CADDO LAKE INSTITUTE

ENVIRONMENTAL FLOWS IN THE CYPRESS RIVER BASIN

Trinity and San Jacinto Rivers and Galveston Bay
Bay Basin Expert Science Team
November 13, 2008
Galveston, Texas

Sustainable Rivers Project

US Army Corps of Engineers®

The Nature Conservancy

Protecting nature. Preserving life.™

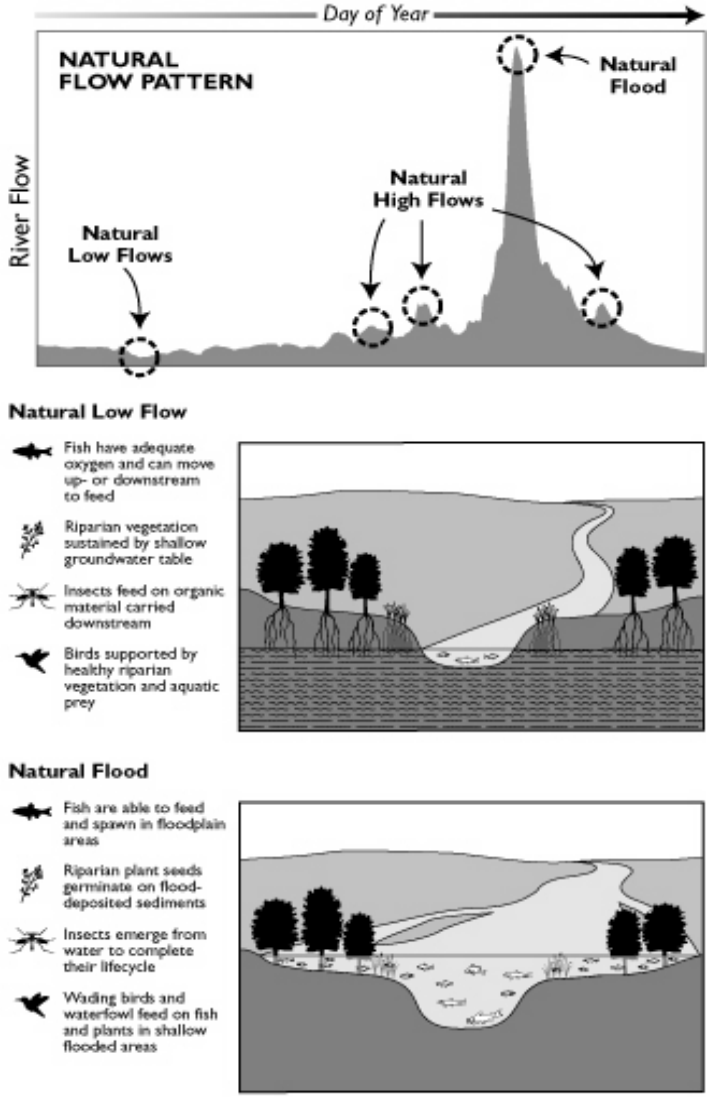


Figure 1-4 Ecosystem functions supported by natural river flows

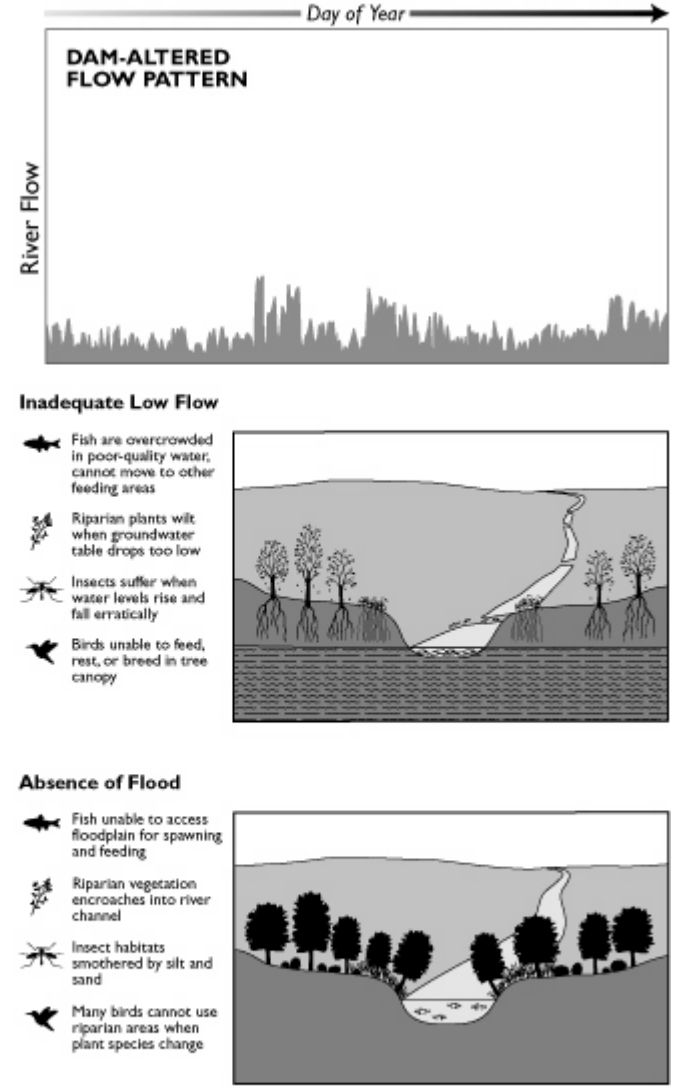
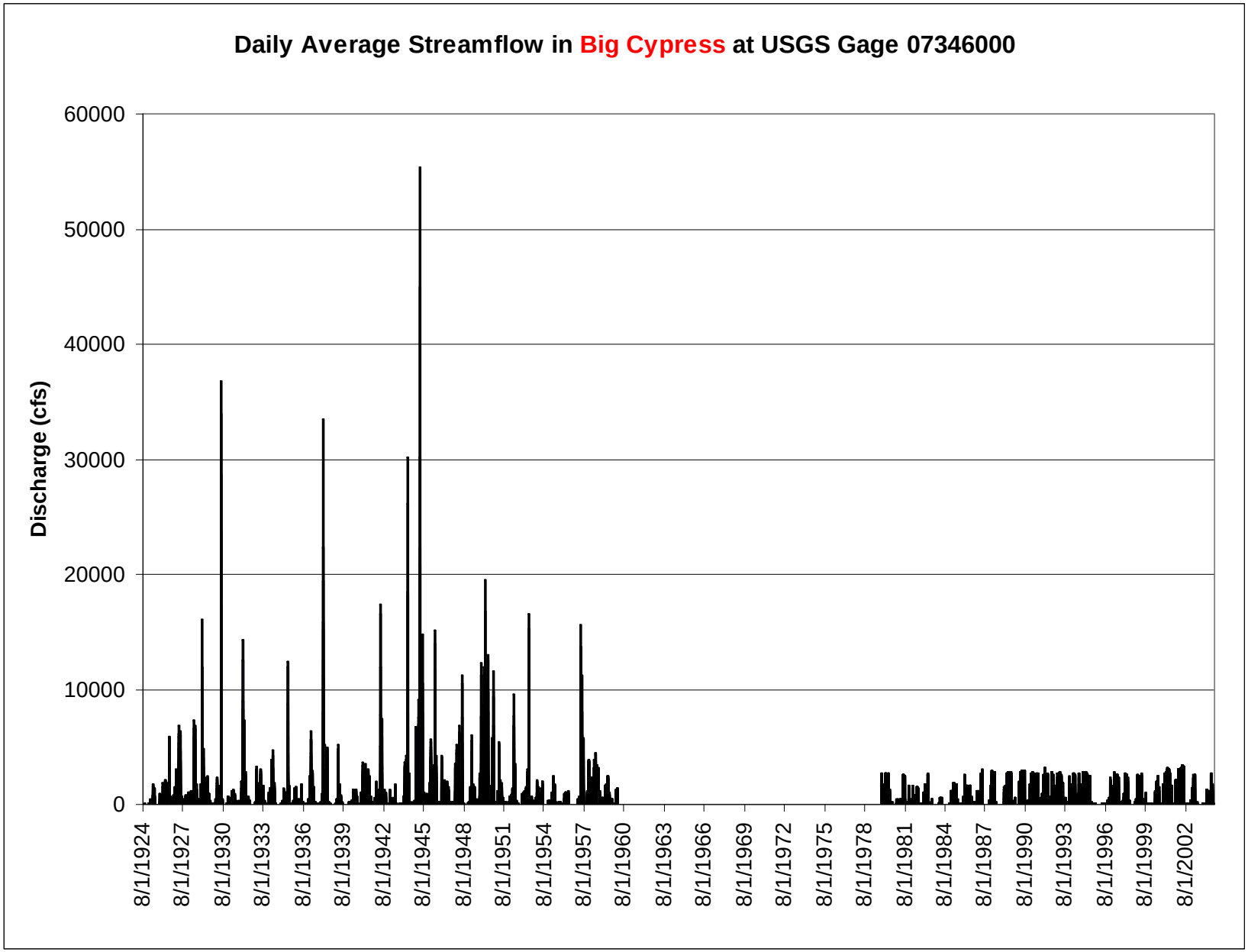


Figure 1-5 A large dam alters river flows and disrupts ecosystem functions

From “Rivers for Life: Managing Water for People and Nature” by Sandra Postel and Brian Richter (Island Press 2003)


Daily Average Streamflow in Big Cypress at USGS Gage 07346000
Discharge (cfs)
60000
50000
40000
30000
20000
10000
0
8/1/1924
8/1/1927
8/1/1930
8/1/1933
8/1/1936
8/1/1939
8/1/1942
8/1/1945
8/1/1948
8/1/1951
8/1/1954
8/1/1957
8/1/1960
8/1/1963
8/1/1966
8/1/1969
8/1/1972
8/1/1975
8/1/1978
8/1/1981
8/1/1984
8/1/1987
8/1/1990
8/1/1993
8/1/1996
8/1/1999
8/1/2002

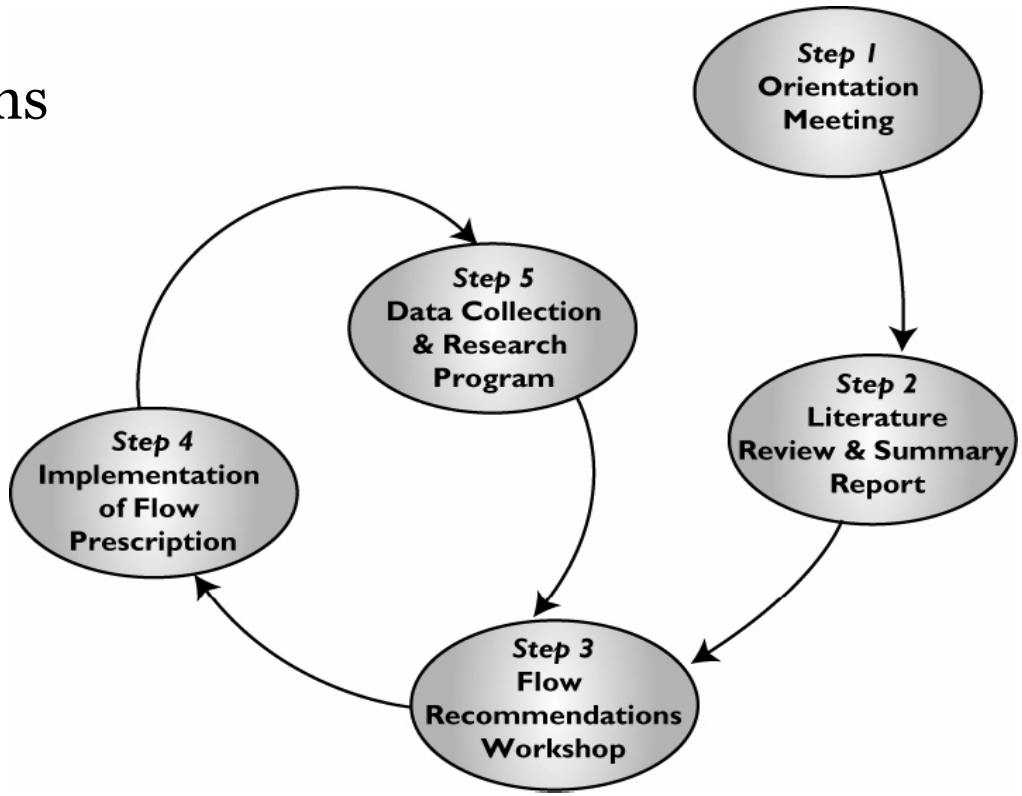
Developing Environmental Flows

Challenges Include:

- identifying what components of flow are ecologically most critical in river and bay systems
- quantifying those flow components to help guide development of flow standards
- achieving these tasks for all rivers within resource constraints while satisfying all stakeholder requirements
- short time line
- incorporating new knowledge and understanding into water management over time

Environmental Flow Recommendations:
A Collaborative and Adaptive Approach

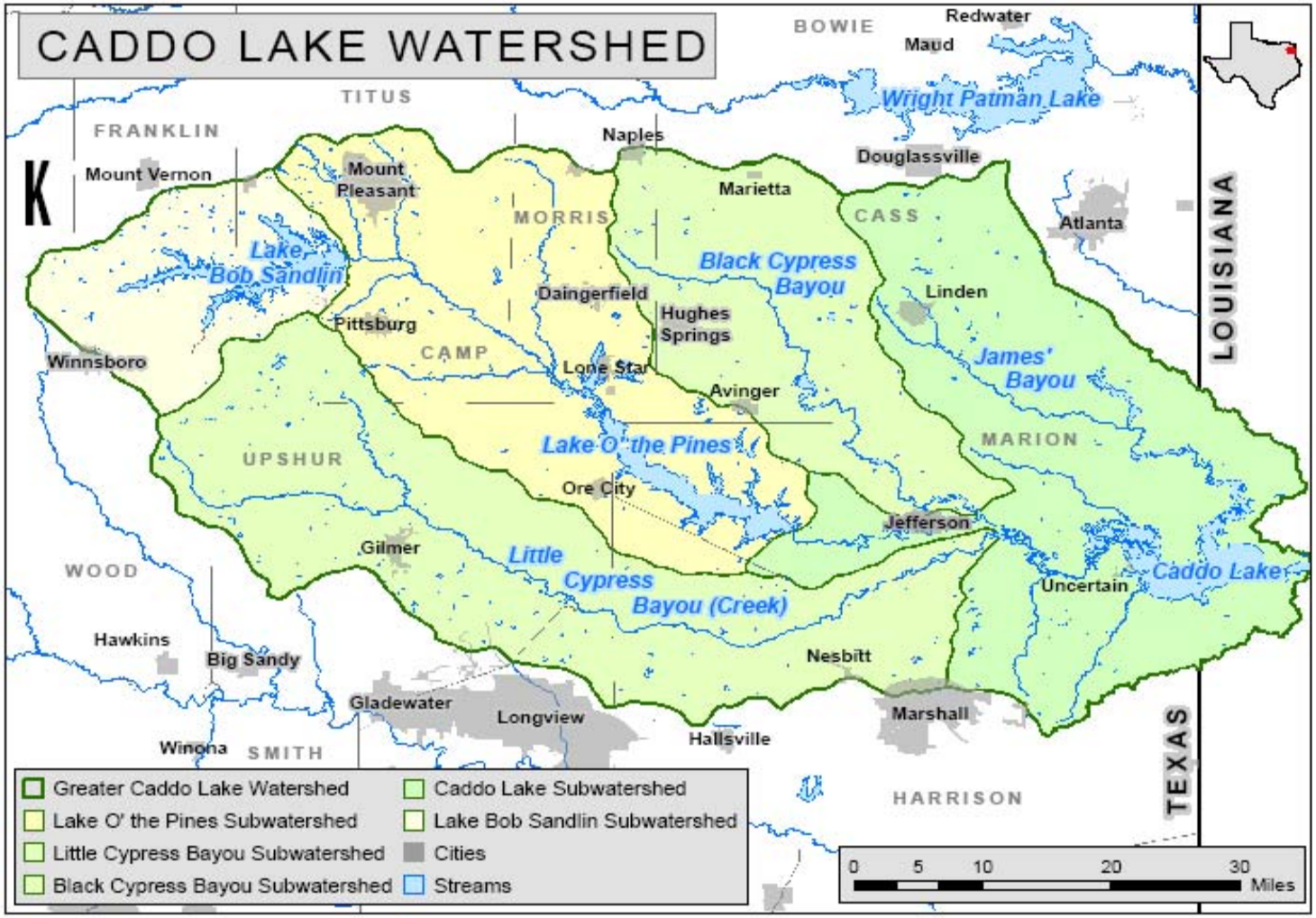
- Adaptive
  - Initial recommendations based on best available science
  - Refinement following flow experiments
- Flexible
  - Inter-disciplinary
  - Accommodates any inputs
  - Time constraints



From Richter et al. 2006. A collaborative and adaptive process for developing environmental flow recommendations. River Research and Applications 22:297-318

Utility for SB3 Environmental Flow Allocation Process

- Its foundation is a synthesis of existing science and analysis tools by an interdisciplinary team of scientists, experts, and stakeholders
- Incorporates and integrates of all types of information (e.g., field studies, hydraulic model outputs), not just IHA
- Generates robust initial recommendations even with limited inputs
- Initial phases are not particularly costly
- Not necessarily just for dams
- One issue: has been utilized primarily in site-specific applications – are other tools for regional or basin-wide scales (e.g., Ecological Limits of Hydrologic Alteration)


CADDO LAKE WATERSHED
BOWIE
Redwater
Maud
Wright Patman Lake
TITUS
FRANKLIN
Naples
Douglassville
Mount Vernon
Mount Pleasant
Marietta
MORRIS
CASS
Atlanta
Lake Bob Sandlin
Black Cypress Bayou
Daingerfield
Linden
Hughes Springs
Pittsburg
CAMP
Winnsboro
Lone Star
James' Bayou
Avinger
Lake O' the Pines
MARION
UPSHUR
Ore City
Jefferson
Gilmer
Little Cypress Bayou (Creek)
Caddo Lake
WOOD
Uncertain
Hawkins
Big Sandy
Nesbitt
Gladewater
Longview
Marshall
Winona
SMITH
Hallsville
HARRISON
LOUISIANA
TEXAS
Greater Caddo Lake Watershed
Lake O' the Pines Subwatershed
Little Cypress Bayou Subwatershed
Black Cypress Bayou Subwatershed
Caddo Lake Subwatershed
Lake Bob Sandlin Subwatershed
Cities
Streams
0 5 10 20 30
Miles

Goals

1. **An Environmental Flow Regime:** Now, a SB 3 Set Aside.

   But more than the SB 3 process

2. **New Operating Plan for Releases from Lake O' the Pines.**

3. **An Long-term Adaptive Management Process:** For continuation of the work.

Answer a Few Questions

Funding

Flows work supported primarily by federal & private funding.
WPP work supported Primarily by EPA, TCEQ and NETMWD

Key Cost

Literature review and report (TX A&M) $70,000

Participation by Scientists

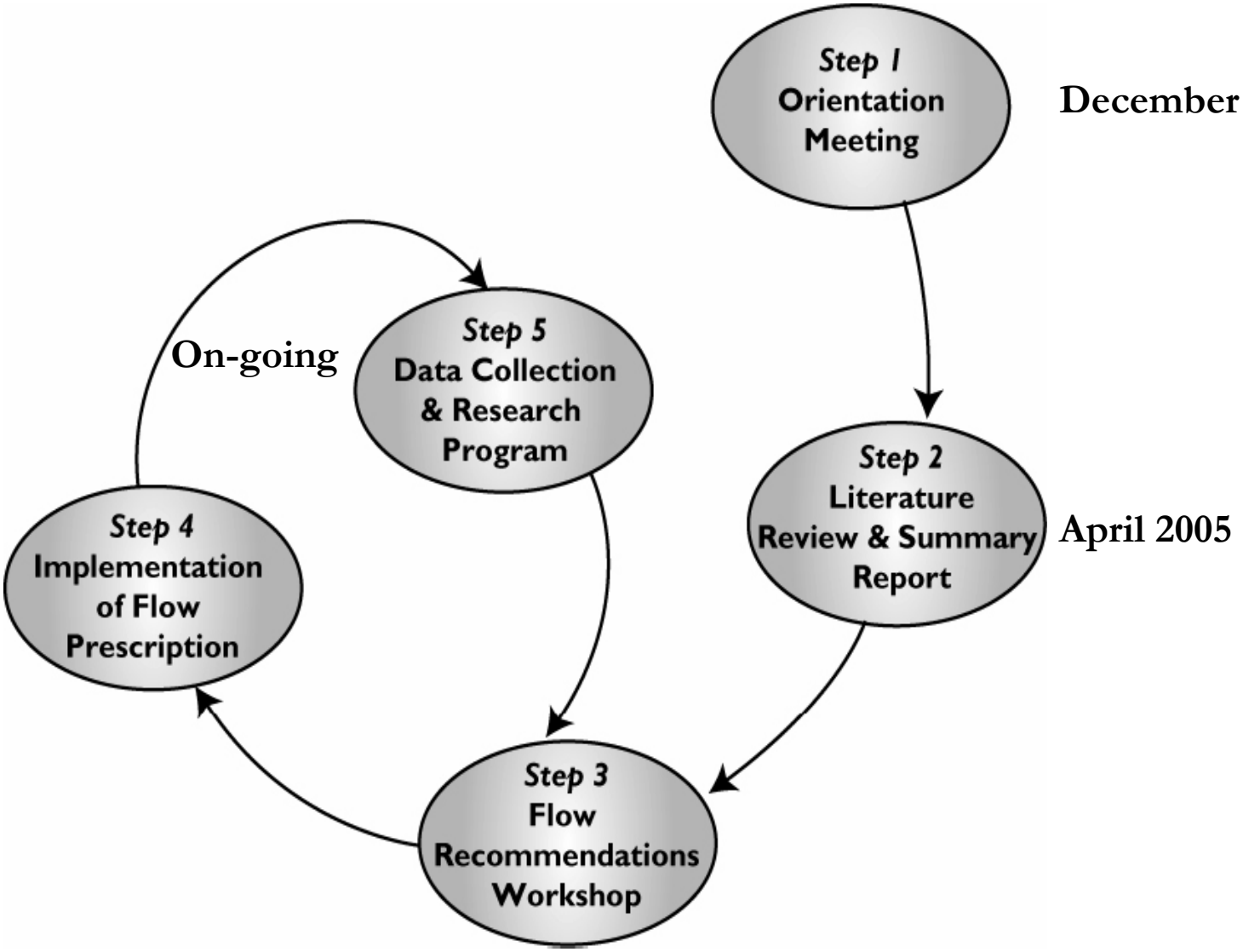
Due to their past work, e.g., proposed reservoirs, barge canal, etc

Stakeholder Engagement

Involved in discussions on reservoirs, barge canal., etc

Examples of 175+ Participants in the Work to Date

- **Local & Regional Governments** – NETMWD, CVND, some local counties and cities.
- **Tx & La State Agencies** – TPWD, TWDB, TCEQ, TSSWCB, LDEQ
- **Federal Agencies** – Corps of Engineers, USGS, USF&WS, National Wetlands Research Center
- **Universities** – East Texas Baptist University, Texas A&M, Texas Tech, LSU Shreveport, TCU, Texas State.
- **Reps from Business and industries** – AEP, Nestle Waters NA, Caddo Lake Chamber of Commerce
- **Others** – Red River Valley Assn., Landowners, Bass Clubs, Ducks Unlimited, Nat. Wildlife Fed.


Step 1
Orientation
Meeting
December 2004
Step 2
Literature
Review & Summary
Report
April 2005
Step 3
Flow
Recommendations
Workshop
May 2005, October 2006 & December 2008
Step 4
Implementation
of Flow
Prescription
Step 5
Data Collection
& Research
Program
On-going

Orientation Meeting

December 2004

Explanation of the Process

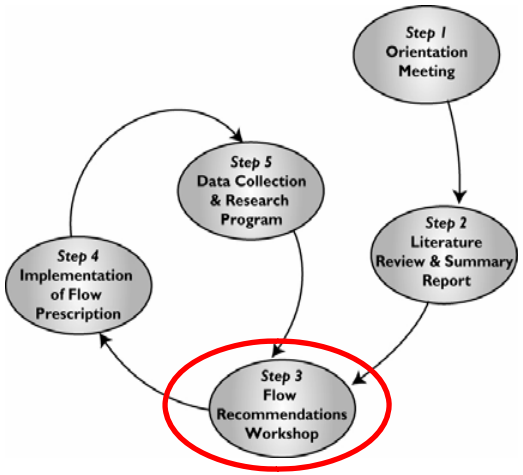
Assessment of Available Resources (personnel and data)

Field Reconnaissance

Literature Review & Summary Report

December 2004 - April 2005

- Riverine Components - Hydrology, Physical Processes, Water Quality, Biology (Aquatic and Terrestrial), Lake and Wetland Issues
- Appendices include land use maps, output from IHA and species lists.
- Annotated Bibliography



Ecosystem Flow Workshop

May 2005

- 2 days, 87 scientists, water managers and local community
- Overview of process and expected results and Presentations of the Summary Report
- Two break-out sessions with two groups each session defined ecological flow recommendations for:
  1. Big Cypress Creek and Caddo Lake
  2. Low Flows and High Flow Pulses/Floods
- Building Blocks for River and Lake
- Prioritized Research Needs
- Operational Constraints, Stakeholder Concerns and Monitoring

Developing Environmental Flows

A Multi-Level Approach

The Common Denominator

- **Low Flows** – Determine the amount of habitat available.
- **High Flow Pulses** – Open up additional habitat area, bring additional food material from upstream areas, moderate temperatures and oxygen levels, clean spawning gravels, and provide cues for migration to spawning areas
- **Floods** – Create the physical template of the river ecosystem, including formation of oxbows (backwaters) and secondary channels, floodplains, and spawning bars, and keep introduced species populations in check

Instream Flow Building Blocks

Big Cypress Creek/ Caddo Lake

Floods

6,000-10,000 cfs for 2-3 days
Every 3-5 years
*Maintain aquatic habitat in floodplain
* Riparian seed dispersal
* Inhibition of upland vegetation for both creek & lake
*Seed dispersal
* Vegetation removal
20,000 cfs for 2-3 days
Every 10 years
*For channel migration

High Flow Pulses

6,000 cfs for 2-3 days
Every 2 years
* For channel maintenance

1,500 cfs for 2-3 days
3-5X a year every year
* 1 occurring in March for Paddlefish
* Sediment transport, oxbow connectivity
•Waterfowl habitat flushing
(Includes December)

Low Flows

40 – 536 cfs
Maintain biodiversity and connectivity (backwater & oxbows)

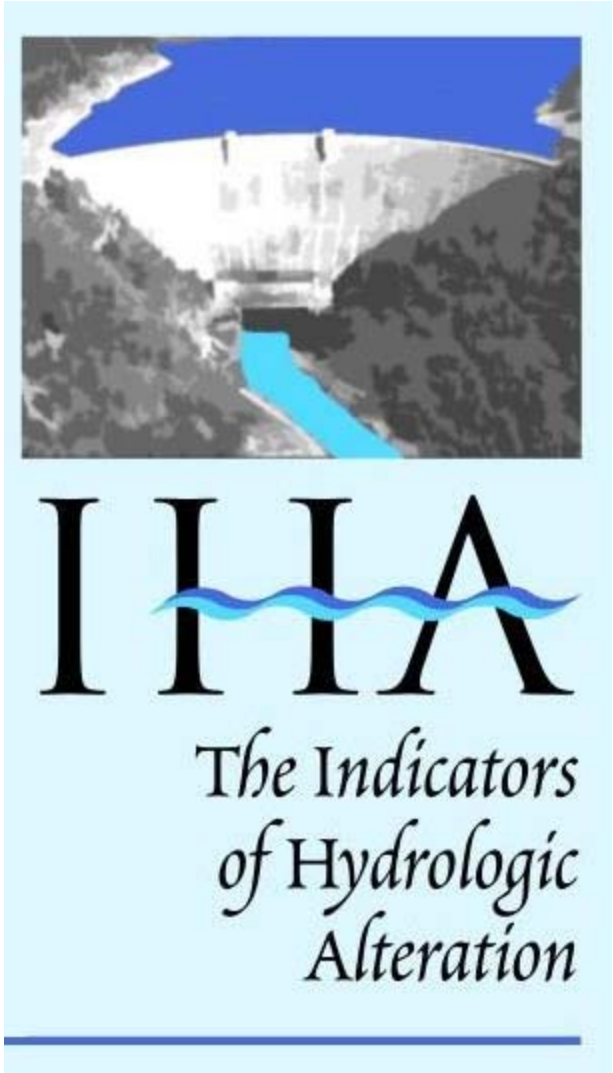
268-347 cfs Pre-dam median	390 - 79 cfs Benthic drift & dispersal, fish spawning	35 - 40 cfs Fish habitat	40 - 117 cfs Pre-dam median
90 cfs Fish habitat	218 – 49 cfs Spawning habitat	13 - 6 cfs Maintain aquatic diversity	40 - 90 cfs Fish habitat

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

Key

- Wet Year
- Avg Year
- Dry Year

Low Flow Targets



- Magnitude, Duration, Frequency, Timing, Rate of Change
- Range of Variation Analysis
- Wet, Normal, Dry
- Flow Regime – Environmental Flow Components

Indicators of Hydrologic Alteration – Environmental Flow Component (EFC)

- Divides the hydrograph into high flow (>75th percentile) and low flow (<50th percentile)
- High flows are further divided into Large Floods (10 year recurrence), Small Floods (2 year recurrence) and High Flow Pulses (rise faster than 25% and fall faster than 10%)
- Low flows also include Extreme Low Flows (<10th percentile)
- Percentile statistics of the low flows for each month are also generated

EFC Defaults

Environmental Flow Component (EFC) analysis computes statistics for five different flow components: extreme low flows, low flows, high flow pulses, small floods, and large floods. If you wish, this analysis may be performed for two separate seasons (see Analysis Days tab).

The parameters used to define EFCs can be set below.

High Flow Pulses

All flows that exceed 75 percent of flows for the period will be classified as high flow pulses.

No flows that are below 50 percent of flows for the period will be classified as high flow pulses.

Between these two flow levels, a high flow pulse will begin when flow increases by more than 25 percent per day, and will end when flow decreases by less than 10 percent per day

Flood Definition

A small flood event is defined as a high flow pulse with a recurrence time of at least: 2.00 years.

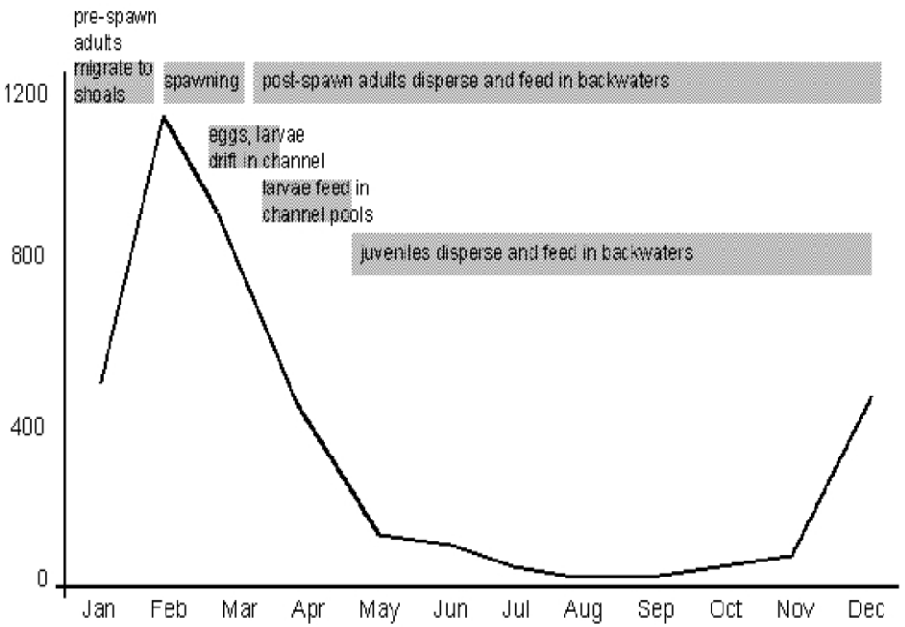
A large flood event is defined as a high flow pulse with a recurrence time of at least: 10.00 years.

Extreme Lowflow Definition

An extreme low flow is defined as a flow in the lowest 10 percent of all low flows in the period.

Relationship between Flow and Life History needs

	Pre-impact period: 1924-1956 (33 years) Pre-Impact				
	10%	25%	50%	75%	90%
EFC Monthly Low Flows					
January-Low Flow	79.60	116.13	267.75	395.88	540.70
February-Low Flow	140.90	195.13	346.50	500.00	521.50
March-Low Flow	153.90	218.25	389.00	535.50	629.00
April-Low Flow	130.60	197.50	332.50	444.00	511.60
May-Low Flow	96.10	113.50	150.00	263.50	478.60
June-Low Flow	24.40	48.88	79.00	139.63	383.30
July-Low Flow	7.69	12.50	39.00	69.50	117.20
August- Low Flow	3.22	5.80	11.50	41.00	62.00
September-Low Flow	2.65	5.65	12.25	31.50	62.15
October-Low Flow	3.92	6.07	26.00	49.00	109.15
November-Low Flow	10.42	26.00	56.00	93.50	306.00
December-Low Flow	29.10	61.25	117.00	274.75	410.40



IHA-EFC Statistics for Big Cypress 1924-1956 (33 years)

	EFC Low Percentiles			Low Flow Building Blocks		
	25th	50th	75th	Dry	Normal	Wet
Jan	116	268	396	**90**	268	396
Feb	195	347	500	**90**	347	500
Mar	218	389	536	218	390	536
Apr	198	333	444	198	330	445
May	114	150	264	114	150	264
Jun	49	79	140	49	79	140
Jul	13	39	70	13	35	70
Aug	6	12	41	6	**40**	41
Sep	6	12	32	6	**40**	**40**
Oct	6	26	49	**40**	**40**	49
Nov	26	56	94	**90**	**90**	94
Dec	61	117	275	**90**	117	275

Instream Flow Building Blocks

Big Cypress Creek/ Caddo Lake

Floods

6,000-10,000 cfs for 2-3 days
Every 3-5 years
*Maintain aquatic habitat in floodplain
* Riparian seed dispersal
* Inhibition of upland vegetation for both creek & lake
*Seed dispersal
* Vegetation removal
20,000 cfs for 2-3 days
Every 10 years
*For channel migration

High Flow Pulses

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* 1 occurring in March for Paddlefish
* Sediment transport, oxbow connectivity
•Waterfowl habitat flushing
(Includes December)

Low Flows

40 – 536 cfs
Maintain biodiversity and connectivity (backwater & oxbows)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
268-347 cfs Pre-dam median		390 - 79 cfs Benthic drift & dispersal, fish spawning				35 - 40 cfs Fish habitat			40 - 117 cfs Pre-dam median		
90 cfs Fish habitat		218 – 49 cfs Spawning habitat				13 - 6 cfs Maintain aquatic diversity			40 - 90 cfs Fish habitat		

Key

- Wet Year
- Avg Year
- Dry Year

High Flow Ecosystem Benefits

- Channel Maintenance - Flushing accumulated fine sediments from gravel, scouring pools, building riffles, removing vegetation from active channel inundating bars and maintaining channel capacity.
- Flood Plain connectivity, Cypress Regeneration and spawning cues
- Channel Forming – large scale fluvial geomorphic adjustments

High Flow
Concepts and Approaches

- Bankfull Discharge – Connectivity
- Effective, Dominate or Channel Forming Discharge – Sediment Transport

- Measure water surface elevation at bankfull
- Model sediment transport capacity
- 2 year return flow

Effective discharge calculation : a practical guide / by David S. Biedenharn ... [et al.] ; prepared for U.S. Army Corps of Engineers. 2000

Big Cypress High Flow Recurrence

Recurrance	PeakFQ	Target
1.5	4,207	
2.0	6,485	6,000
4.0	12,693	
10.0	23,295	20,000

- Channel Maintenance flow – High Flow Pulse 1,500 cfs from IHA
- Bankfull Flow – 2 year recurrence
- Channel Forming Flow – 10 year recurrence

Durations of occurrence adjusted based on professional judgment
Magnitude of bankfull identified as a top research priority

Second Ecosystem Flow Workshop

October 2006 (80 participants)

Instream Flow Building Blocks

Little Cypress Creek

Floods

12,000 cfs for 2-3 days
Every 10 years
*For channel migration
*Maintain aquatic habitat in floodplain
* Riparian seed dispersal
* Inhibition of upland vegetation for both creek & lake
*Seed dispersal
* Vegetation removal

High Flow Pulses

2,700 - 4,000 cfs for 2-3 days
Every 2 years
•For channel maintenance
•* Sediment transport, oxbow connectivity
•Waterfowl habitat flushing
•(Includes December)

Low Flows

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
462	570	548	466	320	179	80	30	33	53	133	250
242	417	415	287	155	96	26	10	10	19	65	144
112	186	219	158	86	38	12	5	5	5	18	68

Base or low flows are to maintain aquatic habitat

Key

- Wet Year
- Avg Year
- Dry Year

Instream Flow Building Blocks

Black Cypress Creek

Floods

8,000 cfs for 2-3 days
Every 10 years
*For channel migration
*Maintain aquatic habitat in floodplain
* Riparian seed dispersal
* Inhibition of upland vegetation for both creek & lake
*Seed dispersal
* Vegetation removal

High Flow Pulses

2,100 - 3,000 cfs for 2-3 days
Every 2 years
•For channel maintenance
•* Sediment transport, oxbow connectivity
•Waterfowl habitat flushing
•(Includes December)

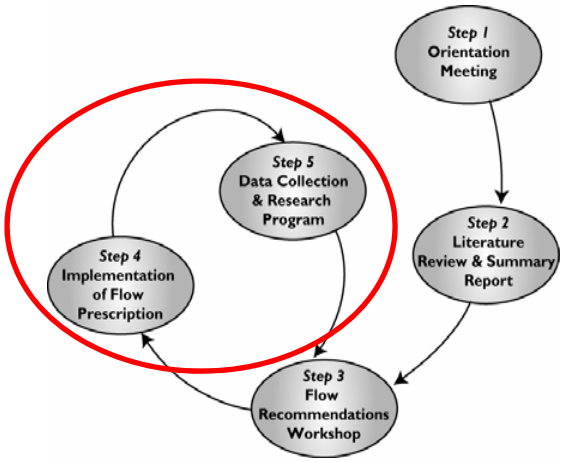
Low Flows

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
322	366	382	327	210	191	63	14	19	45	158	294
222	300	306	205	156	95	32	5	4	13	74	209
125	201	242	140	80	42	11	4	4	4	19	91

Base or low flows are to maintain aquatic habitat

Key

- Wet Year
- Avg Year
- Dry Year



Implementation of Flow Prescription & Data Collection and Research Program

- Installation of new stream gage on Big Cypress at Karnack
- Museum study of historical fish data
- Characterize segment and reach-scale channel geomorphologic features
- Baseline collections of the fish assemblage
- Establish instrumented cross-sections at non-gauged locations.
- Habitat requirements of target organisms
- Modeling to develop Flow-Habitat response Curves & habitat time Series
- Measurements to quantify overbank discharge
- Cross section surveys on Big Cypress to support HEC-RAS development
- Flow-Inundation mapping
- Watershed Protection Plan

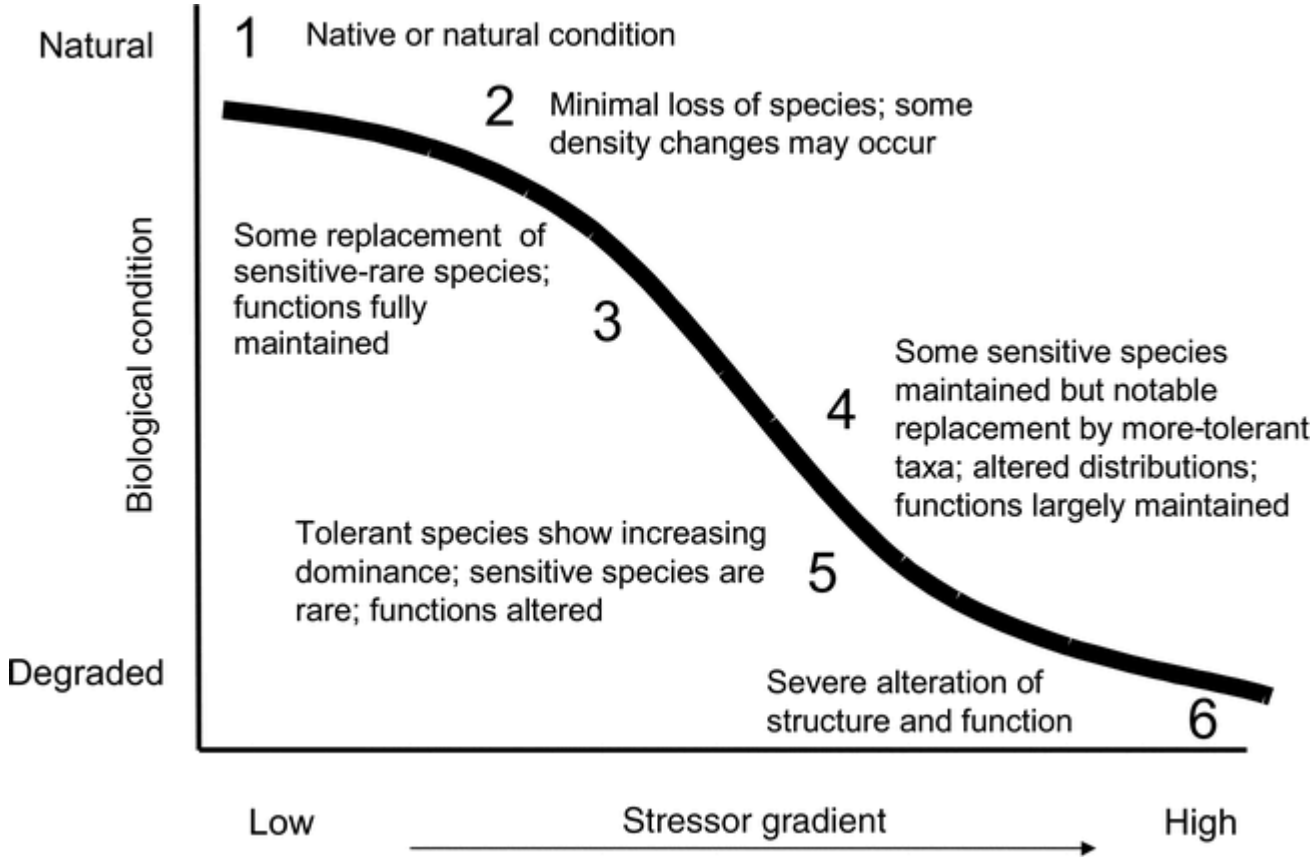
Refinements to the Preliminary Recommendations

- Assembled and analyzed additional data
- Redeveloped existing habitat models
- Collected new field data

SB 2 Texas Instream Flow Program Sound Ecological Environment

A resilient, functioning ecosystem characterized by intact, natural processes and a balanced, integrated, and adaptive community of organisms comparable to that of the natural habitat of a region.

Biological Condition Gradient



Historical Trends in Fish Assemblage

Reproductive Guild	1953-1954	1995	2006
Non guarders			
Open Substratum			
Pelagophils †	22.49	7.25	0.72
Guarders			
Nest Spawners			
Lithophils ∞	7.38	42.58	56.15

- Pelagophils†: Obligate riverine species, broadcast-pawn buoyant eggs within current
- Lithophils∞: Includes most Centrarchidae, spawn elliptical egg envelopes over rock or gravel nests

Base Flows

"*The primary objective of base flow recommendations will be to ensure adequate habitat conditions, including variability, to support the natural biological community of the specific river sub-basin.*"

- Building Blocks derived from IHA with slight modifications
- Texas Instream Flow Program – Habitat Modeling

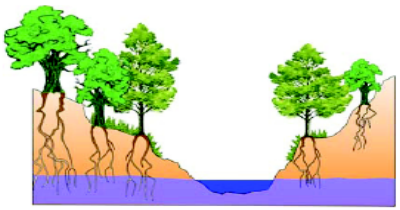
SB2 Subsistence and Base Flows

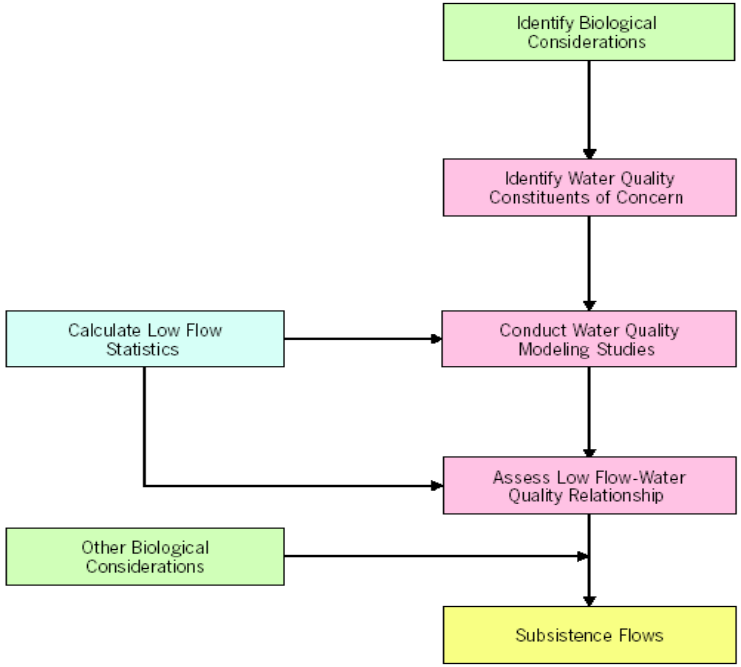
Subsistence Flows

Spatial scale:
River Reach

Temporal scale:
Hourly Flow, Varies from Month to Month

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality



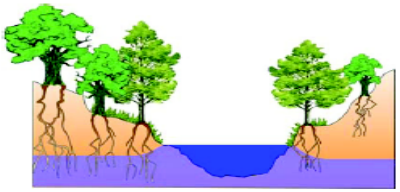


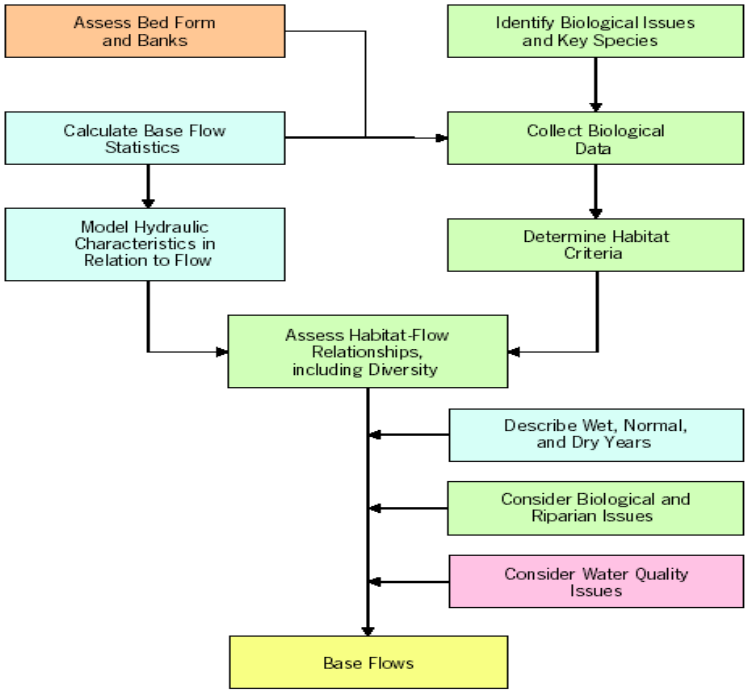
Base Flows

Spatial scale:
River Reach

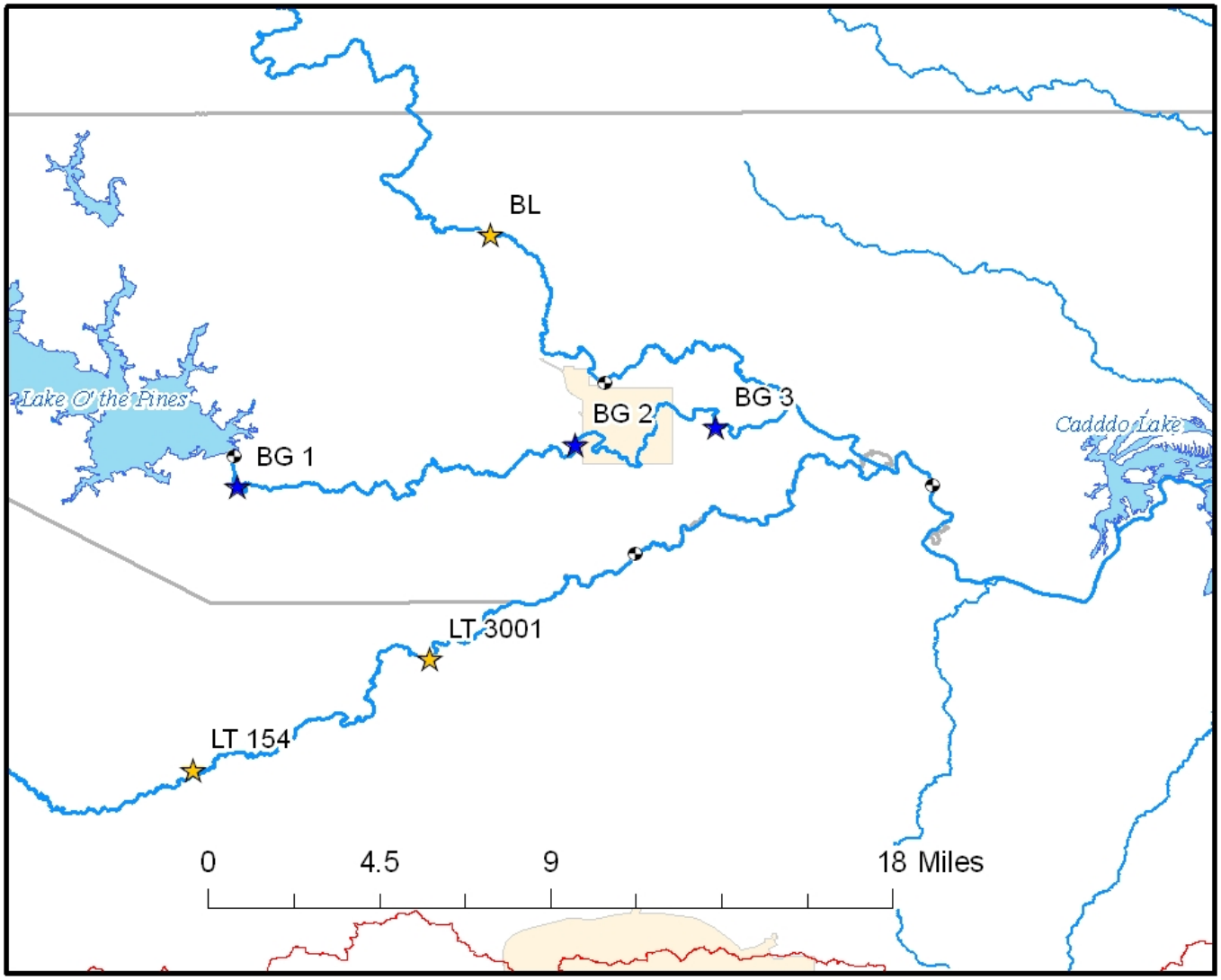
Temporal scale:
Daily Flow Range, Varies from Month to Month

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality

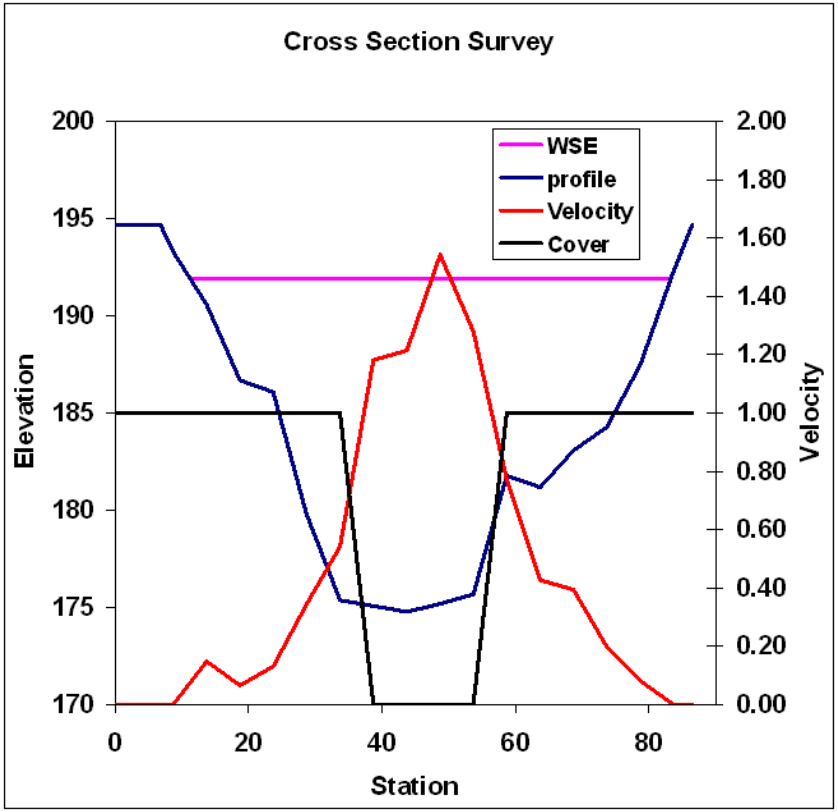


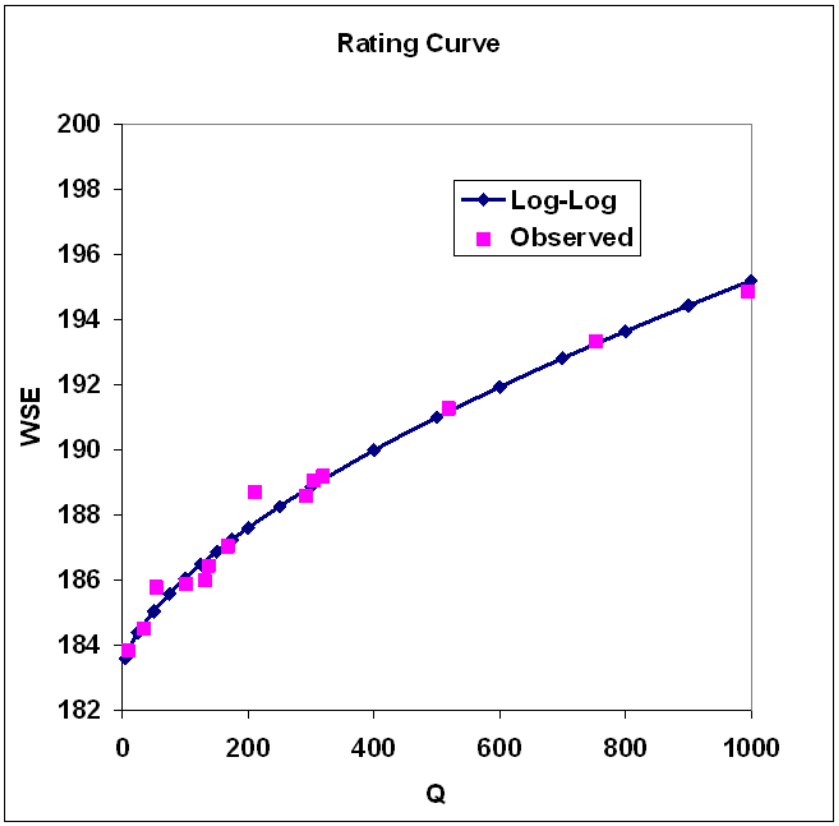


Existing PHABSIM data

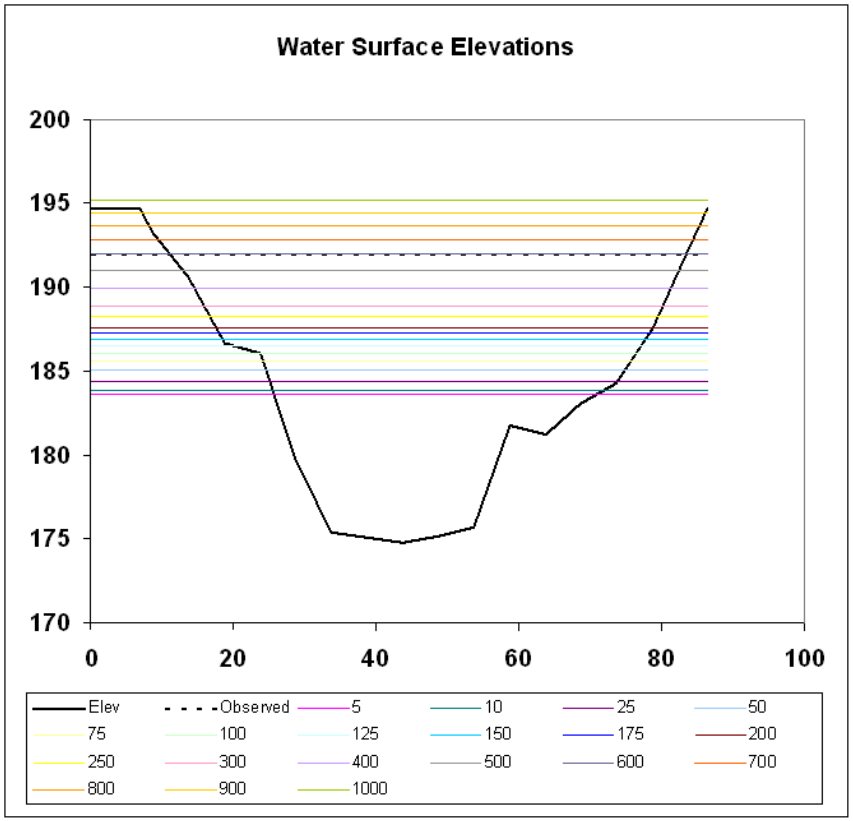


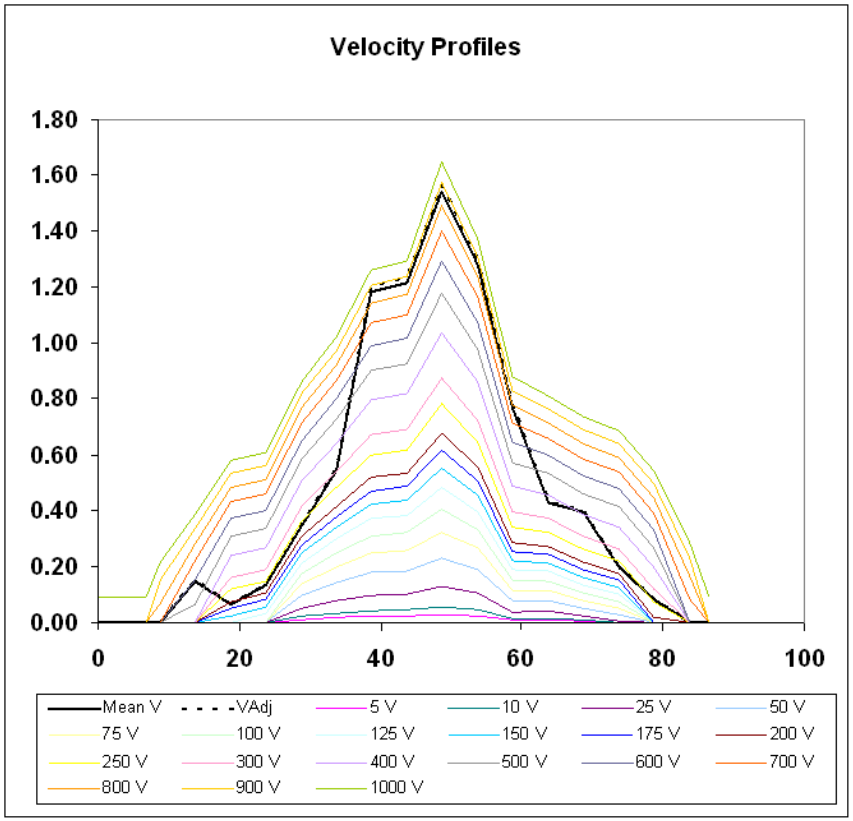
Cross Section Surveys & Rating Curves



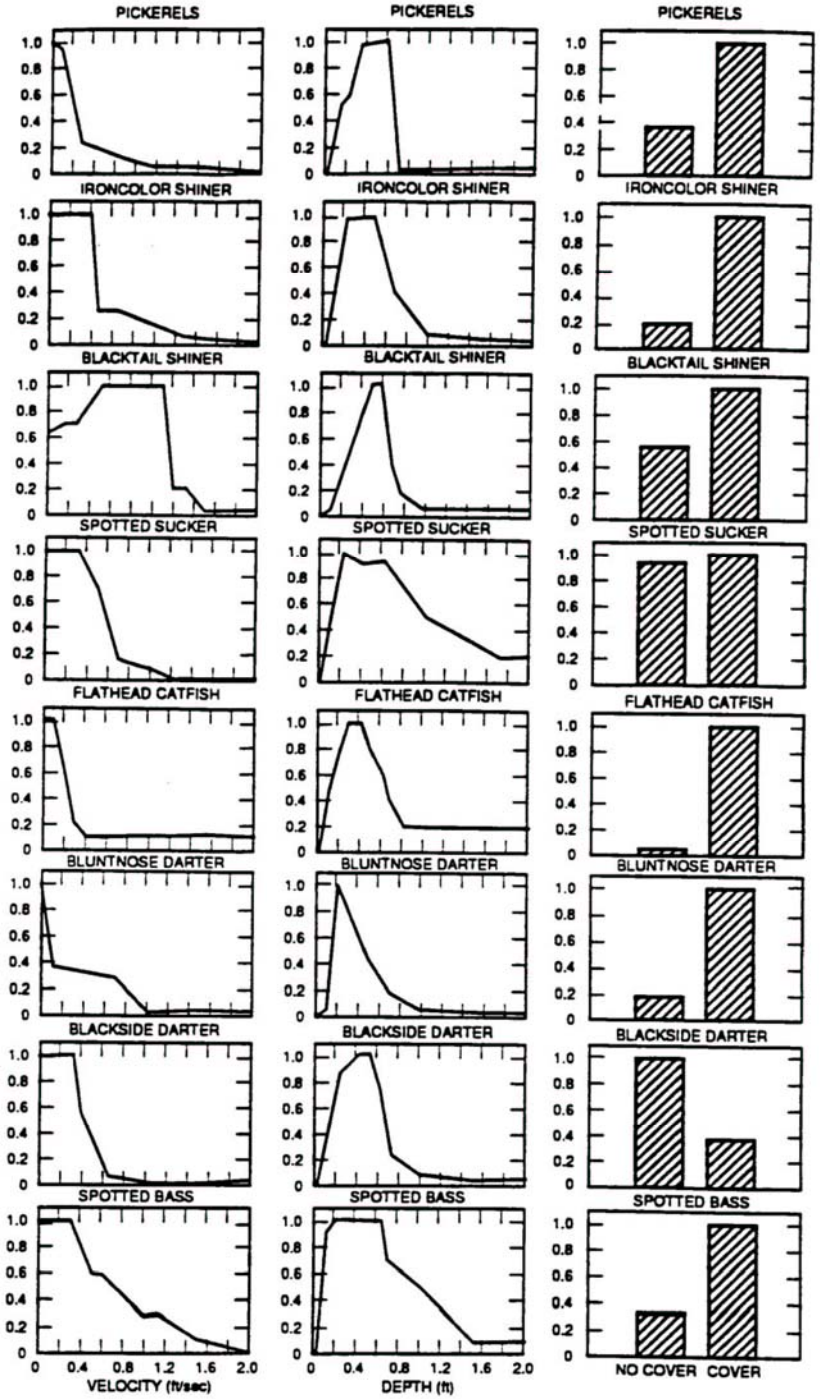


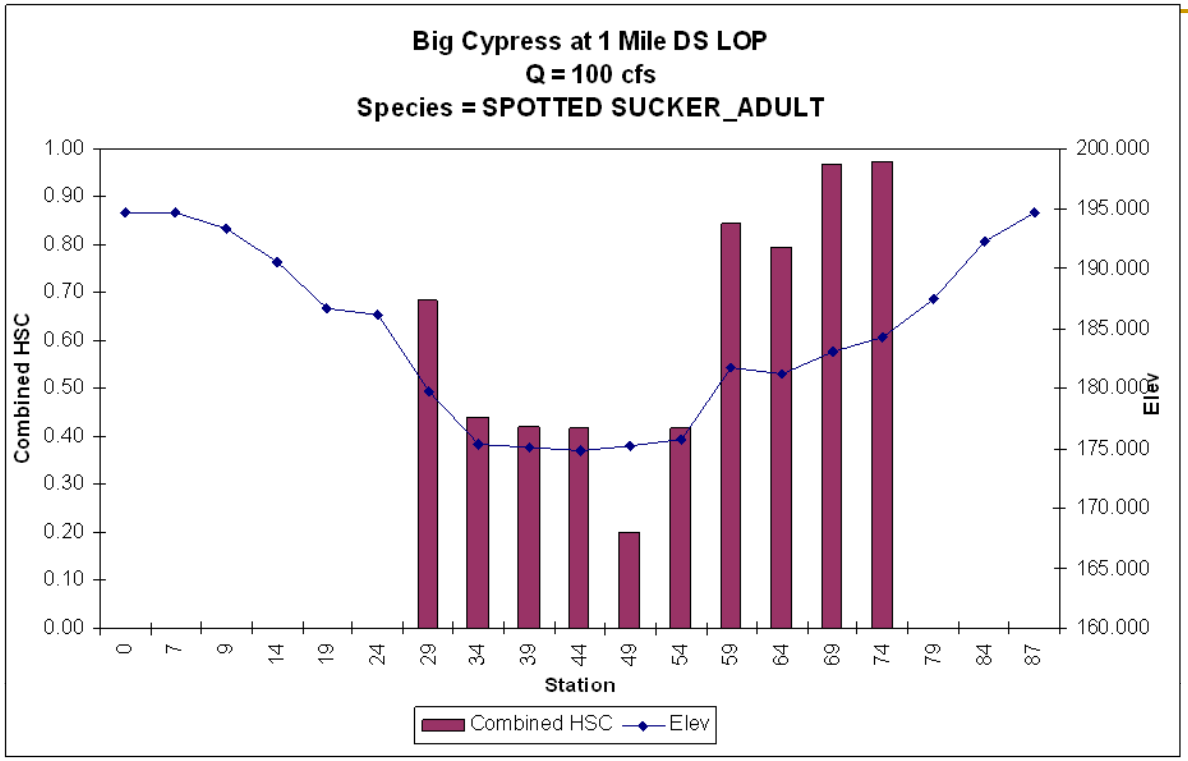
Modeled Depth and Velocity

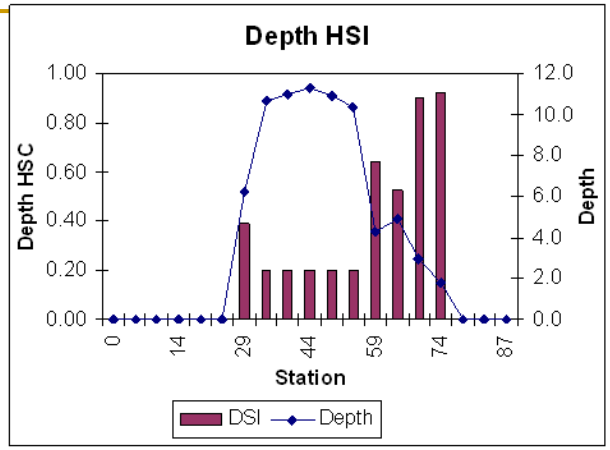


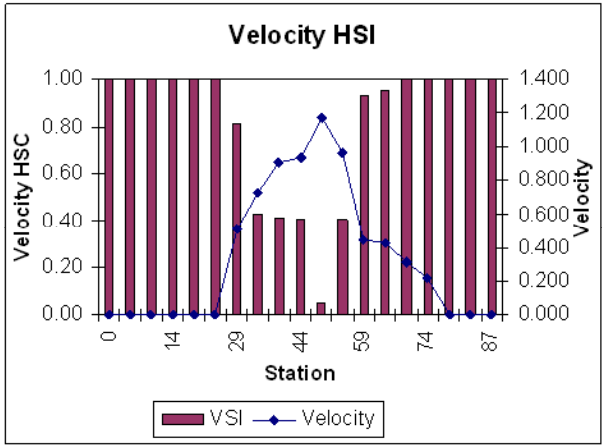


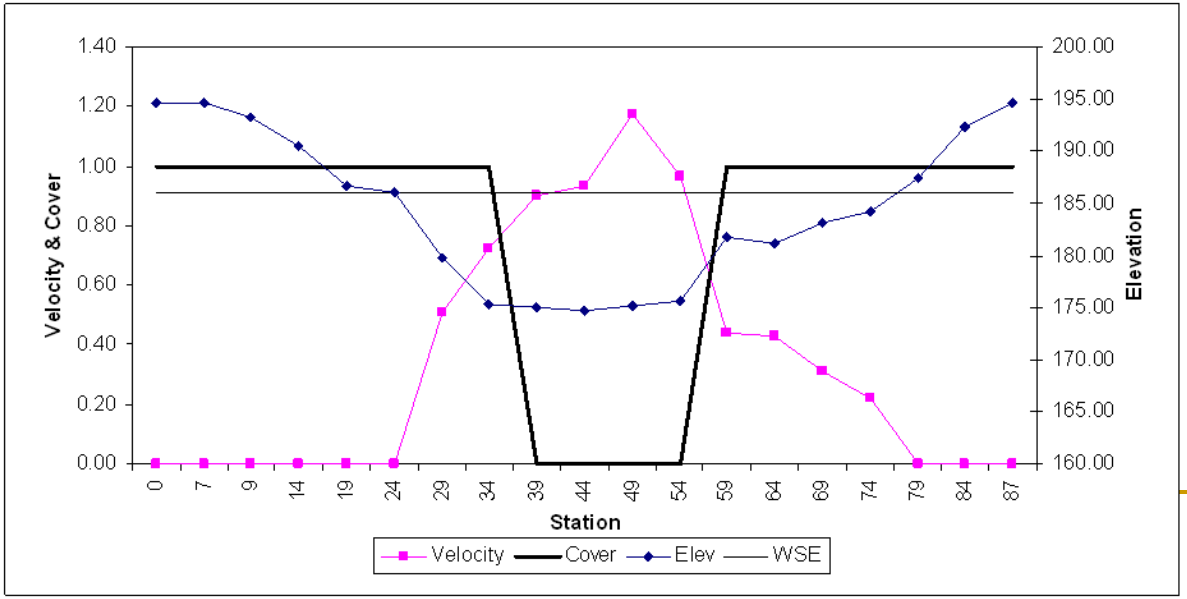
Habitat Suitability Criteria

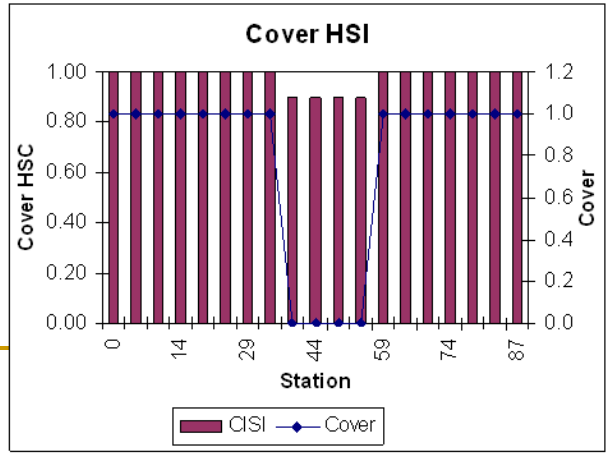



Big Cypress at 1 Mile DS LOP
Q = 100 cfs
Species = SPOTTED SUCKER_ADULT
Combined HSC
Elev
Station
Combined HSC
Elev

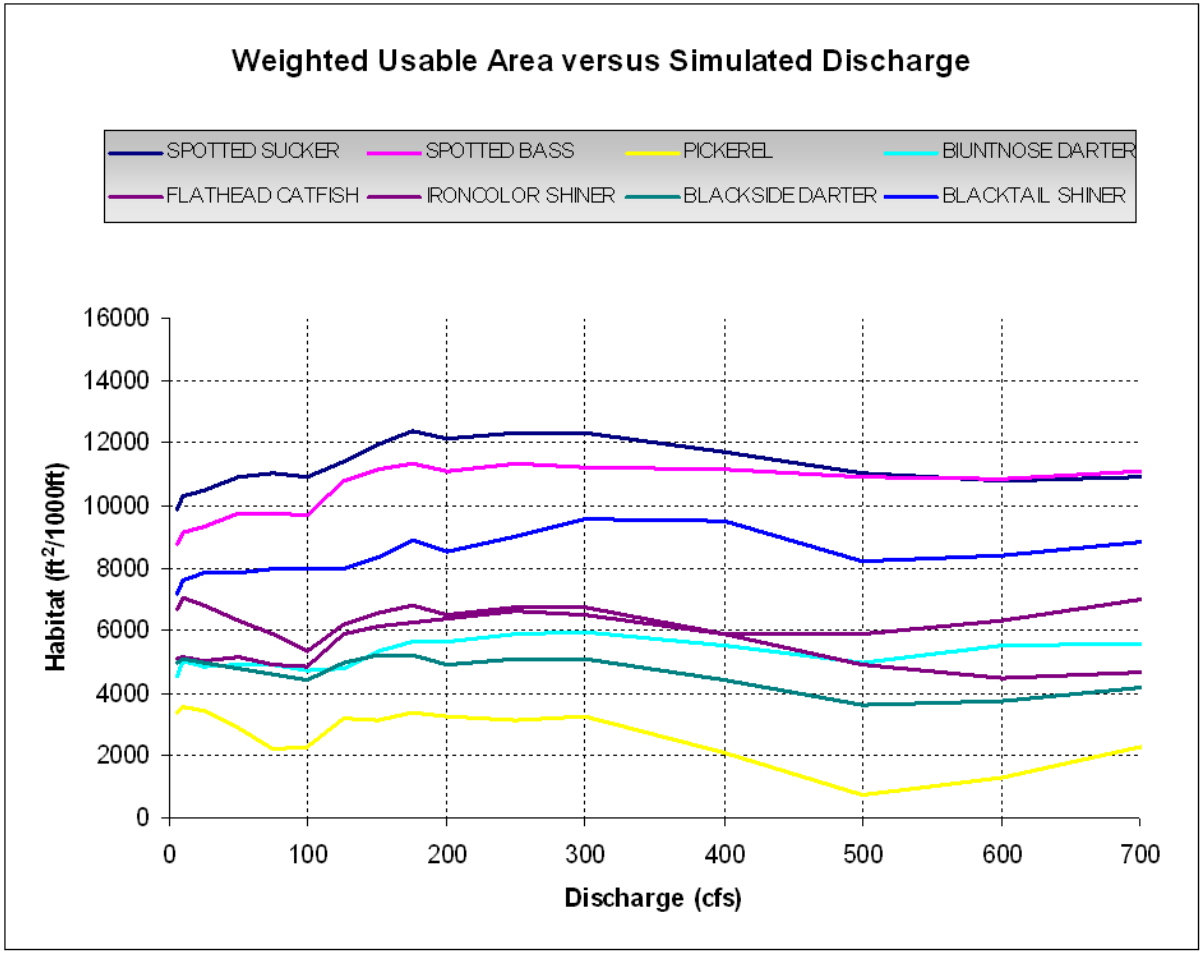

Depth HSI
Depth HSC
Depth
Station
DSI
Depth


Velocity HSI
Velocity HSC
Velocity
Station
VSI
Velocity


Velocity & Cover
Elevation
Station
Velocity
Cover
Elev
WSE


Cover HSI
Cover HSC
Cover
Station
CISI
Cover

Ecological Response Curves
Flow vs. WUA



Application of Building Blocks

	Slack Water					Swift Water		
	Sand and Gravel		Vegitation		Cervice	Sand and Gravel		Cervice
Month	Spotted sucker	Spotted bass	Pickerel	Bluntnose darter	Flathead catfish	Ironcolor shiner	Blackside darter	Blacktail shiner
Jan	12,317	11,308	3,177	5,912	6,587	6,747	5,081	9,187
Feb	12,029	11,197	2,685	5,748	6,203	6,350	4,775	9,523
Mar	11,787	11,168	2,179	5,571	5,924	5,981	4,491	9,496
Apr	12,125	11,208	2,884	5,817	6,313	6,496	4,887	9,534
May	11,972	11,156	3,119	5,359	6,105	6,537	5,198	8,364
Jun	10,998	9,730	2,235	4,874	4,904	5,817	4,564	7,973
Jul	10,652	9,492	3,210	4,880	5,069	6,591	4,874	7,849
Aug	10,736	9,582	3,107	4,884	5,091	6,497	4,835	7,846
Sep	10,736	9,582	3,107	4,884	5,091	6,497	4,835	7,846
Oct	10,736	9,582	3,107	4,884	5,091	6,497	4,835	7,846
Nov	10,952	9,693	2,262	4,786	4,886	5,558	4,485	7,972
Dec	11,232	10,430	2,914	4,768	5,565	5,909	4,797	7,962

	Slack Water					Swift Water		
Month	Spotted sucker	Spotted bass	Pickerel	Bluntnose darter	Flathead catfish	Ironcolor shiner	Blackside darter	Blacktail shiner
Jan	99%	100%	89%	100%	94%	96%	97%	96%
Feb	97%	99%	75%	97%	89%	90%	91%	100%
Mar	95%	98%	61%	94%	85%	85%	86%	99%
Apr	98%	99%	81%	98%	90%	92%	94%	100%
May	97%	98%	88%	90%	87%	93%	100%	88%
Jun	89%	86%	63%	82%	70%	83%	87%	83%
Jul	86%	84%	90%	82%	72%	94%	93%	82%
Aug	87%	84%	87%	82%	73%	92%	93%	82%
Sep	87%	84%	87%	82%	73%	92%	93%	82%
Oct	87%	84%	87%	82%	73%	92%	93%	82%
Nov	88%	85%	63%	81%	70%	79%	86%	83%
Dec	91%	92%	82%	80%	79%	84%	92%	83%

Refinement/Validation of Initial Building Block Recommendations

- Does anything jump out as a concern?
- Does the change in habitat based on pre vs. post LOP conditions suggest a refinement?
- Re-evaluate adjustments from IHA outputs?
- Refinements for declining guilds?
- Do we need all three levels (wet/average/dry)?
- Are the base flows upstream and downstream of Jefferson the same?

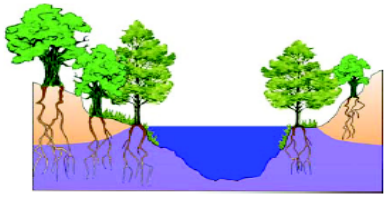
SB2 High Flow Pulses and Overbank Flows

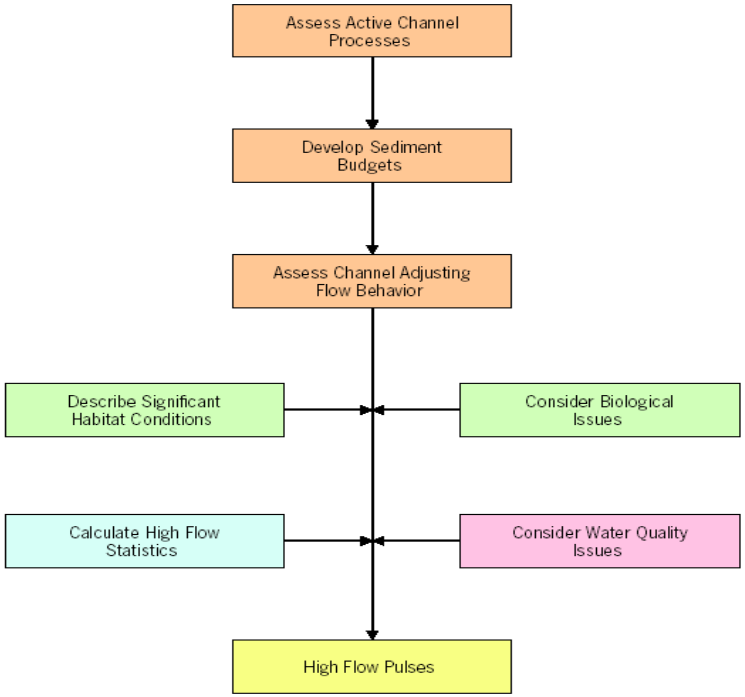
High Flow Pulses

Spatial scale:
River Segment

Temporal scale:
Multiple High Flow, Pulses Throughout the Year

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality



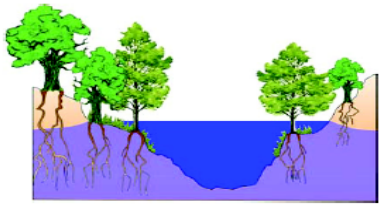


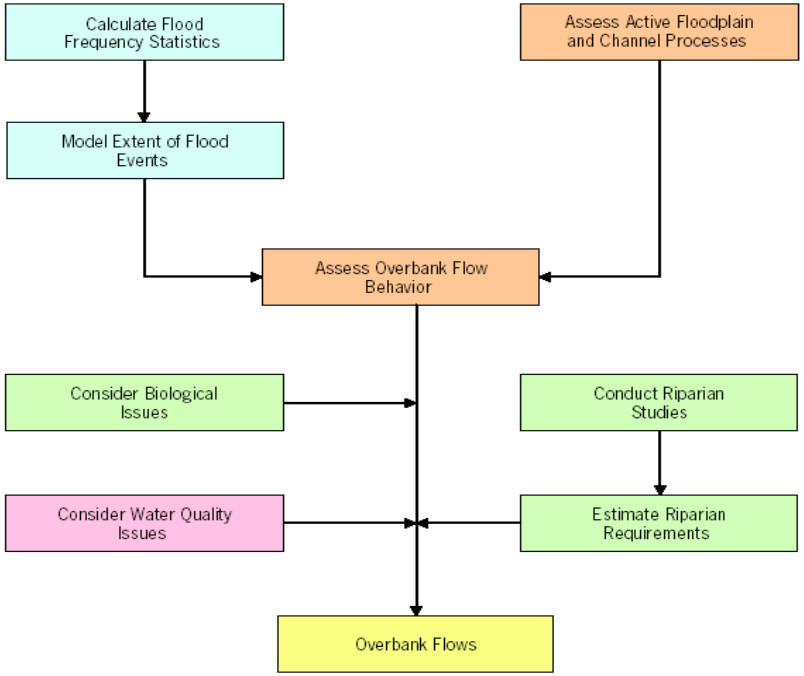
Overbank Flows

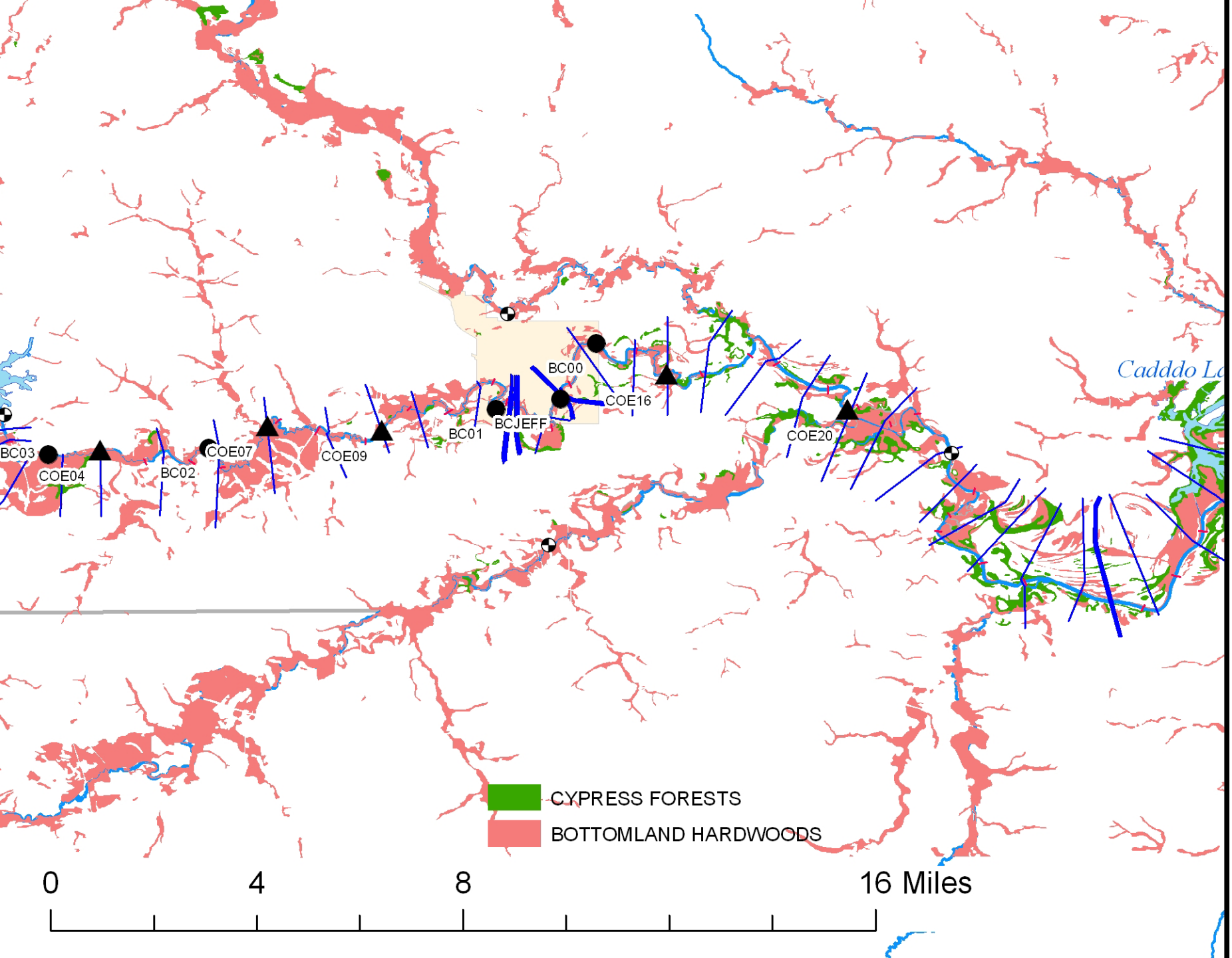
Spatial scale:
River Segment

Temporal scale:
Extreme Flow Events, Occur Less Than Once per Year

Primary discipline:
- Hydrology/Hydraulics
- Biology
- Geomorphology
- Water Quality






BC03
COE04
BC02
COE07
COE09
BC01
BCJEFF
BC00
COE16
COE20
Caddo La
CYPRESS FORESTS
BOTTOMLAND HARDWOODS
0
4
8
16 Miles

Field Data Collection

Pressure transducer installed at each site for continuous monitoring of stage and water temperature

-Base of transducer sensor surveyed in to benchmark of known datum.
-Continuous (hourly beginning in March 06 to August 07) recording of stage and water temperature.
-Transducer data downloaded and units calibrated every 3-4 weeks.

Surveyed channel features including bankfull height, structural components and into connects to floodplain wetlands

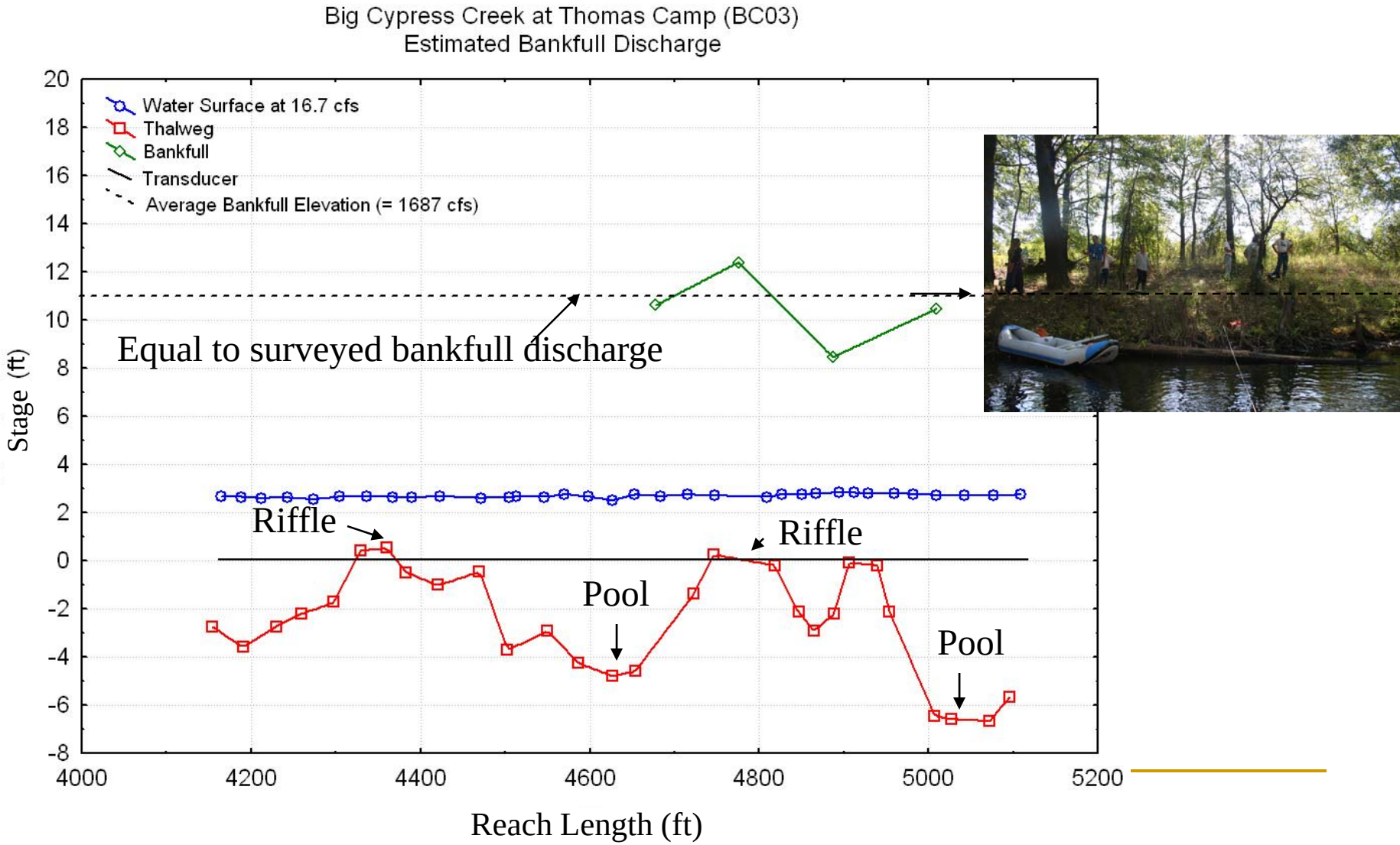
Controlled Release

January 2006

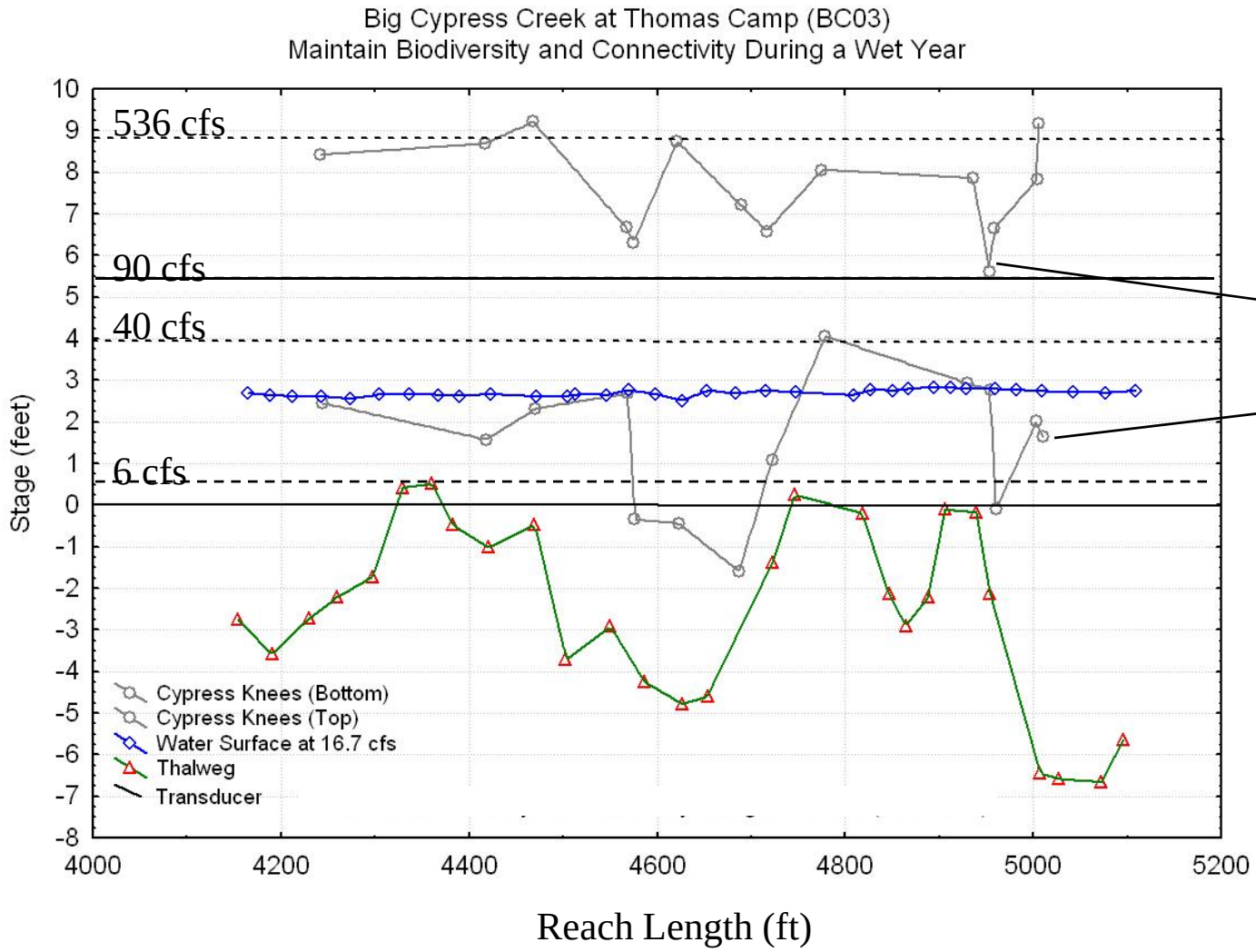
1800 cfs in Jefferson

3000 cfs reaching sloughs

Bankfull discharge ($\overline{X}$ = 1687 cfs) in upstream reach is much less than the 2 to 3-year recurrence discharge of 6,000 cfs that was prescribed



Good agreement between surveyed channel features and the flow prescriptions chosen to maintain longitudinal **connectivity** from dry (6 - 90 cfs) through wet year (40 – 536 cfs)

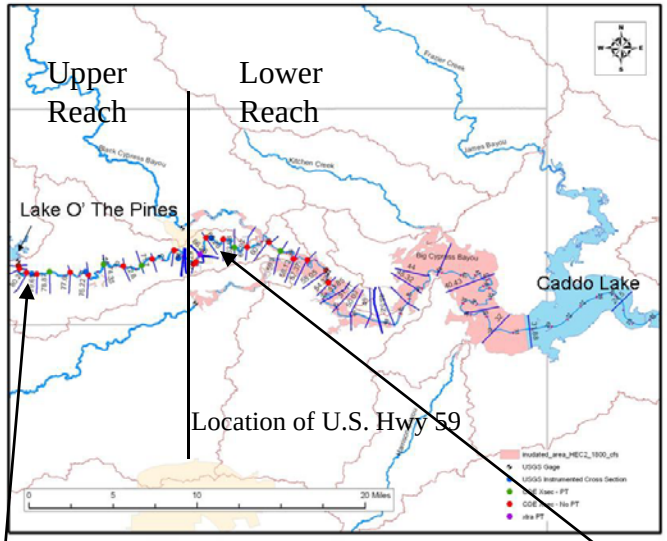


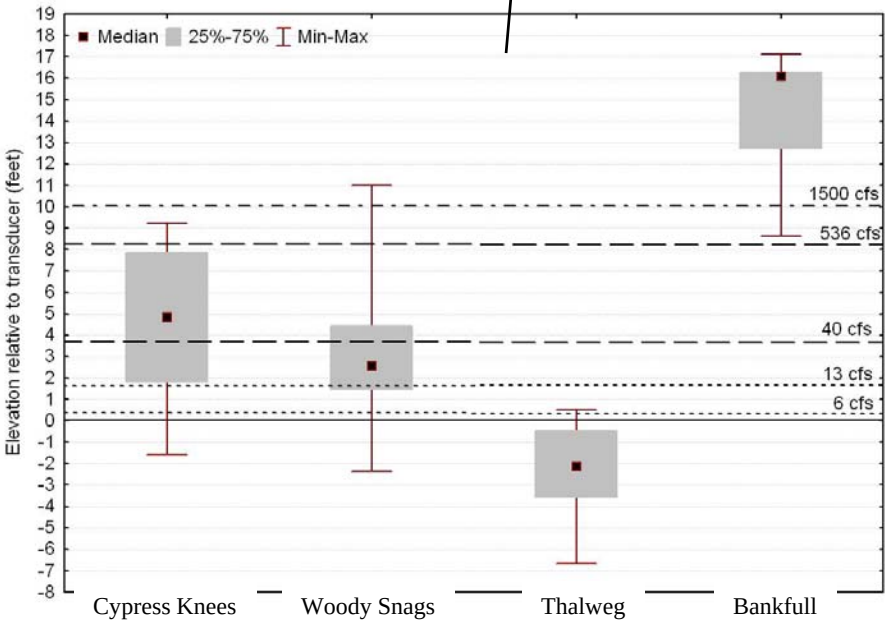
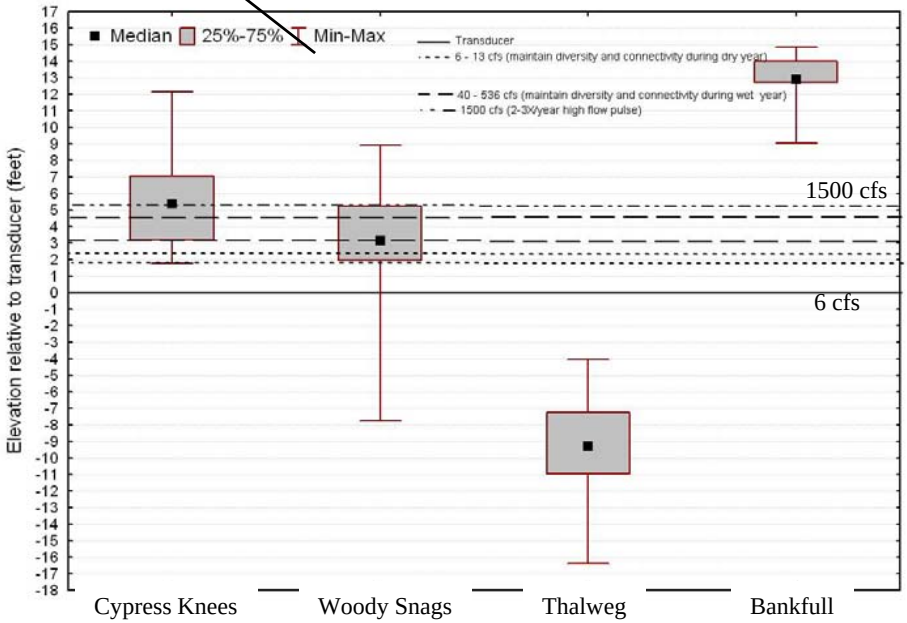
Cypress knees are important structure for aquatic biota

Should Flow Prescriptions be Adjusted for Variability in the Channel?

Upper Reach

Upstream of U.S. Hwy 59



Lower Reach

Downstream of U.S. Hwy 59