Environmental Flows Recommendations Report

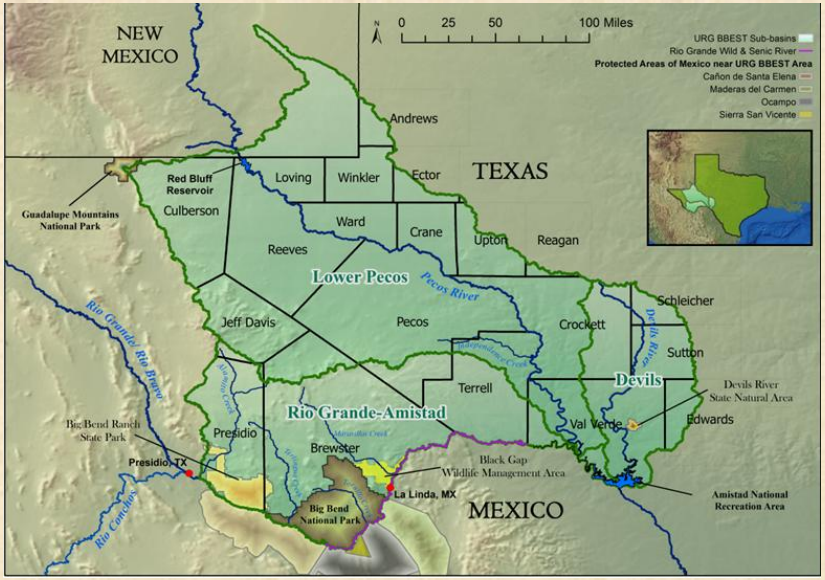
Final Submission to the Environmental Flows Advisory Group, Rio Grande Basin and Bay Area Stakeholders Committee, and Texas Commission on Environmental Quality

Upper Rio Grande Basin and Bay Expert Science Team

July 2012

Upper Rio Grande BBEST

- The Upper Rio Grande BBEST study area includes the Rio Grande basin upstream of Amistad Reservoir and below Presidio, including the Pecos and Devils river basins.



Upper Rio Grande BBEST Membership

- Kevin Urbanczyk — Chair
- Zhuping Sheng — Vice-Chair, Pecos River Subcommittee
- Jeff Bennett — Rio Grande Subcommittee
- David Dean — Rio Grande Subcommittee
- Gary Bryant — Pecos River Subcommittee
- Ryan Smith — Devil's River Subcommittee

Charge

- *Each basin and bay expert science team shall develop environmental flow analyses and a recommended environmental flow regime for the river basin and bay system for which the team is established through a collaborative process designed to achieve a consensus. In developing the analyses and recommendations, the science team must consider all reasonably available science, without regard to the need for the water for other uses, and the science team's recommendations must be based solely on the best science available.*

SB3 Terminology

- *"Environmental flow analysis" means the application of a scientifically derived process for predicting the response of an ecosystem to changes in instream flows or freshwater inflows.*
- *"Environmental flow regime" means a schedule of flow quantities that reflects seasonal and yearly fluctuations that typically would vary geographically, by specific location in a watershed, and that are shown to be adequate to support a* ***sound ecological environment*** *and to maintain the productivity, extent, and persistence of key aquatic habitats in and along the affected water bodies.*

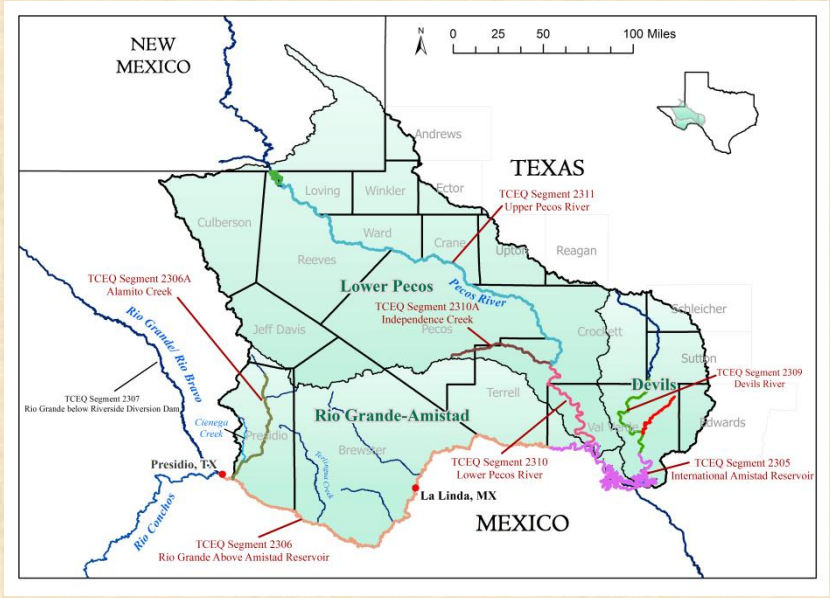
Sound Ecological Environment

- A sound ecological environment is one that:
  - sustains the full complement of the current suite of native species in perpetuity, or at least support the reintroduction of extirpated species,
  - sustains key habitat features required by these species,
  - retains key features of the natural flow regime required by these species to complete their life cycles, and
  - sustains key ecosystem processes and services, such as elemental cycling and the productivity of important plant and animal populations

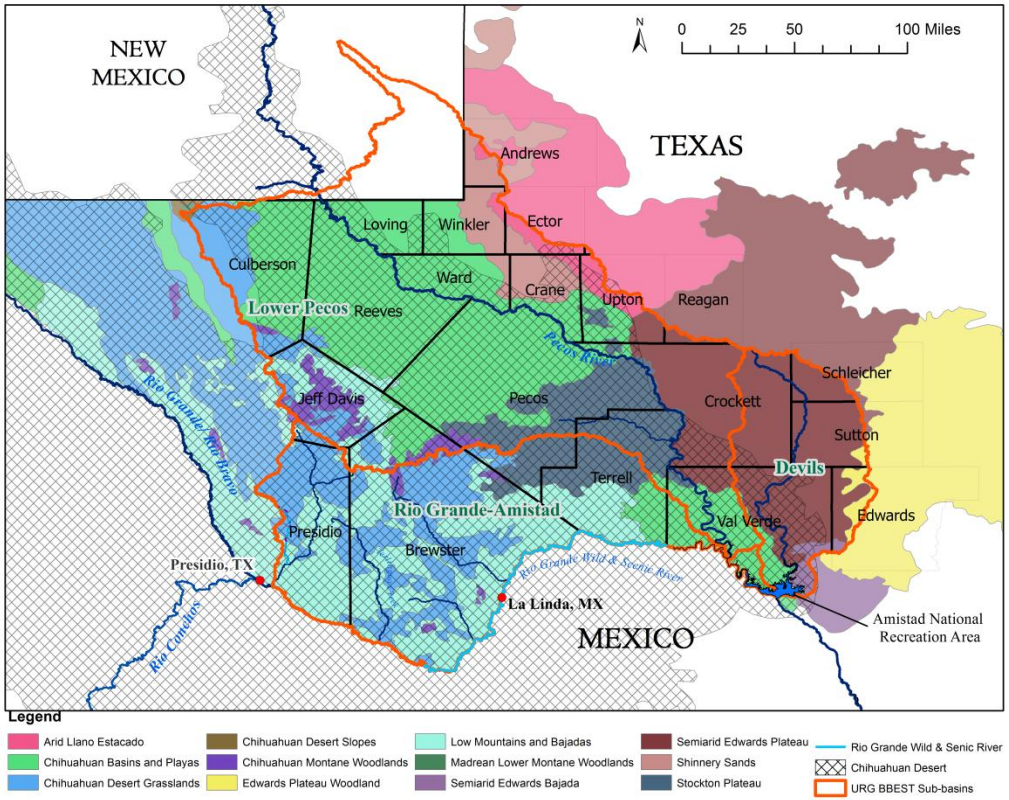
Sound Ecological Environment

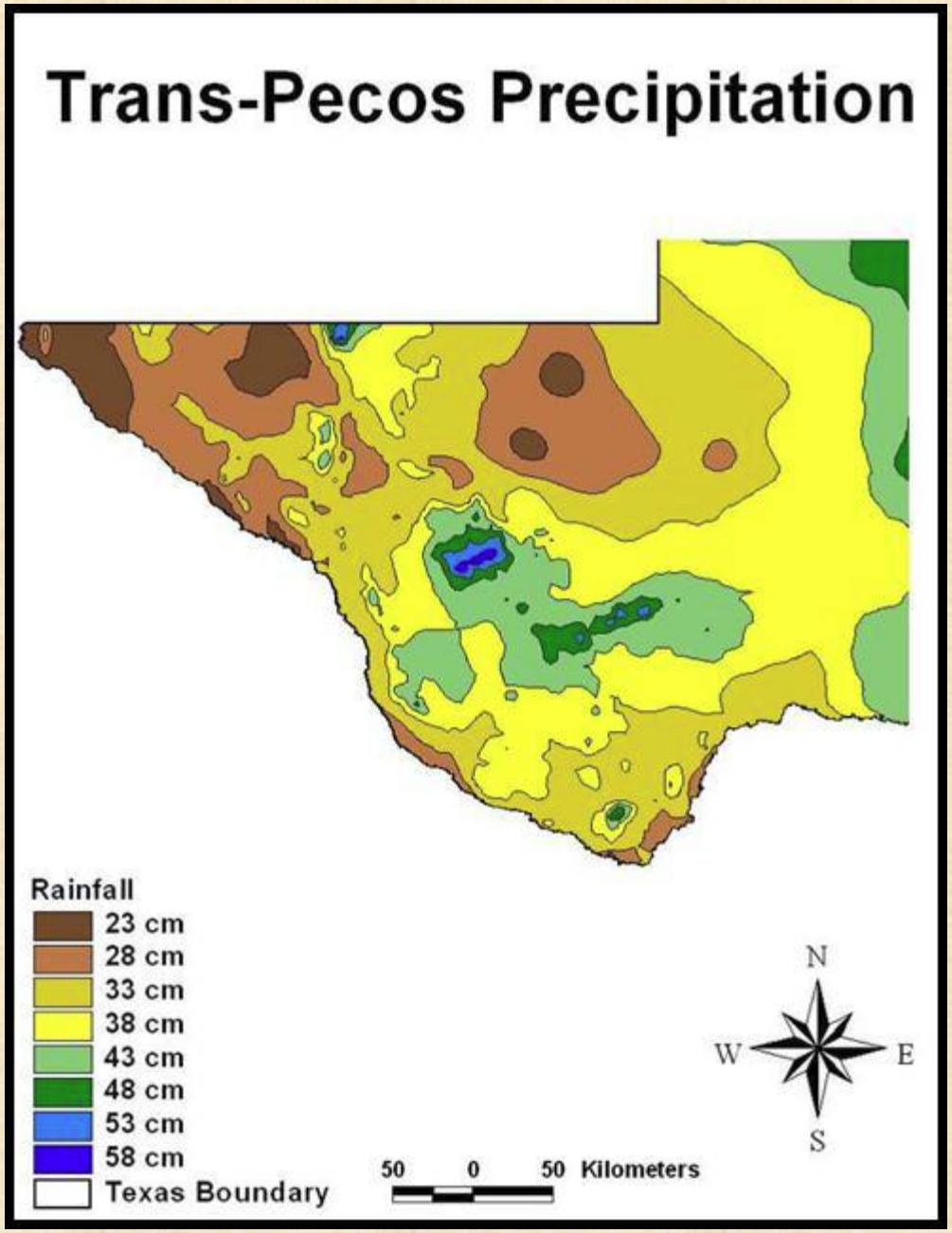
- The Upper Rio Grande BBEST feels that the water bodies of our assigned area are “sound” with two large exceptions:

1) The Pecos River from the New Mexico state line to the confluence with Independence Creek (TCEQ segment 2311) and
2) The Rio Grande upstream of La Linda, Coahuila Mexico (the “Parks reach”).

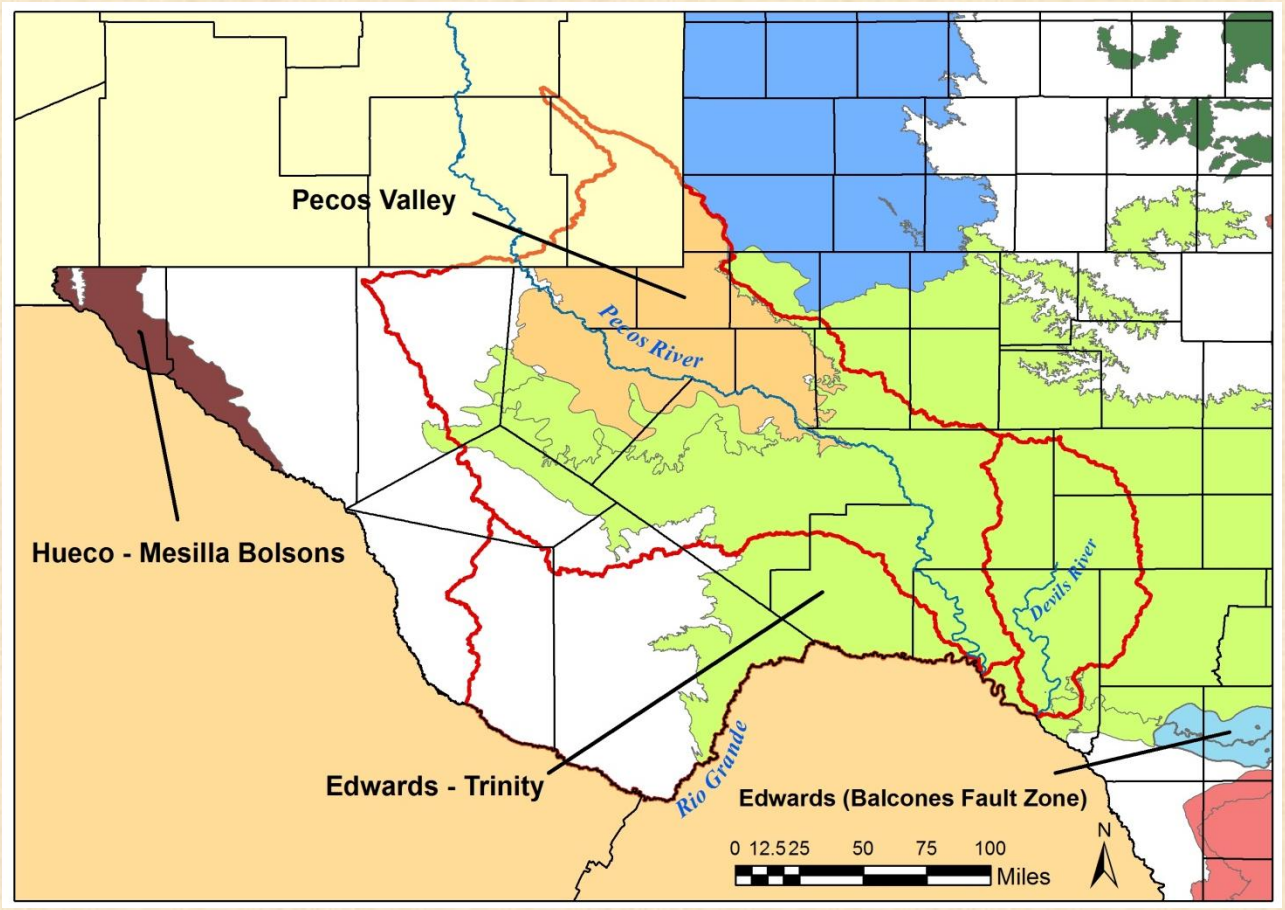


Overview - Ecoregions

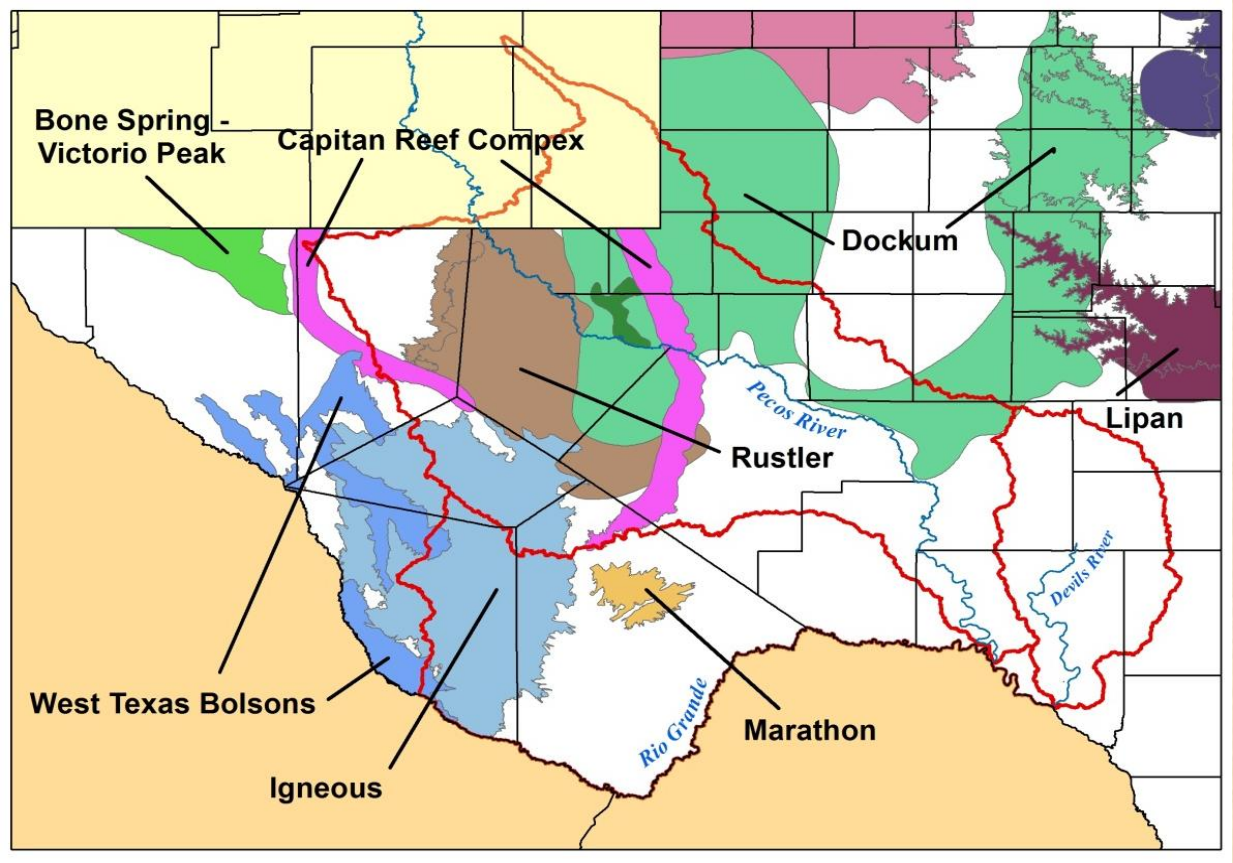



Trans-Pecos Precipitation
Rainfall
23 cm
28 cm
33 cm
38 cm
43 cm
48 cm
53 cm
58 cm
Texas Boundary
50 0 50 Kilometers
N
W
E
S

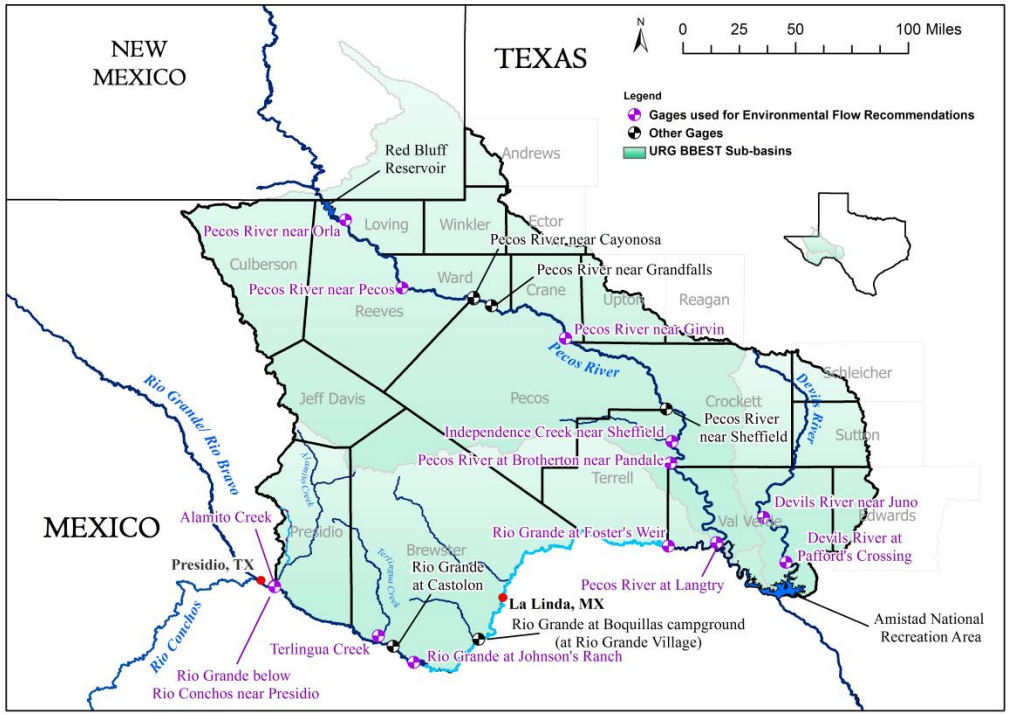
Major Aquifers



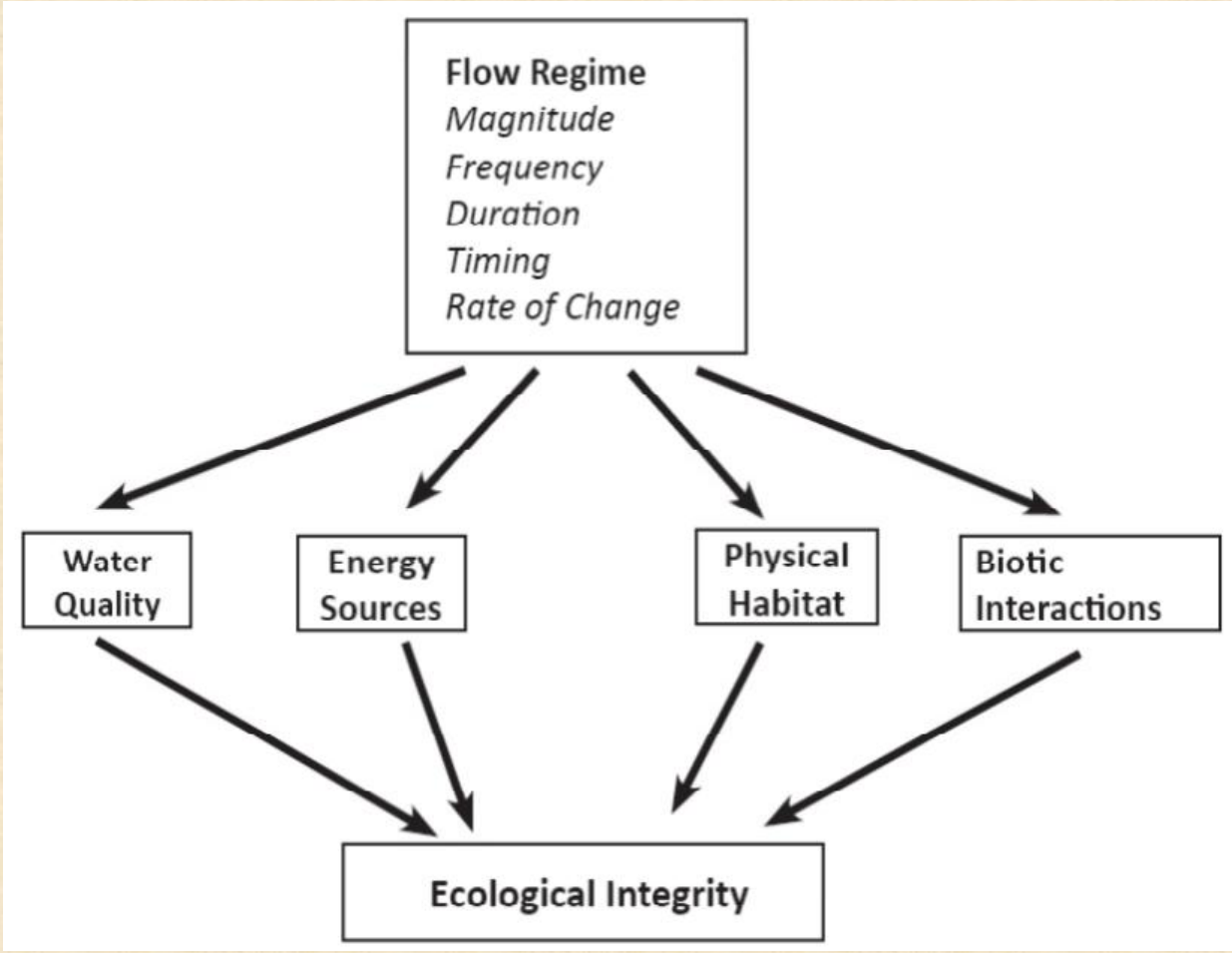
Minor Aquifers



Hydrology, Flow Analysis and Flow Regimes



Components of a Natural Flow Regime



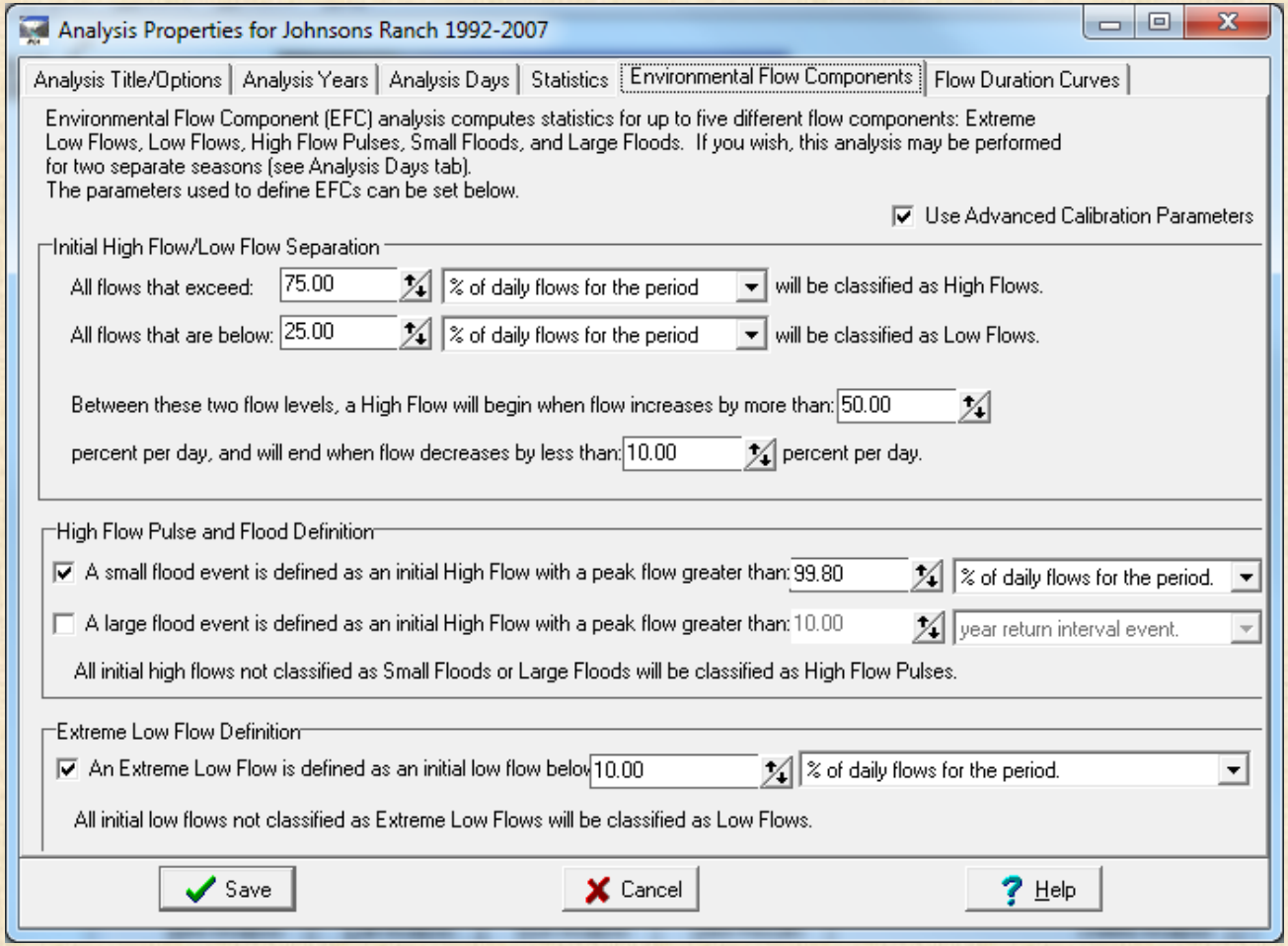
General Flow Components

Component	Hydrology	Geomorphology	Biology	Water Quality
No-Flow Periods	Flow ceases between perennial pools	Encroachment of vegetation	Generally stressful for fish communities	Temperatures rise and oxygen levels decrease. These condition sometimes cause fish kills
Subsistence Flows	Infrequent low flows	Increased deposition of fine and organic particles, encroachment of vegetation	Provide restricted aquatic habitat limit connectivity	Elevate temperature and constituent concentrations Maintain adequate levels of dissolved oxygen
Base Flows	Average flow condition, including variability	Maintain soil moisture and ground water table Maintain a diversity of habitats, Exports or transports sediment?	Provide suitable aquatic habitat, Provide connectivity along channel corridor	Provide suitable in-channel water quality
High Flow Pulses	In channel short duration, high flows	Deposit sediment, development of inset flood plains; Prevent encroachment of riparian vegetation	Serve as recruitment events for organisms; Provide connectivity to near-channel water bodies	Restore in-channel water quality after prolonged low flow periods. Episodic in nature and associated with fish kills (anecdotal, no real investigation of this yet)
Overbank flows	Infrequent high flows that exceed the channel	Provide lateral channel movement and floodplain maintenance; Recharge floodplain water table; form new habitats; flush organic material into channel; Deposit nutrients in floodplain	Provide new life phase cues for organisms; Maintain diversity of riparian vegetation; Provide conditions for seedling development; Provide connectivity to floodplain	Restore water quality in floodplain water bodies
Channel Maintenance	For most streams, channel maintenance occurs mostly during pulse and overbank flows	Long-term maintenance of existing channel morphology	Maintains foundation for physical habitat features instream	Water quality condition like those during pulse overbank flows

Period of Record

Sub-Basin	Site Name	Period of Record
Rio Grande	Alamito Creek	1/1/1932 to 12/31/2009
Rio Grande	Rio Grande below Rio Conchos near Presidio	1/1/1901 to 2/28/1914 and 3/1/1931 to 12/31/1967
Rio Grande	Terlingua Creek	1/1/1932 to 12/31/2009
Rio Grande	Rio Grande at Johnson's Ranch	1/1/1936 to 12/31/1967
Rio Grande	Rio Grande at Foster's Weir	1/1/1962 to 12/31/2009
Pecos River	Pecos River near Orla	1/1/1938 to 12/31/2009
Pecos River	Pecos River near Pecos	1/1/1902 to 12/31/1935
Pecos River	Pecos River near Girvin	1/1/1939 to 12/31/2011
Pecos River	Independence Creek near Sheffield	1/1/1975 to 6/30/1985 and 7/1/2000 to 12/31/2009
Pecos River	Pecos River near Langtry	1/1/1967 to 12/31/2010
Devils River	Devils River near Juno	1/1/1936 to 2/28/1949 and 3/1/1931 to 12/31/1972
Devils River	Devils River at Pafford's Crossing	1/1/1960 to 12/31/2009

IHA

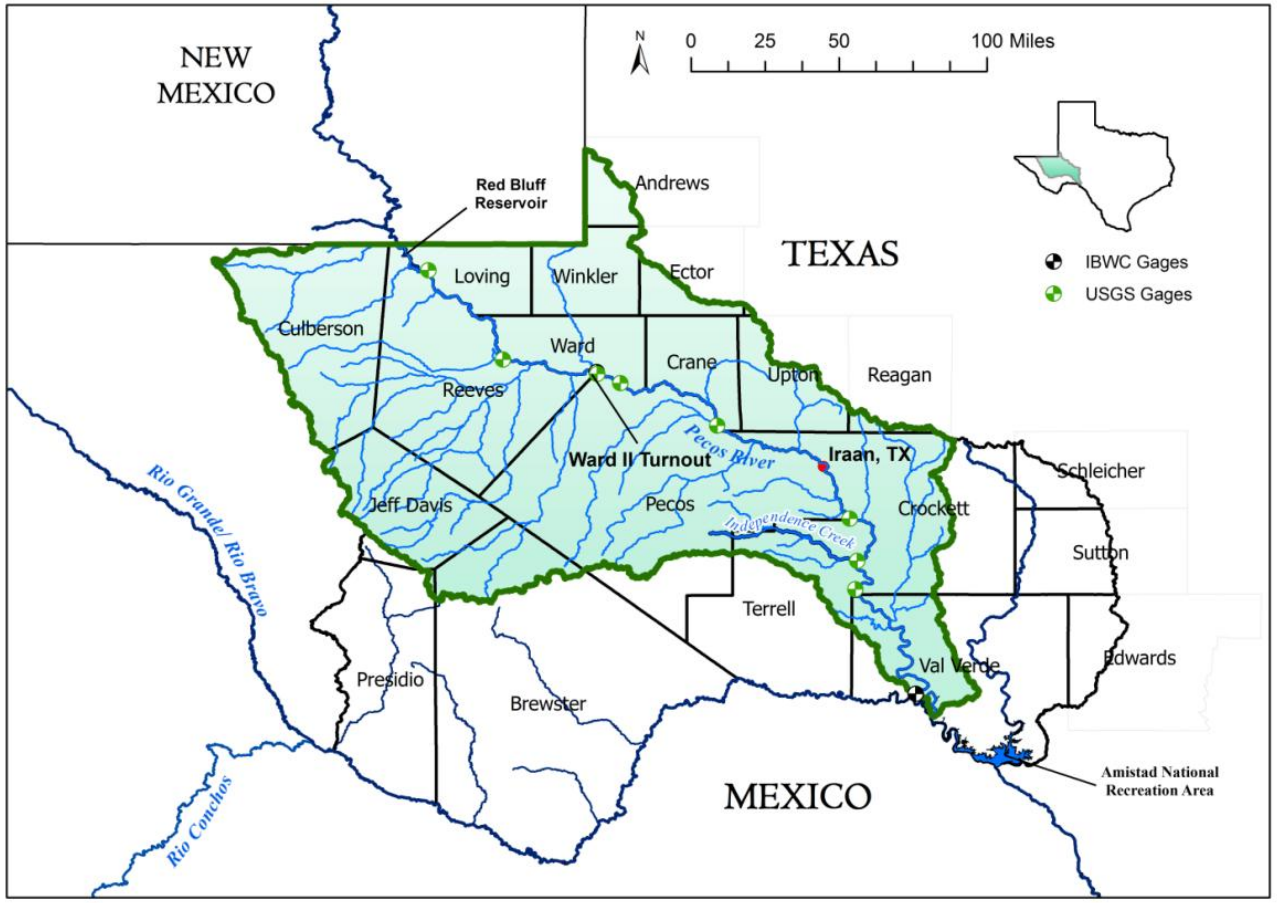

Analysis Properties for Johnsons Ranch 1992-2007
Analysis Title/Options
Analysis Years
Analysis Days
Statistics
Environmental Flow Components
Flow Duration Curves
Environmental Flow Component (EFC) analysis computes statistics for up to five different flow components: Extreme Low Flows, Low Flows, High 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.
Use Advanced Calibration Parameters
Initial High Flow/Low Flow Separation
All flows that exceed: 75.00 % of daily flows for the period will be classified as High Flows.
All flows that are below: 25.00 % of daily flows for the period will be classified as Low Flows.
Between these two flow levels, a High Flow will begin when flow increases by more than: 50.00
percent per day, and will end when flow decreases by less than: 10.00 percent per day.
High Flow Pulse and Flood Definition
A small flood event is defined as an initial High Flow with a peak flow greater than: 99.80 % of daily flows for the period.
A large flood event is defined as an initial High Flow with a peak flow greater than: 10.00 year return interval event.
All initial high flows not classified as Small Floods or Large Floods will be classified as High Flow Pulses.
Extreme Low Flow Definition
An Extreme Low Flow is defined as an initial low flow below 10.00 % of daily flows for the period.
All initial low flows not classified as Extreme Low Flows will be classified as Low Flows.
Save
Cancel
Help

HEFR

Overbank Flows	Qp: 2,469 ft³/s with Average Frequency 1 per 5 years Regressed Volume is 9,996 Regressed Duration is 6											
High Flow Pulses	Qp: 1,459 ft³/s with Average Frequency 1 per 2 years Regressed Volume is 5,763 Regressed Duration is 6											
	Qp: 915 ft³/s with Average Frequency 1 per year Regressed Volume is 3,535 Regressed Duration is 5											
	Qp: 2 ft³/s with Average Frequency 1 per 2 seasons Volume is 1,448 Duration is 4				Qp: 484 ft³/s with Average Frequency 1 per 2 seasons Volume is 1,448 Duration is 4				Qp: 1,250 ft³/s with Average Frequency 1 per 2 seasons Volume is 5,175 Duration is 6			
					Qp: 226 ft³/s with Average Frequency 1 per season Volume is 648 Duration is 4				Qp: 675 ft³/s with Average Frequency 1 per season Volume is 2,700 Duration is 6			
Base Flows (ft³/s)	1.8 (49.5%)				1.8 (36.9%)				1.8 (49.4%)			
	1.4 (67.5%)				1.4 (47.4%)				1.4 (58.5%)			
	1.1 (85.1%)				1.1 (69.5%)				1.1 (74.9%)			
Subsistence Flows (ft³/s)	0.71 (97.8%)				0.71 (87.0%)				0.71 (87.8%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

Rio Grande

Pecos River


NEW MEXICO
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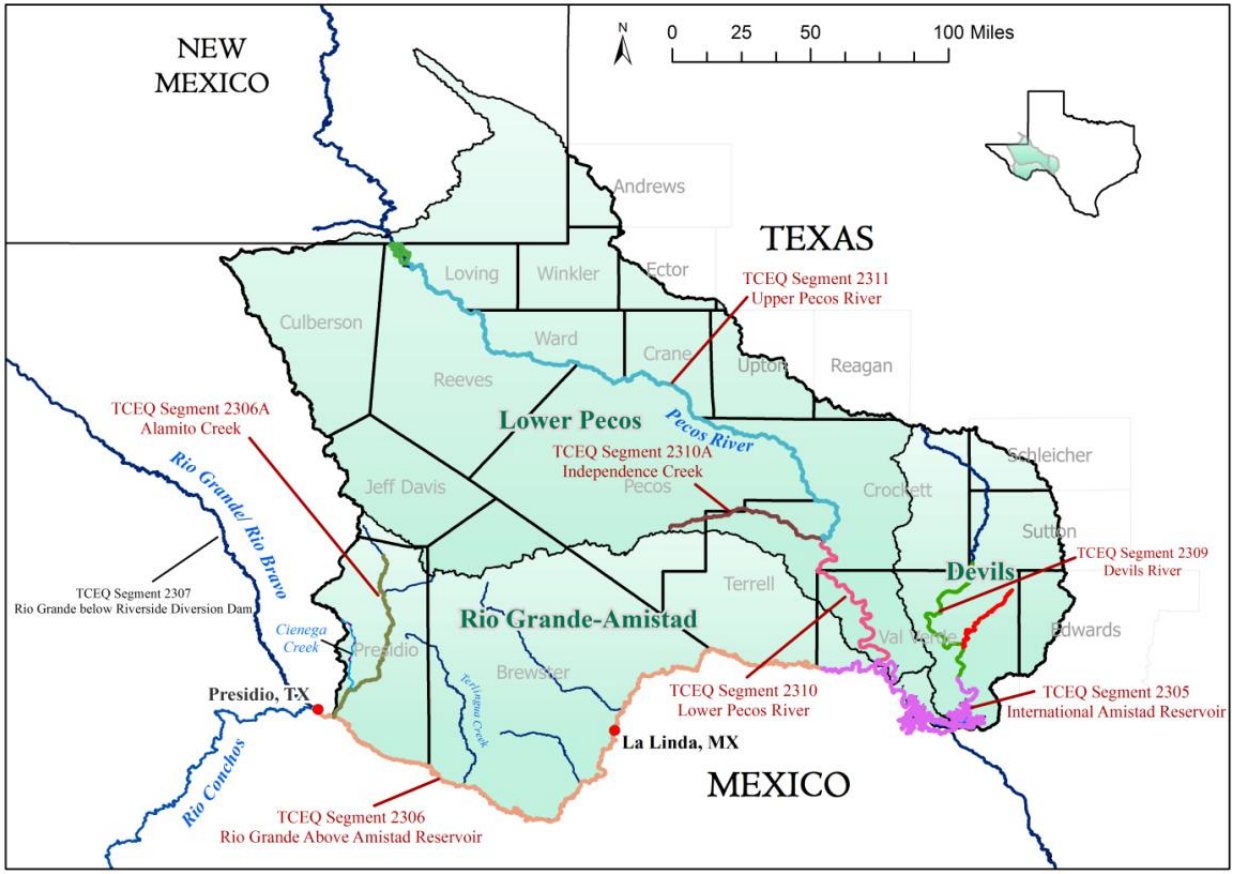
50
100 Miles
Red Bluff Reservoir
Andrews
TEXAS
IBWC Gages
USGS Gages
Loving
Winkler
Ector
Culberson
Ward
Crane
Upton
Reagan
Reeves
Pecos River
Ward II Turnout
Iraan, TX
Schleicher
Jeff Davis
Pecos
Crockett
Independence Creek
Sutton
Terrell
Edwards
Val Verde
Presidio
Brewster
Rio Grande/ Rio Bravo
Amistad National Recreation Area
MEXICO
Rio Conchos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Ector
Culberson
Ward
Crane
Upton
Reagan
Reeves
Lower Pecos
Pecos River
Jeff Davis
Pecos
Crockett
Schleicher
Sutton
Terrell
Devils
Rio Grande-Amistad
Presidio
Brewster
Edwards
Val Verde
Presidio, TX
La Linda, MX
MEXICO
TCEQ Segment 2311
Upper Pecos River
TCEQ Segment 2306A
Alamito Creek
TCEQ Segment 2310A
Independence Creek
TCEQ Segment 2309
Devils River
TCEQ Segment 2307
Rio Grande below Riverside Diversion Dam
Rio Grande/ Rio Bravo
Cienega Creek
Terlingua Creek
TCEQ Segment 2310
Lower Pecos River
TCEQ Segment 2305
International Amistad Reservoir
Rio Conchos
TCEQ Segment 2306
Rio Grande Above Amistad Reservoir

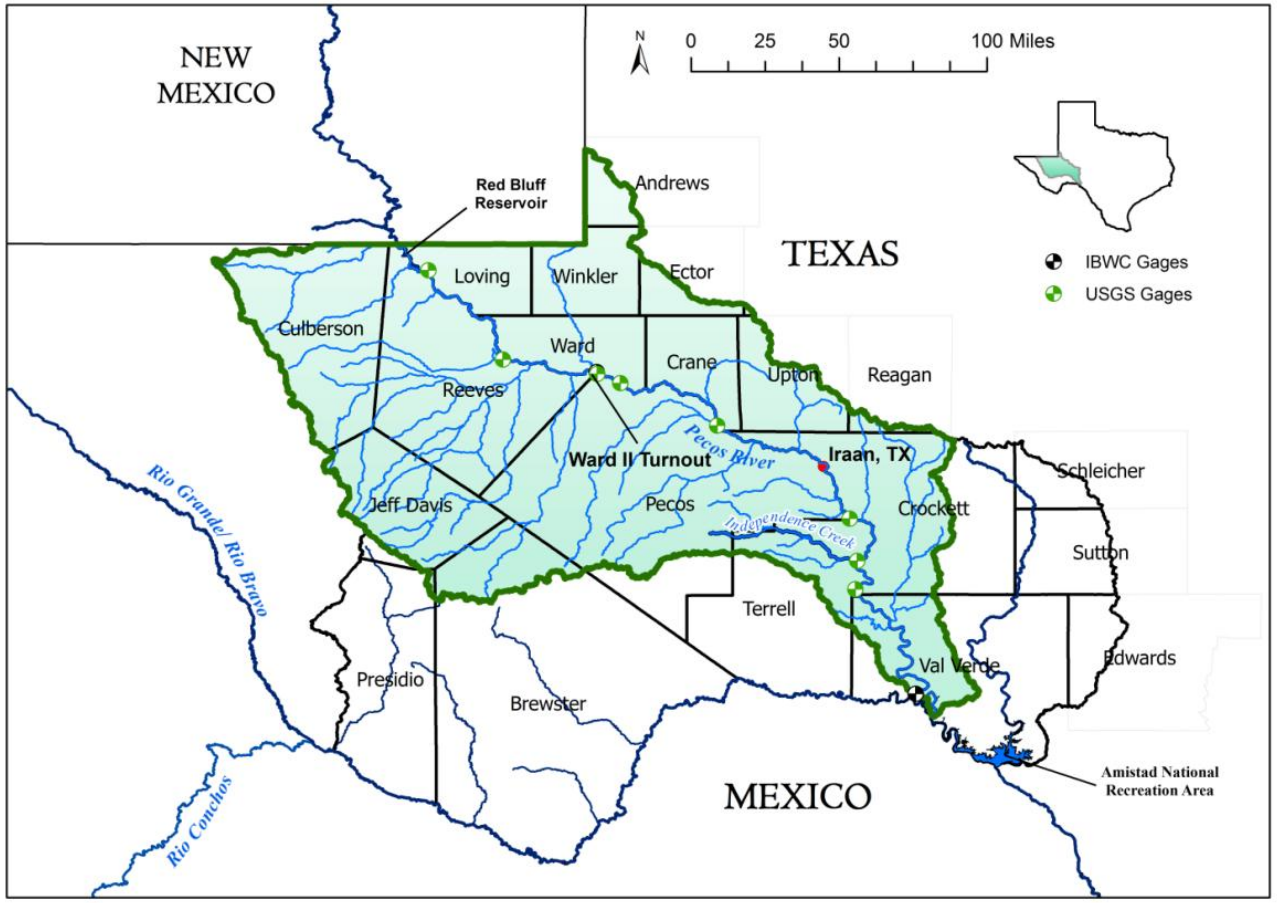
Lower Pecos Segment 2310

Sound Ecological Environment

Upper Pecos Segment 2311

Unsound Ecological Environment

- Water Quality:
  - Dissolved Oxygen Impairment
  - High Total Dissolved Solids
- Fish Communities Have Been Highly Altered
- Not a natural flow regime required to complete the biological life cycles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Red Bluff Reservoir
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IBWC Gages
USGS Gages
Loving
Winkler
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Reagan
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Pecos River
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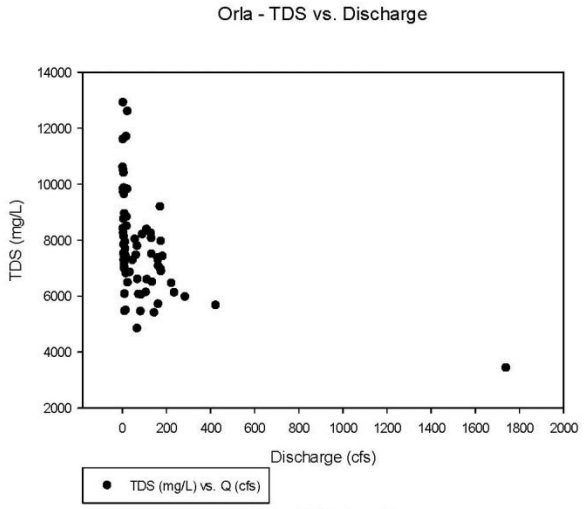
MEXICO
Rio Conchos


Orla - TDS vs. Discharge
TDS (mg/L)
14000
12000
10000
8000
6000
4000
2000
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Discharge (cfs)
TDS (mg/L) vs. Q (cfs)

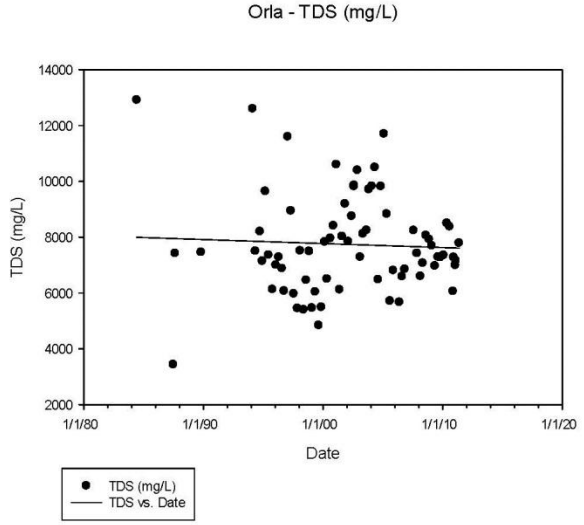

Orla - TDS (mg/L)
TDS (mg/L)
14000
12000
10000
8000
6000
4000
2000
1/1/80
1/1/90
1/1/00
1/1/10
1/1/20
Date
TDS (mg/L)
TDS vs. Date

Table Error! No text of specified style in document.**-1.** Environmental Flow Regime Recommendation, Pecos River near Orla.

Overbank Flows	Qp: 1,770 ft³/s with Average Frequency 1 per 5 years Volume is 8,979 Duration is 23											
High Flow Pulses	Qp: 1,090 ft³/s with Average Frequency 1 per 2 years Volume is 5,617 Duration is 18											
	Qp: 619 ft³/s with Average Frequency 1 per year Volume is 4,687 Duration is 13											
	Qp: 109 ft³/s with Average Frequency 1 per 2 seasons Volume is 4,460 Duration is 6				Qp: 577 ft³/s with Average Frequency 1 per 2 seasons Volume is 19,077 Duration is 15				Qp: 772 ft³/s with Average Frequency 1 per 2 seasons Volume is #N/A Duration is 12			
	Qp: 53 ft³/s with Average Frequency 1 per 2 seasons Volume is #N/A Duration is 4				Qp: 417 ft³/s with Average Frequency 1 per season Volume is 13,530 Duration is 13				Qp: 429 ft³/s with Average Frequency 1 per season Volume is 1,412 Duration is 9			
Base Flows (ft³/s)	17(31.9%)				44(58.5%)				69(52.4%)			
	12(50.1%)				15(72.0%)				33(68.3%)			
	8.8(67.1%)				9.1(82.6%)				12(82.7%)			
Subsistence Flows (ft³/s)	3.3(92.1%)				3.3(96.5%)				3.3(96.6%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

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

Notes:

1. Period of record: 1/1/1938 to 12/31/2009
2. Subsistence and base flows calculated using non-zero flows only.

Notes:

1. Period of record: 1/1/1938 to 12/31/2009

2. Subsistence and base flows calculated using non-zero flows only.

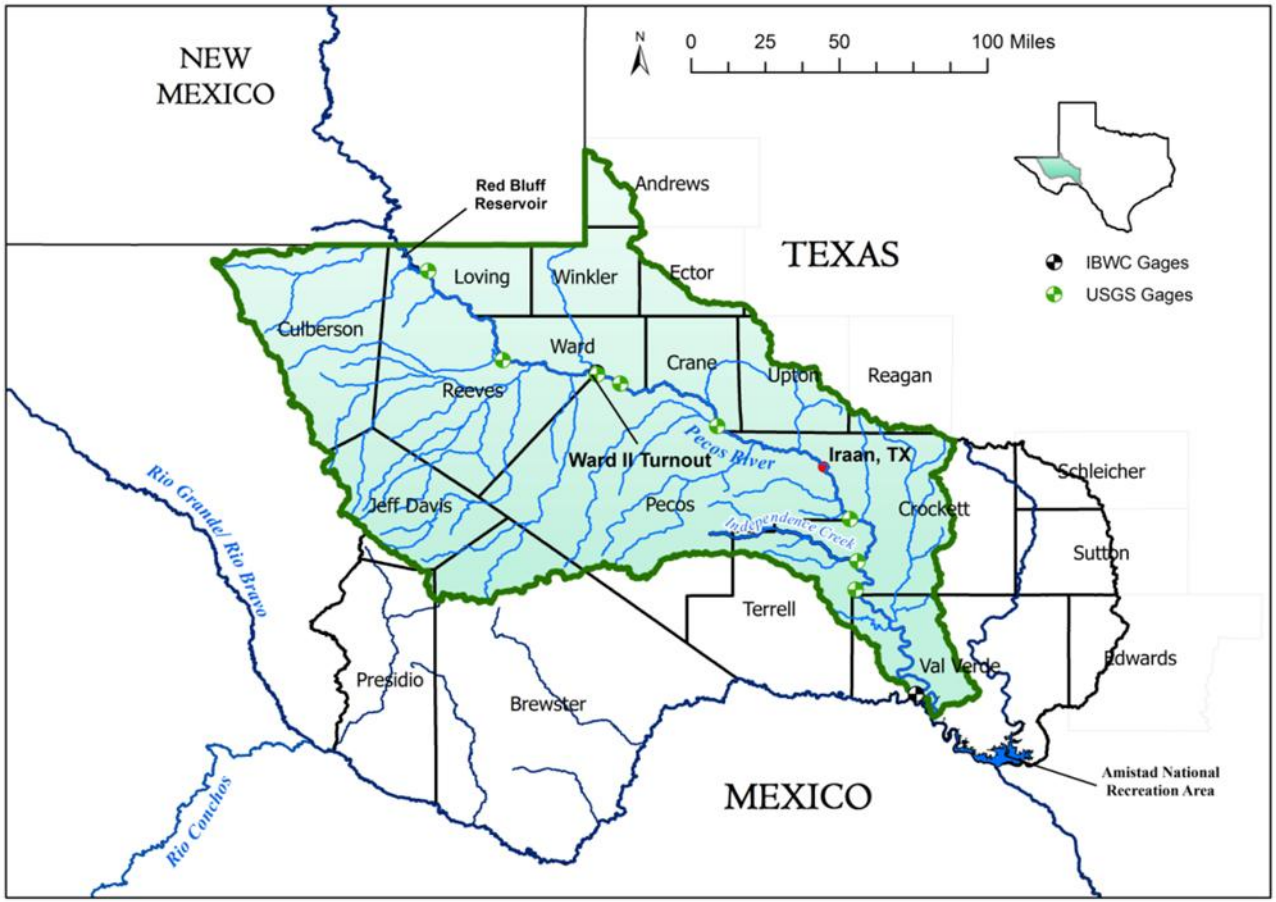

06/22/2012

Table Error! No text of specified style in document.**-1**. Environmental Flow Regime Recommendation, Pecos River near Pecos
.

Overbank Flows	Qp: 3,620 ft³/s with Average Frequency 1 per 5 years Volume is 131,386 Duration is 23											
High Flow Pulses	Qp: 2,180 ft³/s with Average Frequency 1 per 2 years Volume is 77,538 Duration is 19											
	Qp: 1,380 ft³/s with Average Frequency 1 per year Volume is 46,974 Duration is 16											
	Qp: 231 ft³/s with Average Frequency 1 per 2 seasons Volume is 8,297 Duration is 12				Qp: 1,190 ft³/s with Average Frequency 1 per 2 seasons Volume is #N/A Duration is 13				Qp: 1,270 ft³/s with Average Frequency 1 per 2 seasons Volume is 40,068 Duration is 14			
	Qp: 231 ft³/s with Average Frequency 1 per season Volume is 1,581 Duration is 6				Qp: 488 ft³/s with Average Frequency 1 per season Volume is #N/A Duration is 9				Qp: 470 ft³/s with Average Frequency 1 per season Volume is 8,422 Duration is 10			
	Qp: 21 ft³/s with Average Frequency 1 per season Volume is #N/A Duration is 3				Qp: 255 ft³/s with Average Frequency 1 per season Volume is 361 Duration is 7				Qp: 224 ft³/s with Average Frequency 1 per season Volume is #N/A Duration is 8			
Base Flows (ft³/s)	32(45.1%)				78(50.7%)				104(45.0%)			
	9.9(65.5%)				16(66.6%)				30(65.5%)			
	5.7(82.3%)				4.6(82.1%)				5.2(82.3%)			
Subsistence Flows (ft³/s)	0.5(98.8%)				0.4(98.3%)				0.4(98.1%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

Flow Levels	High (75th %ile)	Notes:
	Medium (50th %ile)	1. Period of record: 1/1/1902 to 12/31/1935
	Low (25th %ile)	2. Subsistence and base flows calculated using non-zero flows only.
	Subsistence	


05/23/2011


NEW MEXICO
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100 Miles
Red Bluff Reservoir
Andrews
TEXAS
IBWC Gages
USGS Gages
Loving
Winkler
Ector
Culberson
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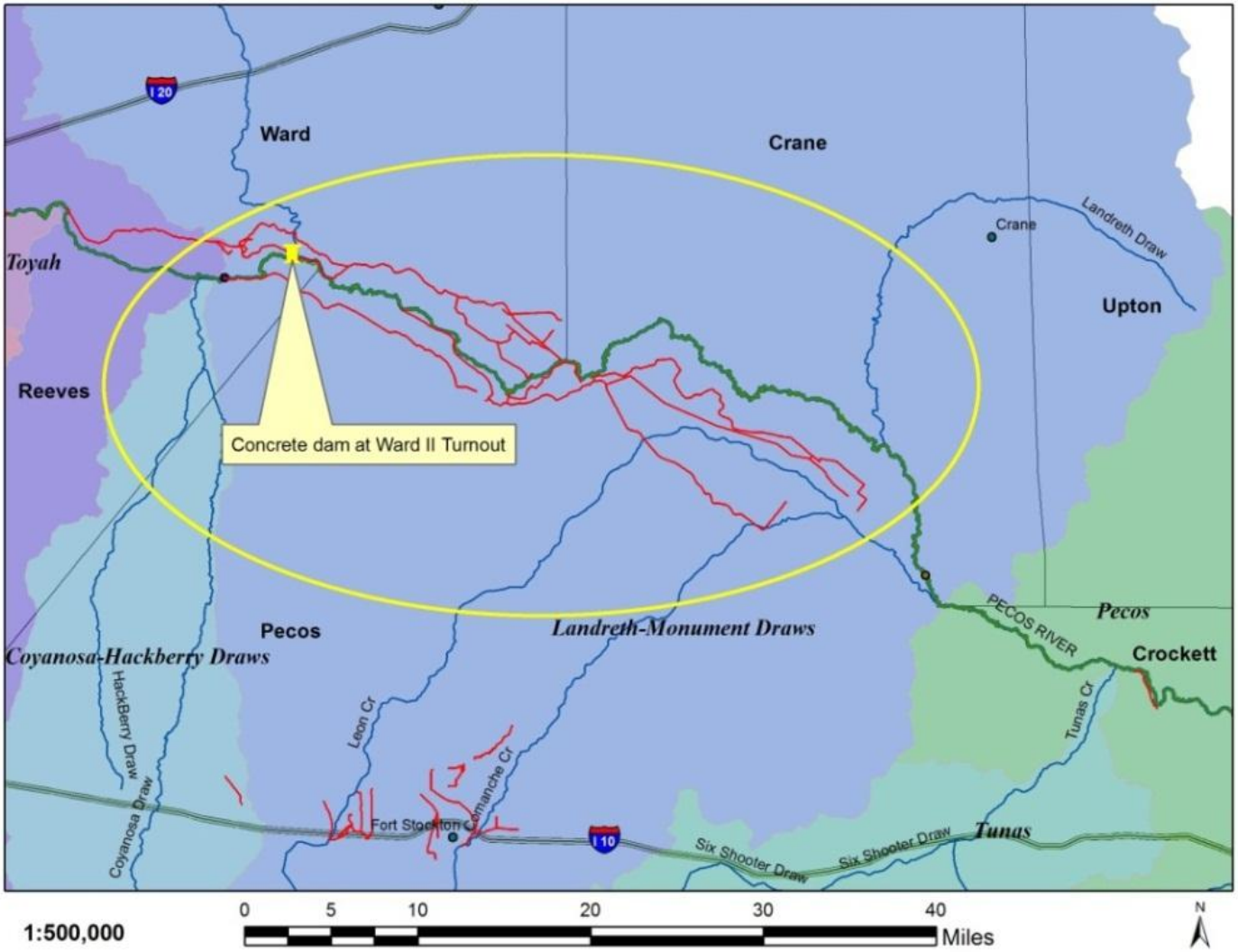
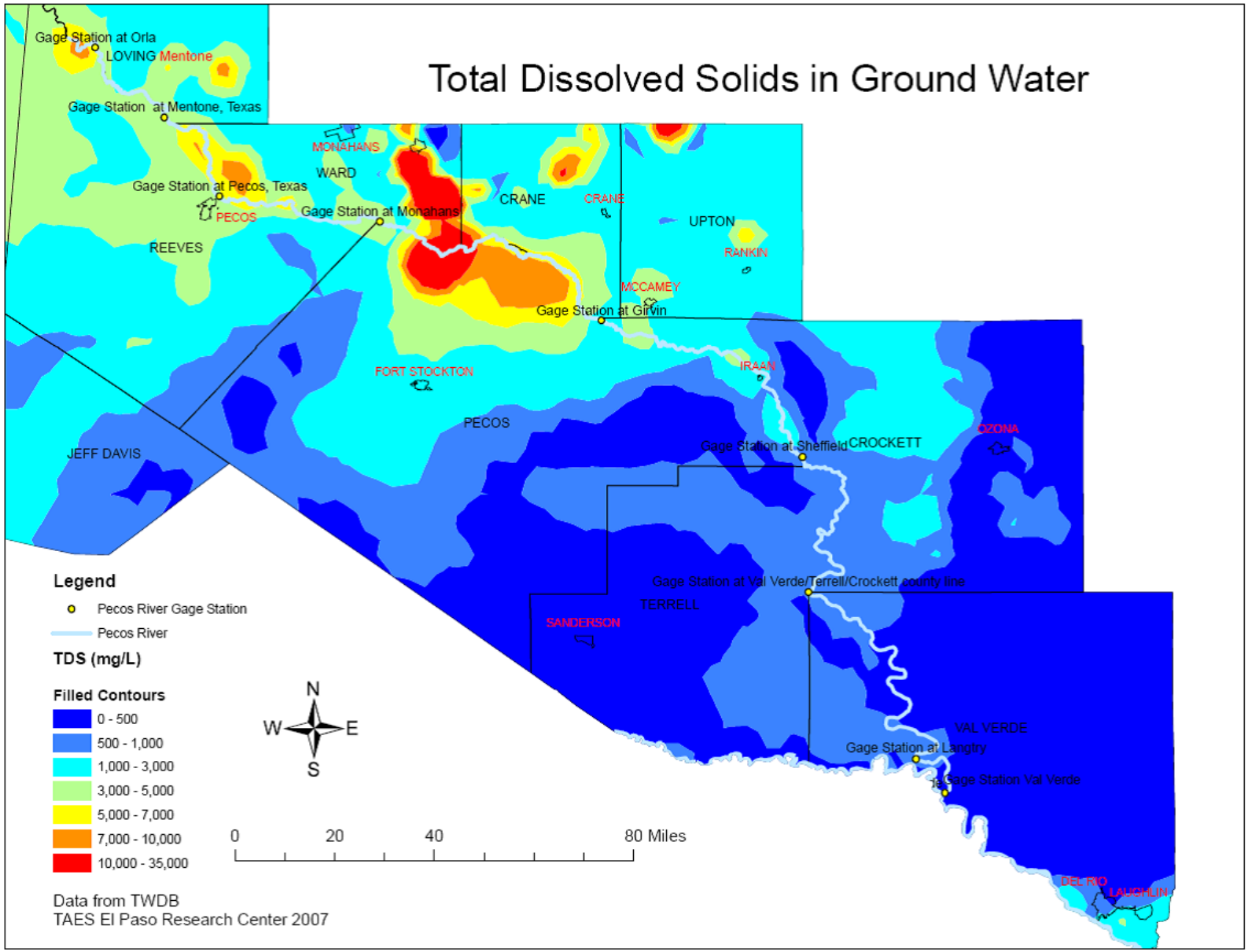
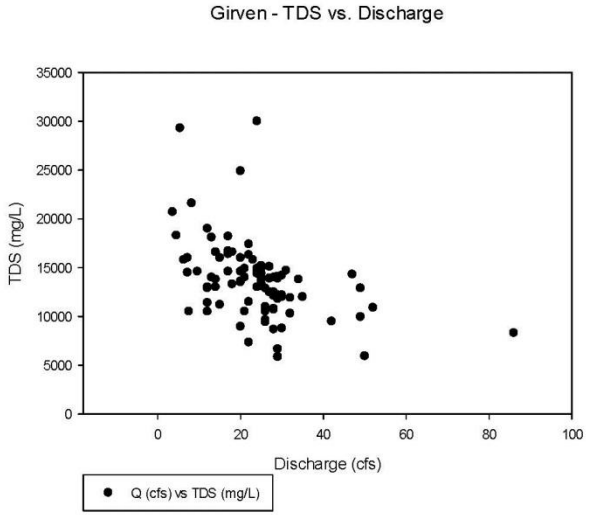
Sutton
Terrell
Edwards
Val Verde
Presidio
Brewster
Rio Grande/ Rio Bravo
Amistad National Recreation Area
MEXICO
Rio Conchos


I 20
Ward
Crane
Toyah
Crane
Landreth Draw
Upton
Reeves
Concrete dam at Ward II Turnout
Pecos
Landreth-Monument Draws
Coyanosa-Hackberry Draws
PECOS RIVER
Pecos
Crockett
HackBerry Draw
Leon Cr
Tunas Cr
Coyanosa Draw
Fort Stockton
Comanche Cr
I 10
Six Shooter Draw
Six Shooter Draw
Tunas
0 5 10 20 30 40
Miles
1:500,000
N


Total Dissolved Solids in Ground Water
Gage Station at Orla
LOVING
Mentone
Gage Station at Mentone, Texas
MONAHANS
WARD
Gage Station at Pecos, Texas
PECOS
Gage Station at Monahans
CRANE
CRANE
UPTON
RANKIN
REEVES
MCCAMEY
Gage Station at Girvin
FORT STOCKTON
IRAAN
PECOS
JEFF DAVIS
Gage Station at Sheffield
CROCKETT
OZONA
Gage Station at Val Verde/Terrell/Crockett county line
TERRELL
SANDERSON
VAL VERDE
Gage Station at Langtry
Gage Station Val Verde
DEL RIO
LAUGHLIN
Legend
Pecos River Gage Station
Pecos River
TDS (mg/L)
Filled Contours
0 - 500
500 - 1,000
1,000 - 3,000
3,000 - 5,000
5,000 - 7,000
7,000 - 10,000
10,000 - 35,000
N
W
E
S
0
20
40
80 Miles
Data from TWDB
TAES El Paso Research Center 2007


Girven - TDS vs. Discharge
TDS (mg/L)
35000
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
Discharge (cfs)
Q (cfs) vs TDS (mg/L)

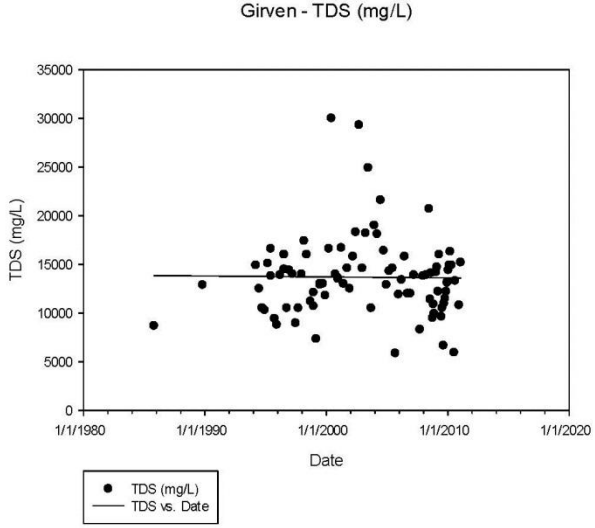
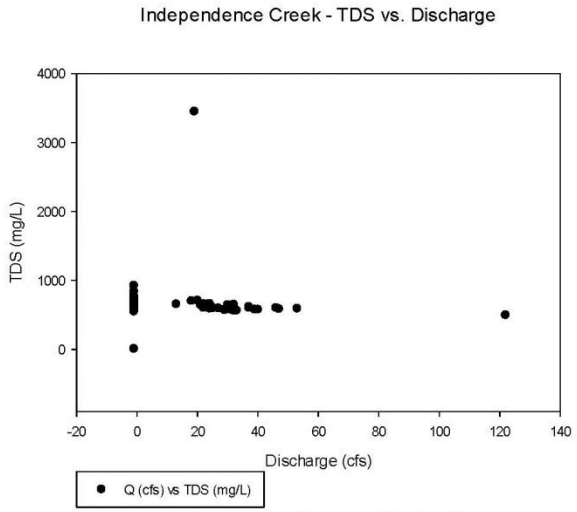

Girven - TDS (mg/L)
TDS (mg/L)
35000
30000
25000
20000
15000
10000
5000
0
1/1/1980
1/1/1990
1/1/2000
1/1/2010
1/1/2020
Date
TDS (mg/L)
TDS vs. Date

Table Error! No text of specified style in document.**-1**. Environmental Flow Regime Recommendation, Pecos River near Girvin.

Overbank Flows	Qp: 923 ft³/s with Average Frequency 1 per 5 years Volume is 34,421 Duration is 35											
High Flow Pulses	Qp: 299 ft³/s with Average Frequency 1 per 2 years Volume is 9,895 Duration is 16											
	Qp: 161 ft³/s with Average Frequency 1 per year Volume is 4,511 Duration is 11											
	Qp: 47 ft³/s with Average Frequency 1 per 2 seasons Volume is 1,903 Duration is 11				Qp: 152 ft³/s with Average Frequency 1 per 2 seasons Volume is 1,756 Duration is 9				Qp: 164 ft³/s with Average Frequency 1 per 2 seasons Volume is 2,043 Duration is 10			
	Qp: 231 ft³/s with Average Frequency 1 per season Volume is 1,581 Duration is 6				Qp: 72 ft³/s with Average Frequency 1 per season Volume is 1,199 Duration is 6				Qp: 100 ft³/s with Average Frequency 1 per season Volume is 1,419 Duration is 7			
	Qp: 21 ft³/s with Average Frequency 1 per season Volume is #N/A Duration is 3				Qp: 44 ft³/s with Average Frequency 1 per season Volume is 1,027 Duration is 4				Qp: 57 ft³/s with Average Frequency 1 per season Volume is 1,008 Duration is 4			
Base Flows (ft³/s)	32(53.1%)				25(45.8%)				27(42.4%)			
	27(70.3%)				19(63.3%)				18(60.1%)			
	22(85.4%)				14(78.7%)				13(73.9%)			
Subsistence Flows (ft³/s)	8.7(100.0%)				6.8(95.8%)				6.3(93.8%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

Flow Levels	High (75th %ile)	Notes:
	Medium (50th %ile)	1. Period of record: 1/1/1939 to 12/31/2011
	Low (25th %ile)	2. Subsistence and base flows calculated using non-zero flows only.
	Subsistence	


Independence Creek - TDS vs. Discharge
TDS (mg/L)
4000
3000
2000
1000
0
-20
0
20
40
60
80
100
120
140
Discharge (cfs)
Q (cfs) vs TDS (mg/L)

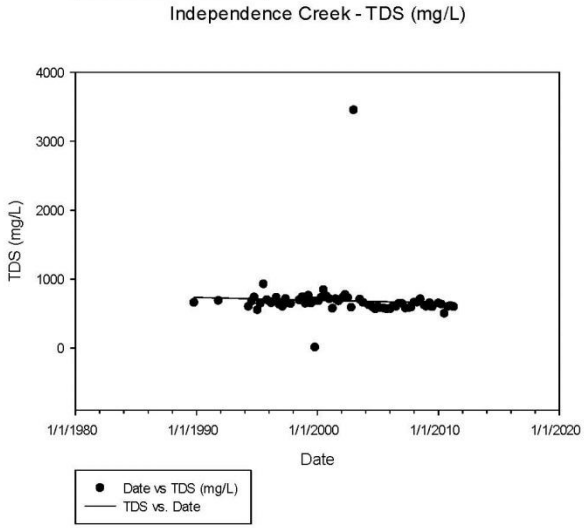

Independence Creek - TDS (mg/L)
TDS (mg/L)
4000
3000
2000
1000
0
1/1/1980
1/1/1990
1/1/2000
1/1/2010
1/1/2020
Date
Date vs TDS (mg/L)
TDS vs. Date

Table Error! No text of specified style in document.**-1**. Environmental Flow Regime Recommendation, Independence Creek near Sheffield.

Overbank Flows	Qp: 1,100 ft³/s with Average Frequency 1 per 5 years Volume is 5,800 Duration is 22											
High Flow Pulses	Qp: 612 ft³/s with Average Frequency 1 per 2 years Volume is 3,863 Duration is 18											
	Qp: 182 ft³/s with Average Frequency 1 per year Volume is 2,114 Duration is 11											
	Qp: 33 ft³/s with Average Frequency 1 per 2 seasons Volume is 2,666 Duration is 15				Qp: 100 ft³/s with Average Frequency 1 per 2 seasons Volume is 1,637 Duration is 8				Qp: 231 ft³/s with Average Frequency 1 per 2 seasons Volume is 1,777 Duration is 9			
					Qp: 42 ft³/s with Average Frequency 1 per season Volume is 1,115 Duration is 7				Qp: 44 ft³/s with Average Frequency 1 per season Volume is 1,013 Duration is 5			
Base Flows (ft³/s)	40				40				40			
	25				25				25			
Subsistence Flows (ft³/s)	18(99.2%)				17(96.1%)				17(92.5%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

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

Notes:

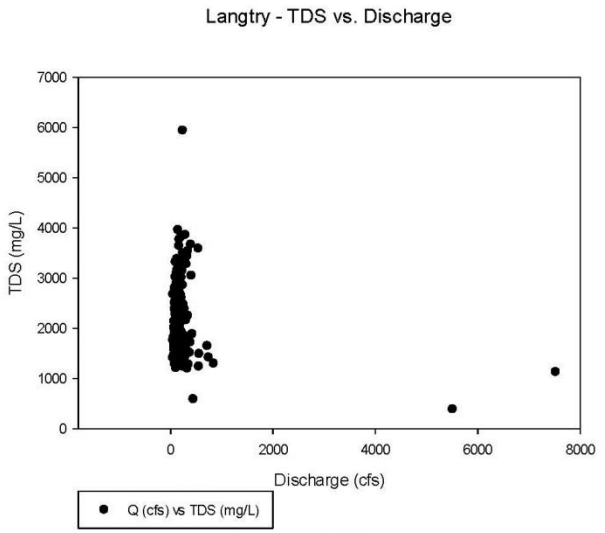
1. Period of record: 1/1/1975 to 2/28/1985 and 3/1/2000 to 12/31/2009

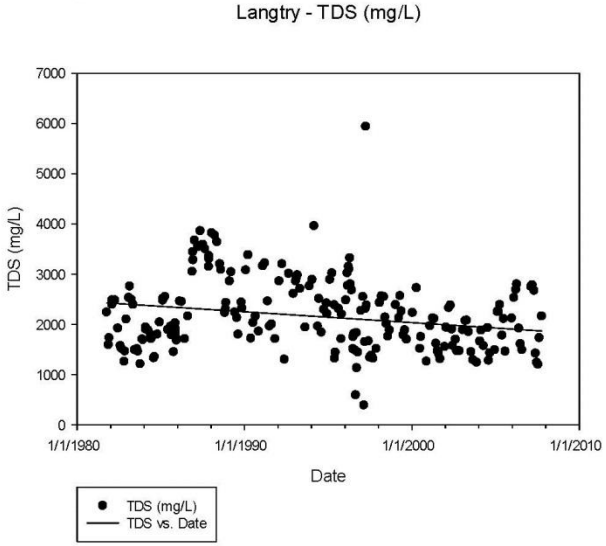
2. Subsistence and base flows calculated using non-zero flows only.

Table Error! No text of specified style in document.**-1**. Environmental flow regime recommendation, Pecos River near Brotherton Ranch.

Overbank Flows	No flow recommendations											
High Flow Pulses	No flow recommendations											
Base Flows (cfs)	101				90				90			
	80				60				62			
Subsistence Flows (cfs)	39				39				39			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

Flow Levels	High (75th %ile)	Notes:
	Medium (50th %ile)	1. Period of record: 1/1/2008 to 12/31/2010
	Low (25th %ile)	2. Subsistence and base flows calculated using non-zero flows only.
	Subsistence	


Langtry - TDS vs. Discharge
TDS (mg/L)
7000
6000
5000
4000
3000
2000
1000
0
0
2000
4000
6000
8000
Discharge (cfs)
Q (cfs) vs TDS (mg/L)


Langtry - TDS (mg/L)
TDS (mg/L)
7000
6000
5000
4000
3000
2000
1000
0
1/1/1980
1/1/1990
1/1/2000
1/1/2010
Date
TDS (mg/L)
TDS vs. Date

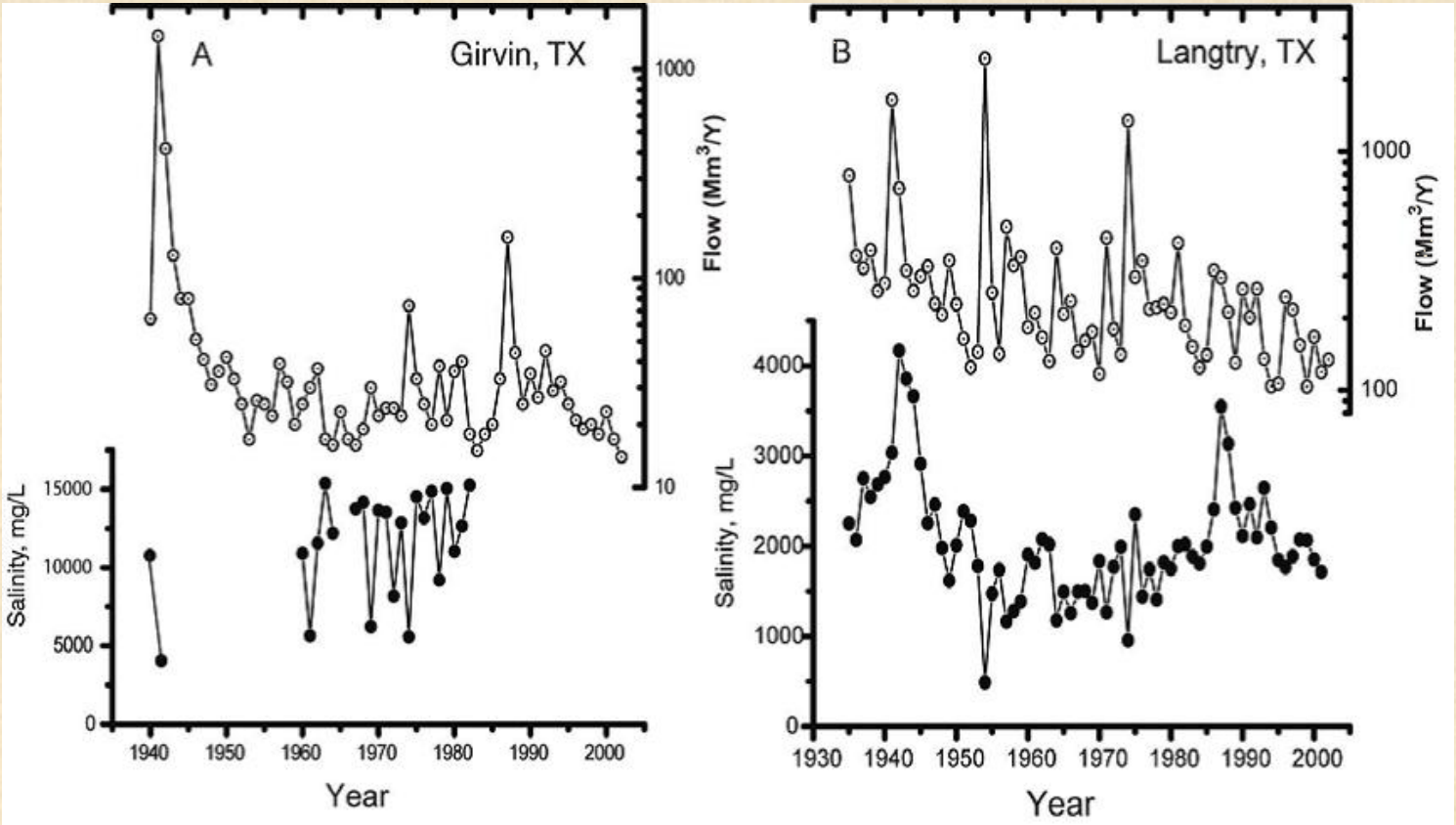


Fig. 9 Historical records of flow and salinity at Girvin and Langtry (original data at Girvin from USGS, these at Langtry from IBWC).

Table Error! No text of specified style in document.**-1**. Environmental Flow Regime Recommendation, Pecos River at Langtry.

Overbank Flows	Qp: 15,540 ft³/s with Average Frequency 1 per 5 years Volume is 63,337 Duration is 22											
High Flow Pulses	Qp: 7,593 ft³/s with Average Frequency 1 per 2 years Volume 35,590 Duration is 17											
	Qp: 3,991 ft³/s with Average Frequency 1 per year Volume is 23,372 Duration is 14											
					Qp: 2,670 ft³/s with Average Frequency 1 per 2 seasons Volume is 15,836 Duration is 9				Qp: 6,357 ft³/s with Average Frequency 1 per 2 seasons Volume is 33,460 Duration is 17			
					Qp: 569 ft³/s with Average Frequency 1 per season Volume is 6,871 Duration is 6				Qp: 1,441 ft³/s with Average Frequency 1 per season Volume is 14,961 Duration is 9			
					Qp: 252 ft³/s with Average Frequency 1 per season Volume is 5,468 Duration is 4				Qp: 459 ft³/s with Average Frequency 1 per season Volume is 11,300 Duration is 5			
Base Flows (ft³/s)	182(51.8%)				158(47.4%)				163(47.2%)			
	154(69.1%)				131(65.3%)				135(60.9%)			
	133(85.0%)				109(80.5%)				108(73.7%)			
Subsistence Flows (ft³/s)	70(99.9%)				76(97.6%)				76(93.3%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

Flow Levels	High (75th %ile)	Notes:
	Medium (50th %ile)	1. Period of record: 1/1/1967 to 12/31/2010
	Low (25th %ile)	2. Subsistence and base flows calculated using non-zero flows only.
	Subsistence	

Adaptive Management

- Gage Maintenance
- Complete Water Balance for the Pecos River
- Sediment Transport and Geomorphic Processes
- Benthic and Mussel Health
- Water Quality vs Flow

Concerns

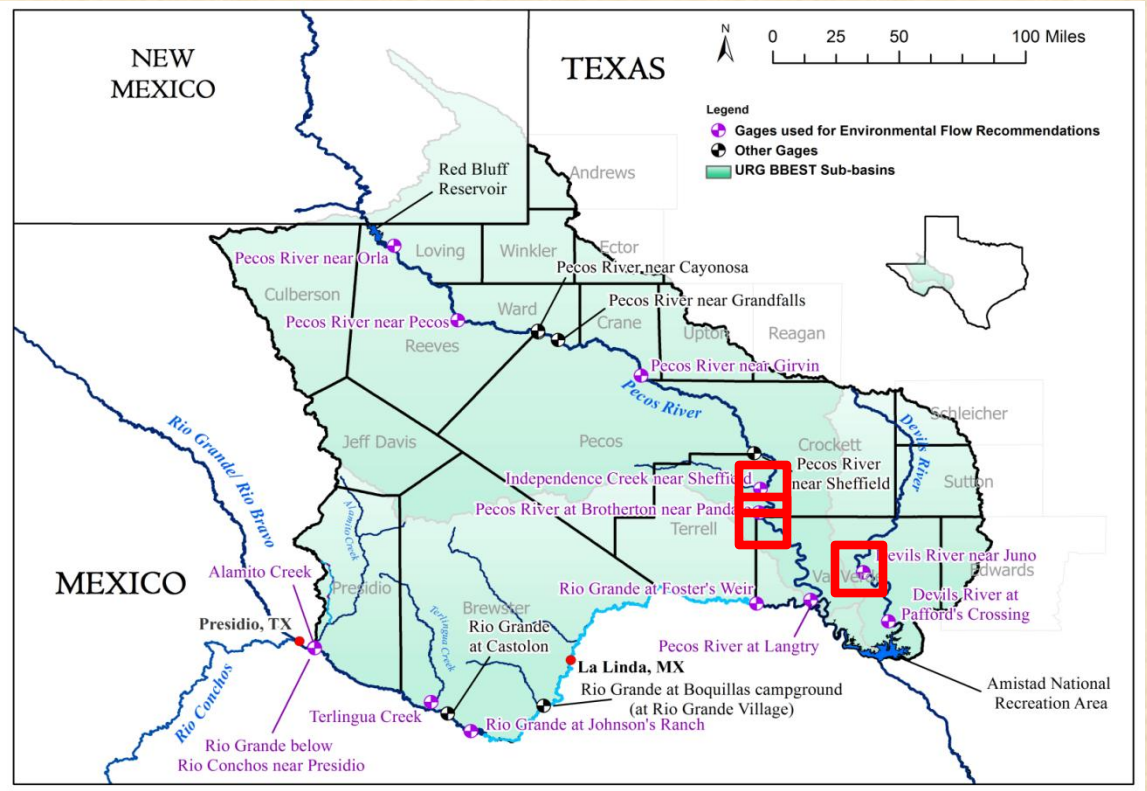
- Improper Flushing of the Pecos River
- Potential need for a River Authority
- Groundwater Extraction for Exporting for Municipal Authorities
- Growing momentum to declare the Pecos River as an inland saline water body.

Biology Overlay

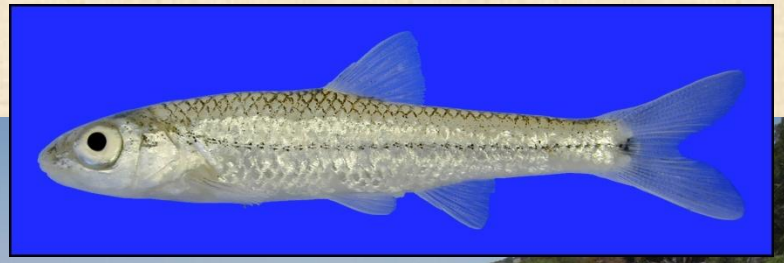
Component	Hydrology	Geomorphology	Biology	Water Quality
No-Flow Periods	Flow ceases between perennial pools	Encroachment of vegetation	Generally stressful for fish communities	Temperatures rise and oxygen levels decrease. These condition sometimes cause fish kills
Subsistence Flows	Infrequent low flows	Increased deposition of fine and organic particles, encroachment of vegetation	Provide restricted aquatic habitat limit connectivity	Elevate temperature and constituent concentrations Maintain adequate levels of dissolved oxygen
Base Flows	Average flow condition, including variability	Maintain soil moisture and ground water table Maintain a diversity of habitats, Exports or transports sediment?	Provide suitable aquatic habitat, Provide connectivity along channel corridor	Provide suitable in-channel water quality
High Flow Pulses	In channel short duration, high flows	Deposit sediment, development of inset flood plains; Prevent encroachment of riparian vegetation	Serve as recruitment events for organisms; Provide connectivity to near-channel water bodies	Restore in-channel water quality after prolonged low flow periods. Episodic in nature and associated with fish kills (anecdotal, no real investigation of this yet)
Overbank flows	Infrequent high flows that exceed the channel	Provide lateral channel movement and floodplain maintenance; Recharge floodplain water table; form new habitats; flush organic material into channel; Deposit nutrients in floodplain	Provide new life phase cues for organisms; Maintain diversity of riparian vegetation; Provide conditions for seedling development; Provide connectivity to floodplain	Restore water quality in floodplain water bodies
Channel Maintenance	For most streams, channel maintenance occurs mostly during pulse and overbank flows	Long-term maintenance of existing channel morphology	Maintains foundation for physical habitat features instream	Water quality condition like those during pulse overbank flows

Biology Overlay – Flow-Habitat

- 3 sites with groundwater fed base flow maintaining habitats
  - Pecos River (sound)
  - Independence Creek
  - Devils River (1)



Fish Habitats

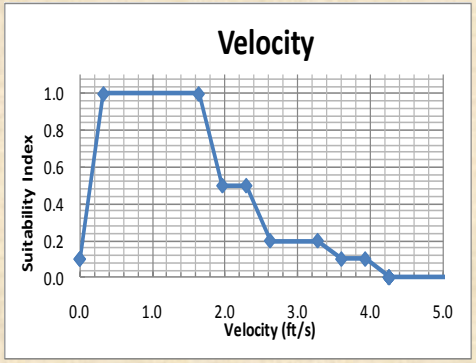


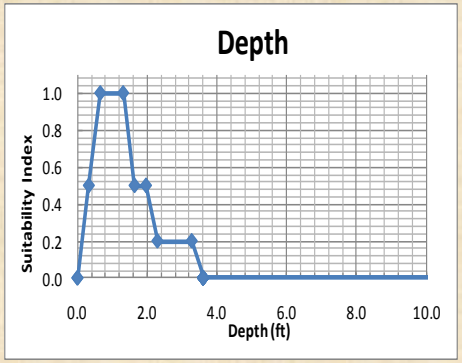
Focal Fish Species

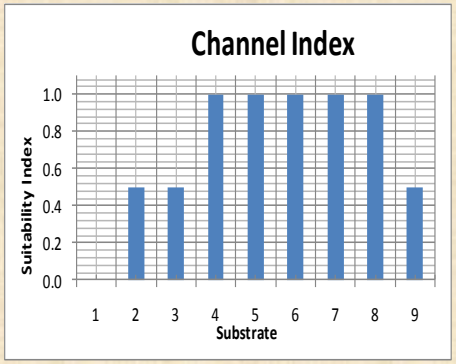
Focal Species	Devils	Indy	Pecos	Riffle	Shallow Run	Deep Run	Shallow Pool	Deep Pool
Manantial roundnose minnow	Yes	Yes	Yes	x	X	x		
Devils river minnow	Yes					X		
Proserpine shiner	Yes	Yes	Yes	x	X	x		
Texas shiner	Yes	Yes	Yes		x	X	x	
Tamaulipas shiner			Yes		X	x		
Sand shiner	Yes	Yes			X	X	X	
Headwater catfish		Yes				X	x	x
Gray redhorse	Yes	Yes	Yes			X	x	x
Mexican tetra	Yes	Yes	Yes		X	X		
Largemouth bass	Yes	Yes	Yes			x	x	X
Longear sunfish	Yes	Yes	Yes		x	x	X	x
Rio Grande darter	Yes	Yes	Yes	X	X			
Rio Grande cichlid	Yes	Yes	Yes					X

Habitat Suitability Criteria

- How do we know what is suitable instream habitat?
- Quantitative habitat preferences
  - Velocity, depth and substrate type
- Using data from research at our sites

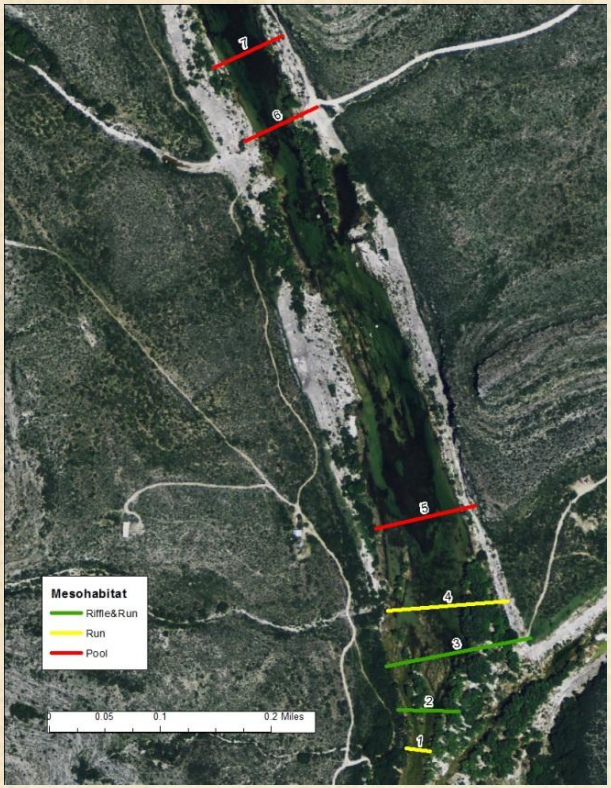


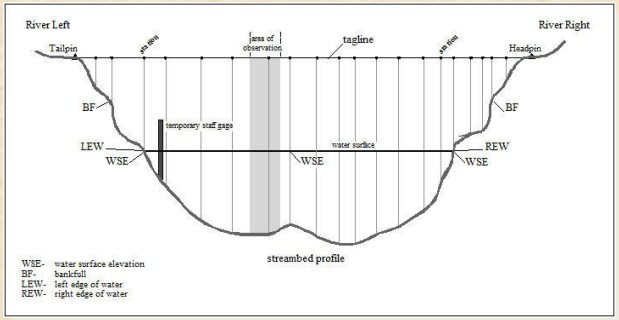


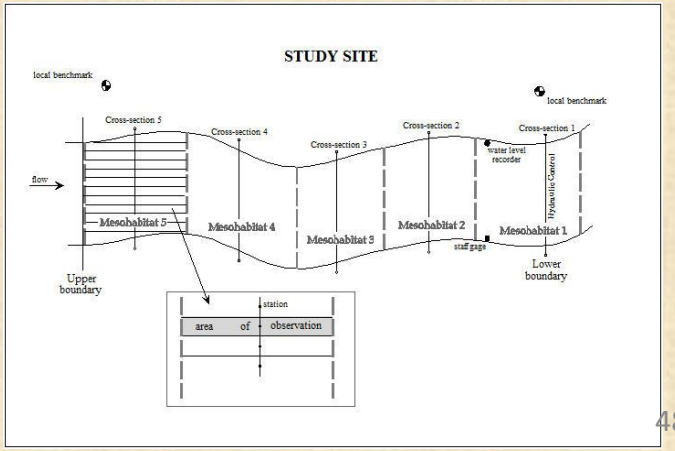


Modeling Approach

- Assistance from TPWD, TWDB, Sul Ross State Univ with fieldwork
- Contracted for development of models (Trungale Science and Engineering) (Appendix 3.4 in report)



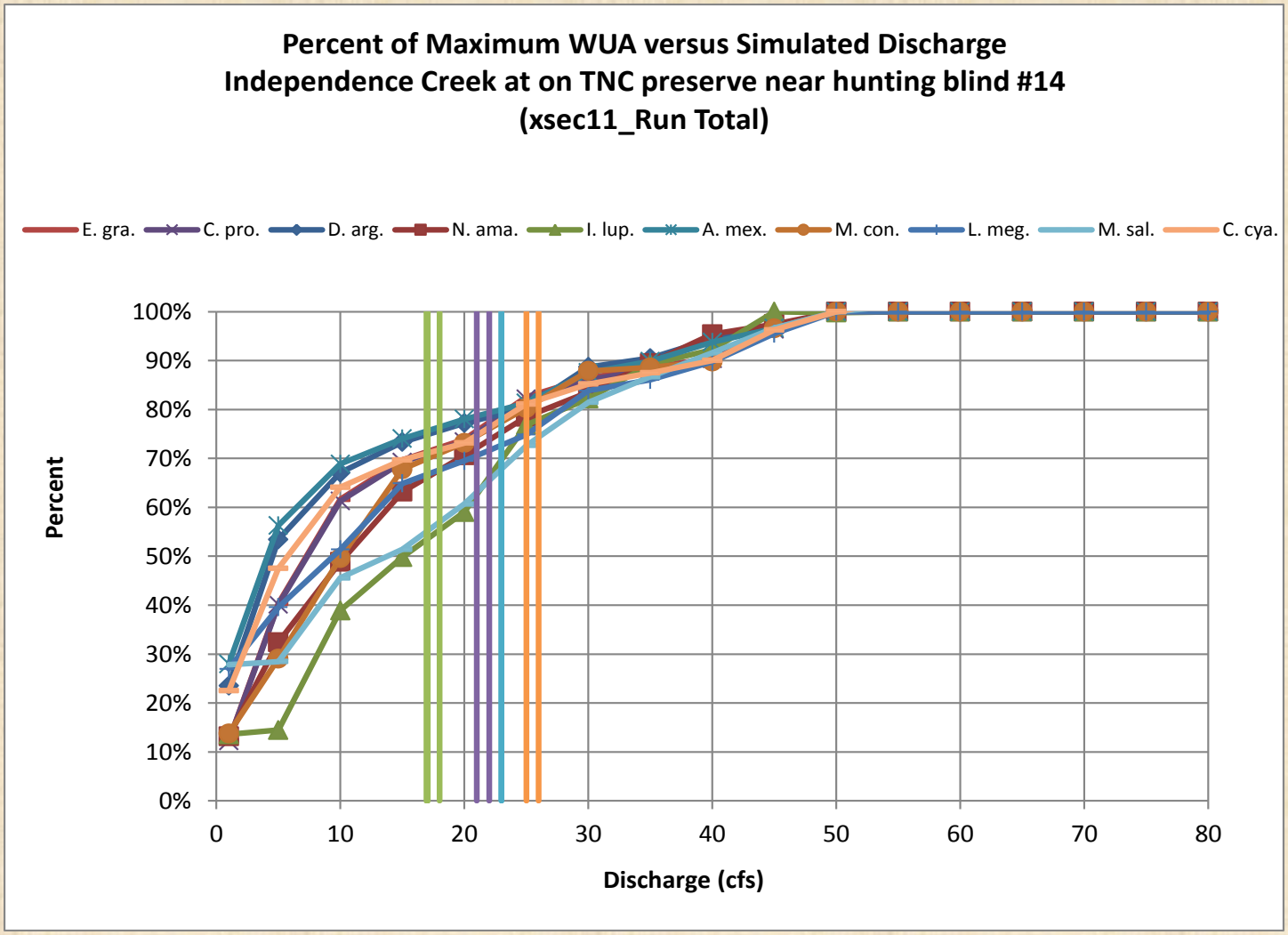




Habitat Analysis

- Base flow recommendations need to maintain enough habitat for species in their “preferred” habitat types
- How much is “enough” habitat?
  - Used percent of maximum habitat (% WUA) as the measure
  - Imperiled species – 75% in base-low, 90% in base-medium
  - Other species – 75% in base-medium
- Time series – framework for evaluating potential standards

Independence Creek Results



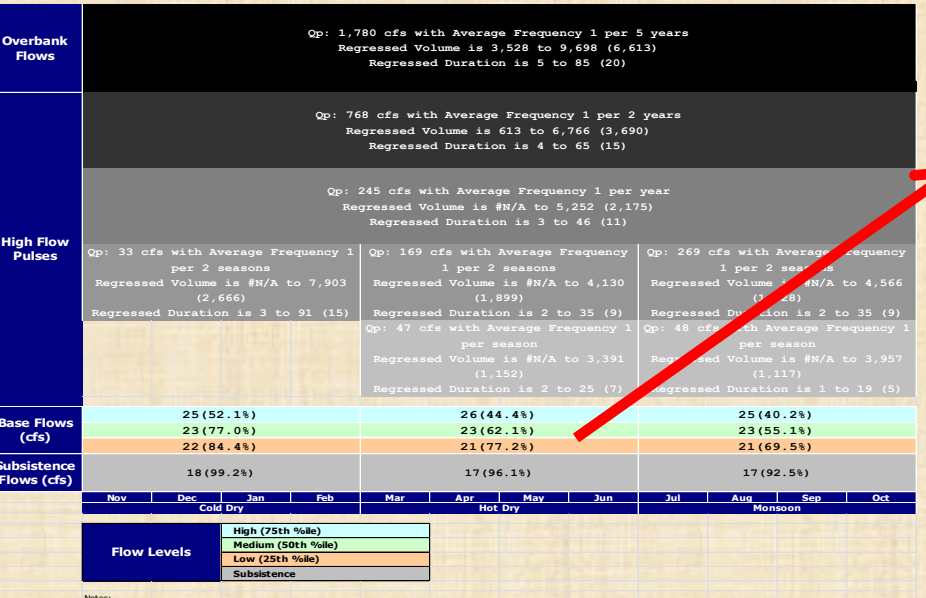
Indy Creek

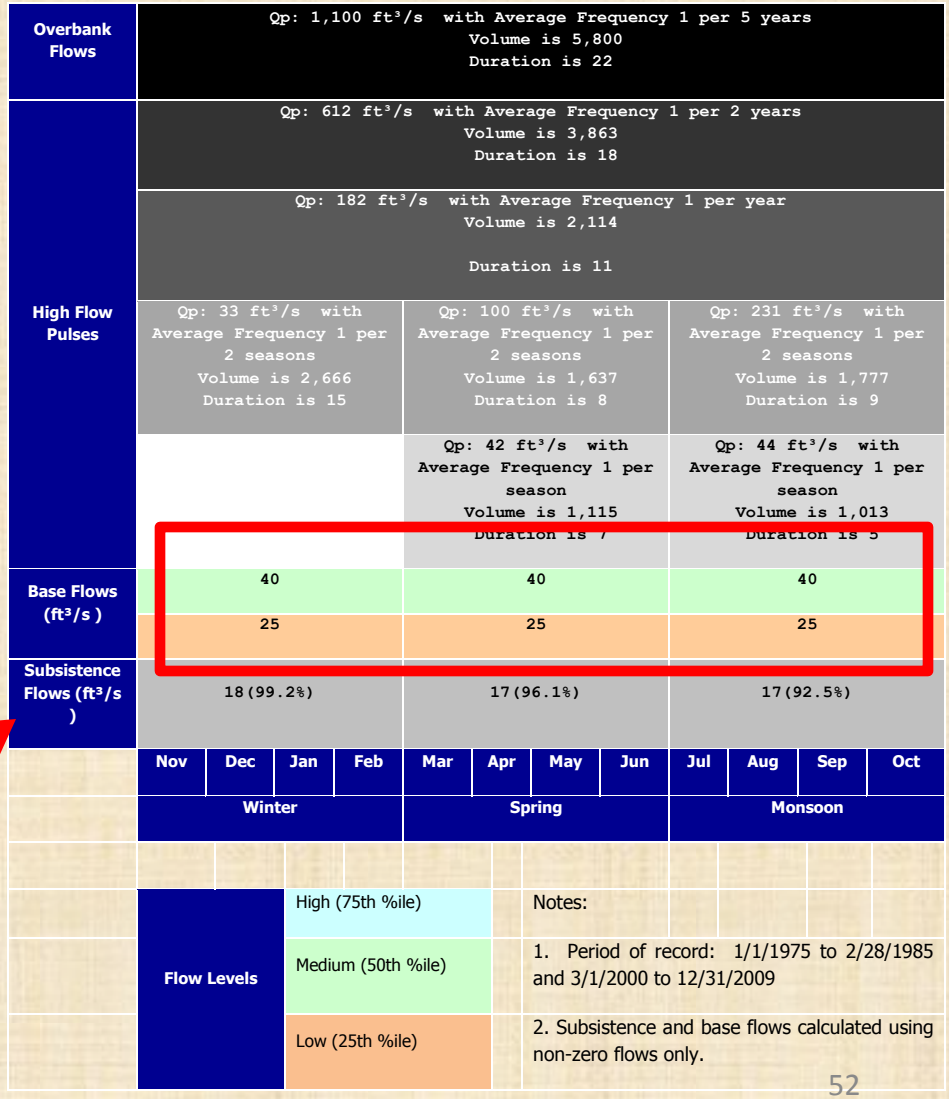
- 40 cfs needed to meet criteria for all species
- 2 in riffles
- 2 in runs

Modeled Flow (FT^3/S)	C. pro.	D. arg.	N. ama.	M. con.	I. lup.	A. mex.	M. sal.	L. meg.	E. gra.	C. cya.
1	12%	31%	2%	1%	0%	32%	0%	1%	12%	13%
5	51%	58%	48%	43%	16%	60%	13%	35%	51%	49%
10	65%	68%	66%	71%	65%	68%	55%	55%	65%	60%
15	69%	74%	73%	78%	70%	74%	63%	66%	69%	64%
20	71%	79%	79%	80%	85%	78%	79%	74%	71%	68%
25	80%	81%	83%	84%	91%	82%	86%	81%	80%	78%
30	83%	94%	86%	86%	93%	93%	91%	86%	83%	82%
35	85%	96%	95%	87%	96%	96%	95%	88%	85%	84%
40	91%	98%	98%	87%	97%	97%	97%	90%	91%	91%
45	97%	99%	99%	98%	99%	99%	99%	99%	97%	98%
50	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
55	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
60	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
65	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
70	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
75	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
80	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
85	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
90	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
95	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
100	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
125	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
150	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
175	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
200	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
250	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
300	100%	100%	100%	100%	100%	89%	100%	100%	100%	100%
350	100%	100%	100%	100%	100%	87%	100%	100%	100%	100%
400	100%	100%	100%	100%	100%	83%	100%	100%	100%	100%
500	100%	92%	100%	100%	100%	81%	100%	96%	100%	100%

Independence Creek Regime

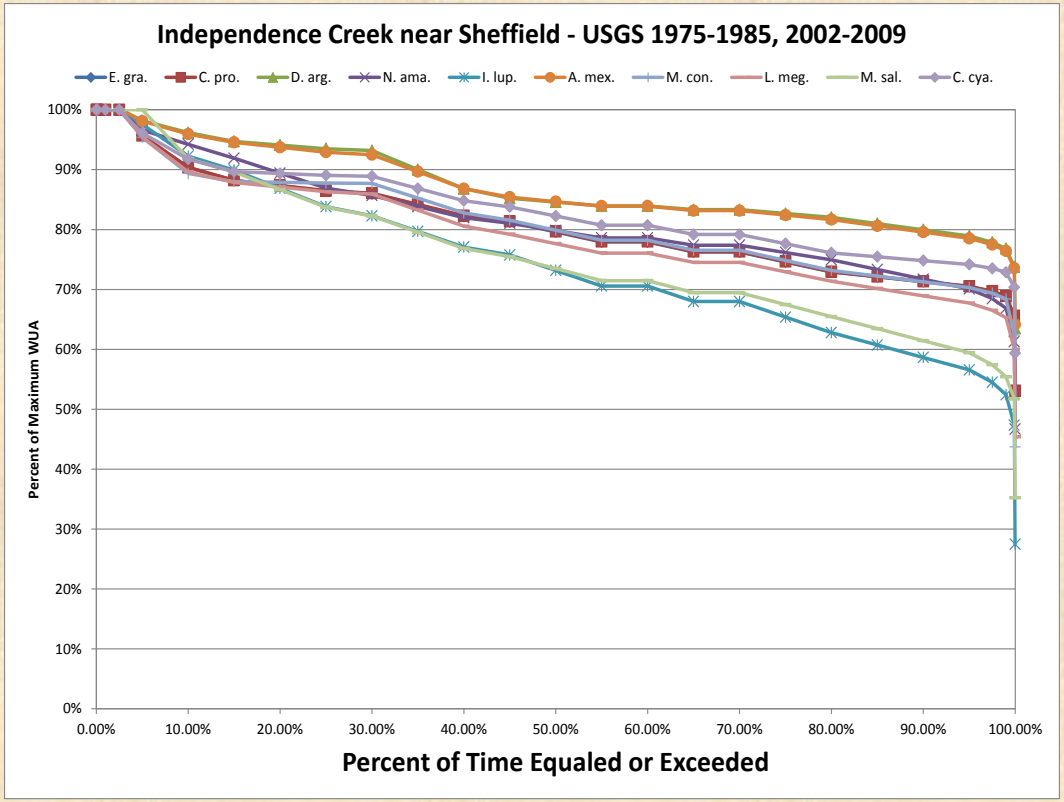
- HEFR + biology overlay
- Reduced to 2 tiers
- 25 cfs, 40 cfs





Independence Creek

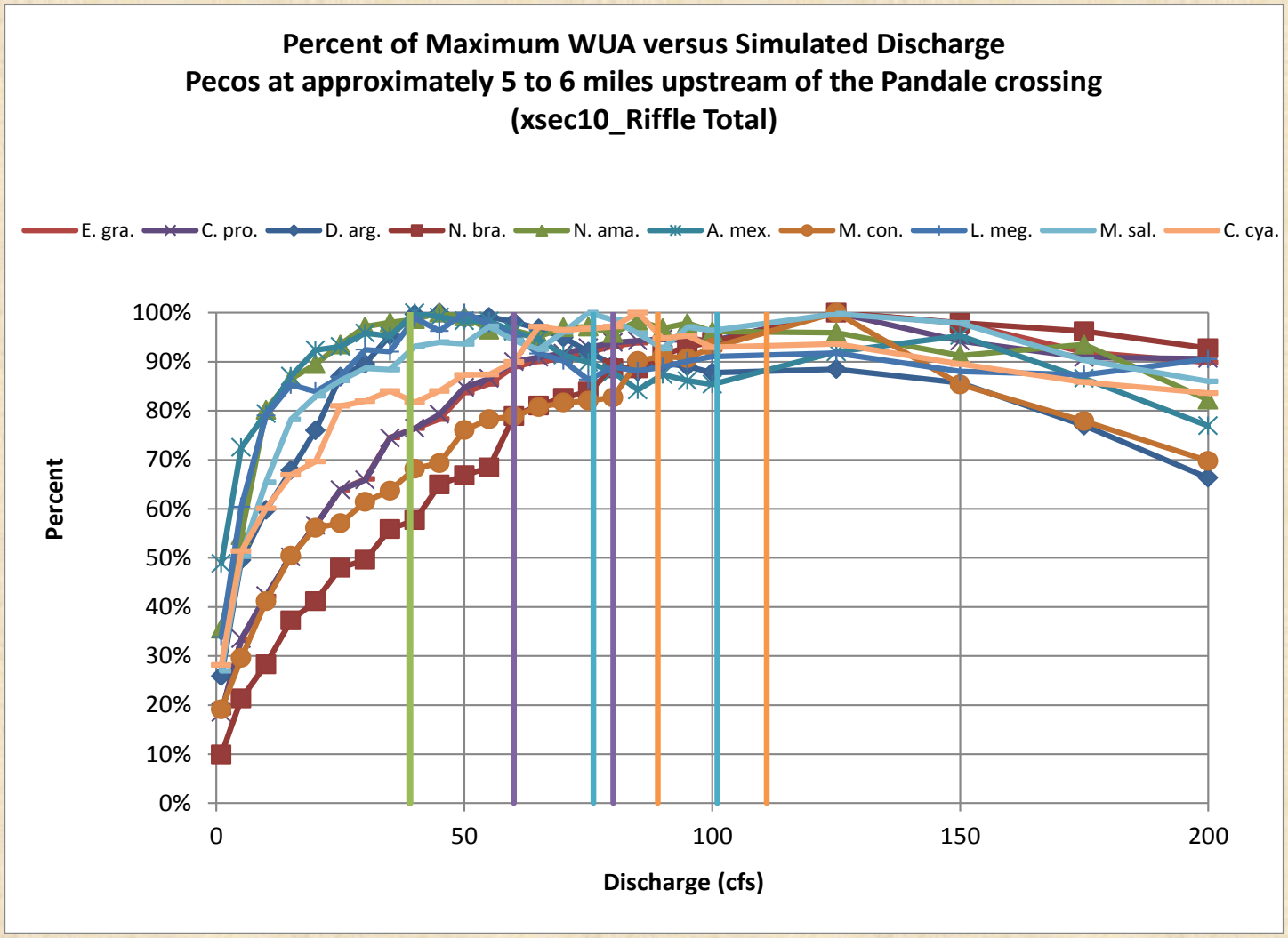
- Habitat time series analysis
- Can serve as an aid in evaluating standards
- E.g., no more than 10% decrease in frequency of meeting 90% threshold for imperiled species



Pecos River at Brotherton Ranch Near Pandale

- In the “sound” reach
- Only 5 years of data
- No HEFR analysis
- Did abbreviated hydrologic analysis to get some idea of initial numbers

Pecos Pandale



Pecos Pandale

- 90 cfs needed to meet criteria for all species
- 1 in riffles

Modeled Flow (FT^3/S)	C. pro.	D. arg.	N. ama.	N. bra.	M. con.	A. mex.	L. meg.	M. sal.	E. gra.	C. cya.
1	19%	26%	36%	10%	19%	49%	34%	27%	18%	28%
5	34%	50%	55%	21%	30%	73%	60%	50%	33%	51%
10	42%	60%	80%	28%	41%	79%	79%	65%	42%	60%
15	50%	68%	86%	37%	50%	87%	85%	78%	50%	67%
20	57%	76%	89%	41%	56%	92%	84%	83%	57%	70%
25	64%	87%	94%	48%	57%	93%	87%	86%	64%	81%
30	66%	90%	97%	50%	61%	96%	92%	89%	66%	82%
35	74%	95%	98%	56%	64%	95%	92%	88%	75%	84%
40	76%	100%	99%	58%	68%	100%	99%	93%	76%	82%
45	79%	100%	100%	65%	69%	99%	96%	94%	78%	84%
50	85%	99%	99%	67%	76%	98%	100%	94%	84%	87%
55	87%	99%	97%	68%	78%	98%	98%	97%	85%	87%
60	90%	98%	96%	79%	79%	96%	95%	94%	89%	90%
65	91%	97%	95%	81%	81%	95%	92%	93%	90%	97%
70	92%	95%	97%	83%	82%	91%	90%	96%	91%	96%
75	93%	92%	97%	84%	82%	90%	86%	100%	92%	97%
80	94%	89%	96%	89%	83%	88%	89%	99%	93%	97%
85	94%	88%	98%	89%	90%	84%	88%	96%	94%	100%
90	95%	90%	97%	91%	91%	87%	89%	93%	95%	95%
95	94%	89%	98%	93%	91%	86%	90%	97%	95%	95%
100	94%	88%	96%	94%	93%	85%	91%	96%	94%	93%
125	100%	88%	96%	100%	100%	92%	92%	100%	100%	94%
150	94%	86%	91%	98%	85%	95%	88%	98%	98%	90%
175	91%	77%	94%	96%	78%	87%	87%	90%	92%	86%
200	91%	66%	82%	93%	70%	77%	91%	86%	90%	84%
250	82%	52%	82%	85%	53%	71%	81%	77%	71%	68%
300	69%	44%	93%	81%	48%	71%	65%	77%	56%	54%
350	60%	37%	90%	72%	53%	66%	59%	68%	47%	48%
400	49%	32%	83%	65%	49%	64%	30%	43%	42%	40%
500	34%	27%	64%	51%	34%	57%	21%	28%	30%	29%

Pecos Pandale

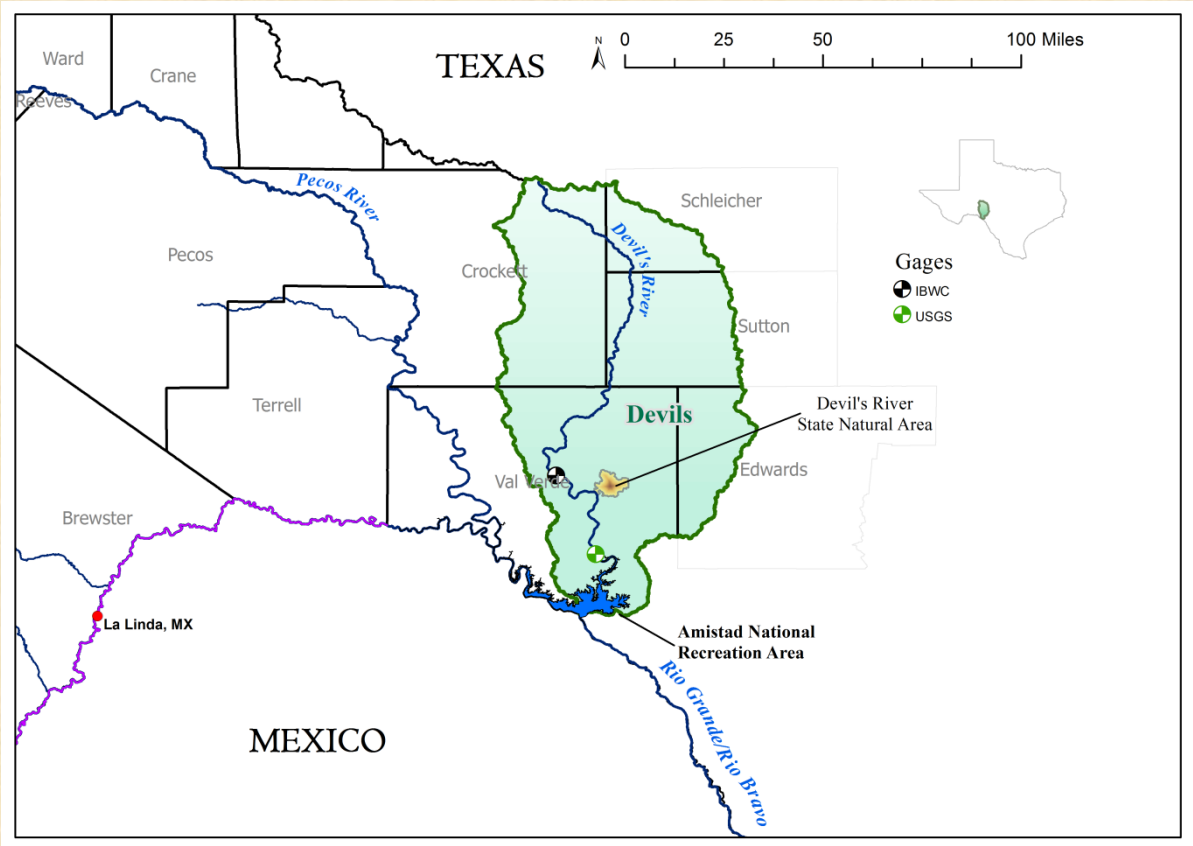
Overbank Flows	No flow recommendations											
High Flow Pulses	No flow recommendations											
Base Flows (cfs)	101				90				90			
	80				60				62			
Subsistence Flows (cfs)	39				39				39			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

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

Notes:

1. Period of record: 1/1/2008 to 12/31/2010
2. Subsistence and base flows calculated using non-zero flows only.

Devils River Sub-basin

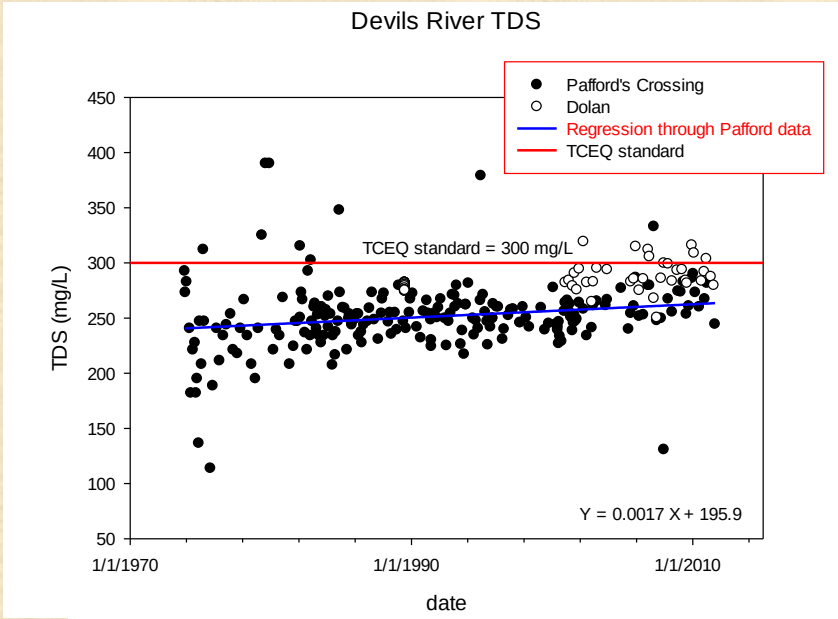


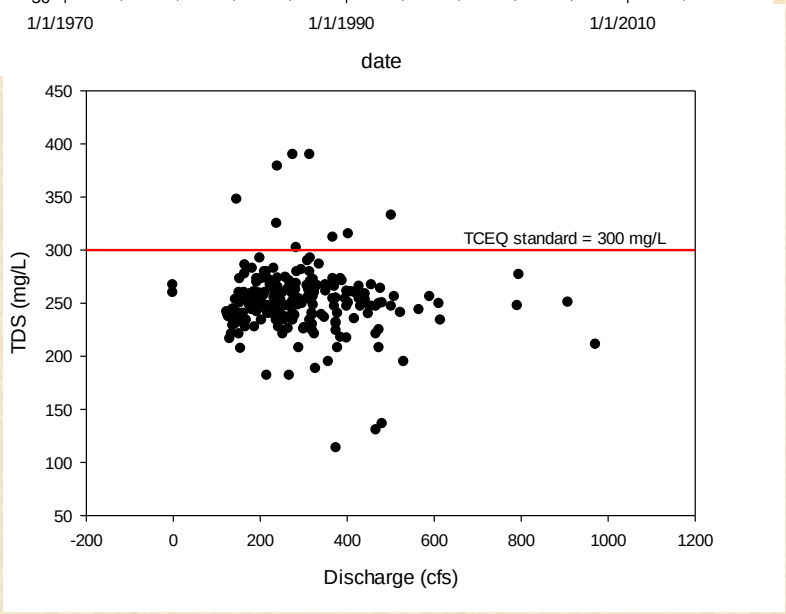
Devils River

- Sound
  - High water quality
  - Rare and unique species
  - Groundwater
- 2 gages for flow recommendations
- HEFR, water quality, biology overlay

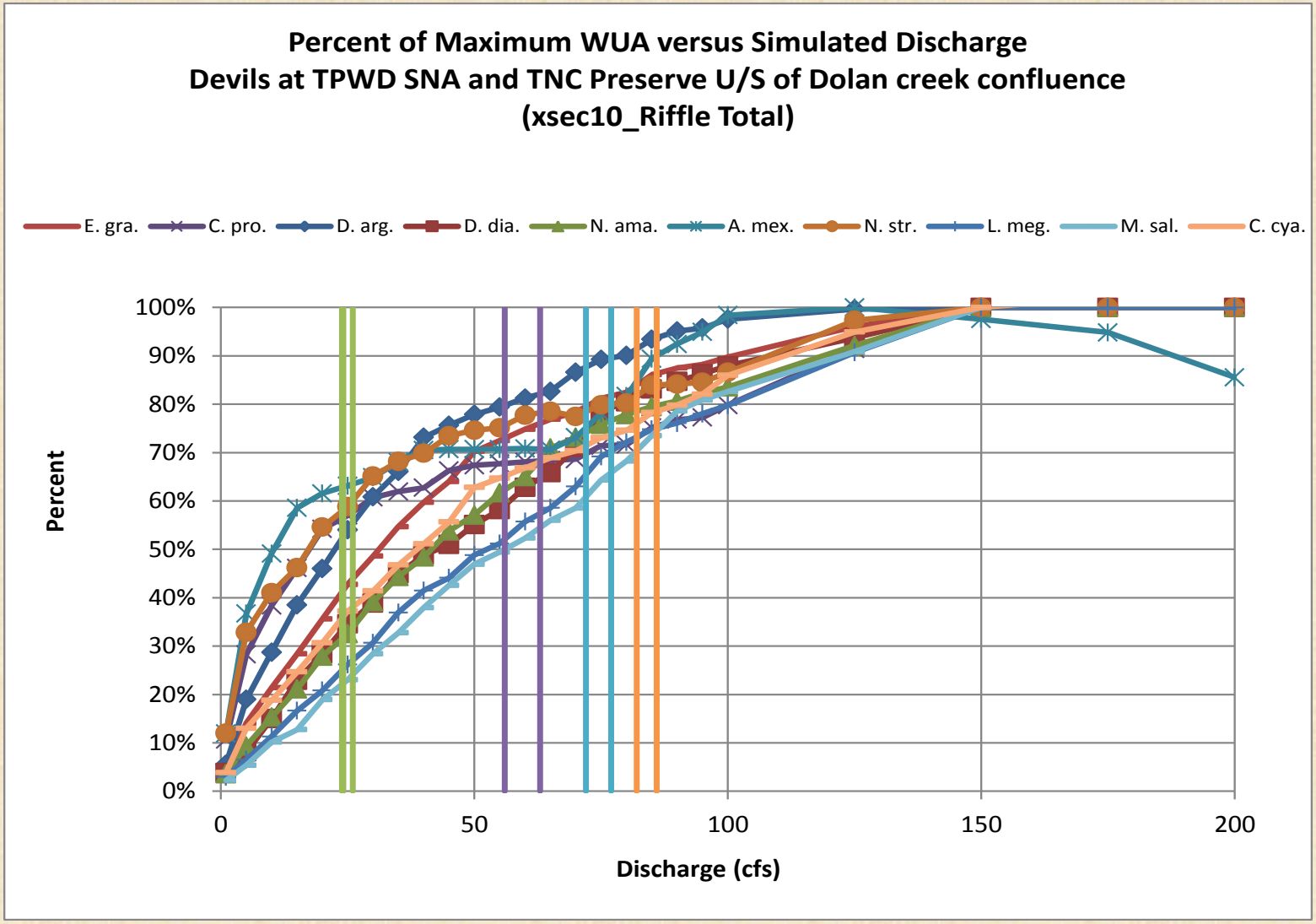
Water Quality

- No water quality impairments
- Somewhat increasing total dissolved solids
- Does not appear to be flow related





Devils River near Juno



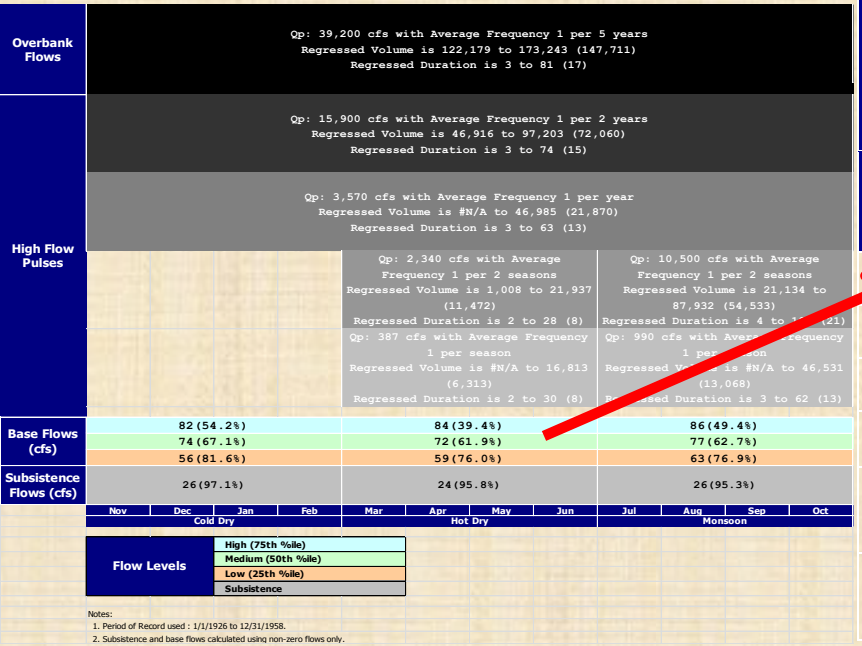
Devils

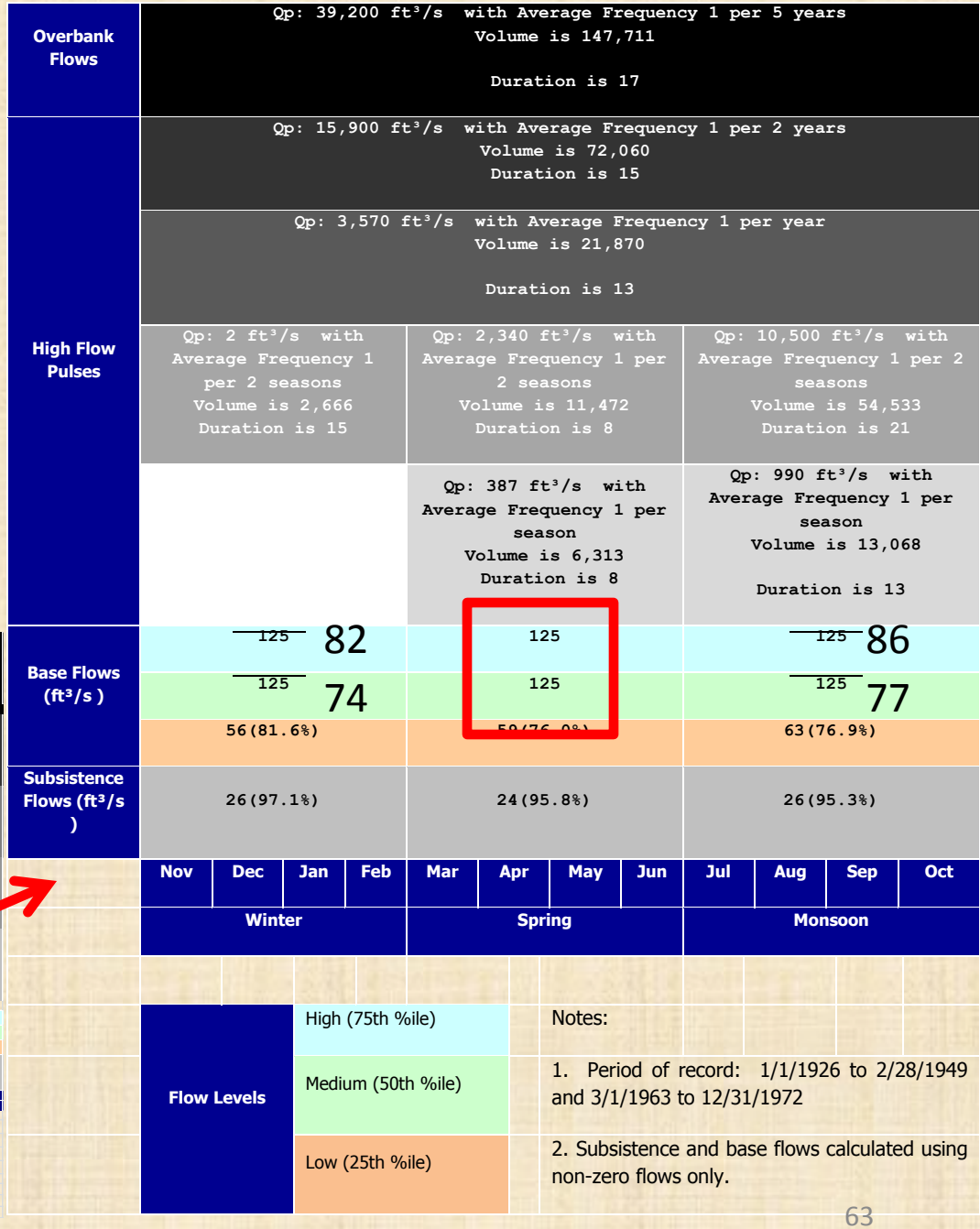
- 125 cfs needed to meet criteria for all species
- 1 in riffle

Modeled Flow (FT^3/S)	C. pro.	D. arg.	D. dia.	N. ama.	N. str.	A. mex.	M. sal.	L. meg.	E. gra.	C. cya.
1	11%	6%	4%	4%	12%	12%	2%	3%	5%	4%
5	28%	19%	8%	9%	33%	37%	5%	7%	14%	13%
10	38%	29%	15%	15%	41%	49%	10%	11%	21%	19%
15	46%	39%	23%	21%	46%	59%	13%	17%	28%	25%
20	54%	46%	28%	28%	55%	62%	19%	21%	36%	31%
25	57%	54%	35%	33%	59%	63%	23%	26%	43%	37%
30	61%	61%	39%	39%	65%	65%	28%	31%	49%	41%
35	62%	66%	45%	44%	68%	68%	33%	37%	55%	47%
40	63%	73%	49%	48%	70%	71%	38%	41%	60%	51%
45	66%	76%	51%	54%	73%	71%	43%	44%	64%	56%
50	67%	78%	55%	57%	75%	71%	47%	49%	70%	63%
55	68%	79%	58%	62%	75%	71%	49%	51%	72%	65%
60	68%	81%	63%	65%	78%	71%	52%	56%	75%	67%
65	68%	83%	66%	71%	79%	71%	56%	59%	77%	69%
70	69%	87%	71%	73%	77%	73%	59%	63%	78%	70%
75	71%	89%	78%	76%	80%	78%	64%	69%	81%	73%
80	72%	90%	80%	78%	80%	82%	68%	72%	82%	75%
85	75%	93%	83%	79%	84%	89%	73%	75%	86%	78%
90	77%	95%	85%	81%	84%	92%	79%	76%	87%	80%
95	77%	96%	86%	82%	85%	95%	81%	78%	88%	82%
100	80%	98%	88%	84%	87%	98%	83%	80%	90%	86%
125	91%	100%	94%	92%	97%	100%	91%	91%	96%	95%
150	100%	100%	100%	100%	100%	98%	100%	100%	100%	100%
175	100%	100%	100%	100%	100%	95%	100%	100%	100%	100%
200	100%	100%	100%	100%	100%	86%	100%	100%	100%	100%
250	100%	100%	100%	100%	100%	86%	100%	100%	100%	100%
300	100%	100%	100%	100%	100%	87%	100%	100%	100%	100%
350	100%	98%	100%	100%	100%	86%	100%	100%	100%	100%
400	100%	92%	100%	100%	100%	85%	100%	100%	97%	100%
500	100%	79%	100%	100%	100%	69%	100%	100%	87%	100%

Devils River near Juno

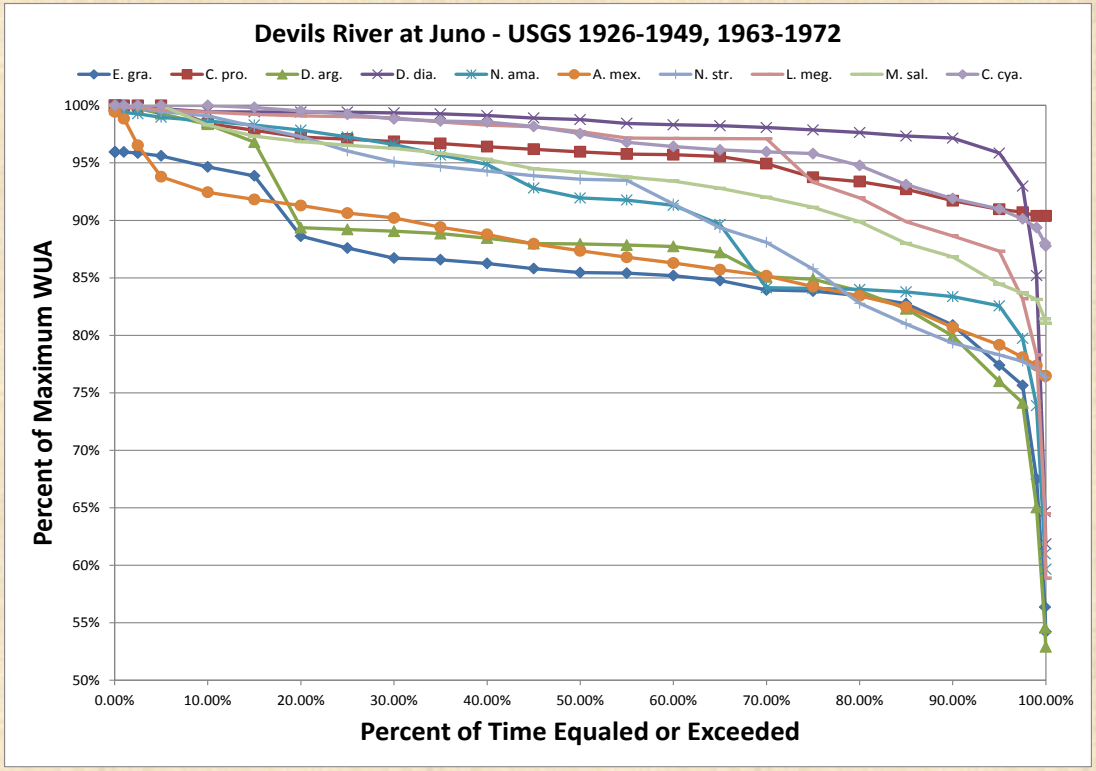
- HEFR
- Plus, Biology overlay





Devils River near Juno

- Habitat time series analysis
- Can serve as an aid in evaluating standards
- E.g., no more than 10% decrease in frequency of meeting 90% threshold for imperiled species



Devils River at Pafford's Crossing

Overbank Flows	Qp: 34,110 ft³/s with Average Frequency 1 per 5 years Volume is 148,364 Duration is 22											
High Flow Pulses	Qp: 10,100 ft³/s with Average Frequency 1 per 2 years Volume 59,961 Duration is 16											
	Qp: 3,673 ft³/s with Average Frequency 1 per year Volume is 34,752 Duration is 13											
					Qp: 1,462 ft³/s with Average Frequency 1 per 2 seasons Volume is 21,327 Duration is 9				Qp: 6,816 ft³/s with Average Frequency 1 per 2 seasons Volume is 46,548 Duration is 14			
					Qp: 558 ft³/s with Average Frequency 1 per season Volume is 17,374 Duration is 7				Qp: 1,872 ft³/s with Average Frequency 1 per season Volume is 27,781 Duration is 9			
									Qp: 318 ft³/s with Average Frequency 1 per season Volume is 27,781 Duration is 9			
Base Flows (ft³/s)	243 (56.5%)				253 (41.5%)				238 (49.7%)			
	200 (69.0%)				207 (59.3%)				206 (62.9%)			
	175 (81.3%)				160 (74.5%)				166 (76.5%)			
Subsistence Flows (ft³/s)	84 (96.3%)				91 (94.1%)				87 (94.7%)			
	Nov	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
	Winter				**Spring**				**Monsoon**			

Flow Levels	High (75th %ile)	Notes:
	Medium (50th %ile)	1. Period of record: 1/1/1960 to 12/31/2009
	Low (25th %ile)	2. Subsistence and base flows calculated using non-zero flows only.

Devils River – Adaptive Management

- Geomorphological overlay to ensure adequate HFP's to maintain channel processes
- Better understand groundwater relatedness and potential effects of groundwater development on ability to maintain SEE through permit conditions
- Refine habitat analysis to strengthen base flows
- Better understand flow biology
- Evaluate flow gage performance, relation of USGS period to current IBWC period