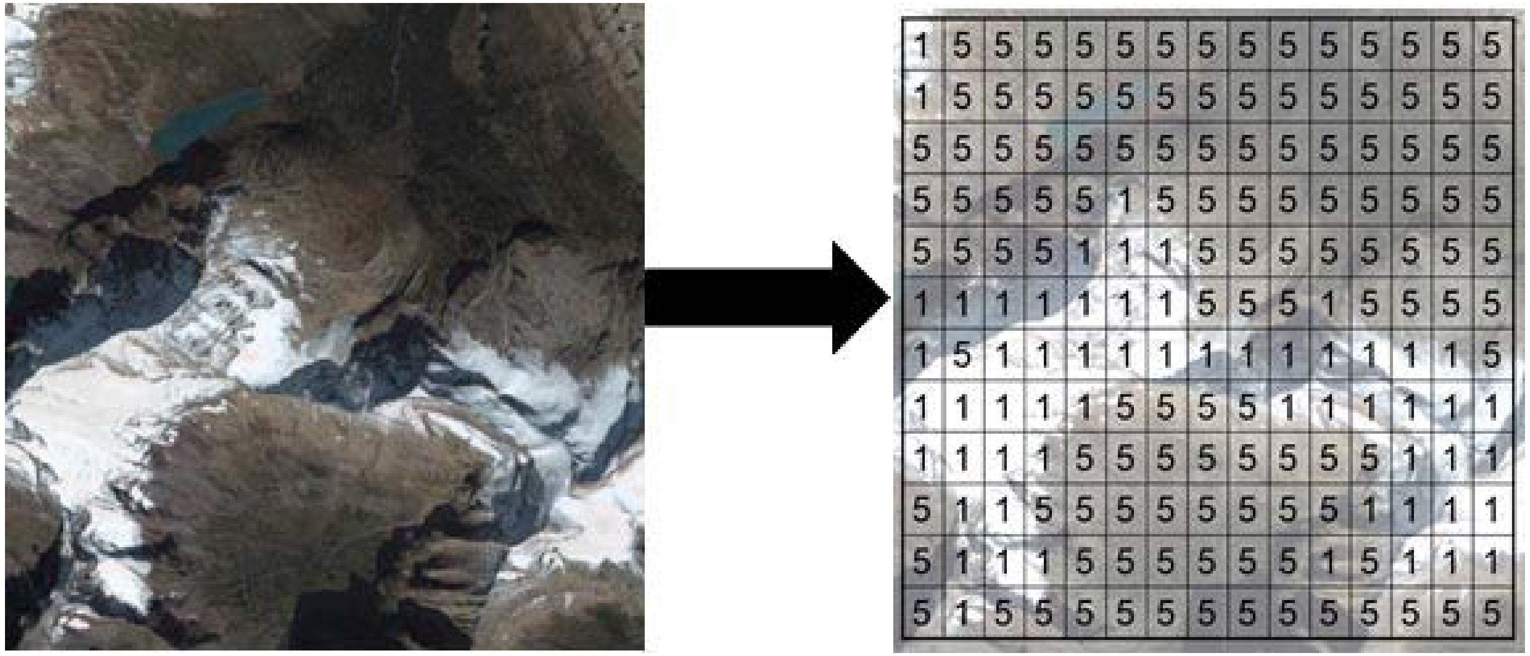
Image: Map of the Flathead River Drainage in Montana identifying barriers to fish movement.

Image Credit: [University of Montana RAP]

2. Landscape/Environmental Variable Analysis

Resistance Map Layers

- Each cell for a variable is assigned a weight based on how that variable effects movement, survival, abundance, or reproduction [2]
  - This identifies the relative "cost" of animal movement through the image



Example of species movement (or gene flow) across the landscape where the species of interest prefers snow cover to bare landscape

Image Credit: University of Montana RAP

2. Landscape/Environmental Variable Analysis

Resistance Map Layers

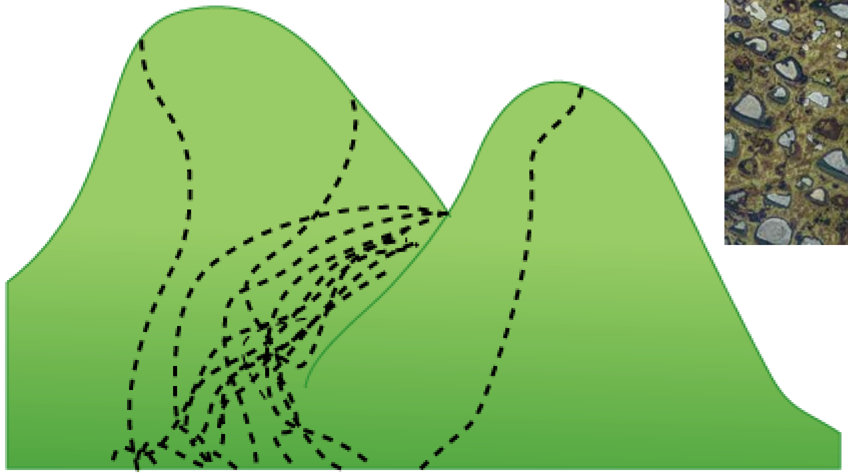
- How to assign “weights”
  - Where will individuals move to-from?
  - What in the environment might enhance or limit this movement?
  - How might this affect variations in future individuals or populations?

- Data used to identify **pathways AND barriers** to gene flow
  - Can be difficult to determine how factors are weighted
  - In Freshwater systems, barriers can be damns, changes in water quality parameters (e.g. temperature, chlorophyll-a), streamflow direction, changes to stream size, etc.

3. Modeling Movement Pathways

Resistance Map Layer "Weights"

- Analyze this through the use of connectivity modeling
- How will the individual move?
  - 2 models:
    - Least-cost path
    - Circuit theory



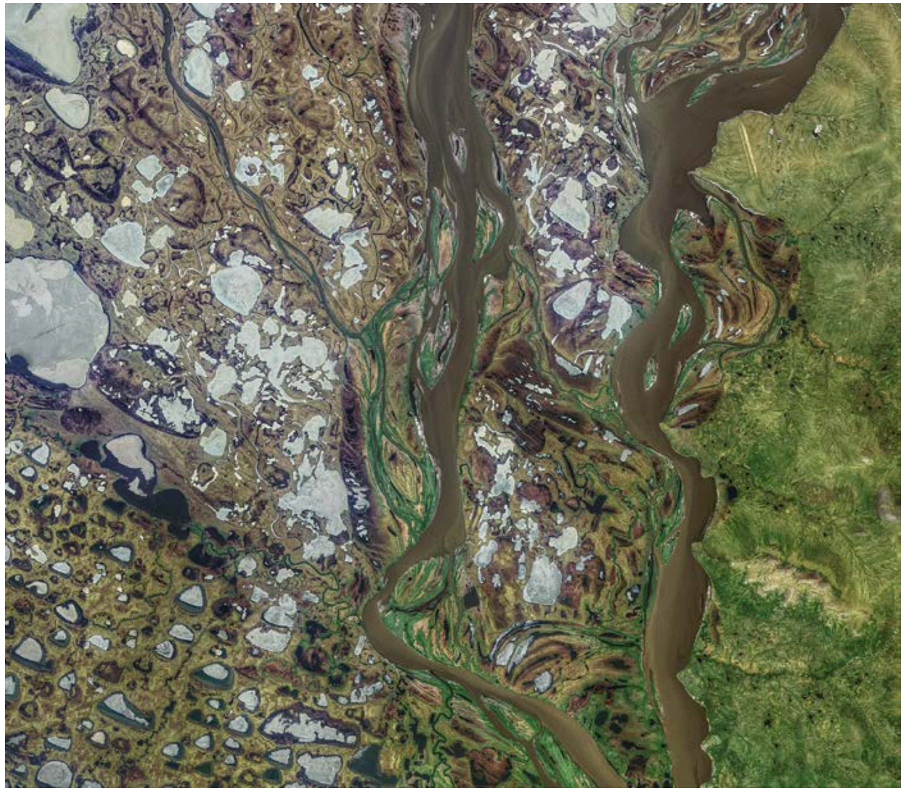
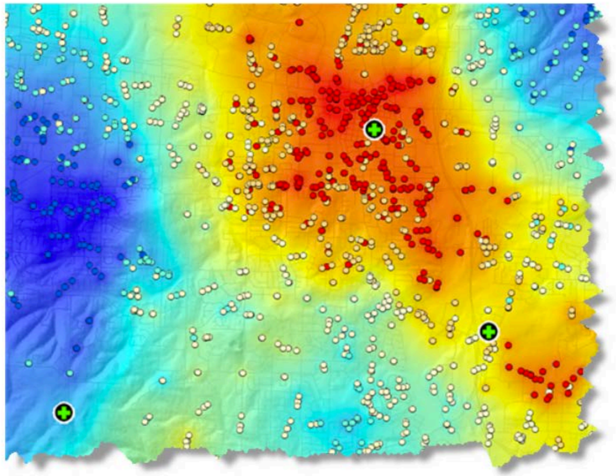


Image Credit: (Left) Conservation Corridor

4. Statistical Analyses

Approaches

- Common approaches to identify spatial genetic patterns:
  - Regression analysis
  - Spatial autocorrelation
  - Bayesian clustering
  - Multivariate analyses
  - Mantel’s test
- For detailed information on these tests see: Manel et al., 2003 [4]



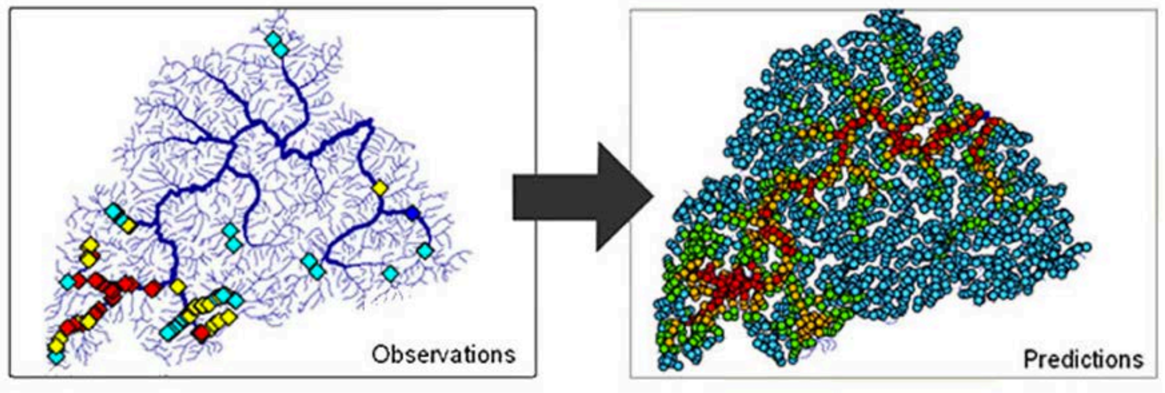


Image Credits: (Top Left) ArcGIS Pro; (Top Right) Robert J. Hijmans; (Bottom) NOAA and ACEMS

5. Vulnerability Assessments

- Identify the degree of future risks from climatic change and to identify vulnerable areas to provide a solid foundation for climatic change mitigation planning (IPCC, 2007).
  - **For Freshwater systems**: species are sensitive to temperature shifts and altered stream flows

Image Credit: (Left) NASA ABoVE

Case Study Examples

Tropical Fish in Thailand

- Effects of landscape features on tropical fish in the Nan river of Thailand
- Landcover and stream order (size)mapping
- Individual sampling and genetic diversity indices assessed
- Examined correlations between landscape features and genetic diversity (allelic richness) and genetic differentiation
- 4 genetic clusters identified in different regions of the Nan River: river topology plays a role

Above: *Garra cambodgiensis* (Stone lapping minnow).
Right: Landcover and stream order map with sample locations of fish

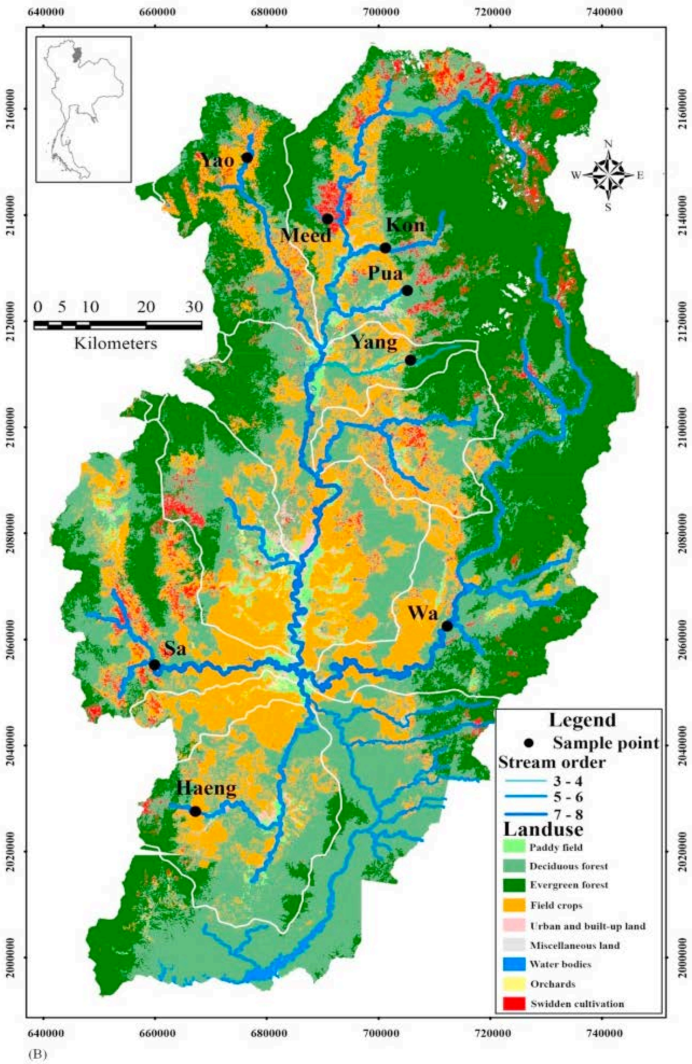


Image Credits: (Top left) Diszhal.info; (Right) Jaisuk and Senanan, 2018

Brook Charr in Canada

- Influence of habitat on genetic diversity in La Mauricie National Park (LMNP) [5]
- Sampled Brook Charr in 26 lakes, representative of seven different drainage system
- Use of statistical technique canonical correspondence analysis (CCA)
  - Multivariate analysis
- What variables (lake elevation or drainage pattern) can best account for genetic diversity?
  - **Altitude:** accounted for significant proportion of genetic diversity
  - **Lake size**: not a contributing factor

Please refer to last slide for reference; Image Credits: (Top) Yan Lassalle, Canadian Geographic; (Bottom) Maryland DNR

Pythons in South Florida

- Invasive constrictors snakes pose a threat to native species [6]
- Species-specific genetic tests for pythons, boa constructors, and anacondas
  - Burmese pythons detected in over half of the field locations
    - And along the northern edge of the known population boundary
- These data can be used for conservation efforts

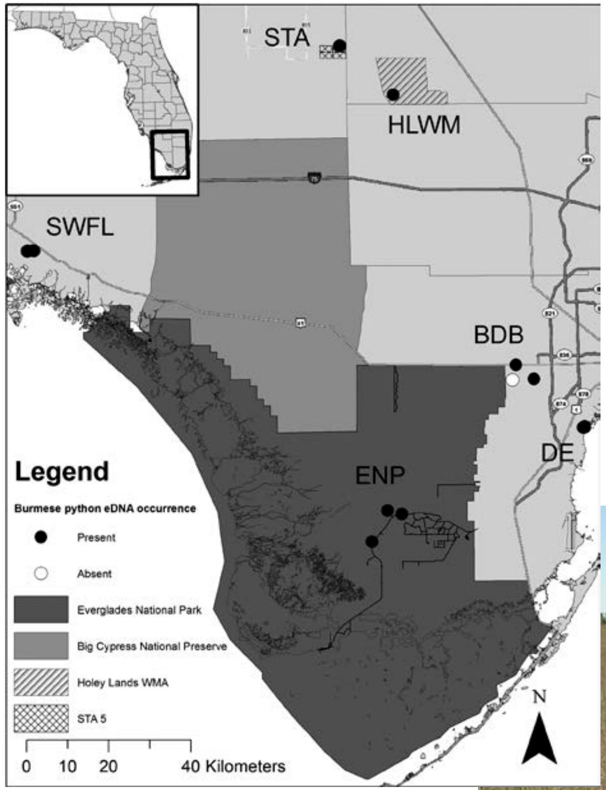


Image Credits: (Top) Hunter et al., 2015); (Bottom) USGS

Biodiversity in California and Florida

- NASA-funded M-BON projects using eDNA and remote sensing
- NASA-data used: MODIS and VIIRS (SST, Ocean color) and Landsat (land cover classification, bathymetry)
- Use of eDNA genetic markers to provide snapshot of biodiversity across various groups
  – Data collection in the Monterey Bay and in Florida Keys
- Higher biodiversity of plankton and vertebrates in warmer waters in Florida and Monterey Bay

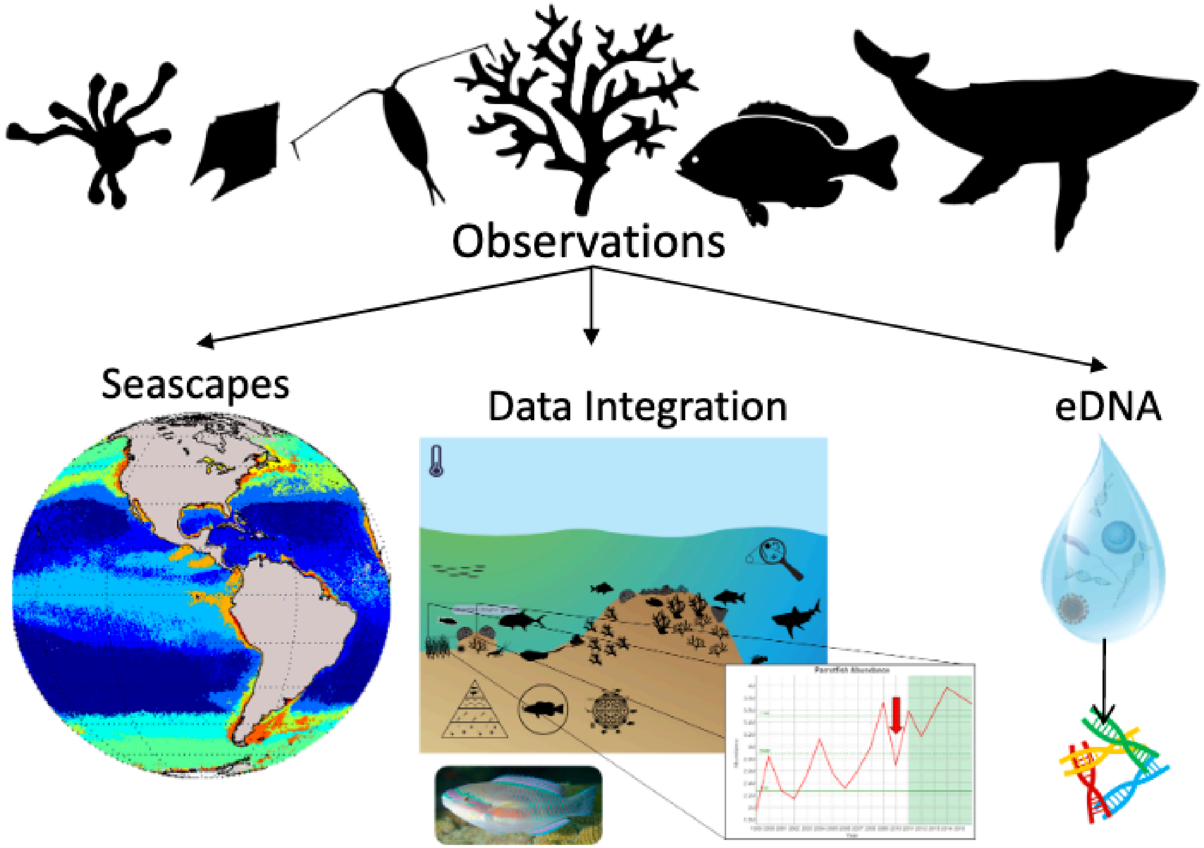


Image Credit: Muller-Karger (USF), Chavez (MBARI), 2018

Steelhead Trout in the Pacific Northwest

- Fiver metapopulations of threatened steelhead trout in Columbia River Basin
- Riverscape genetics to assess climate and habitat influences on genetic differentiation (FST)
- Wintertime precipitation correlated to FST
- Under increased precipitation: certain populations will become more fragmented
- Managers can use this to monitor species and conduct management activities to reduce or prevent fragmentation

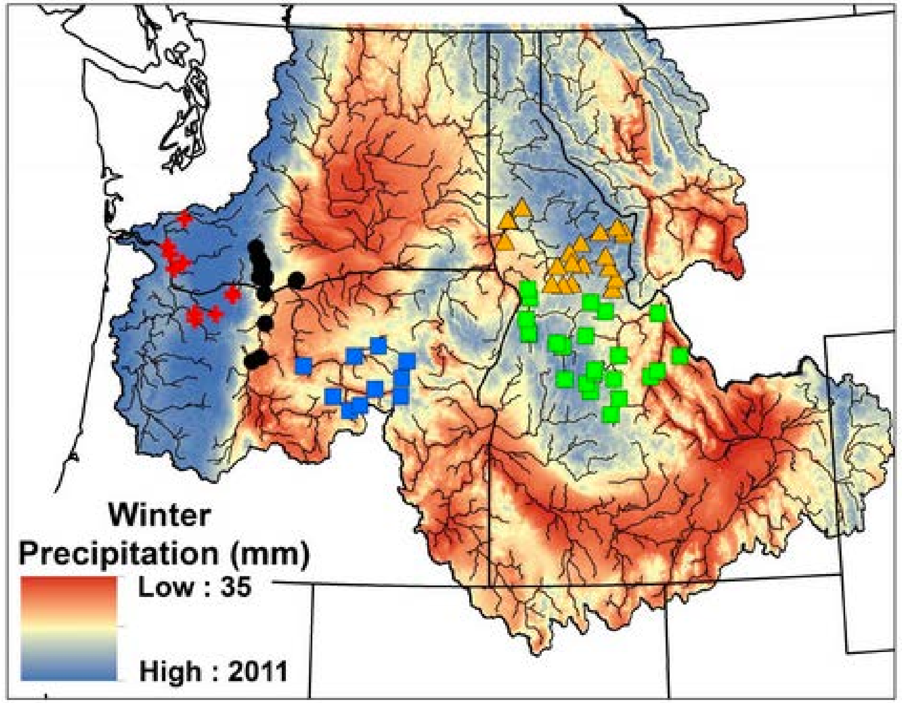


Image Credits: (Top) NOAA; (Bottom) Hand et al., 2015

Riverscape Analysis Project (RAP)

Salmon Habitat Importance

- **Salmonids**: a culturally and economically critical keystone species
- North Pacific Rim rivers and coastal systems are critical habitats for spawning and juvenile salmon
- Freshwater habitat often poorly defined
- Human development and climate change present challenges to these ecosystems
- Need to define and prioritize effective conservation strategies
  – Robust classification of rivers to map habitat quality and abundance needed
  – **Riverscape Analysis Project (RAP)**

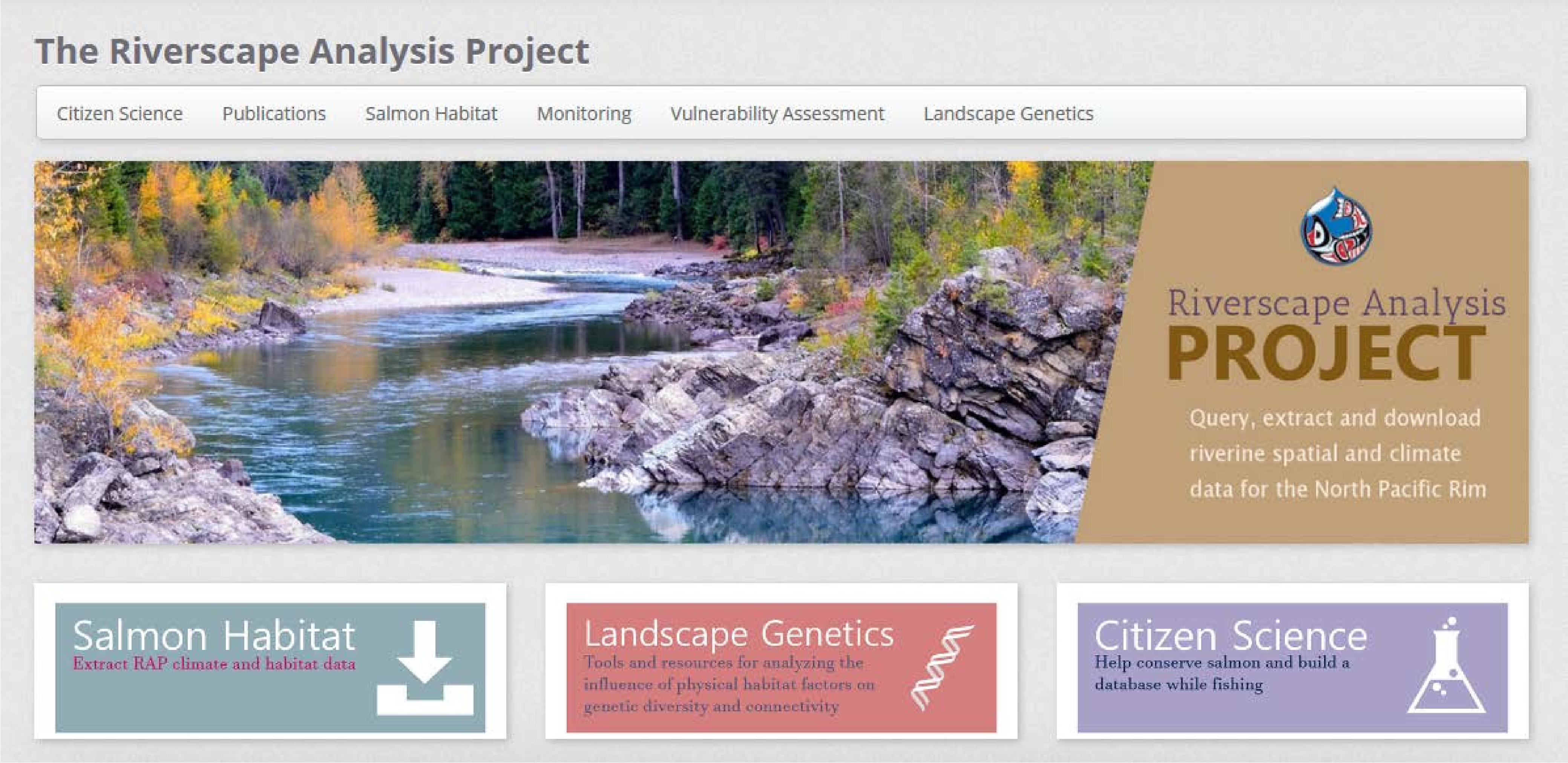
Image Credit: Kevin Schafer, WWF

Riverscape Analysis Project

- Web-Based Decision Support System (DSS)
  - Datasets, tools, and educational resources for salmonid conservation across the North Pacific Rim (NPR) Rivers
- Features
  - Download remote sensing data
  - Access habitat classification and suitability rankings
  - Conduct climate change vulnerability assessments
  - Access riverscape genetic analyses
  - Access genetic and demographic monitoring

The Riverscape Analysis Project (RAP)

http://www.ntsg.umt.edu/rap/default.php



RAP: Citizen Science

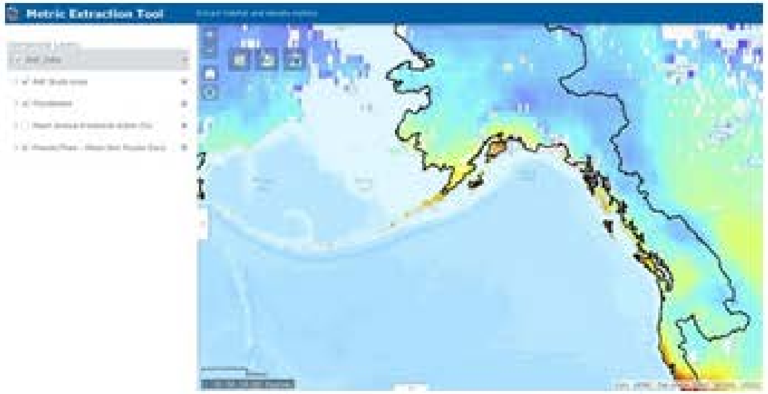
- Contribute to the RAP project through collecting trout genetic samples
  - Fin clips
  - Fish length measurements
  - Pictures
- Contact the team to contribute!
- Email Gordon Luikat with "citizen science" in the subject line

Image Credit: RAP

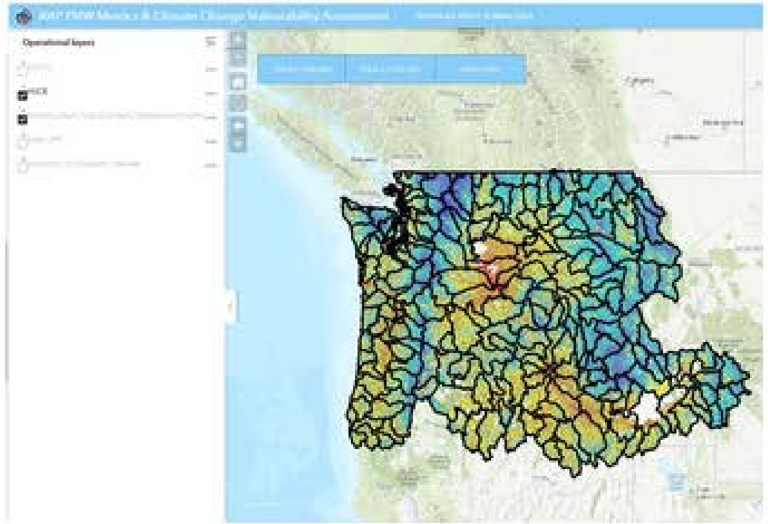
RAP Tool Demonstration

Salmon Habitat Tools

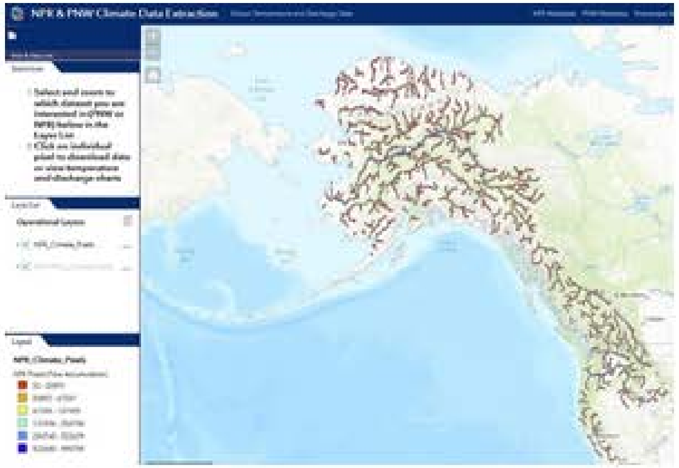
[Metric Extraction Tool: Extract habitat and climate data (Freeze/Thaw and Fractional Water)]



[PNW Climate Change Vulnerability Assessment Tool (HUC 12 scale)]



[NPR & PNW Climate Extraction Data (Stream Temperature & Flow)]



NPR Habitat and Climate Metric Extraction Tool   Extract Metrics by sub-watershed   Metadata   Habitat Data Dictionary   Riverscape Analysis Project

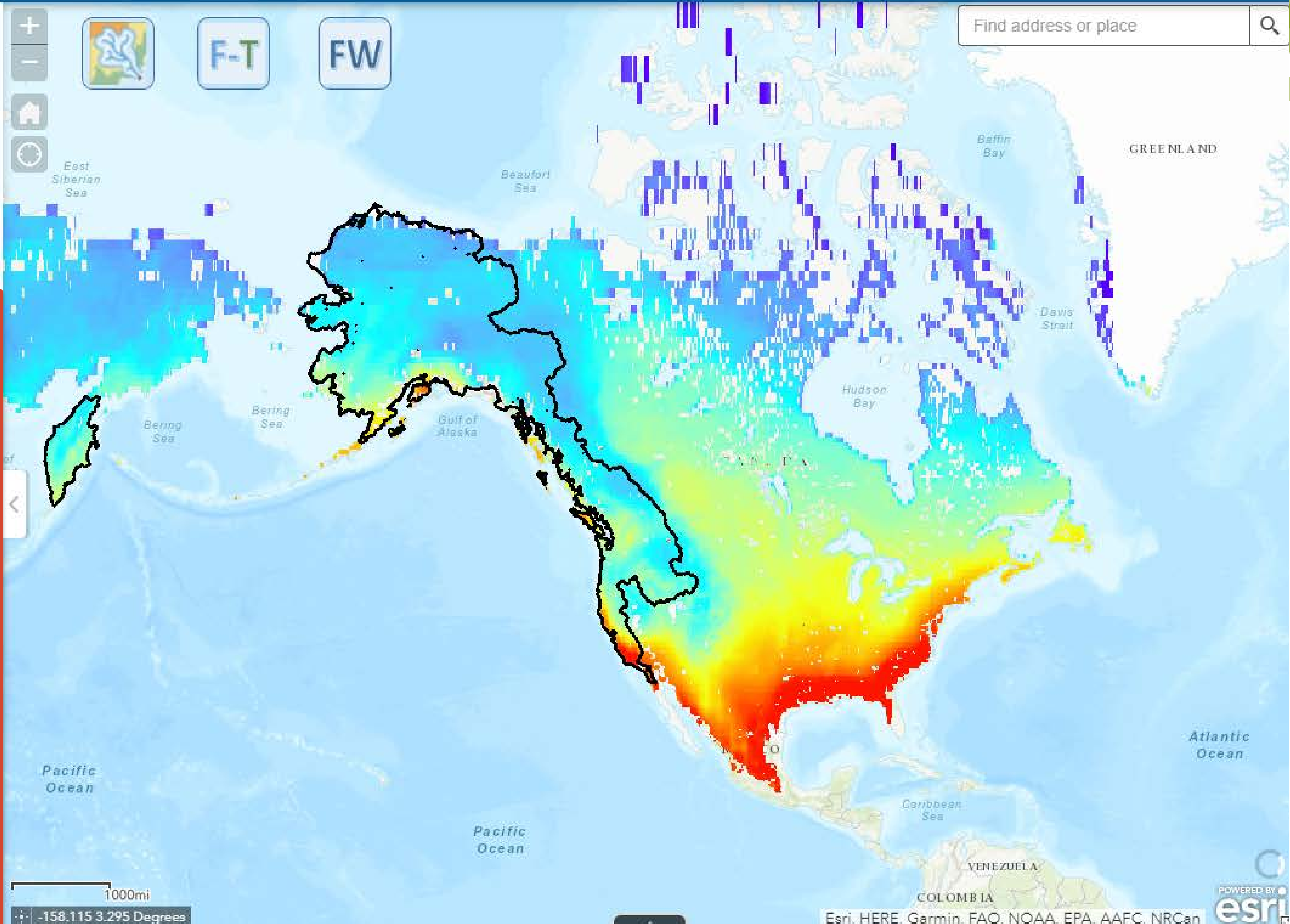
Directions:

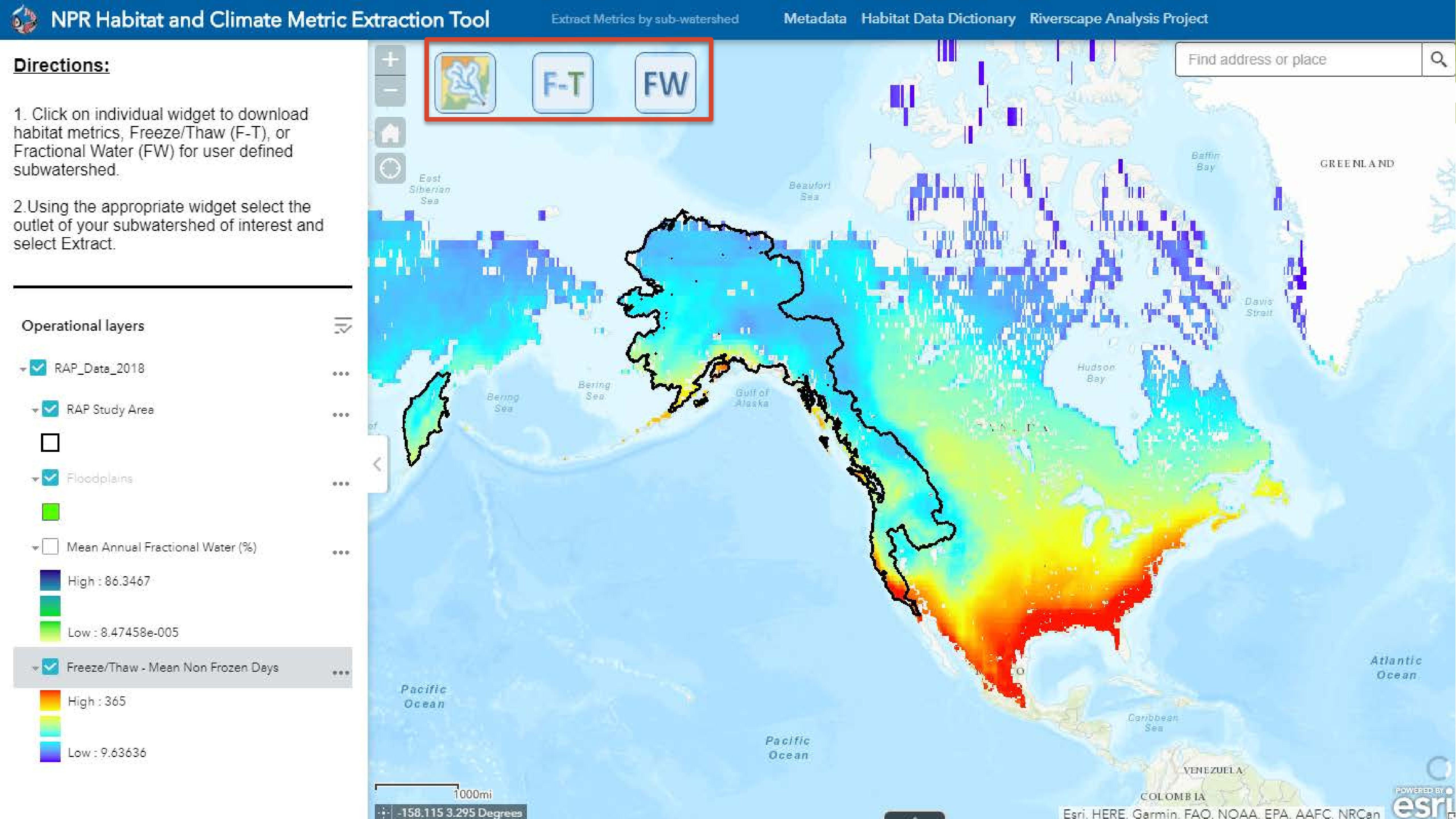
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.

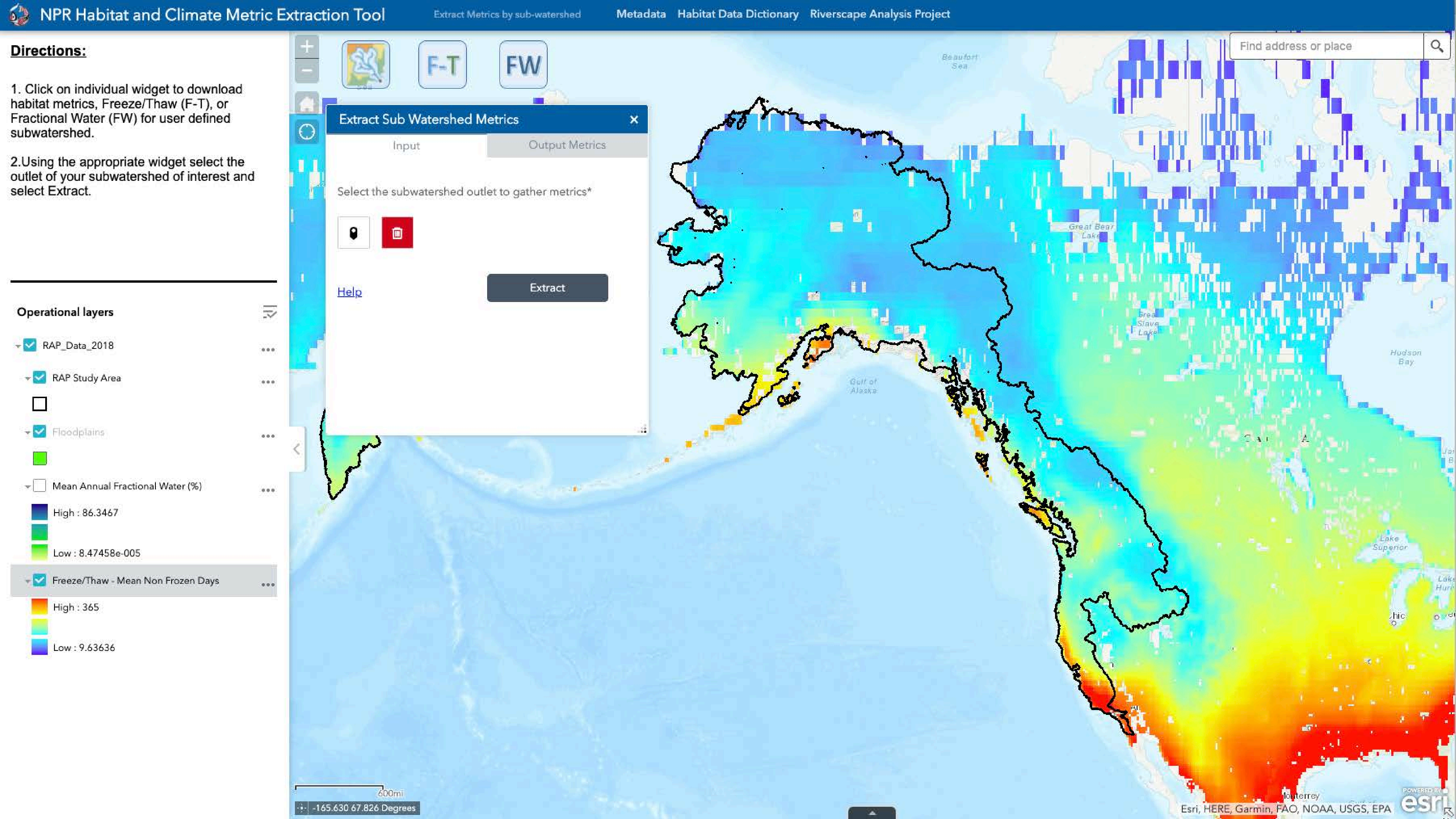
2. Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.

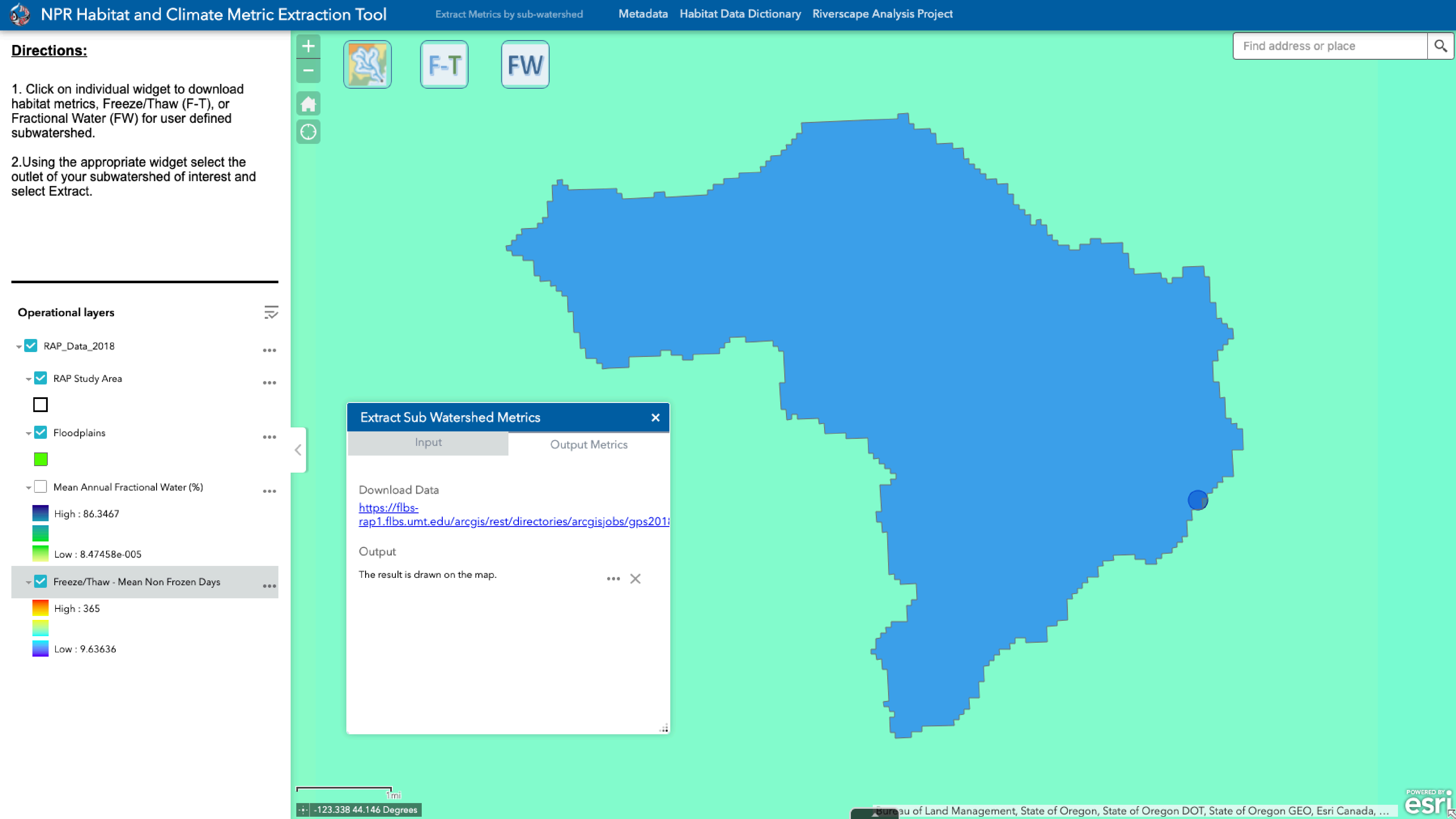
Operational layers

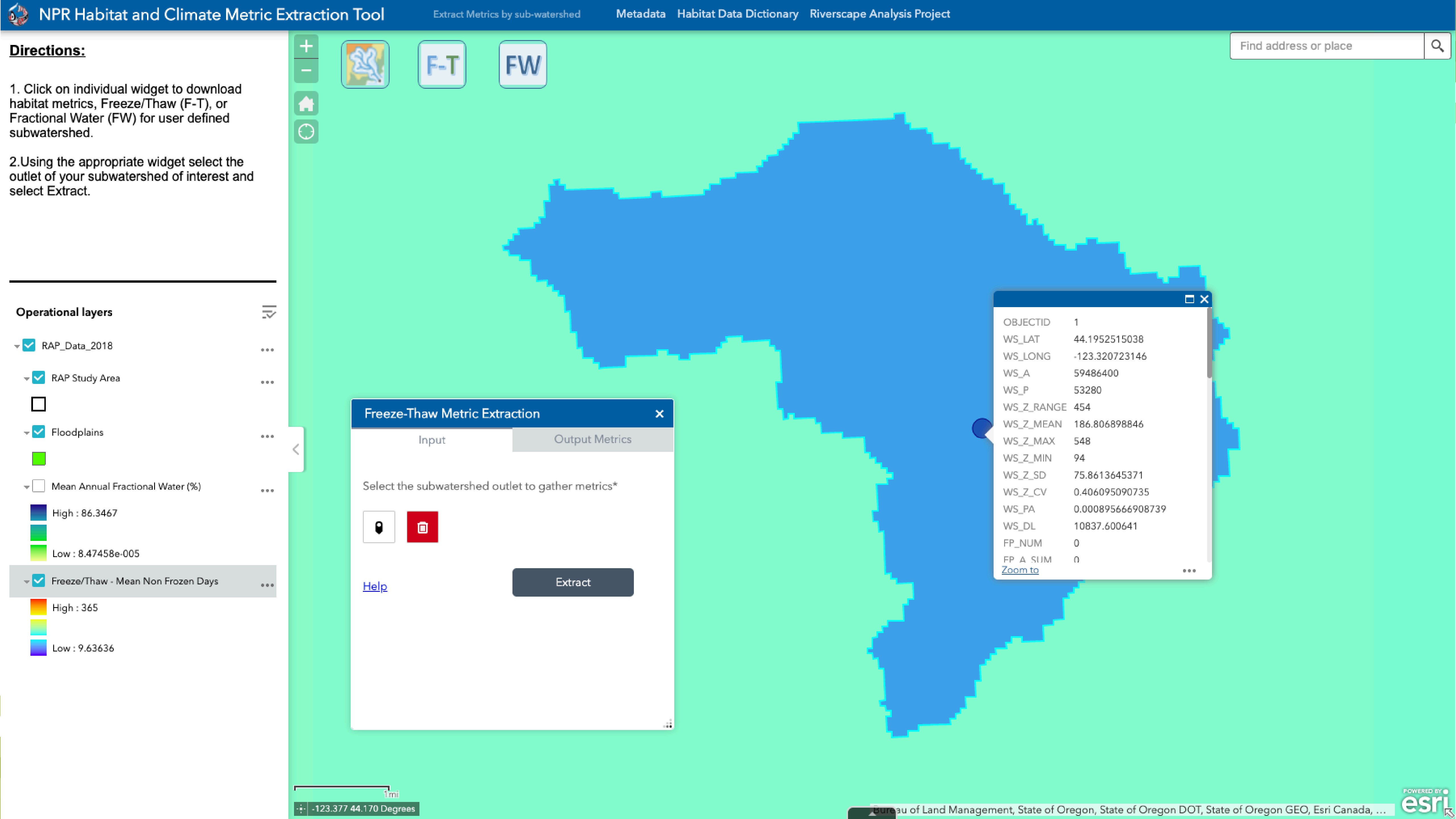
- RAP_Data_2018
  - RAP Study Area
  - Floodplains
  - Mean Annual Fractional Water (%)
    - High : 86.3467
    - Low : 8.47458e-005
  - Freeze/Thaw - Mean Non Frozen Days
    - High : 365
    - Low : 9.63636

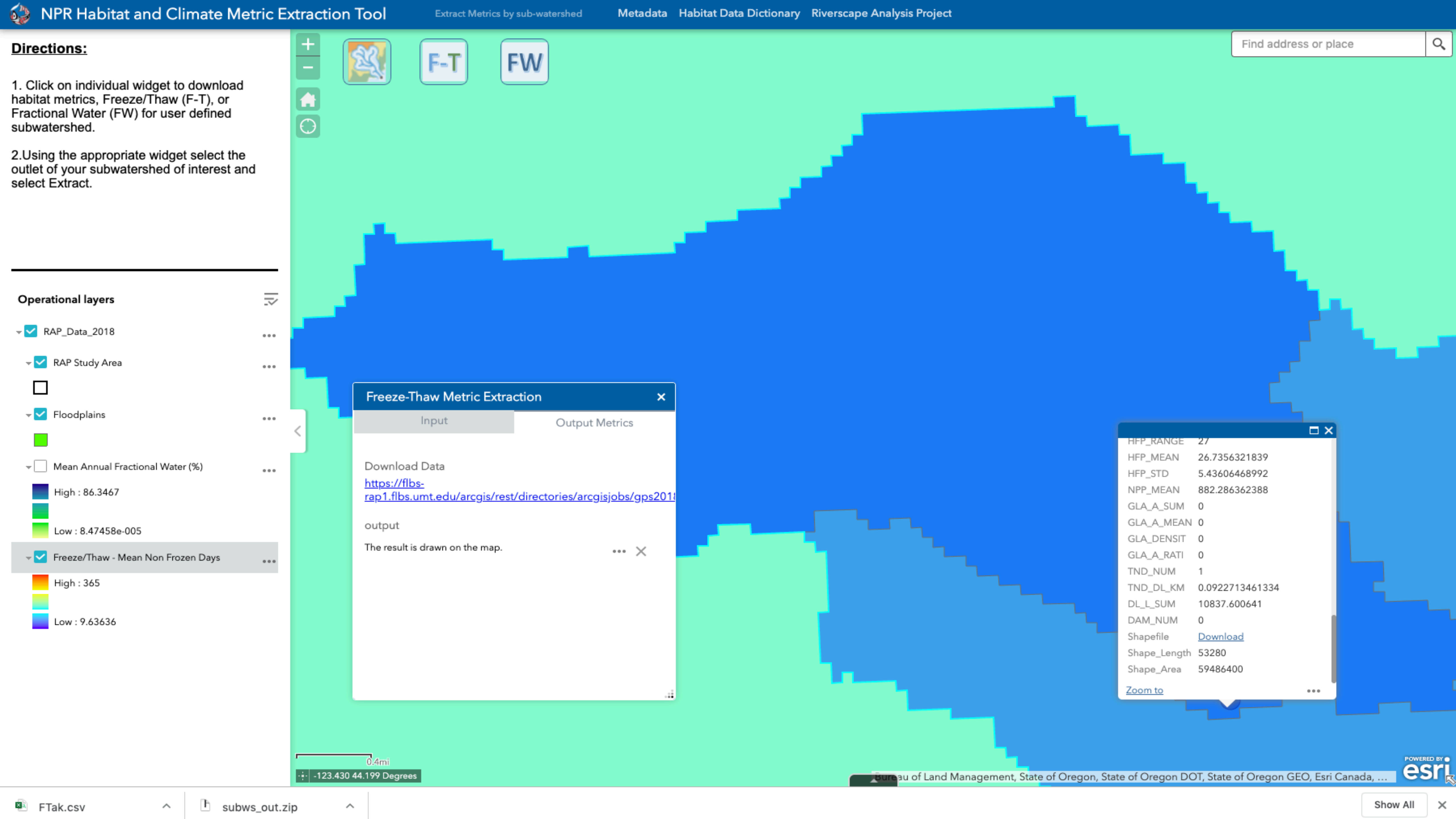


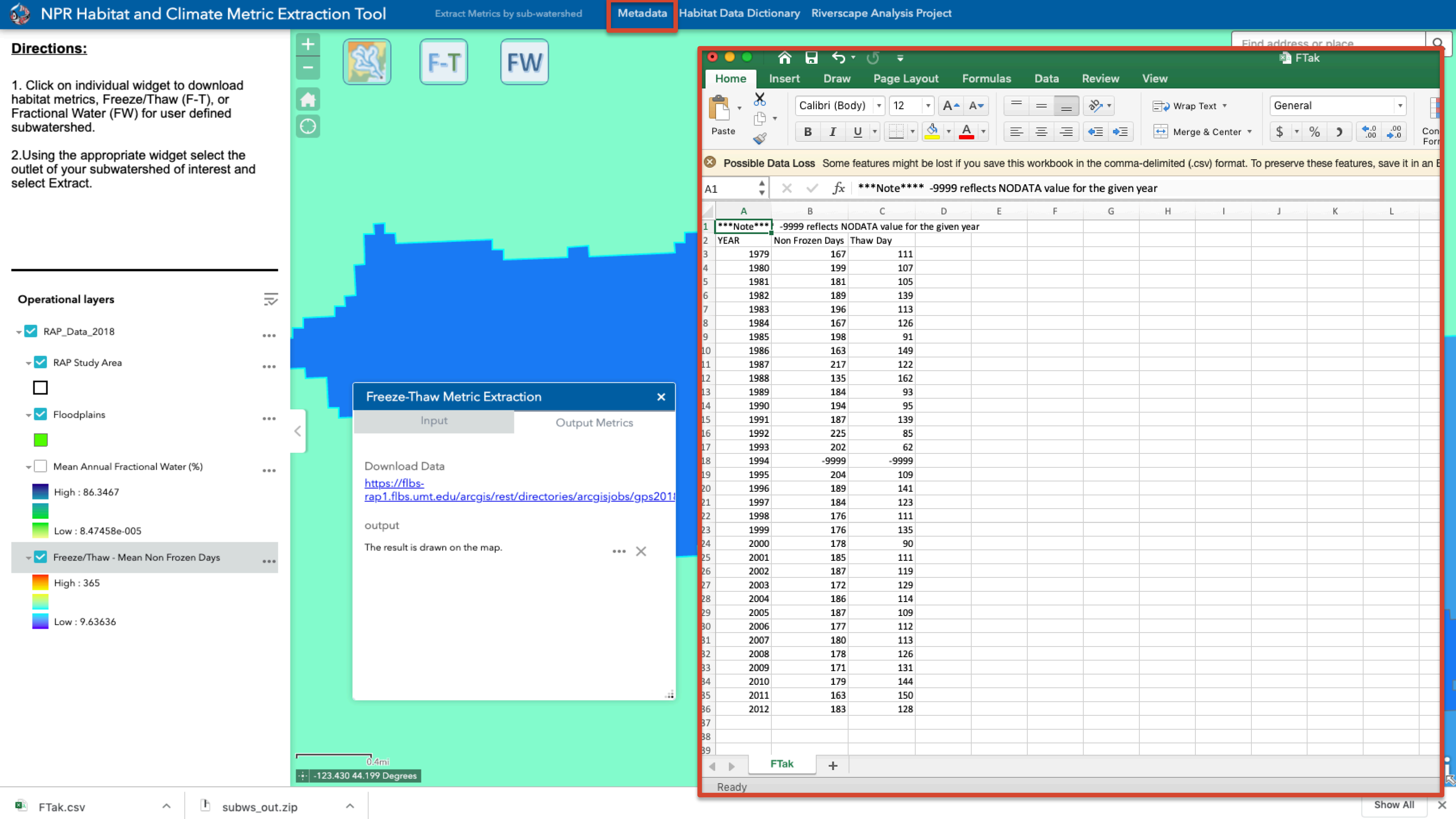

NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
F-T
FW
Find address or place
East Siberian Sea
Beaufort Sea
Baffin Bay
GREENLAND
Davis Strait
Hudson Bay
Bering Sea
Gulf of Alaska
Pacific Ocean
Atlantic Ocean
Caribbean Sea
VENEZUELA
COLOMBIA
1000mi
-158.115 3.295 Degrees
Esri, HERE, Garmin, FAO, NOAA, EPA, AAFC, NRCan
POWERED BY esri


NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Find address or place
F-T
FW
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Extract Sub Watershed Metrics
Input
Output Metrics
Select the subwatershed outlet to gather metrics*
Help
Extract
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
Beaufort Sea
Great Bear Lake
Great Slave Lake
Hudson Bay
Gulf of Alaska
Lake Superior
600mi
-165.630 67.826 Degrees
Esri, HERE, Garmin, FAO, NOAA, USGS, EPA

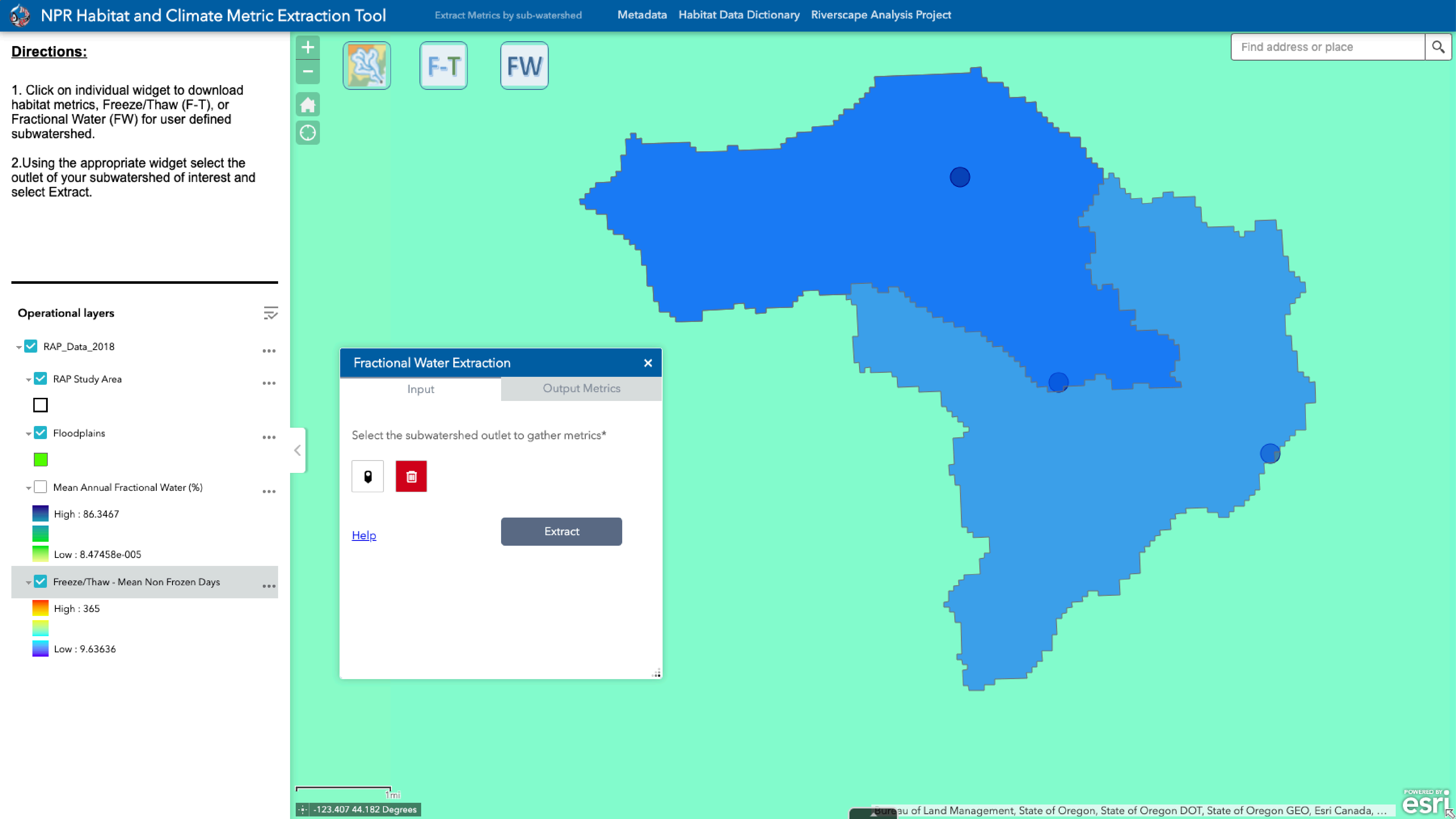

NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
F-T
FW
Find address or place
Extract Sub Watershed Metrics
Input
Output Metrics
Download Data
https://flbs-rap1.flbs.umt.edu/arcgis/rest/directories/arcgisjobs/gps201
Output
The result is drawn on the map.
1mi
-123.338 44.146 Degrees
Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, ...
POWERED BY esri

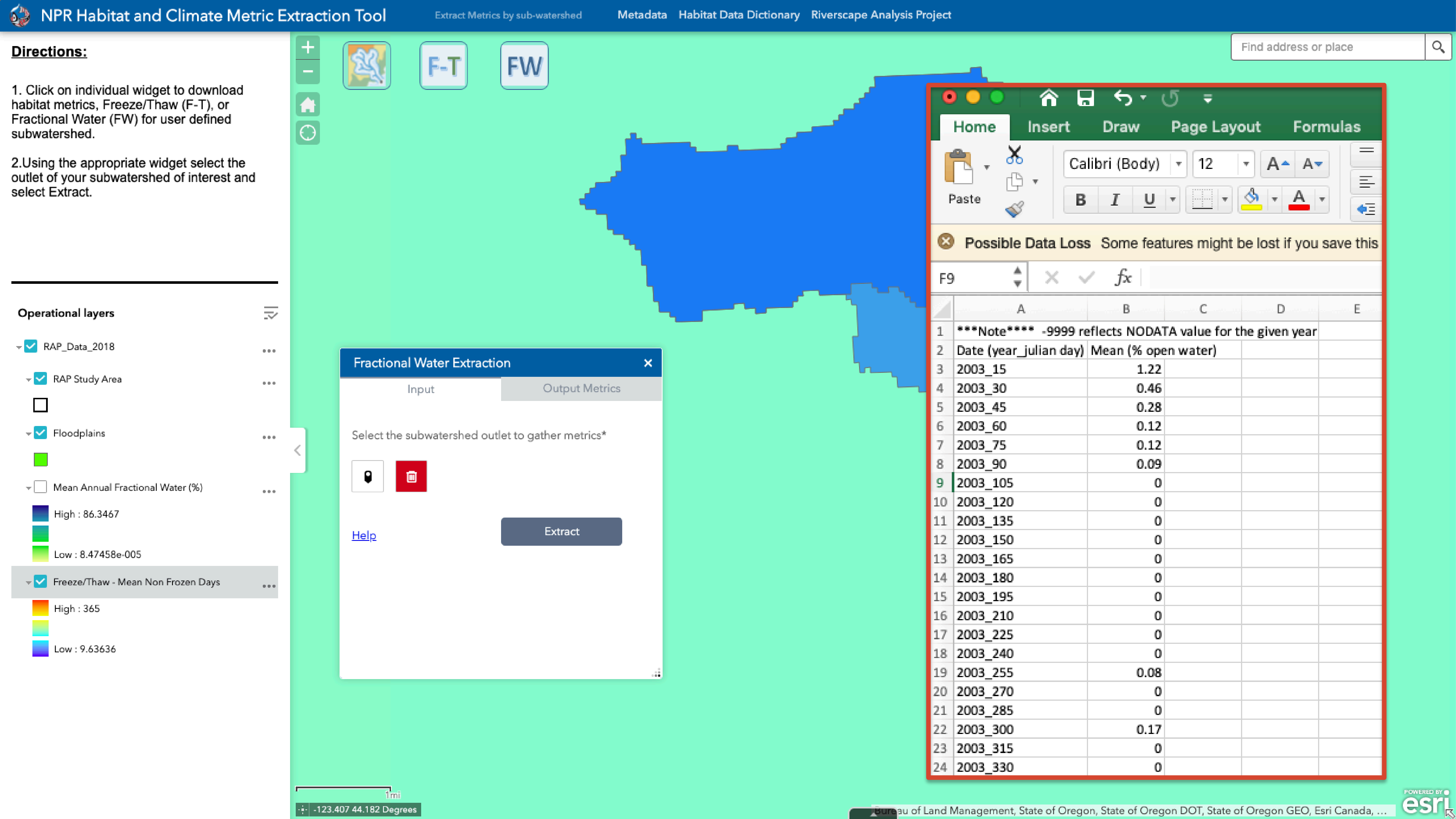

NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Find address or place
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
F-T
FW
Freeze-Thaw Metric Extraction
Input
Output Metrics
Select the subwatershed outlet to gather metrics*
Help
Extract
OBJECTID 1
WS_LAT 44.1952515038
WS_LONG -123.320723146
WS_A 59486400
WS_P 53280
WS_Z_RANGE 454
WS_Z_MEAN 186.806898846
WS_Z_MAX 548
WS_Z_MIN 94
WS_Z_SD 75.8613645371
WS_Z_CV 0.406095090735
WS_PA 0.000895666908739
WS_DL 10837.600641
FP_NUM 0
Zoom to
1mi
-123.377 44.170 Degrees
Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, ...
POWERED BY esri


NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
F-T
FW
Find address or place
Freeze-Thaw Metric Extraction
Input
Output Metrics
Download Data
https://flbs-rap1.flbs.umt.edu/arcgis/rest/directories/arcgisjobs/gps201
output
The result is drawn on the map.
HFP_RANGE 27
HFP_MEAN 26.7356321839
HFP_STD 5.43606468992
NPP_MEAN 882.286362388
GLA_A_SUM 0
GLA_A_MEAN 0
GLA_DENSIT 0
GLA_A_RATI 0
TND_NUM 1
TND_DL_KM 0.0922713461334
DL_L_SUM 10837.600641
DAM_NUM 0
Shapefile Download
Shape_Length 53280
Shape_Area 59486400
Zoom to
0.4mi
-123.430 44.199 Degrees
Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, ...
POWERED BY esri
FTak.csv
subws_out.zip
Show All



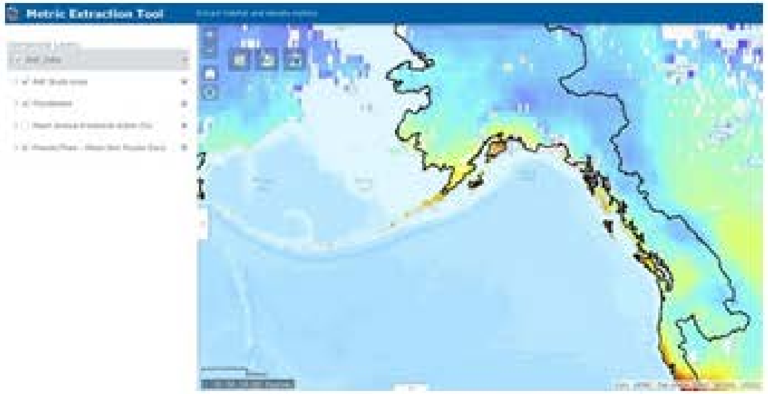
YEAR	Non Frozen Days	Thaw Day
1979	167	111
1980	199	107
1981	181	105
1982	189	139
1983	196	113
1984	167	126
1985	198	91
1986	163	149
1987	217	122
1988	135	162
1989	184	93
1990	194	95
1991	187	139
1992	225	85
1993	202	62
1994	-9999	-9999
1995	204	109
1996	189	141
1997	184	123
1998	176	111
1999	176	135
2000	178	90
2001	185	111
2002	187	119
2003	172	129
2004	186	114
2005	187	109
2006	177	112
2007	180	113
2008	178	126
2009	171	131
2010	179	144
2011	163	150
2012	183	128


NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Find address or place
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
F-T
FW
Fractional Water Extraction
Input
Output Metrics
Select the subwatershed outlet to gather metrics*
Help
Extract
1mi
-123.407 44.182 Degrees
Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, ...
POWERED BY esri

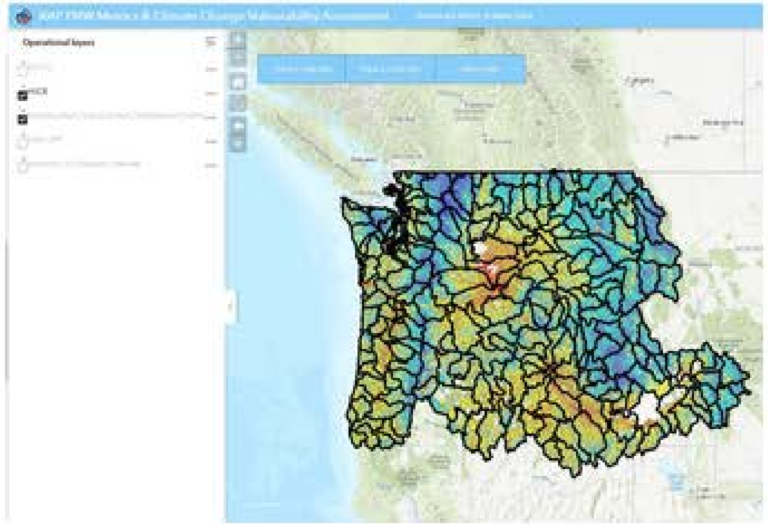

NPR Habitat and Climate Metric Extraction Tool
Extract Metrics by sub-watershed
Metadata
Habitat Data Dictionary
Riverscape Analysis Project
Find address or place
Directions:
1. Click on individual widget to download habitat metrics, Freeze/Thaw (F-T), or Fractional Water (FW) for user defined subwatershed.
2.Using the appropriate widget select the outlet of your subwatershed of interest and select Extract.
Operational layers
RAP_Data_2018
RAP Study Area
Floodplains
Mean Annual Fractional Water (%)
High : 86.3467
Low : 8.47458e-005
Freeze/Thaw - Mean Non Frozen Days
High : 365
Low : 9.63636
F-T
FW
Fractional Water Extraction
Input
Output Metrics
Select the subwatershed outlet to gather metrics*
Help
Extract
Home
Insert
Draw
Page Layout
Formulas
Paste
Calibri (Body)
12
Possible Data Loss Some features might be lost if you save this
F9
Note* -9999 reflects NODATA value for the given year
Date (year_julian day) Mean (% open water)
2003_15 1.22
2003_30 0.46
2003_45 0.28
2003_60 0.12
2003_75 0.12
2003_90 0.09
2003_105 0
2003_120 0
2003_135 0
2003_150 0
2003_165 0
2003_180 0
2003_195 0
2003_210 0
2003_225 0
2003_240 0
2003_255 0.08
2003_270 0
2003_285 0
2003_300 0.17
2003_315 0
2003_330 0
1mi
-123.407 44.182 Degrees
Bureau of Land Management, State of Oregon, State of Oregon DOT, State of Oregon GEO, Esri Canada, ...
esri

Salmon Habitat Tools

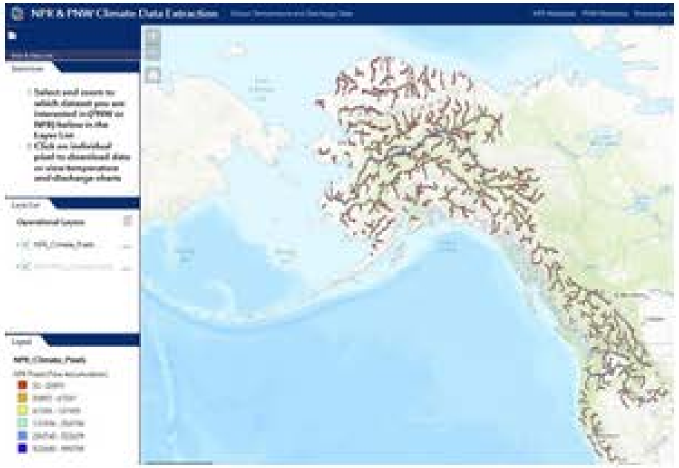
Metric Extraction Tool: Extract habitat and climate data (Freeze/Thaw and Fractional Water)



PNW Climate Change Vulnerability Assessment Tool (HUC 12 scale)



NPR & PNW Climate Extraction Data (Stream Temperature & Flow)



NPR & PNW Climate Data Extraction

Extract Temperature and Discharge Data | NPR Metadata | PNW Metadata | Riverscape Analysis Project

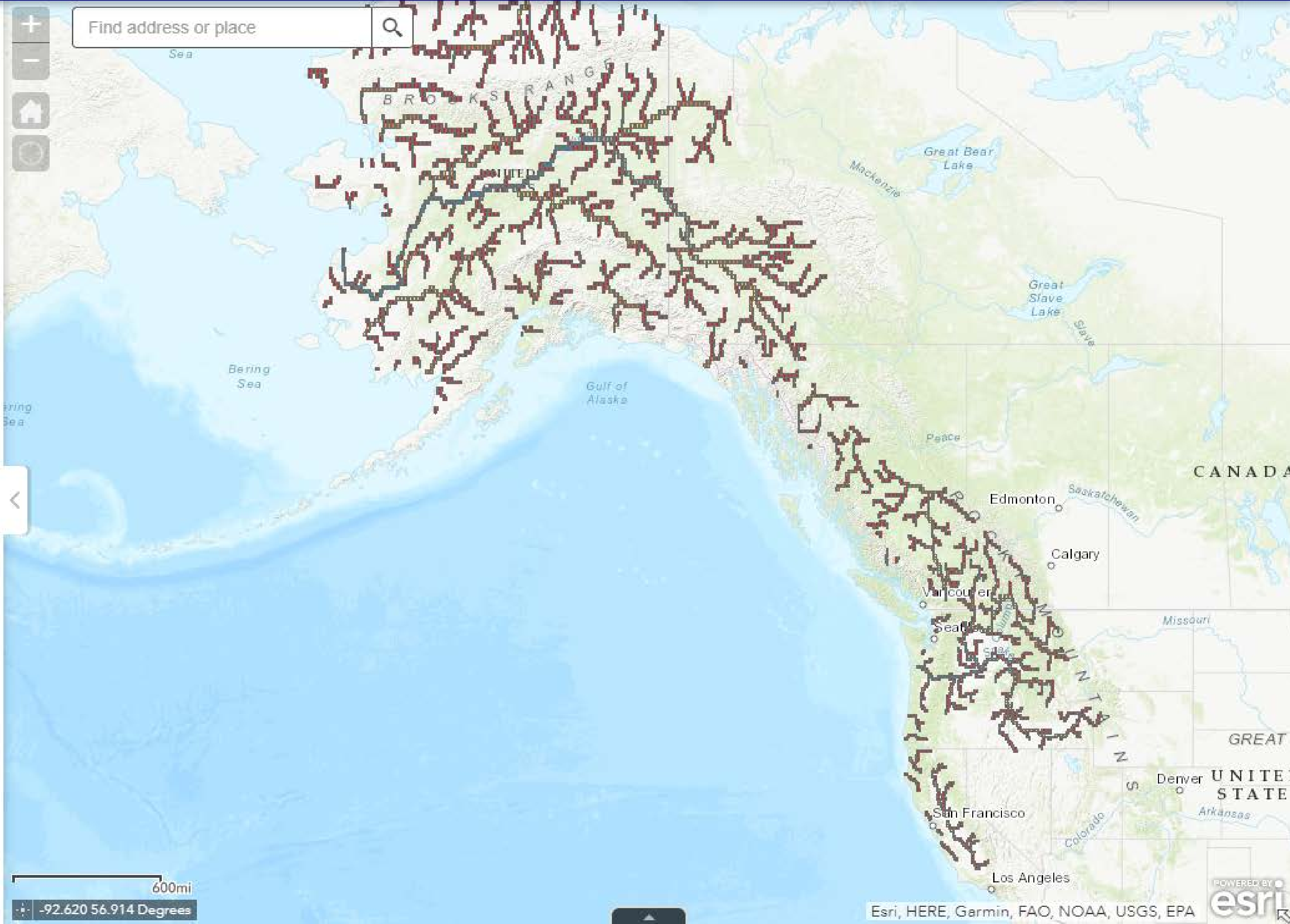
Directions:

1) Zoom to your area of interest and select the dataset (PNW or NPR) you are interested in retrieving data.

2) Click on an individual pixel to download data in a CSV format or to view temperature and discharge charts.

Operational layers

- NPR and PNW Climate Pixels
  - NPR_Pixels (Flow Accumulation)
    - 52 - 20891
    - 20892 - 67267
    - 67268 - 137455
    - 137456 - 254744
    - 254745 - 522679
    - 522680 - 990759
  - PNW_Pixels (Flow Accumulation)
    - 10 - 190
    - 191 - 630
    - 631 - 1490
    - 1491 - 4161
    - 4162 - 19456



NPR & PNW Climate Data Extraction | Extract Temperature and Discharge Data | NPR Metadata | PNW Metadata | Riverscape Analysis Project

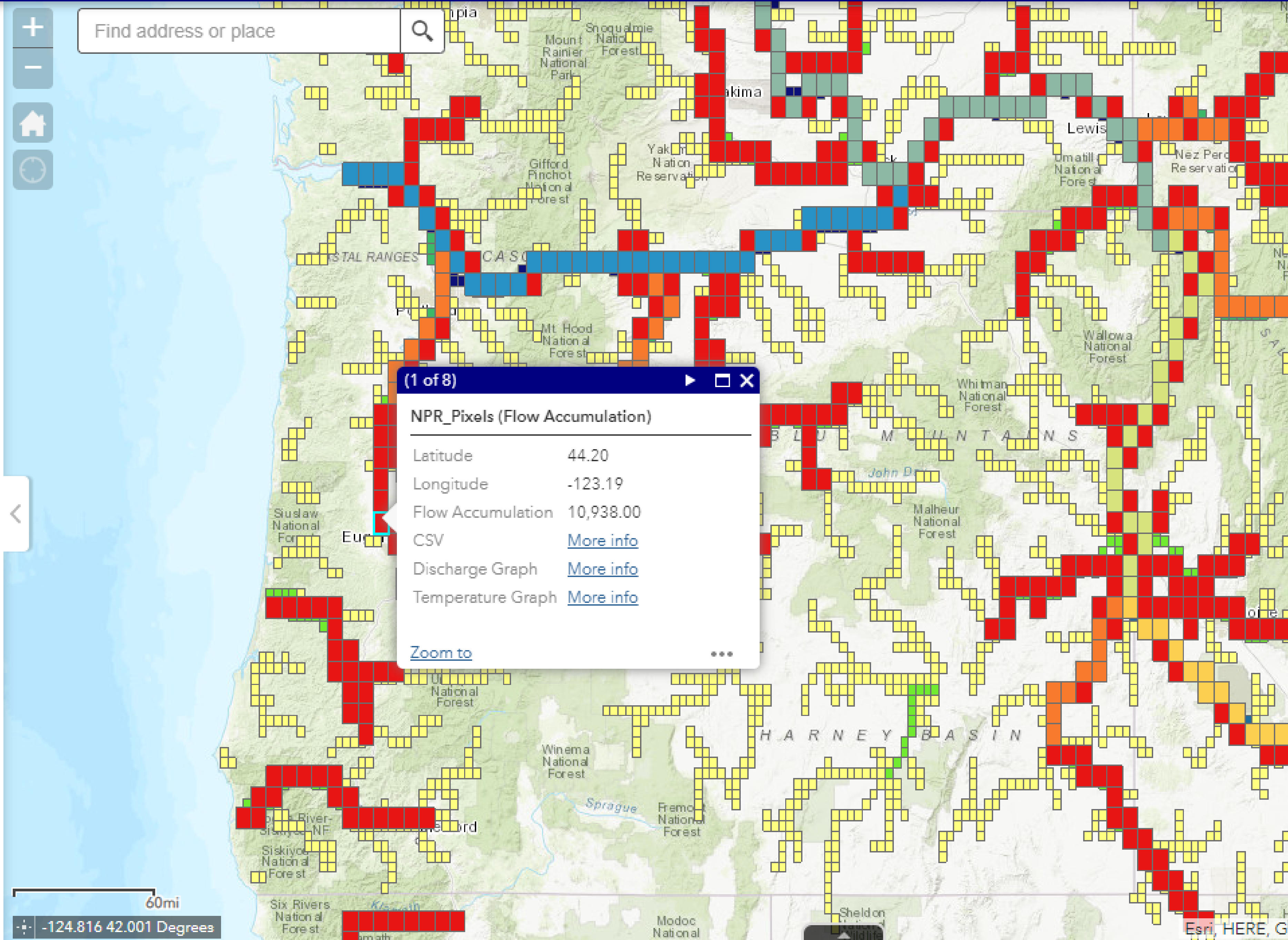
Directions:

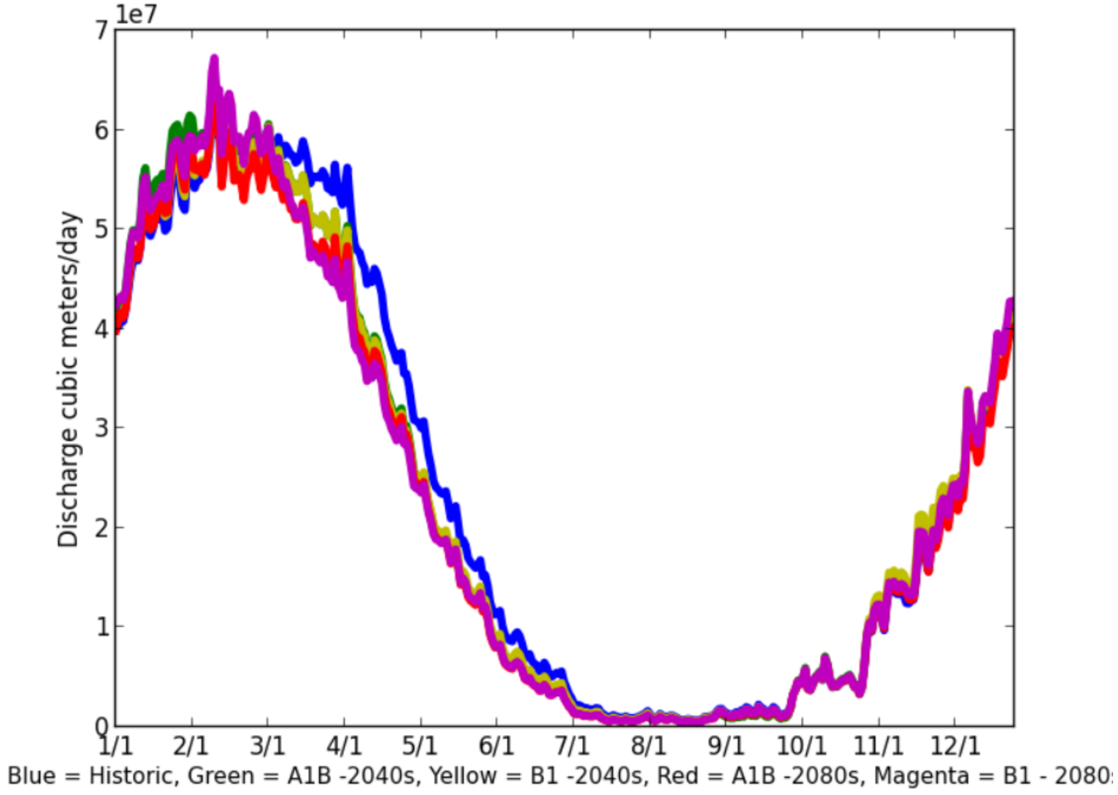
1) Zoom to your area of interest and select the dataset (PNW or NPR) you are interested in retrieving data.

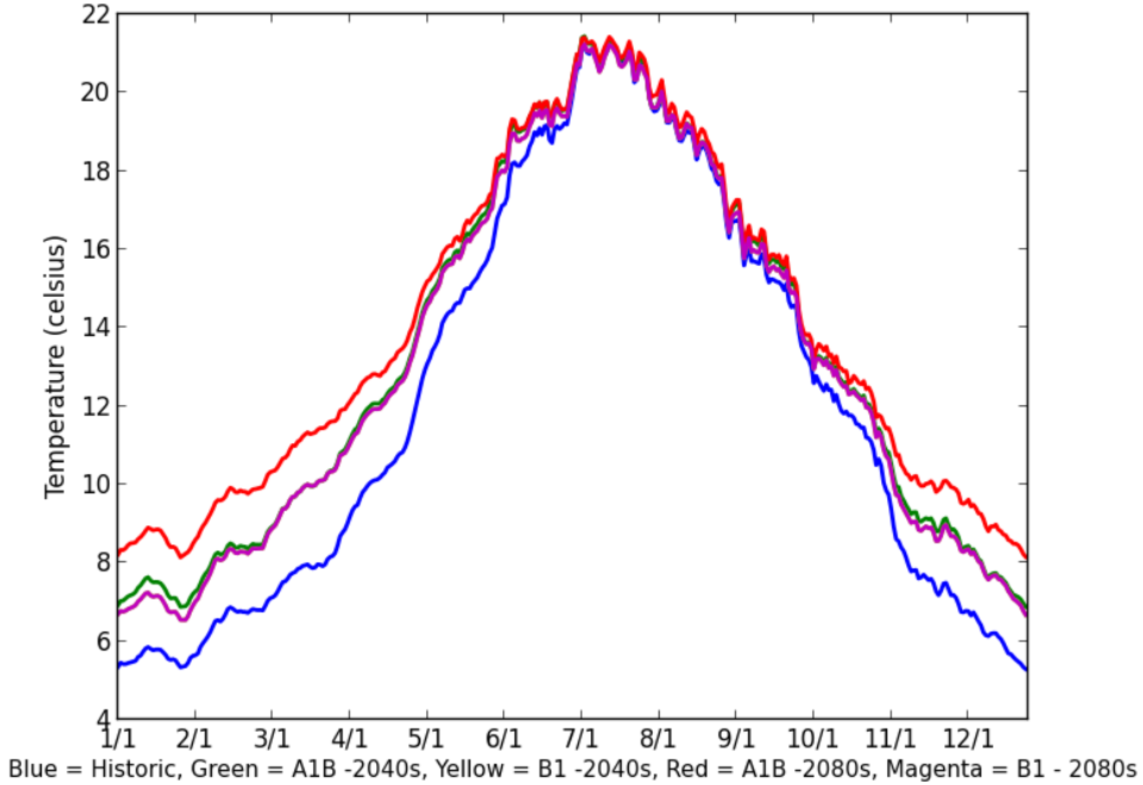
2) Click on an individual pixel to download data in a CSV format or to view temperature and discharge charts.

Operational layers

- NPR and PNW Climate Pixels
  - NPR_Pixels (Flow Accumulation)
    - 52 - 20891
    - 20892 - 67267
    - 67268 - 137455
    - 137456 - 254744
    - 254745 - 522679
    - 522680 - 990759
  - PNW_Pixels (Flow Accumulation)
    - 10 - 190
    - 191 - 630
    - 631 - 1490
    - 1491 - 4161
    - 4162 - 19456

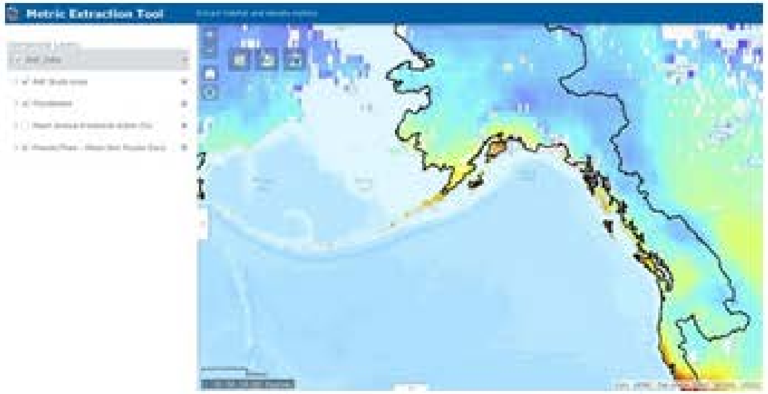



1e7
Discharge cubic meters/day
1/1 2/1 3/1 4/1 5/1 6/1 7/1 8/1 9/1 10/1 11/1 12/1
Blue = Historic, Green = A1B -2040s, Yellow = B1 -2040s, Red = A1B -2080s, Magenta = B1 - 2080s

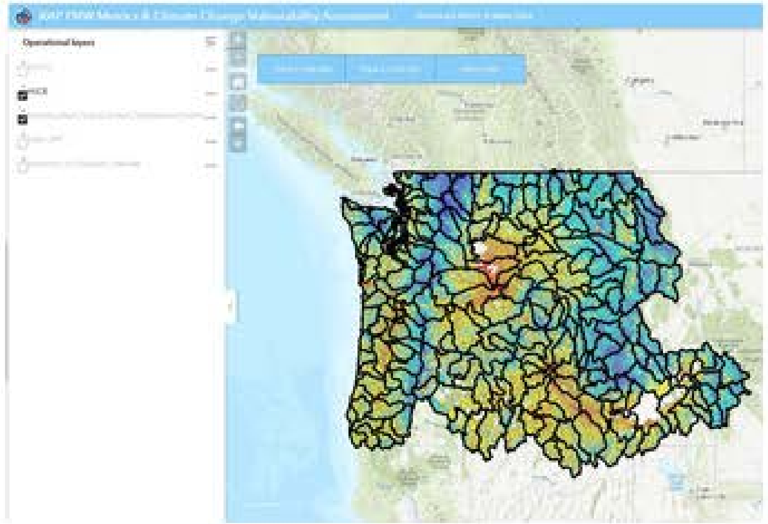

Temperature (celsius)
1/1 2/1 3/1 4/1 5/1 6/1 7/1 8/1 9/1 10/1 11/1 12/1
Blue = Historic, Green = A1B -2040s, Yellow = B1 -2040s, Red = A1B -2080s, Magenta = B1 - 2080s

Salmon Habitat Tools

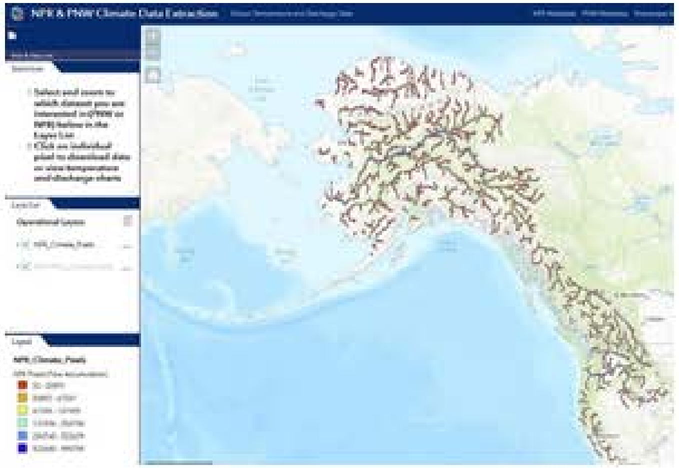
Metric Extraction Tool: Extract habitat and climate data (Freeze/Thaw and Fractional Water)



PNW Climate Change Vulnerability Assessment Tool (HUC 12 scale)



NPR & PNW Climate Extraction Data (Stream Temperature & Flow)



Bull Trout Example

- RAP team tests if patterns of genetic diversity in Bull Trout of the Columbia River Basin were related to climatic variation and habitat features
- Compared allelic richness to:
  - Total stream length
  - Bathymetry
  - Winter flood frequency
  - Maximum summer temperature
- Genetic diversity strongly linked to stream temperatures and winter flooding
  - Increases under climate change scenarios will adversely affect ecological and evolutionary processes for Bull Trout

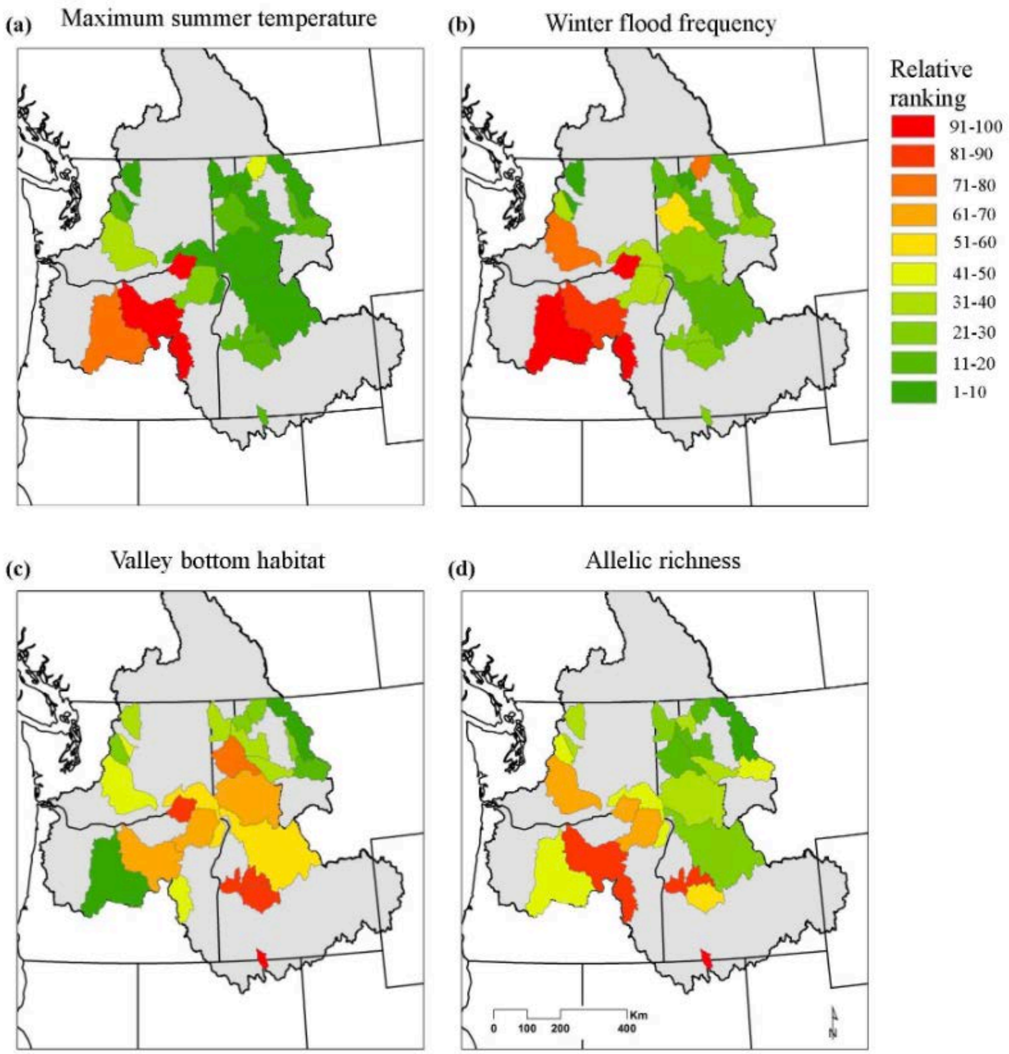
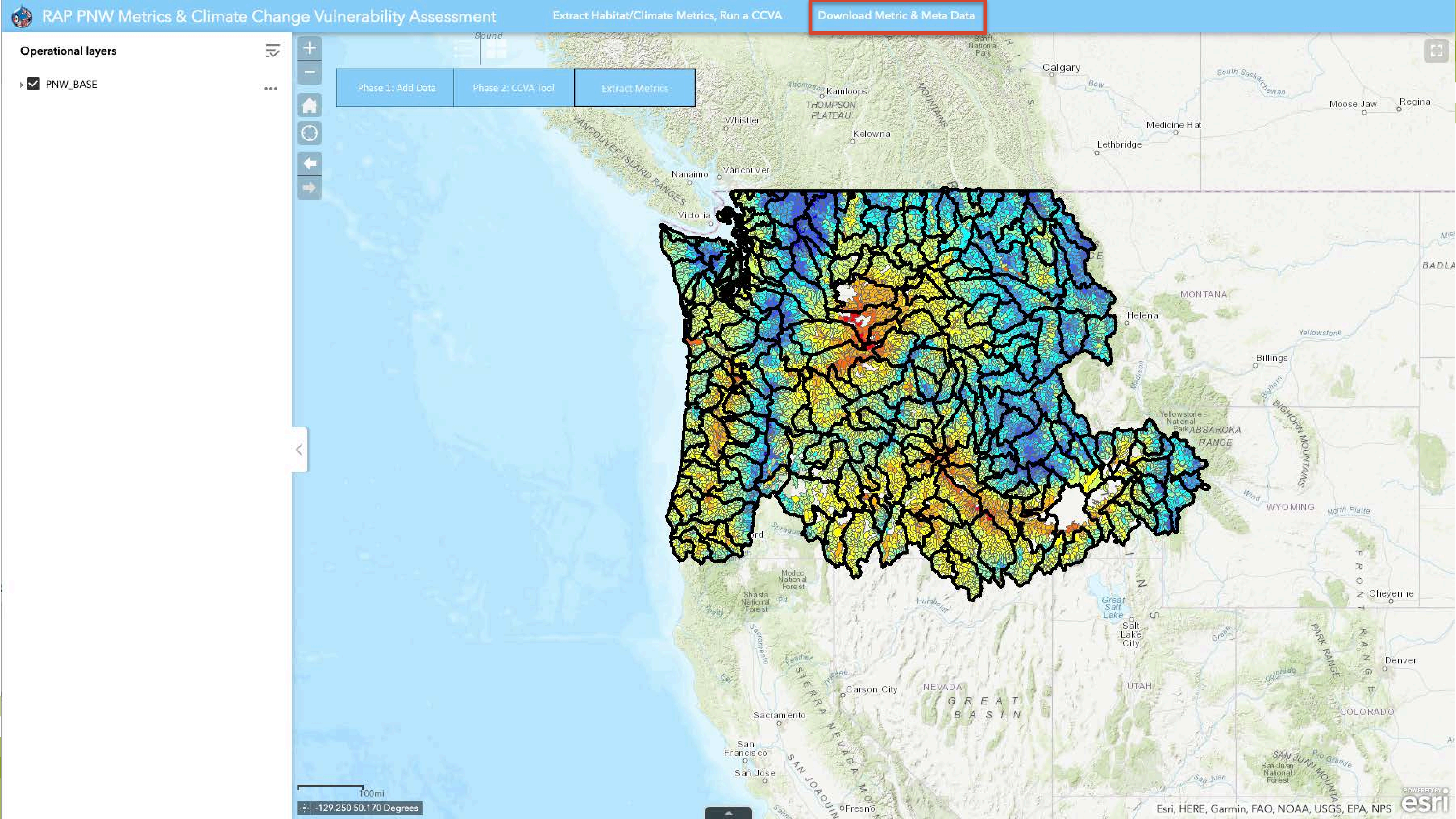
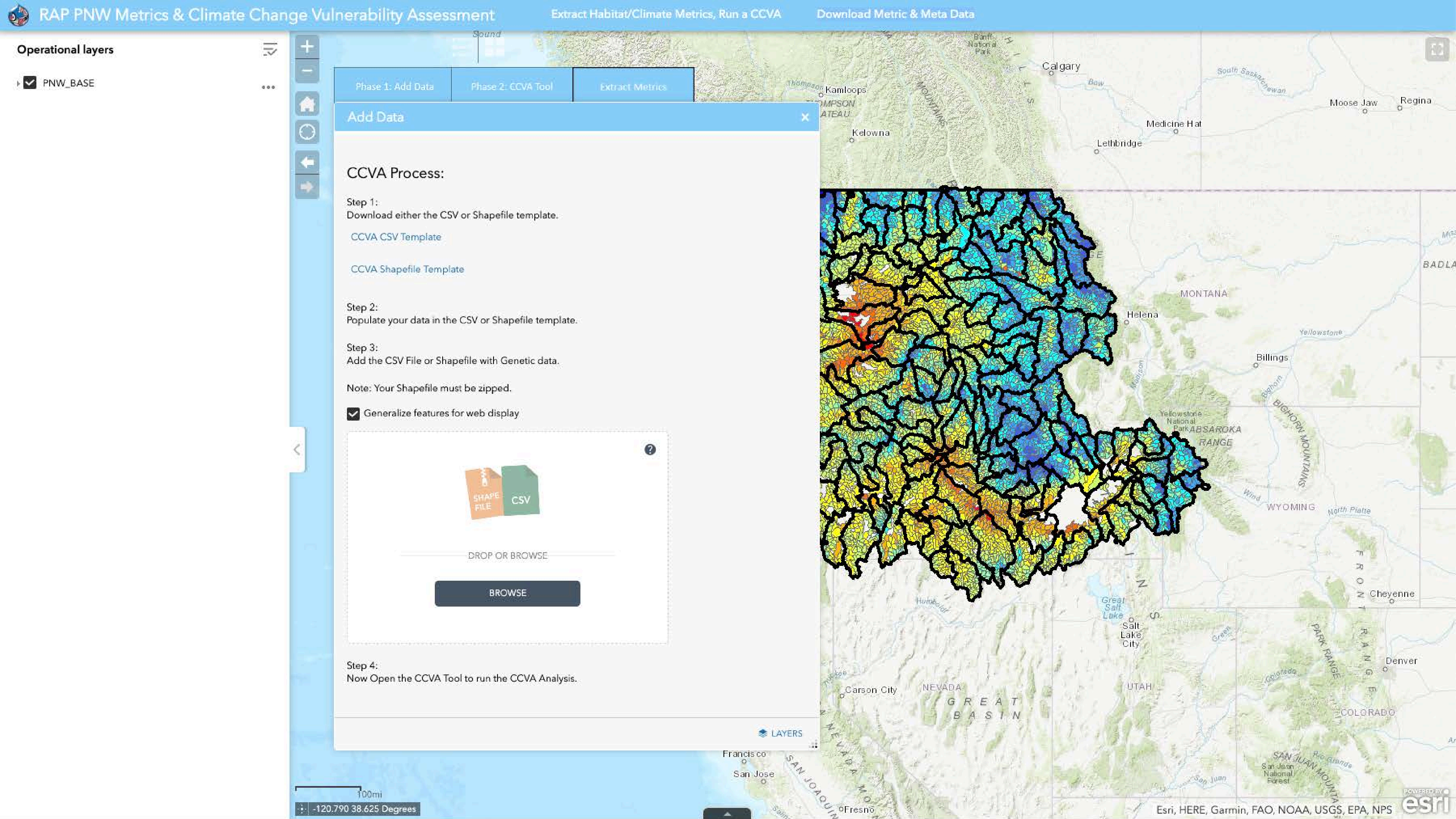
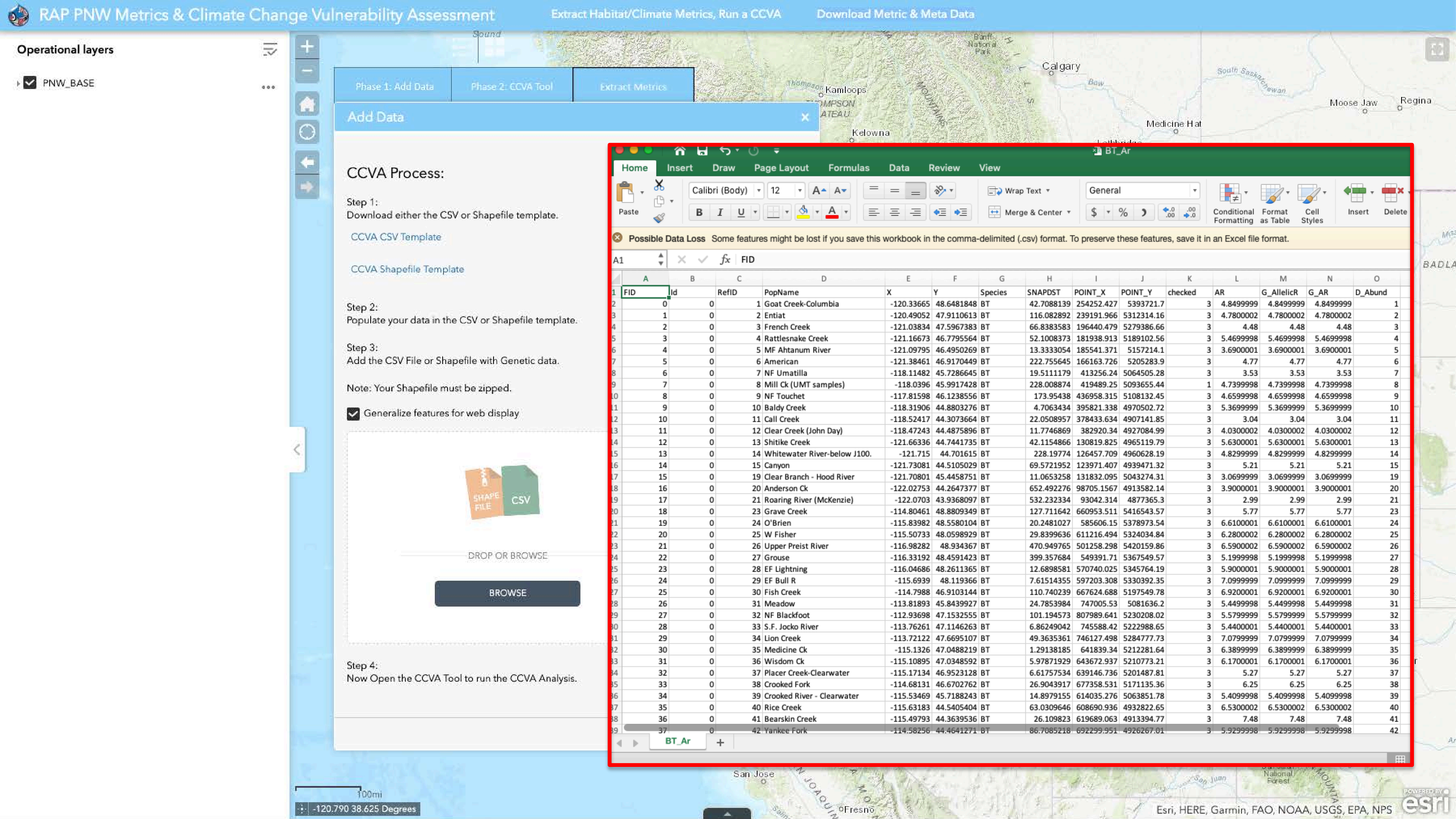


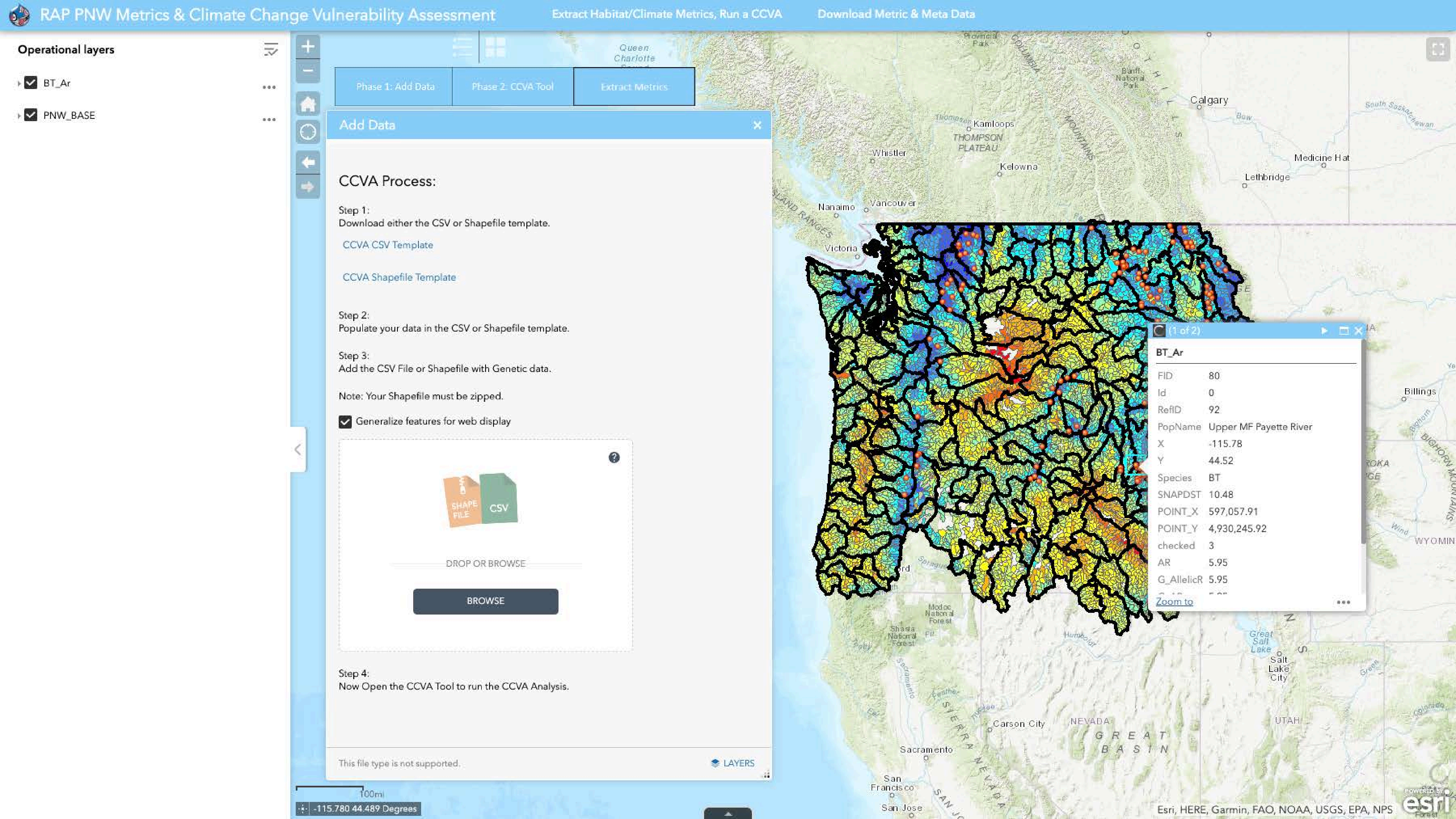
Image Credit: [Kovach et al, 2015]


RAP PNW Metrics & Climate Change Vulnerability Assessment
Extract Habitat/Climate Metrics, Run a CCVA
Download Metric & Meta Data
Operational layers
PNW_BASE
Phase 1: Add Data
Phase 2: CCVA Tool
Extract Metrics
Calgary
Kamloops
THOMPSON PLATEAU
Whistler
Kelowna
Medicine Hat
Lethbridge
Moose Jaw
Regina
Nanaimo
Vancouver
Victoria
VANCOUVER ISLAND RANGES
MONTANA
Helena
Billings
WYOMING
Cheyenne
Great Salt Lake
Salt Lake City
UTAH
Denver
COLORADO
NEVADA
GREAT BASIN
Carson City
Sacramento
San Francisco
San Jose
Fresno
100mi
-129.250 50.170 Degrees
Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS


RAP PNW Metrics & Climate Change Vulnerability Assessment
Extract Habitat/Climate Metrics, Run a CCVA
Download Metric & Meta Data
Operational layers
PNW_BASE
Phase 1: Add Data
Phase 2: CCVA Tool
Extract Metrics
Add Data
CCVA Process:
Step 1:
Download either the CSV or Shapefile template.
CCVA CSV Template
CCVA Shapefile Template
Step 2:
Populate your data in the CSV or Shapefile template.
Step 3:
Add the CSV File or Shapefile with Genetic data.
Note: Your Shapefile must be zipped.
Generalize features for web display
SHAPE FILE
CSV
DROP OR BROWSE
BROWSE
Step 4:
Now Open the CCVA Tool to run the CCVA Analysis.
LAYERS
Calgary
Kamloops
Kelowna
Medicine Hat
Lethbridge
Moose Jaw
Regina
MONTANA
Helena
Billings
WYOMING
Cheyenne
Salt Lake City
Denver
UTAH
COLORADO
NEVADA
GREAT BASIN
Carson City
San Jose
Fresno
100mi
-120.790 38.625 Degrees
Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS



FID	Id	RefID	PopName	X	Y	Species	SNAPDST	POINT_X	POINT_Y	checked	AR	G_AllelicR	G_AR	D_Abund
0	0	1	Goat Creek-Columbia	-120.33665	48.6481848	BT	42.7088139	254252.427	5393721.7	3	4.8499999	4.8499999	4.8499999	1
1	0	2	Entiat	-120.49052	47.9110613	BT	116.082892	239191.966	5312314.16	3	4.7800002	4.7800002	4.7800002	2
2	0	3	French Creek	-121.03834	47.5967383	BT	66.8383583	196440.479	5279386.66	3	4.48	4.48	4.48	3
3	0	4	Rattlesnake Creek	-121.16673	46.7795564	BT	52.1008373	181938.913	5189102.56	3	5.4699998	5.4699998	5.4699998	4
4	0	5	MF Ahtanum River	-121.09795	46.4950269	BT	13.3333054	185541.371	5157214.1	3	3.6900001	3.6900001	3.6900001	5
5	0	6	American	-121.38461	46.9170449	BT	222.755645	166163.726	5205283.9	3	4.77	4.77	4.77	6
6	0	7	NF Umatilla	-118.11482	45.7286645	BT	19.5111179	413256.24	5064505.28	3	3.53	3.53	3.53	7
7	0	8	Mill Ck (UMT samples)	-118.0396	45.9917428	BT	228.008874	419489.25	5093655.44	1	4.7399998	4.7399998	4.7399998	8
8	0	9	NF Touchet	-117.81598	46.1238556	BT	173.95438	436958.315	5108132.45	3	4.6599998	4.6599998	4.6599998	9
9	0	10	Baldy Creek	-118.31906	44.8803276	BT	4.7063434	395821.338	4970502.72	3	5.3699999	5.3699999	5.3699999	10
10	0	11	Call Creek	-118.52417	44.3073664	BT	22.0508957	378433.634	4907141.85	3	3.04	3.04	3.04	11
11	0	12	Clear Creek (John Day)	-118.47243	44.4875896	BT	11.7746869	382920.34	4927084.99	3	4.0300002	4.0300002	4.0300002	12
12	0	13	Shitike Creek	-121.66336	44.7441735	BT	42.1154866	130819.825	4965119.79	3	5.6300001	5.6300001	5.6300001	13
13	0	14	Whitewater River-below J100.	-121.715	44.701615	BT	228.19774	126457.709	4960628.19	3	4.8299999	4.8299999	4.8299999	14
14	0	15	Canyon	-121.73081	44.5105029	BT	69.5721952	123971.407	4939471.32	3	5.21	5.21	5.21	15
15	0	19	Clear Branch - Hood River	-121.70801	45.4458751	BT	11.0653258	131832.095	5043274.31	3	3.0699999	3.0699999	3.0699999	19
16	0	20	Anderson Ck	-122.02753	44.2647377	BT	652.492276	98705.1567	4913582.14	3	3.9000001	3.9000001	3.9000001	20
17	0	21	Roaring River (McKenzie)	-122.0703	43.9368097	BT	532.232334	93042.314	4877365.3	3	2.99	2.99	2.99	21
18	0	23	Grave Creek	-114.80461	48.8809349	BT	127.711642	660953.511	5416543.57	3	5.77	5.77	5.77	23
19	0	24	O'Brien	-115.83982	48.5580104	BT	20.2481027	585606.15	5378973.54	3	6.6100001	6.6100001	6.6100001	24
20	0	25	W Fisher	-115.50733	48.0598929	BT	29.8399636	611216.494	5324034.84	3	6.2800002	6.2800002	6.2800002	25
21	0	26	Upper Preist River	-116.98282	48.934367	BT	470.949765	501258.298	5420159.86	3	6.5900002	6.5900002	6.5900002	26
22	0	27	Grouse	-116.33192	48.4591423	BT	399.357684	549391.71	5367549.57	3	5.1999998	5.1999998	5.1999998	27
23	0	28	EF Lightning	-116.04686	48.2611365	BT	12.6898581	570740.025	5345764.19	3	5.9000001	5.9000001	5.9000001	28
24	0	29	EF Bull R	-115.6939	48.119366	BT	7.61514355	597203.308	5330392.35	3	7.0999999	7.0999999	7.0999999	29
25	0	30	Fish Creek	-114.7988	46.9103144	BT	110.740239	667624.688	5197549.78	3	6.9200001	6.9200001	6.9200001	30
26	0	31	Meadow	-113.81893	45.8439927	BT	24.7853984	747005.53	5081636.2	3	5.4499998	5.4499998	5.4499998	31
27	0	32	NF Blackfoot	-112.93698	47.1532555	BT	101.194573	807989.641	5230208.02	3	5.5799999	5.5799999	5.5799999	32
28	0	33	S.F. Jocko River	-113.76261	47.1146263	BT	6.86249042	745588.42	5222988.65	3	5.4400001	5.4400001	5.4400001	33
29	0	34	Lion Creek	-113.72122	47.6695107	BT	49.3635361	746127.498	5284777.73	3	7.0799999	7.0799999	7.0799999	34
30	0	35	Medicine Ck	-115.1326	47.0488219	BT	1.29138185	641839.34	5212281.64	3	6.3899999	6.3899999	6.3899999	35
31	0	36	Wisdom Ck	-115.10895	47.0348592	BT	5.97871929	643672.937	5210773.21	3	6.1700001	6.1700001	6.1700001	36
32	0	37	Placer Creek-Clearwater	-115.17134	46.9523128	BT	6.61757534	639146.736	5201487.81	3	5.27	5.27	5.27	37
33	0	38	Crooked Fork	-114.68131	46.6702762	BT	26.9043917	677358.531	5171135.36	3	6.25	6.25	6.25	38
34	0	39	Crooked River - Clearwater	-115.53469	45.7188243	BT	14.8979155	614035.276	5063851.78	3	5.4099998	5.4099998	5.4099998	39
35	0	40	Rice Creek	-115.63183	44.5405404	BT	63.0309646	608690.936	4932822.65	3	6.5300002	6.5300002	6.5300002	40
36	0	41	Bearskin Creek	-115.49793	44.3639536	BT	26.109823	619689.063	4913394.77	3	7.48	7.48	7.48	41
37	0	42	Yankee Fork	-114.58256	44.4641271	BT	86.7085218	692299.951	4926267.01	3	5.9299998	5.9299998	5.9299998	42


RAP PNW Metrics & Climate Change Vulnerability Assessment
Extract Habitat/Climate Metrics, Run a CCVA
Download Metric & Meta Data
Operational layers
BT_Ar
PNW_BASE
Phase 1: Add Data
Phase 2: CCVA Tool
Extract Metrics
Add Data
CCVA Process:
Step 1:
Download either the CSV or Shapefile template.
CCVA CSV Template
CCVA Shapefile Template
Step 2:
Populate your data in the CSV or Shapefile template.
Step 3:
Add the CSV File or Shapefile with Genetic data.
Note: Your Shapefile must be zipped.
Generalize features for web display
SHAPE FILE
CSV
DROP OR BROWSE
BROWSE
Step 4:
Now Open the CCVA Tool to run the CCVA Analysis.
This file type is not supported.
LAYERS
(1 of 2)
BT_Ar
FID 80
Id 0
RefID 92
PopName Upper MF Payette River
X -115.78
Y 44.52
Species BT
SNAPDST 10.48
POINT_X 597,057.91
POINT_Y 4,930,245.92
checked 3
AR 5.95
G_AllelicR 5.95
Zoom to
100mi
-115.780 44.489 Degrees
Calgary
Kamloops
Kelowna
Vancouver
Victoria
Nanaimo
Whistler
Medicine Hat
Lethbridge
Billings
Carson City
Sacramento
San Francisco
San Jose
Salt Lake City
NEVADA
UTAH
G R E A T
B A S I N
Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS

Operational layers

- BT_Ar
- PNW_BASE

Phase 1: Add Data | Phase 2: CCVA Tool | Extract Metrics

CCVA BT

CCVA Input Module | Results

About:

The CCVA is a Climate Change Vulnerability Assessment. A CCVA takes into account 3 major components of vulnerability: exposure, sensitivity and adaptive capacity. Its output is a relative ranking of environmental and climatic variables (to represent exposure) coupled with user defined variables (genetic and/or demograhic variables to represent sensitivity and adaptive capacity). The base framework is based off of Wade et al 2017 "Accounting for adaptive capacity and uncertainty in assessments of species' climate-change vulnerability"

Genetic Map Layer*

BT_Ar

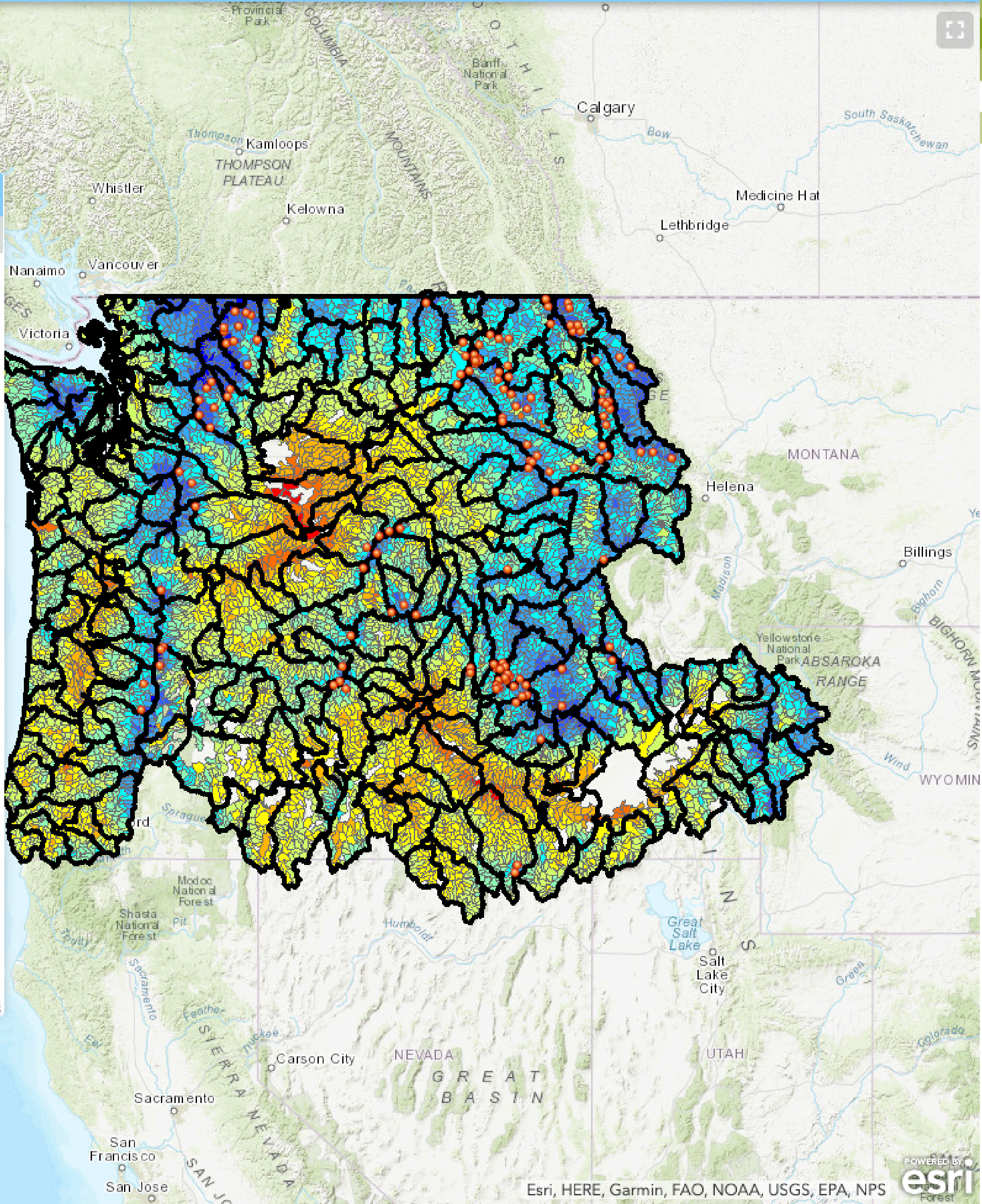
Habitat Variables*

- [x] 'River Density'
- [x] 'Proportion Floodplain'
- [x] 'Mean NPP for Riparian area'
- [x] 'Dam Density'
- [x] 'Proportion Natural Cover in HUC'
- [x] 'Mean Slope'

Future Climate Variables

- [x] 'Norwest 2040s Stream Temperature'
- [x] 'Winter Flow 2040s 95% threshold'

Run CCVA



100mi
-125.888 41.335 Degrees

Esri, HERE, Garmin, FAO, NOAA, USGS, EPA, NPS

RAP PNW Metrics & Climate Change Vulnerability Assessment | Extract Habitat/Climate Metrics, Run a CCVA | Download Metric & Meta Data

Operational layers

- BT_Ar
- Relative Basin CCVA Ranking (Rankings are available in the Legend)
  - output
    - 0.0 - 10.0
    - 10.0 - 20.0
    - 20.0 - 30.0
    - 30.0 - 40.0
    - 40.0 - 50.0
    - 50.0 - 60.0
    - 60.0 - 70.0
    - 70.0 - 80.0
    - 80.0 - 90.0
    - 90.0 - 100.0
- PNW_BASE
  - HUC8
  - HUC 12
  - Norwest August Mean Temperature Celsius (Historic 1993 - 2011) per HUC12
  - Proportion Floodplain Habitat per HUC12
  - Mean Riparian NPP per HUC12

Phase 1: Add Data | Phase 2: CCVA Tool | Extract Metrics

CCVA BT

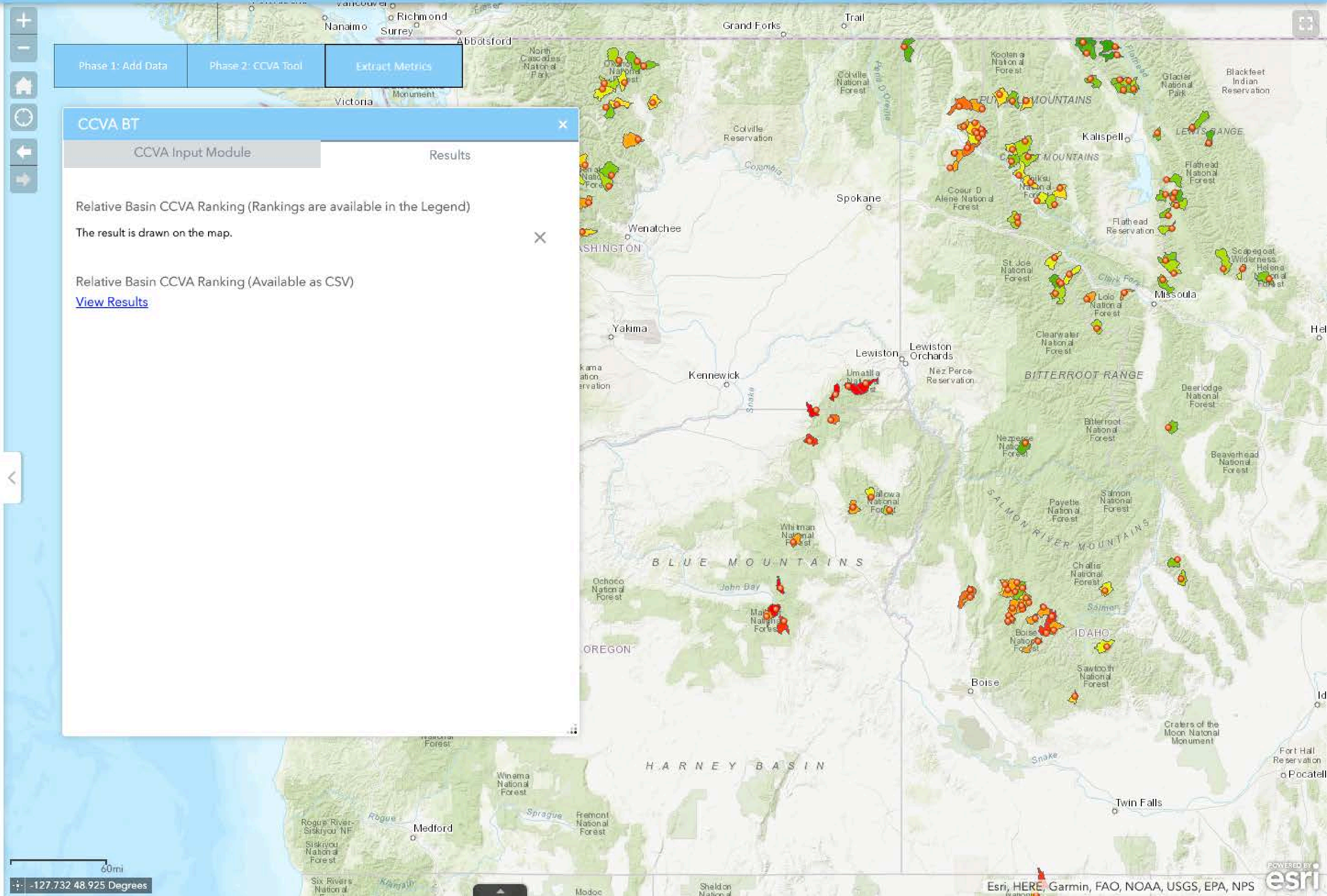
CCVA Input Module | Results

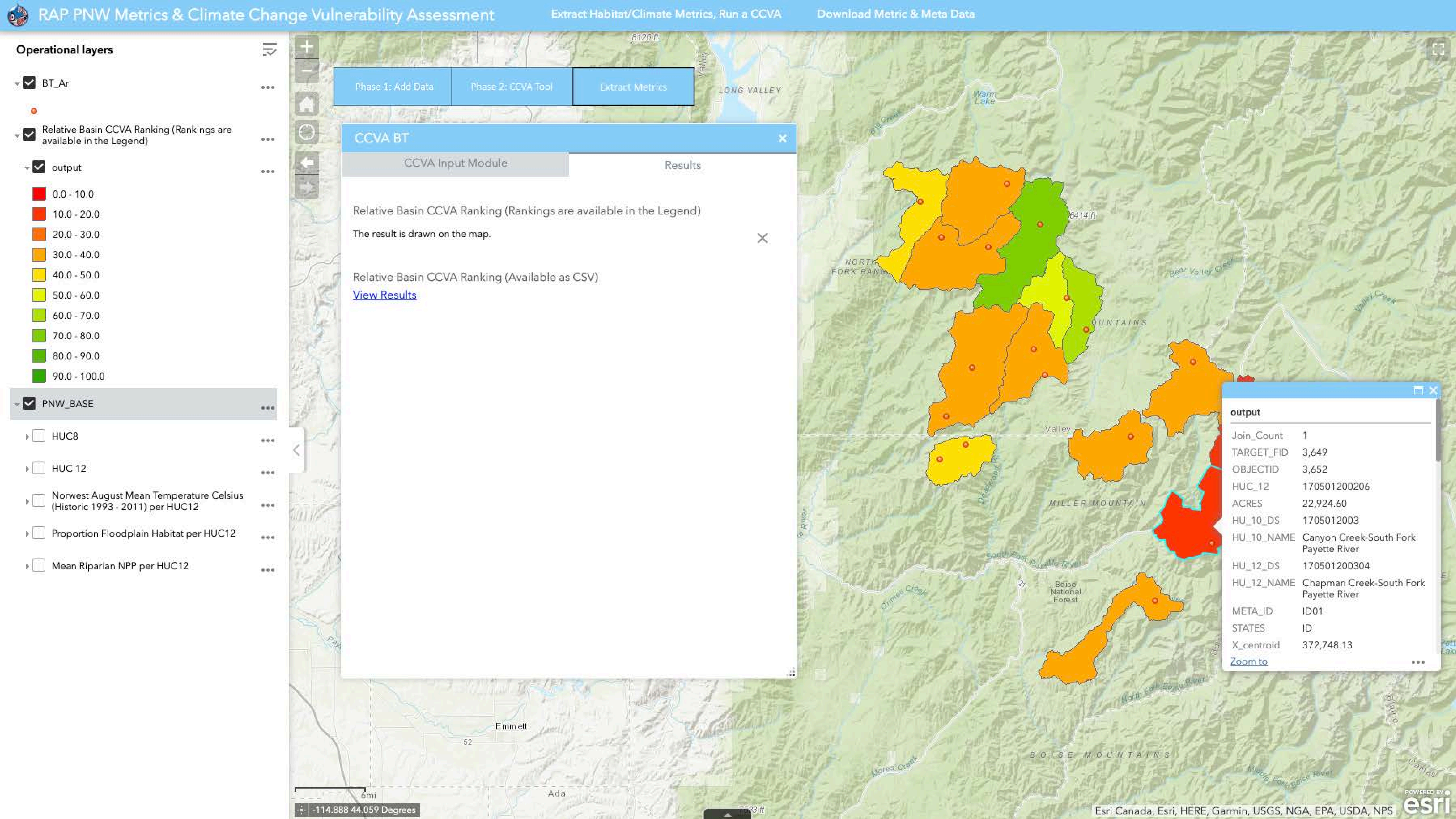
Relative Basin CCVA Ranking (Rankings are available in the Legend)

The result is drawn on the map.

Relative Basin CCVA Ranking (Available as CSV)

View Results





RAP PNW Metrics & Climate Change Vulnerability Assessment
Extract Habitat/Climate Metrics, Run a CCVA
Download Metric & Meta Data
Operational layers
BT_Ar
Relative Basin CCVA Ranking (Rankings are available in the Legend)
output
0.0 - 10.0
10.0 - 20.0
20.0 - 30.0
30.0 - 40.0
40.0 - 50.0
50.0 - 60.0
60.0 - 70.0
70.0 - 80.0
80.0 - 90.0
90.0 - 100.0
PNW_BASE
HUC8
HUC 12
Norwest August Mean Temperature Celsius (Historic 1993 - 2011) per HUC12
Proportion Floodplain Habitat per HUC12
Mean Riparian NPP per HUC12
Phase 1: Add Data
Phase 2: CCVA Tool
Extract Metrics
CCVA BT
CCVA Input Module
Results
Relative Basin CCVA Ranking (Rankings are available in the Legend)
The result is drawn on the map.
Relative Basin CCVA Ranking (Available as CSV)
View Results
output
Join_Count 1
TARGET_FID 3,649
OBJECTID 3,652
HUC_12 170501200206
ACRES 22,924.60
HU_10_DS 1705012003
HU_10_NAME Canyon Creek-South Fork Payette River
HU_12_DS 170501200304
HU_12_NAME Chapman Creek-South Fork Payette River
META_ID ID01
STATES ID
X_centroid 372,748.13
Zoom to
LONG VALLEY
Warm Lake
NORTH FORK RANGE
MILLER MOUNTAIN
Boise National Forest
BOISE MOUNTAINS
Emmett
Ada
6mi
-114.888 44.059 Degrees
Esri Canada, Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS
esri

Summary

- Landscape genetics can be a powerful tool to study freshwater species and their vulnerability to changing conditions
  - eDNA can be used for elusive and/or sensitive species to estimate abundance and understand genetic diversity
- Remote sensing, GIS, and modeling technology is key in multi-step vulnerability assessments
- The Riverscape Analysis project provides information, opportunities for citizen science, and multiple online tools for acquiring and analyzing freshwater habitats in the Pacific Northwestern region of the U.S.

Contacts

- ARSET Land Management & Wildfire Contacts
  – Amber McCullum: AmberJean.Mccullum@nasa.gov
  – Juan Torres-Perez: juan.l.torresperez@nasa.gov
- General ARSET Inquiries
  – Ana Prados: aprados@umbc.edu
- ARSET Website:
  – http://arset.gsfc.nasa.gov

National Aeronautics and Space Administration

Next Session: Freshwater Health Index (FHI)

Amber McCullum & Juan Torres-Pérez

1 October, 2019

Thank You!

References

1. Thomsen and Willerslev, 2014
2. Schwartz et al. 2009
3. McRae et al., 2008
4. Manel et al., 2003
5. Angers et al., 2002
6. Hunter et al., 2015