Using Geospatial Indicators of Watershed Condition to Support Freshwater Conservation Actions

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National Training Workshop on Water Quality Data, Assessment, and Plans
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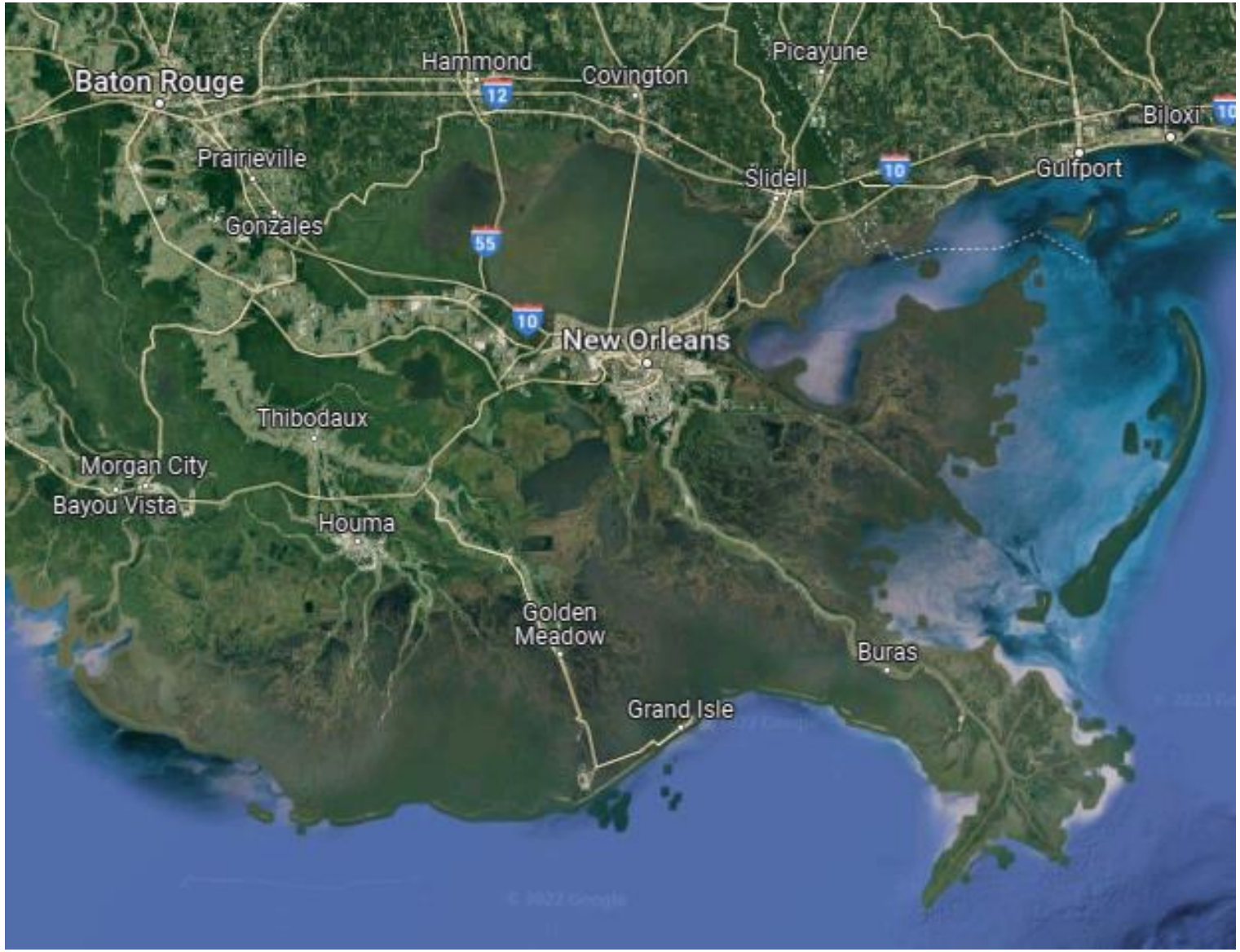
Outline –

- Ryan Hill
  - Overview of geospatial data (StreamCat), Indices of watershed and catchment integrity
- Luisa Riato
  - Application of IWI/ICI and StreamCat datasets in stream conservation
- Marc Weber
  - Accessing and using the StreamCat Data

Understanding rivers

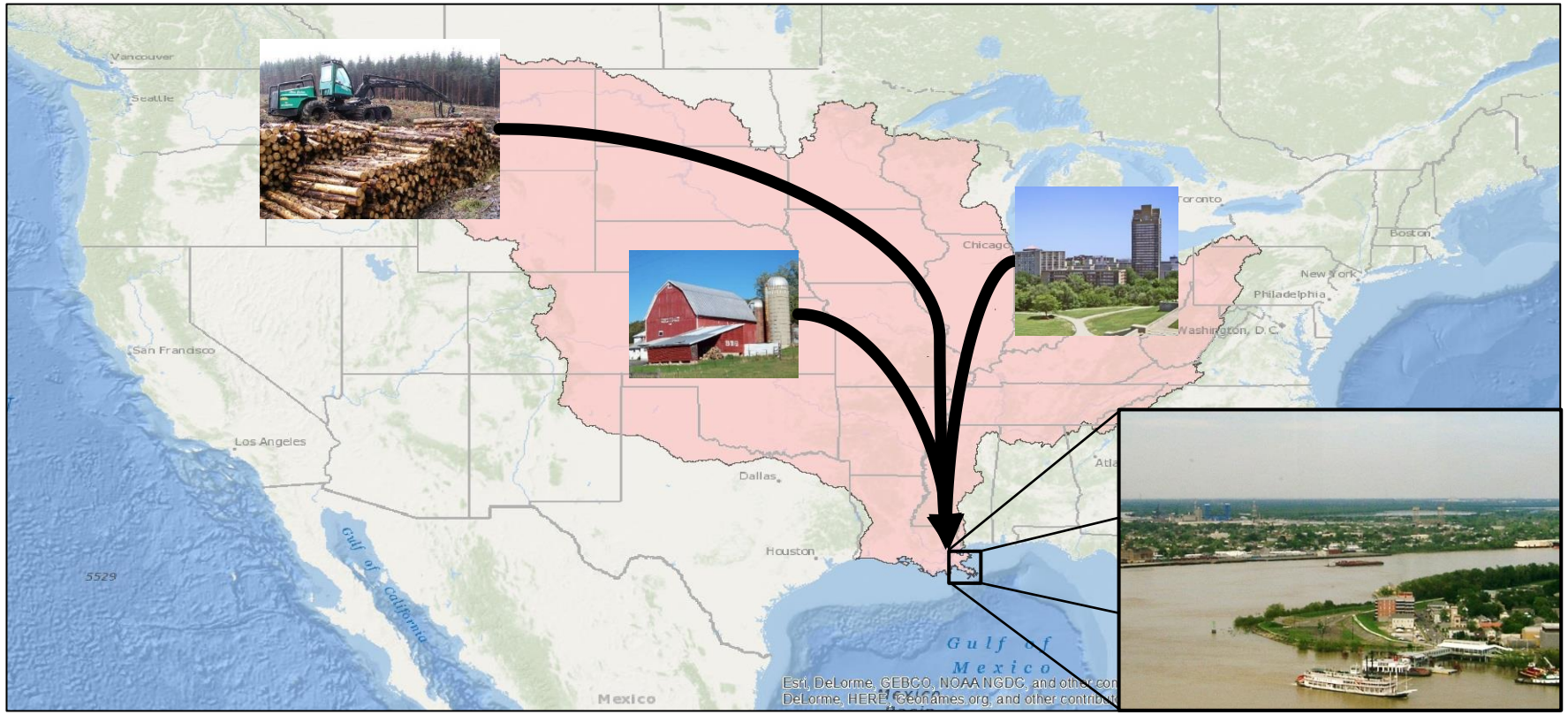
Understanding a river requires more than knowing what is nearby

Agriculture composes 0.2% of land area near outlet of Mississippi



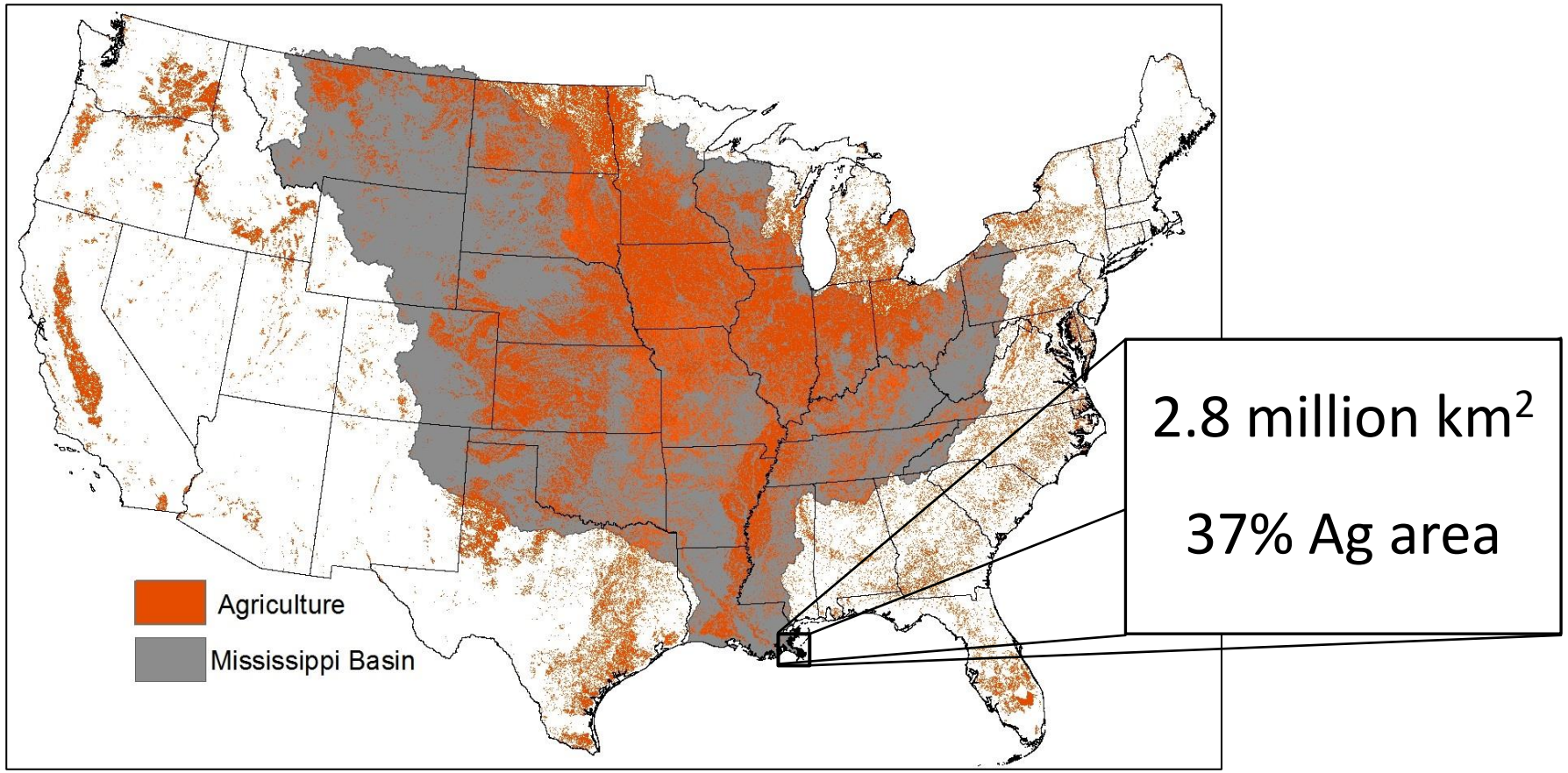
Understanding rivers

Rivers integrate upstream features



Understanding rivers

Understanding a river means understanding the watershed

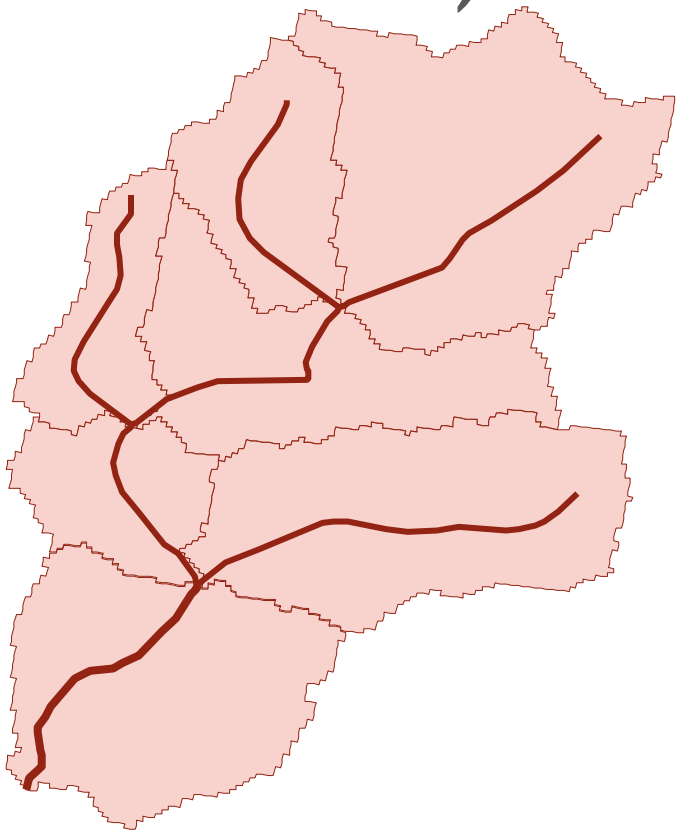


Overview of Data

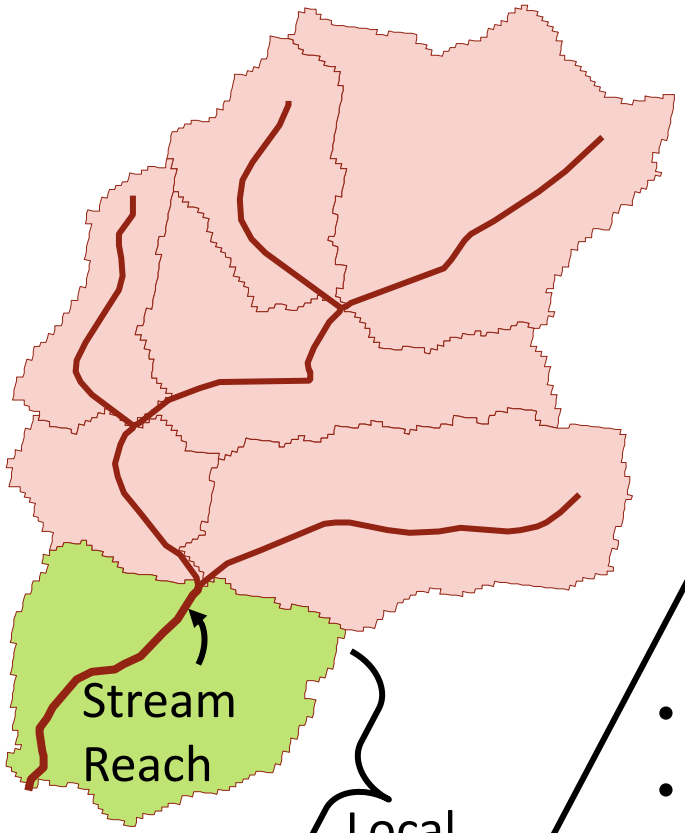
NHDPlusV2	StreamCat	ICI/IWI
Existing geospatial framework	Suite of watershed metrics we calculated with the NHDPlusV2	Family of indicators built from StreamCat data

Overview of Data – NHDPlus (version 2)

- NHD – Line network of streams
- 2 resolutions (24k versus 100K)
- Combined with digital elevation data to make value added product – NHDPlus (version 2)
- NHDPlusV2 available at 100K resolution
- Available for download by hydrologic region (e.g., Columbia River Basin)



Overview of Data – NHDPlus (version 2)

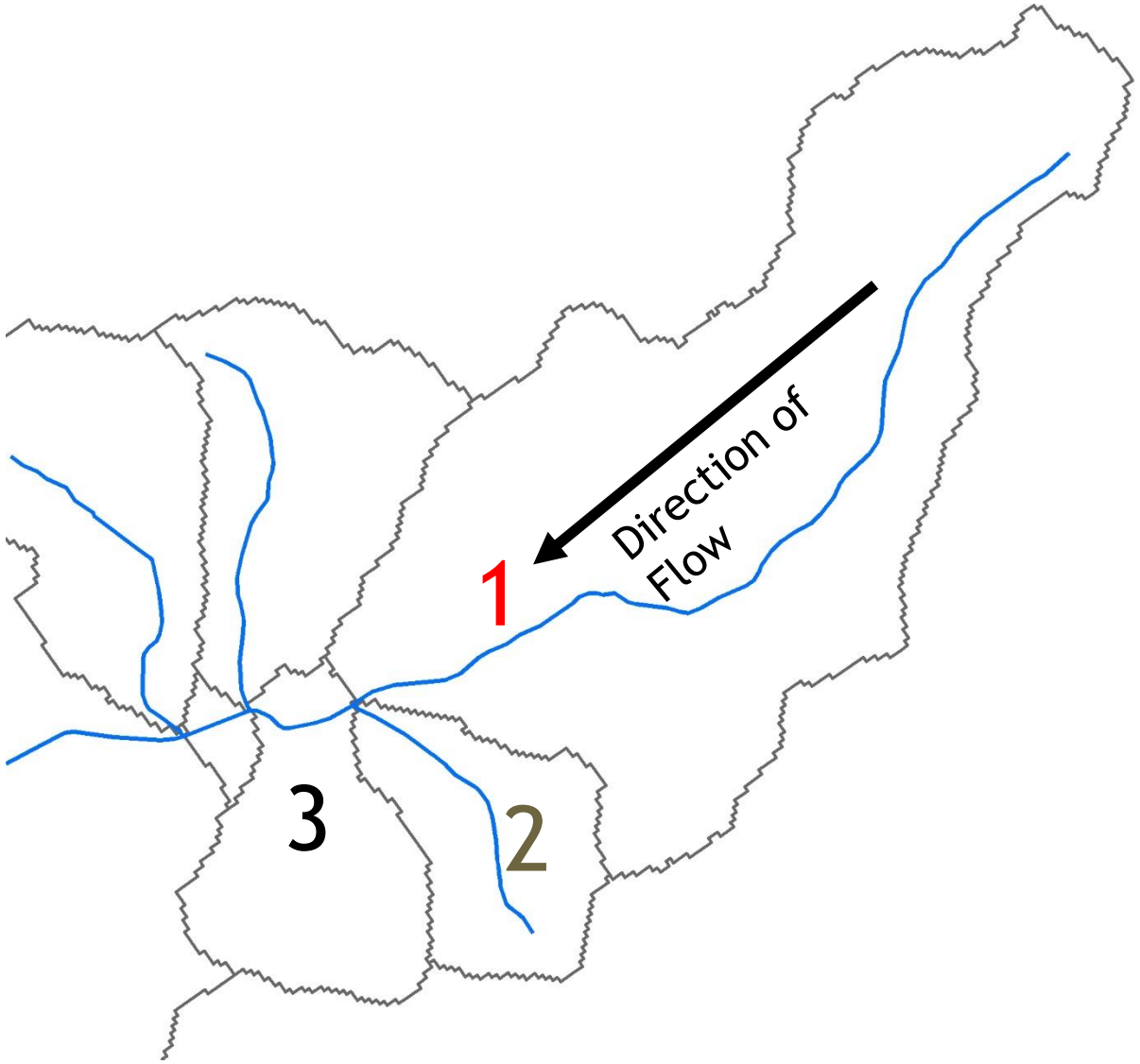


Network watershed

- 1:100,000 scale
- 2.6 million stream reaches with catchments

https://github.com/NelsonMinar/vector-river-map

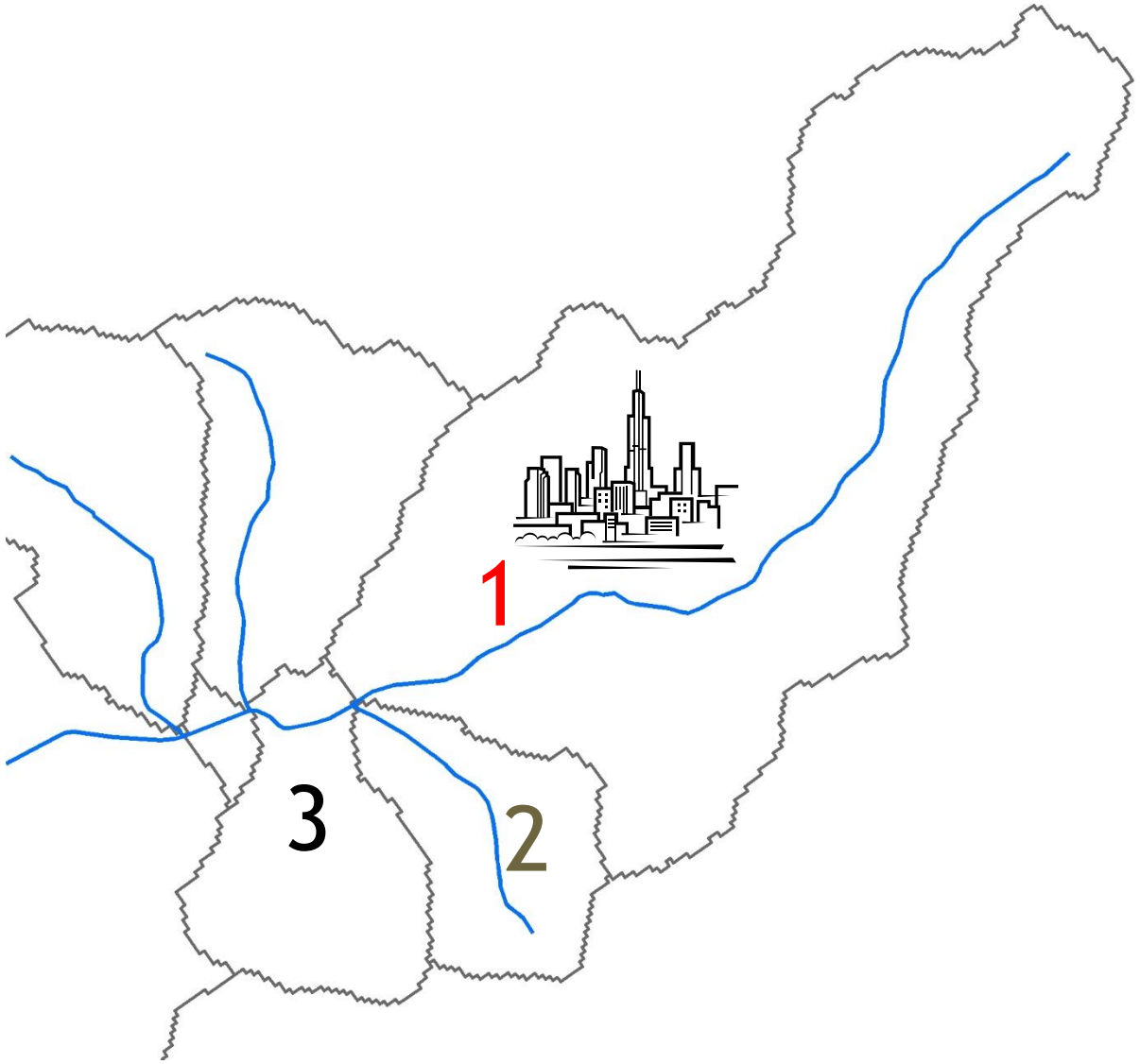
Overview of Data – StreamCat



Topology (from-to relationships)

FROM	TO
-	1
-	2
1	3
2	3
.	.
.	.
.	.

Overview of Data – StreamCat



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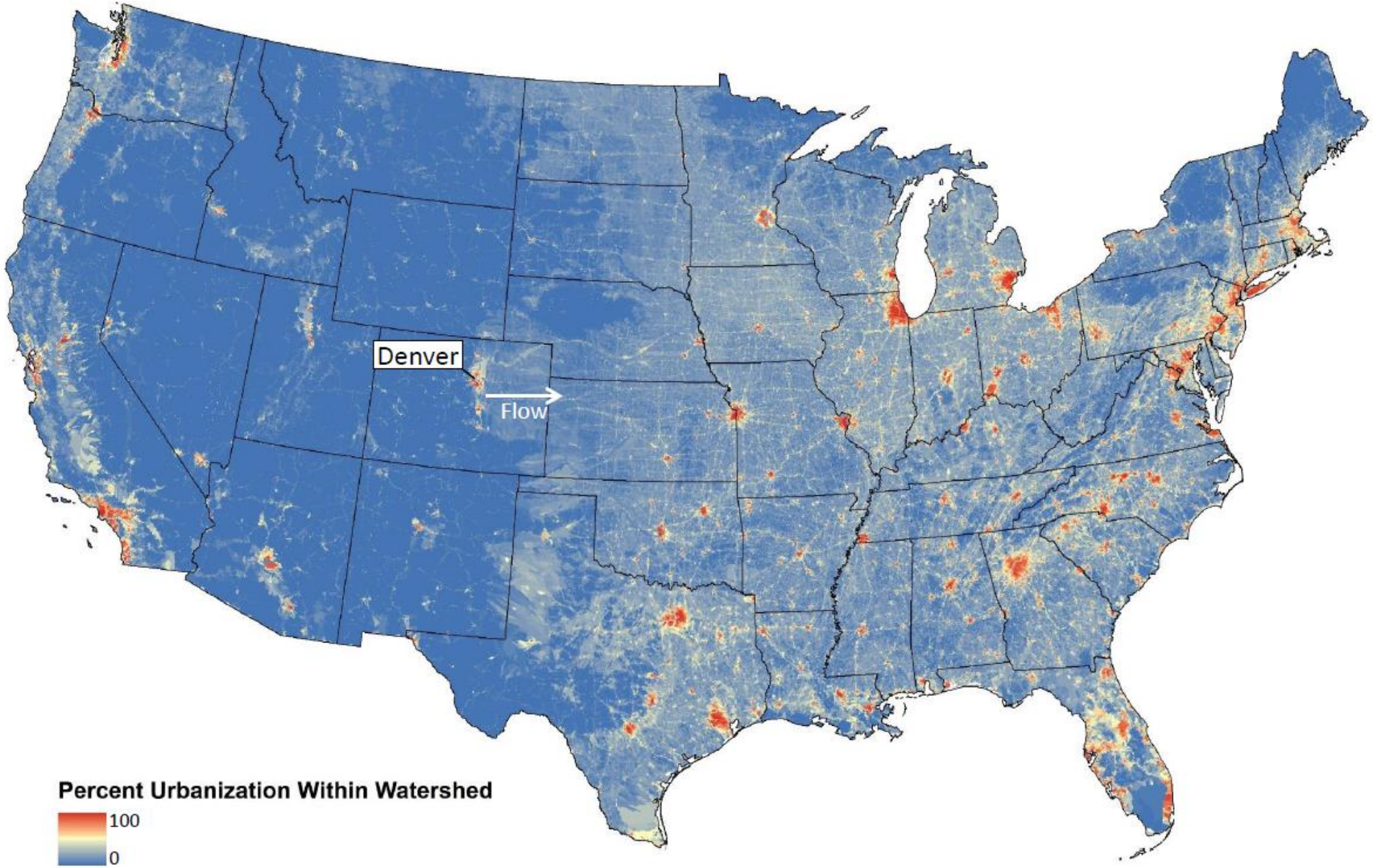
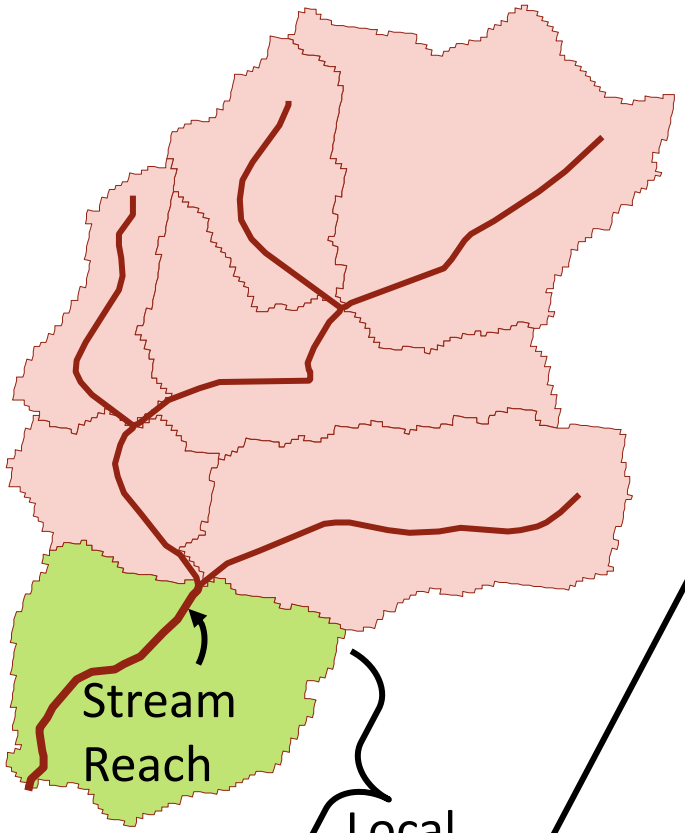
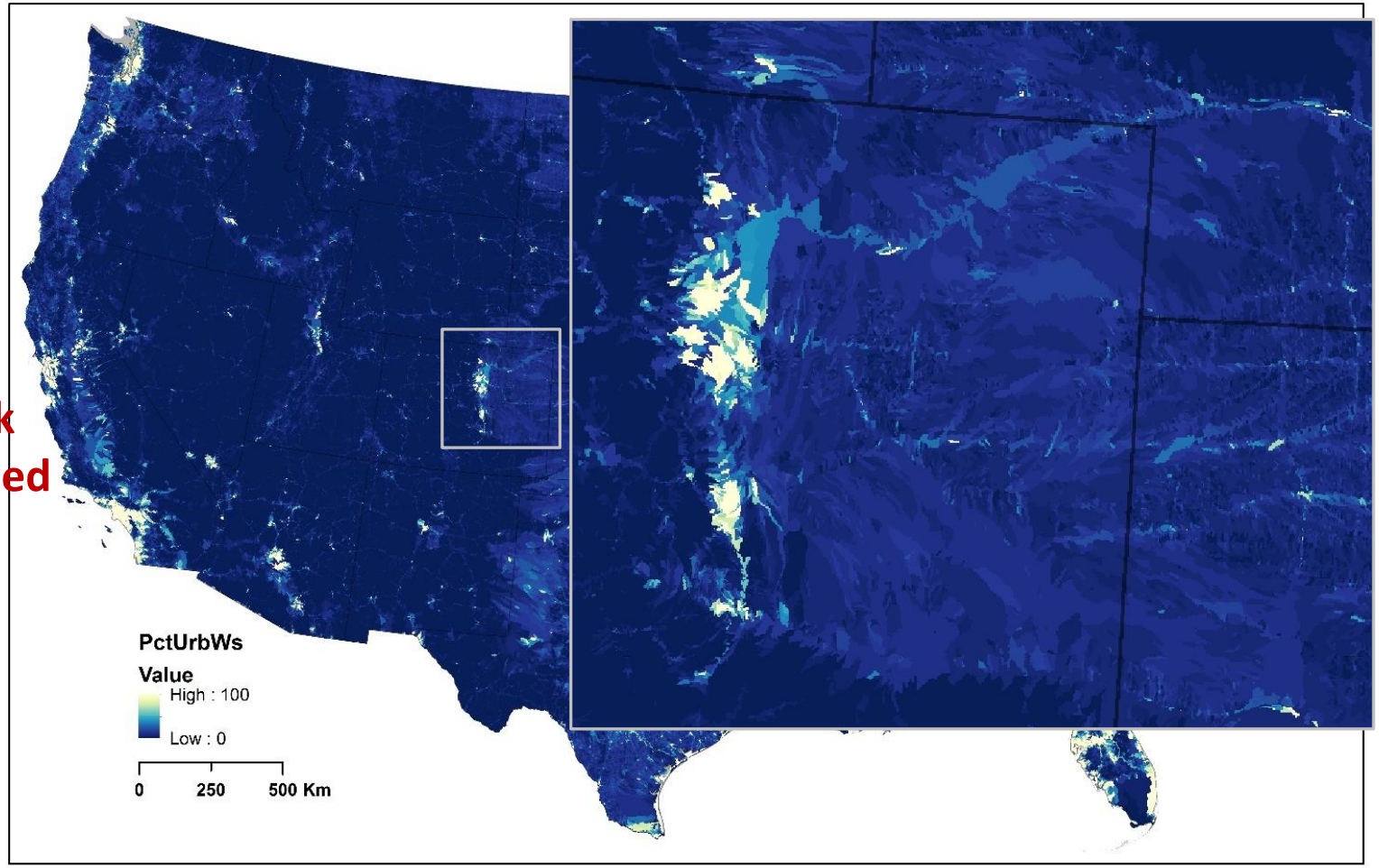


Overview of Data – StreamCat



Network watershed



Overview of Data – StreamCat

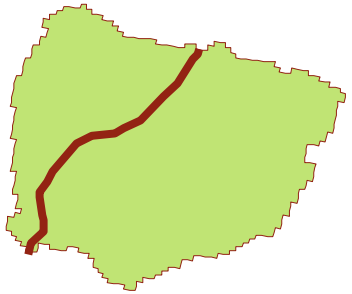
Variable	Class
agricultural land cover on slopes ≥ 10%	disturb
agricultural land cover on slopes ≥ 20%	disturb
average runoff 1971 – 2000	natural
cattle density on farmland	disturb
commercial/industrial	disturb
cultivated crops	disturb
dam density	disturb
Dam storage in basin (DAMSTOR)	disturb
deciduous forest	natural
deciduous evergreen mixed forest	natural
estimated groundwater use	disturb
estimated surface water use	disturb
evergreen forest	natural
grassland/herbaceous	natural
ground water residence time index	natural
high intensity residential	disturb
high intensity urban	disturb
Housing unit density (HUDEN)	disturb
human population density	disturb
Imperviousness	disturb
Linear distance of sampling site to nearest canal/ditch/pipeline (DIST_CANAL_NEAR)	disturb
local catchment area	natural
low intensity urban	disturb
mainstem stream classified as "Canal", “Ditch”, "Pipeline" or "Artificial"	disturb
mean annual air temperature	natural
mean annual precipitation	natural
mean basin elevation	natural
medium intensity urban	disturb
mining density	disturb

Variable	Class
mixed forest	natural
network catchment area	natural
NPDES density	disturb
open space urban	disturb
open water	natural
open wetlands	natural
pasture/hay	disturb
reach elevation	natural
reach linkage number	natural
reach slope	natural
reach stream order	natural
Road density in watershed (ROADDEN)	disturb
road length density	disturb
road/stream intersections	disturb
shrub/scrub	natural
soil depth to water table	natural
soil organic matter	natural
soil permeability	natural
soil permeability	natural
soil rock depth	natural
soils - percent clay	natural
soils - percent sand	natural
Sum of 251 major pesticide compounds (PESTIC)	disturb
Superfund National Priority List density	disturb
surficial lithography	natural
total nitrogen yield	disturb
total phosphorus yield	disturb
Toxics release inventory density	disturb
Urban + crops + pasture land cover in 600-m mainstem buffer (URBCP_MAINS)	natural
woody wetlands	natural

>500 metrics

Overview of Data – StreamCat

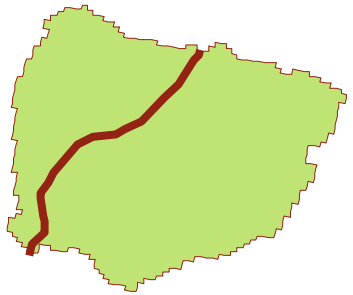
Each stream or local catchment
has a unique ID called a “COMID”



	A	B	C	D	E	F	G
1	COMID	CatAreaSqKm	WsAreaSqKm	CatPctFull	WsPctFull	ClayCat	ClayWs
2	5882819	0.12	5.61	0	91.57		6.08
3	5881421	0.53	0.53	48.40	48.40	6.44	6.44
4	5881415	10.43	10.43	99.99	99.99	5.68	5.68
5	5881737	1.58	1.58	100	100	6.43	6.43
6	5881745	1.59	2.04	100	100	6.11	6.18
7	5881921	0.05	0.45	100	100	6.41	6.44
8	5881499	0.41	0.41	100	100	6.44	6.44
9	5881485	0.45	4.08	100	100	6.11	6.27
10	5881733	4.58	4.58	100	100	6.11	6.11
11	5881731	3.16	3.16	90.55	90.55	6.25	6.25

Overview of Data – StreamCat

Local catchment metrics are identified with “Cat”



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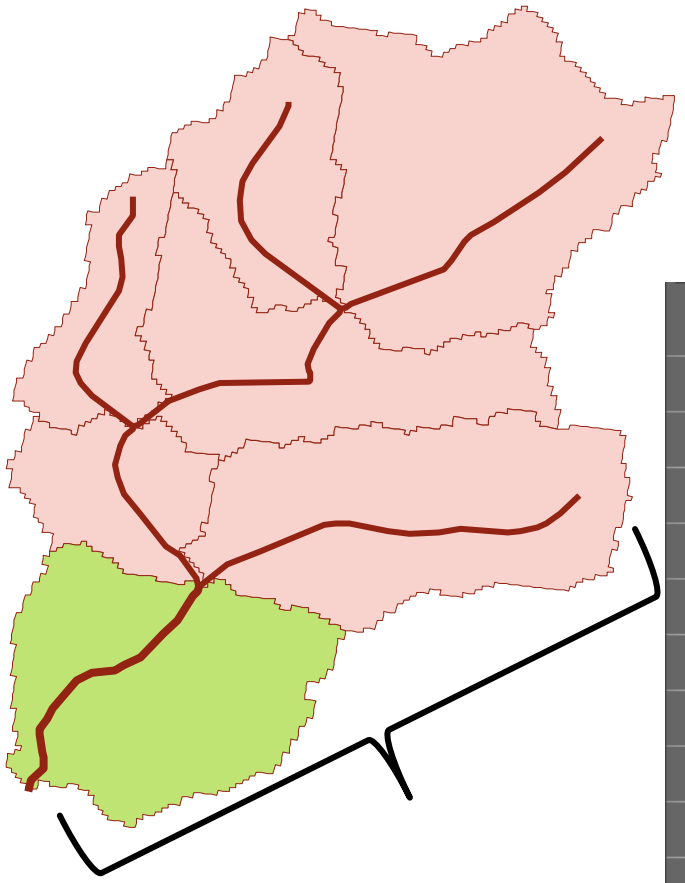
Overview of Data – StreamCat



Ws includes local catchment + upstream catchments

Full watershed metrics are identified with “Ws”

	A	B	C	D	E	F	G
1	COMID	CatAreaSqKm	WsAreaSqKm	CatPctFull	WsPctFull	ClayCat	ClayWs
2	5882819	0.12	5.61	0	91.57		6.08
3	5881421	0.53	0.53	48.40	48.40	6.44	6.44
4	5881415	10.43	10.43	99.99	99.99	5.68	5.68
5	5881737	1.58	1.58	100	100	6.43	6.43
6	5881745	1.59	2.04	100	100	6.11	6.18
7	5881921	0.05	0.45	100	100	6.41	6.44
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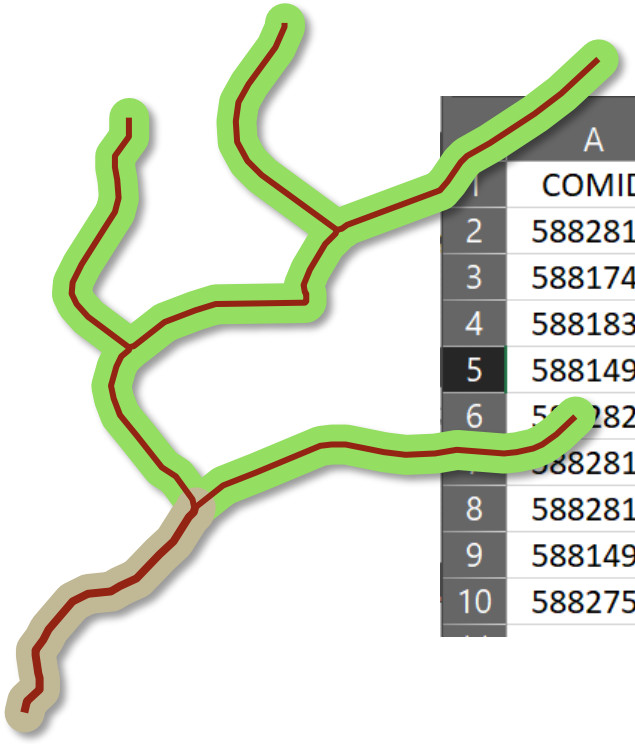
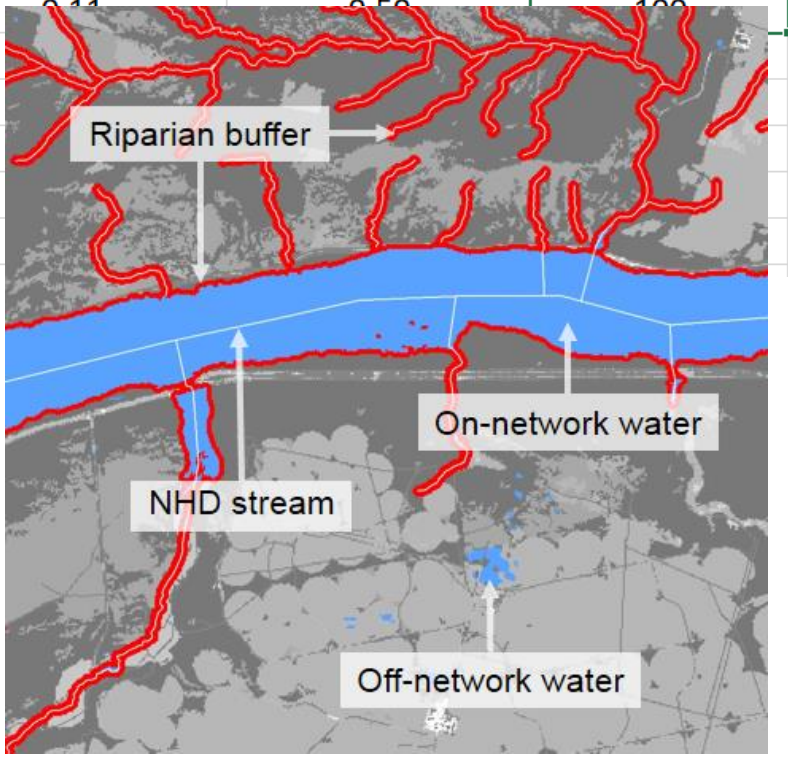
9	5881485	0.45	4.08	100	100	6.11	6.27
10	5881733	4.58	4.58	100	100	6.11	6.11
11	5881731	3.16	3.16	90.55	90.55	6.25	6.25

Overview of Data – StreamCat

100-m riparian buffers available for some metrics (“Rp100”)

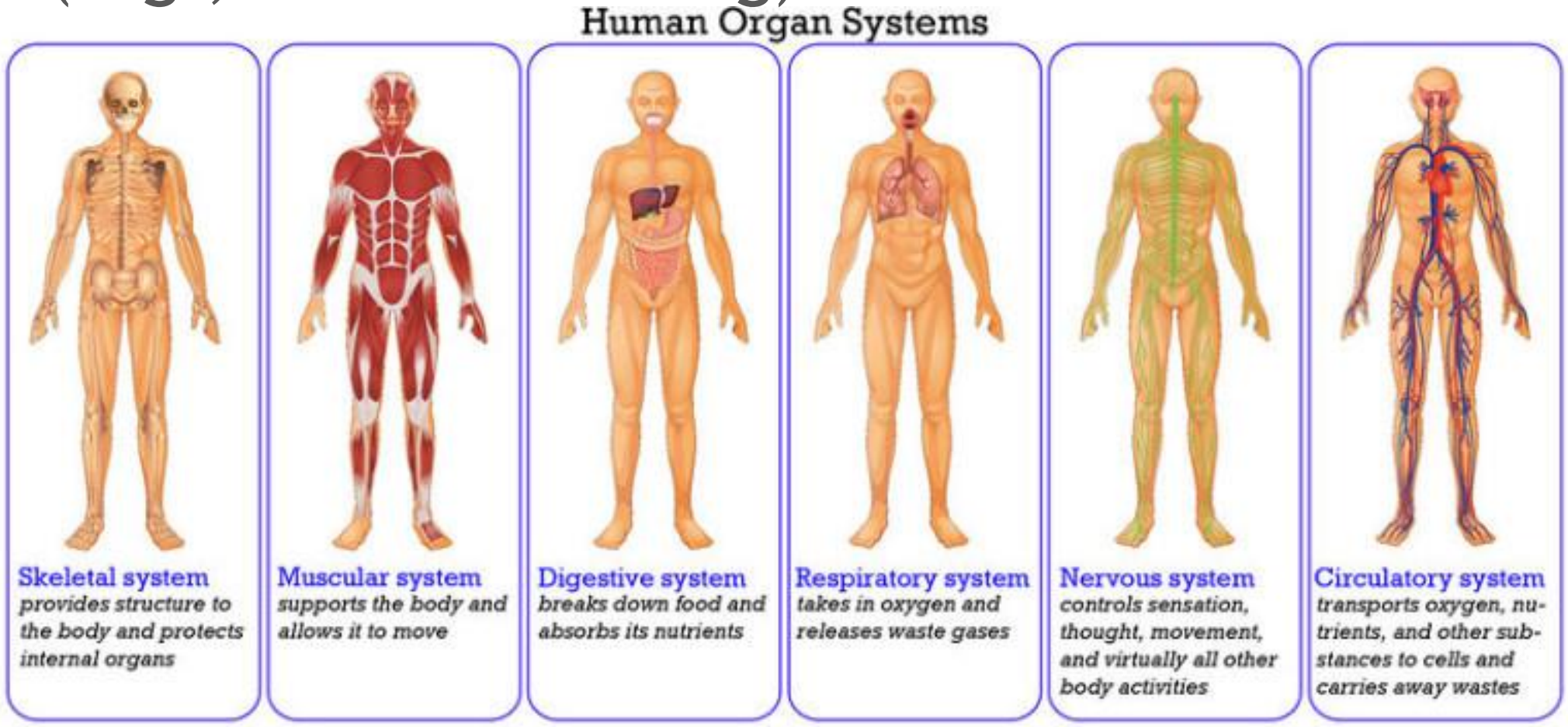


	A	B	C	D	E	F	G
1	COMID	CatAreaSqKmRp100	WsAreaSqKmRp100	CatPctFullRp100	WsPctFullRp100	HUDen2010CatRp100	HUDen2010WsRp100
2	5882819	0.08	1.77	100	100	34.81	34.83
3	5881749	0.60	13.58	100	100	34.82	90.94
4	5881835	0.28	13.86	100	100	39.82	89.91
5	5881495				100	30.99	112.41
6	5[illegible]2821				100	39.54	39.24
7	[illegible]882815				100	38.23	38.23
8	5882817				100	34.81	34.63
9	5881493				100	30.99	118.10
10	5882755				100	34.81	34.63



Overview of Data – Watershed Integrity

- Concept borrows from human health perspective
- Can estimate risk based on things like behavior (e.g., diet or smoking)



Overview of Data – Watershed Integrity

Six key functions must be present for a watershed to have integrity (Flotemersch et al. 2015):

1. Hydrologic regulation
2. Regulation of water chemistry
3. Sediment regulation
4. Hydrologic connectivity
5. Temperature regulation
6. Habitat provision

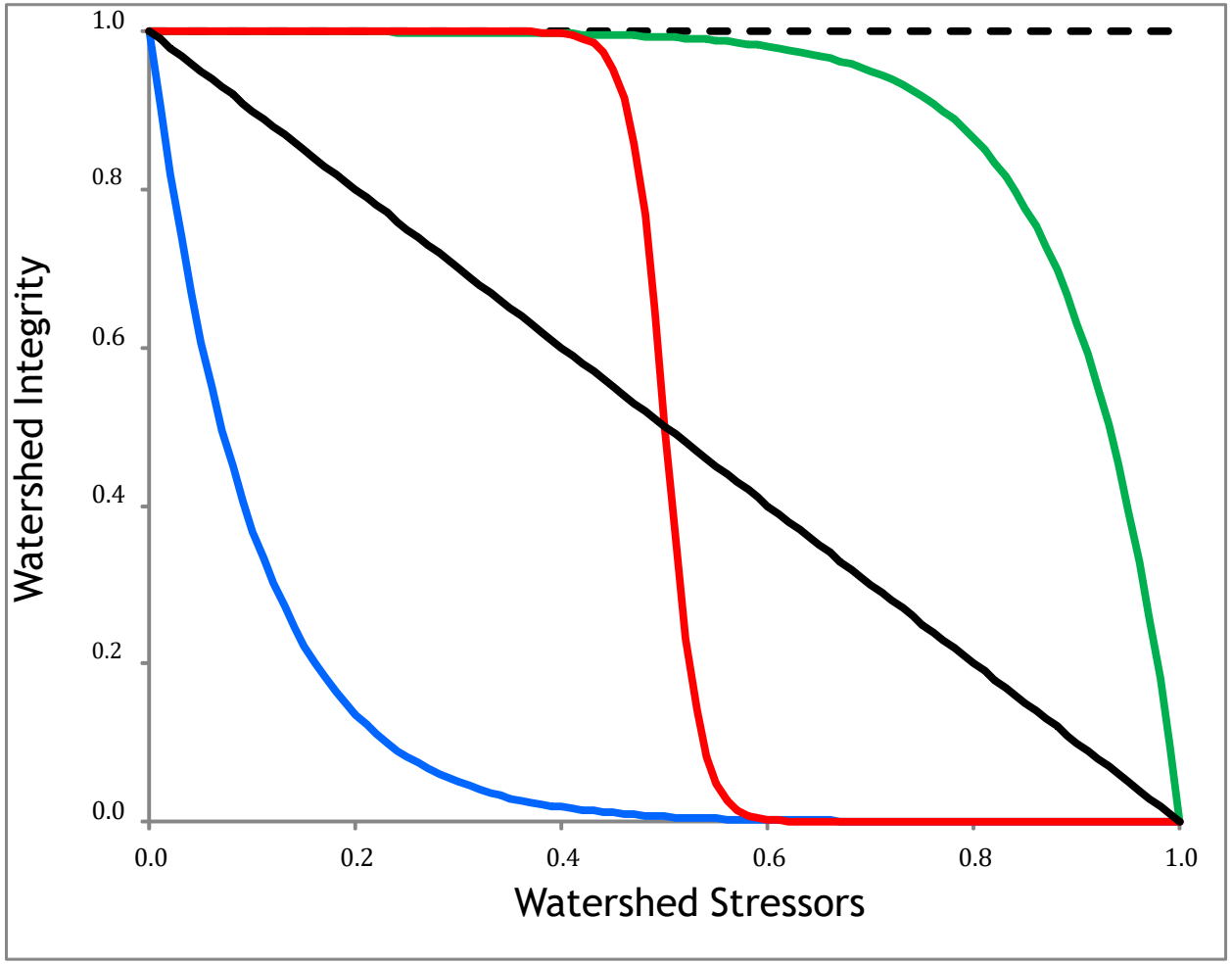
Overview of Data – Watershed Integrity

Key function	Description	Major stressors	
		Within channel	Outside channel
Hydrologic regulation (HYD)	Maintenance of the natural timing, pattern, supply, and storage of water that flows through the watershed	• Presence and volumes of reservoirs (NABD) • Stream channelization and levee construction (NA)	• Percent of the watershed comprising agricultural land use (NLCD) • Total length and density of canals/ditches (NHD) • Percent imperviousness of human-related landscapes (NLCD) • Alteration to and spatial arrangement of riparian vegetation (LANDFIRE) • Boundaries, depths, and flows of aquifers (NA) • Groundwater use (NA)*
Regulation of water chemistry (CHEM)	Maintenance of the natural timing, supply, and storage of the major chemical constituents of freshwaters: nutrients (nitrogen & phosphorus), salinity or conductivity, total dissolved solids, hydrogen ions (pH), and naturally occurring minor constituents (e.g., heavy metals)	• Presence and volumes of reservoirs (NABD) • Stream channelization and levee construction (NA)	• Atmospheric deposition of anthropogenic sources of nitrogen and acid rain (NADP) • Percent of watershed composed of agricultural land uses (NLCD) • Fertilizer application rates (FERT) • Presence and density of wastewater treatment facilities (NPDES), industrial facilities (TRI), superfund sites (SUPERFUND), and mines (MINES) • Cattle density (NA)* • Alteration to and spatial arrangement of riparian vegetation (LANDFIRE) • Chemical constituents of groundwater (NA)

Flotemersch et al. 2015

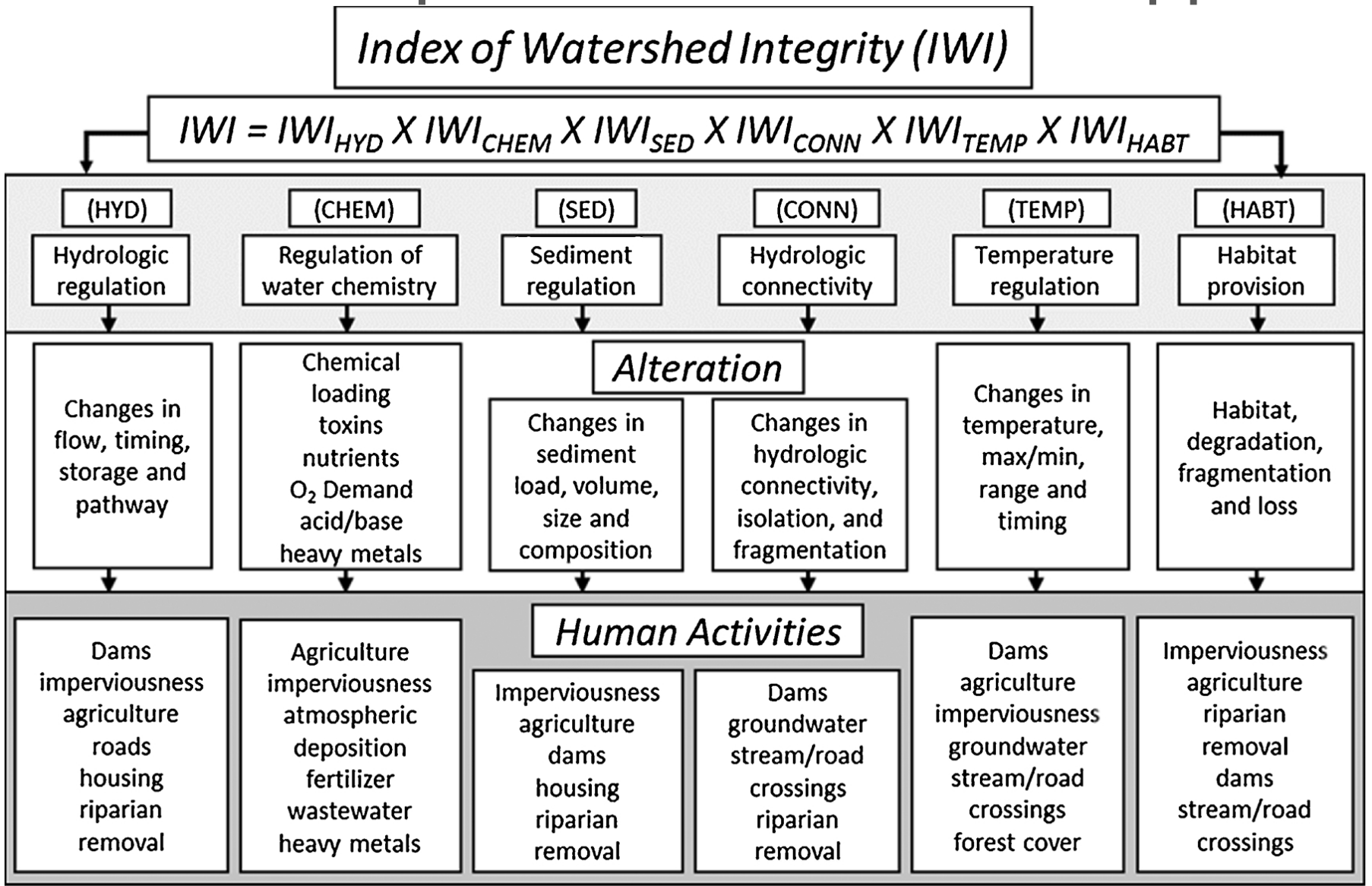
Overview of Data – Watershed Integrity

Response to stress can be approximated with a variety of potential curves – first cut was negative linear



Overview of Data – Watershed Integrity

StreamCat + Conceptual Model + Linear Approximation



Overview of Data – Watershed Integrity

StreamCat + Conceptual Model + Linear Approximation

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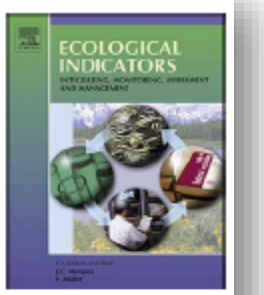


Research paper

Mapping watershed integrity for the conterminous United States

Darren J. Thornbrugh[a,1], Scott G. Leibowitz[b,*], Ryan A. Hill[a], Marc H. Weber[b], Zachary C. Johnson[a], Anthony R. Olsen[b], Joseph E. Flotemersch[c], John L. Stoddard[b], David V. Peck[b]

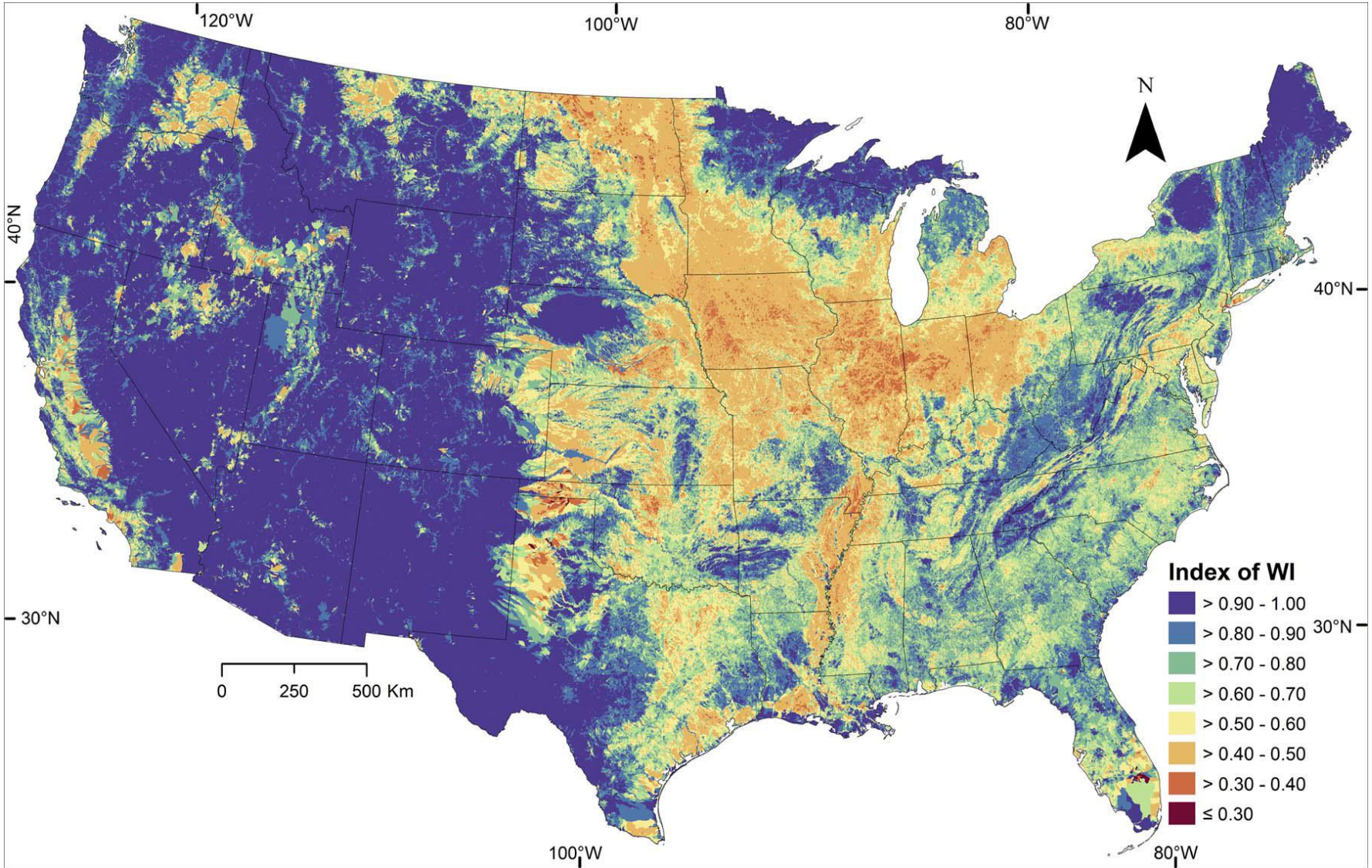
[a] Oak Ridge Institute for Science and Education (ORISE) Post-Doctoral Fellow c/o U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, Western Ecology Division, 200 SW 35th St., Corvallis, OR 97333, USA

[b] U.S. Environmental Protection Agency, National Health and Environmental Effects Research Laboratory, 200 SW 35th St., Corvallis, OR 97333, USA

[c] U.S. Environmental Protection Agency, National Exposure Research Laboratory, 26 W. Martin Luther King Dr., Cincinnati, OH 45268, USA

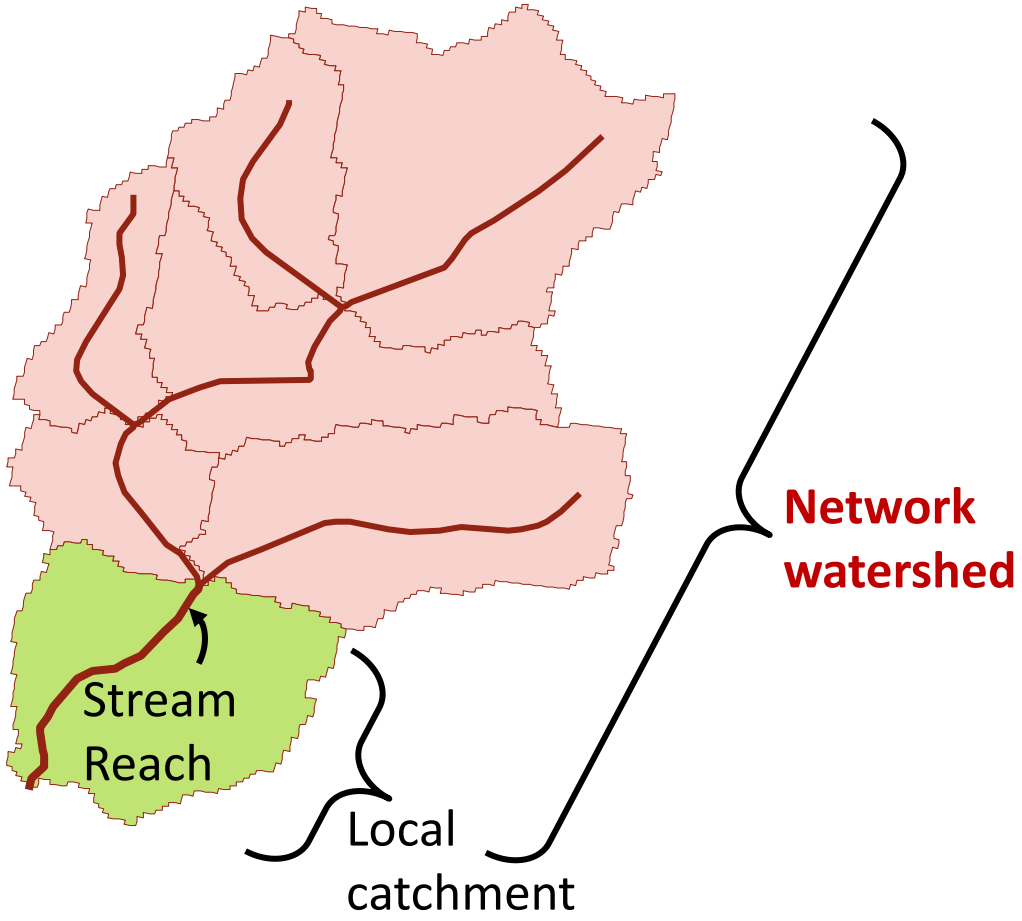
Overview of Data – Watershed Integrity

Index of Watershed Integrity (IWI)



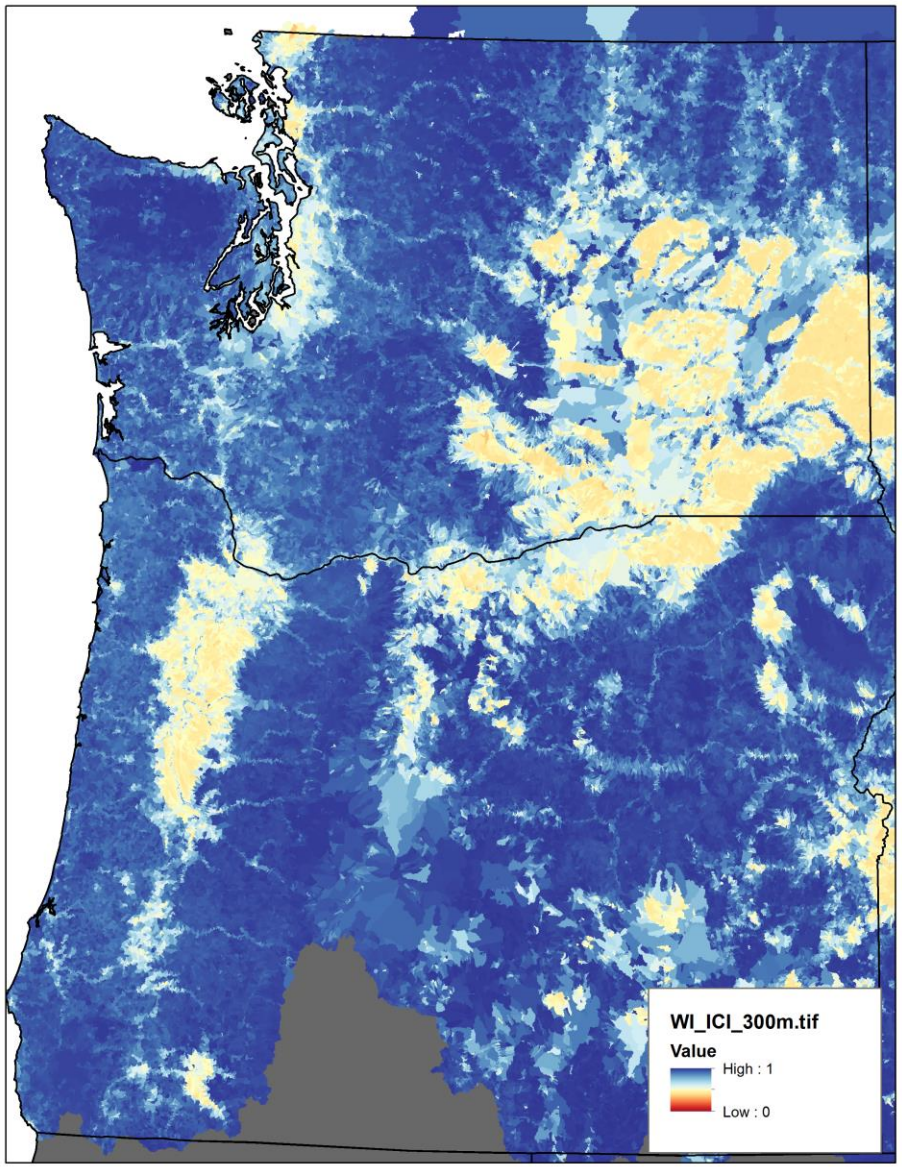
Overview of Data – Watershed Integrity

Concept expanded to local catchments

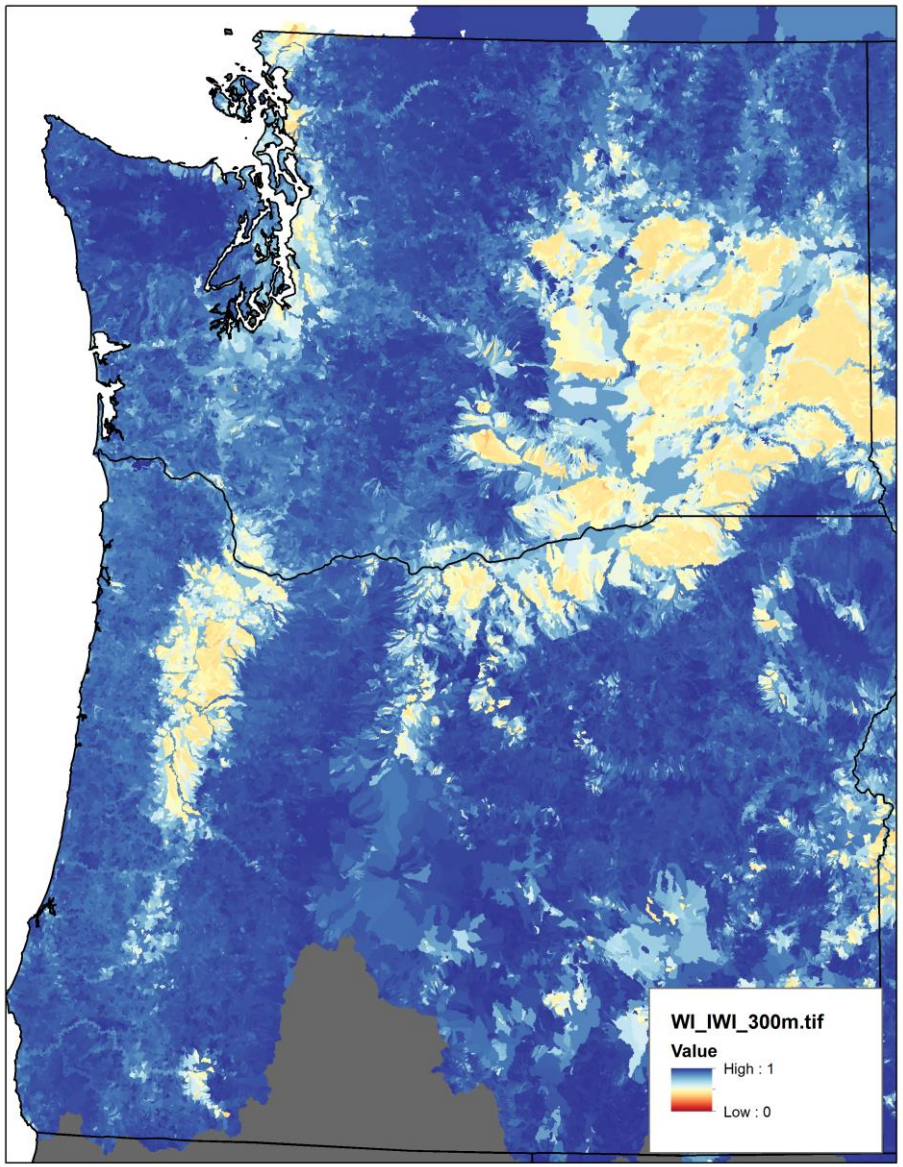


Overview of Data – Watershed Integrity

ICI



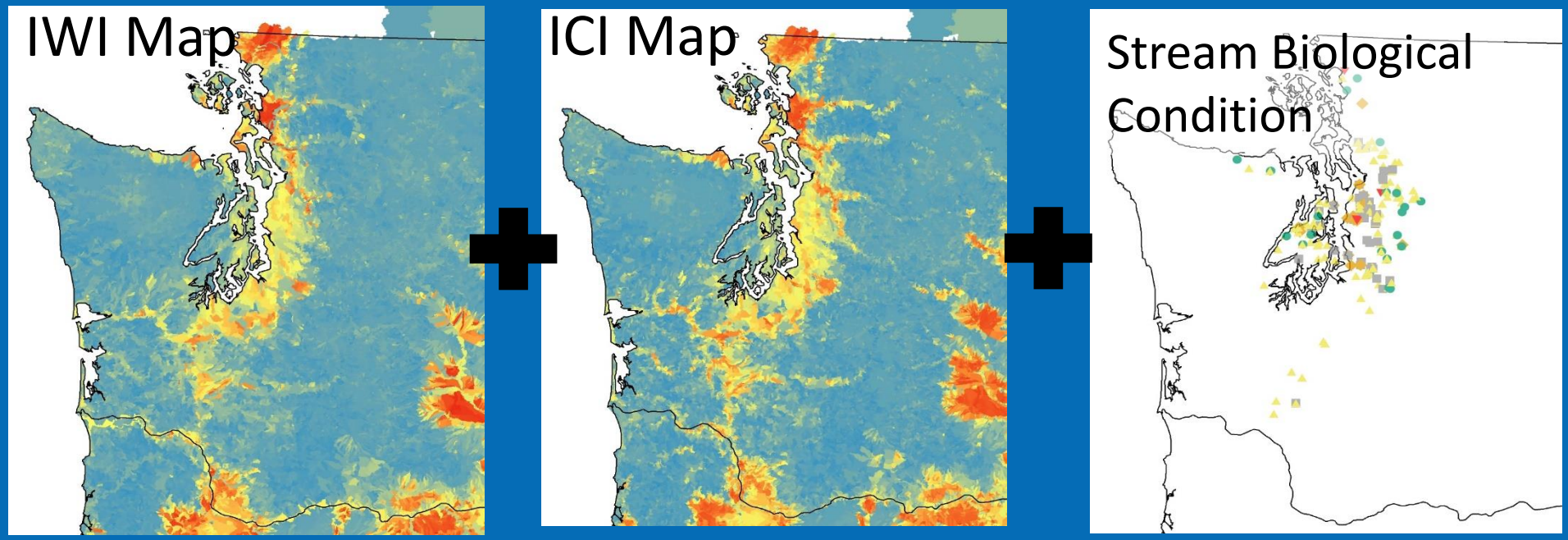
IWI



Application of IWI/ICI and StreamCat Datasets in Stream Conservation

Luisa Riato

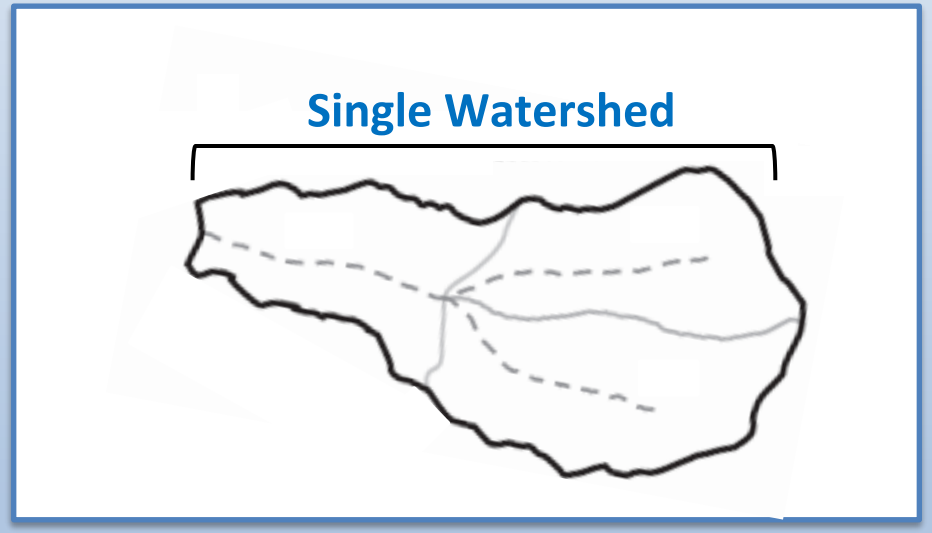
ORISE Post-Doctoral Fellow
EPA Center for Public Health and Environmental Assessment



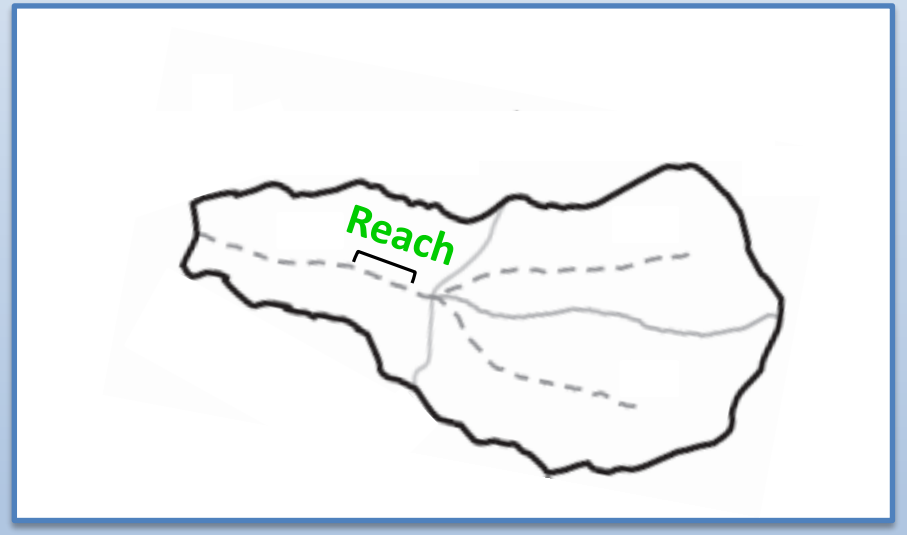
Office of Research and Development
CPHEA/Pacific Ecological Systems Division

Stream Management:

Historically at Single Spatial Scale
e.g., a Watershed or Stream Reach



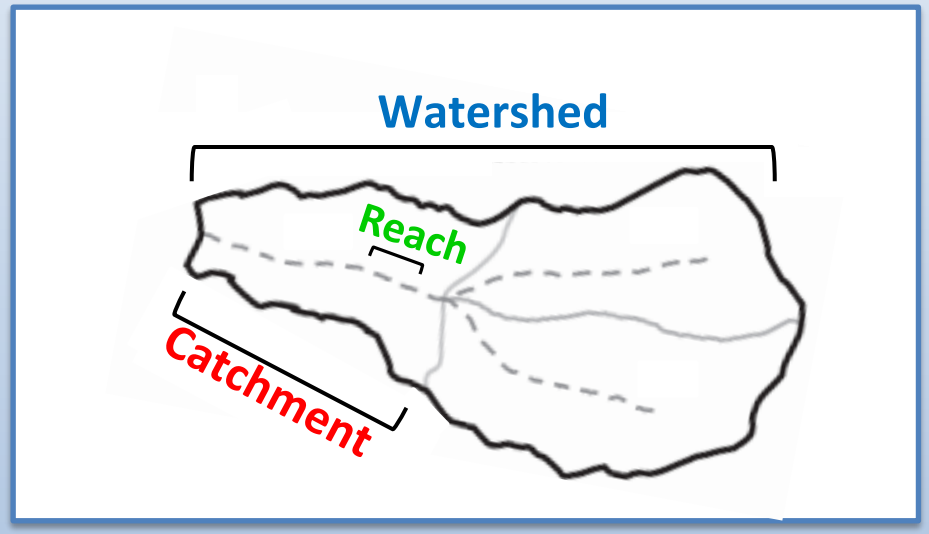
OR



Hill et al. 2016. JAWRA

Stream Management at Multiple Spatial Scales

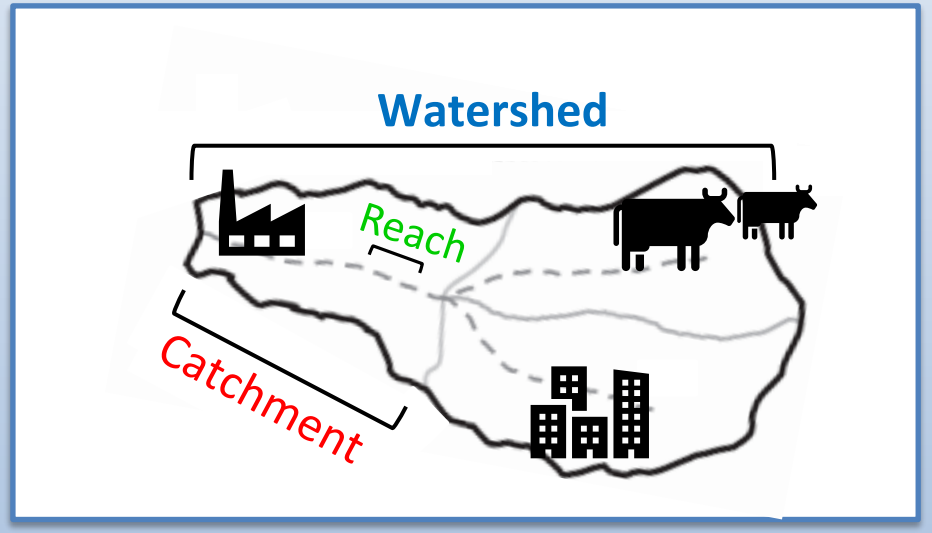
Watershed, Catchment and Stream-Reach scale



- Identify scale(s) which biological condition is responding to stress
- Best spatial scale(s) for management action
- Prioritize streams for effective restoration/protection

Need Framework To Link:

Landscape Information at Multiple Spatial Scales



Stream Biological Condition Data

Framework that Enables Flexibility

Stream Biological Condition Data

Benthic Index of Biotic Integrity (B-IBI)

OR

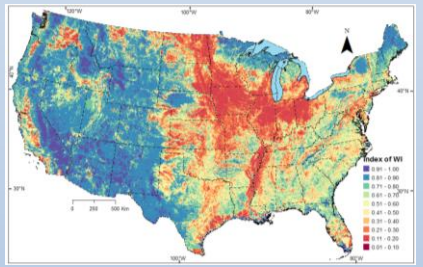
National Rivers and Streams Assessment (NRSA) MMI

OR

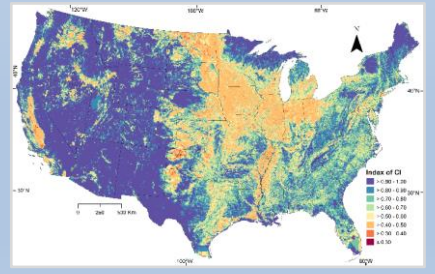
Biological Condition Gradient (BCG)

Landscape Integrity Data

State or Regional Watershed/Catchment/Reach Integrity data



National Index of Watershed Integrity (IWI)

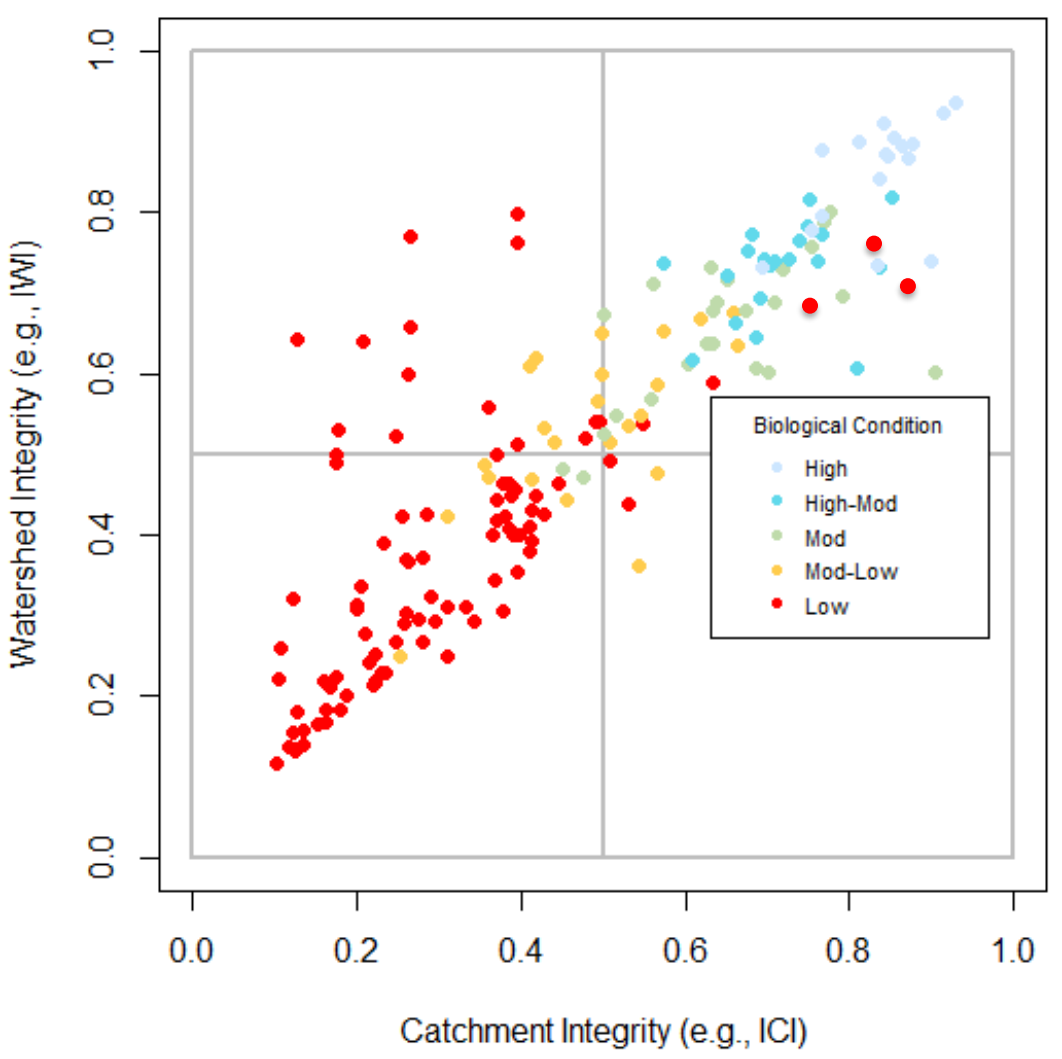


National Index of Catchment Integrity (ICI)

StreamCat data

Linking Stream Biological Condition with Watershed and Catchment Integrity

<u>Upper left quadrant</u>
Possible Candidates for Restoration – High IWI, Low ICI

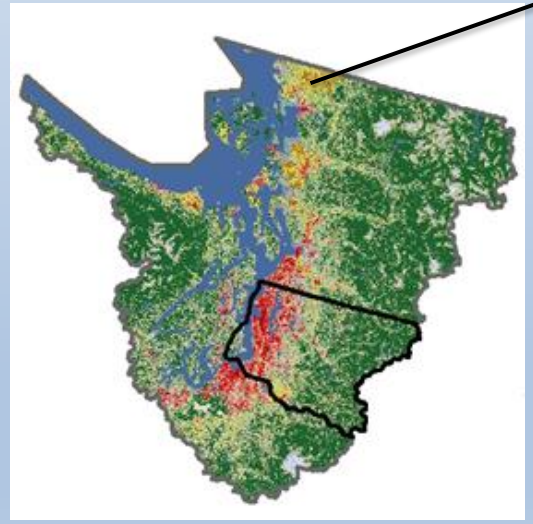


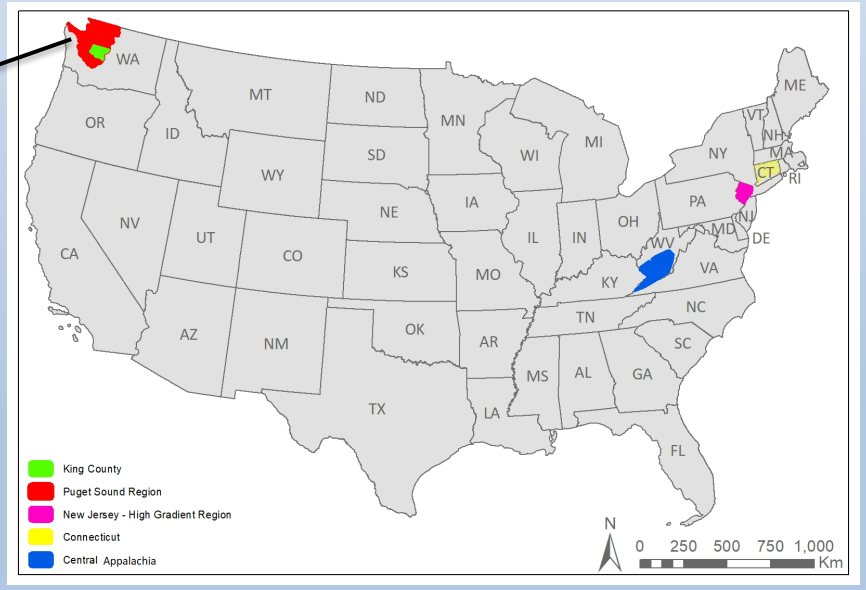
<u>Upper right quadrant</u>
Best candidates for Protection/Restoration – High IWI, High ICI

<u>Lower Left & Right quadrants</u>
Worst Candidates for Restoration – Low IWI

Case Study 1: Puget Lowland Region/King County (WA)

Aim: Link Stream Biological Condition with Two Scales of Integrity - Watershed & Catchment





Case Study 1: Puget Lowland/King County (WA)

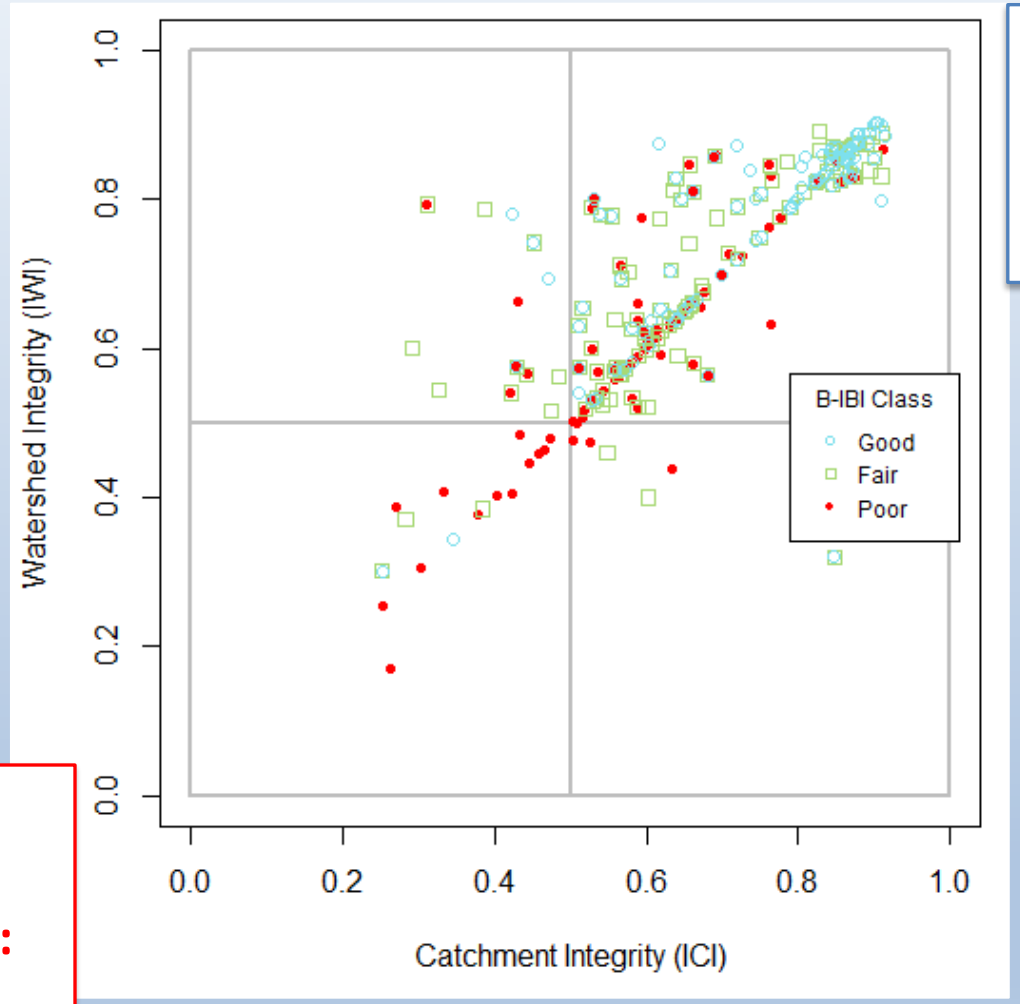
Biological data

- Macroinvertebrate Benthic Index of Biotic Integrity (B-IBI)
- 782 B-IBI samples - Good, Fair or Poor condition

Watershed and Catchment Integrity data

- IWI & ICI values

Linking Macroinvertebrate B-IBI with IWI and ICI

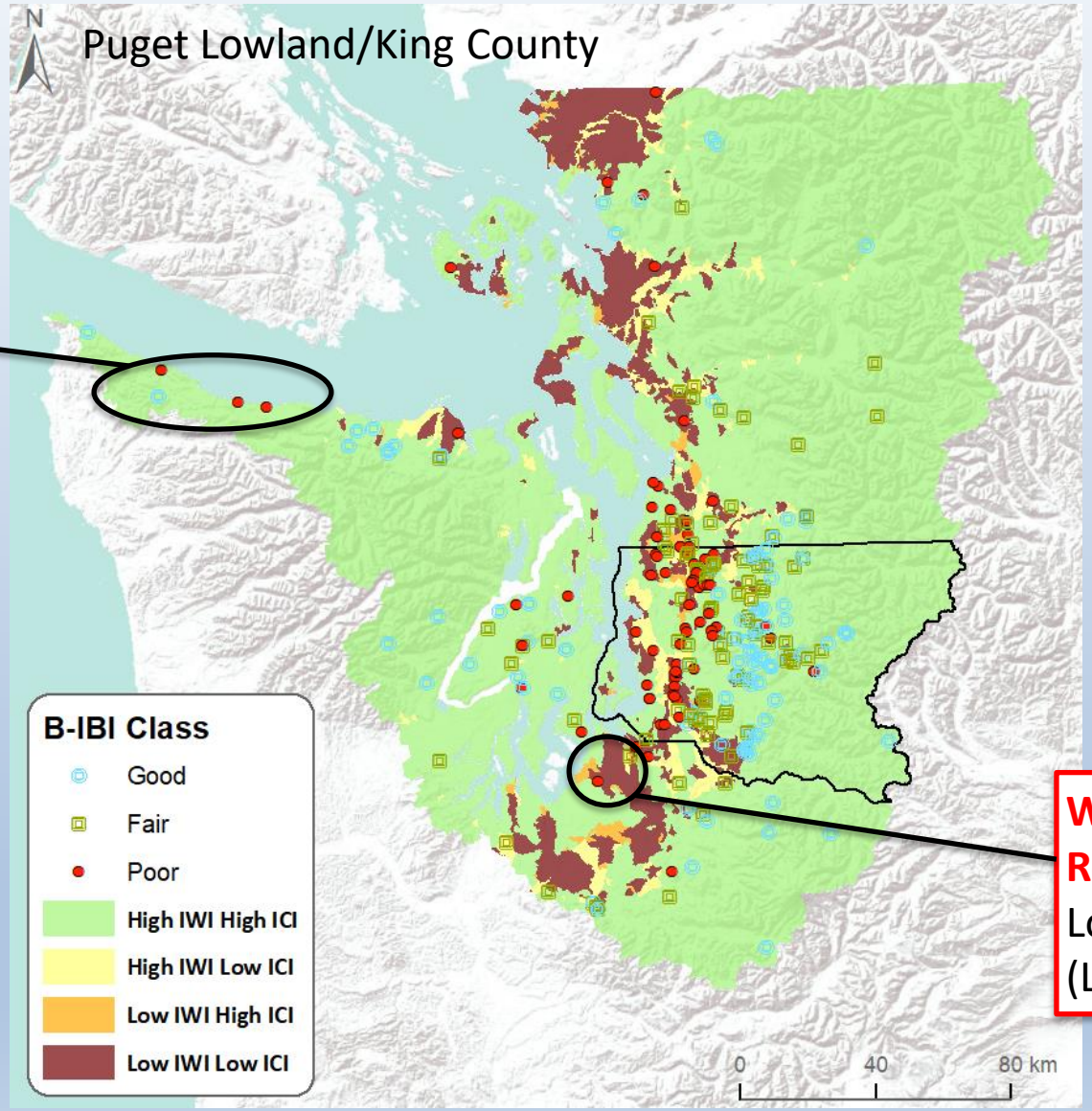


Best Candidates for Feasible/Effective Protection & Restoration: High IWI, High ICI

Protection & Restoration Less Feasible/Effective: Low IWI

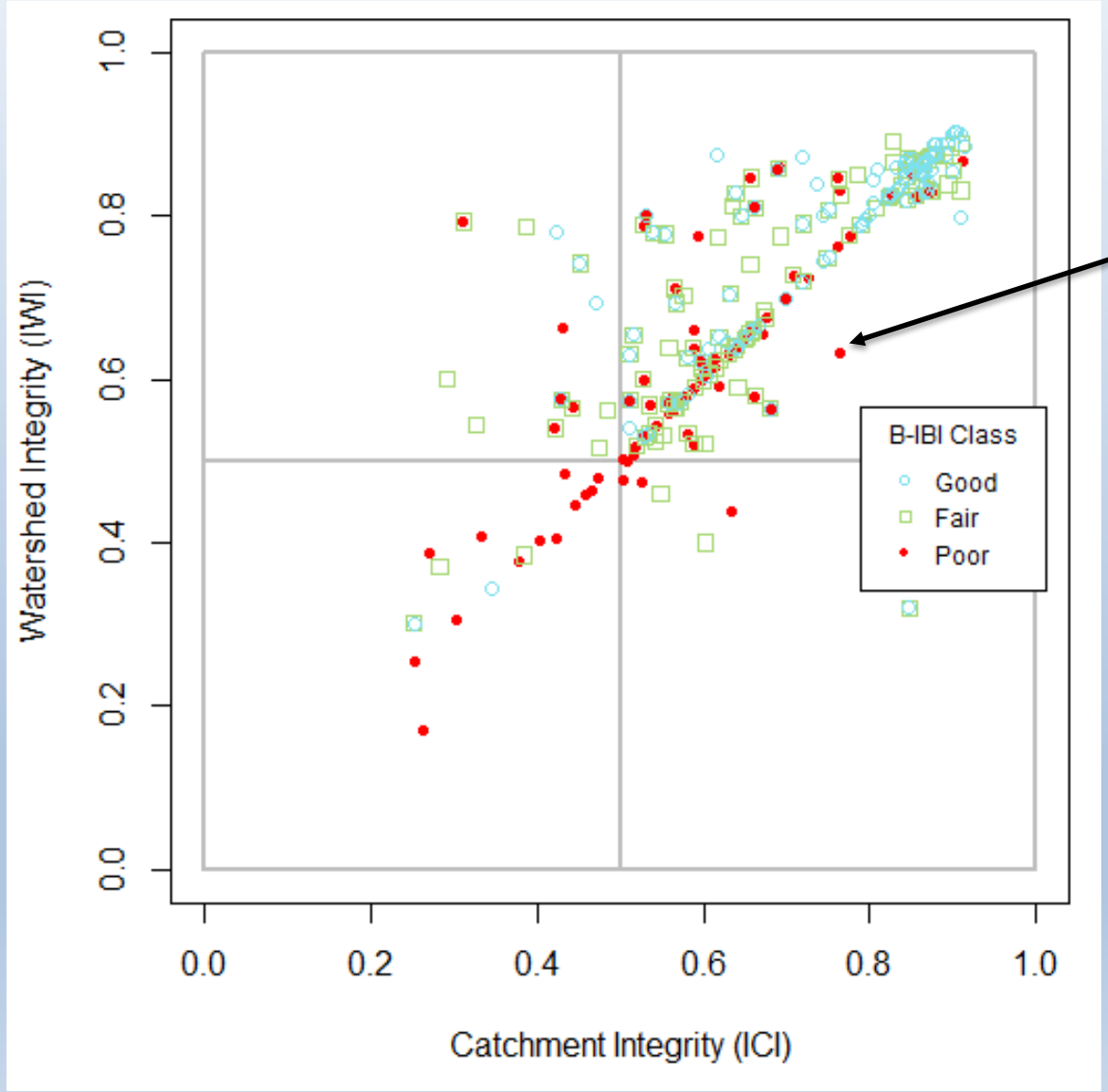
Linking Macroinvertebrate B-IBI with IWI and ICI

Best Candidates for Restoration/Protection
High Integrity Watersheds/Catchments



Worst Candidates for Restoration
Low Integrity Watersheds (Low IWI)

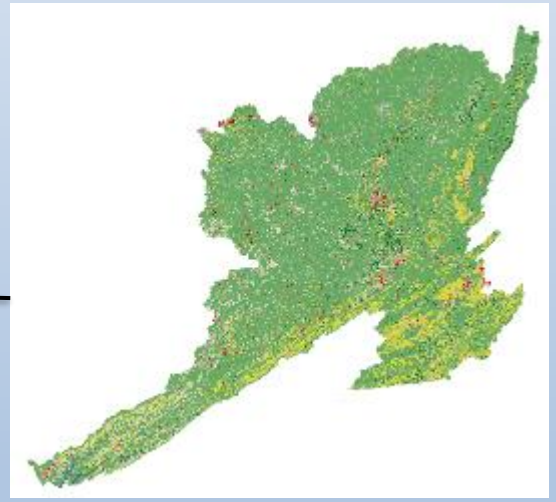
Puget Lowland/King County
Macroinvertebrate B-IBI with IWI and ICI



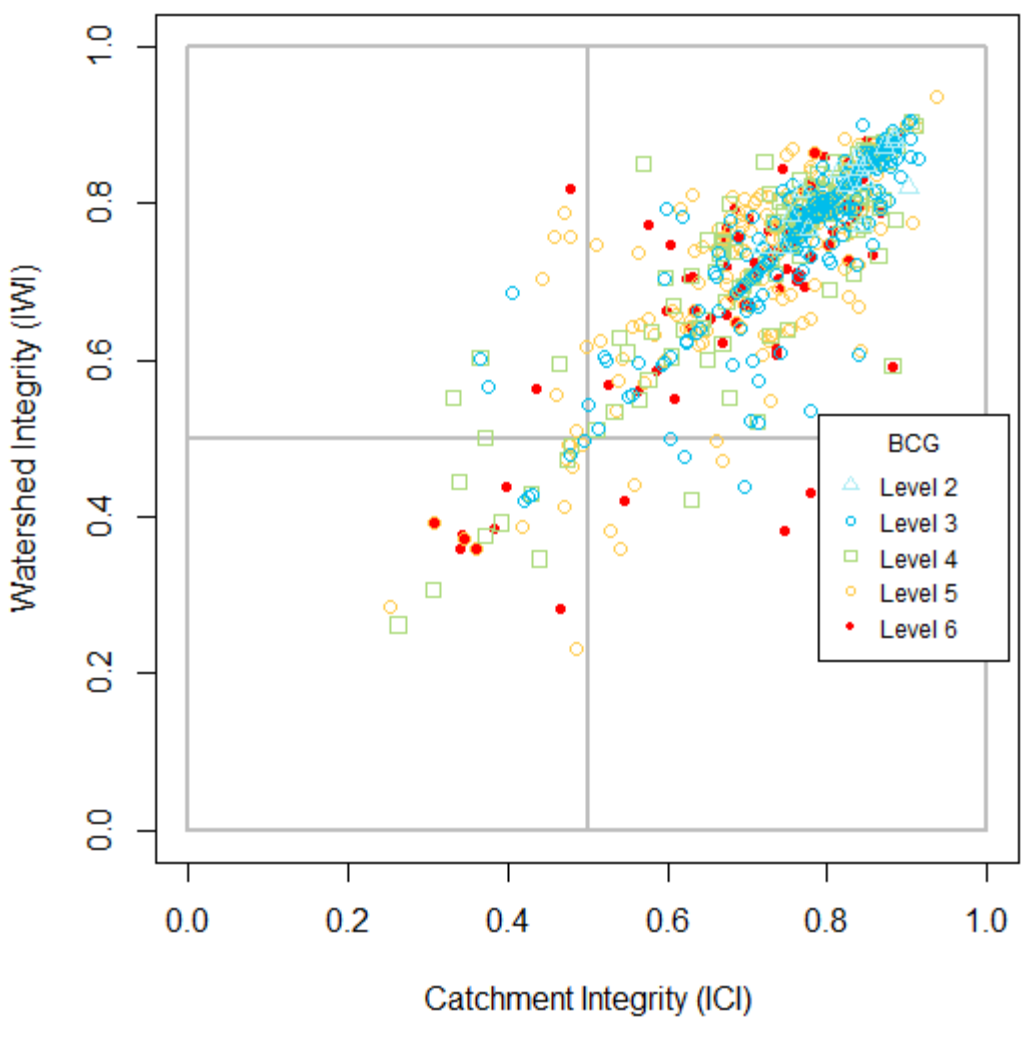
Underperforming Sites:
Poor sites in High Integrity Watersheds/Catchments

Case Study 2: Central Appalachia Region

Aim: Link Stream Biological Condition with Three Scales of Integrity – Watershed, Catchment & Reach



Linking Macroinvertebrate BCG with IWI and ICI



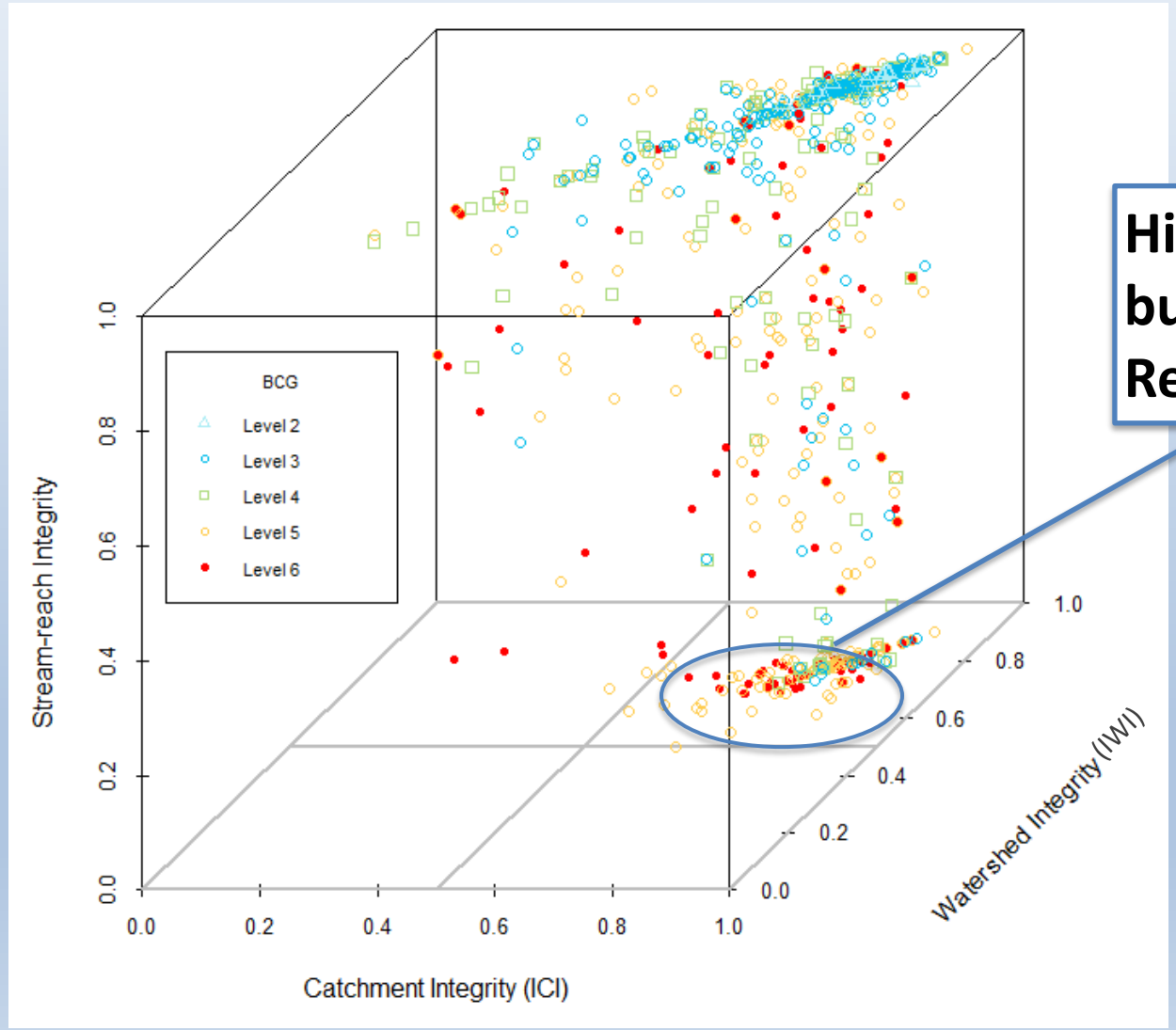
Upper Right Quadrant

High Integrity Watersheds/Catchments

39% Good sites (BCG 2 & 3)

50% IMPAIRED (BCG 5 &6)?

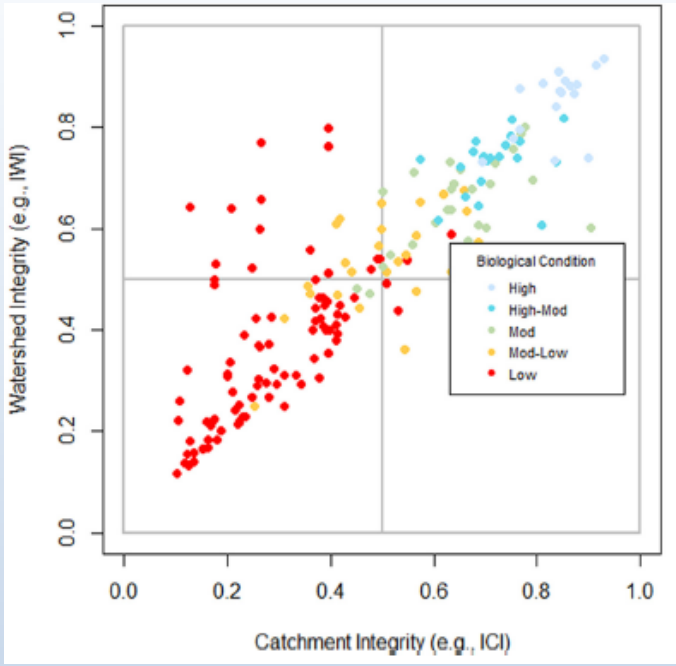
Linking Macroinvertebrate BCG with IWI, ICI & Reach-scale Integrity

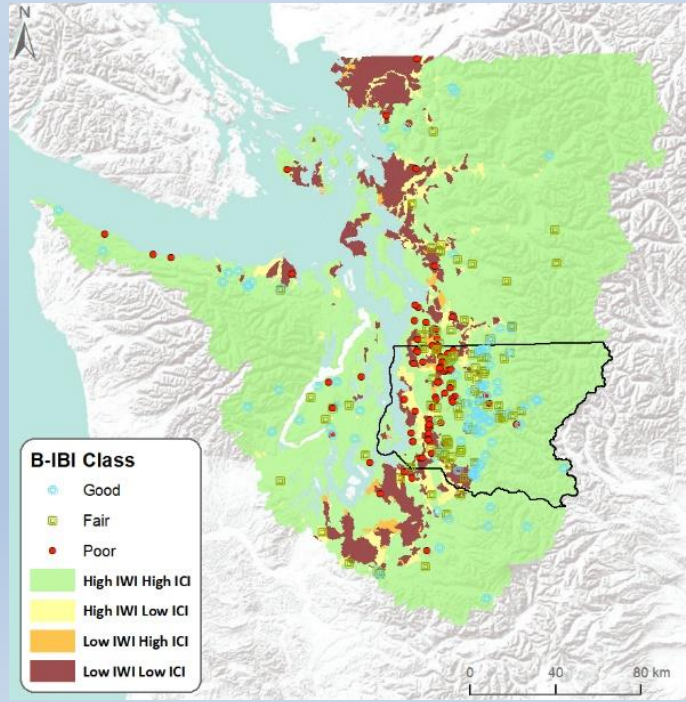


High IWI, High ICI but Low Stream-Reach Integrity

Summary: Multiscale framework

- ❑ Simple, flexible tool
- ❑ Apply to <u>any</u> geographic scale and biological taxa
- ❑ Optimal management decisions
  - ➢ Prioritize streams for protection and restoration
  - ➢ Identify best spatial scale for management

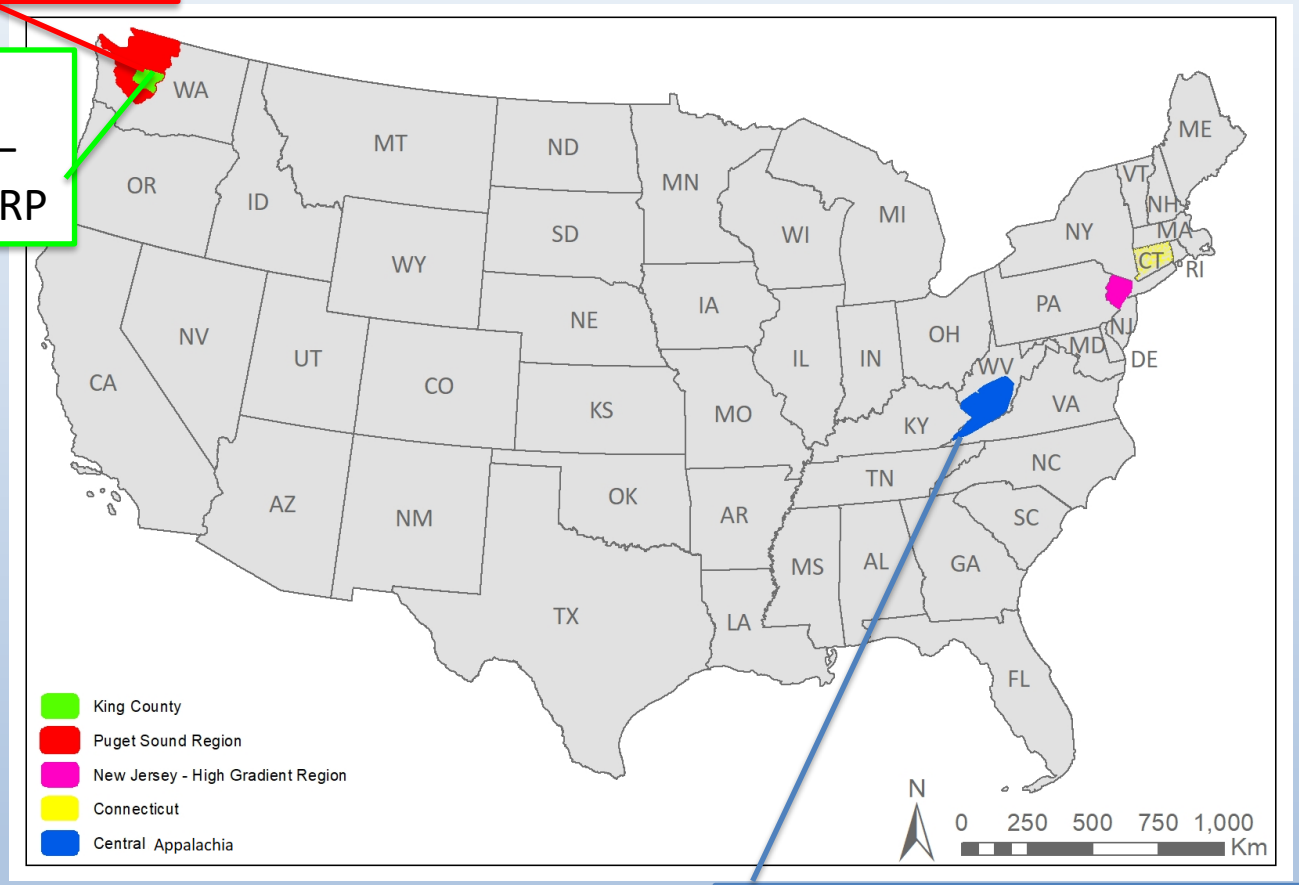




Acknowledgements

Puget Sound Region
Chad Larson - WA DOE

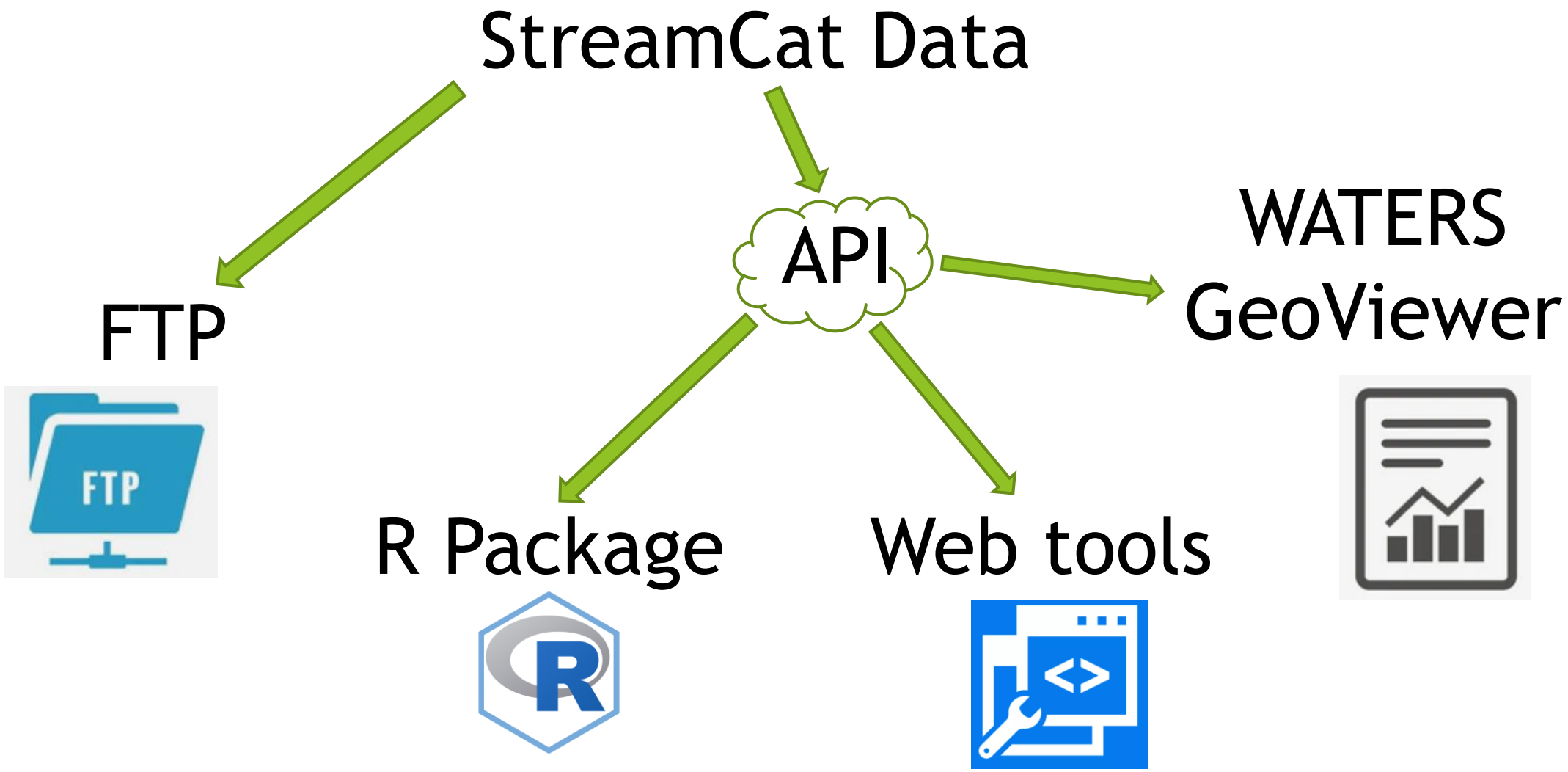
King County
Kate Macneale –
King County DNRP



Central Appalachia
Lou Reynolds – USEPA Region 3
Jason Hill/Emma Jones - VA DEQ
John Wirts - WV DEP

Riato et al. 2020. STOTEN; DOI: 10.1016/j.scitotenv.2020.139699.

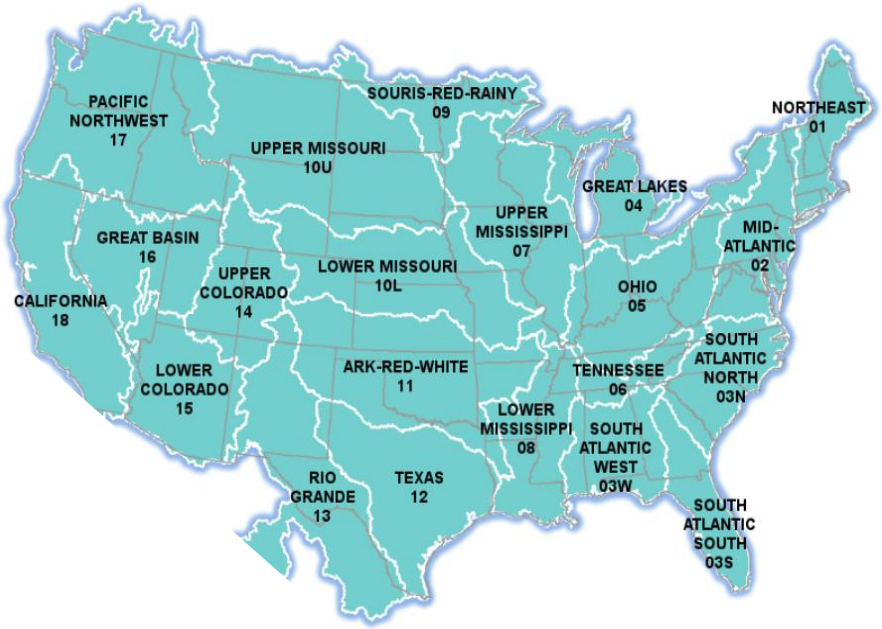
Accessing and Using StreamCat Data



Accessing and Using StreamCat Data

Data available as zipped .csv files by:

- NHDPlus Hydroregion
- US State



- AgMidHiSlopes_Region01.zip
- AgMidHiSlopes_Region02.zip
- AgMidHiSlopes_Region03N.zip
- AgMidHiSlopes_Region03S.zip
- AgMidHiSlopes_Region03W.zip
- AgMidHiSlopes_Region04.zip
- AgMidHiSlopes_Region05.zip
- AgMidHiSlopes_Region06.zip

- NLCD2001_AR.zip
- NLCD2001_AZ.zip
- NLCD2001_CA.zip
- NLCD2001_CO.zip
- NLCD2001_CT.zip
- NLCD2001_DE.zip
- NLCD2001_FL.zip
- NLCD2001_GA.zip

Accessing and Using StreamCat Data

Metric .csv files look like:

COMID	CatAreaSqKm	WsAreaSqKm	CatPctFull	WsPctFull	ClayCat	ClayWs	SandCat	SandWs
22220519	30.3867	251.2179	100	100	32.6803	10.5478	22.2715	38.689
22220973	2.4354	2.4354	100	100	6.5947	6.5947	39.3678	39.3678
22221761	17.9739	17.9739	100	100	12.2642	12.2642	38.8328	38.8328
22220819	5.8194	49.8987	100	100	6.2451	6.3618	43.5937	40.8023
22221927	4.7646	227.8494	100	100	8.0137	7.8918	42.2042	38.2363
10313430	46.5363	440.2233	100	100	7.6801	9.9608	25.4083	29.194
22221763	16.2495	125.7507	100	100	51.21	41.3177	12.801	16.4106
9.32E+08	9.6642	113.4702	100	100	11.0082	9.8198	31.22	34.7847
22222007	5.6943	29.385	100	100	8.9843	8.4582	37.6079	37.3055
10313588	54.1071	54.1071	100	100	10.9005	10.9005	25.6186	25.6186
10313416	0.6921	1.9413	100	100	5.42	5.42	44.6373	44.6004
22220983	6.5862	179.6715	100	100	6.6474	6.2196	51.1417	41.7342
22220811	0.1008	42.0759	100	100	6.11	6.3719	41.9298	40.4589

COMID	CatAreaSqKm	WsAreaSqKm	CatPctFull	WsPctFull	PctUrbLo2019Cat	PctUrbMd2019Cat	PctUrbHi2019Cat	PctUrbLo2019Ws	PctUrbMd2019Ws	PctUrbHi2019Ws
718276	2.3103	2.3103	100	100	0.12	0.08	0.04	0.12	0.08	0.04
718808	3.9429	3.9429	100	100	0.64	0.18	0	0.64	0.18	0
718792	5.8995	5.8995	100	100	0.5	0.15	0	0.5	0.15	0
718288	2.8125	2.8125	100	100	0.38	0.26	0.03	0.38	0.26	0.03
718882	3.6603	3.6603	100	100	0	0	0	0	0	0
718338	0.4491	5.292	100	100	0	0	0	0.17	0.15	0.03
719118	0.0027	2.0403	100	100	0	0	0	0	0	0.04
718834	2.9943	2.9943	100	100	0	0	0	0	0	0
718062	0.036	8.0676	100	100	0	0	0	0.22	0.11	0
718216	4.6404	8.685	100	100	0.21	0	0.04	0.22	0.08	0.04
718234	2.3391	10.8954	100	100	2.46	0.69	0.08	1.16	0.66	0.07
718938	13.0401	13.0401	100	100	0.27	0.08	0	0.27	0.08	0
718452	3.6702	3.6702	100	100	0.22	0.27	0	0.22	0.27	0

Variables in EVERY file

- COMID – the unique NHDPlus identifier
- Area for local catchment and watershed
- Coverage of the dataset – i.e. missing data

Variables for specific metrics

- Each metric shown at both:
  - Catchment scale
  - Watershed scale
  - Some at riparian buffer

Accessing and Using StreamCat Data

Advantage of current .csv delivery method:

- Simple, open, machine-readable format

Limitations of current .csv delivery method:

- Extra work to assemble all metrics or desired metrics for certain state / region
- Extra work to pull together a particular metric across states / regions
- Data difficult to ingest directly into models or applications

Accessing and Using StreamCat Data

Why a REST API?

A REST (Representational State Transfer) API (Application Programming Interface) is:

1. Lightweight – they rely on http standard and are format-agnostic
2. Independent – Client and server independent – data storage separate from UI and server
3. Scalable and flexible – separation of client and server allows easy scaling, developers can easily integrate REST APIs

Accessing and Using StreamCat Data

Example: We want fertilizer applied within catchment # 179

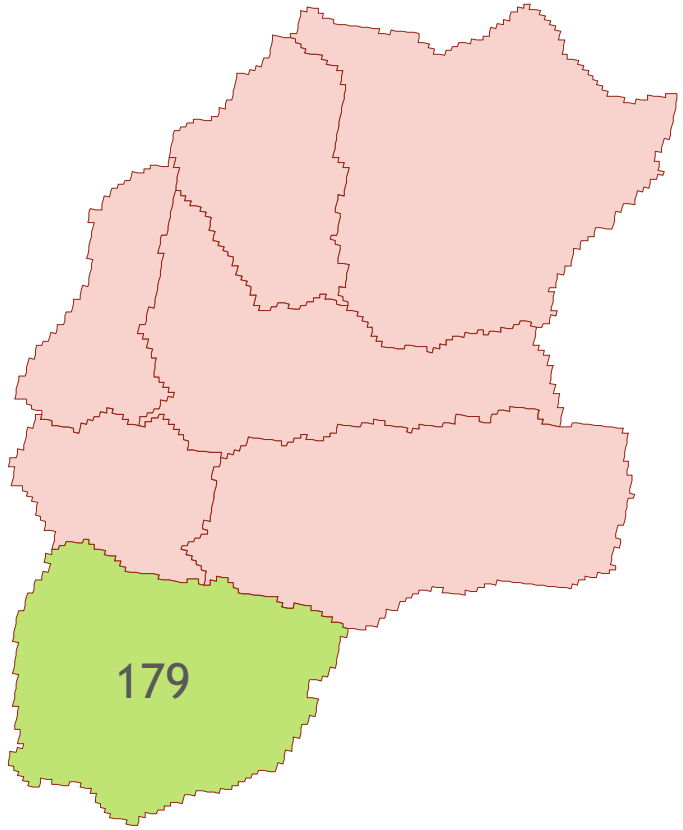
http://v26267mcpk506/StreamCat/v1/stable/metrics?name=fert&areaOfInterest=catchment&comid=179

The base URL of the service

The metric to return – Any StreamCat metric

The area of interest – can be:

- Catchment
- Watershed
- Riparian buffer



Accessing and Using StreamCat Data

Example: We want fertilizer applied within watershed # 179

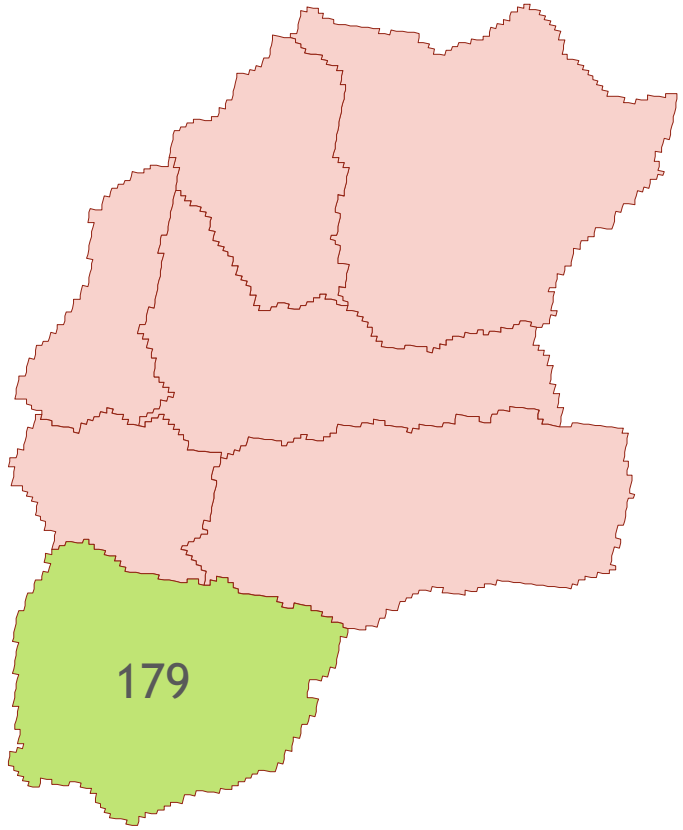
http://v26267mcpk506/StreamCat/v1/stable/metrics?name=fert&areaOfInterest=watershed&comid=179

The base URL of the service

The metric to return – Any StreamCat metric

The area of interest – can be:

- Catchment
- Watershed
- Riparian buffer



Accessing and Using StreamCat Data

Example: We want percent urban for CONUS

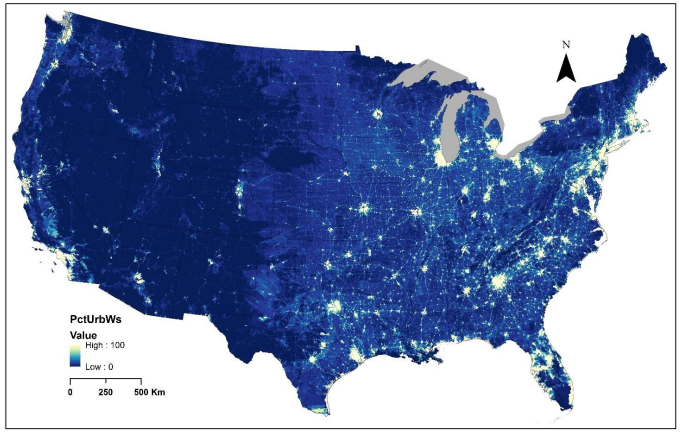
http://v26267mcpk506/StreamCat/v1/stable/metrics?name=pcturbmd2019&conus=true

The base URL of the service

The metric to return – Any StreamCat metric

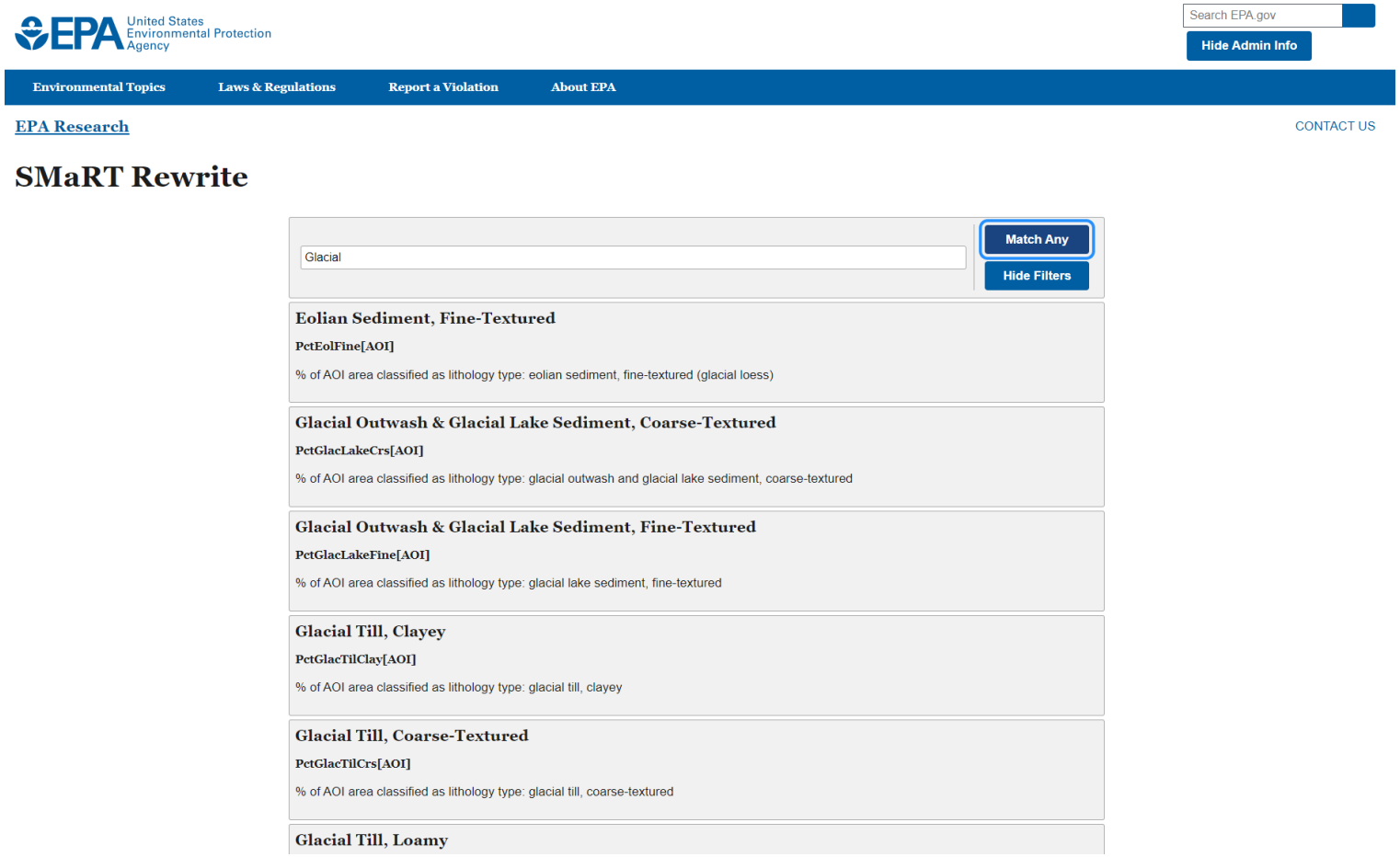
Staged geography – Available options are:

1. Conus
2. State
3. County
4. NHDPlus hydroregion



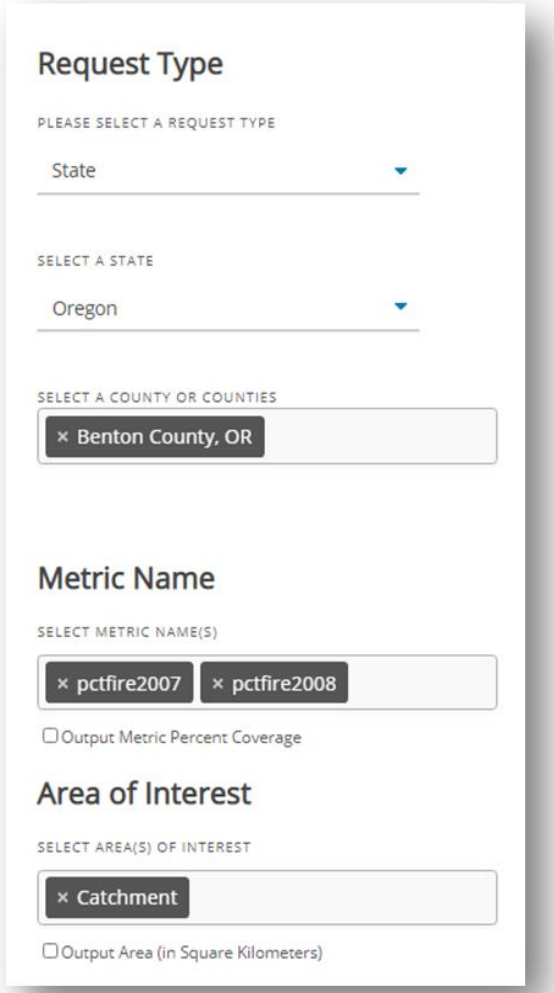
Accessing and Using StreamCat Data

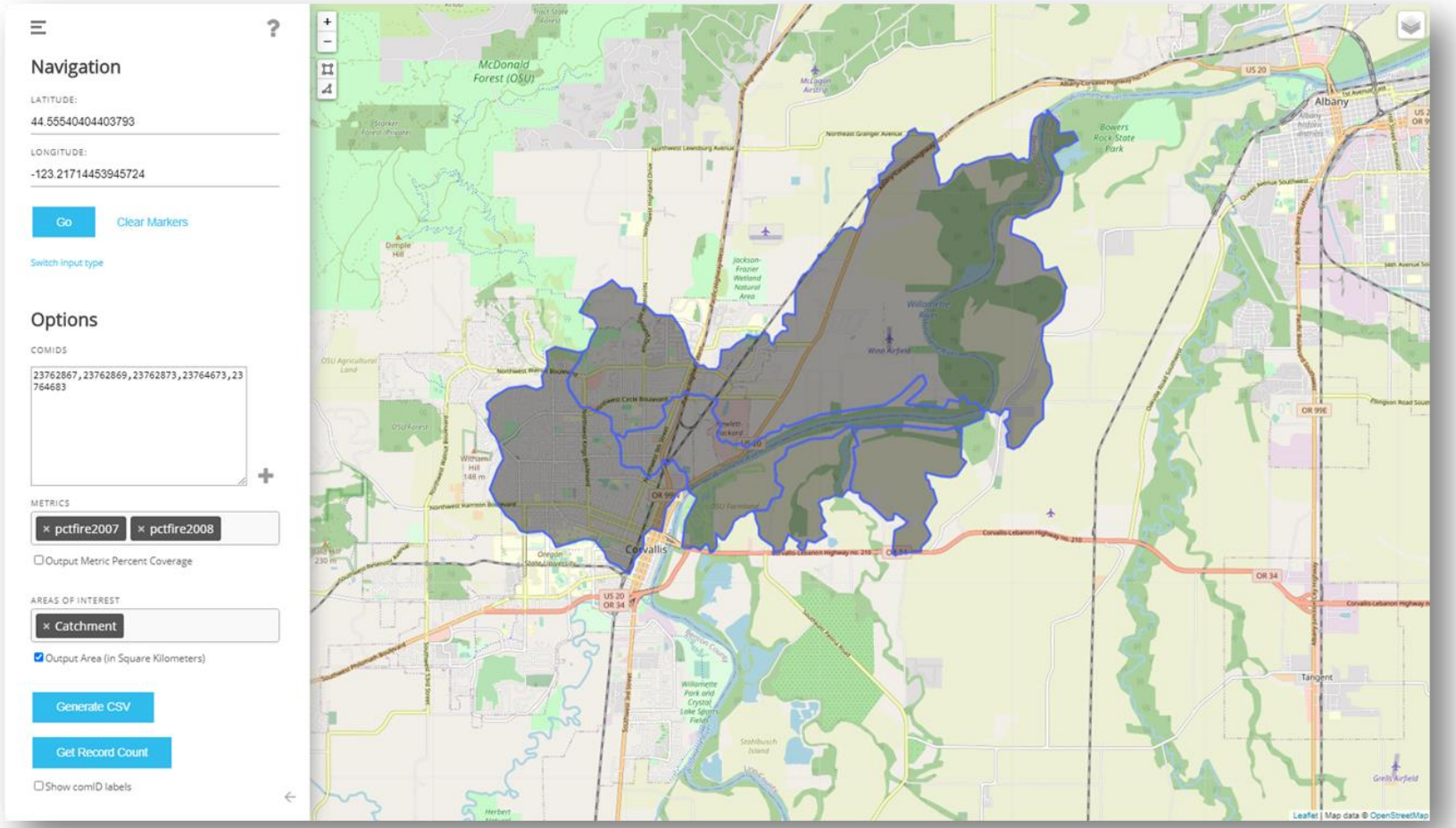
Accessing using REST API –
Search for a particular metric and get details



Accessing and Using StreamCat Data

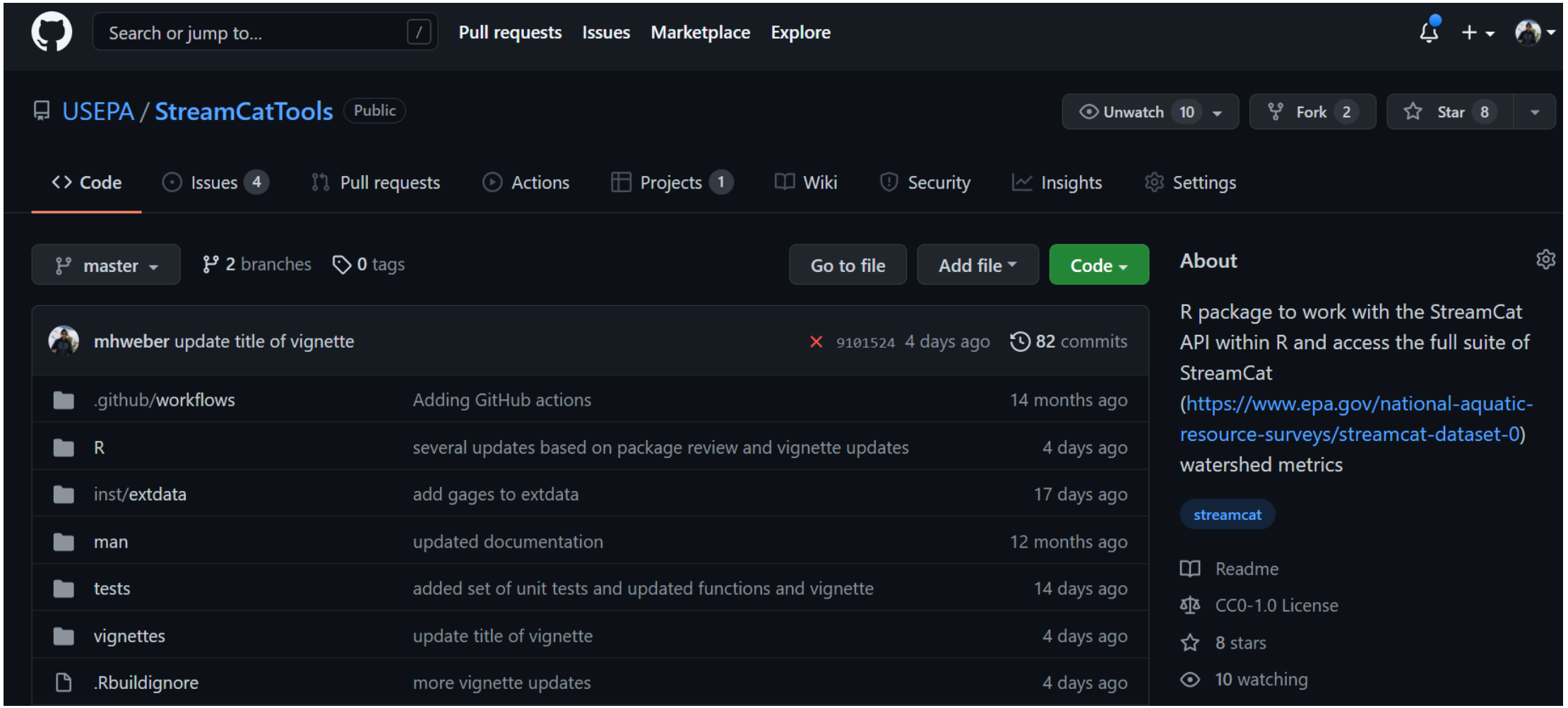
Web Tool and Web Map API Interface





Accessing and Using StreamCat Data

StreamCatTools R Package



Accessing and Using StreamCat Data

StreamCatTools R Package

- 0.1 Installing and loading StreamCatTools
- 0.2 Background
- 0.3 Example One
- 0.4 Example Two
- 0.5 Example Three
- 0.6 Example Four
- 0.7 Example Five
- 0.8 Example Six
- 0.9 Example Seven
- 0.10 Example Eight

Introduction

Marc Weber

0.1 Installing and loading StreamCatTools

To install, currently you need to install from GitHub using devtools

After installing load the library

0.2 Background

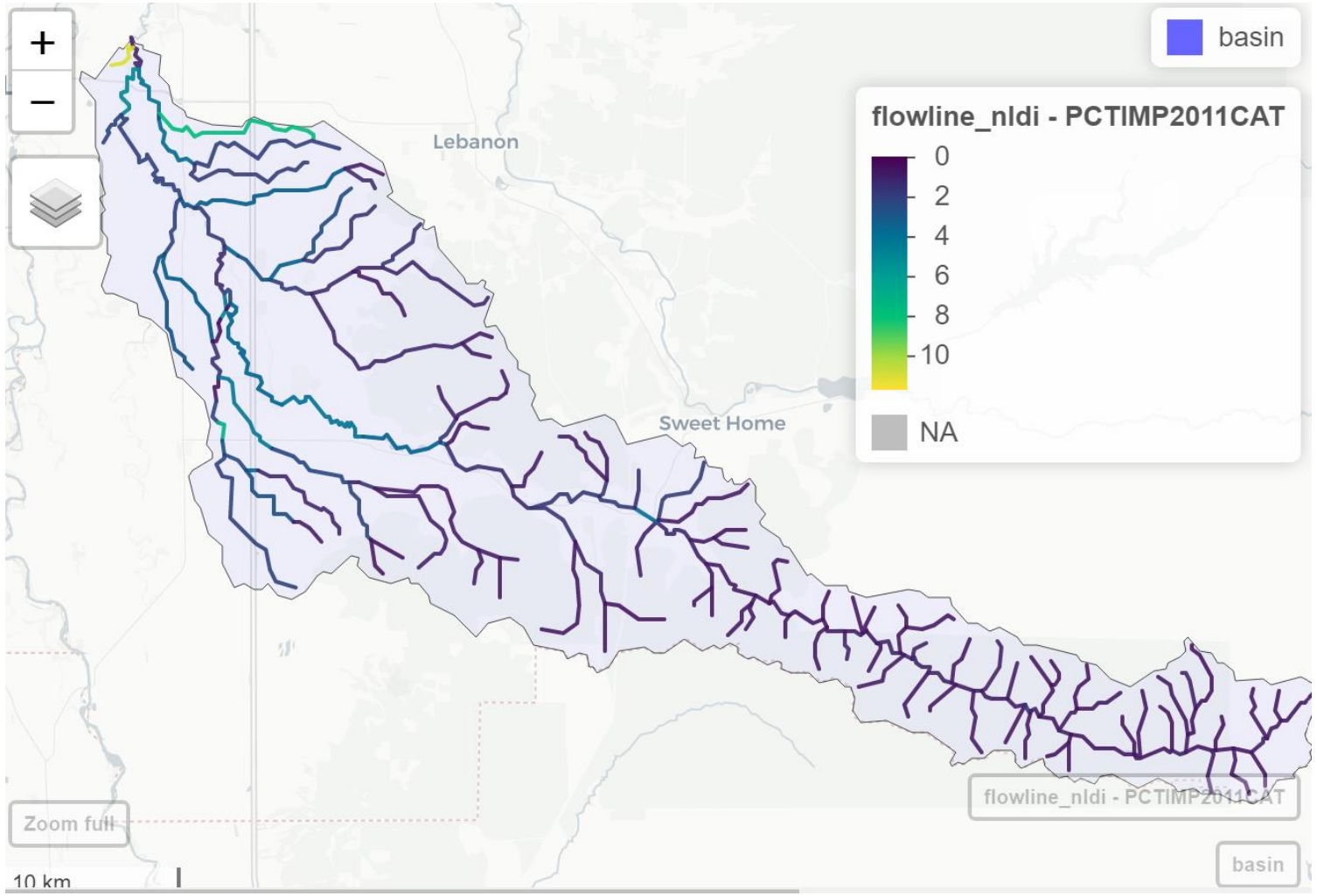
The `StreamCatTools` package was designed to simplify the use of StreamCat data in R, leveraging the new API for StreamCat.

0.2.1 StreamCat API

We can actually pull data into R from the StreamCat API by simply using the `read_csv` function from the `readr` package. We have to hard-wire parameters and are limited in the number of records returned through a `GET` request.

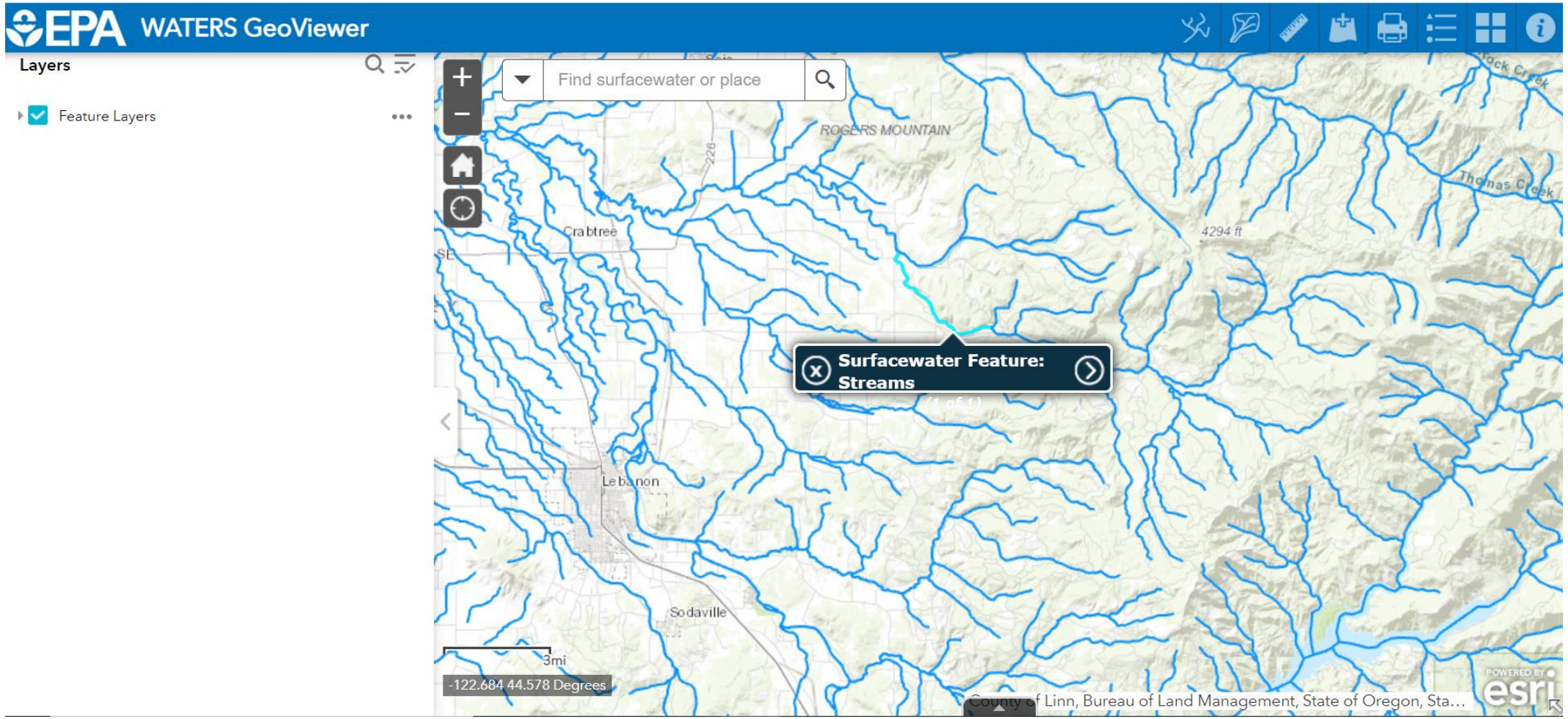
Accessing and Using StreamCat Data

StreamCatTools R Package



Accessing and Using StreamCat Data

WATERS GeoViewer



Accessing and Using StreamCat Data

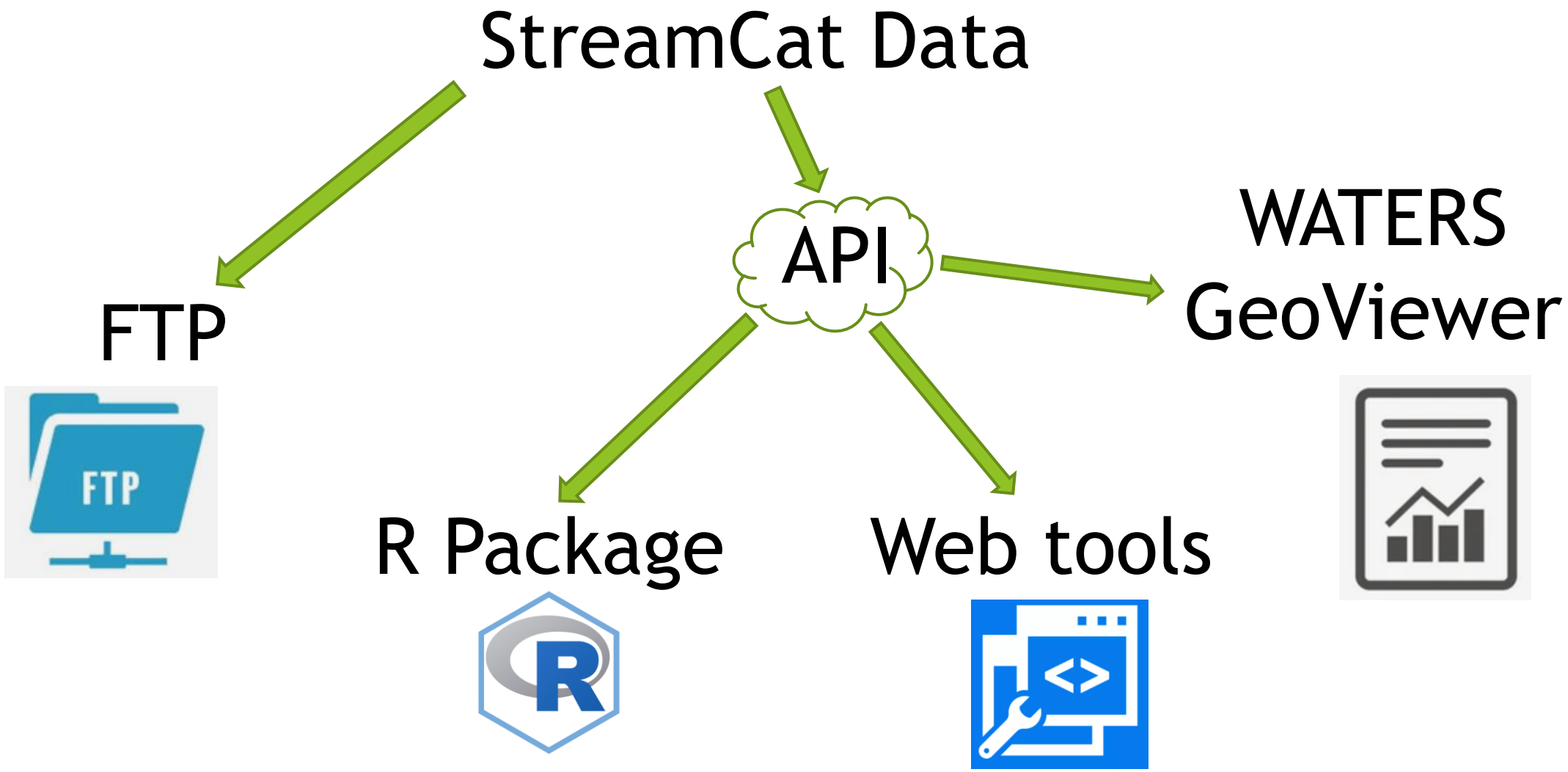
Waters Watershed Report Characterization - StreamCat

2006 National Land Cover Database Impervious Surfaces	Value	AOI Percent Covered*
Mean imperviousness of anthropogenic surfaces within catchment.	0.29%	100.00%
Mean imperviousness of anthropogenic surfaces within watershed.	0.02%	100.00%

Mine Density Active Mines and Mineral Plants in the US	Value	AOI Percent Covered*
Density of georeferenced mines and mineral plants within the local catchment.	0 sites/km²	100.00%
Density of georeferenced mines and mineral plants within the upstream watershed.	0 sites/km²	100.00%

National Anthropenic Barrier Dataset	Value	AOI Percent Covered*
Density of georeferenced dams within the local catchment (dams/square km).	0 dams/km²	100.00%
Density of georeferenced dams within the total upstream watershed (dams/square km).	0 dams/km²	100.00%
Mean NID storage volume of all dam reservoirs (NID_STORA in NID) within the local catchment (cubic meters/square km).	0 m³/km²	100.00%
Mean NID storage volume of all dam reservoirs (NID_STORA in NID) within the total upstream watershed (cubic meters/square km).	0 m³/km²	100.00%
Mean normal storage volume of all dam reservoirs (NORM_STORA in NID) within the local catchment (cubic meters/square km).	0 m³/km²	100.00%
Mean normal storage volume of all dam reservoirs (NORM_STORA in NID) within the total upstream watershed (cubic meters/square km).	0 m³/km²	100.00%

Accessing and Using StreamCat Data

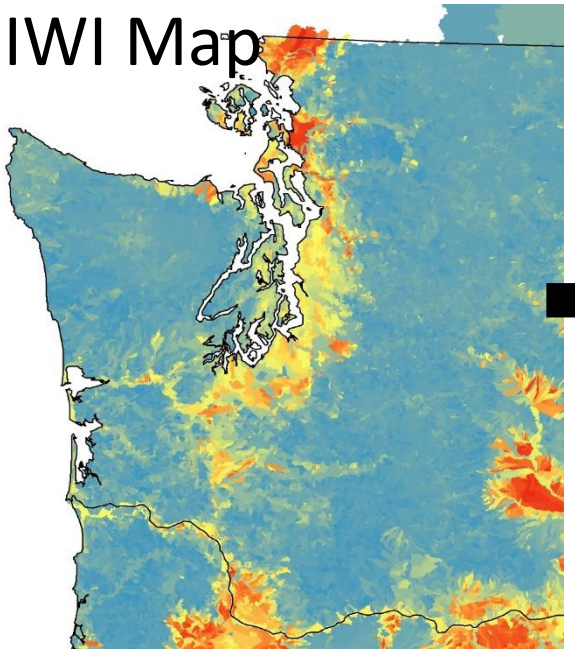


Conclusions

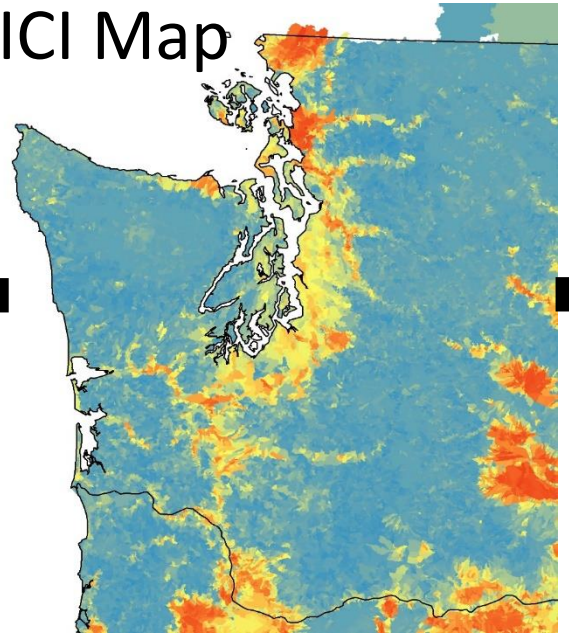
- StreamCat and ICI/IWI available for 2.6 million streams segments of the U.S.
- IWI/ICI + additional information can help to understand and prioritize stream conservation actions
- Accessibility to StreamCat, ICI/IWI + hundreds of other metrics will greatly expand very soon

Questions?

IWI Map



ICI Map



Stream Biological Condition