Nueces River and Corpus Christi and Baffin Bays Basin and Bay Expert Science Team (Nueces BBEST)

Environmental Flows Recommendations Report

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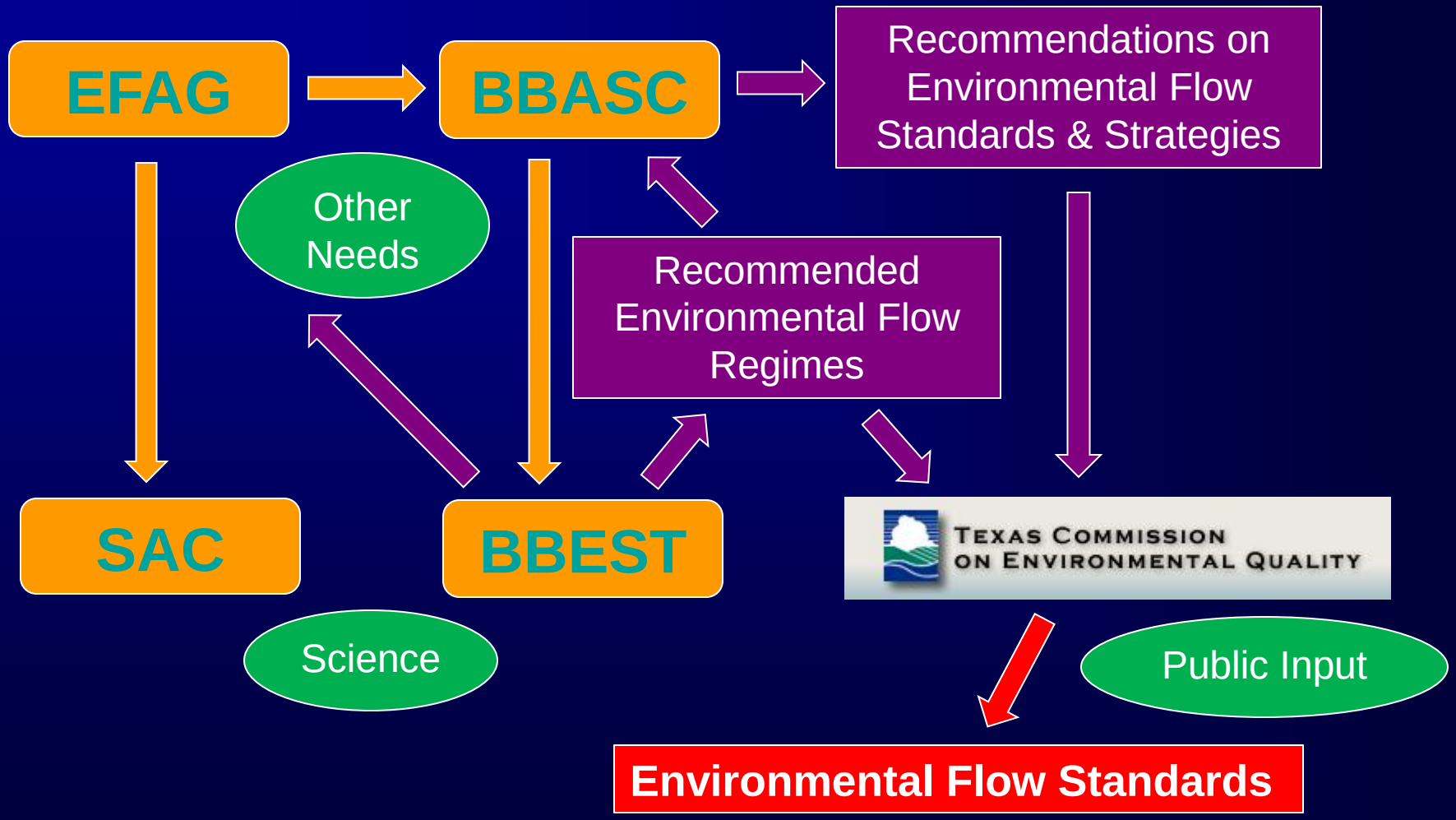
Topics of Discussion

1) Nueces BBEST & Recommendations Report Contents
2) Instream Flow Analyses & Recommendations
3) Example Applications of Instream Flow Recommendations
4) Estuarine Inflow Analyses & Recommendations

SB3 Environmental Flows Process



Basin & Bay Expert Science Team (BBEST)

Member	Hydrology	Instream	Estuary
Sam Vaugh, Chair	★		
Rocky Freund, Vice Chair	✓	✓	
Dave Buzan		★	✓
Greg Stunz			★
Tom Arsuffi		✓	
Ken Dunton			✓
Ben Hodges	✓		✓
David Hoeinghaus	✓	✓	
Ryan Smith	✓	✓	
Lonnie Stewart	✓	✓	
Jace Tunnell			✓
Lance Williams		✓	

Nueces BBEST Recommendations Report

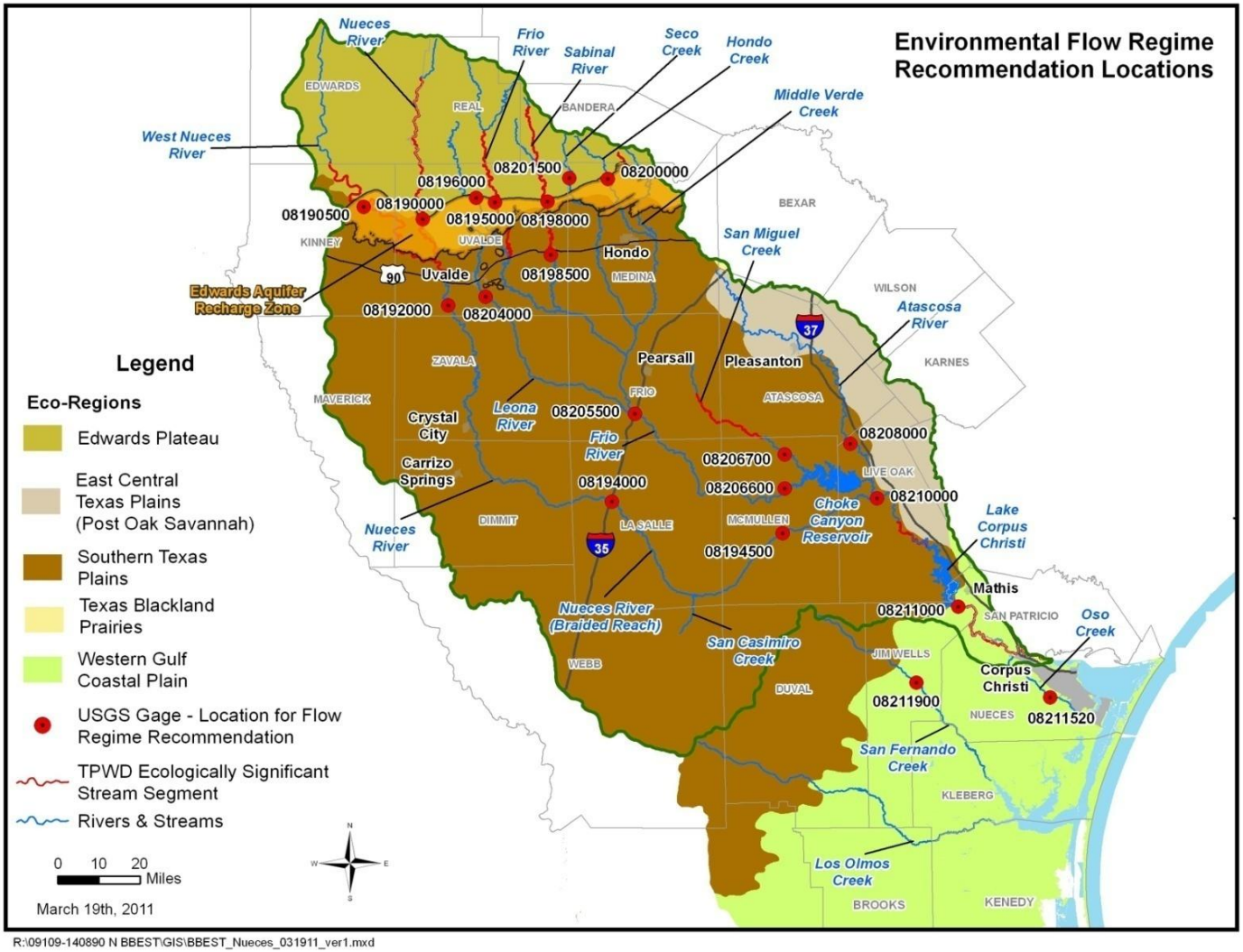
1) Preamble – Sound Ecological Environment
2) Overview of Watersheds & Bays
3) Instream Flow Analyses
4) Freshwater Inflow & Estuary Analyses
5) Integration of Instream Flow & Estuary Inflow Regimes
6) Environmental Flow Regime Recommendations
7) Adaptive Management
8) References

Instream Flow Regime Recommendations

1) Geographic Scope
2) Sound Ecological Environments
3) Hydrology-based Environmental Flow Regimes (HEFR)
4) Instream Biology Overlay (Flow-Habitat Analyses)
5) Water Quality Overlay
6) Geomorphology Overlay
7) Riparian Biological Overlay

Geographic Scope

Recommendation Locations



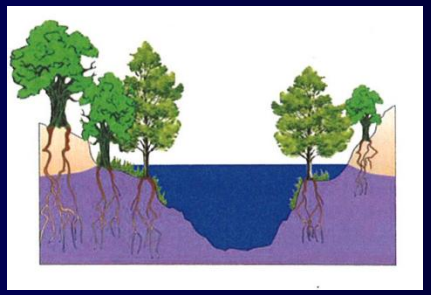
Sound Ecological Environments

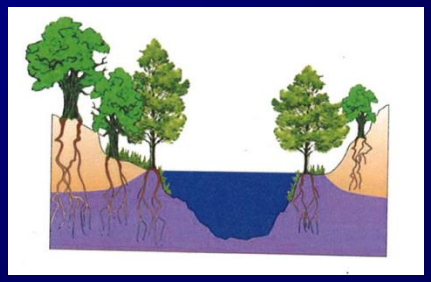
1) Sixteen (16) Stream Locations w/ Limited Modifications
2) Four (4) Stream Locations w/ Significant Modifications
   a) Nueces River nr Three Rivers (Choke Canyon Reservoir)
   b) Nueces River nr Mathis (Choke Canyon Reservoir / Lake Corpus Christi System)
   c) Oso Creek at Corpus Christi (Effluent)
   d) San Fernando Creek nr Alice (Effluent)

Flow Regime Components & HEFR Analyses

1) IHA Hydrographic Separation
2) Season Selections
3) Perennial & Intermittent Streams
4) HEFR Results
5) Consideration of Streamflow Trends

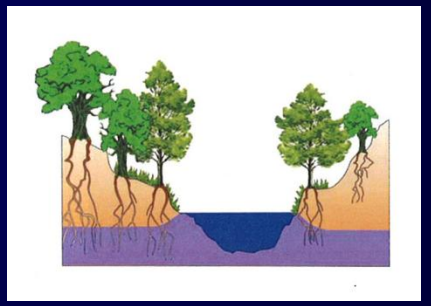
Overbank

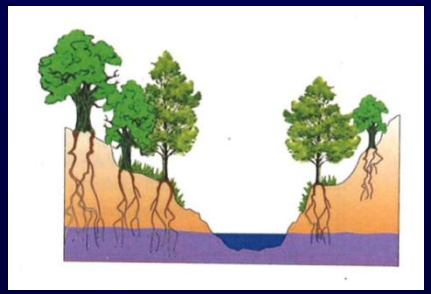




High Pulse

Base





Subsistence

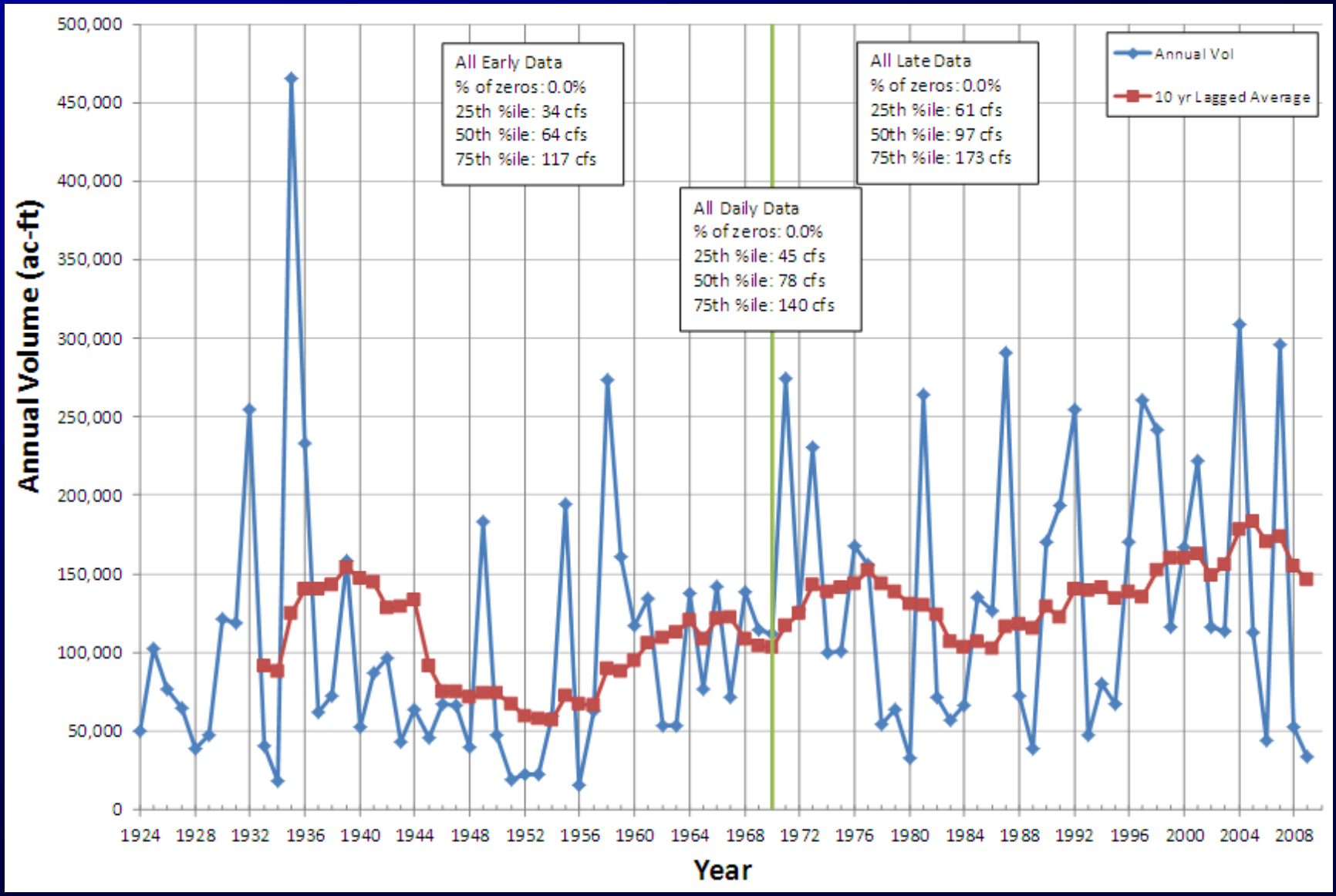
Hydrology-based Environmental Flow Regime (HEFR) Methodology

HEFR is used to provide an initial characterization of environmental systems with readily available data in the absence of definitive data relating flow alteration to ecological response.

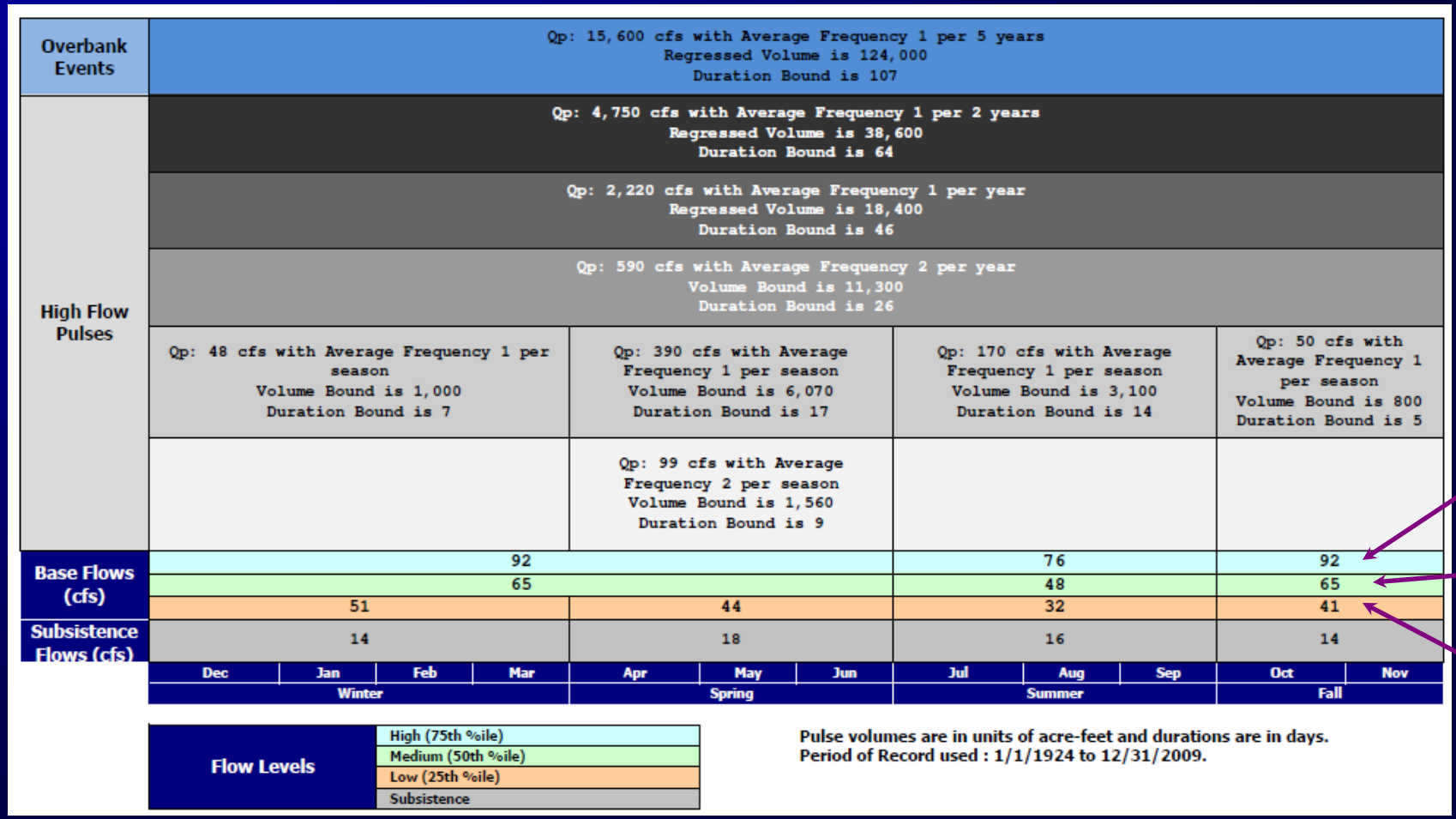
Advantages:

1) **Hydrology is a key variable for instream environmental flows.**
2) **Consistent with TIFP and SAC guidance.**
3) **Lengthy records at multiple streamflow gage locations.**

Hydrology - Nueces River @ Laguna



Instream Flow Regime Recommendation



Overbank Events	Qp: 15,600 cfs with Average Frequency 1 per 5 years Regressed Volume is 124,000 Duration Bound is 107			
High Flow Pulses	Qp: 4,750 cfs with Average Frequency 1 per 2 years Regressed Volume is 38,600 Duration Bound is 64			
	Qp: 2,220 cfs with Average Frequency 1 per year Regressed Volume is 18,400 Duration Bound is 46			
	Qp: 590 cfs with Average Frequency 2 per year Volume Bound is 11,300 Duration Bound is 26			
	Qp: 48 cfs with Average Frequency 1 per season Volume Bound is 1,000 Duration Bound is 7	Qp: 390 cfs with Average Frequency 1 per season Volume Bound is 6,070 Duration Bound is 17	Qp: 170 cfs with Average Frequency 1 per season Volume Bound is 3,100 Duration Bound is 14	Qp: 50 cfs with Average Frequency 1 per season Volume Bound is 800 Duration Bound is 5
		Qp: 99 cfs with Average Frequency 2 per season Volume Bound is 1,560 Duration Bound is 9		
Base Flows (cfs)	92		76	92
	65		48	65
Subsistence Flows (cfs)	51	44	32	41
	14	18	16	14
	Dec, Jan, Feb, Mar	Apr, May, Jun	Jul, Aug, Sep	Oct, Nov
	Winter	Spring	Summer	Fall

Wet

Avg

Dry

Flow Levels
High (75th %ile)
Medium (50th %ile)
Low (25th %ile)
Subsistence

Pulse volumes are in units of acre-feet and durations are in days.
Period of Record used : 1/1/1924 to 12/31/2009.

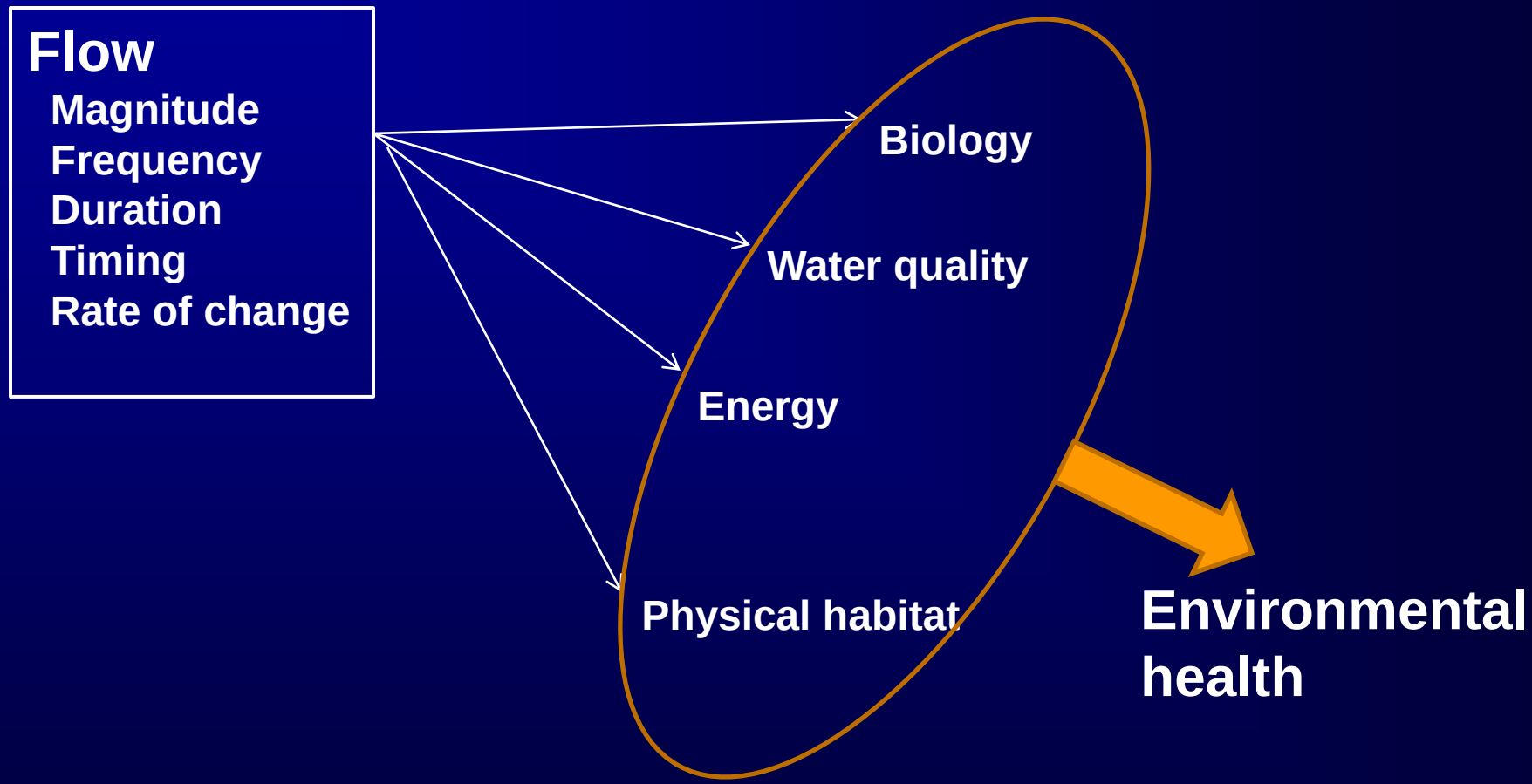
Nueces River @ Laguna (NRL)

Instream Flow Analyses

1) Instream Biology Overlay (Flow-Habitat Analyses)
2) Water Quality Overlay
3) Geomorphology Overlay
4) Riparian Overlay

Natural Flow Paradigm

(adapted from Poff et al., 1997)



Aquatic Animals

- 80 fish species
  - 5 habitats (riffles, runs, pools)
  - State fish of Texas
- 11 freshwater clam (mussel) species
  - 1 state-threatened species
- Variety of aquatic insects and river shrimp

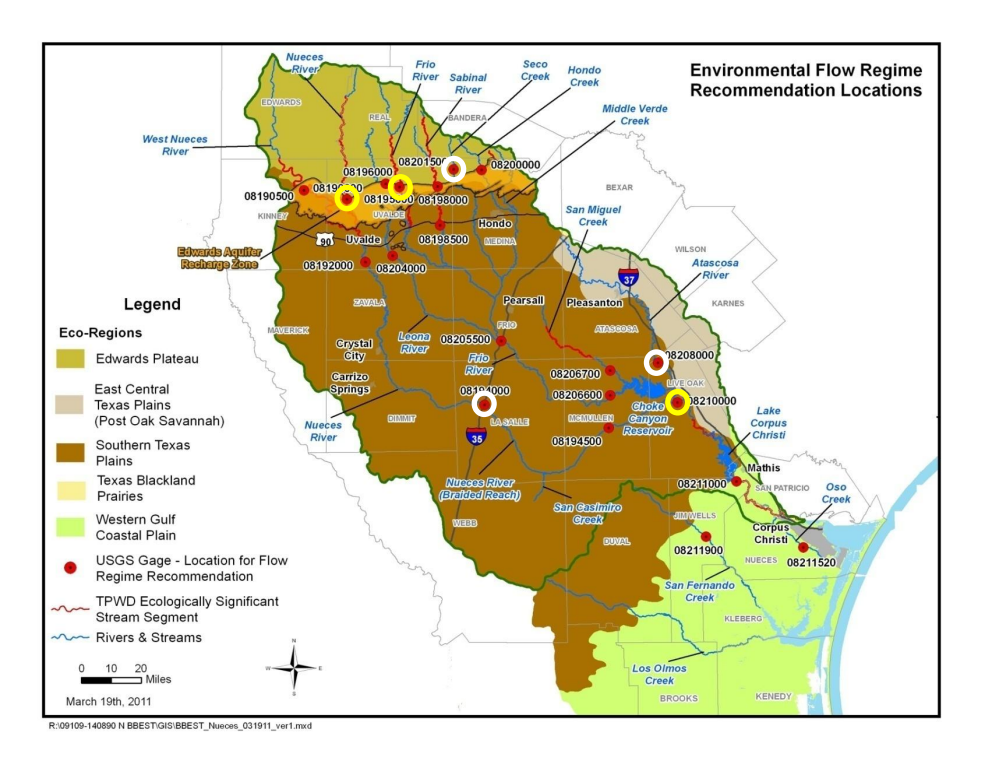
Instream Habitat - Biology Overlay

- Are our hydrology-based flow recommendations adequate to maintain instream habitats?
  - Emphasis on base flows, but also subsistence, HFPs

- If not, evaluate appropriate modifications to the hydrology-based flow regimes
  - Adjust hydrogaphic separation and/or HEFR parameterization
  - Adjust site-specific flow recommendations

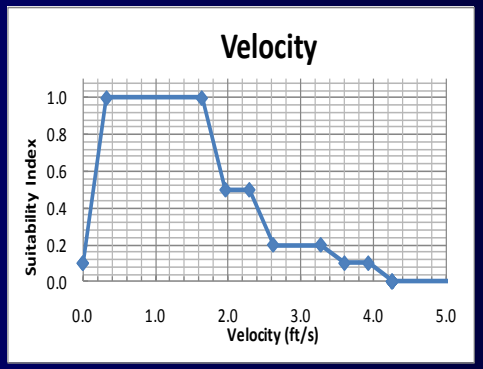
Background, Methods

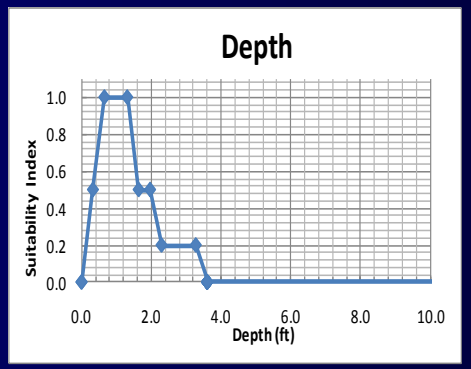
- No existing flow-habitat studies in the Nueces Basin
- Prioritize site-specific field data
- Sites – 6 winnowed to 3 (low or no flow at 3)
  - Nueces River @ Laguna
  - Frio River @ Concan
  - Nueces River @ Three Rivers

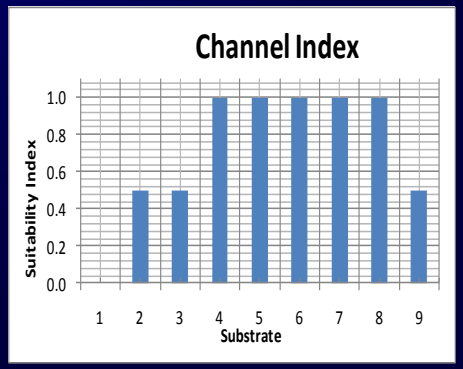


Background, Methods

- Focal species not habitat guilds
  - 8 at Laguna, Concan
  - 13 at Three Rivers
- Habitat Suitability Criteria
  - No data from our sites or from within Nueces Basin
  - TPWD, BIO-WEST database
    - Added data for 3 species
  - NPTL for D, V
  - Modified for substrate
    - All classes set to 1, reduced best professional judgement

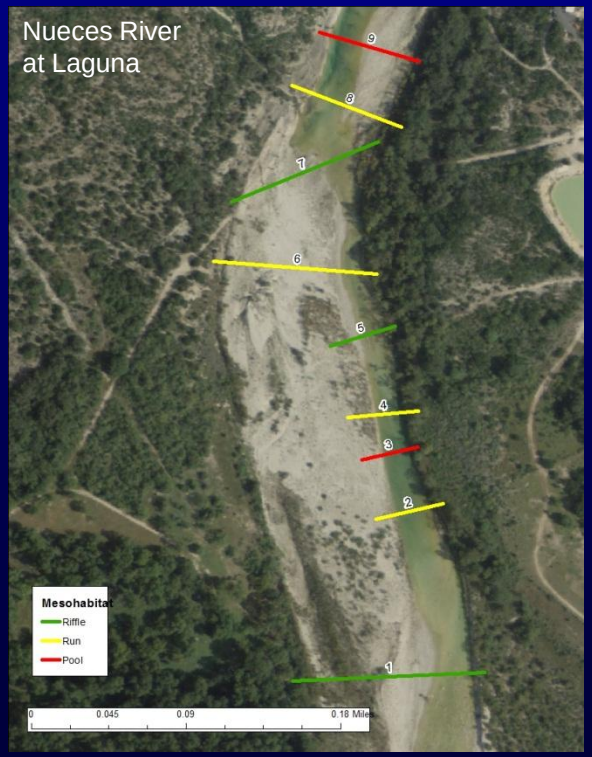


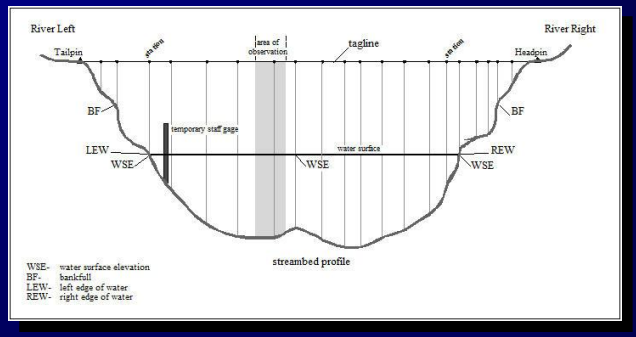


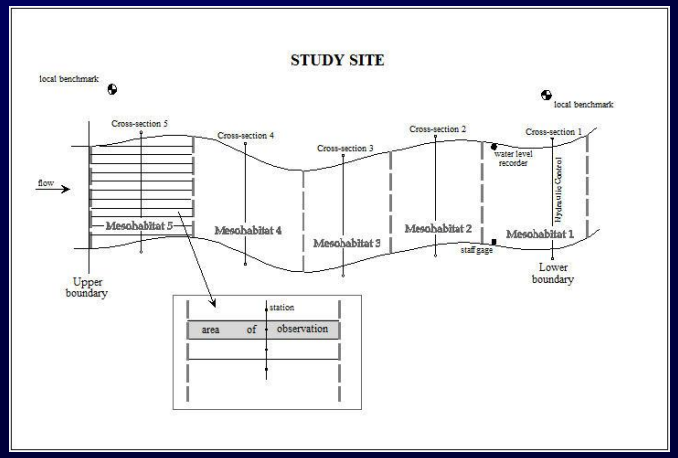


Methods, Contract

1) Contracted for Development of Instream Flow-Habitat Relationships with TWDB & TPWD technical support.
2) Method – modified PHabSim
3) Products – report, Excel tool (PHabExcel)





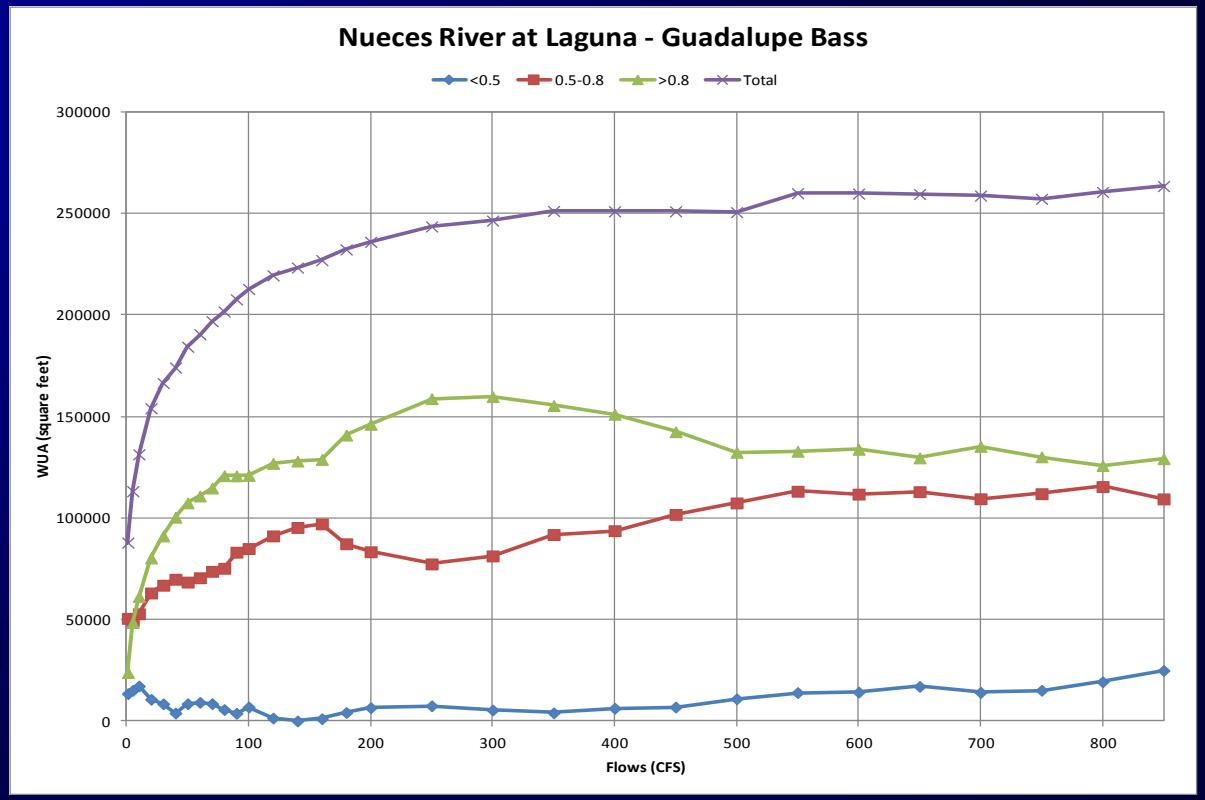


Methods, Decision Points

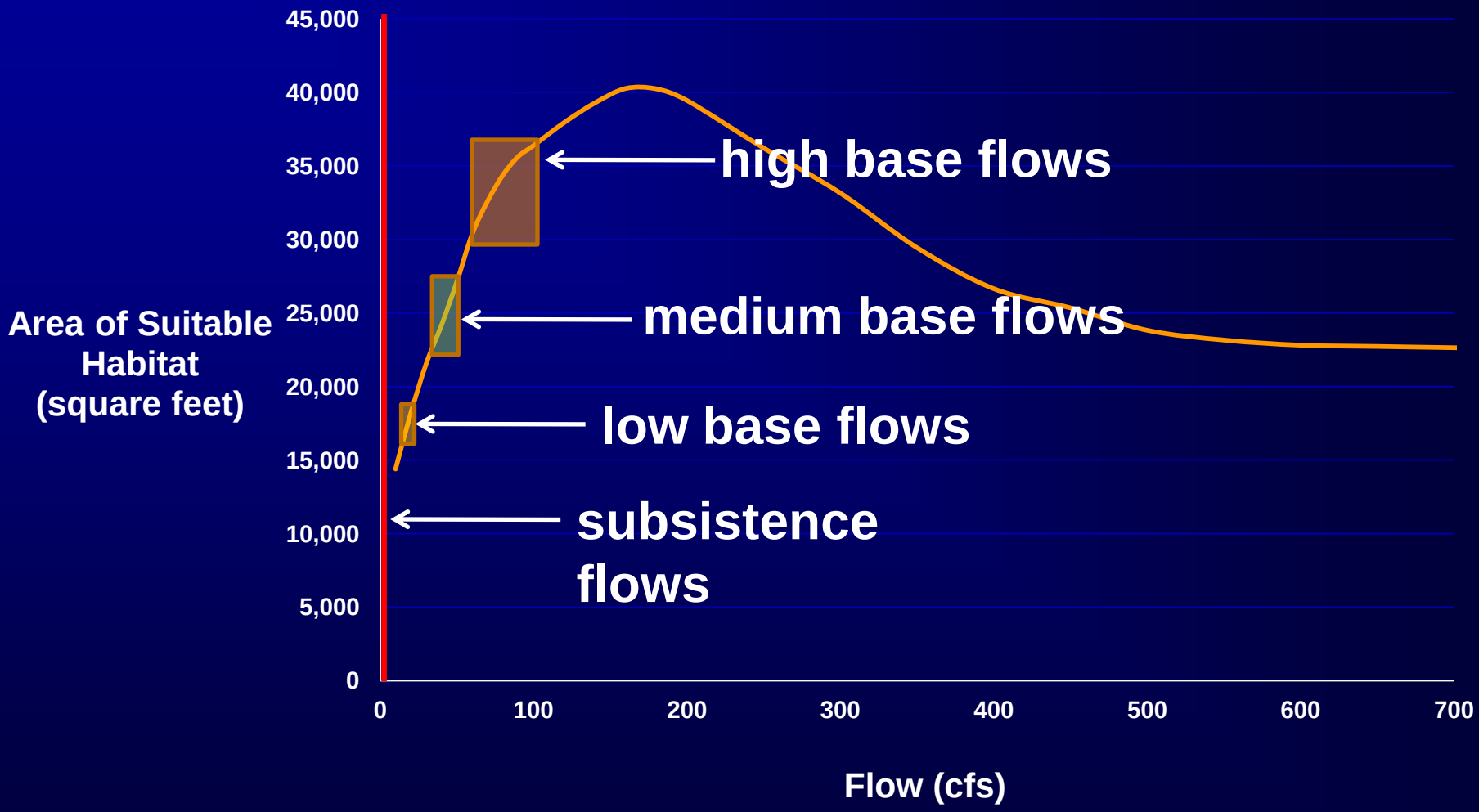
- Measure
  - WUA and % of maximum WUA
- Quality threshold
  - Minimum habitat suitability score to evaluate highest quality habitats
- "Enoughness"
  - 75% of max WUA for base flow (at least one season-base flow level), 20% for subsistence
- Cross-section subsets?
  - All cross-sections, but results for riffle, run, pool subsets in Appendix
- Time series

Laguna – Habitat Quality

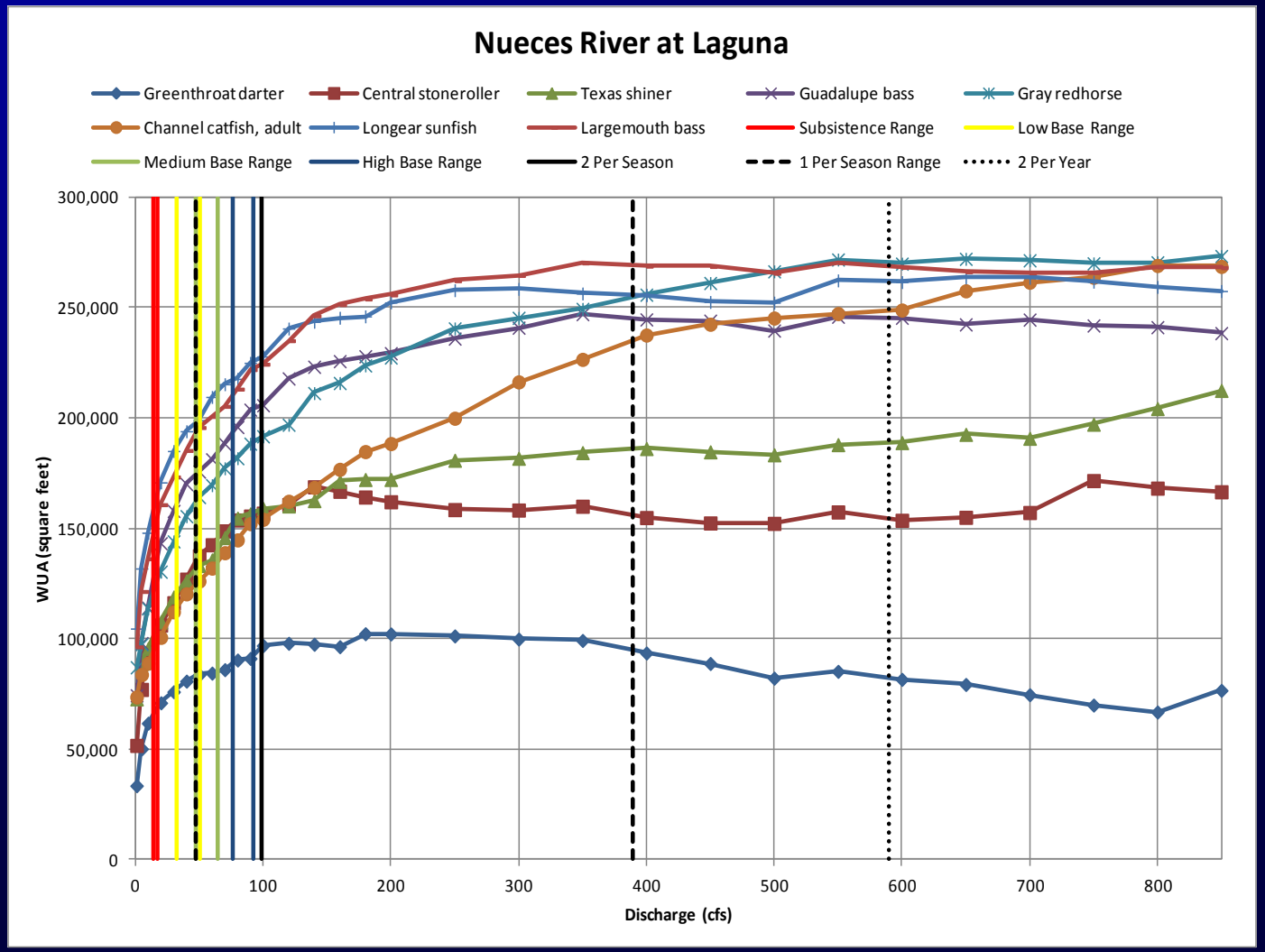
- Minimum threshold applied to aggregate suitability score
- Evaluated three ranges of habitat quality
  - <0.5, 0.5-0.8, >0.8
- >= 0.5 for decision making
- Comment on patterns in all 3



Analytical Approach

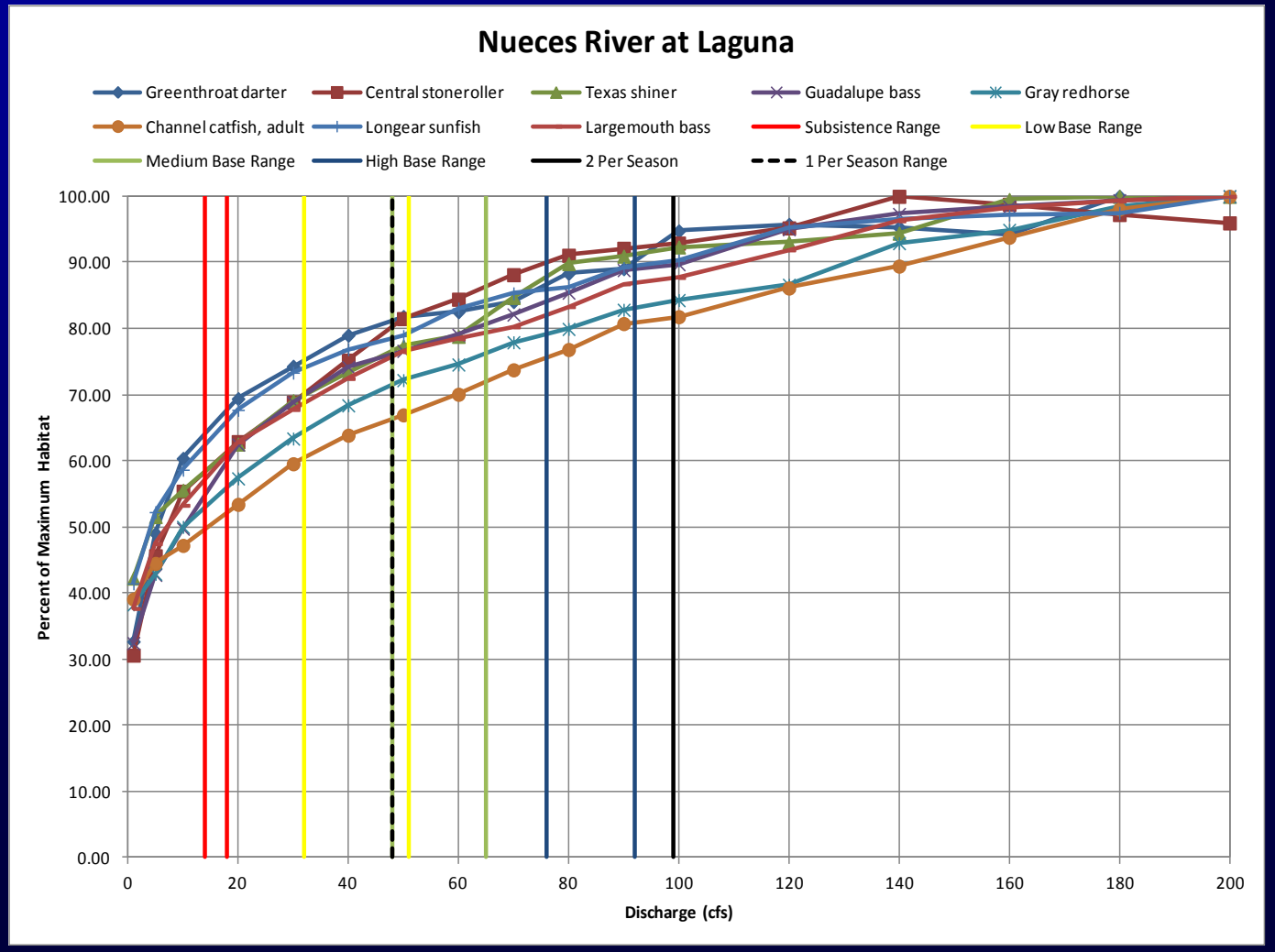


Laguna – WUA, 0.5 Quality Threshold



Laguna – % Max WUA, 0.5 Threshold

How much is "enough"? – we used 75% for base flows, 20% for subsistence



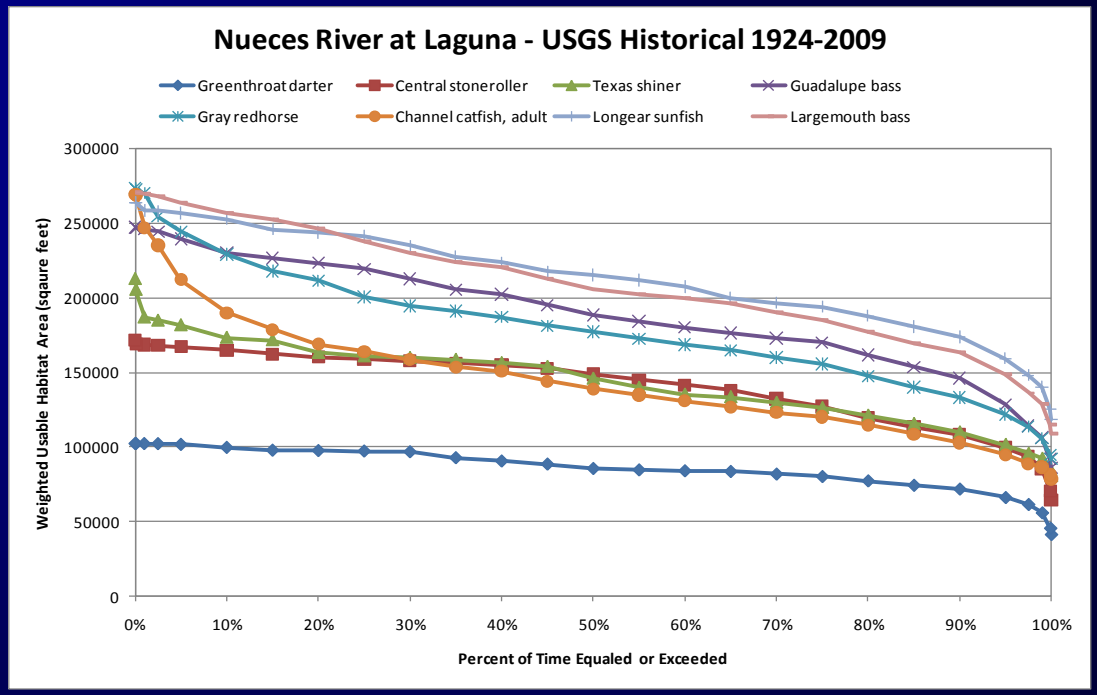
Laguna – "enoughness" assessment

- Percent of maximum WUA thresholds
  - 75% for base flows
  - 20% for subsistence flows
- Emphasis on Base-Medium
  - Base-High for deeper water species)
- Other sites:
  - More over 75% at Concan
  - Less over 75% at Three Rivers

Focal Species	Flow Component	Percent of Maximum Weighted Usable Area			
		Winter	Spring	Summer	Fall
Greenthroat darter	Subsistence	64%	68%	66%	63%
	Base-Low	82%	80%	75%	79%
	Base-Medium	84%	83%	81%	83%
	Base-High	91%	89%	87%	93%
Central stoneroller	Subsistence	58%	61%	60%	58%
	Base-Low	82%	78%	70%	76%
	Base-Medium	88%	86%	80%	85%
	Base-High	92%	92%	90%	93%
Texas shiner	Subsistence	58%	61%	60%	58%
	Base-Low	78%	75%	70%	74%
	Base-Medium	84%	81%	77%	80%
	Base-High	92%	91%	88%	92%
Guadalupe bass	Subsistence	55%	60%	57%	54%
	Base-Low	77%	75%	70%	74%
	Base-Medium	82%	80%	76%	80%
	Base-High	89%	87%	84%	89%
Gray redhorse	Subsistence	53%	56%	54%	52%
	Base-Low	72%	70%	64%	69%
	Base-Medium	78%	76%	71%	75%
	Base-High	83%	82%	79%	84%
Channel catfish, adult	Subsistence	50%	52%	51%	49%
	Base-Low	67%	65%	60%	64%
	Base-Medium	73%	71%	66%	71%
	Base-High	81%	79%	76%	81%
Longear sunfish	Subsistence	62%	66%	64%	61%
	Base-Low	79%	78%	74%	77%
	Base-Medium	85%	84%	78%	83%
	Base-High	90%	88%	86%	90%
Largemouth bass	Subsistence	57%	61%	59%	56%
	Base-Low	77%	74%	69%	73%
	Base-Medium	80%	79%	76%	79%
	Base-High	87%	85%	82%	87%

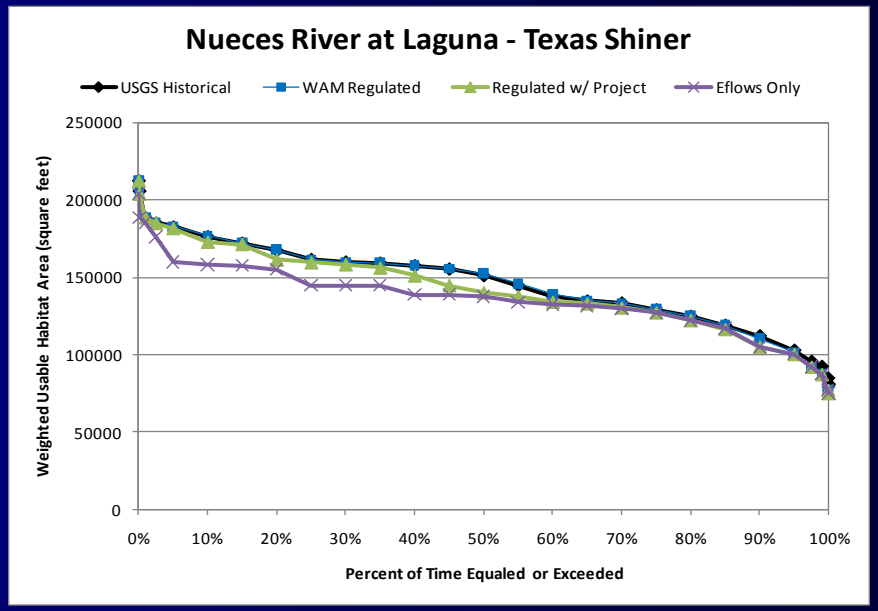
Laguna – Habitat Time Series

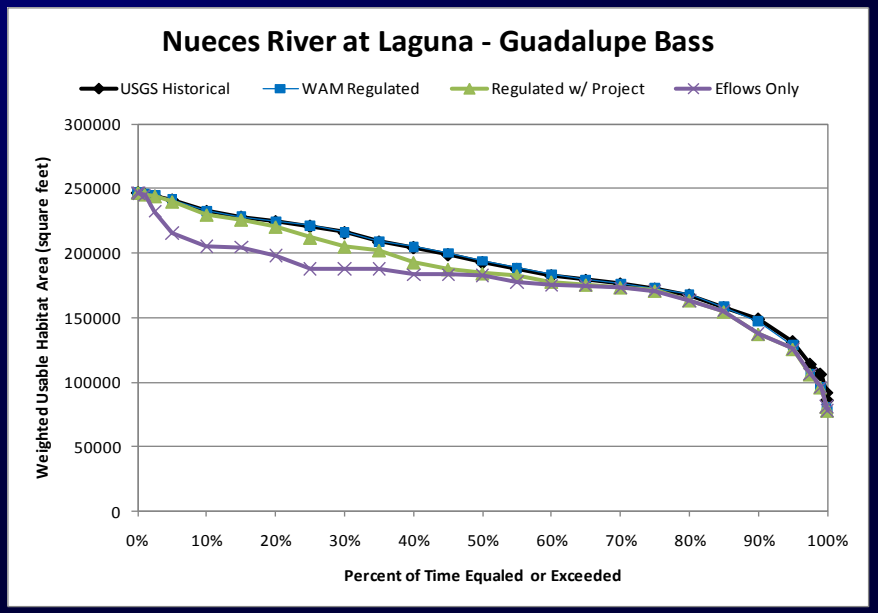
- Habitat time series and attainment frequency of 75% threshold
  - USGS full period for all 3 sites
  - FRAT output for 3 scenarios at Laguna
  - Pre-/post-Choke Canyon for Three Rivers
- Just modeled flows (not all flows



Laguna – Habitat Time Series

- Evaluation of instream habitat under example application scenarios
- FRAT used to generate flow time series
- 4 scenarios
  - USGS historical
  - WAM regulated baseline
  - Project with flow recommendations
  - Flow recommendations only





Laguna – Habitat Time Series

Percent Exceedence Level	Greenthroat darter			Central stoneroller			Texas shiner			Guadalupe bass			Gray redhorse			Channel catfish, adult			Longear sunfish			Largemouth bass		
	USGS	Project	Eflows	USGS	Project	Eflows	USGS	Project	Eflows	USGS	Project	Eflows	USGS	Project	Eflows	USGS	Project	Eflows	USGS	Project	Eflows	USGS	Project	Eflows
99.99%	41%	35%	35%	38%	33%	33%	47%	44%	44%	38%	34%	34%	41%	39%	39%	42%	40%	40%	47%	43%	43%	43%	39%	39%
99.9%	45%	37%	37%	42%	35%	35%	49%	45%	45%	40%	35%	35%	42%	40%	40%	43%	41%	41%	50%	44%	44%	45%	40%	40%
99%	55%	48%	48%	51%	44%	44%	54%	51%	51%	46%	42%	42%	47%	43%	43%	46%	44%	44%	56%	51%	51%	50%	47%	47%
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85%	74%	73%	73%	69%	68%	68%	69%	68%	68%	69%	67%	68%	63%	62%	62%	60%	58%	58%	73%	72%	72%	68%	67%	67%
80%	78%	76%	76%	74%	72%	72%	72%	71%	71%	73%	71%	71%	67%	66%	66%	63%	62%	61%	76%	75%	75%	72%	70%	70%
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30%	95%	91%	84%	94%	92%	88%	93%	92%	84%	94%	89%	82%	86%	84%	78%	85%	81%	73%	95%	90%	85%	91%	87%	80%
25%	95%	94%	84%	94%	93%	88%	94%	93%	84%	96%	92%	82%	90%	85%	78%	88%	84%	73%	96%	93%	85%	95%	90%	80%
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15%	96%	96%	91%	96%	95%	92%	100%	100%	92%	99%	99%	89%	99%	95%	83%	98%	94%	81%	98%	97%	90%	99%	98%	87%
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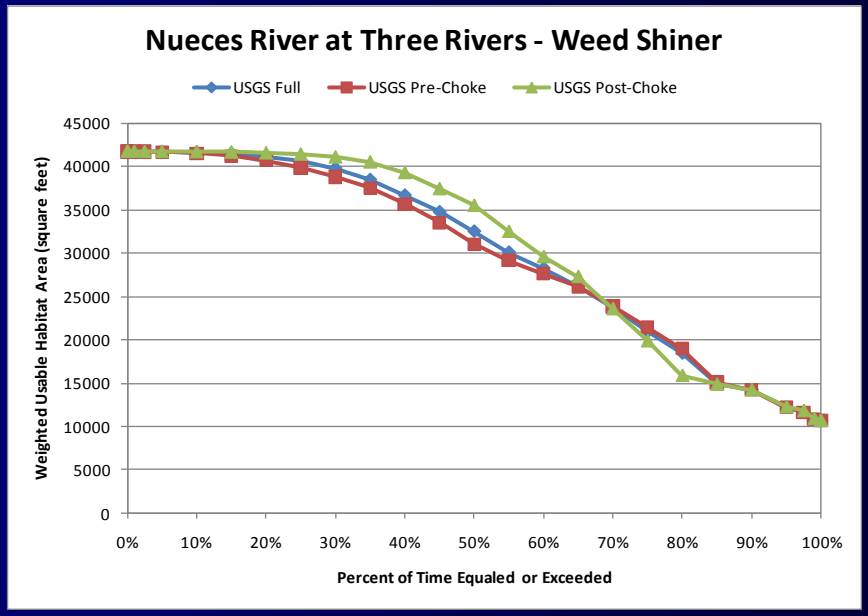
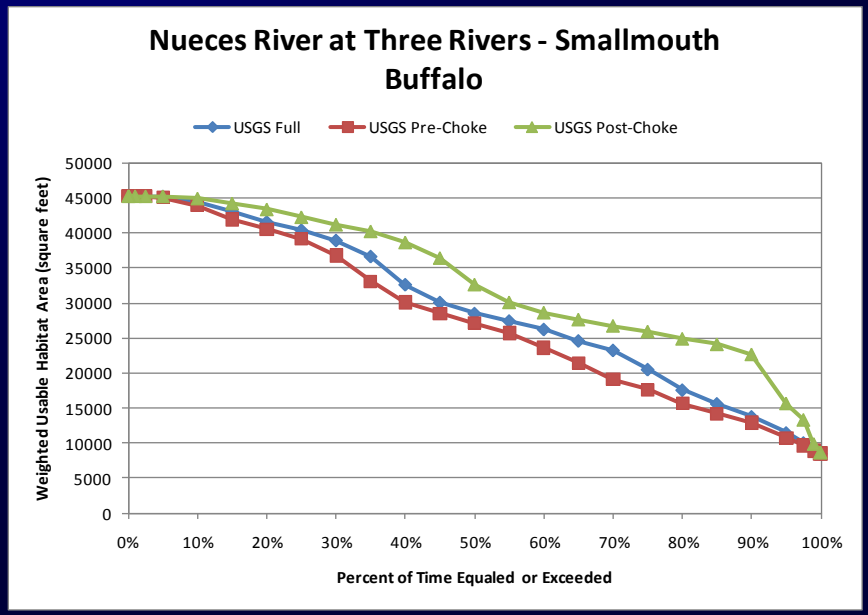
3%	100%	100%	96%	100%	99%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
1%	100%	100%	99%	100%	100%	98%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
0.1%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
0.01%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Three Rivers – Habitat Time Series

- Evaluation of instream habitat under 3 periods of record (USGS gage)
  - Pre-Choke Canyon Reservoir
  - Post-Choke Canyon Reservoir
  - Full period (which was used for flow recommendations)





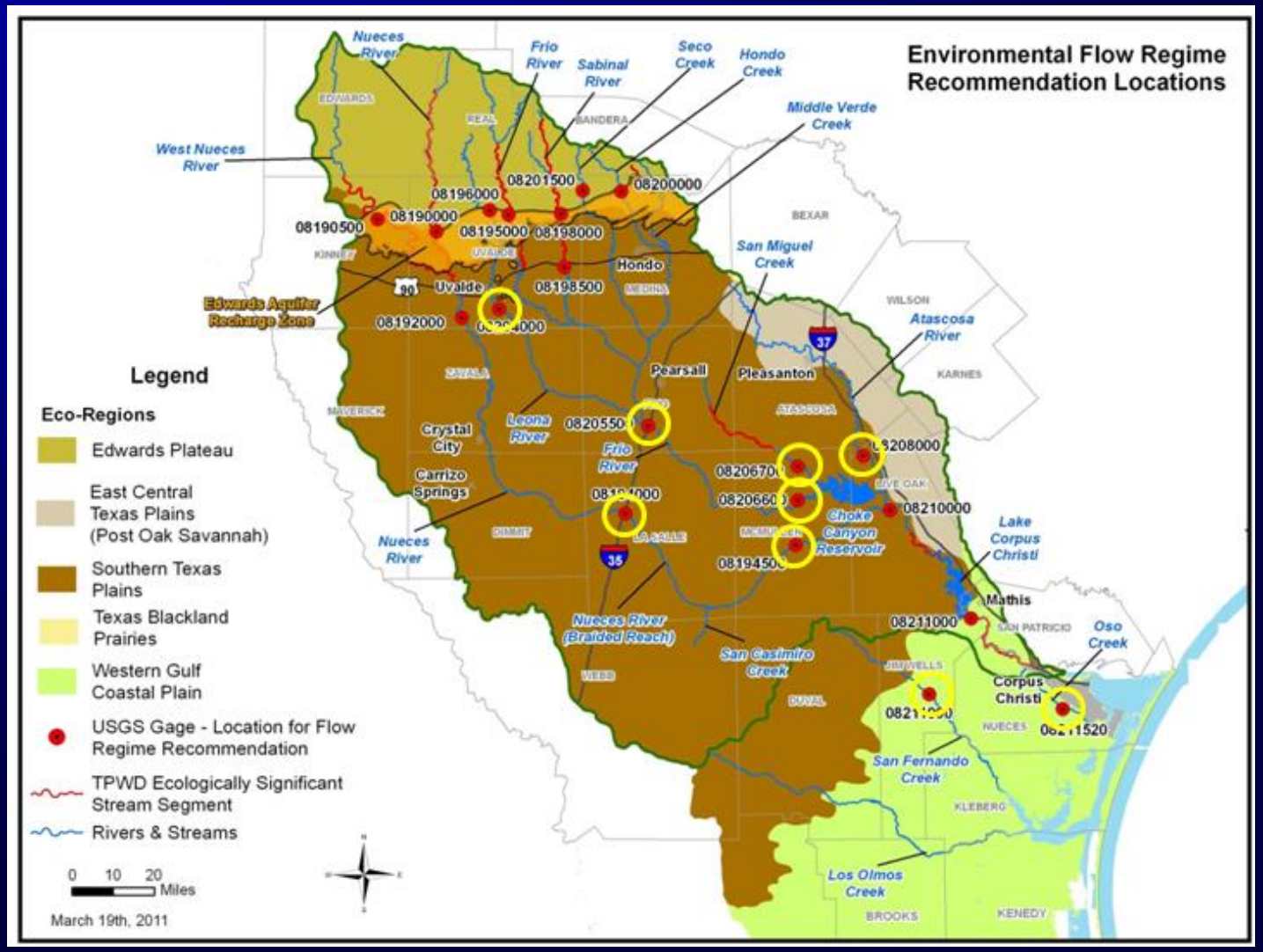
Overlay Conclusions

- OVERLAY RESULTS: No modifications to hydrology-based flow regimes
- Rational and Observations:
  - Hydrology-based flow recommendations do maintain habitats
  - But, even small reduction from our base flows notably reduces habitat area
  - Time series
    - Similar historical attainment frequencies at 2 HC sites, much lower at Three Rivers
    - Flow recommendations did not reduce frequencies much at Laguna
    - Example off-channel project at Laguna had little effect
    - Choke Canyon did have effect on Three Rivers

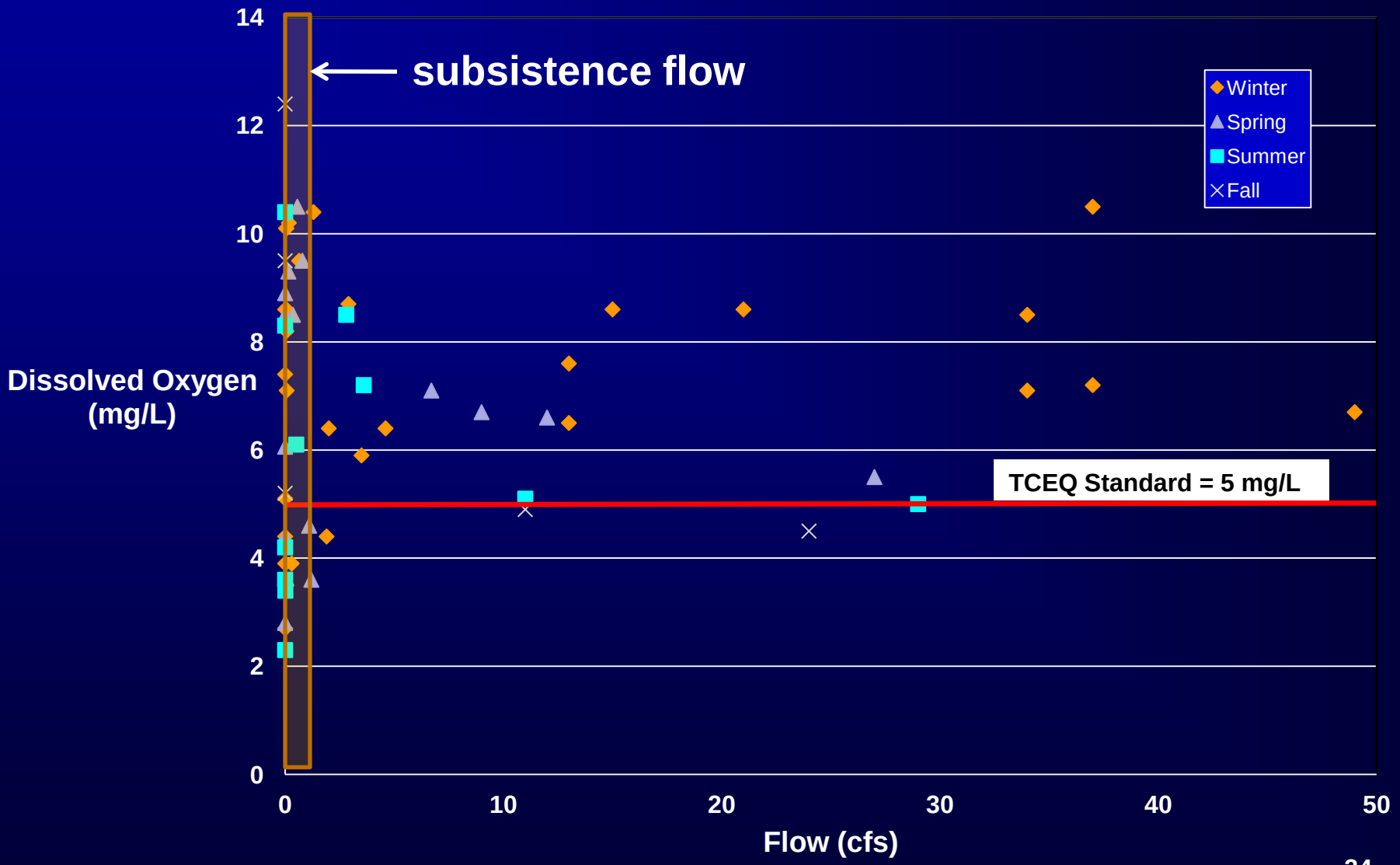
Uncertainty and Adaptive Management

- What are sources of uncertainty
  - Habitat suitability criteria – no data from our sites, data from out of basin
  - Hydraulics – field data on depth and velocity from only one very low flow at 2 of 3 sites
  - Stage-discharge rating curves
- Suggestions for addressing these in adaptive management/work plan, including:
  - Do analysis at more sites, data from more flows, site-specific habitat data for fishes, consider other methods (habitat mapping)

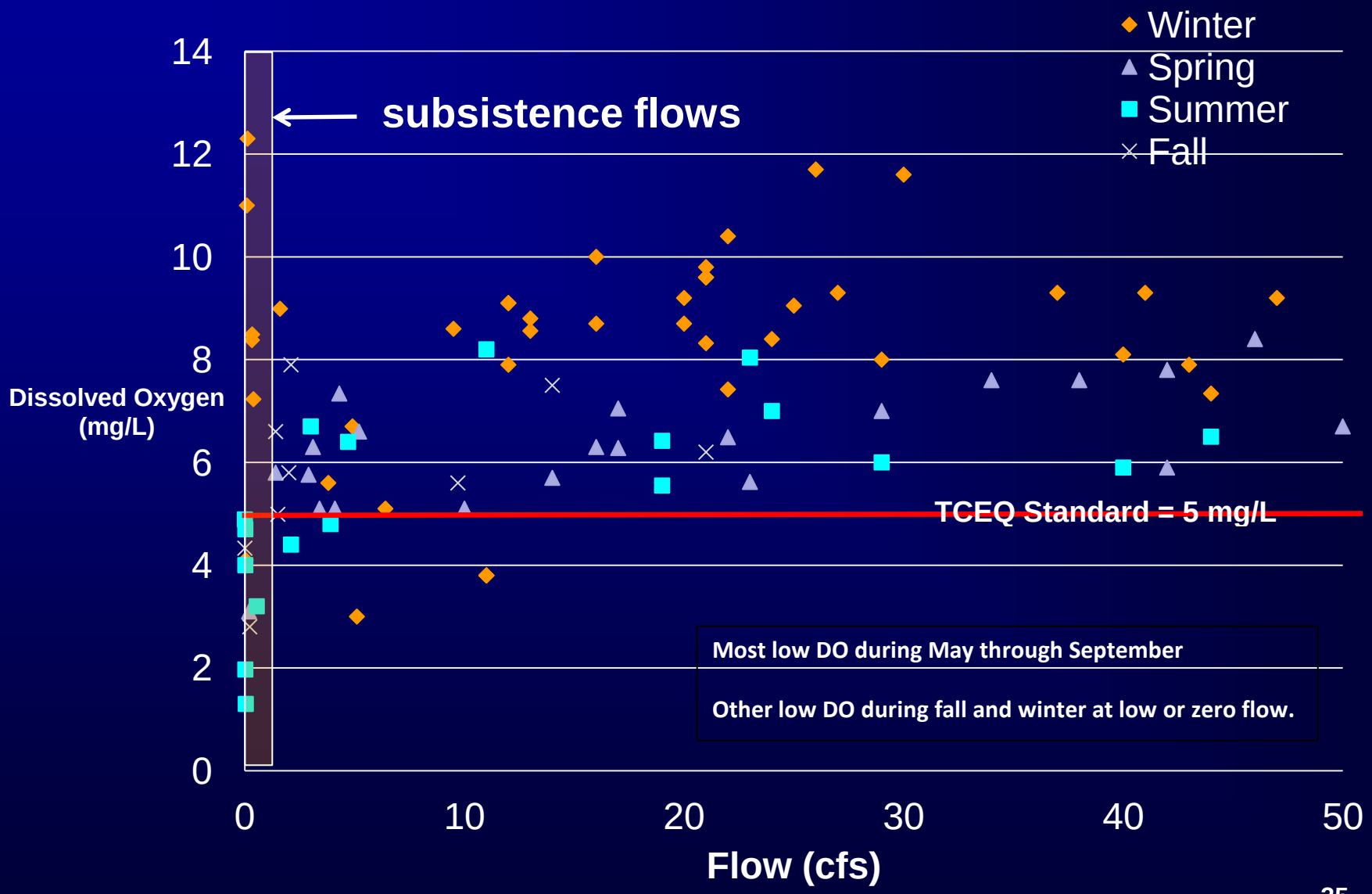
Water Quality: Sites with Low Dissolved Oxygen Data



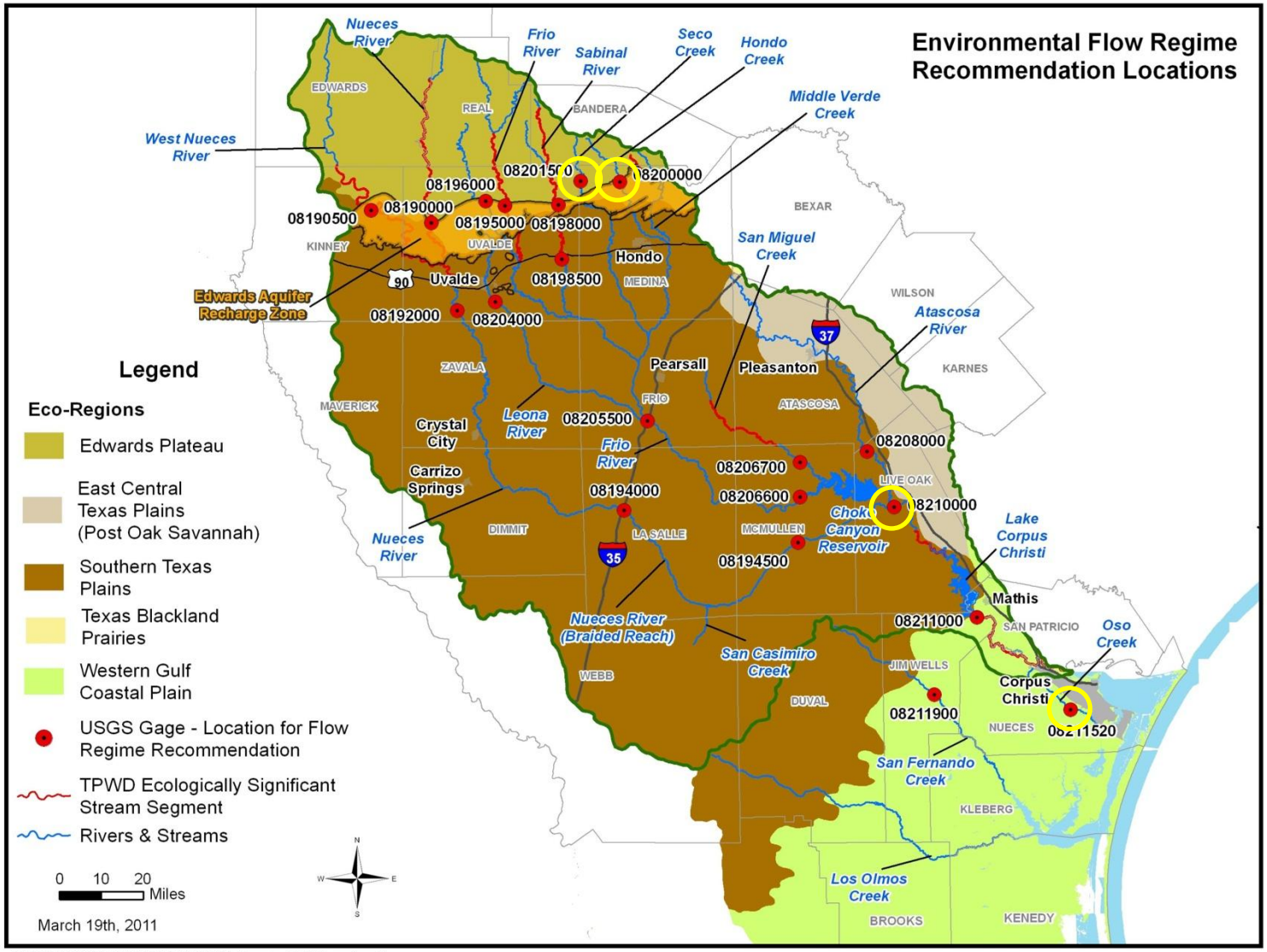
Nueces at Cotulla: Oxygen



Frio at Tilden: Oxygen



Locations w/ High Temp. Observations



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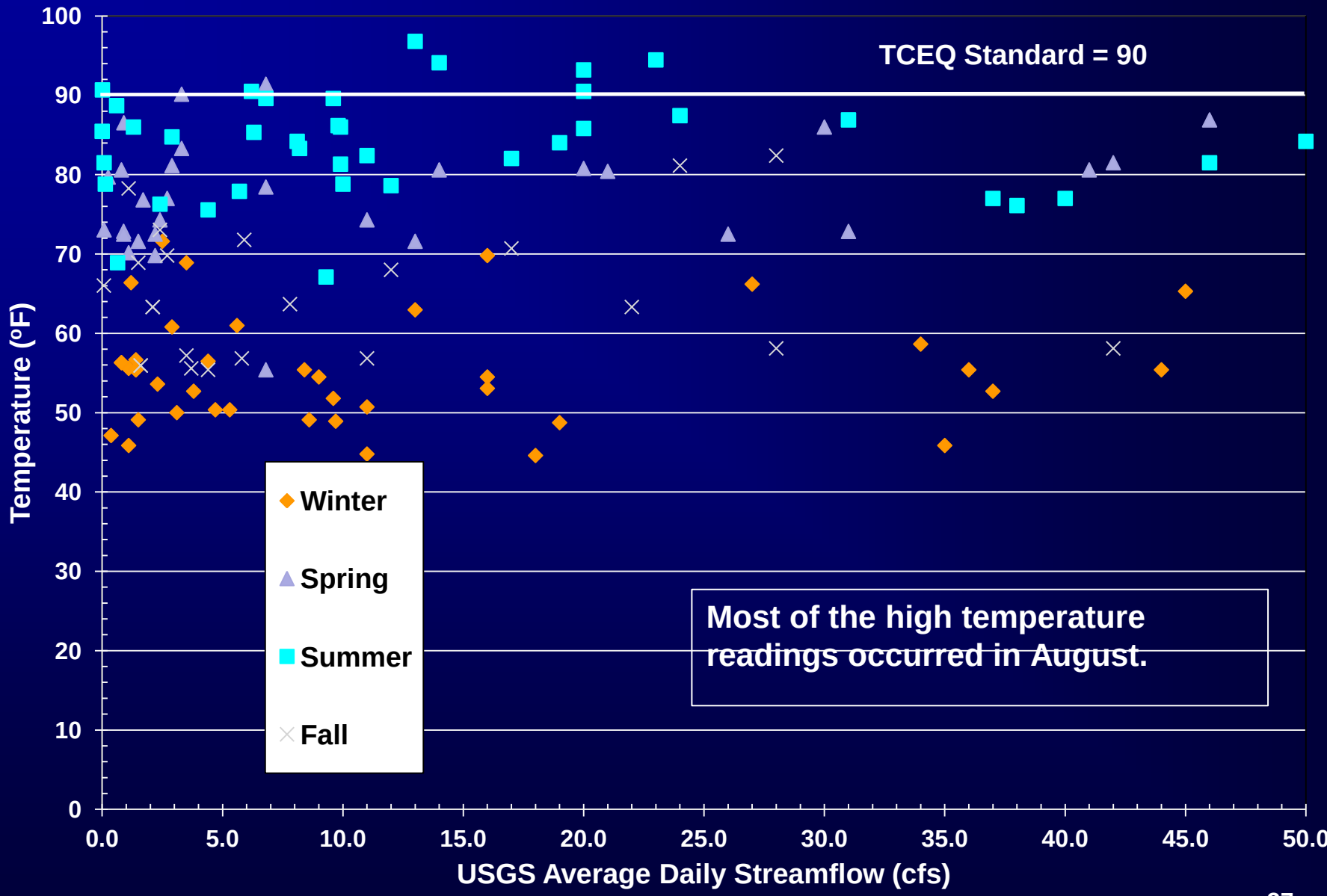
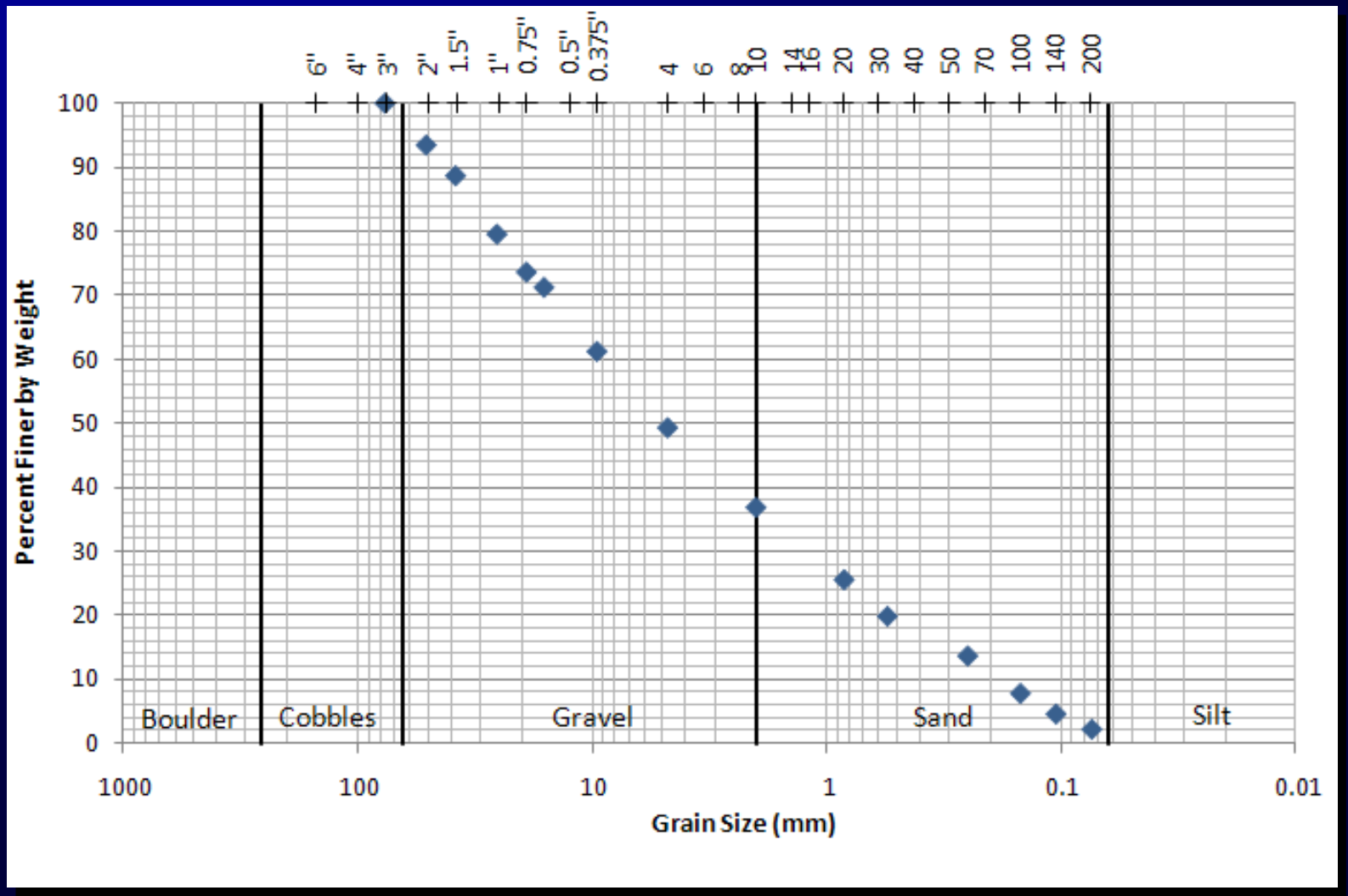
Hondo Creek nr Tarpley

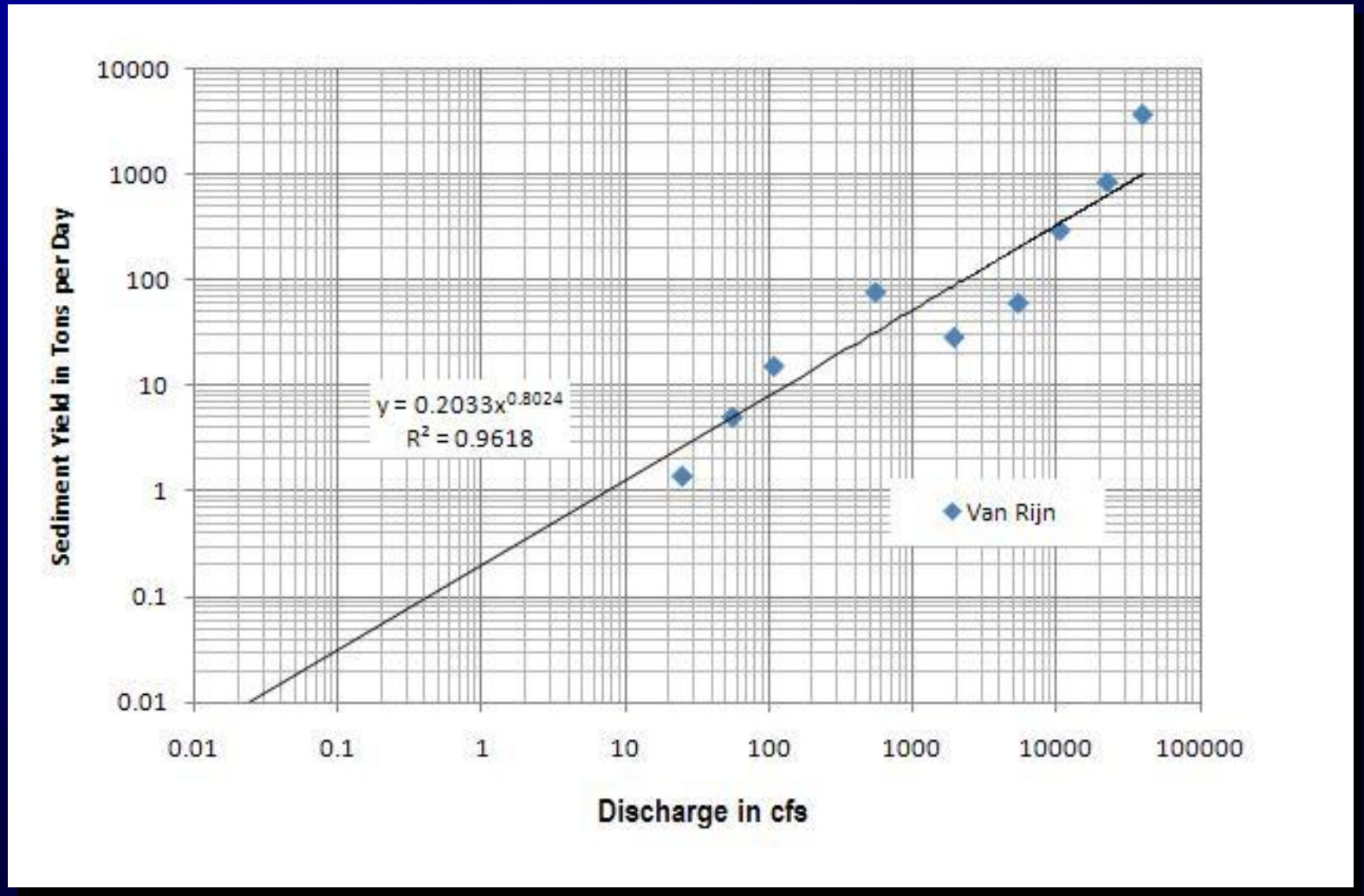


Hondo Creek

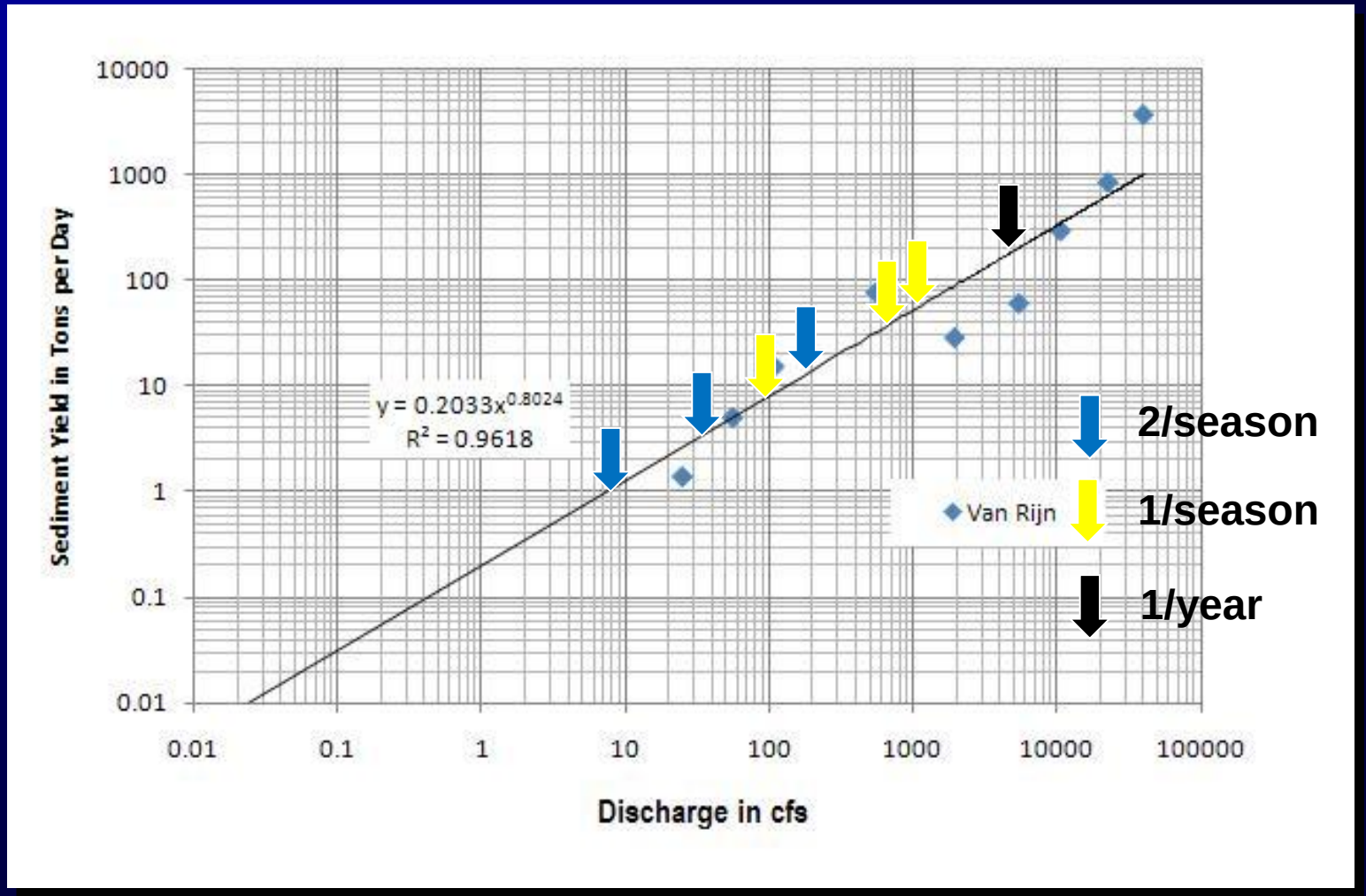
Geomorphology
Nueces at Cotulla: Sediment Size



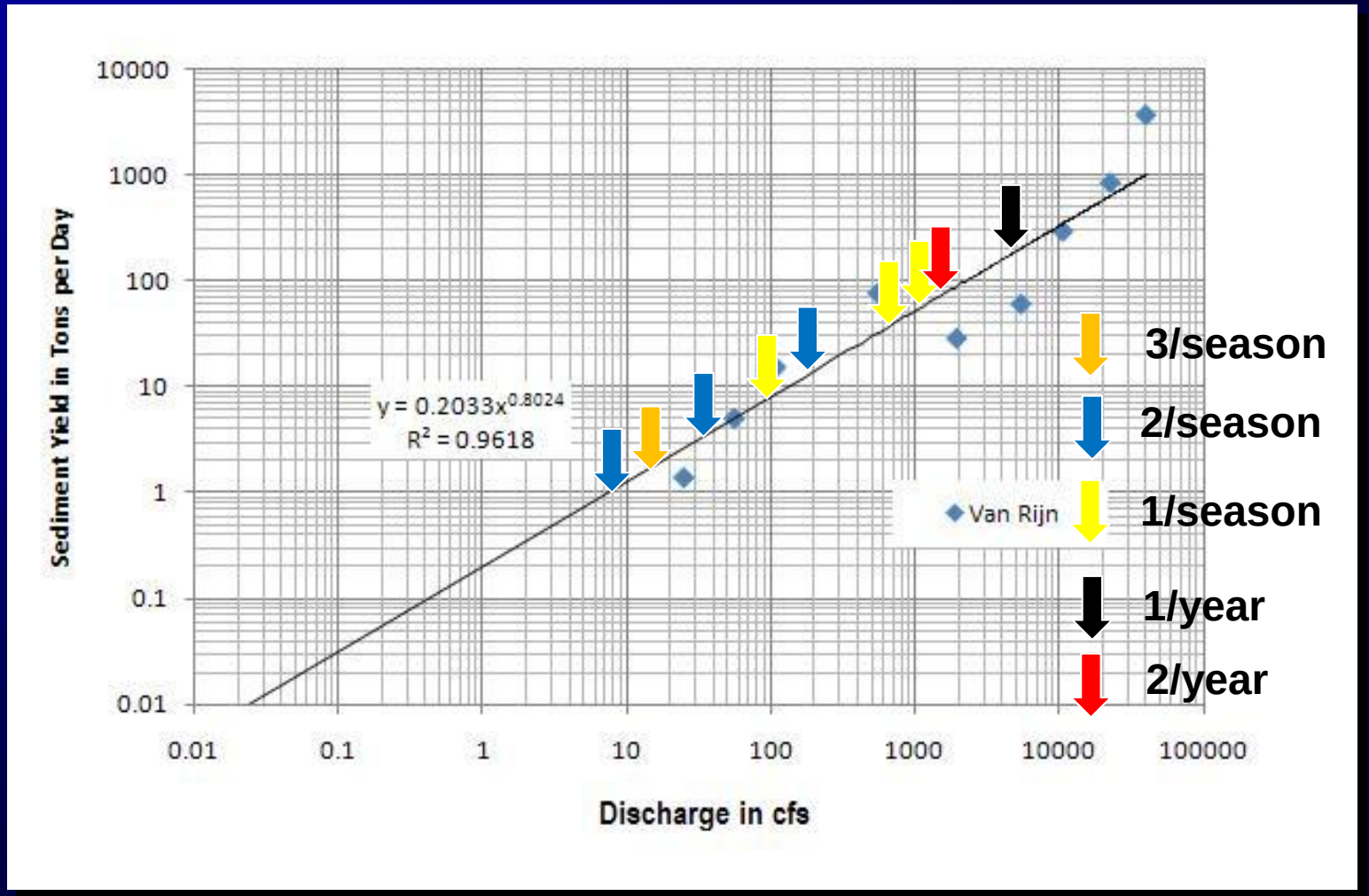
Nueces at Cotulla: Sediment Transport



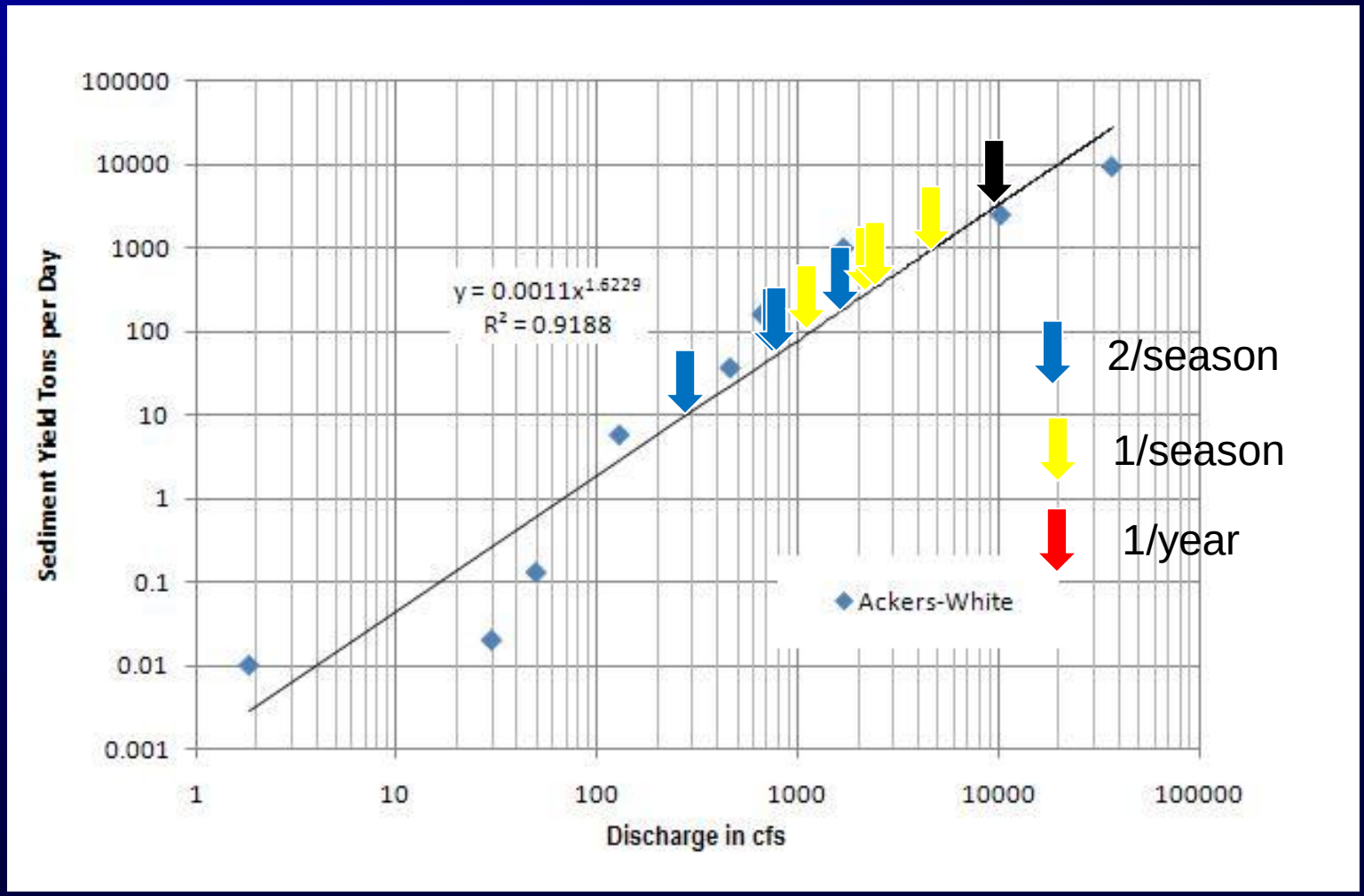
Nueces at Cotulla: Sediment Transport



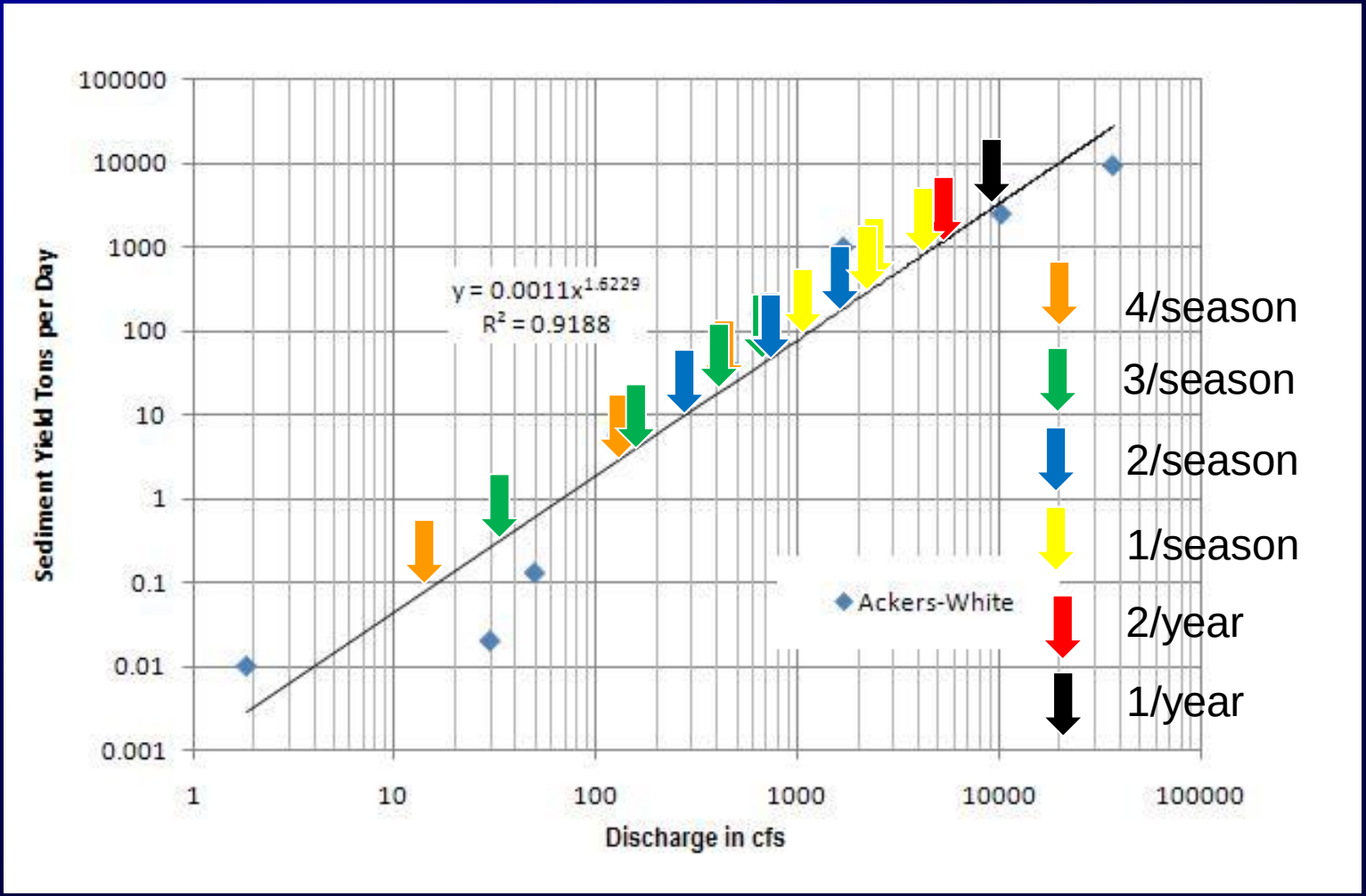
Nueces at Cotulla: Sediment Transport



Nueces at Three Rivers: Sediment Transport



Nueces at Three Rivers: Sediment Movement



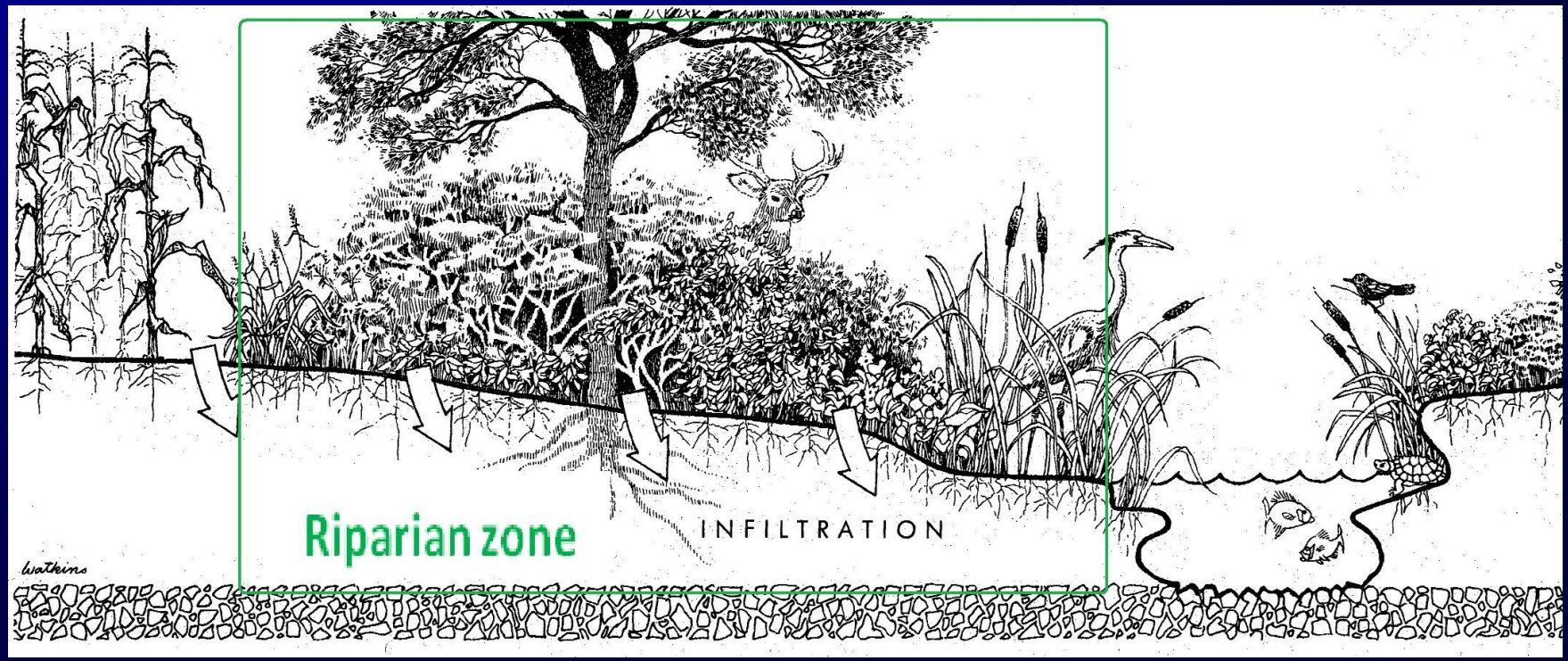
Sediment Transport:
Nueces at Cotulla: Period of Record Effect

	Average Annual Water (acre-feet)	Average Annual Sediment Moved (Tons)
1934 – 1996 (Baseline) (WAM regulated flows)	**181,000 (100%)**	**4,050 (100%)**
1924 – 1969	194,000 (**108%**)	4,130 (**102%**)
1970 – 2009	172,000 (**95%**)	4,170 (**103%**)
1924 – 2009	184,000 (**102%**)	4,150 (**102%**)

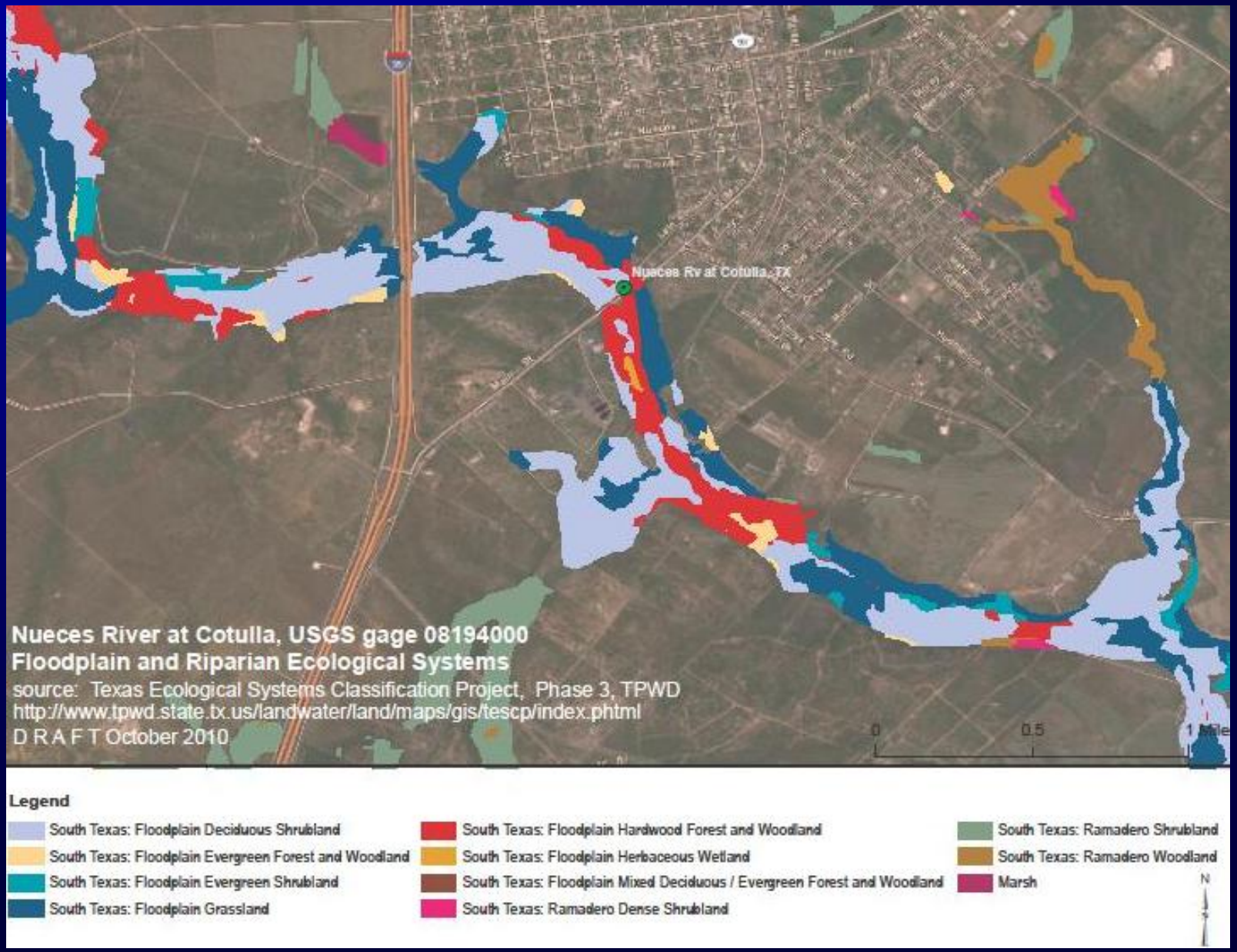
Sediment Transport:
Nueces at Cotulla: Pulse Effect

	Average Annual Water (acre-feet)	Average Annual Sediment Moved (Tons)
1934 – 1996 (Baseline) (WAM regulated flows)	**181,000 (100%)**	**4,050 (100%)**
Upper bound: Volume and duration, 2/yr pulses and seasonal pulses	30,800 **(17%)**	1,660 **(41%)**
Central tendency: Volume and duration, all pulses	21,800 **(12%)**	1,230 **(30%)**
Seasonal pulses only: Central tendency of volume and duration	8,010 **(4%)**	640 **(16%)**

Riparian Zone



Nueces at Cotulla Riparian/Floodplain

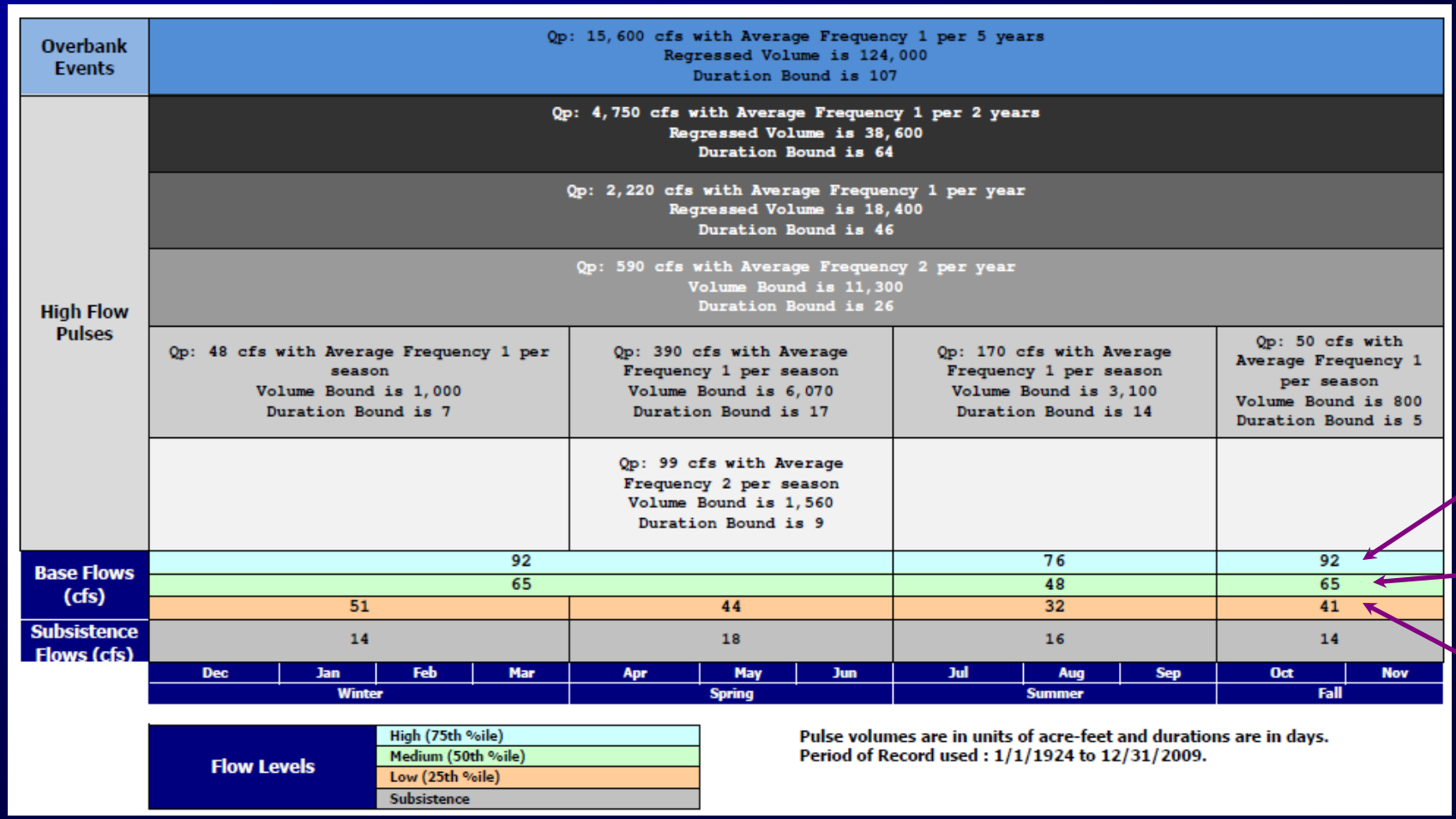


Riparian Zone: San Miguel Creek

Example Application of Environmental Flow Regime Recommendations

1) Run-of-River Diversion (up to 400 cfs) from the Nueces River near Laguna with and Off-Channel Storage Reservoir (44,000 acft).
2) This is a theoretical project for illustrative purposes only. No such project is recommended in any current regional or state water plan.

Instream Flow Regime Recommendation



Overbank Events	Qp: 15,600 cfs with Average Frequency 1 per 5 years Regressed Volume is 124,000 Duration Bound is 107			
High Flow Pulses	Qp: 4,750 cfs with Average Frequency 1 per 2 years Regressed Volume is 38,600 Duration Bound is 64			
	Qp: 2,220 cfs with Average Frequency 1 per year Regressed Volume is 18,400 Duration Bound is 46			
	Qp: 590 cfs with Average Frequency 2 per year Volume Bound is 11,300 Duration Bound is 26			
	Qp: 48 cfs with Average Frequency 1 per season Volume Bound is 1,000 Duration Bound is 7	Qp: 390 cfs with Average Frequency 1 per season Volume Bound is 6,070 Duration Bound is 17	Qp: 170 cfs with Average Frequency 1 per season Volume Bound is 3,100 Duration Bound is 14	Qp: 50 cfs with Average Frequency 1 per season Volume Bound is 800 Duration Bound is 5
		Qp: 99 cfs with Average Frequency 2 per season Volume Bound is 1,560 Duration Bound is 9		
Base Flows (cfs)	92		76	92
	65		48	65
	51	44	32	41
Subsistence Flows (cfs)	14	18	16	14
	Dec, Jan, Feb, Mar	Apr, May, Jun	Jul, Aug, Sep	Oct, Nov
	Winter	Spring	Summer	Fall

Wet

Avg

Dry

Flow Levels
High (75th %ile)
Medium (50th %ile)
Low (25th %ile)
Subsistence

Pulse volumes are in units of acre-feet and durations are in days.
Period of Record used : 1/1/1924 to 12/31/2009.

Nueces River @ Laguna (NRL)

Hydrologic Conditions

1) Use cumulative streamflow volumes for the preceding 12 months to define hydrologic conditions for the following season. Set trigger volumes such that Dry, Average, and Wet conditions will apply 25%, 50%, and 25% of the time, respectively.
2) Subsistence hydrologic conditions are a sub-category of Dry hydrologic conditions with trigger volumes set such that Subsistence conditions apply 10% of the time.
3) Hydrologic conditions apply to base flows and determine when passage of only Subsistence flows may be allowable.

Instream Flow Regime Recommendation Application Example

Flow Regime → **Permit Conditions**

Nomenclature

Q = Inflow (varies daily)

S = Subsistence Flow (varies w/ season)

B = Base Flow (varies w/ season & hydrologic condition)

P_i = Pulse Flow (varies w/ season & applicable tier)*

* Up to six tiers of pulses (2/season, 1/season, 2/year, 1/year, 1/2–years, and/or 1/5–years) are potentially applicable at Laguna in a season. Up to eight tiers (4/season, 3/season, and those listed above) are potentially applicable at some other sites.

Subsistence Hydrologic Condition Base Flow Application Example

Situation

a) $Q < S$

b) $B > Q > S$

c) $P_i > Q > B$

d) $Q > P_i$

Inflow Pass-Through

a) Q (inflow)

b) S (subsistence flow)

c) B (base flow)

d) Min (P_i or Q) until volume or duration has passed

Dry Hydrologic Condition
Base Flow Application Example

Situation

a) $Q < S$

b) $B > Q > S$

c) $P_i > Q > B$

d) $Q > P_i$

Inflow Pass-Through

a) Q (inflow)

b) Q (inflow)

c) B (base flow)

d) Min (P_i or Q) until volume or duration has passed

Average or Wet Hydrologic Conditions Base Flow Application Example

Situation

a) $Q < B$

b) $P_i > Q > B$

c) $Q > P_i$

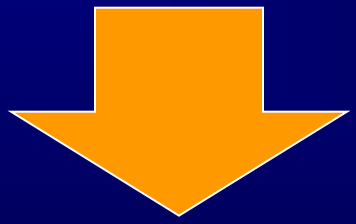
Inflow Pass-Through

a) Q

b) B

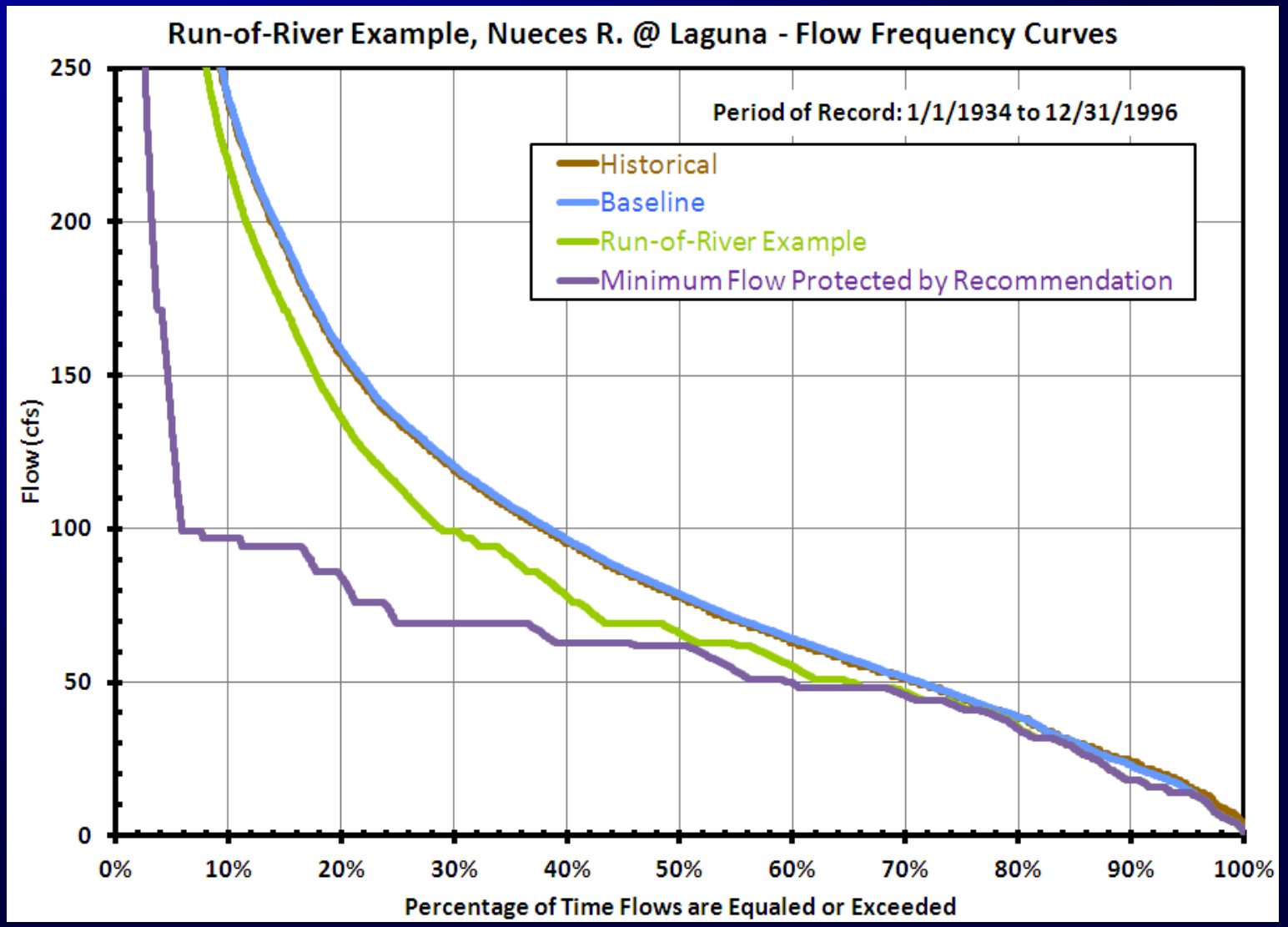
c) Min (P_i or Q) until volume or duration pass

The Flow Regime Application Tool (FRAT) May be Used to Perform Example Applications of Potential Instream Flow Regime Recommendations

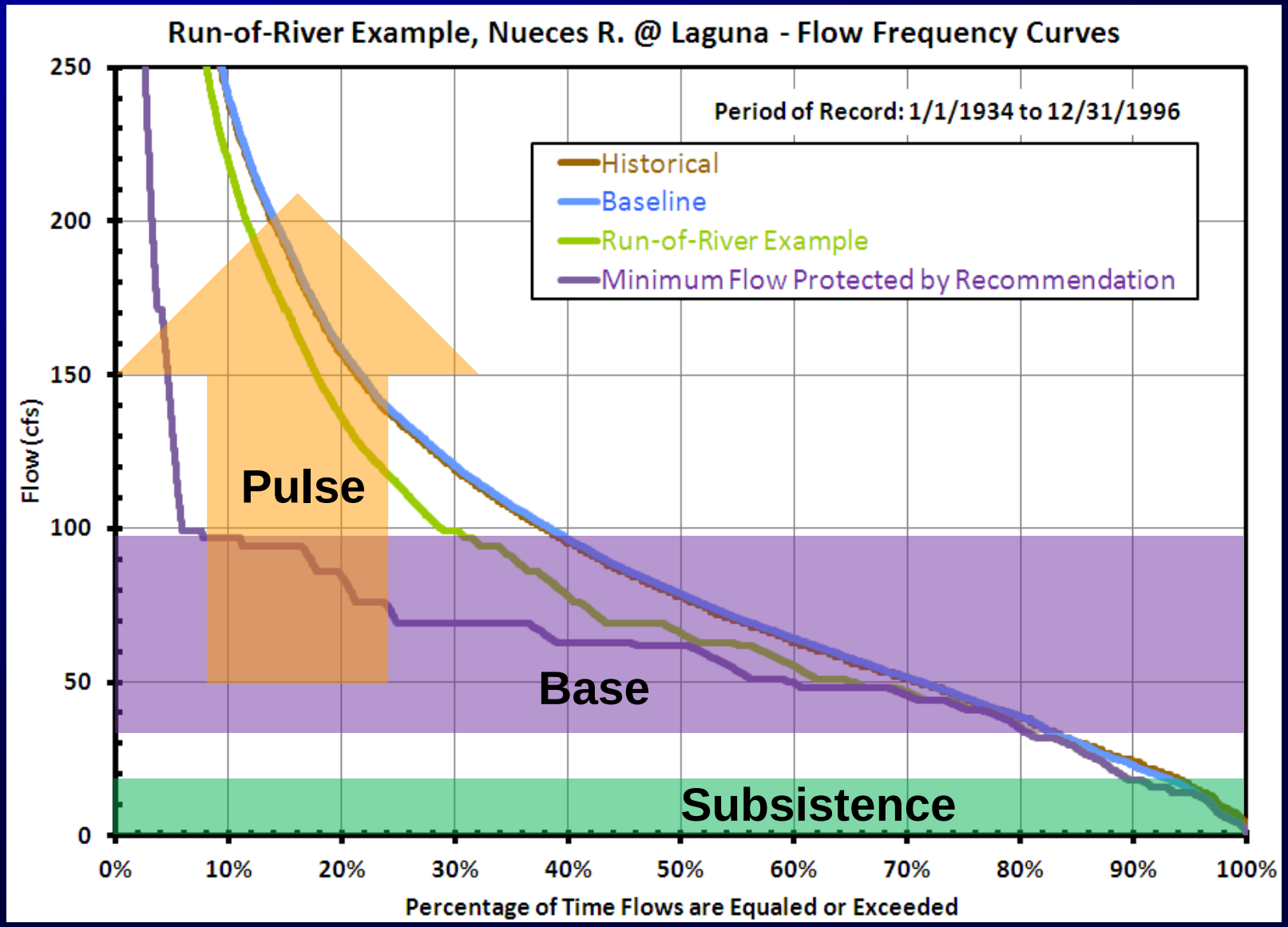


The BBEST Considers Resulting Flows to Assess Adequacy to Support a Sound Ecological Environment

Example Application of Instream Flow Regime Recommendations

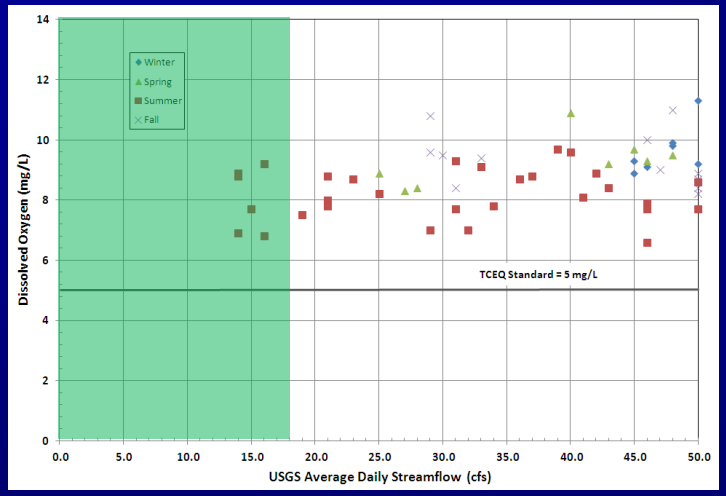


Flow Regime Components

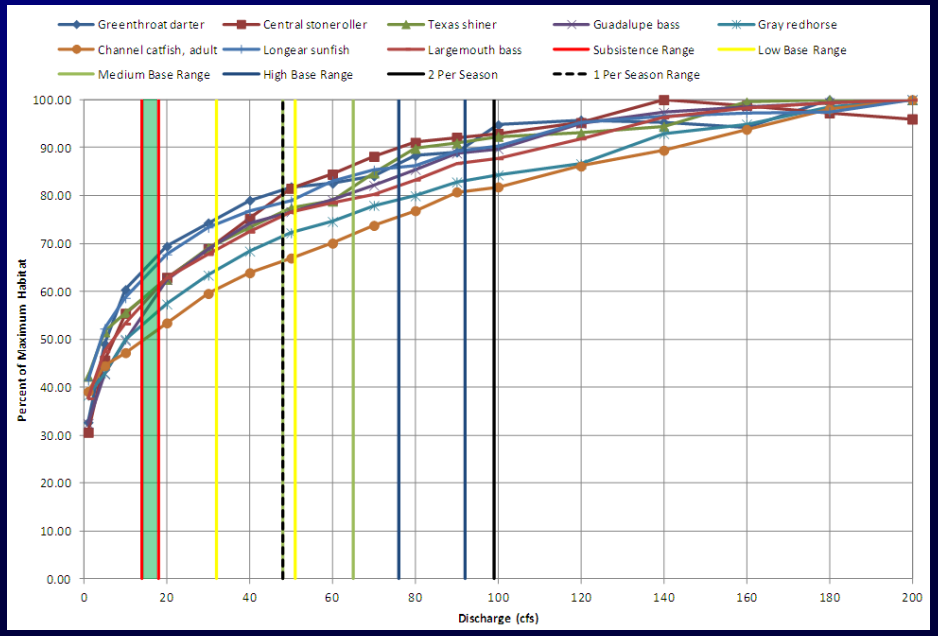


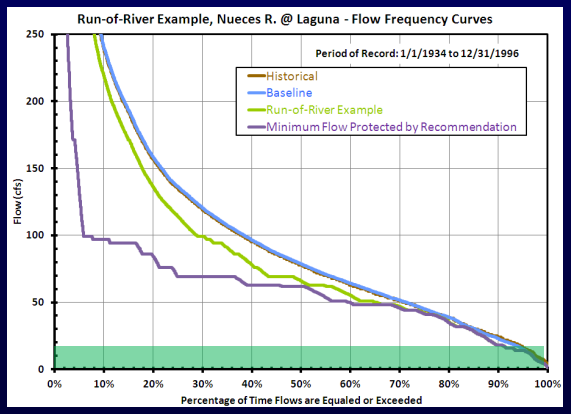
Ecological Significance - Subsistence

Water Quality

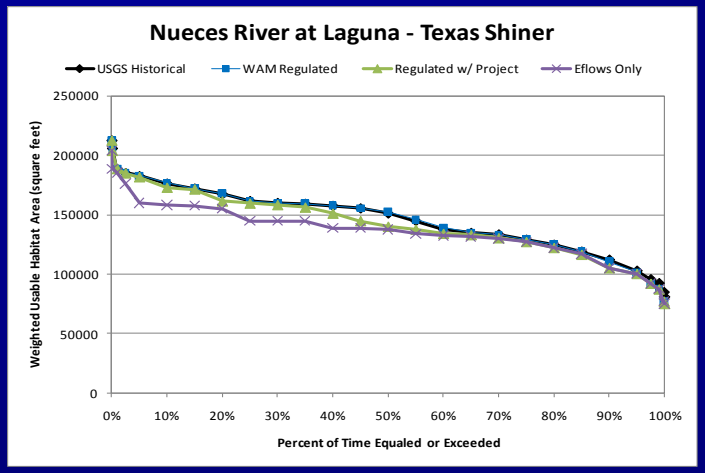


Aquatic Habitat

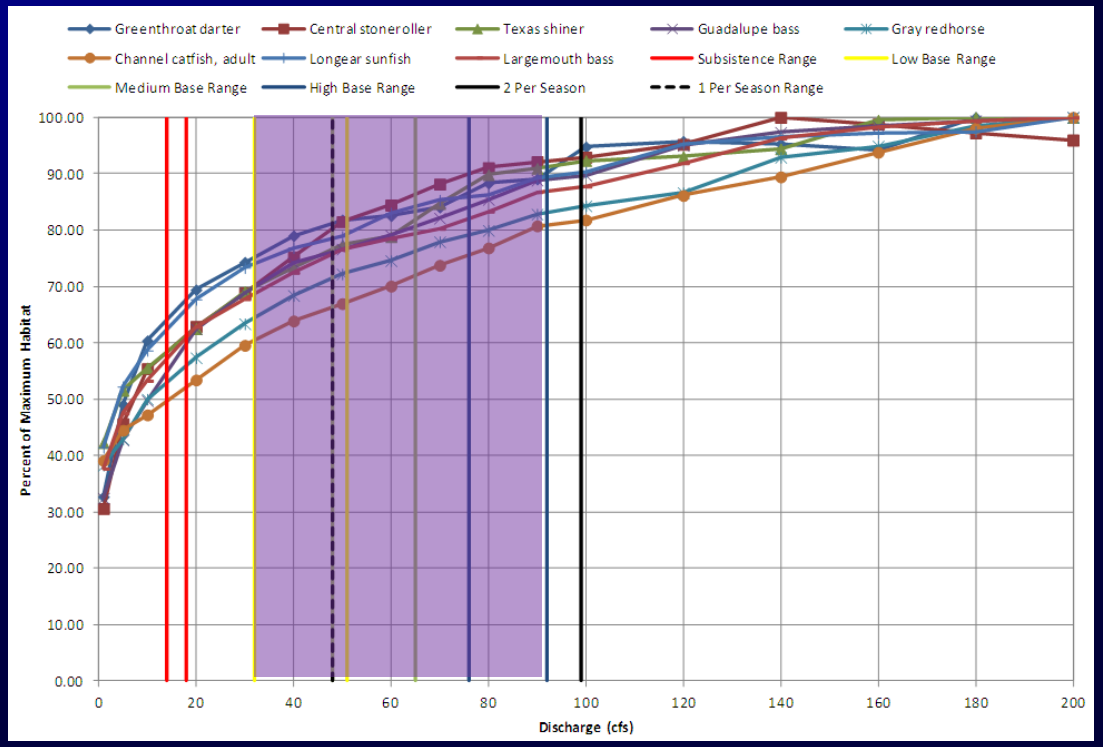


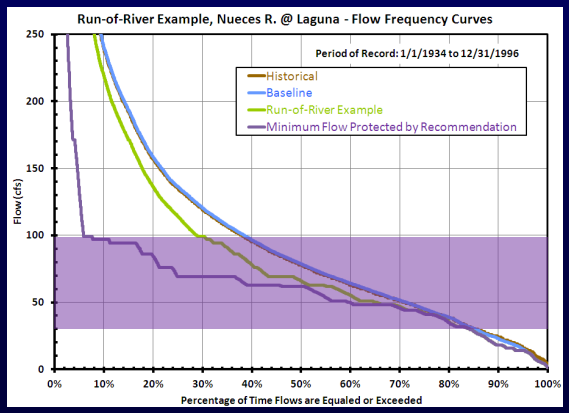


Ecological Significance - Base



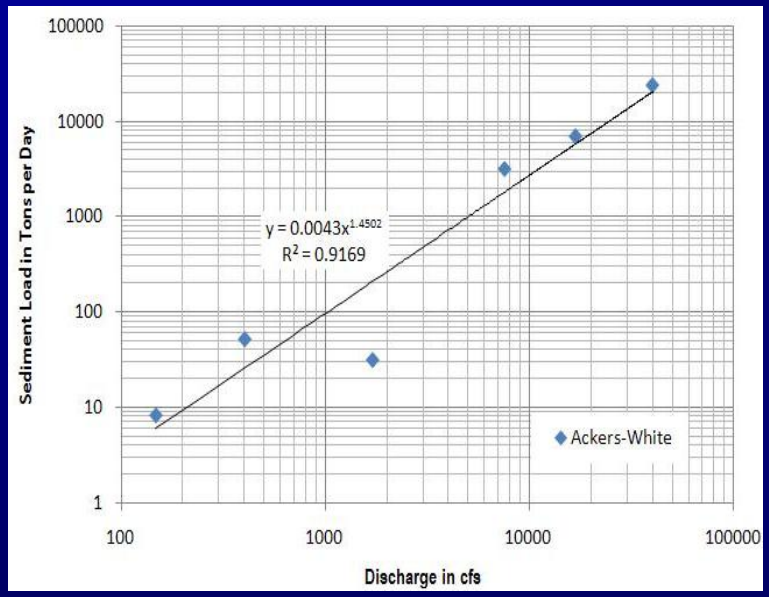
Aquatic Habitat

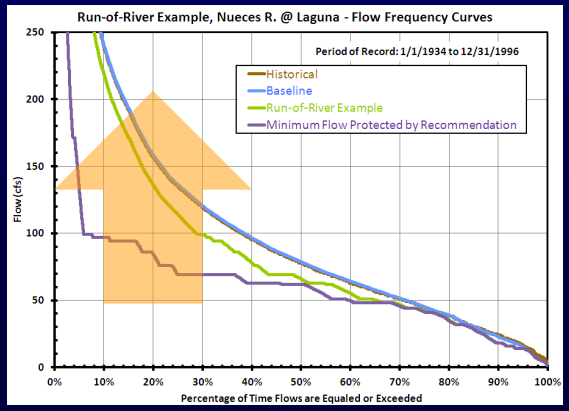




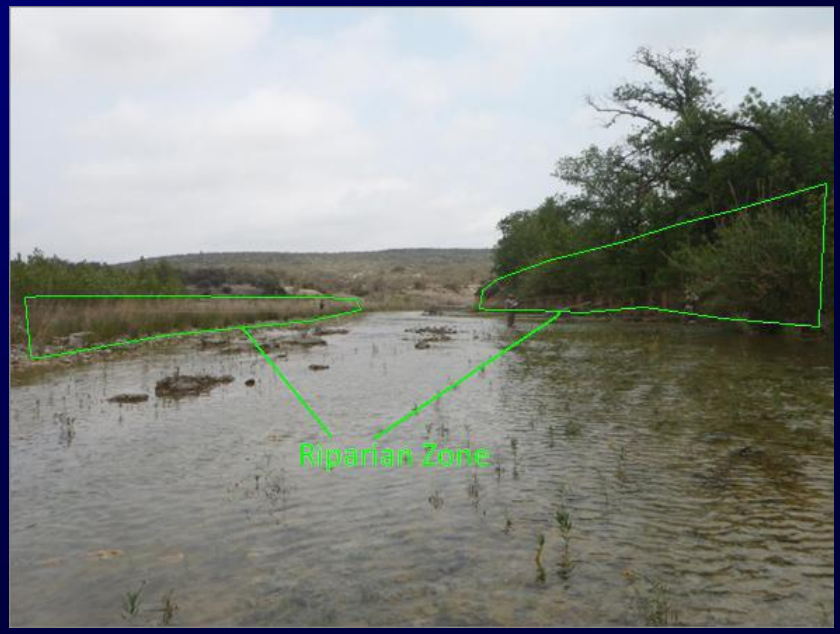
Ecological Significance - Pulses

Geomorphology

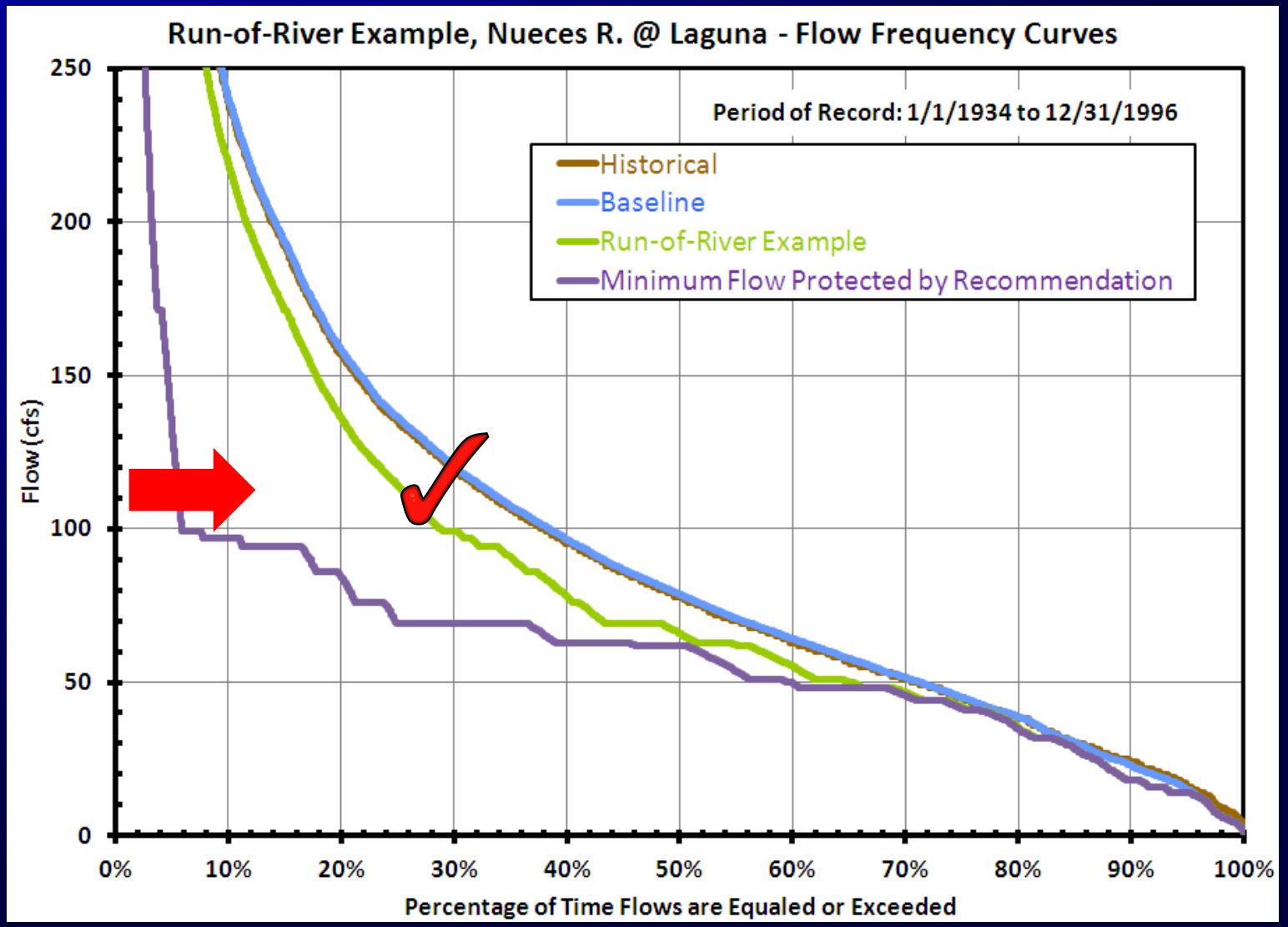




Riparian Ecology

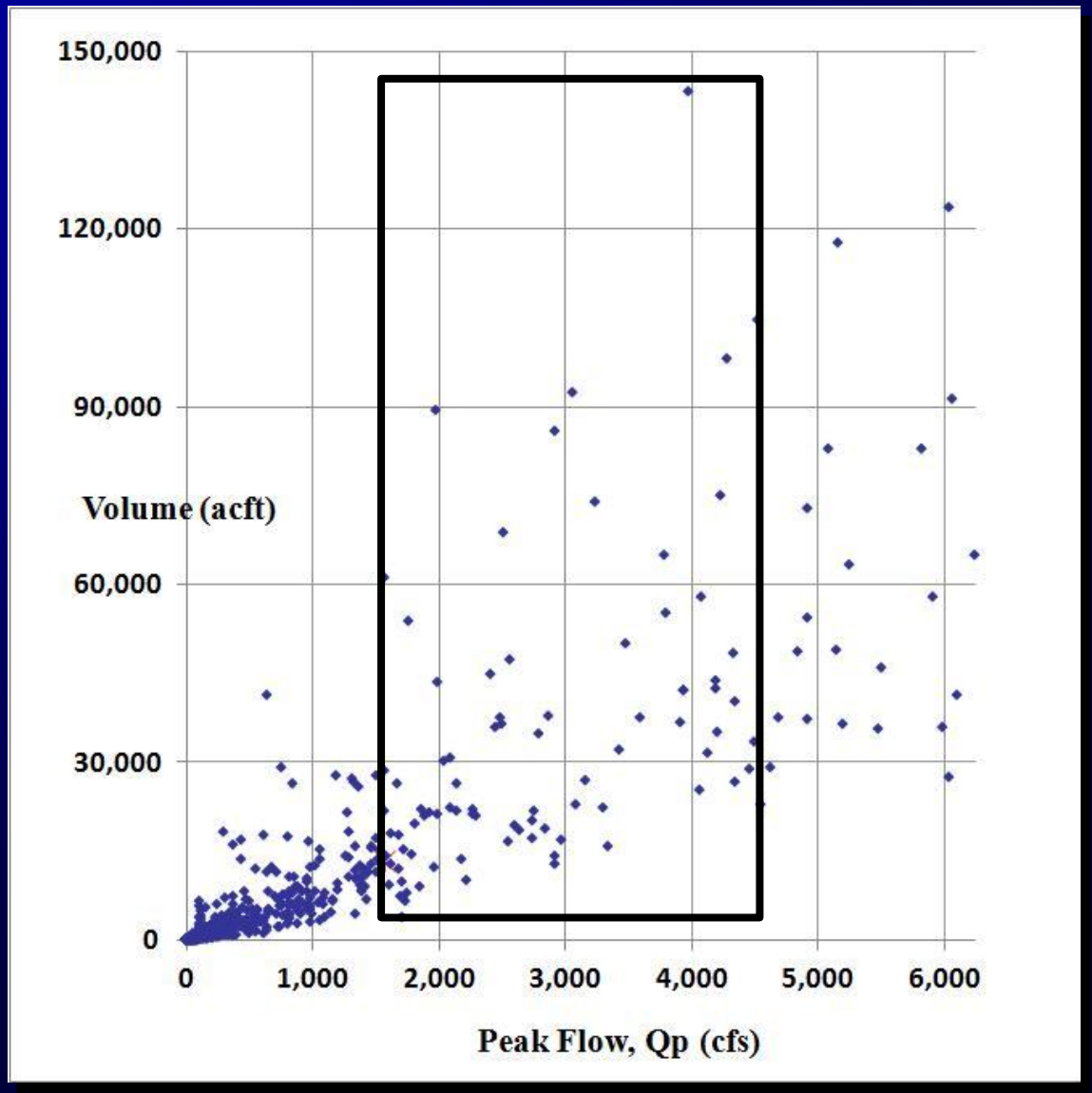


Example Application of Instream Flow Regime Recommendations



Questions, Comments, & Discussion

Nueces at Cotulla: 2/yr Pulse, Volume Bounds



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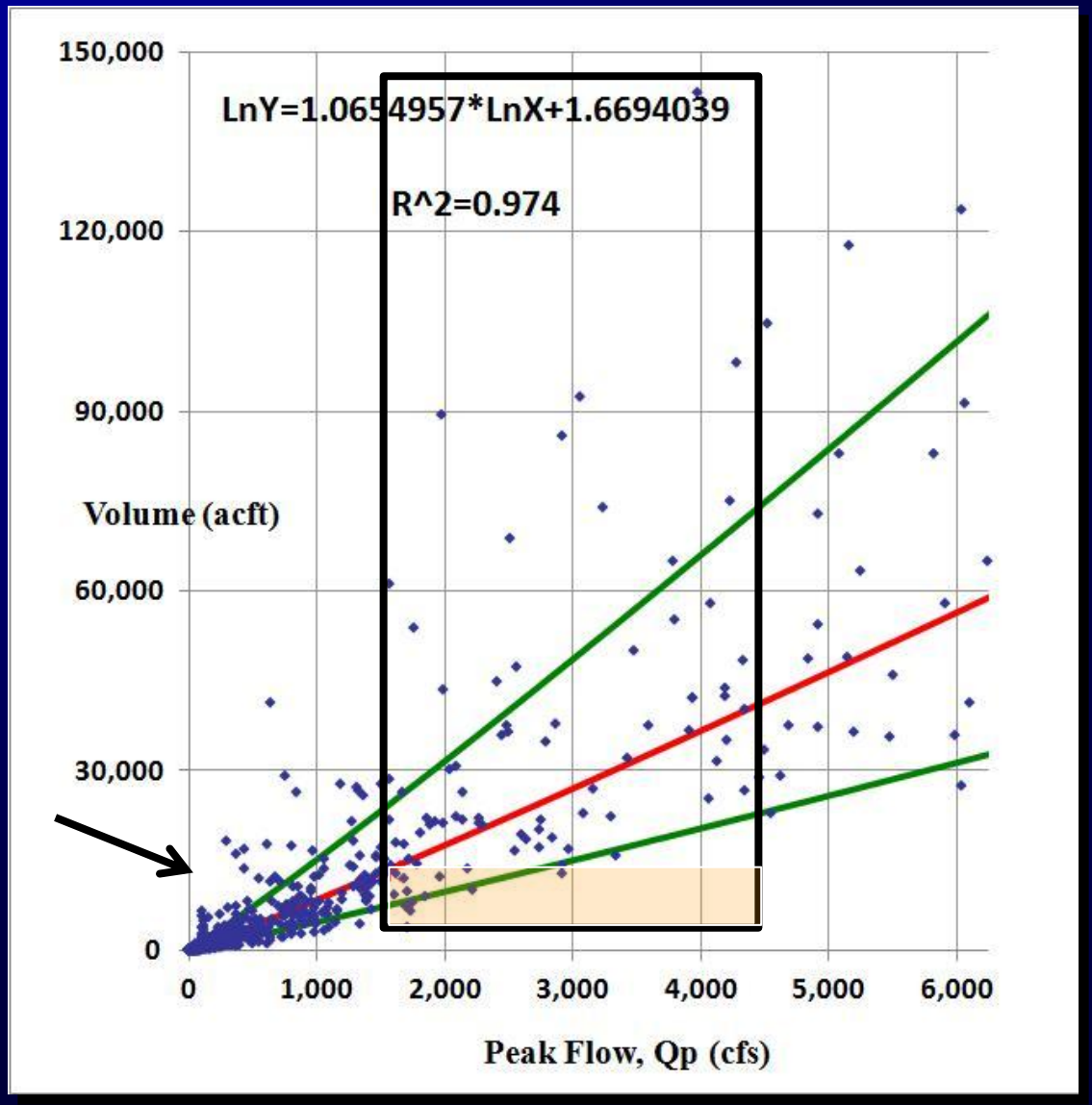

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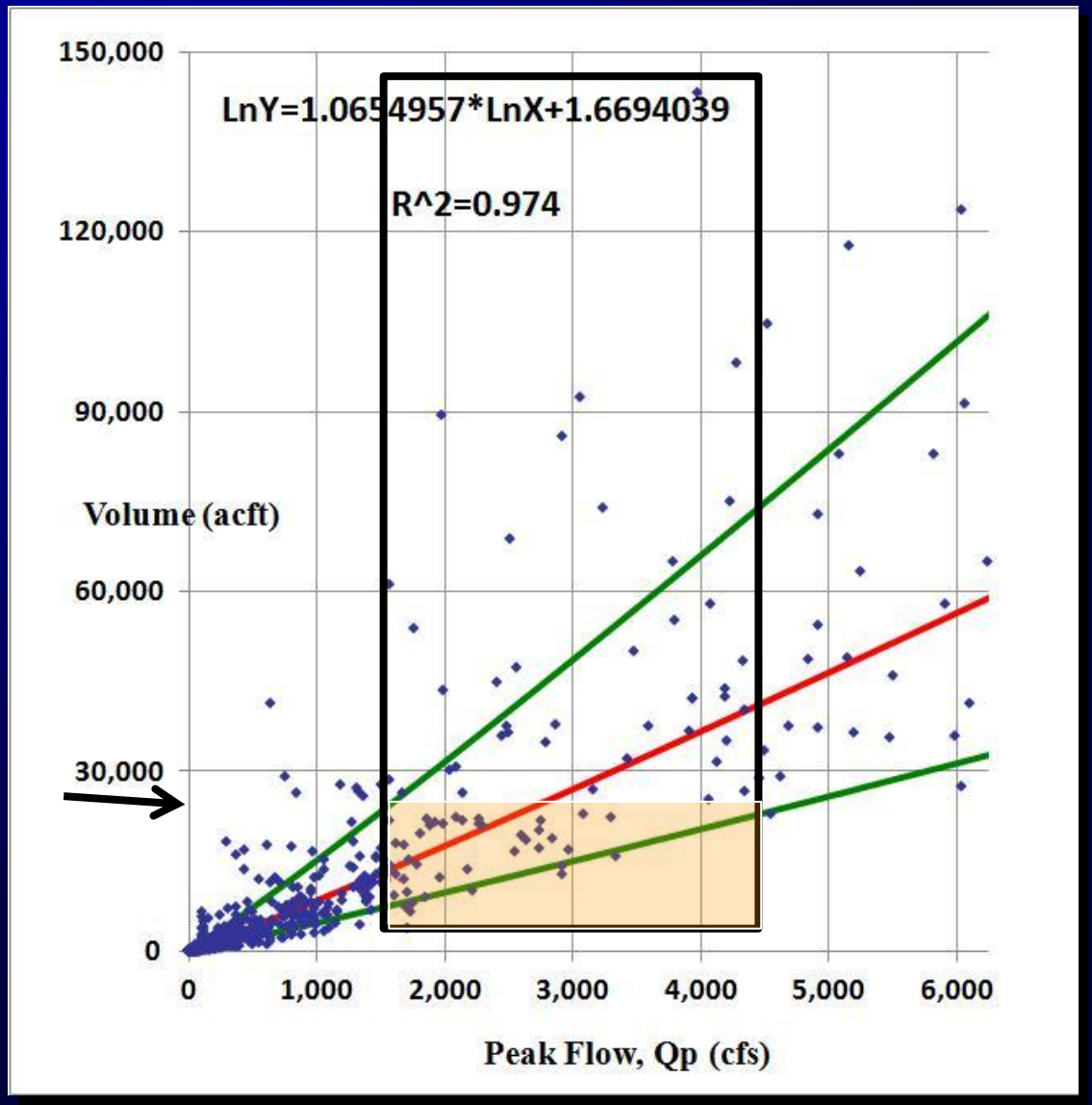

USGS

USGS 08195000 Frio Rv at Concan, TX