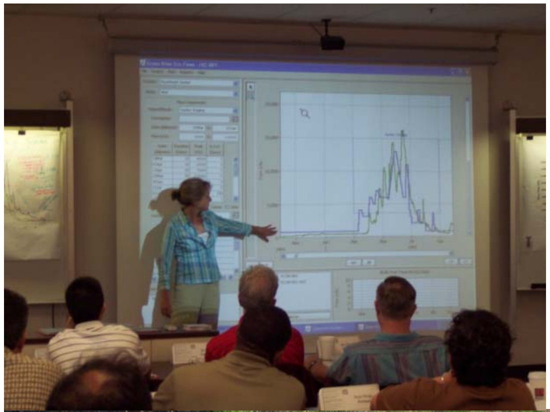
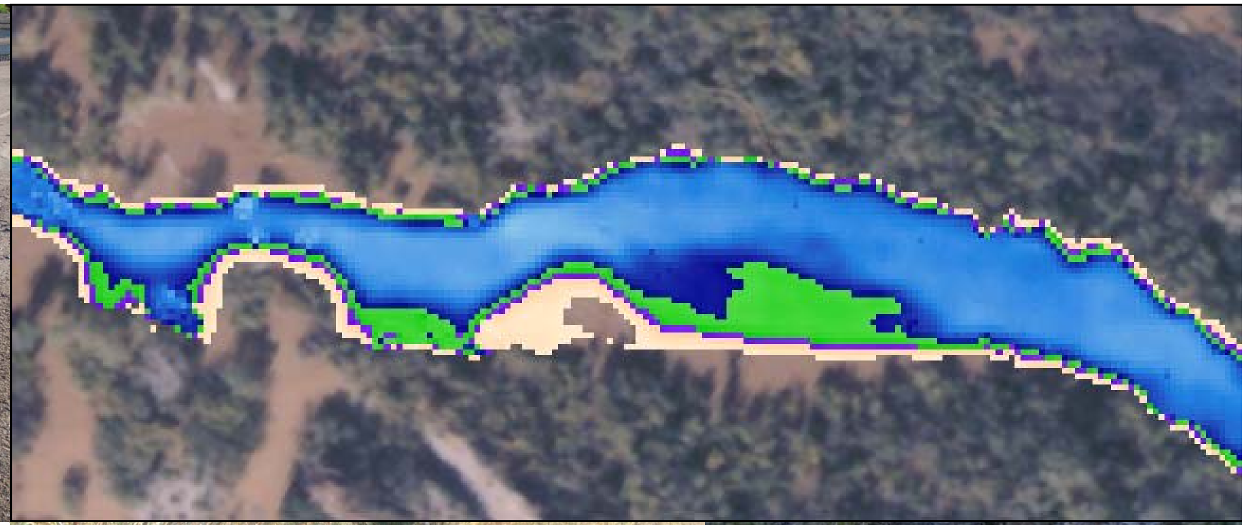


HEC-EFM and GeoEFM
Tools for restoration planning

John Hickey, HEC



Outline

<u>Concepts: Let's think about…</u>

- Ecosystems associated with rivers and wetlands
- Human influences
- Hydrographs

<u>Intro for Ecosystem Functions Model</u>

- How does EFM allow users to investigate hydrographs?

Outline

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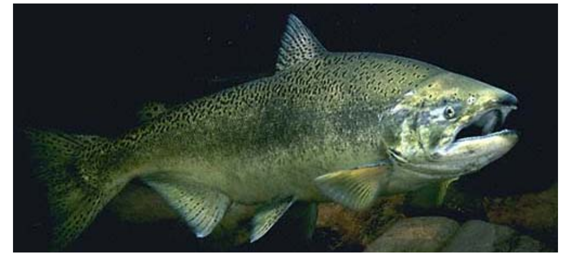
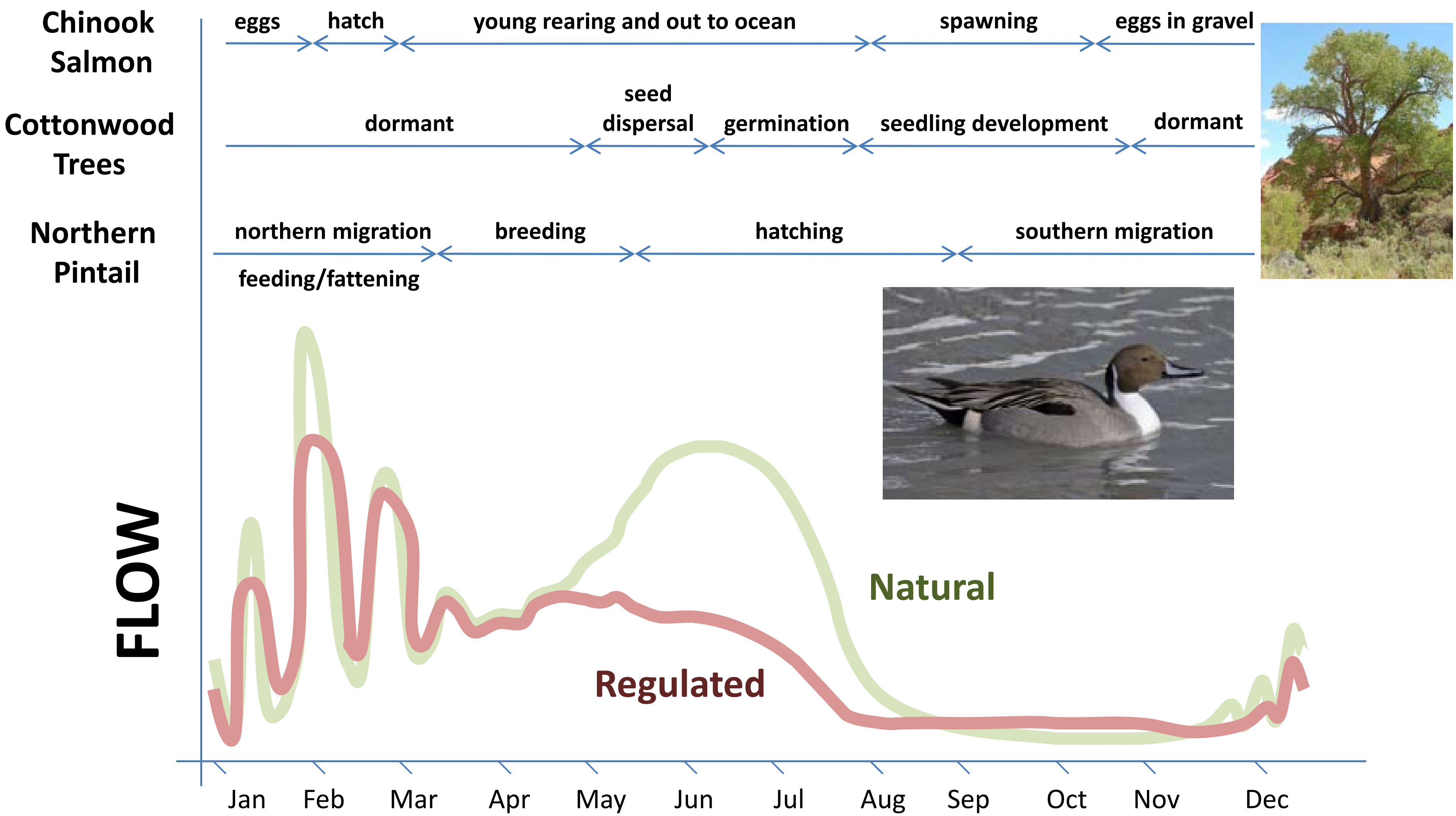
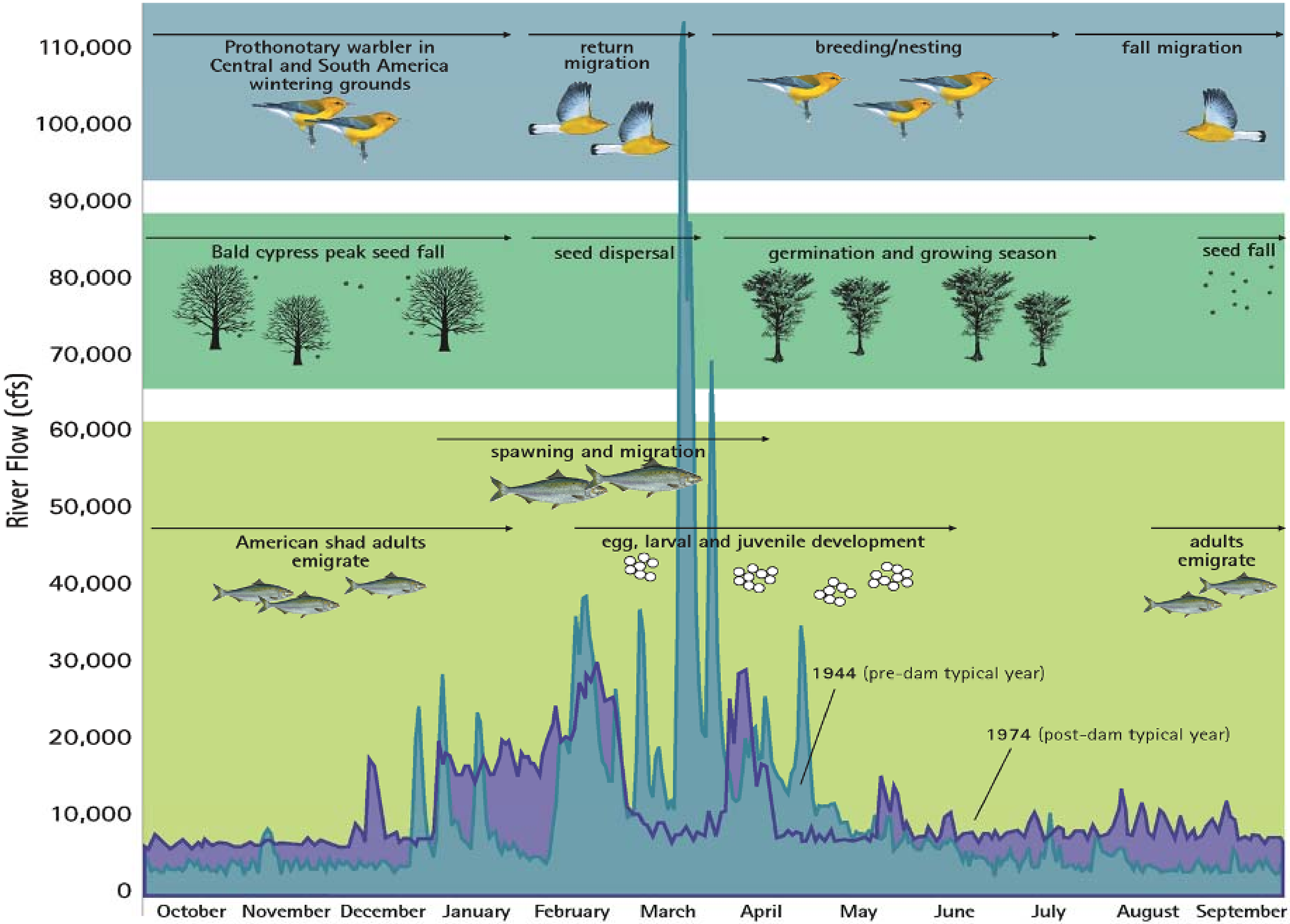
Hydrology and Ecology

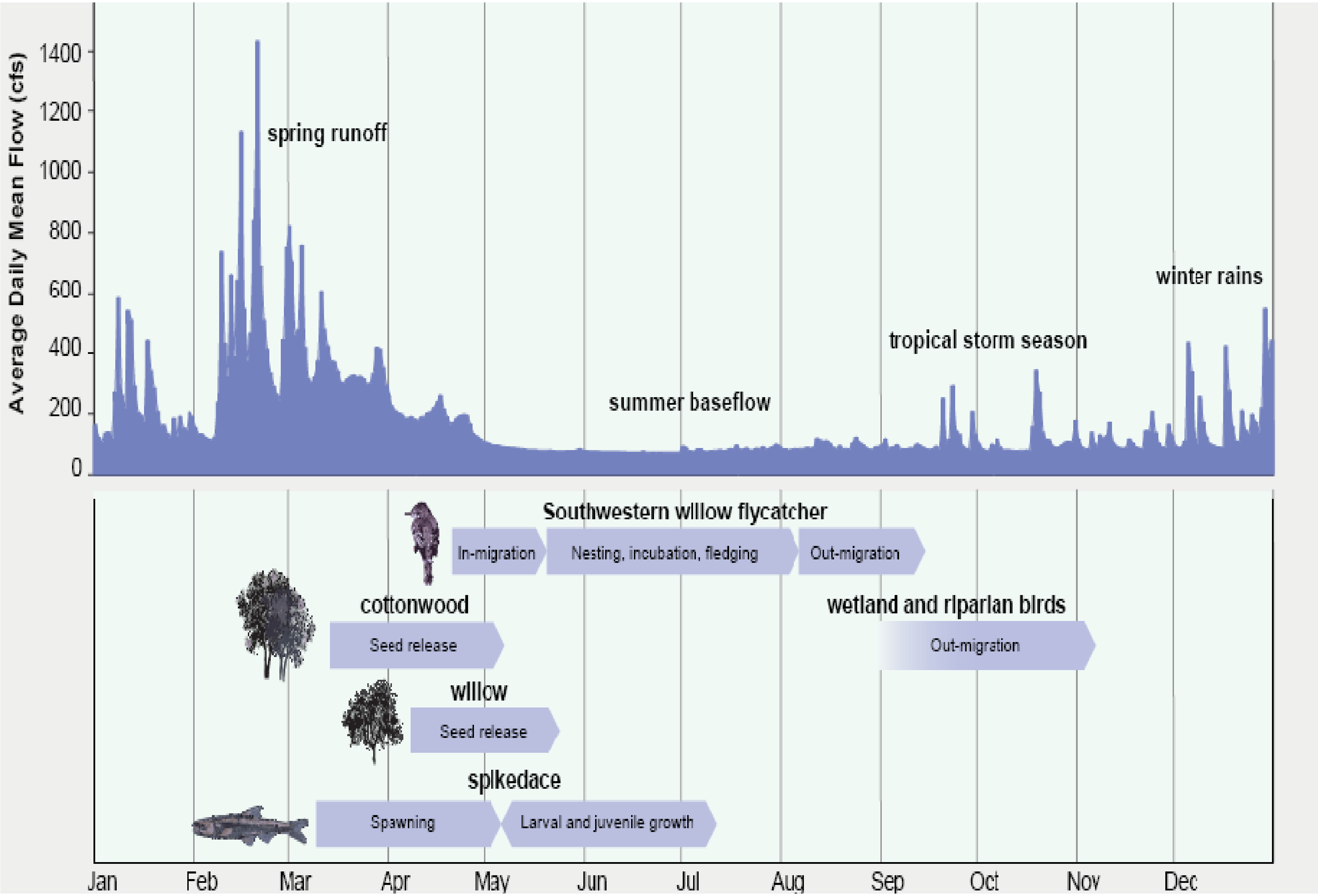




Ecological Model of the Savannah River



Model for a Southwestern River Ecosystem



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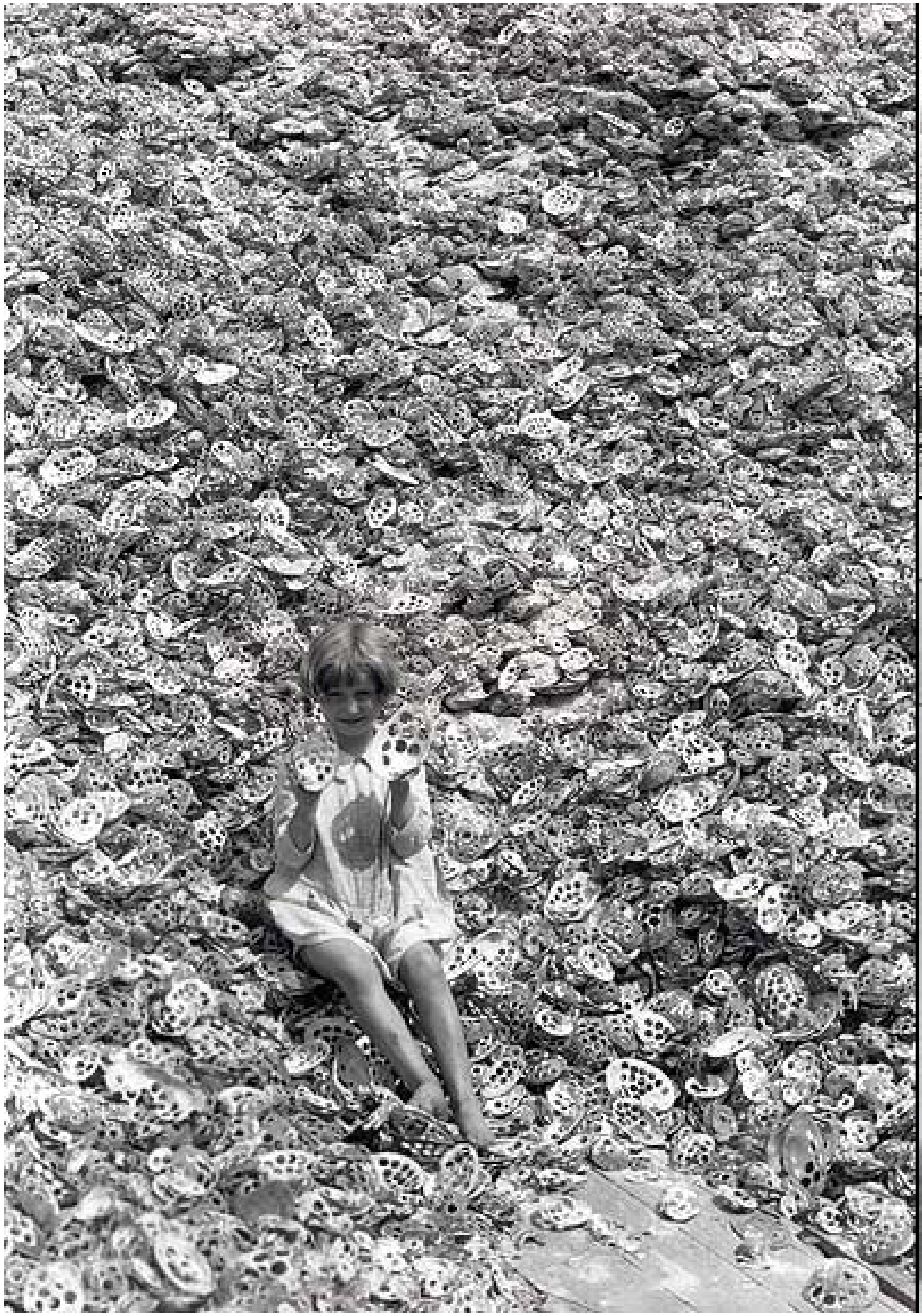
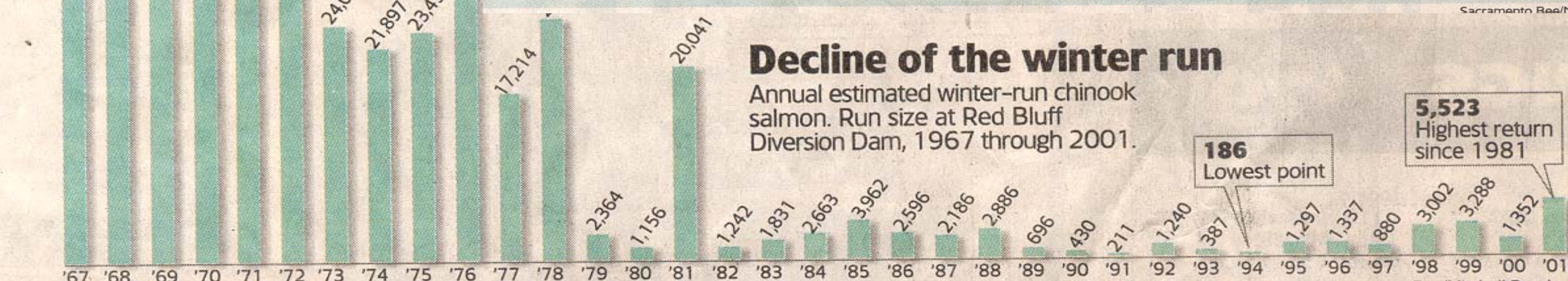
Water Quality



Winter-run salmon coming back

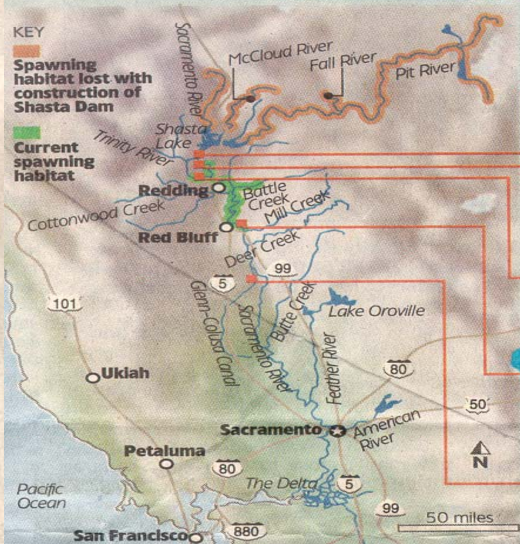


"Is this a success story? I suppose so. … (But) there's still a lot more to be done, and it took a long time to get here."

Dan Frost

Redding attorney who advocates for salmon and other fish in the Sacramento River

MAJOR PROJECTS



Winter-run salmon almost went extinct in the early 1990s. Since then, federal and state agencies have spent more than $200 million to help revive this species, as well as other fish that spawn in the upper Sacramento River.

Shasta Dam: $80 million
Using underwater robots, engineers added a temperature control device that allows cold water to be released from varying depths of Lake Shasta. The device helps ensure that salmon downstream have the ideal water temperatures to spawn – lower than 57 degrees.

Livingston Stone National Fish Hatchery: $900,000
To jump-start the numbers of winter-run salmon, the federal government built an emergency hatchery at the base of Shasta Dam in 1997. Each year, the hatchery raises and releases more than 100,000 winter-run fingerlings, some of which are now returning to the upper Sacramento after three years at sea.

Iron Mountain Mine: $30 million
Some of the world's most acidic water washes from this ripped-apart mountain during heavy rains. To prevent this waste from flushing into the river and killing fish, private contractors, under direction from the U.S. Environmental Protection Agency, built a new treatment plant in 1994. It now neutralizes 90 percent of the mine's caustic runoff.

Red Bluff Diversion Dam: $20 million
Since 1966, this 752-foot-wide dam has spanned the Sacramento River, shunting water into the Tehama-Colusa irrigation canal and blocking 40 miles of habitat for migrating fish. The U.S. Bureau of Reclamation now keeps the dam's 11 gates open from September through May, and is considering building a pumping plant for the canal, so the gates can stay up year-round. It has also improved fish screens at the dam.

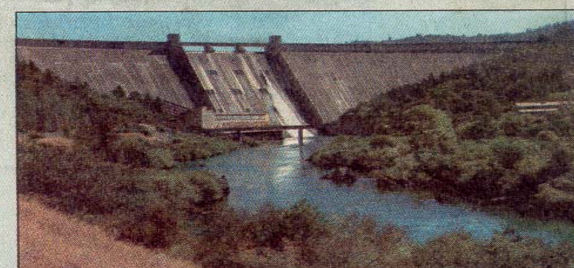
Glenn-Colusa fish screens: $75 million
Starting in the 1930s, pumps that diverted water from the river to Glenn-Colusa Irrigation District killed millions of young salmon. Four years ago, the district obtained federal and state money to help it install improved fish screens on the pumps.

Winter-run salmon

Winter-run chinook salmon are unique to the Sacramento River, and differ from other salmon in several ways.

	Winter-run salmon	Fall-run salmon
Peak migration upriver	March	September
Peak spawning period	May – June	October-November
Typical spawning age	3 years	4 years
Peak migration of young salmon to sea	September	January-March
Status	Endangered	Not listed

Sources: U.S. Bureau of Reclamation; U.S. Environmental Protection Agency; California Department of Fish and Game; National Marine Fisheries Service; U.S. Fish and Wildlife Service



Sacramento Bee/Chris Crewell

Shasta Dam at Shasta Lake

Sacramento Bee/Mitchell Brooks

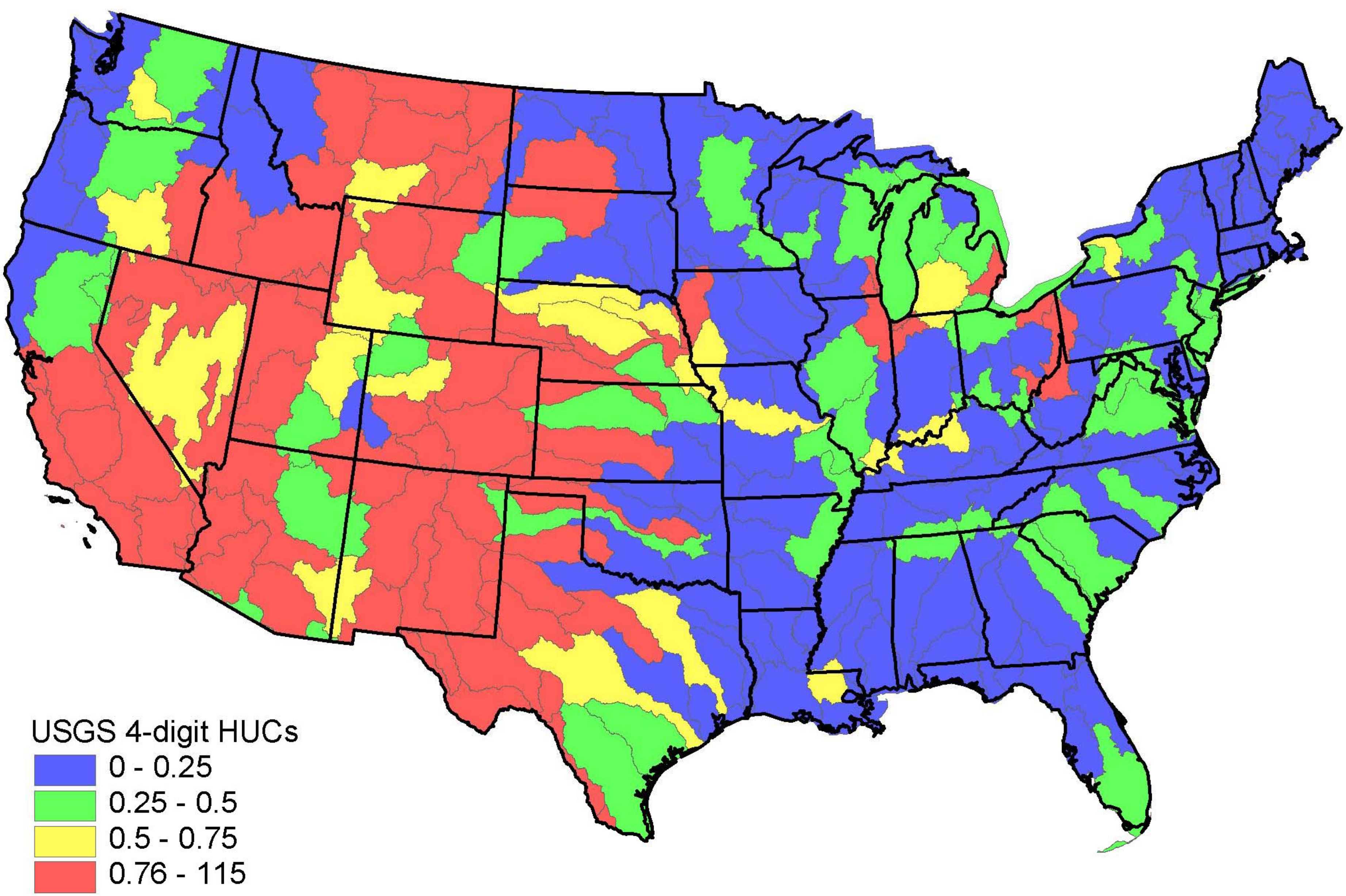
Decline of the winter run

Annual estimated winter-run chinook salmon. Run size at Red Bluff Diversion Dam, 1967 through 2001.

Source: California Department of Fish and Game

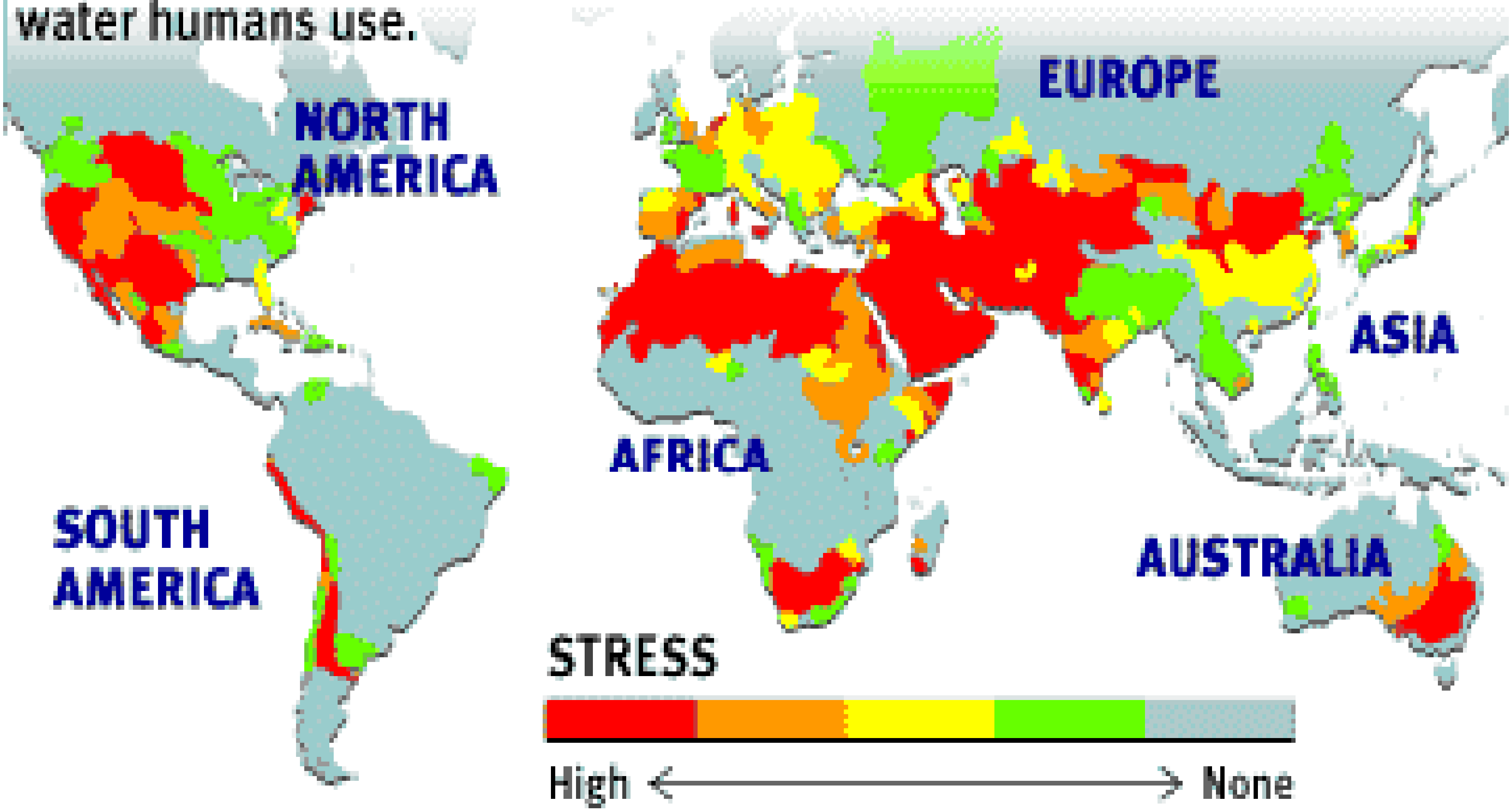
Sacramento Bee/Mitchell Brooks

Water Development in United States



Ratio of water consumed relative to annual average surface flow

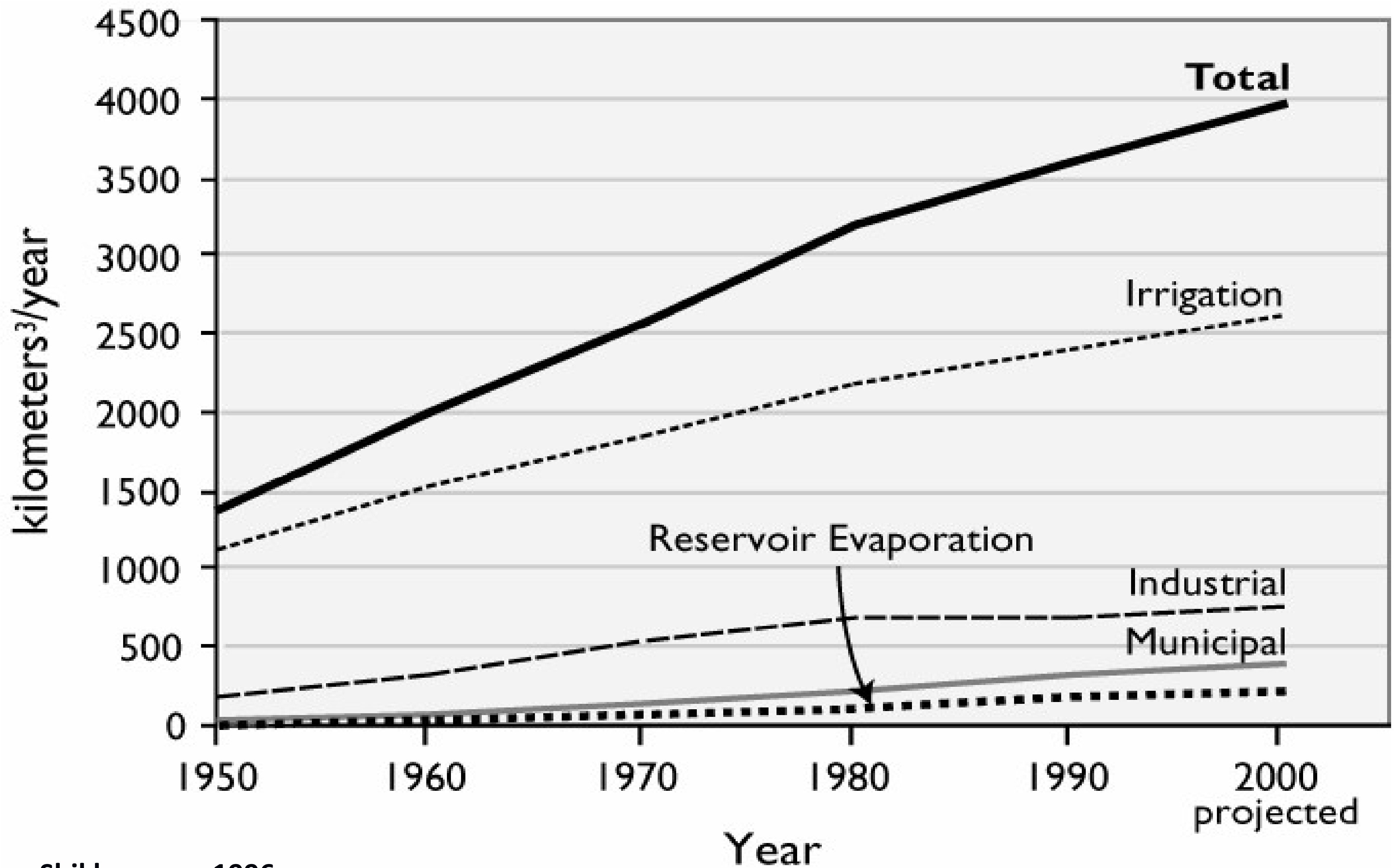
Stressed out This map shows stress on the world's major river basins, comparing the amount of water available to the amount of water humans use.



SOURCE: World Commission on Water in the 21st Century

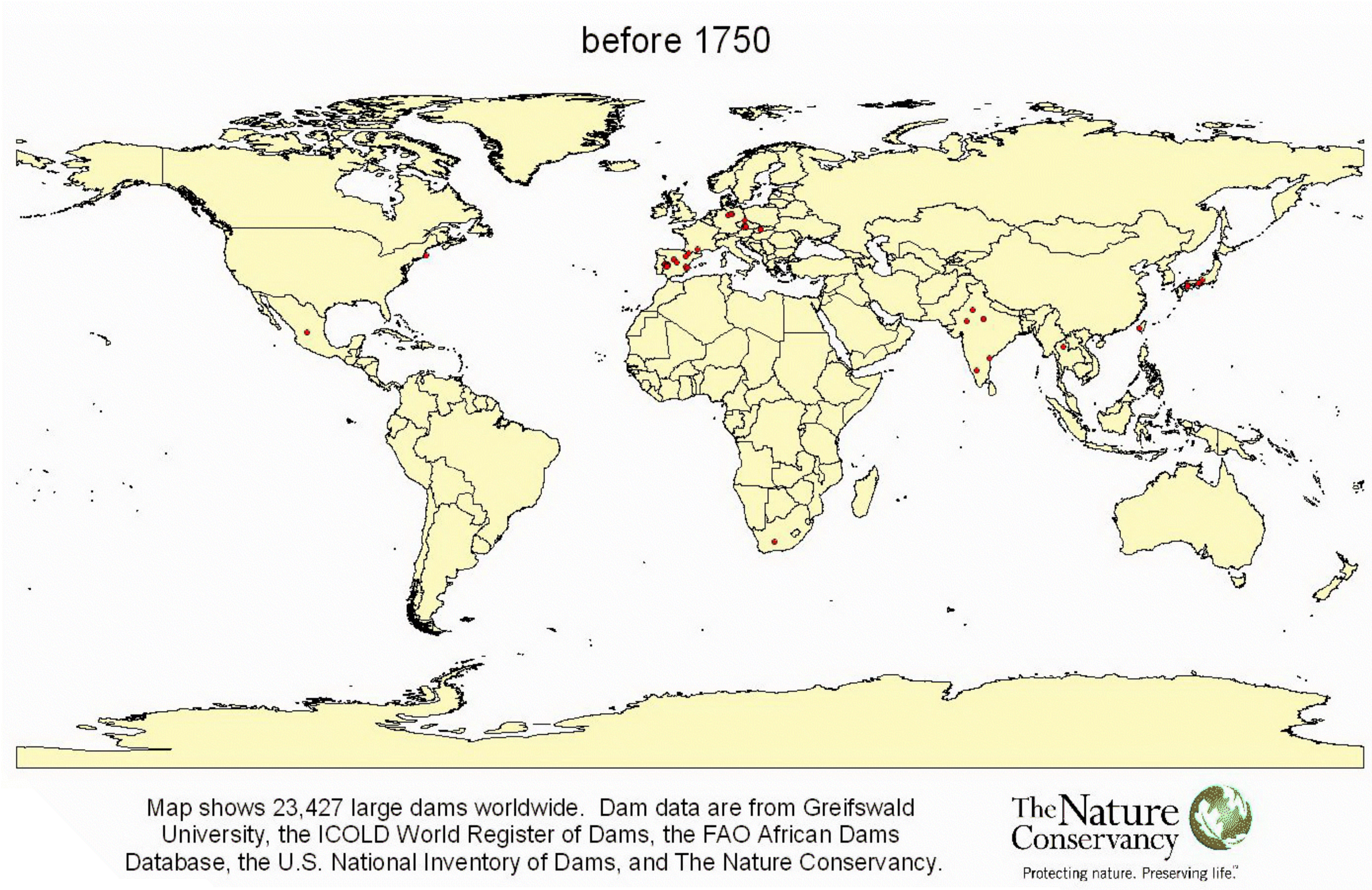
MSNBC

Global Water Consumption

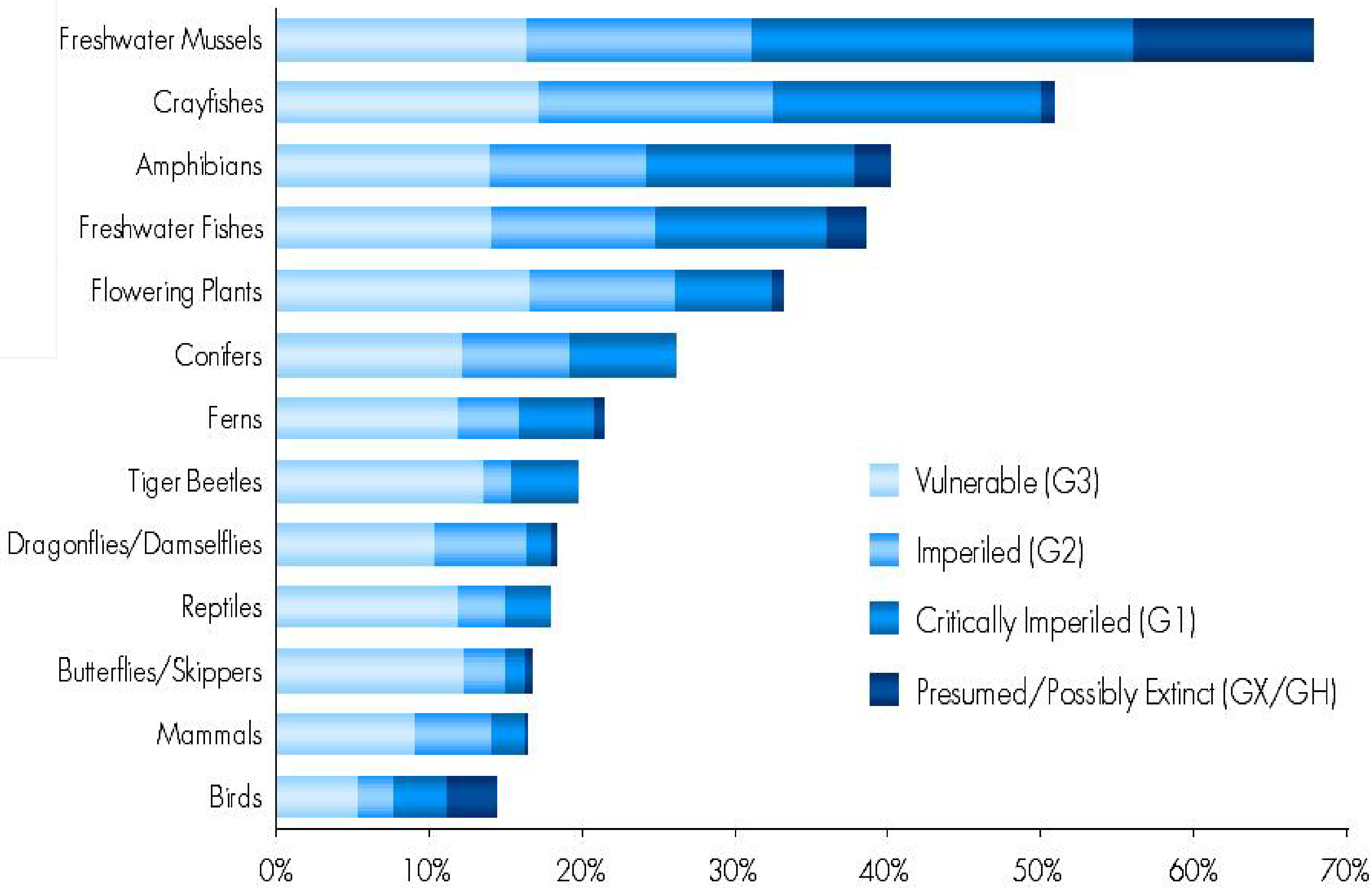


Shiklomanov 1996

The History of Global Dam Development



Proportion of U.S. Species at Risk



<u>Source</u>: *Precious Heritage* (TNC 2000)

Outline

<u>Concepts: Let's think about…</u>

- Ecosystems associated with rivers and wetlands
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- Hydrographs

<u>Intro for Ecosystem Functions Model</u>

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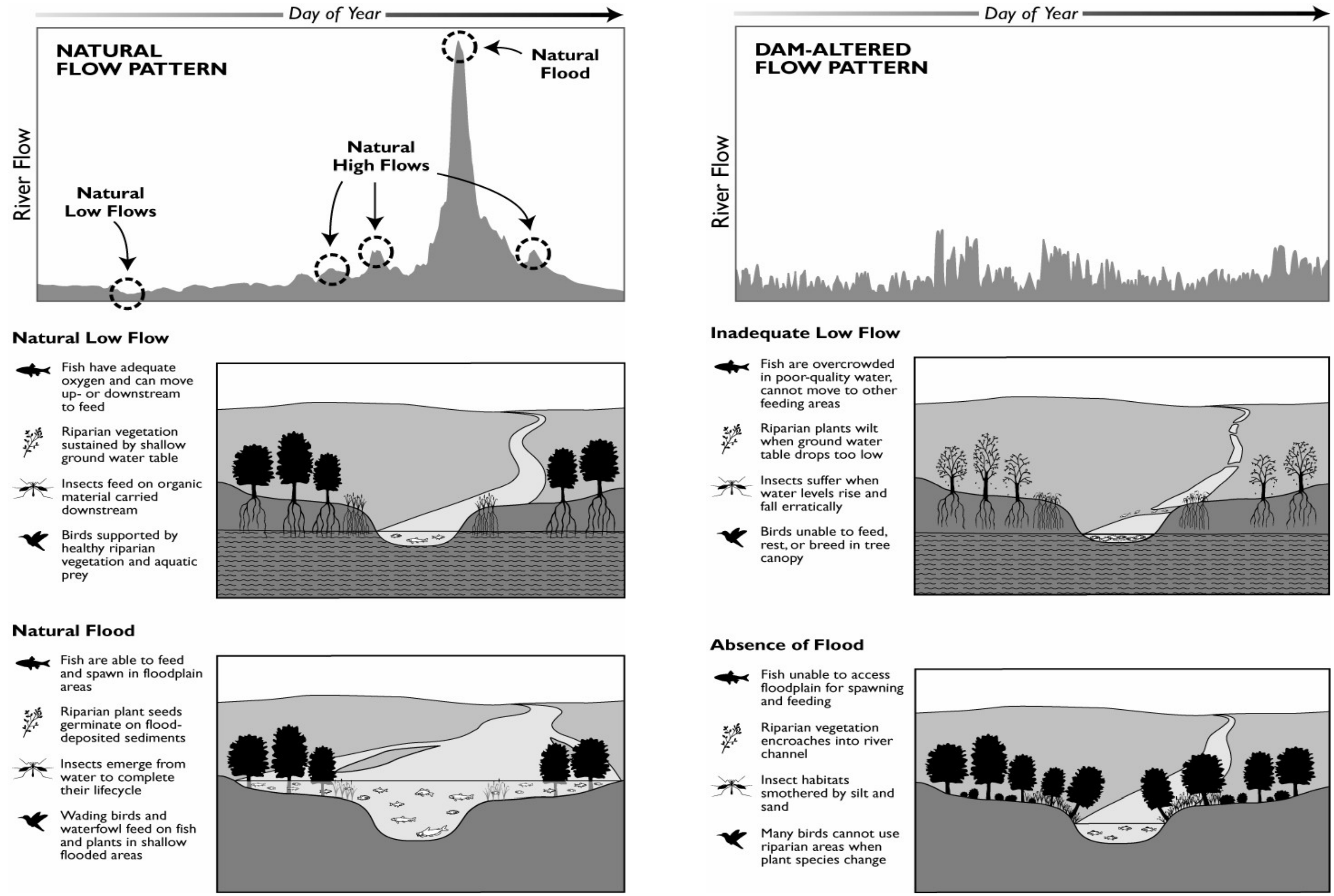
Connections between Flow and Ecology



Postel and Richter, 2003.

Getting into EFM…

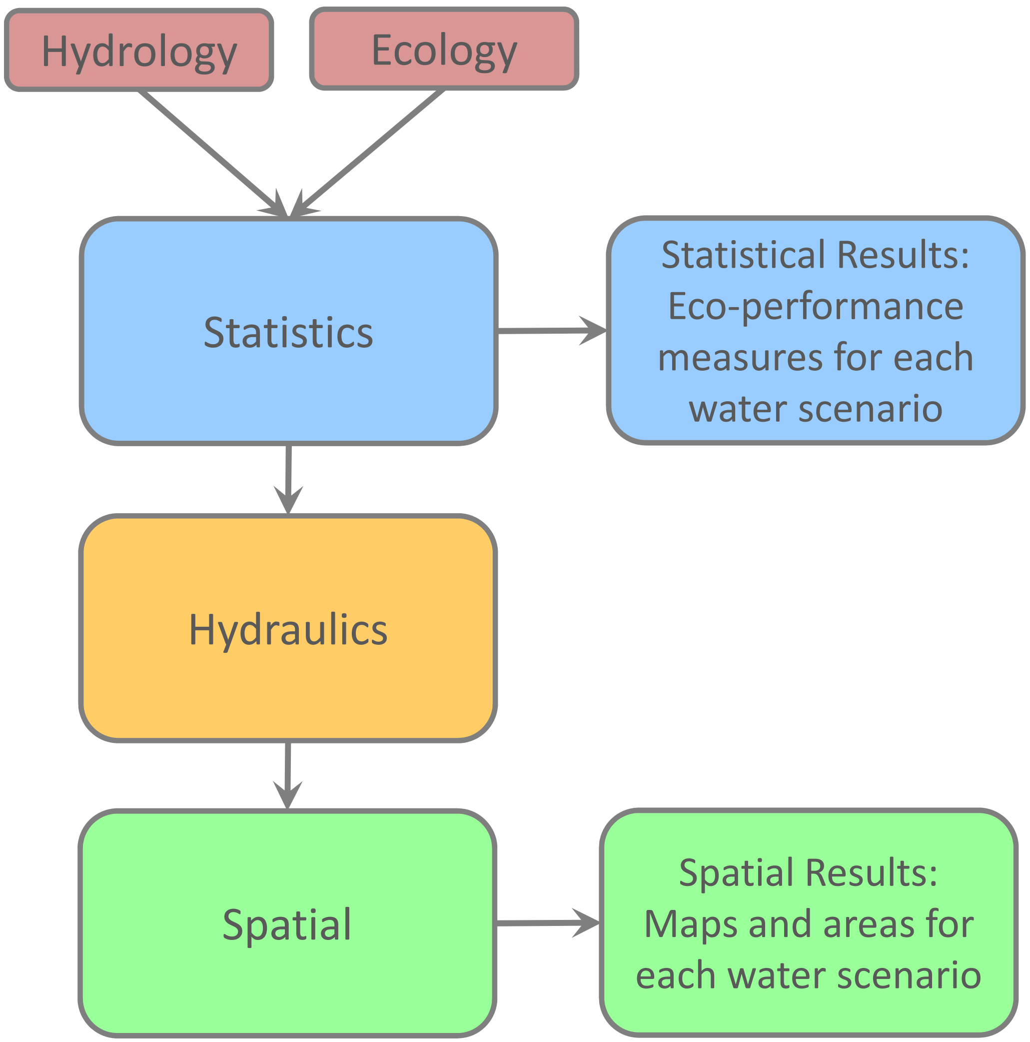
Key points so far

- Ecosystems evolve in concert with hydrologic patterns
- Humans alter natural hydrologic patterns
- If understood, connections between ecology and hydrology can be used to help guide water and ecosystem management

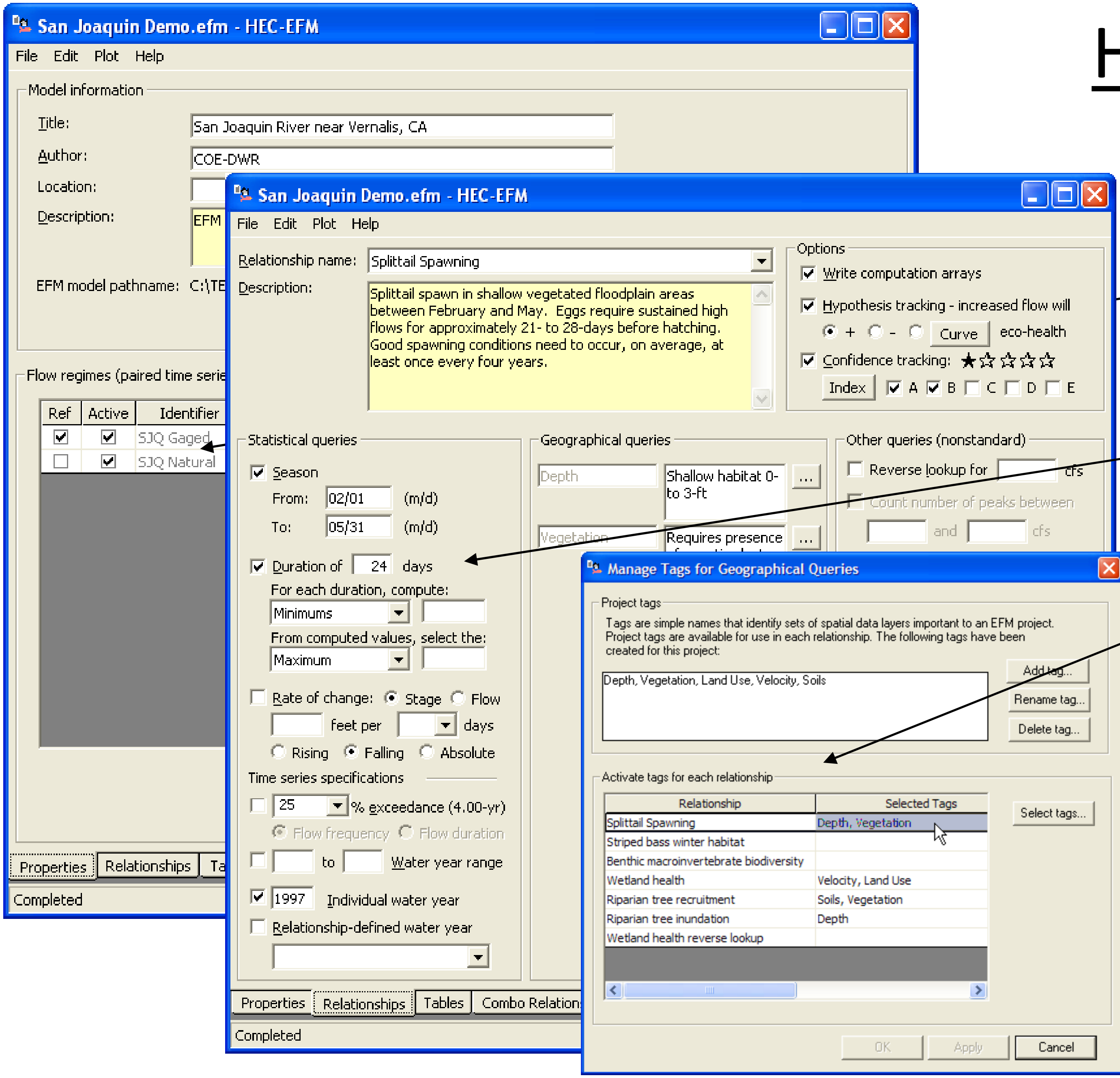
Intro for Ecosystem Functions Model

- How does EFM allow users to look at hydrographs?

Ecosystem Functions Model (EFM) Process



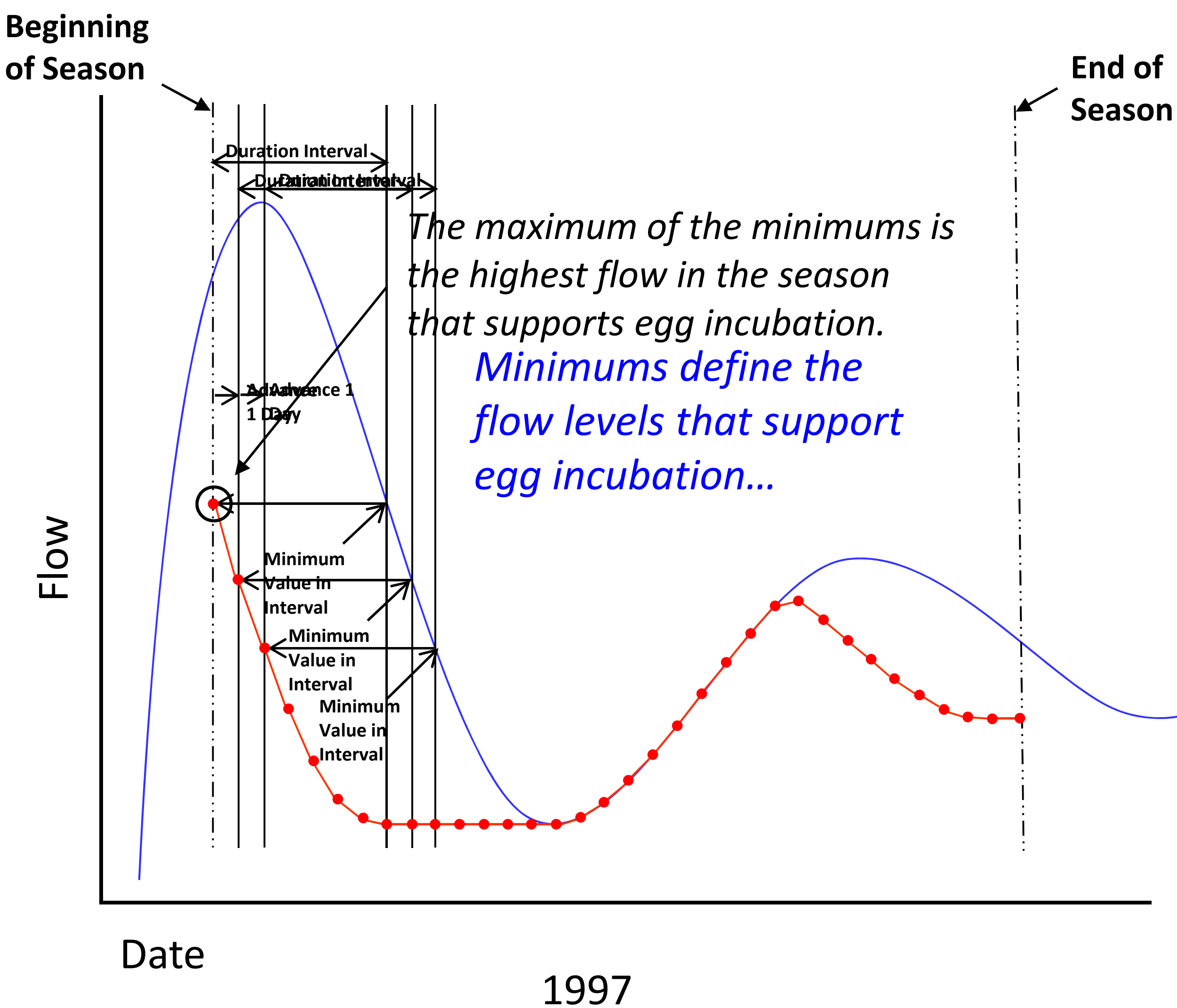
HEC-EFM



- Analyze up to ~37,000 flow regimes at once
- User-defined stats link hydro and ecology
- Geo queries add spatial aspects to relationships

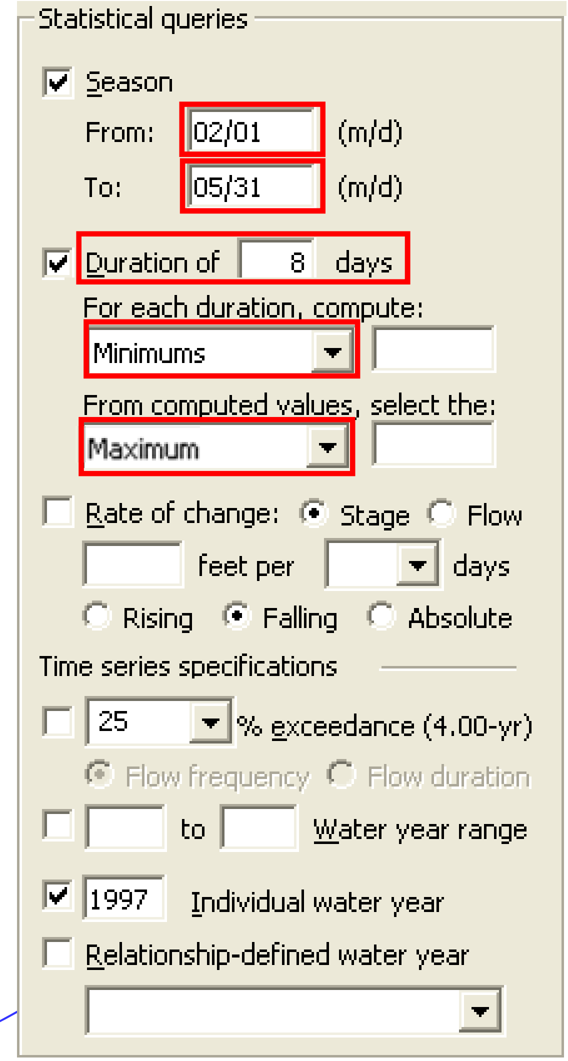
Helps determine eco-responses to changes in river and wetland flow regimes…

EFM Math: Splittail Spawning

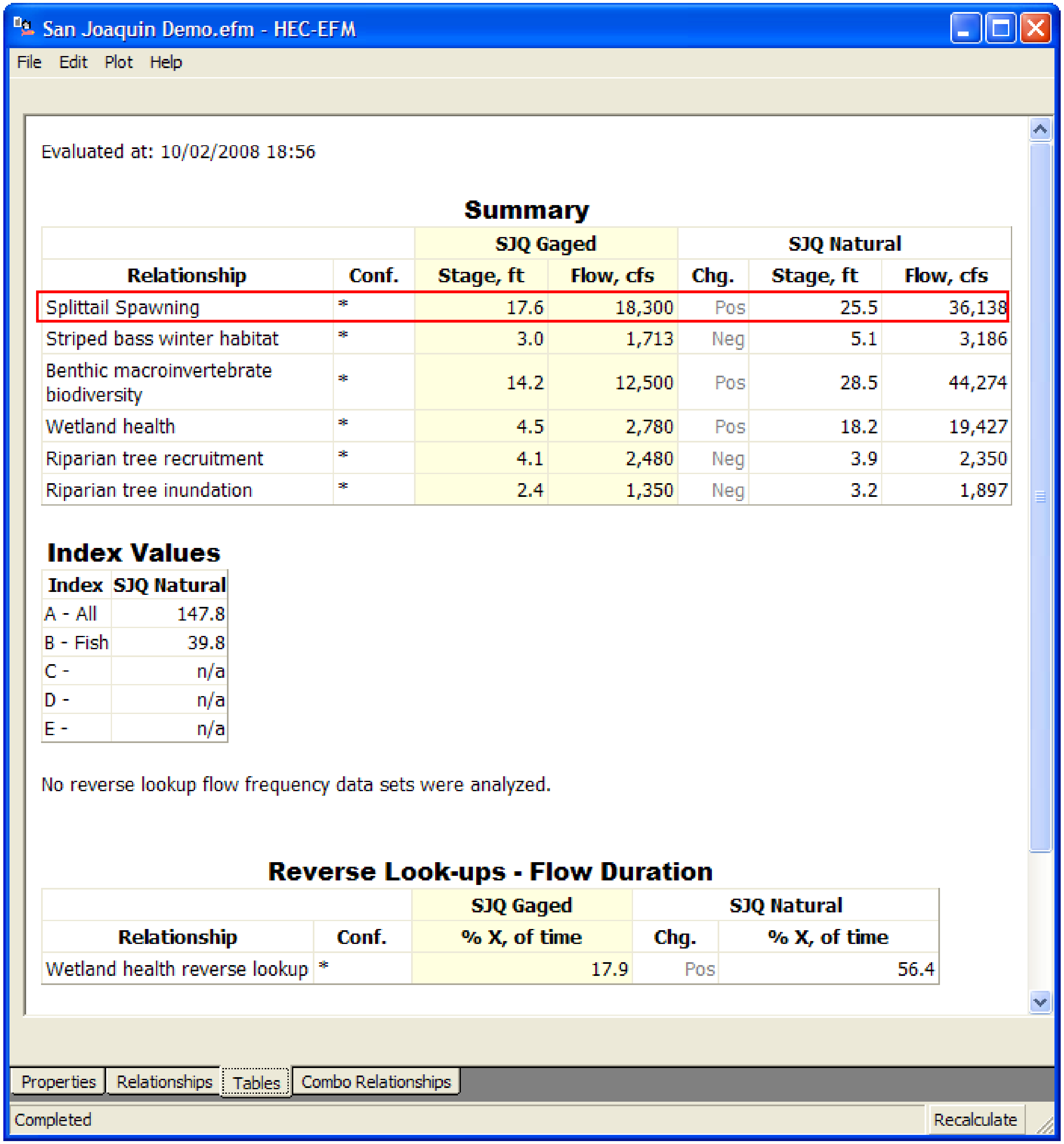


The maximum of the minimums is the highest flow in the season that supports egg incubation.

Minimums define the flow levels that support egg incubation…



Feature has been used for fish spawning and vegetation drowning…



Evaluated at: 10/02/2008 18:56

Summary

		SJQ Gaged		SJQ Natural		
Relationship	**Conf.**	**Stage, ft**	**Flow, cfs**	**Chg.**	**Stage, ft**	**Flow, cfs**
Splittail Spawning	*	17.6	18,300	Pos	25.5	36,138
Striped bass winter habitat	*	3.0	1,713	Neg	5.1	3,186
Benthic macroinvertebrate biodiversity	*	14.2	12,500	Pos	28.5	44,274
Wetland health	*	4.5	2,780	Pos	18.2	19,427
Riparian tree recruitment	*	4.1	2,480	Neg	3.9	2,350
Riparian tree inundation	*	2.4	1,350	Neg	3.2	1,897

Index Values

Index	SJQ Natural
A - All	147.8
B - Fish	39.8
C -	n/a
D -	n/a
E -	n/a

No reverse lookup flow frequency data sets were analyzed.

Reverse Look-ups - Flow Duration

		SJQ Gaged	SJQ Natural	
Relationship	**Conf.**	**% X, of time**	**Chg.**	**% X, of time**
Wetland health reverse lookup	*	17.9	Pos	56.4

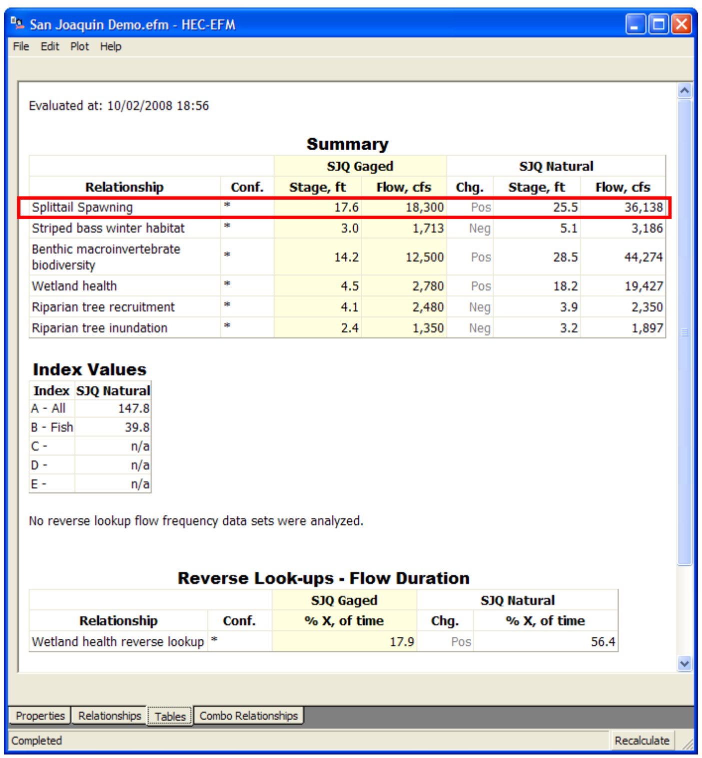
HEC-EFM

- Uses daily time series of flow and stage
- Computes statistics that are eco-relevant (as defined by users)
- Compare management scenarios for multiple eco-relationships

Statistical results investigated spatially with hydraulic models and GIS…

HEC-EFM - from Statistical to Spatial…

- Statistical results are input to hydraulic models to develop:
  - *Water surface profiles*
  - *Depth and velocity grids*
  - *Inundation boundary maps*
  - *Shear stress…*


San Joaquin Demo.efm - HEC-EFM
File Edit Plot Help

Evaluated at: 10/02/2008 18:56

Summary

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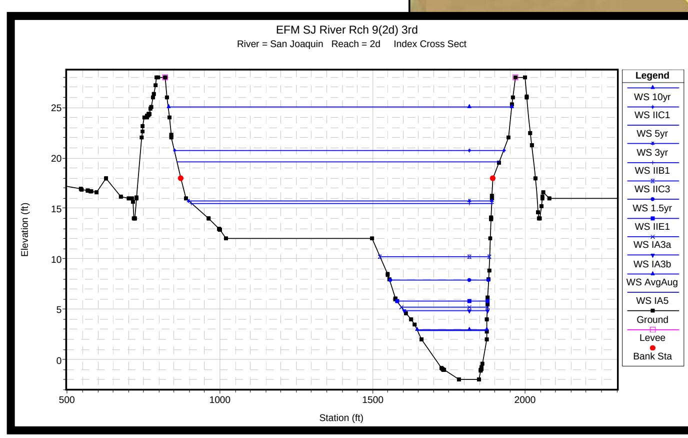
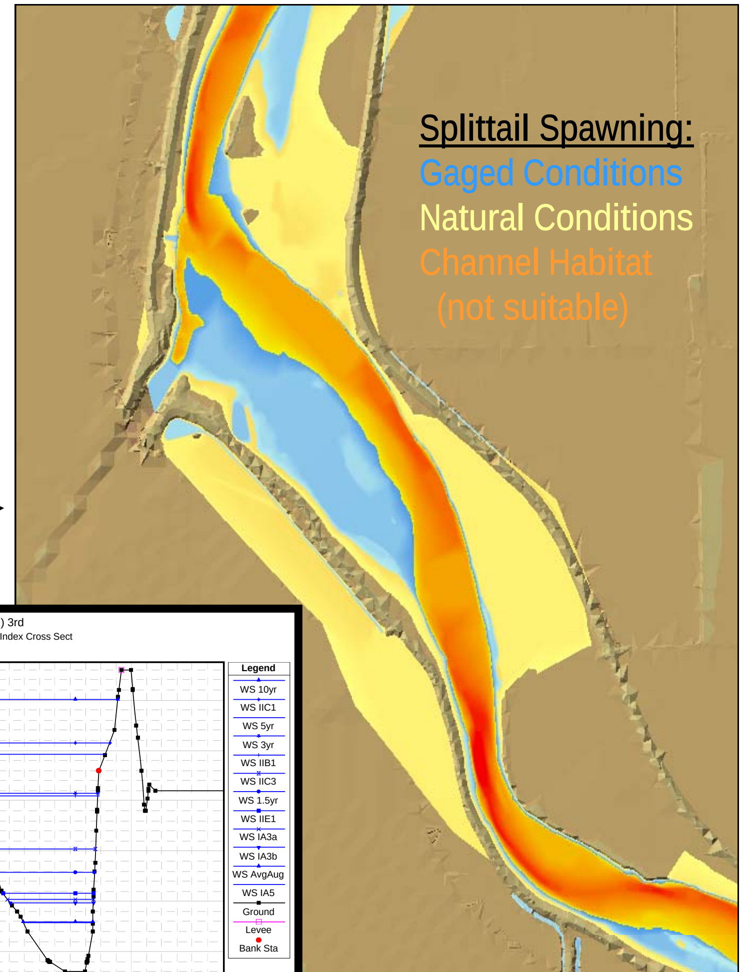
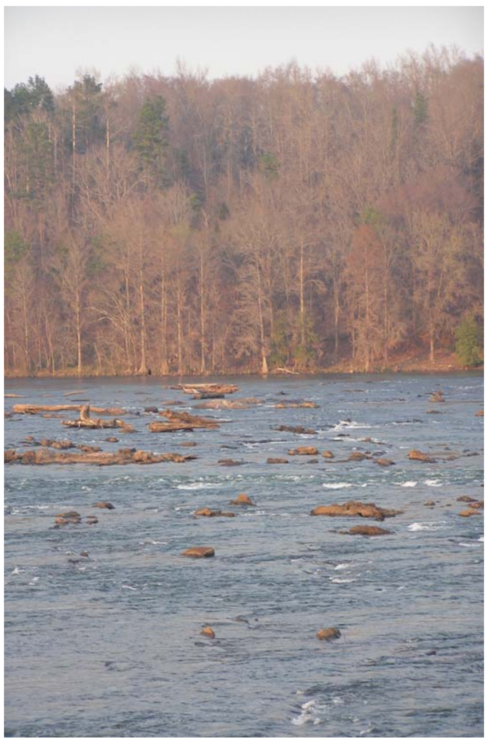




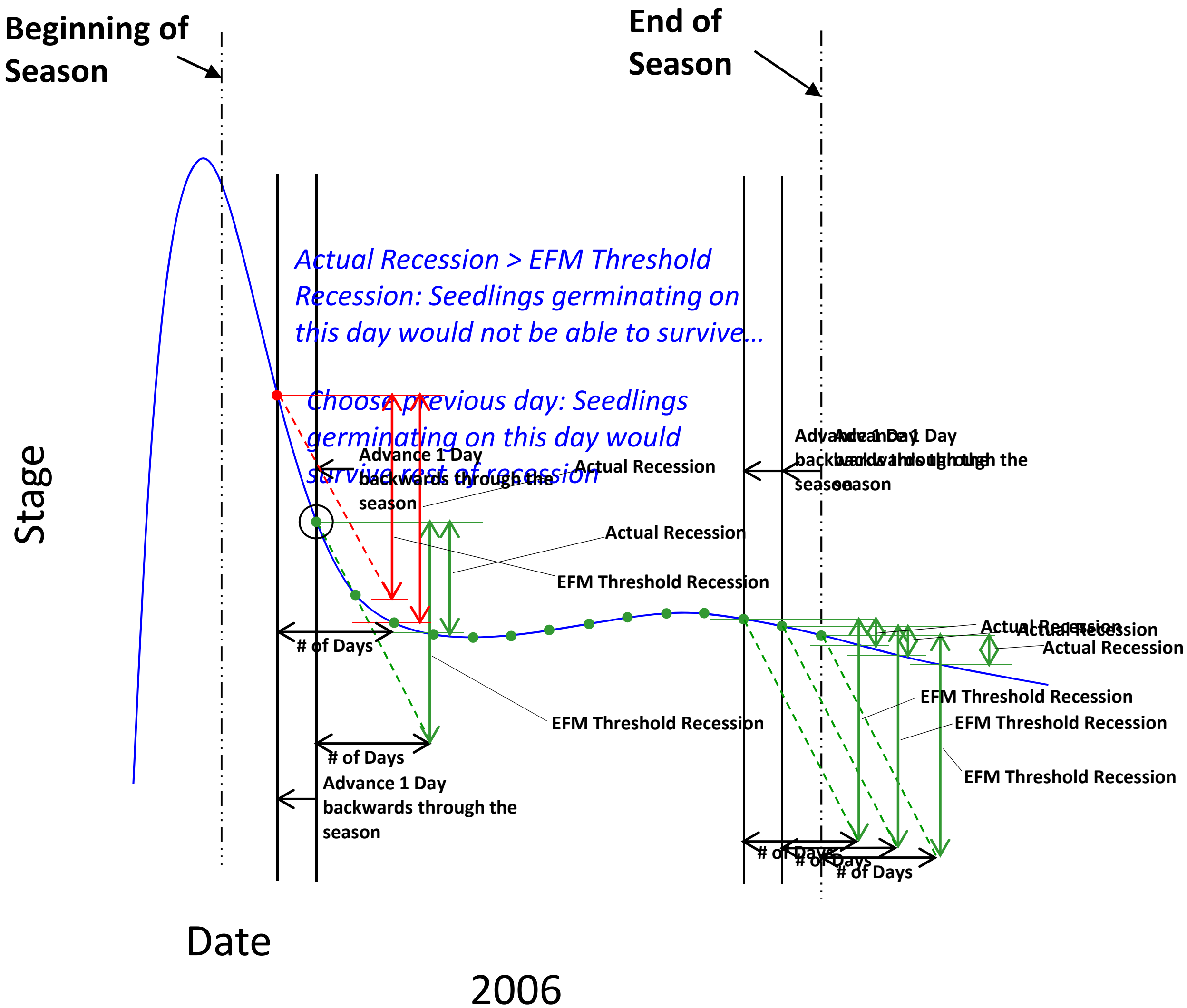
EFM Applications and Relationships…

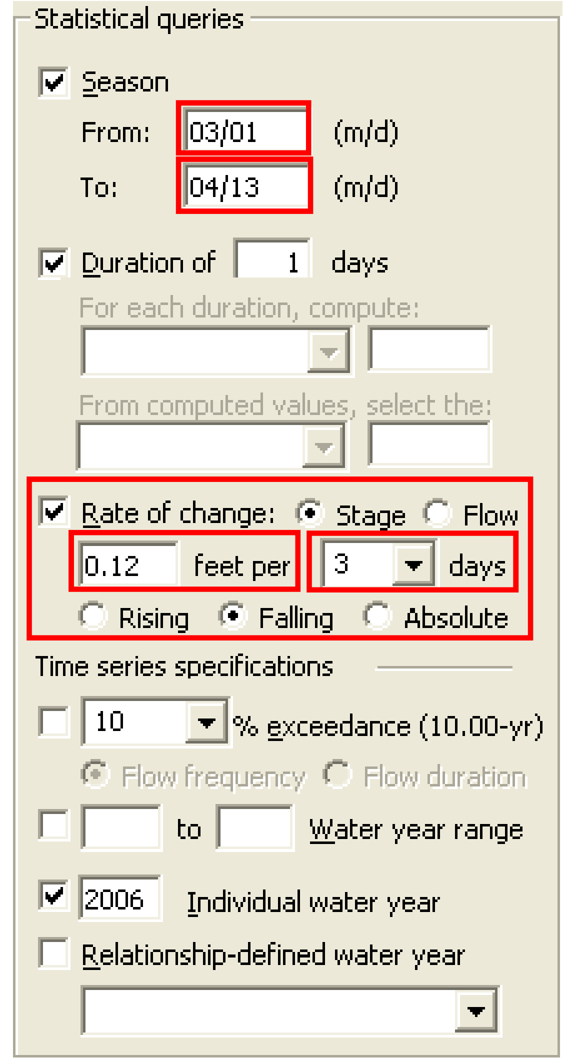


- Farmington River, CT…………..*Floodplain forest, shrubs, buttonbush*
- Sandy River Delta, OR…………….*Chinook salmon*
- Bill Williams River, AZ…………..*Cottonwood, willow, saltcedar*
- Mississippi River, MO…………..*Waterfowl, bluegill, plants*
- Truckee River, NV…………………*Mayflies and cottonwood*
- Ashuelot Rivers, NH………………*Mussels, host fish*
- Savannah River, GA/SC…………*Shad, bass, shoals lily*
- Sacramento/San Joaquin, CA…*Splittail, geomorph, LWD*


EFM Application – Cottonwood
Bill Williams River, AZ
Colorado R.
Verde R.
Salt R.
Phoenix
Gila R.
Yuma
Tucson
DA = 5200 sq. mi.

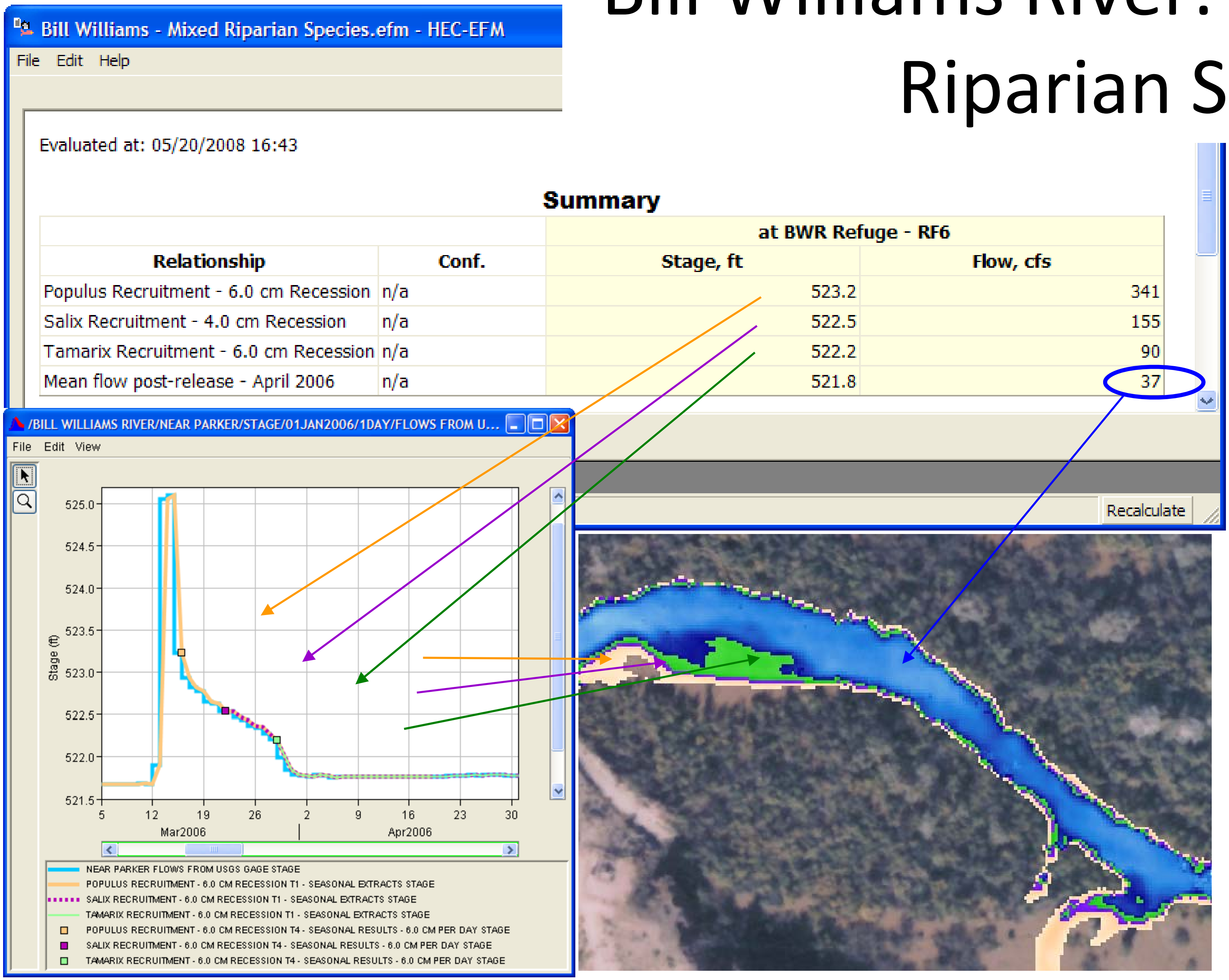
EFM Math - Cottonwoods





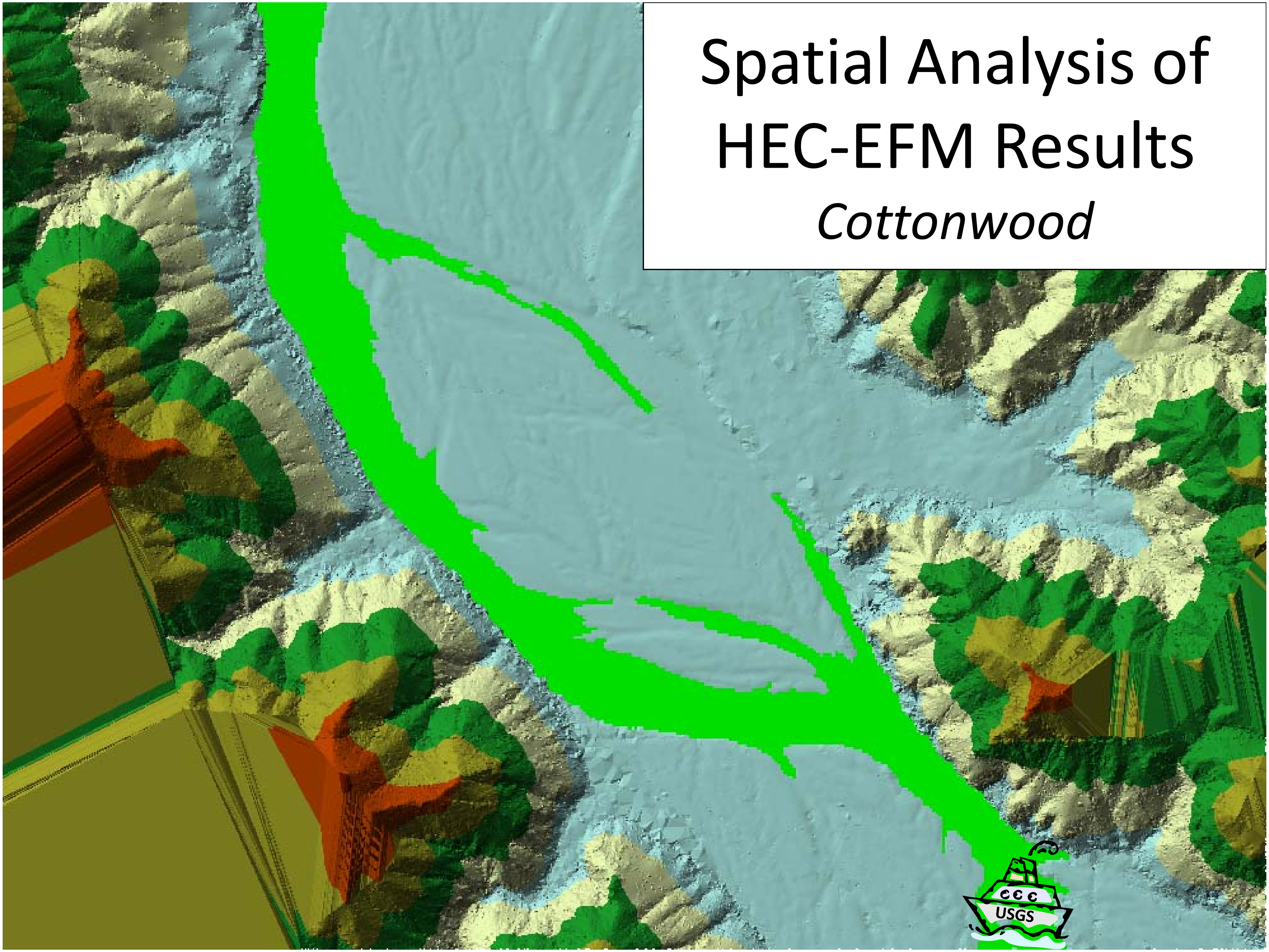
Feature has been used for cottonwood, willow, and saltcedar seedling recruitment…

Bill Williams River: Mixed Riparian Species

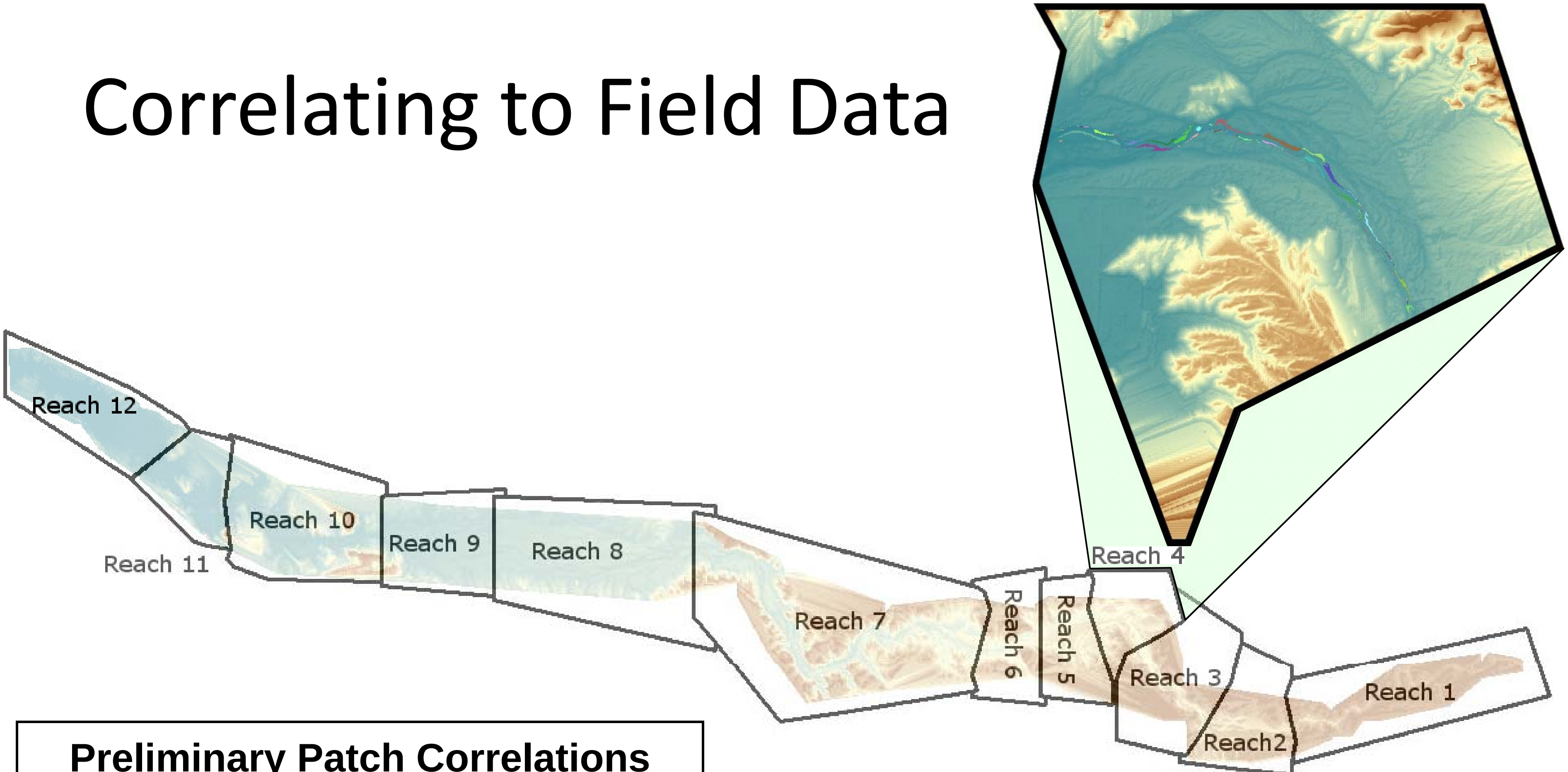


Spatial Analysis of HEC-EFM Results

Cottonwood



Correlating to Field Data



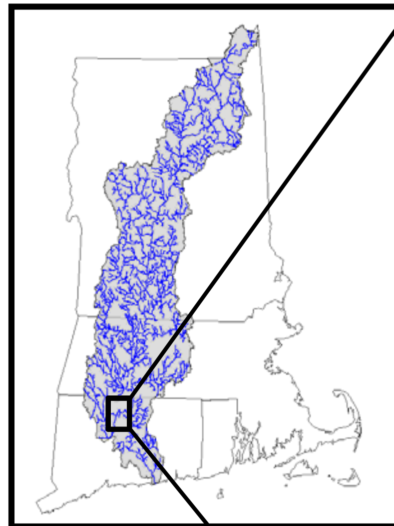
Preliminary Patch Correlations		
	Species	**Correlation**
Simulated v. Observed Patches	Cottonwood	0.77
	Willow	0.81
	Tamarisk	0.82

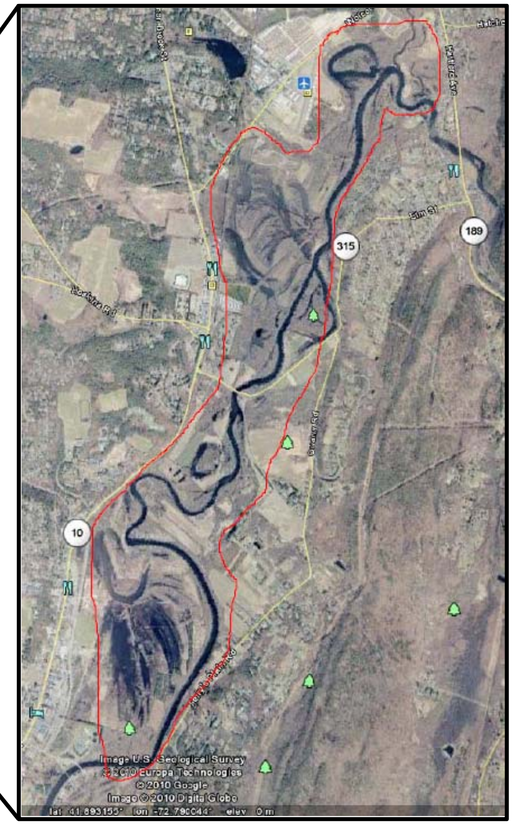
Floodplain Vegetation

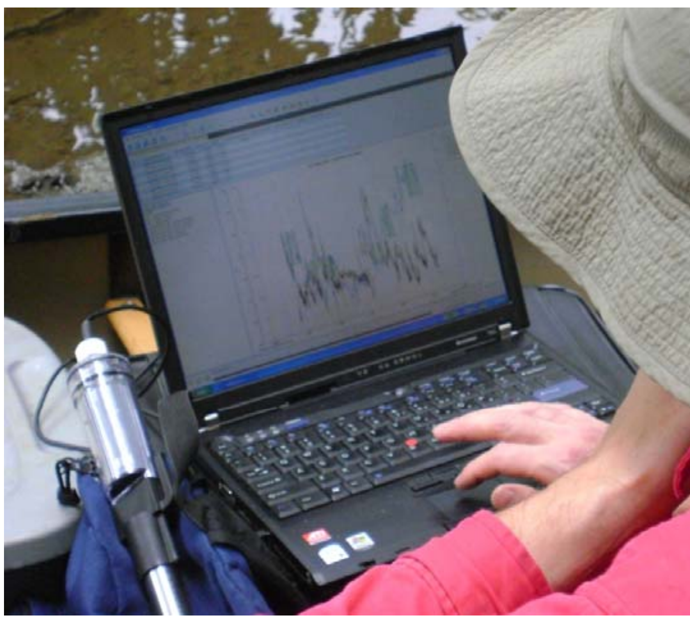
Farmington River, CT

Field Work: Vegetation Survey

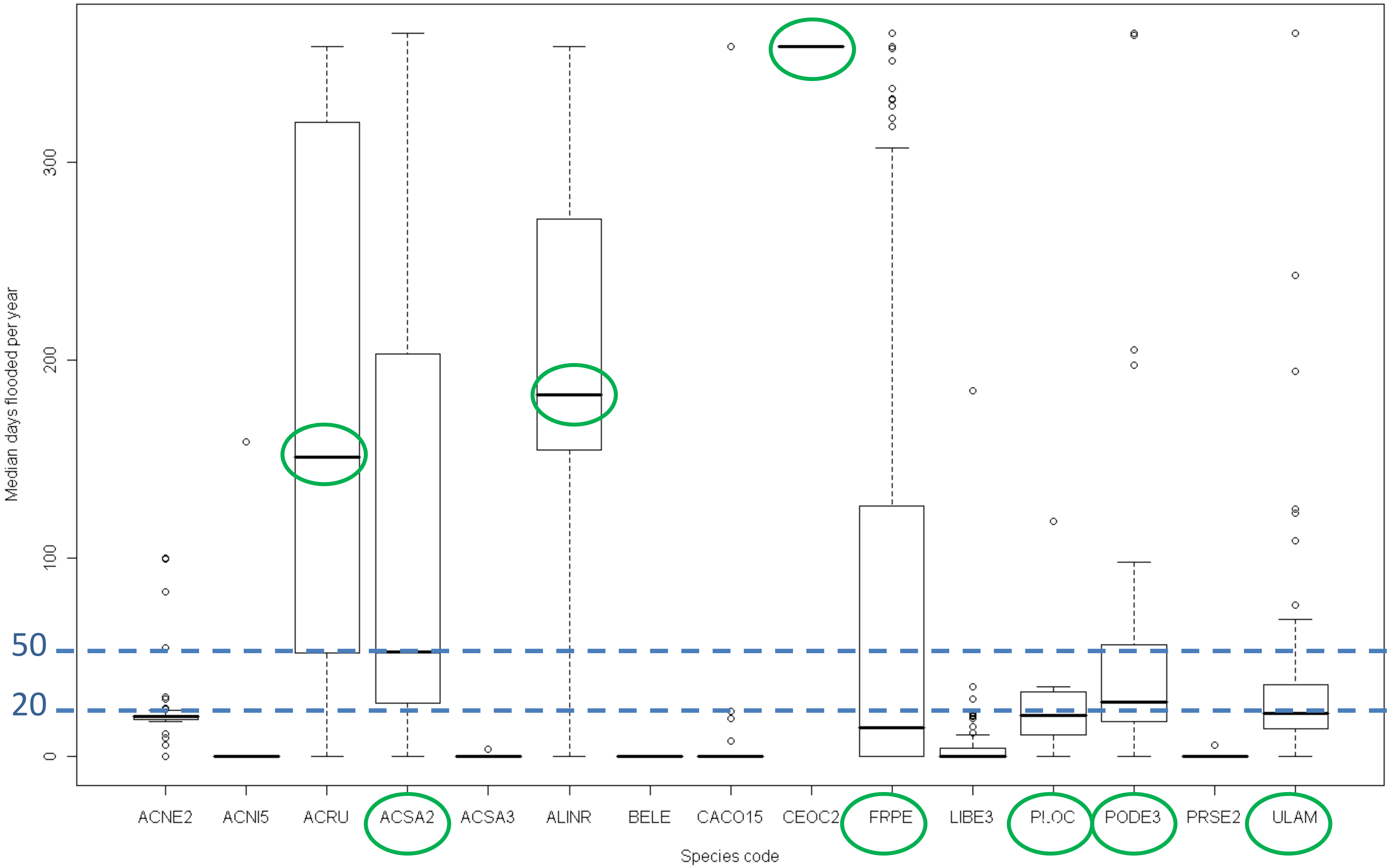
- Survey vegetation and elevation data along floodplain transects
- Monitor channel water levels with pressure transducer
- *How much flooding is needed for healthy floodplain ecosystem?*



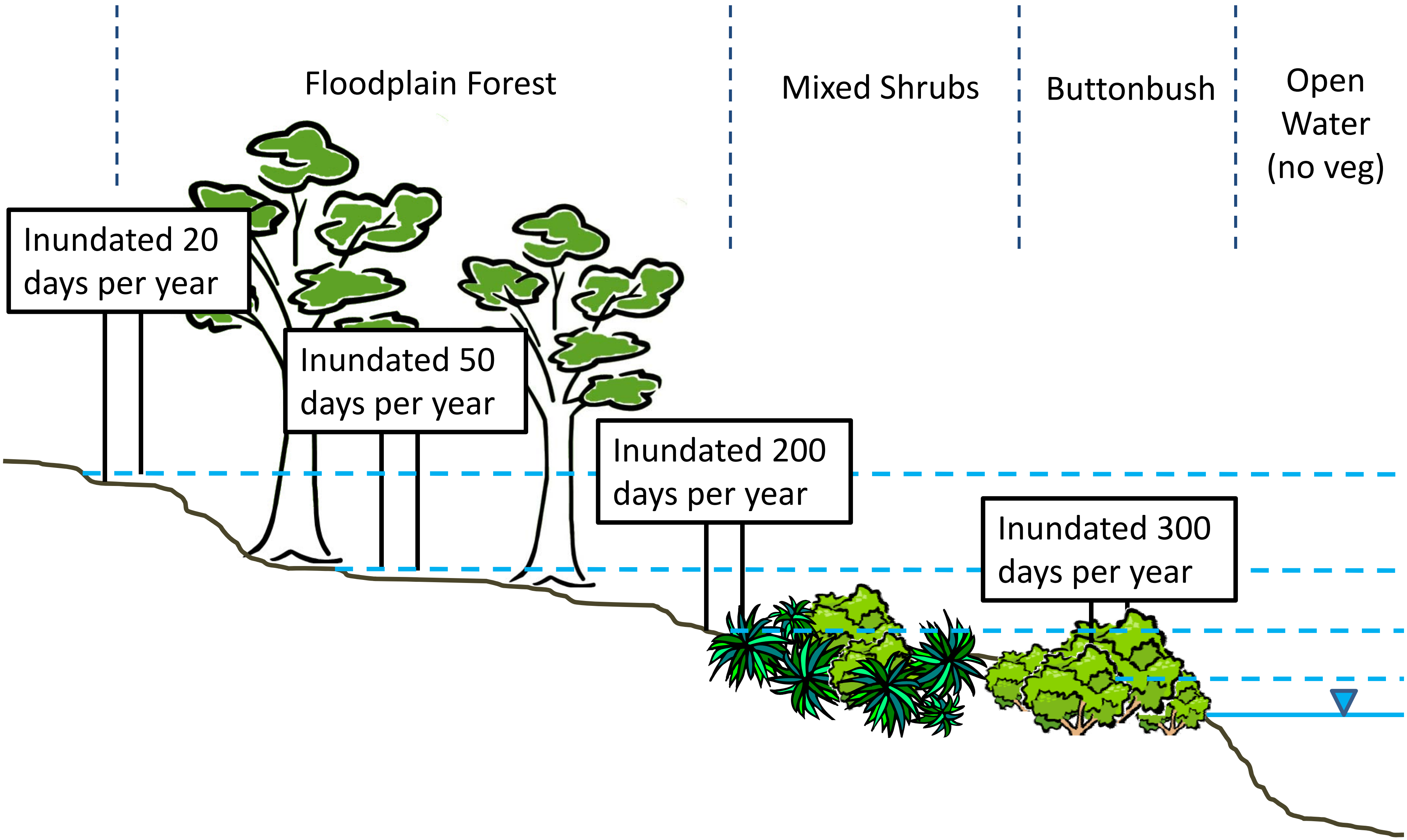




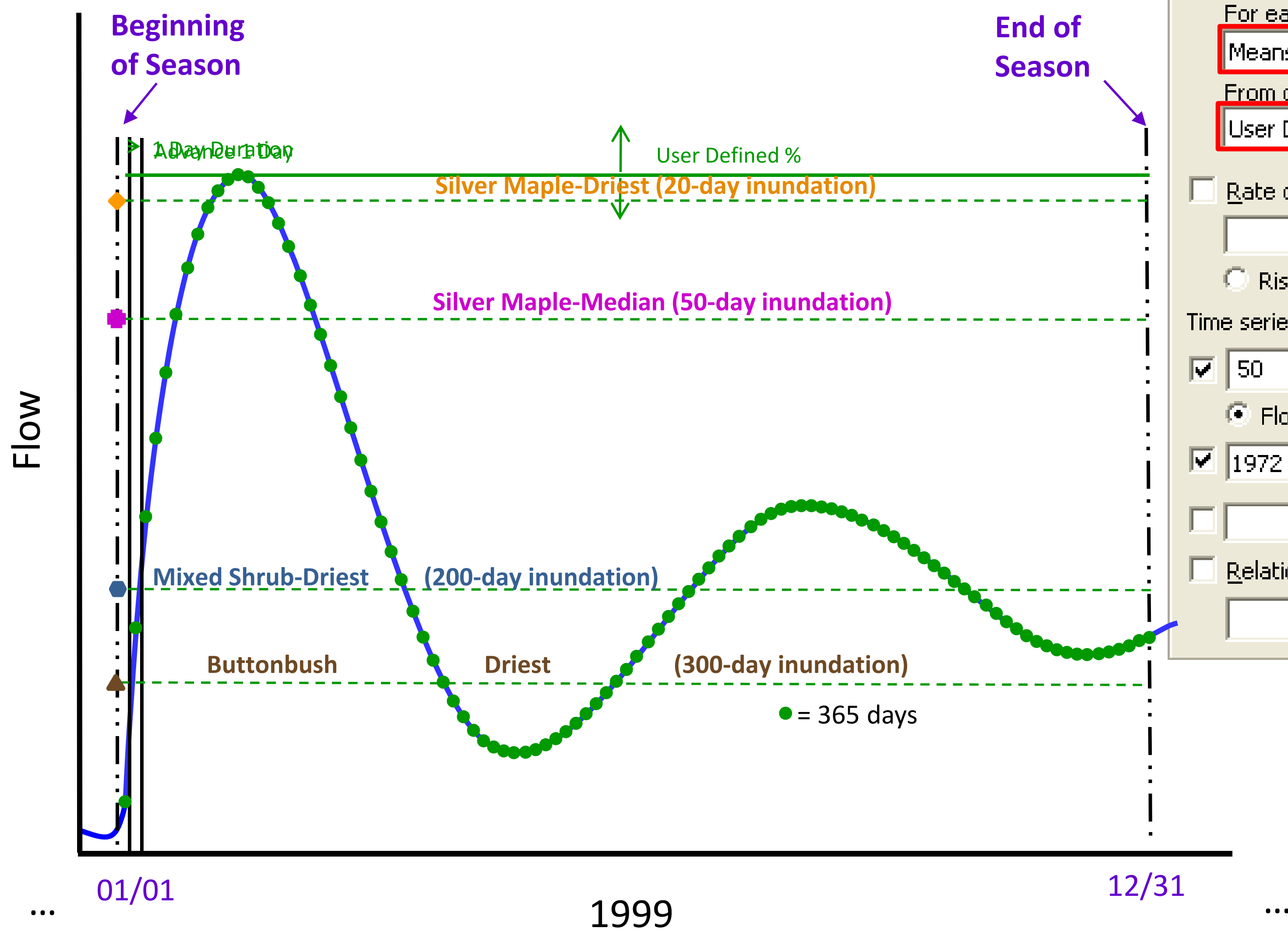
Tree results: Duration of flooding

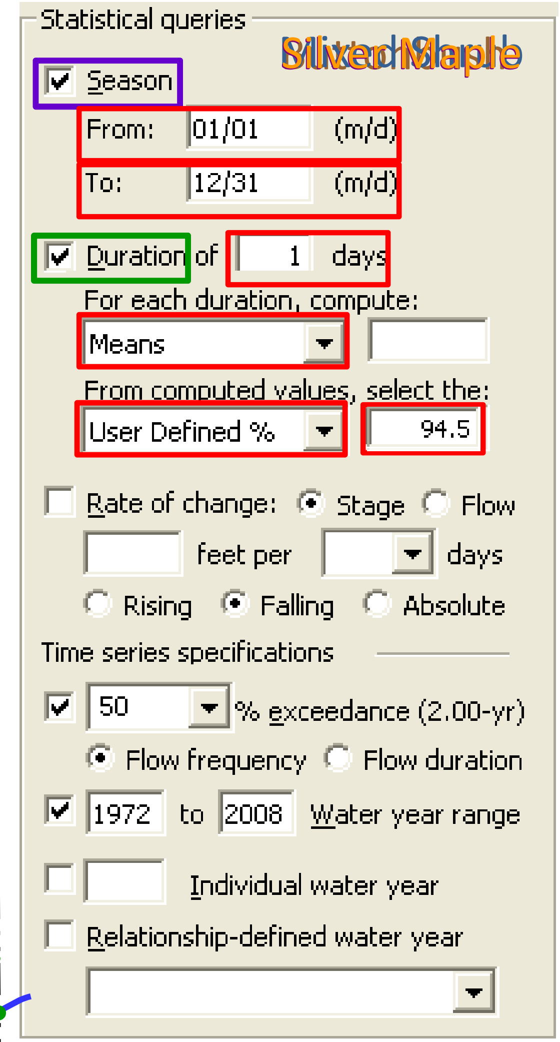


Floodplain Vegetation

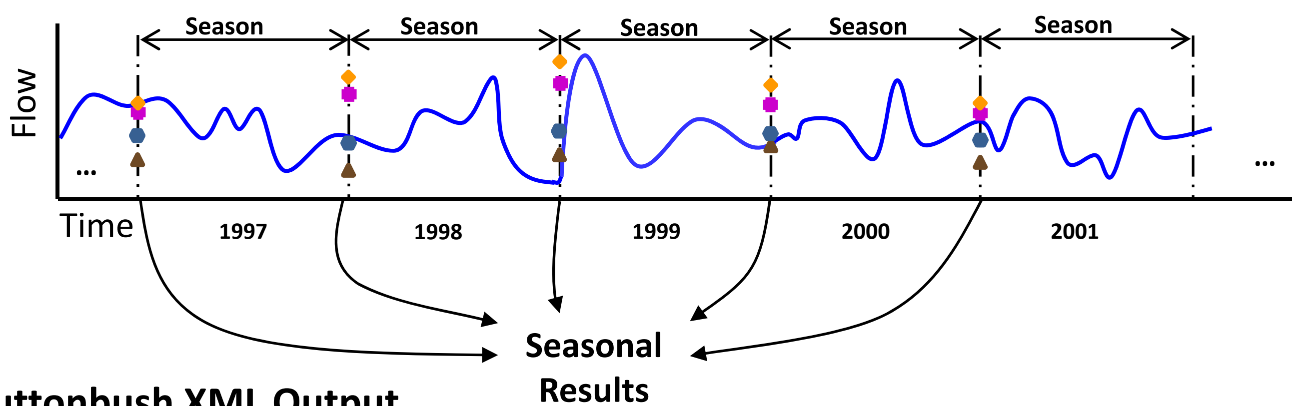


EFM Math: Floodplain Vegetation



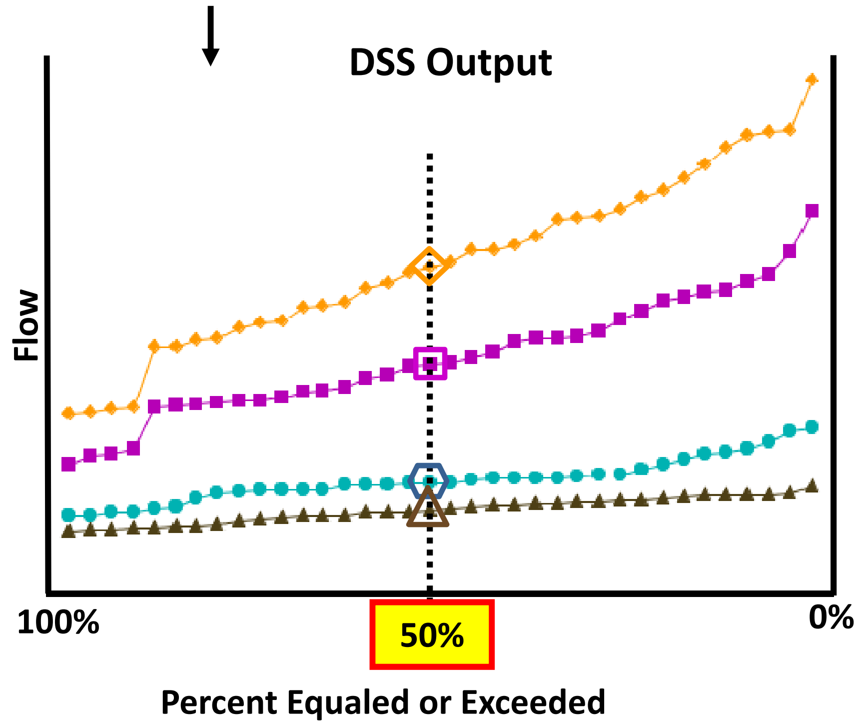


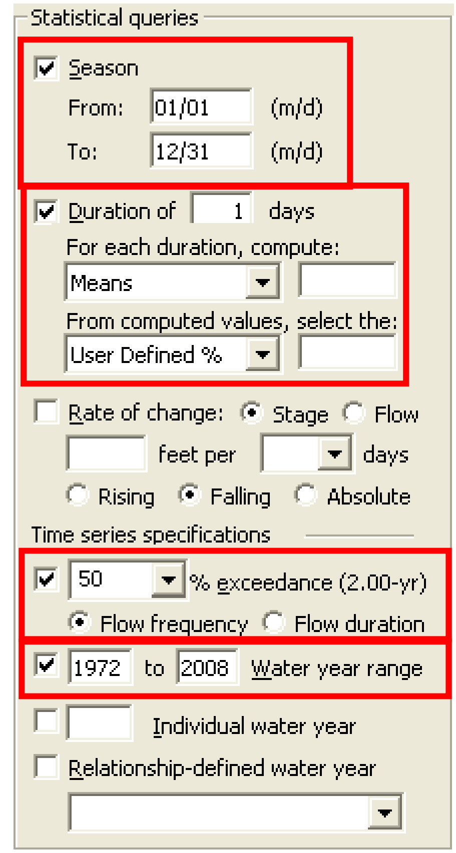
Each year is considered and then ranked…



Buttonbush XML Output

Rank	Frequency	WY	Flow	Stage
1	.0270	1972	726.0	726.000
2	.0541	1979	659.9	659.880
3	.0811	1973	641.9	641.940
4	.1081	2006	640.0	640.000
5	.1351	1975	639.0	639.000
6	.1622	2003	636.8	636.790
7	.1892	1992	620.6	620.592
8	.2162	1996	594.1	594.148
9	.2432	2004	581.0	581.000
10	.2703	2000	580.0	580.000
11	.2973	1990	575.8	575.820
12	.3243	1989	572.9	572.910
13	.3514	1994	555.0	554.970
14	.3784	1976	553.0	553.000
15	.4054	1987	529.9	529.910
16	.4324	1986	525.9	525.940
17	.4595	1974	524.0	524.000
18	.4865	1991	494.9	494.940
	.5000		490.5	490.470
19	.5135	1983	486.0	486.000
20	.5405	1993	461.9	461.940
21	.5676	1984	460.0	460.000
22	.5946	1982	459.7	459.730
23	.6216	1998	430.9	430.910
24	.6487	2005	430.0	430.000
25	.6757	1988	424.0	424.000
26	.7027	1978	409.0	409.000
27	.7297	1999	390.0	389.970
28	.7568	1997	389.0	388.970
29	.7838	2007	343.0	343.000
30	.8108	1995	326.8	326.820
31	.8378	1977	322.9	322.940
32	.8649	1985	313.0	313.000
33	.8919	1981	309.9	309.940
34	.9189	2001	305.0	304.970
35	.9460	1980	290.6	290.592
36	.9730	2002	274.0	274.000

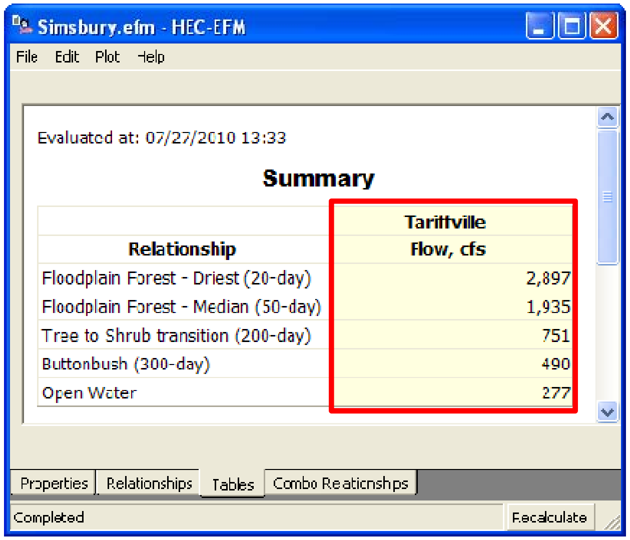


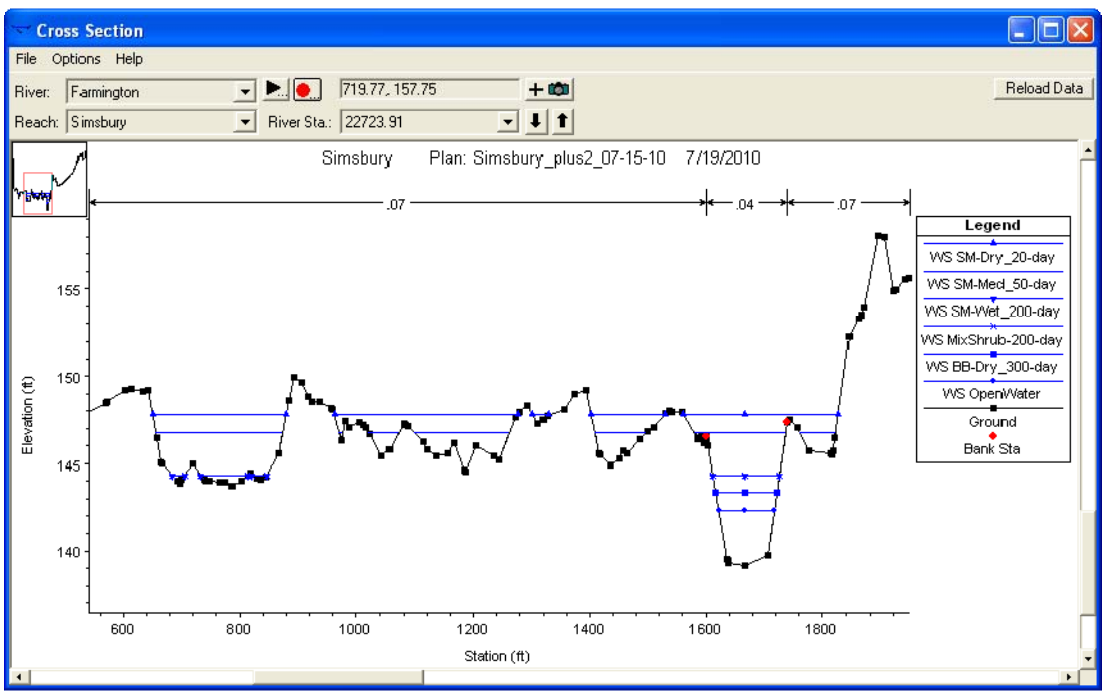


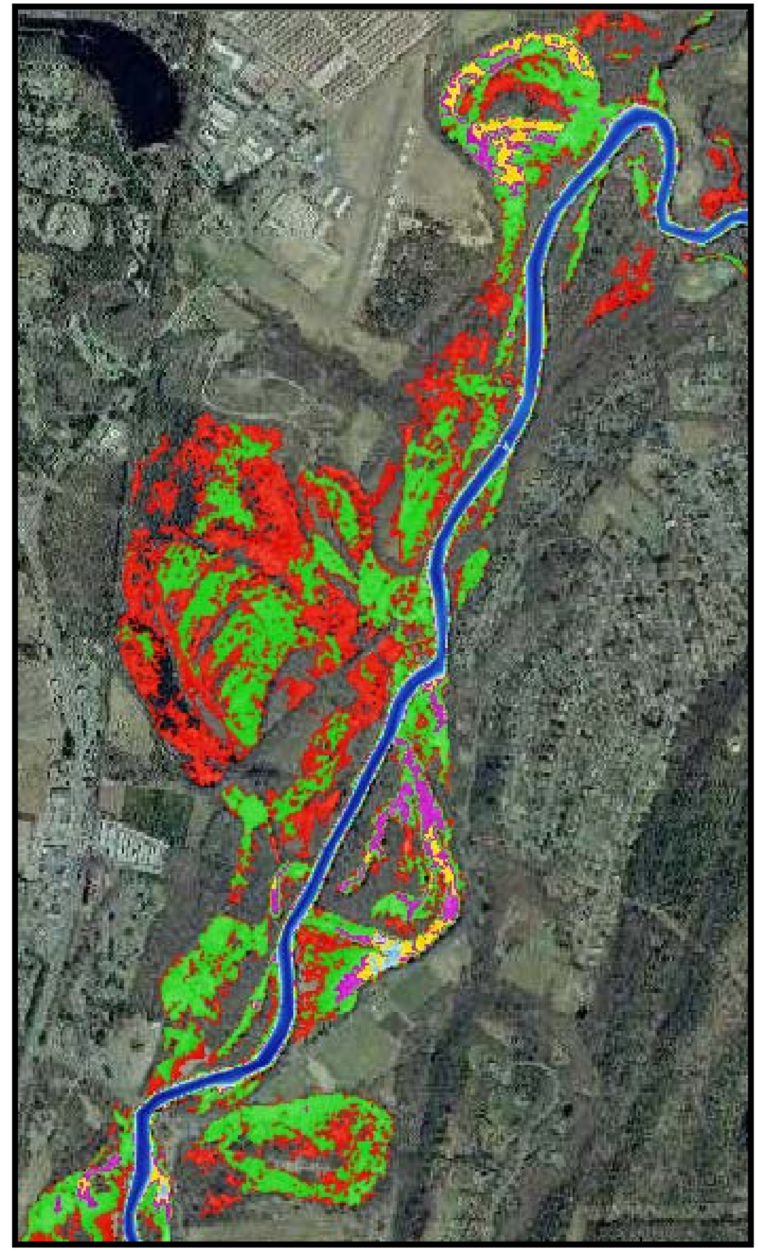
◆ Silver Maple-driest (20-d inundation)
■ Silver Maple-median (50-d inundation)
● Mixed Shrub-driest (200-d inundation)
▲ Buttonbush-driest (300- inundation)

Statistical results reported in EFM interface and used in river hydraulic models for mapping…

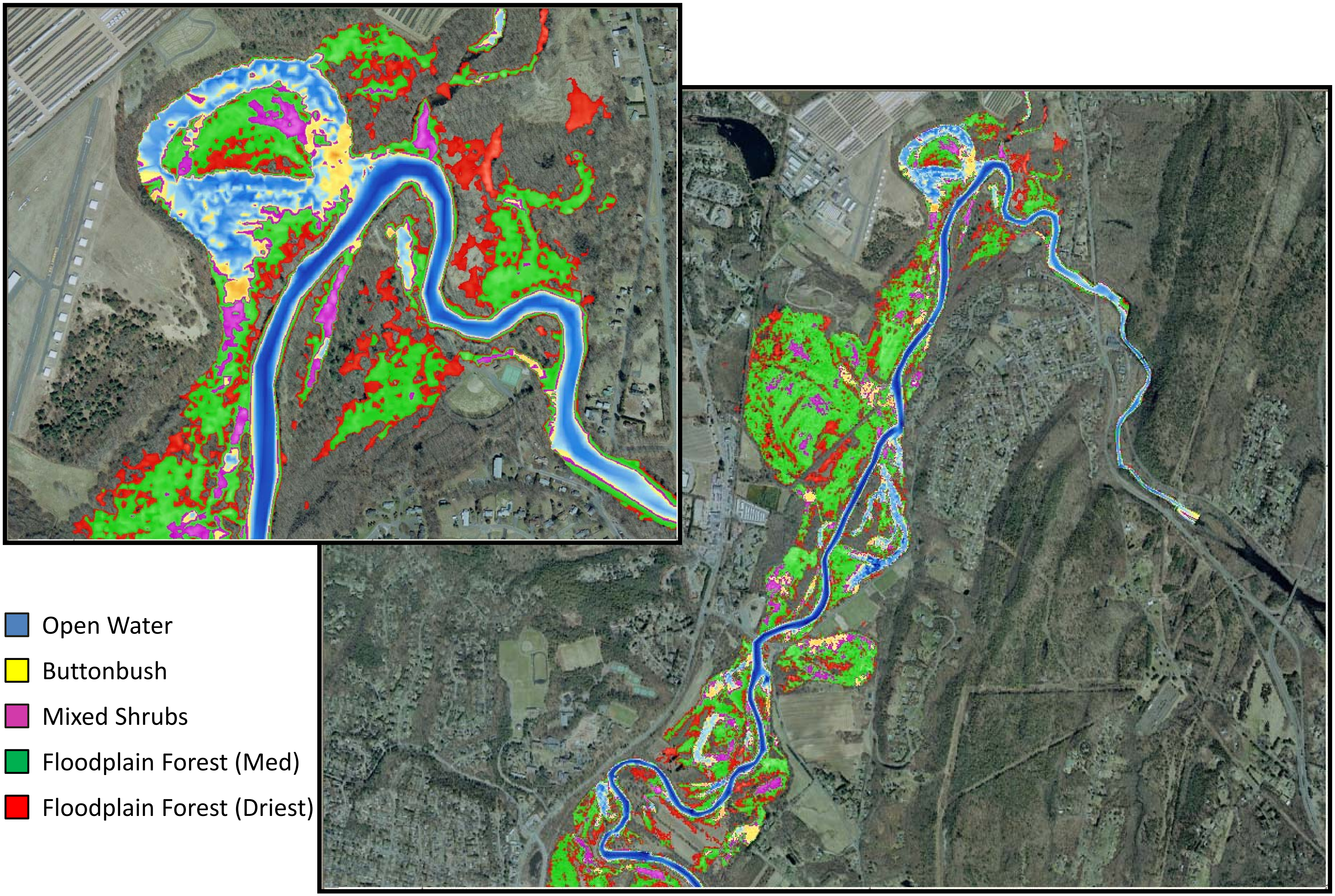
HEC-EFM – From Statistical to Spatial…



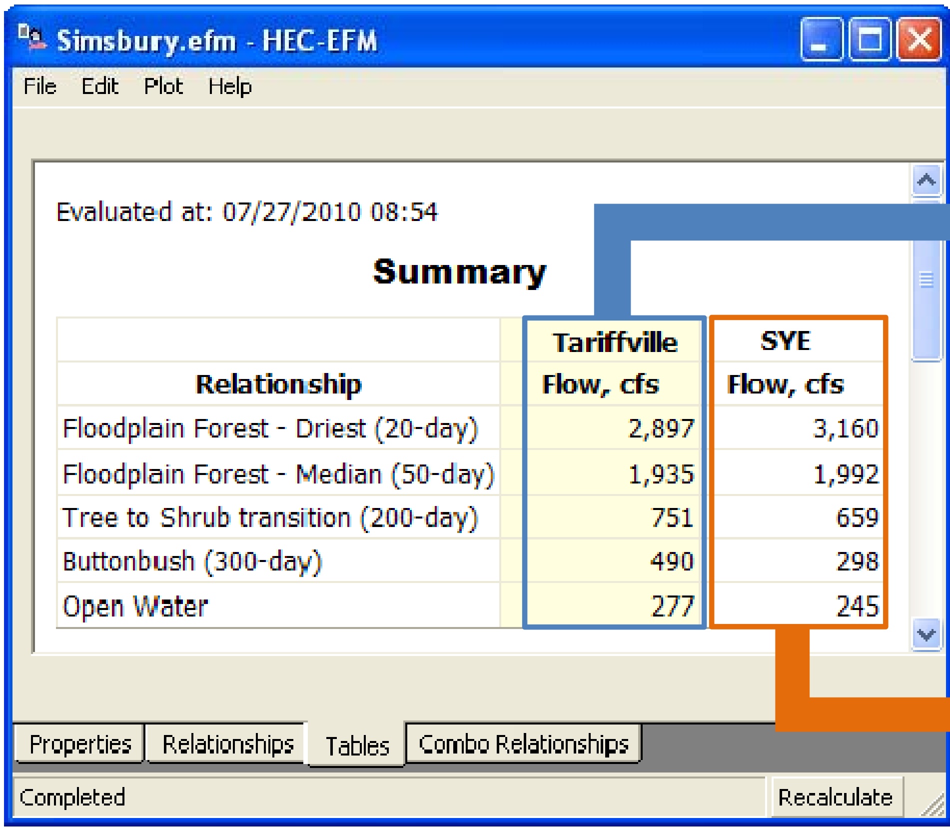




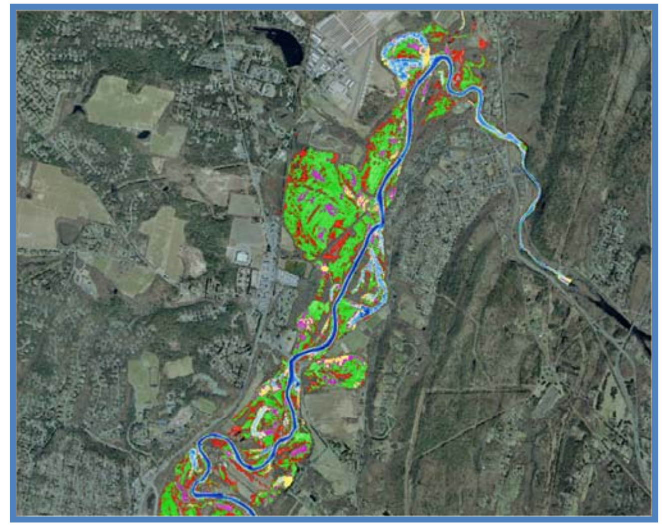
Gaged Simulated Vegetation Communities

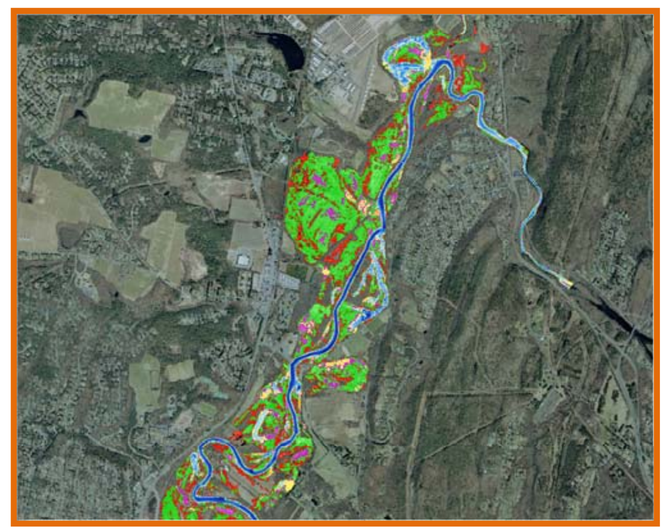


Comparing Flow Regimes: Gaged and Natural



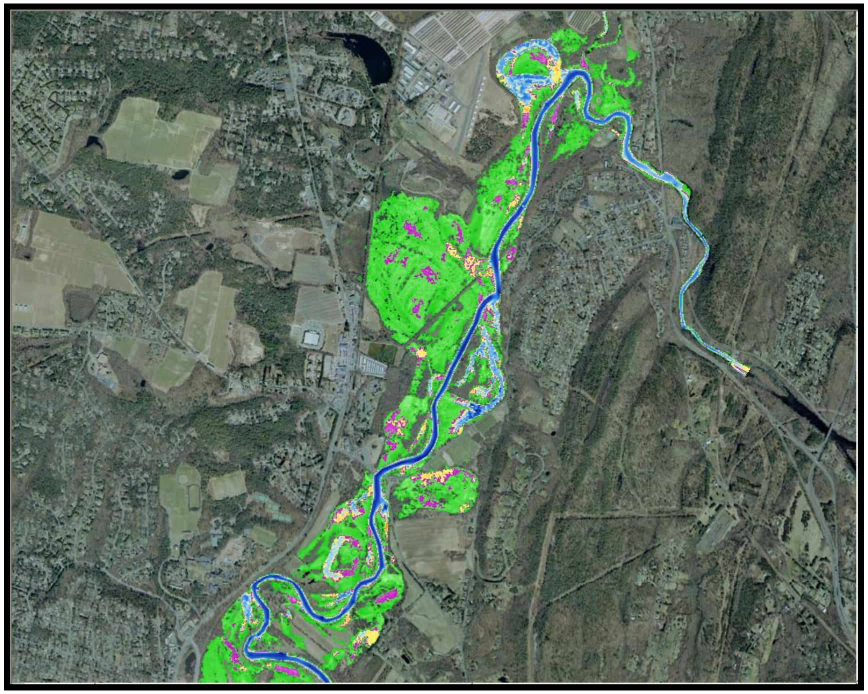
Relationship	Tariffville Flow, cfs	SYE Flow, cfs
Floodplain Forest - Driest (20-day)	2,897	3,160
Floodplain Forest - Median (50-day)	1,935	1,992
Tree to Shrub transition (200-day)	751	659
Buttonbush (300-day)	490	298
Open Water	277	245



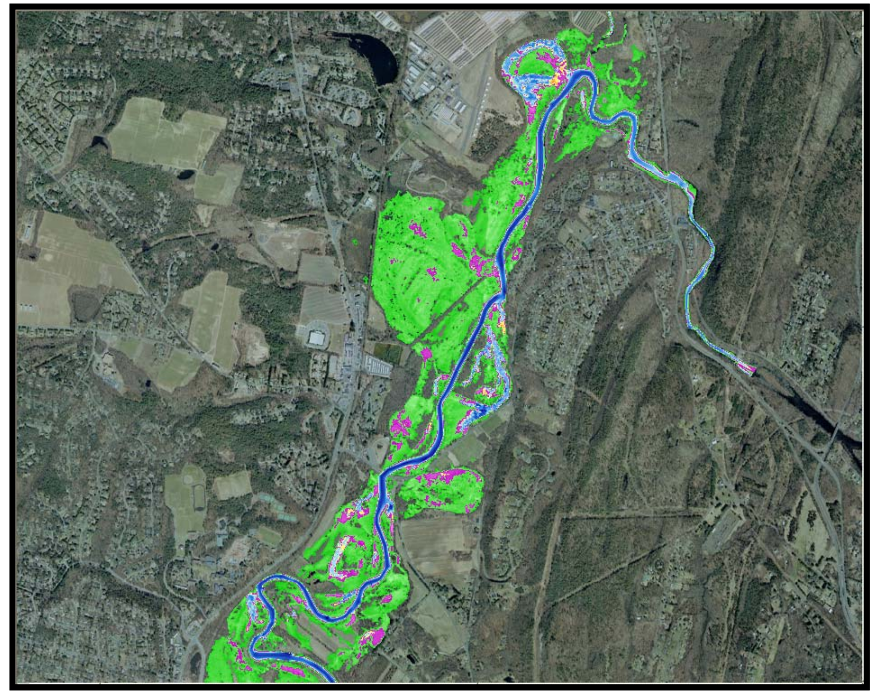


Comparing Flow Regimes: Gaged and Nat

Gaged

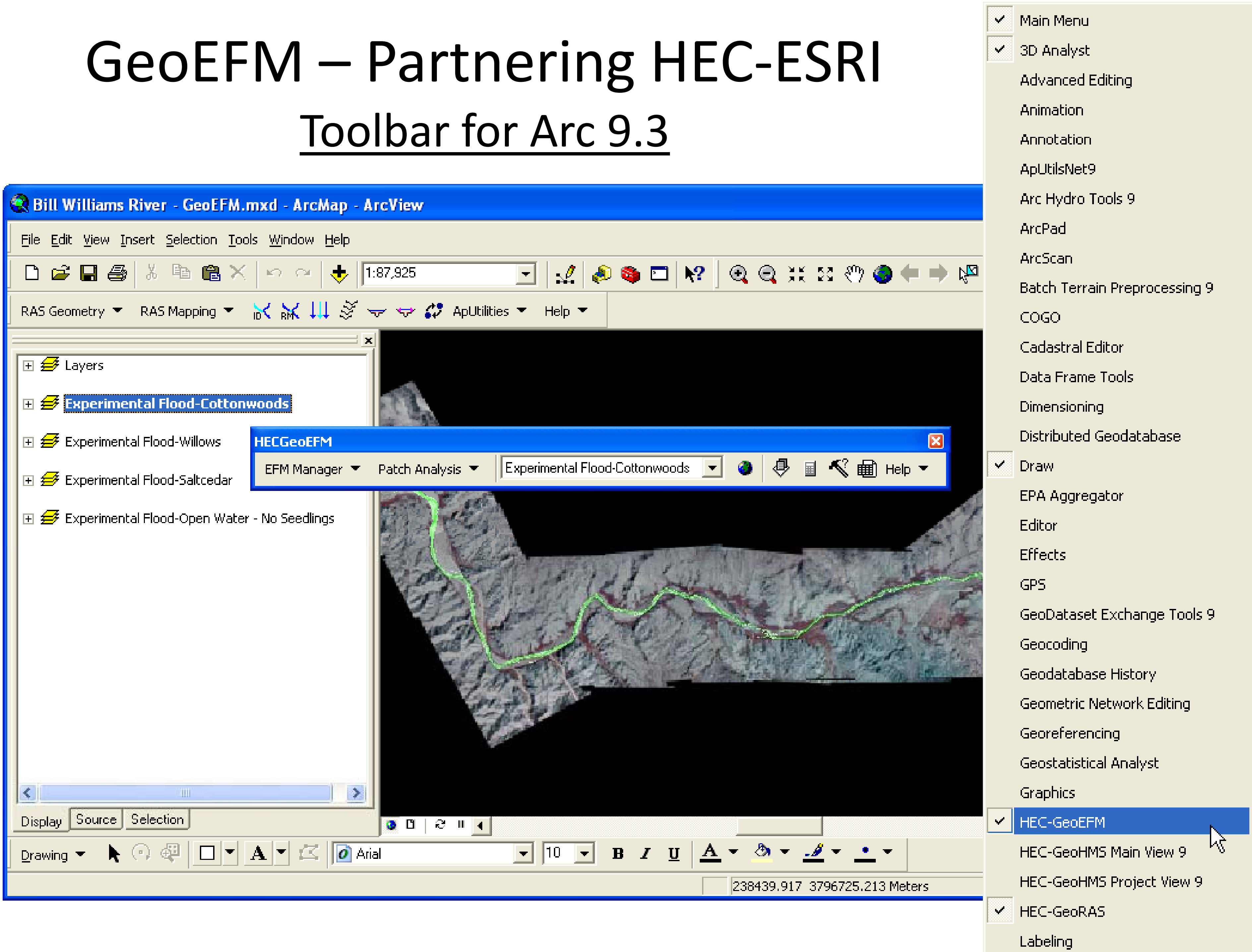


Natural

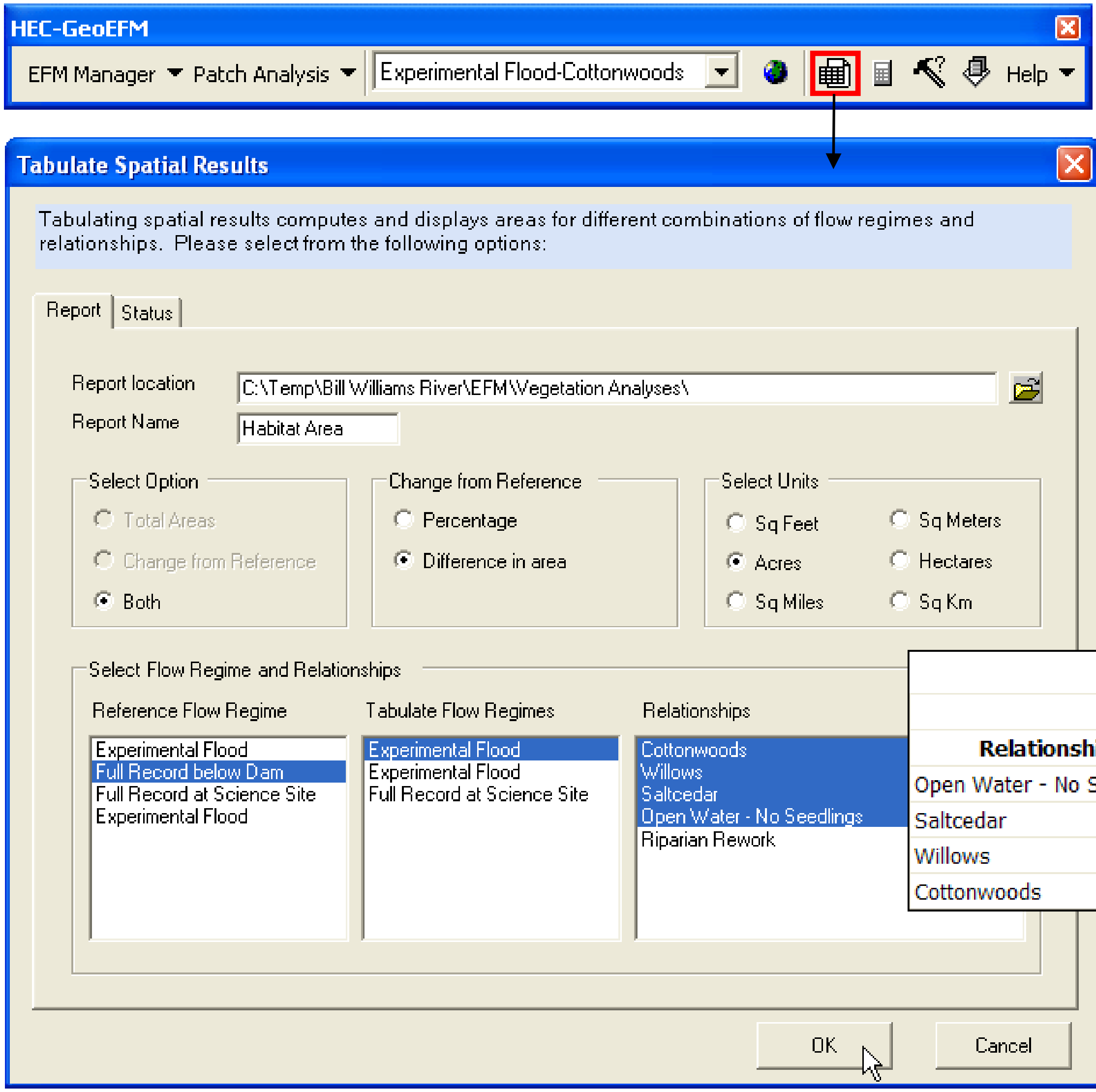


GeoEFM – Partnering HEC-ESRI

Toolbar for Arc 9.3



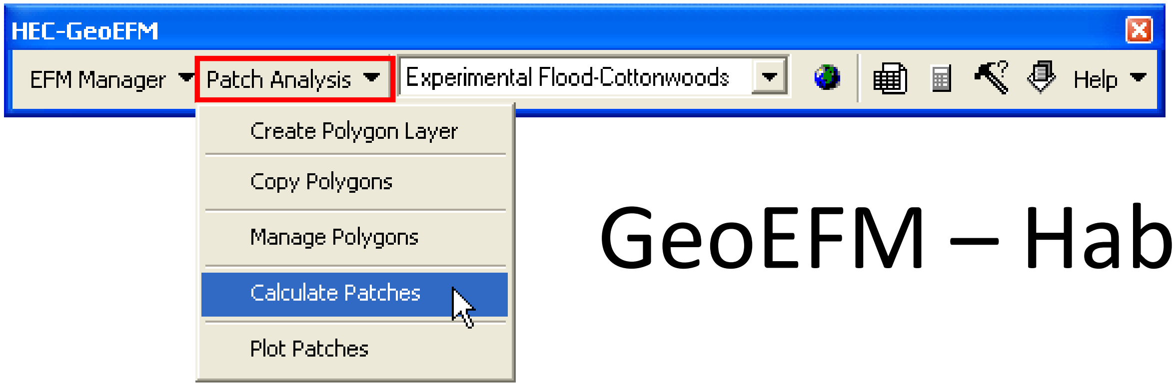
GeoEFM – Habitat Area



...compute/tabulate habitat areas for different management or restoration scenarios

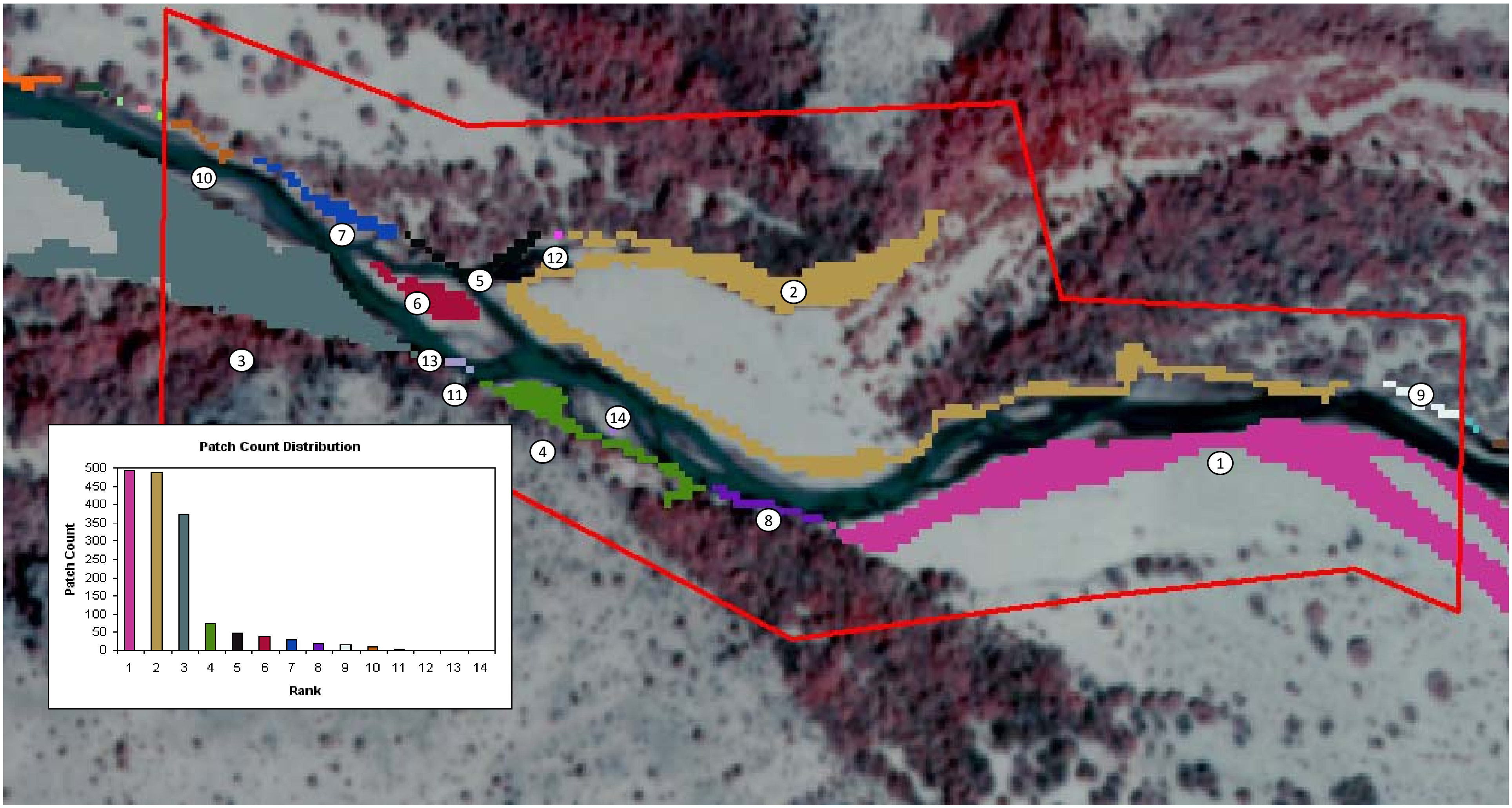
Summary

	Full Record below Dam	Experimental Flood	
Relationship	**Area, acres**	**Area, acres**	**Change, acres**
Open Water - No Seedlings	429	429	.0
Saltcedar	431	576	145.0
Willows	468	891	423.7
Cottonwoods	649	1,080	431.2

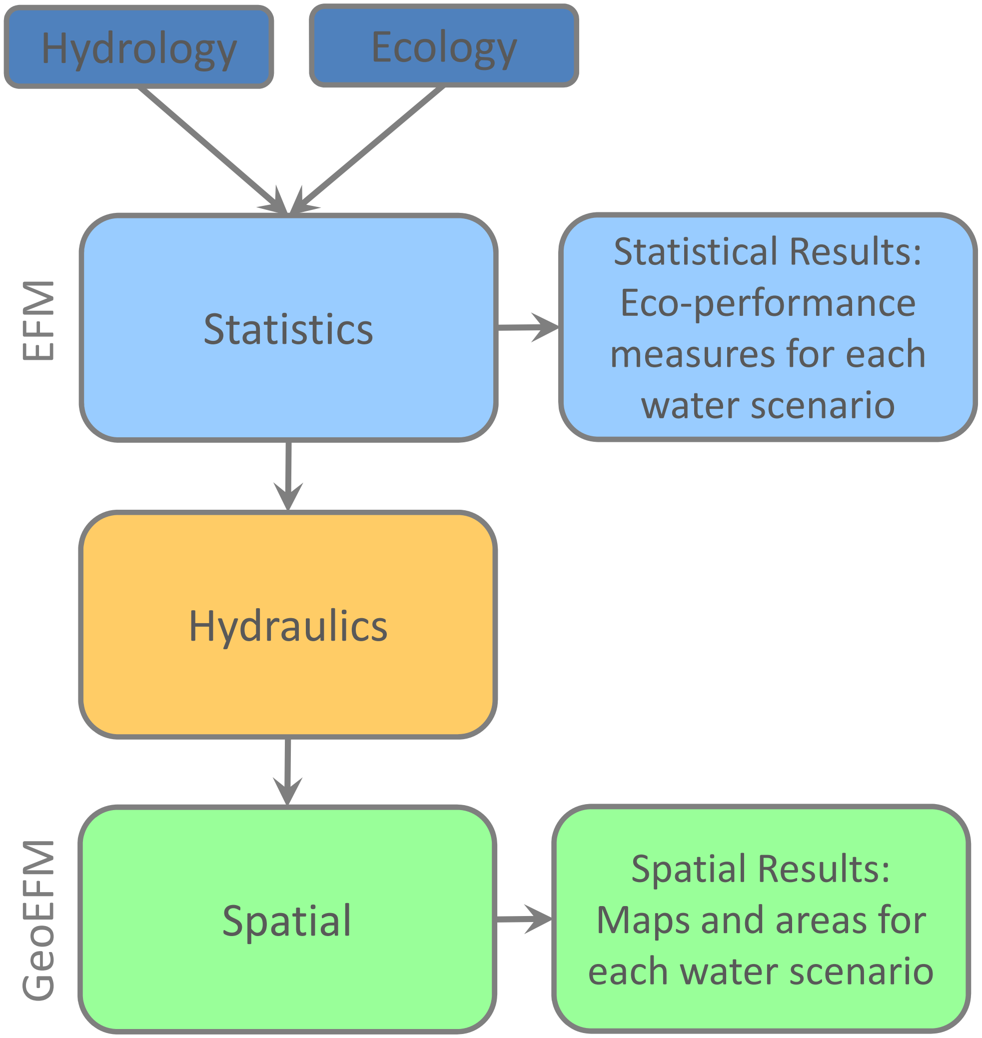


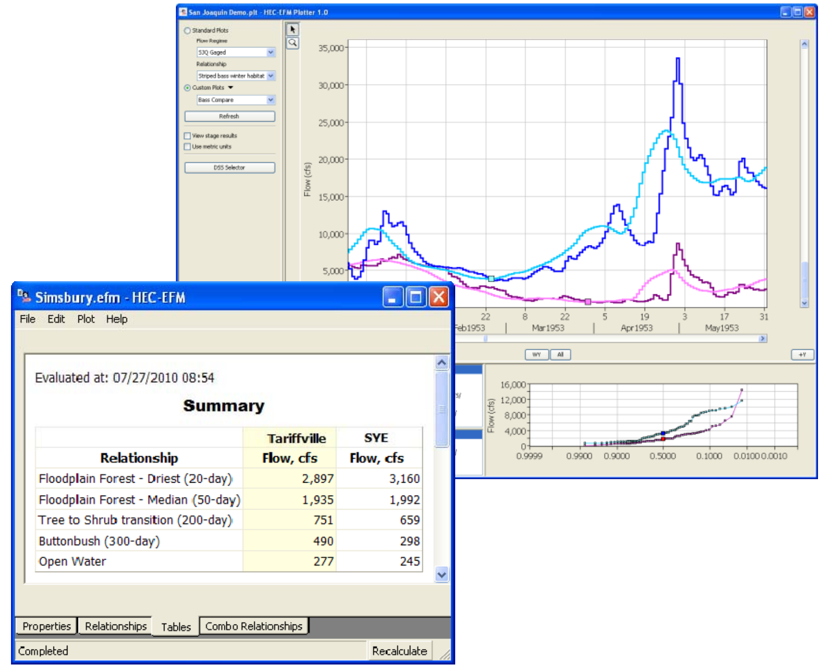
...corridors, distribution, interaction

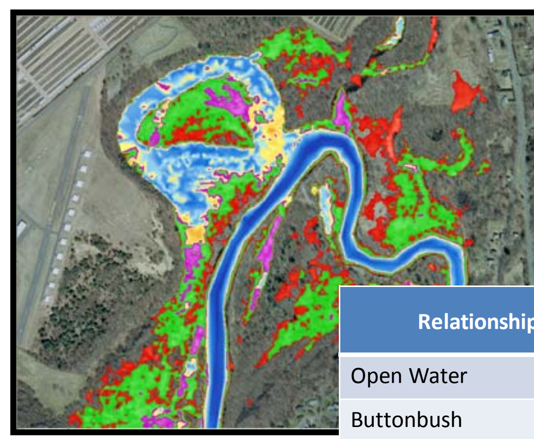
GeoEFM – Habitat Connectivity



Ecosystem Functions Model (EFM) Process

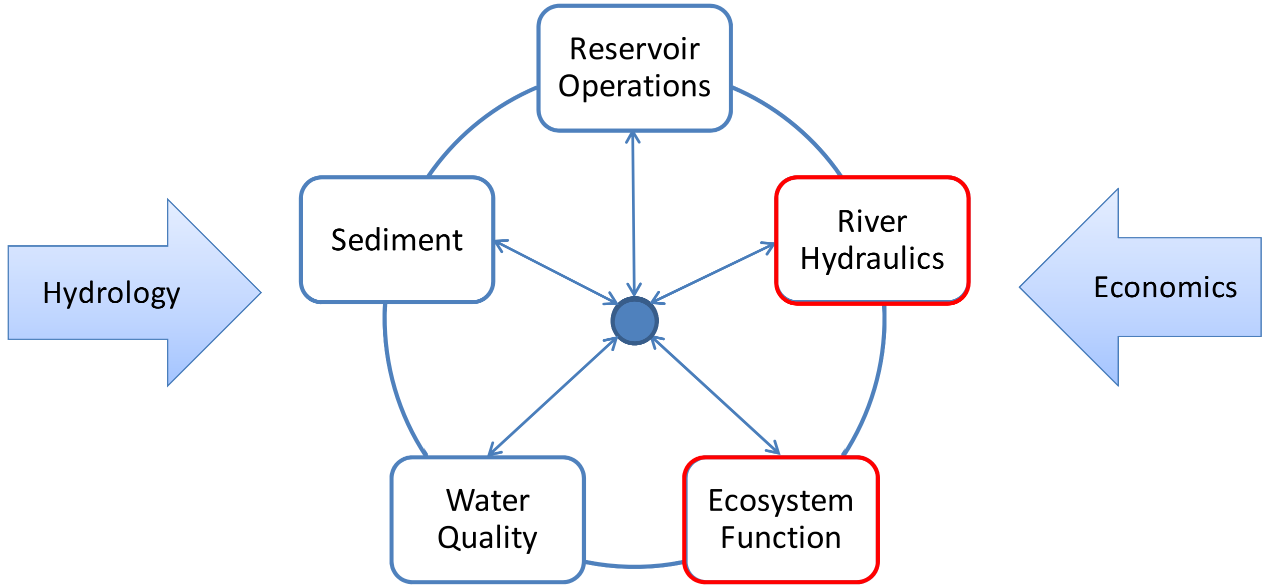






Relationships	Gaged (acres)	SYE (acres)
Open Water	196	184
Buttonbush	79	20
Mixed Shrubs	113	147
Floodplain Forest	762	842

HEC-EFM Summary



- “Flow Regimes” = water management and/or ecosystem restoration scenarios
- “Relationships” = connections between hydrology and ecology

- EFM is generic…can be used to test many different types of Relationships
- EFM is powerful…can be used to test many different Flow Regimes

- Statistical output (direction of eco-change and magnitude of eco-change)
- Spatial output via hydraulic models (habitat areas and habitat connectivity)

For more information…

- www.hec.usace.army.mil/software/hec-efm/
- www.hec.usace.army.mil/software/hec-efm-plotter/
- www.hec.usace.army.mil/software/hec-geoefm/ *(…coming soon)*

EFM references

Shafroth et al. 2010. Ecosystem effects of **environmental flows**: modelling and **experimental floods** in a dryland river. Freshwater Biology - January 2010.

USACE. 2009. HEC-EFM - Ecosystem Functions Model - Quick Start Guide - Version 2.0. Hydrologic Engineering Center, Davis, CA.

Hautzinger, Hickey, and Walker. 2008. **How Much Water** Do Stream-Dependent Species Need? Southwest Hydrology - July/August 2008.

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USACE and Reclamation Board, State of California. 2002. **Ecosystem Functions** Model - Technical Studies Documentation, Appendix G. Sacramento and San Joaquin Rivers Basin Comprehensive Study, Sacramento, CA. http://www.compstudy.net/reports.html

Jones and Stokes. 2000. Final functional relationships for the Ecosystem Functions Model, Sacramento and San Joaquin River Basins Comprehensive Study, Sacramento, CA.