Tapoco License Proceeding FERC P- 2169

Cheoah River Instream Flow Assessment

2001 – 2005

Robert H. Deibel

Flow 2018

Ft Collins, CO

April 24, 2018

Approaching the Problem

Art or Science?

vs.

“There are known knowns. These are things we know that we know. There are known unknowns. That is to say, there are things that we know we don't know. But there are also unknown unknowns. There are things we don't know we don't know.”

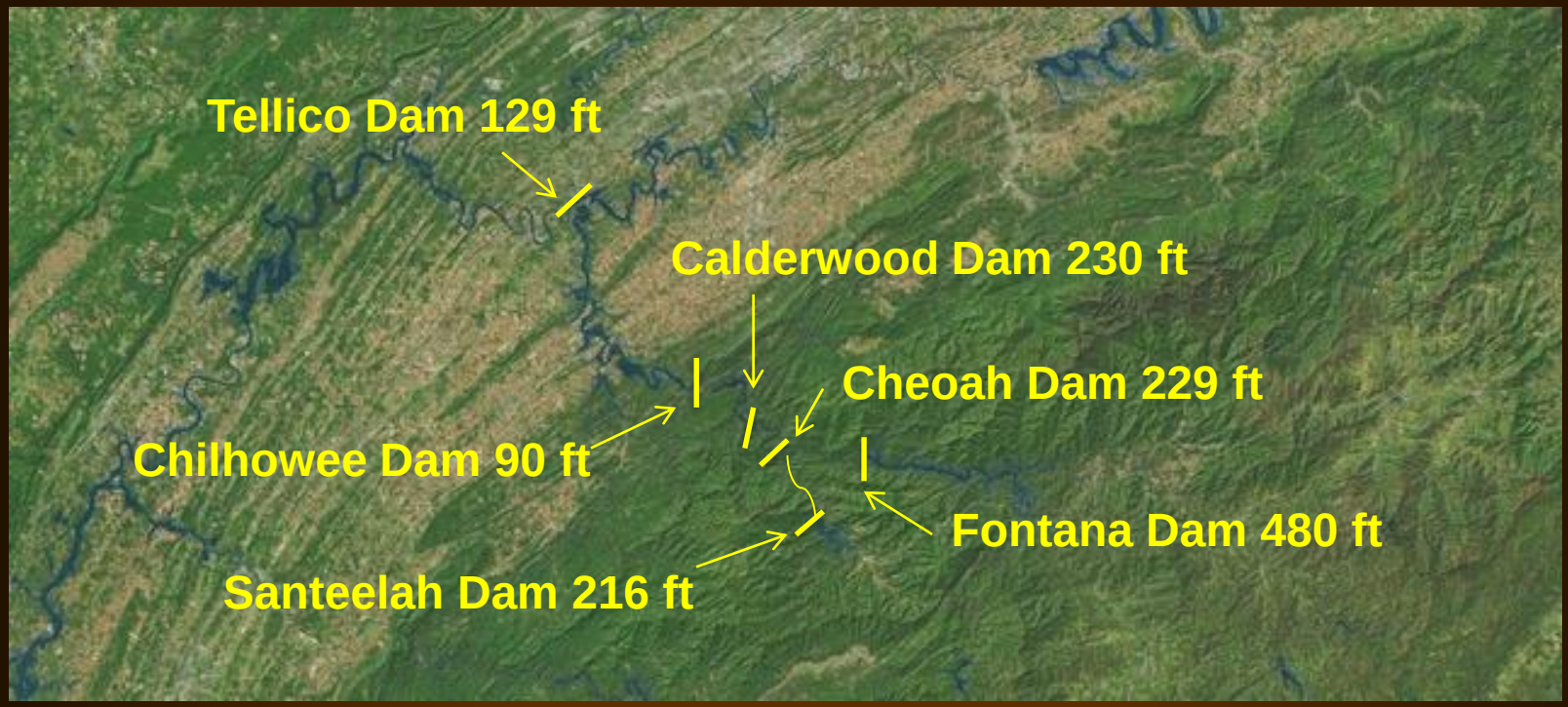
Donald Rumsfeld

Sage Advice

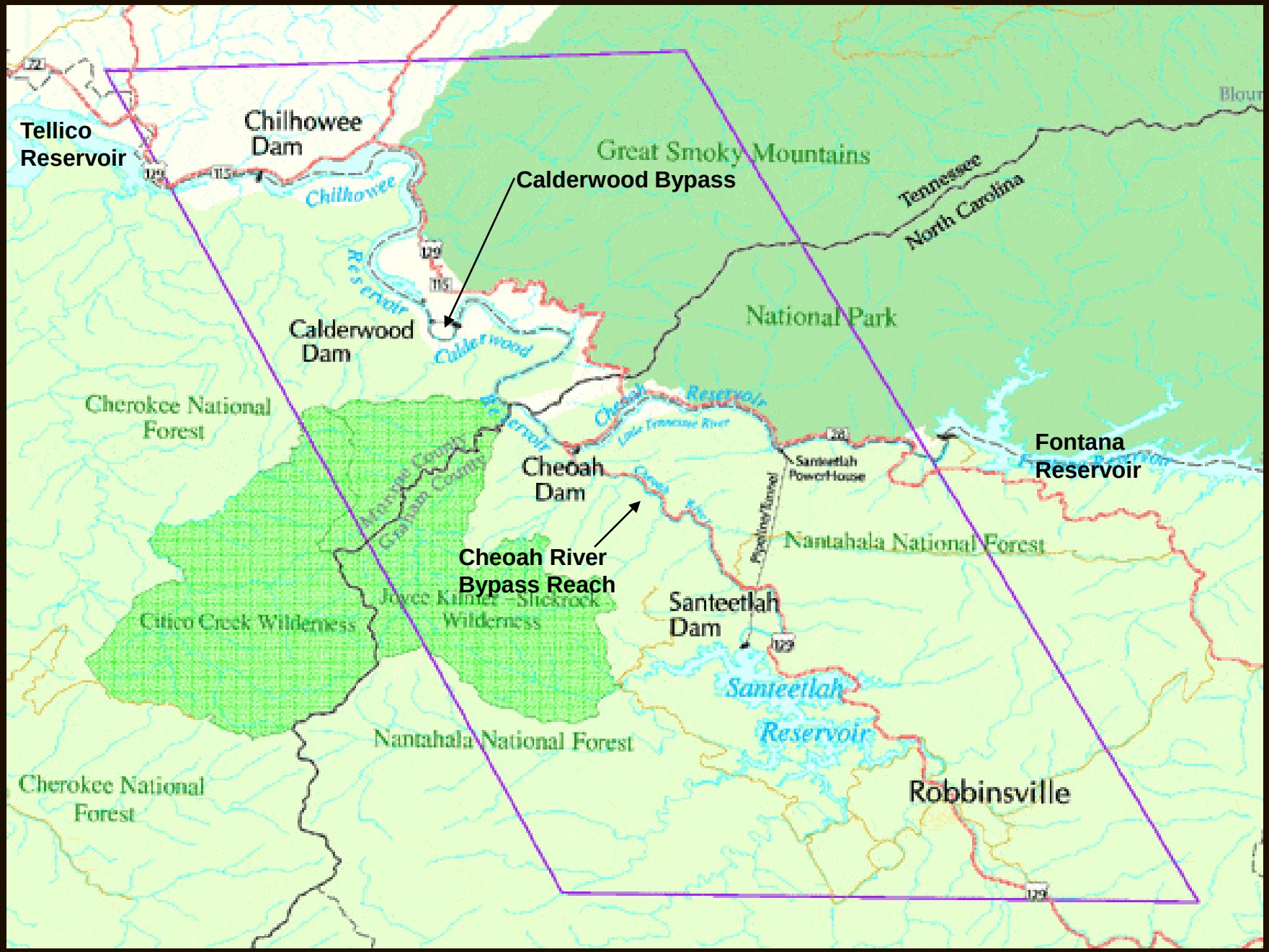
Local Forest Fishery Biologist greets me at the Knoxville Airport and instantly conveys:

“Hey Deibel – this isn’t the West Coast so don’t think you’re going to get the same level of mitigation one might get in CA, OR or WA.”

Stunned at first but the feedback was very helpful to help frame the problem and define scope of opportunities and thus, technical approach.



Physical Setting


Tellico Reservoir
Chilhowee Dam
Chilhowee Reservoir
Calderwood Bypass
Calderwood Dam
Calderwood Reservoir
Great Smoky Mountains
National Park
Tennessee
North Carolina
Cherokee National Forest
Cheoah Reservoir
Cheoah Dam
Fontana Reservoir
Santeetlah Powerhouse
Cheoah River Bypass Reach
Nantahala National Forest
Citico Creek Wilderness
Joyce Kilmer - Slickrock Wilderness
Santeetlah Dam
Santeetlah Reservoir
Robbinsville
Nantahala National Forest
Cherokee National Forest

Agency objectives

- Restore Aquatic Conditions in the Cheoah River – targeting native fish and mussels
- Accommodate recreation needs for river based recreation $local economic value$

Technical Aspects of Flow Analysis

- Hydrologic analysis;
- Hydraulic habitat/diversity analysis;
- Magnitude, Frequency, Timing and Duration of high flow events;
- Analysis of rate of stage change for ascending and descending limbs of representative hydrographs;
- Substrate analysis;

Approach

- Literature Review of Biological Impacts of High Pulsed Flows
- Cheoah River Site Specific Considerations
- Hydrology Analysis - Cheoah and Regional Reference Streams
- Potential Mitigation Measures via a Settlement Agreement

Approach

- Document *potential* biological impacts of recreational flow releases
- Examine ways in which recreational flow releases might be provided while *minimizing* biological impacts
- Develop basis for agency recommendations on annual hydrograph at a monthly time step *f*(water year)
- Integrating recreational flow releases into annual hydrograph

Working Assumptions

- Flow variability and high flows are important aspects of a natural flow regime
- Hydrologic variability is a critical component of aquatic community structure
- Most impacts probably occur when the range, rate, or seasonality of the flow regime gets outside the range to which biota are adapted

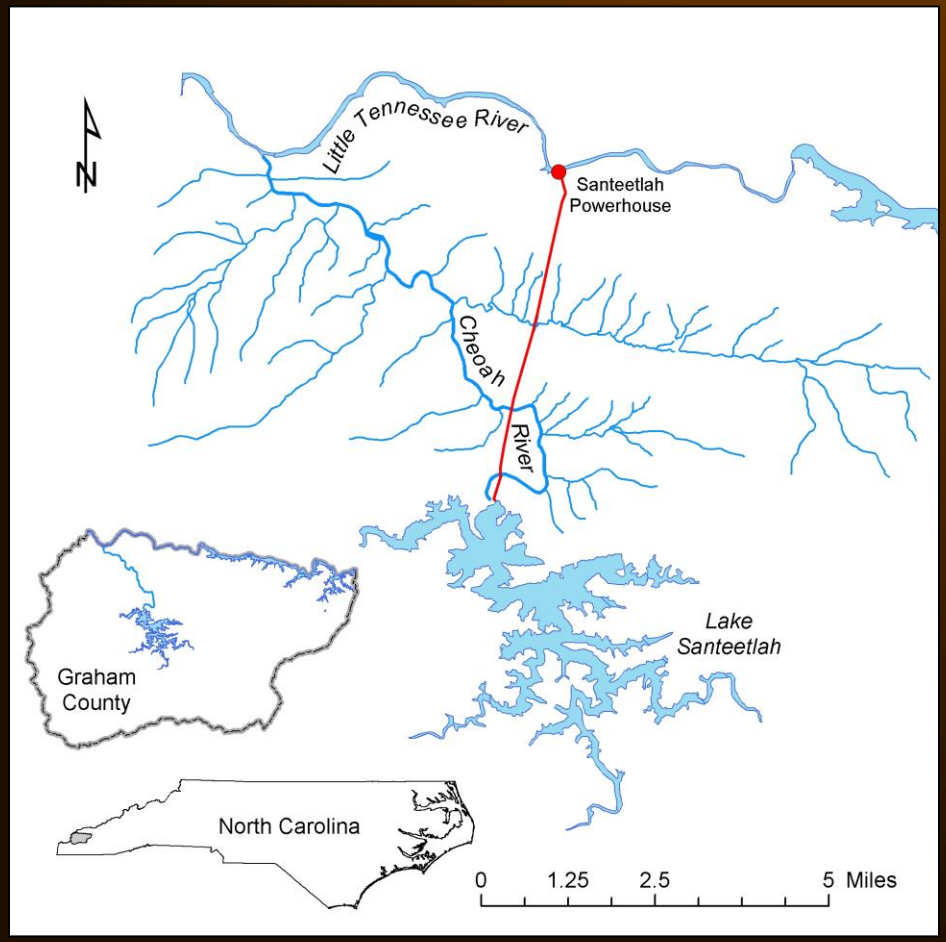
Working Assumptions

- Reduced Productivity
- Stranding of fish/amphibians/invertebrates
- Displacement and drift especially larval fishes;
- Disruption or elimination of spawning success or completion of life histories – fish and mussels;

From 2001 – Tech Memo

- Spawning activities and the rearing of *young fish with poor swimmi*ng abilities are the life stages that are of greatest concern. ..Larval and young fish have poor swimming abilities and limited ability to react to rapidly changing flows, potentially resulting in mortality or displacement.
- The mechanisms of impacts of recreational flow releases on aquatic biota include exposing organisms to excessive velocities, downstream drift or displacement, stranding of organisms as flow rapidly decline, interruption of spawning or other biologically important functions.
- Although reproduction within the aquatic community (fish, mussels, and aquatic insects) occurs throughout the year, spawning and rearing of young fishes is concentrated in the spring and summer.
- Changing flows and high flows are natural parts of rivers, and fish are adapted to a certain degree to those changes. However, in natural systems, high flows typically rise and fall more slowly, and rapid changes in flows.
- There may be opportunities to modify the seasonal timing, duration, and ramping rates of recreational boating releases to minimize impacts on the aquatic biota.

Santeetlah Development



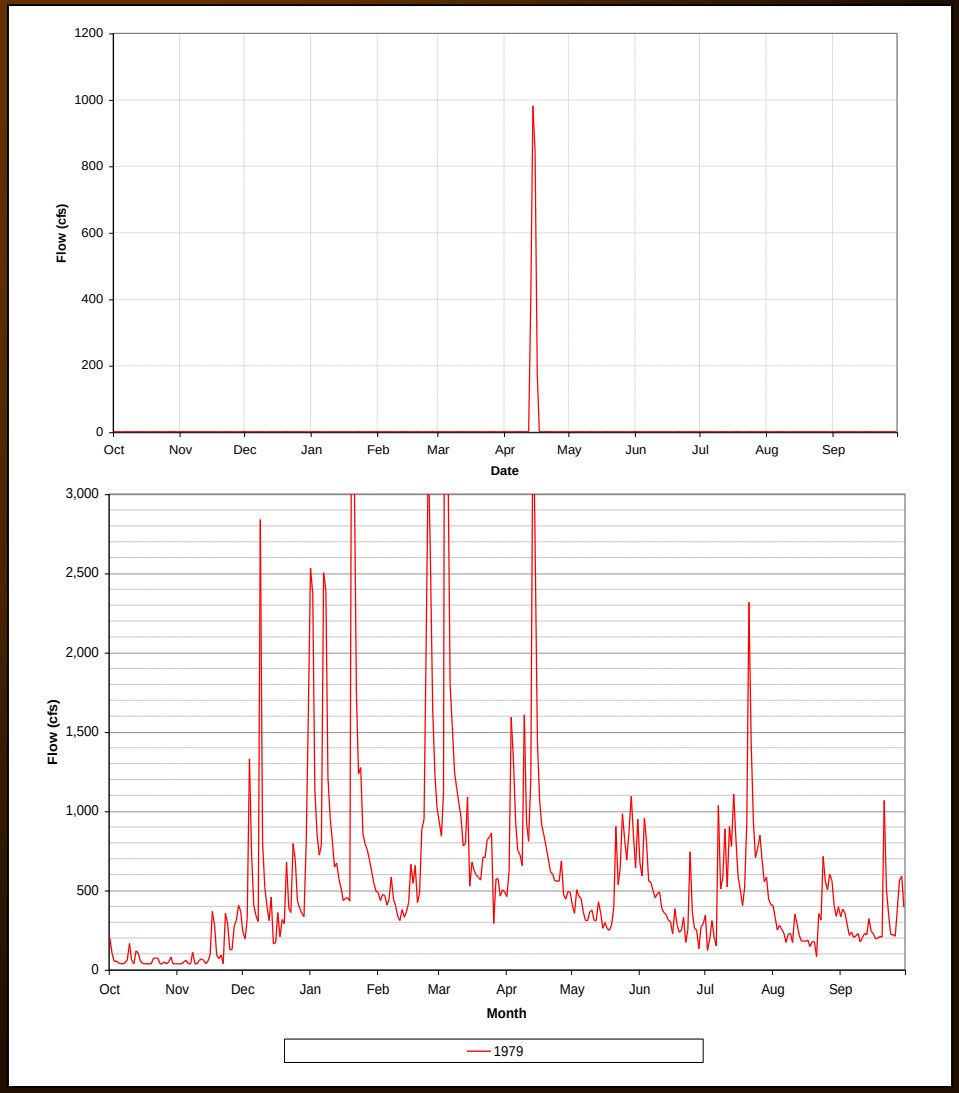
- Dam completed - 1928
- Impoundment - 2,881 ac
- Drainage area - 176 miles^2
- Avg. annual inflow - 480 cfs
- Storage – 158,000 ac-ft
- Hydraulic capacity - 950 cfs
- Vertical head - 660 ft
- Installed capacity - 49.2 MW
- Bypass reach - 9.3 miles

Cheoah River Resource Objectives

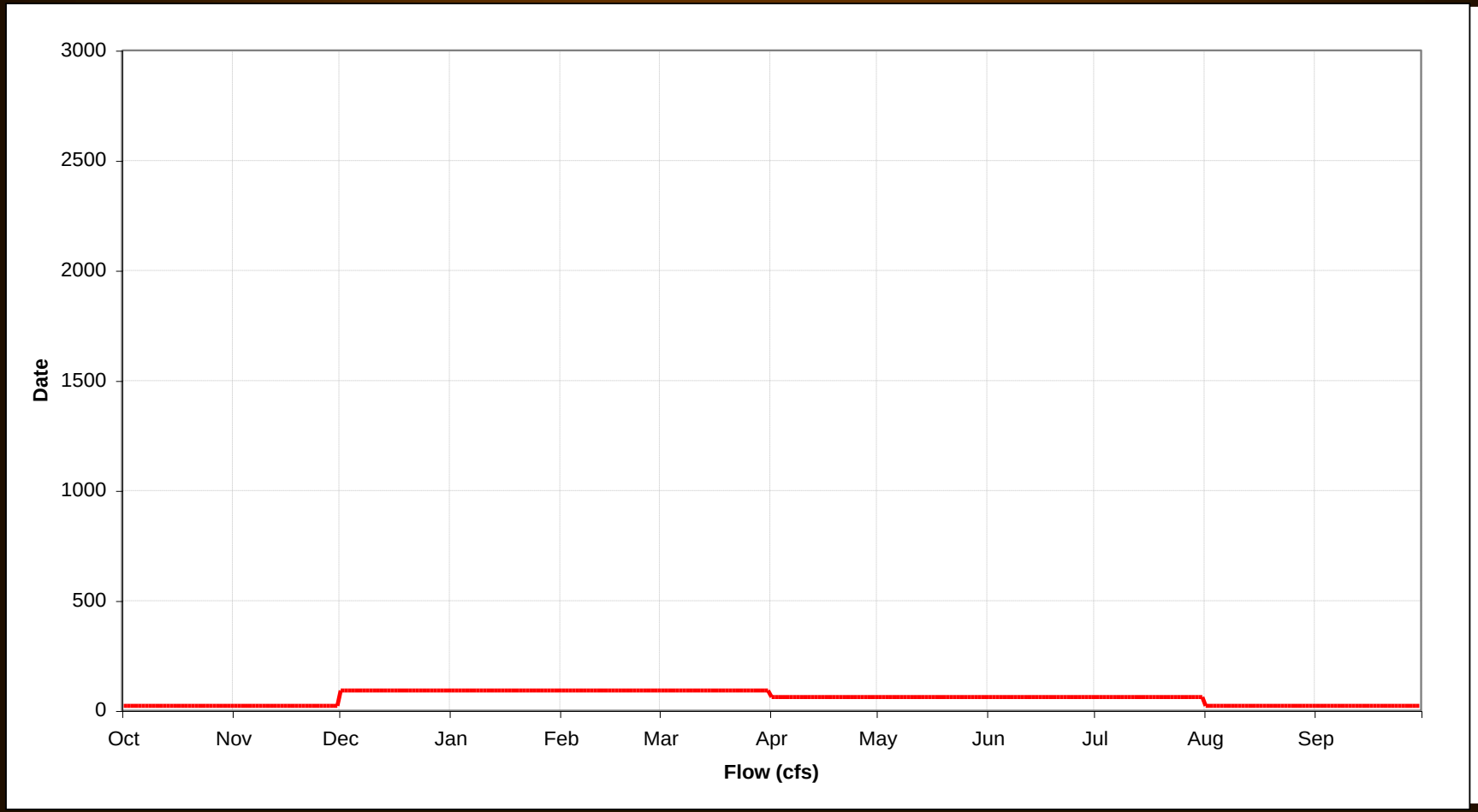
- Provide Flows below Santeetlah Dam to protect and restore:
  - Native fish;
  - Native invertebrates – mussels;
  - Amphibians;
  - Channel conditions;
  - Riparian vegetation;
- Provide Recreation flows to meet demand for whitewater rafting and boating;
- Maintain Santeetlah Lake levels at desired levels;

Cheoah River

- Valley constrained, bedrock controlled
- Step-pool morphology interspersed with boulder-strewn runs
- Median gradient - 1.73%
- Pre-2005 License = No minimum flow requirements
- Vegetation encroachment
- Highly altered system



Hydrology Comparison



PHABSIM Analysis

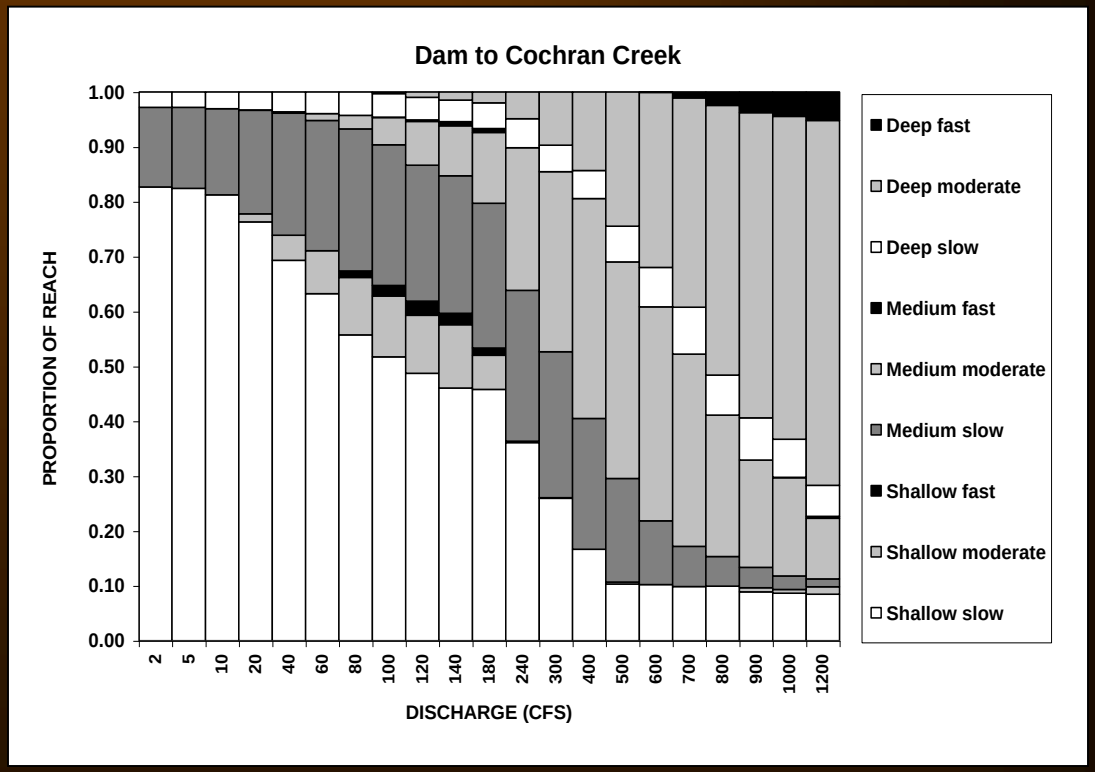
- 4 Study Sites w a total of 35 transects;
- PHABSIM species/life stage analysis:
  - Northern Hog sucker – riffles/pools current
  - Smallmouth bass
  - Mottled sculpin
  - Central stoneroller
  - Benthic macroinvertebrates

PHABSIM Summary

- N hog sucker – rapid increase 100 cfs then tapers off;
- SMBass - rapid increase 100 cfs then tapers off;
- RBT - rapid increase 100 cfs levels out to ~ 400 cfs & then tapers off;
- Mottled sculpin – gradual increase 0 – 1200 cfs;
- Central Stone roller – increased to 50 – 100 cfs then dropped quickly;
- Bugs – increased up to 100 – 200 cfs then gradual decrease;

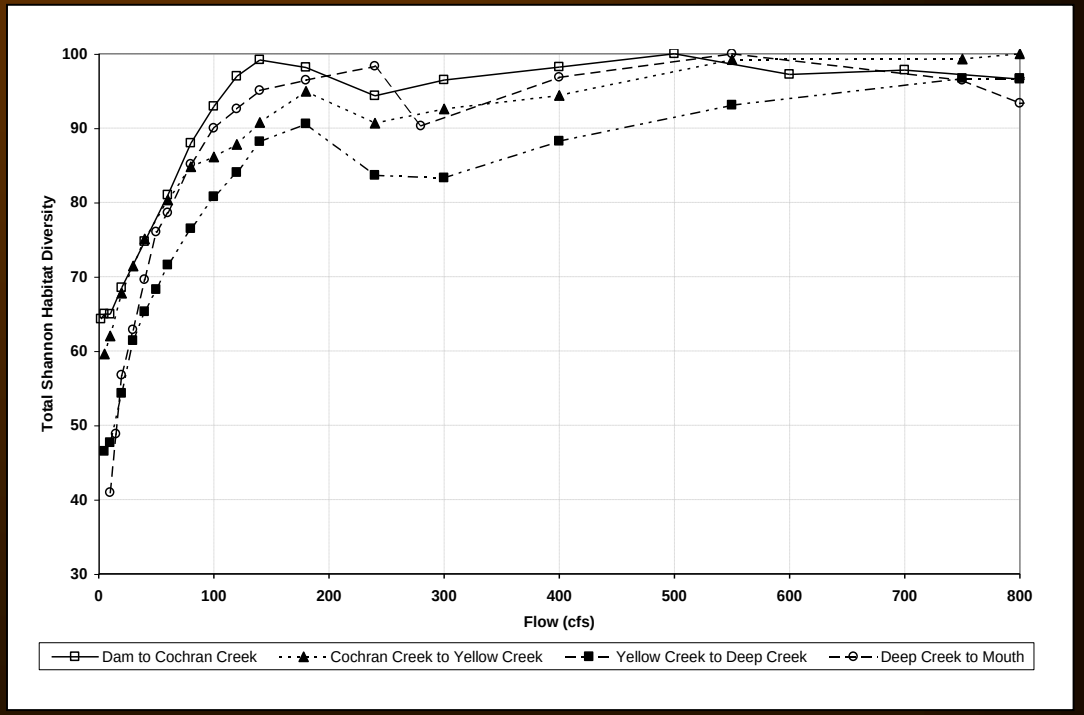
Mesohabitat Availability

- **Shallow and medium depth, fast water mesohabitats important**
  - **Riffle productivity**
  - **Fluvial specialist fish assemblage**
- **Seasonally abundant (e.g., spawning periods)**
- **Minimal amounts at discharges <50 cfs**



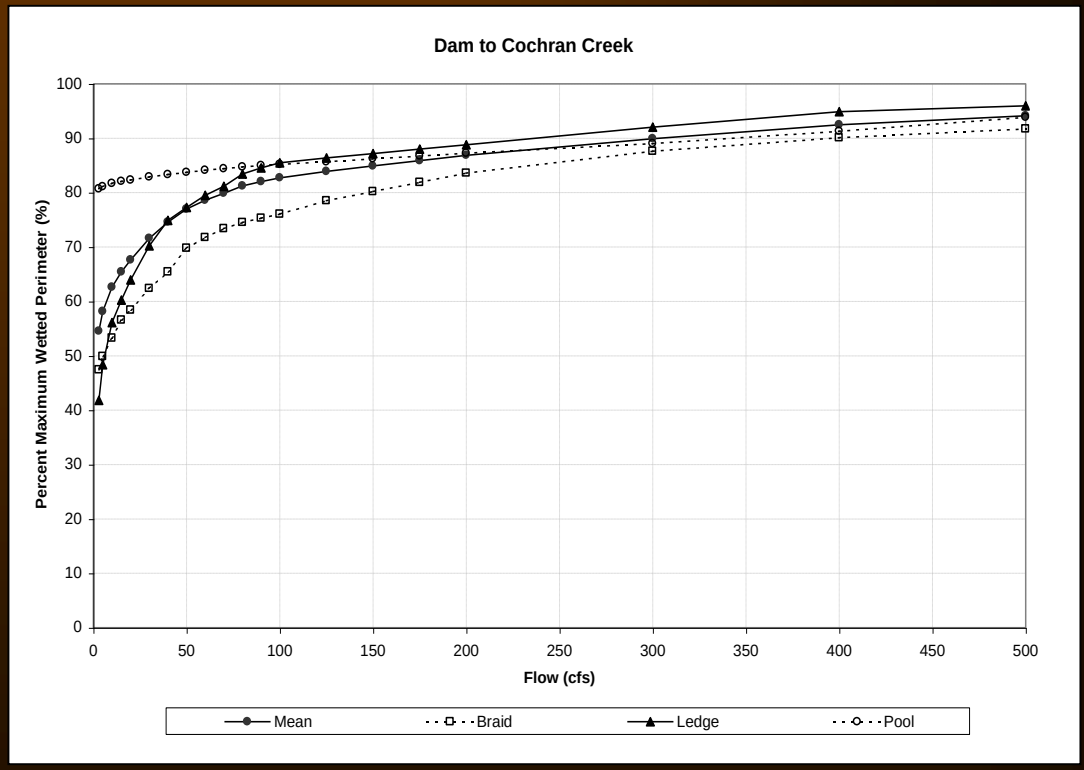
Habitat Diversity

- Calculated Habitat Diversity Indices on Mesohabitat results
- General habitat diversity and fish species diversity significantly correlated
- Adequate levels at all reaches and all seasons, except during lowest flow months



Wetted Perimeter Analysis

- Index of wetted channel area, related to habitat availability at low flows
- Breakpoints indicative of suboptimal conditions
- Complex habitats exhibit more drastic decline



Base Flow Recommendation (cfs)

Month											
JAN	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
160	175	175	175	160	125	80	50	50	50	70	130

Provides for aquatic habitat protection and seasonal variability

Strong justification

- **Supported by multiple analyses**
- **General congruence of data**

Provided a baseline for comparison of other flow alternatives

High Flow Component

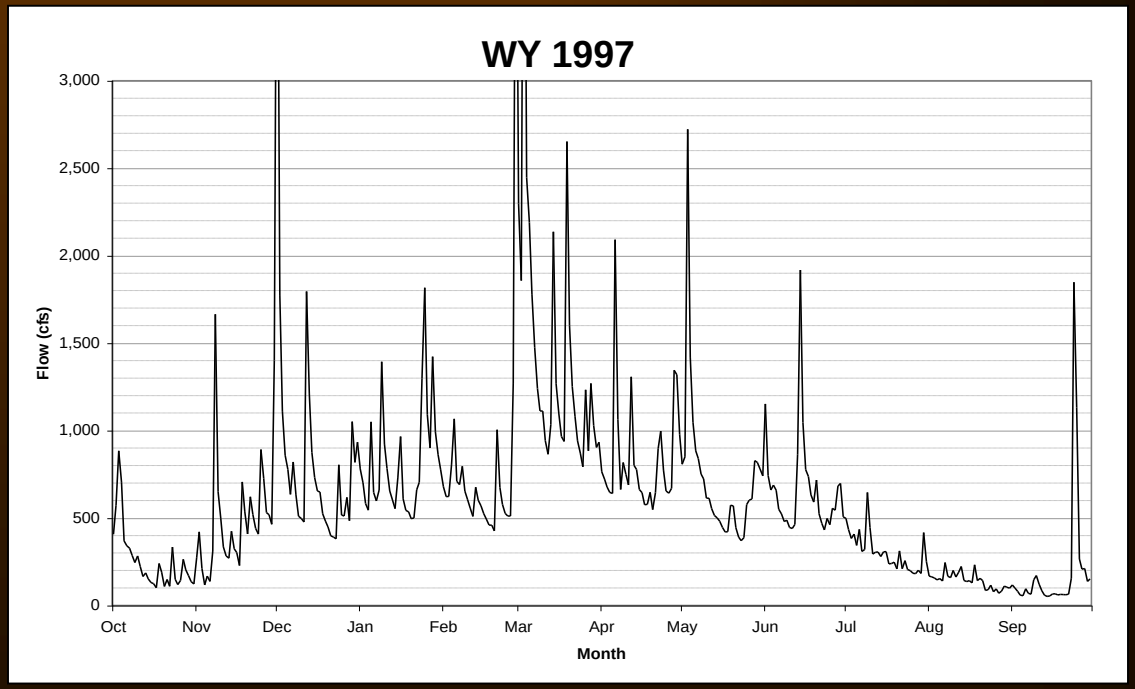
- Outline a high flow release regime more compatible with fish and aquatic biota considerations
- Patterned after natural high flow regime
- Not designed to explicitly accommodate whitewater boating, but expected to provide some level of recreation
- Defined target high flow events to accommodate rafting experience based on flow releases and feedback from rafting community
- Correct scaling of high flow magnitudes to base flows was not rigorously pursued

Definition of a High Flow Event

- Average daily flow that exceeds some threshold
- Optimal rafting conditions - 1,000 cfs
- Base inflows approach 700 cfs in some months, used as threshold value
- Identifiable peak and duration

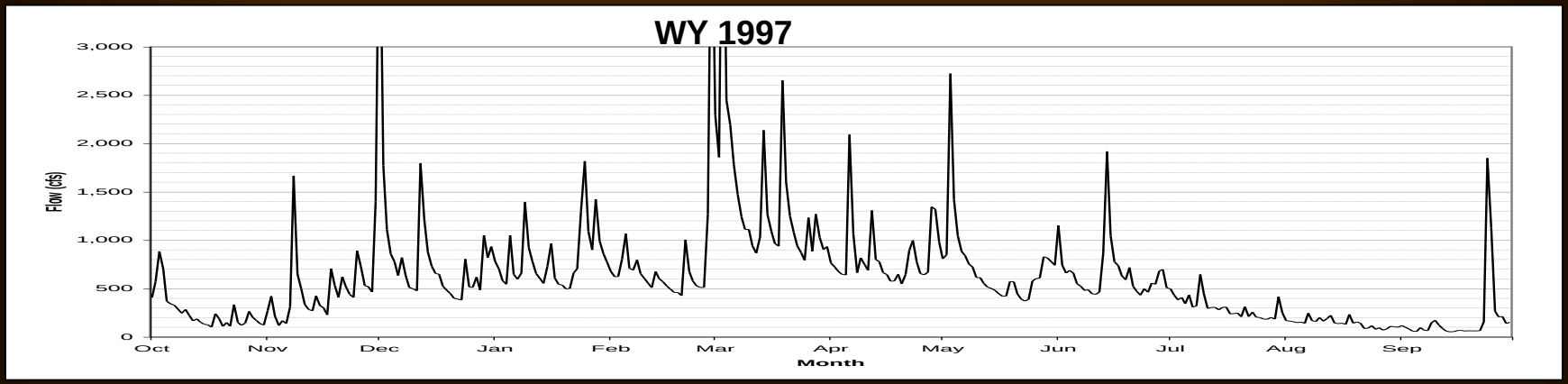
High Flow Event Analysis

- Basis - high flow event regime evident in project inflow record
- High flows occur throughout the year
- Most common Fall through Spring
- Distinct seasonal patterns
  - Magnitude
  - Frequency
  - Duration



Generalized Life History Table

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Spawn												
Fry												
Salamander							Egg laying		Larvae			
Mussels										Glochidia discharged		



Hydrograph Shape

- Regional reference stream hydrology
  - Peaks quickly attained, well defined
  - Gradual return to base flows
- Ecologically important
- Provide extended range of recreational opportunities
- Greater water usage

High Flow Regime Recommendation

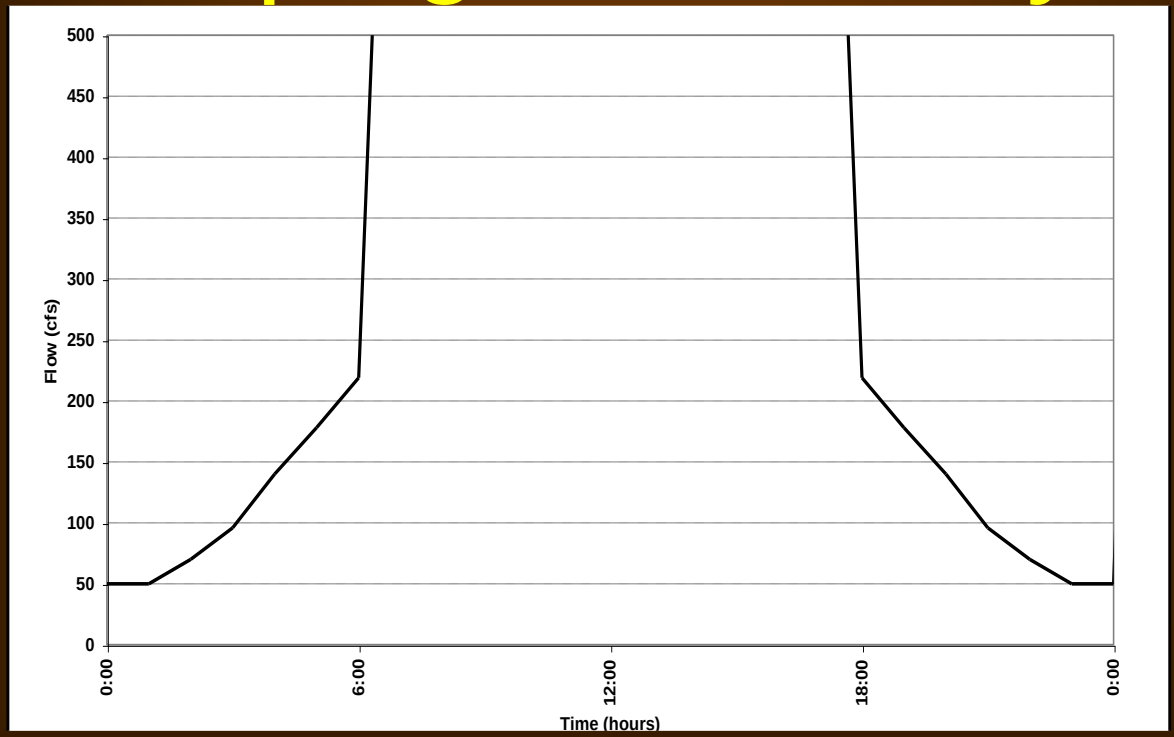
Regime Component	Month												Annual range	
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	Min.	Max.
No. of events	2-3	2	2	2	1	1	0-1	0-1	0-1	0-1	1	2-3	13	19
Duration (days)	3	3	3	2	2	1	1	1	1	1	1	2	30	39
Peak flow (cfs)	1,100	1,250	1,100	1,050	1,050	950	1,050	850	1,050	1,300	1,100	1,150	850	1,300

Median values chosen to represent typical conditions

Provides for intra- and inter-annual variation

Guidelines, considerable flexibility in scheduling and attaining recommended high flows

Ramping Rate Analysis



Regional reference ramping rates - typically <2 in/hr
Rise rates may exceed, but originate from base flows of 200 to 600 cfs
Linked to wetted perimeter, potential for displacement or stranding
Ramping requirement - 2 in/hr at flows less than 200 cfs
Agrees well with research by others

Ave. Rate Change WP (ft/cfs)

		0 – 100 cfs	100 – 200 cfs	200 – 300 cfs	300 – 1200 cfs
Upper Reach	Ledge	.95	.07	.06	.02
	Braid	.57	.13	.08	.03
Lower Reach	High Gradient Riffle	.50	.08	.02	.01
	Pool	.14	.03	.04	.01

Substrate Analysis

- Estimated Current Bedload Supply
  - Range 0 yd^3/yr to 630 yd^3/yr
- Analysis concluded project reduced gravel to river by 3,700 yd^3/yr
- Estimated that adding about 500 yd^3/yr would restore the pre-project texture surface conditions

Summary of Steps

- Cheoah River = Oasis in a Landscape of series of reservoirs;
- Initial assessment that Cheoah River is a high priority flowing stream for restoration – fish, amphibian, mussels;
- Conducted a PHABSIM – important hydraulic model;
- Hydraulic information from PHABSIM used in Wetted Perimeter and Habitat Diversity analyses;
- Compared pre- and post-project hydrology for magnitude, frequency and timing
  - (including rate of change on ascending and descending limbs of hydrograph);
- Integrated high flow events targeting whitewater rafting and sediment routing to mimic natural timing, frequency & duration;
- Estimated amount of sediment to restore substrate conditions;

Settlement Agreement/Project License Conditions

	Jan	Feb	Mar	April	May	June	July	August	Sept	Oct	Nov	Dec
Tier A (cfs)	50	100	100	100	90	60	60	50	50	50	50	60
Tier B (cfs)	50	90	90	90	80	60	50	40	40	40	40	50

Flow Release Triggers:

-Tiered flow levels based on 25th percentile of historical average daily inflow

-Licensee shall determine the aquatic base flow for each month by calculating the average daily inflow (ADI) value for the three preceding months.

-If ADI > 25th Percentile for three proceeding months then release Tier A;

If ADI < 25th Percentile for three proceeding months then release Tier B;

High Flow Releases

- Over 90% of scheduled high flow releases occur in Fall through Spring;
- Only 8 out of 97 high flow event days in any consecutive 5 year period would occur July – October (< 10%)

High Flows	Year 1		Year 2		Year 3		Year 4		Year 5		Magnitude (cfs)[3]		
	Events	Total Days Per Month	Events	Total Days Per Month	Events	Total Days Per Month	Events	Total Days Per Month	Events	Total Days Per Month	Day 1	Day 2	Day 3
January													
February	1	2	1	2	1	2	1	2	1	2	1000	Var[1]	
March	1	3	1	3	1	3	1	3	1	3	1000	600[2]	300
April	2	5	3	6	2	5	2	5	3	6	1000	850	300
May	2	4	2	4	3	6	3	6	3	6	1000	850	
June	1	2	1	2					1	2	1000	850	
July					1	2					1000	850	
August							1	1			1000		
September	1	1			1	1					1000		
October	1	1	1	1			1	1			1000		
November	1	1	1	1	1	1	1	1	1	1	1000		
December													
Total Per Year:	10	19	10	19	10	20	10	19	10	20			

1 600 cfs from hour 15 to hour 19, 400 cfs from hour 20 to hour 34; 200 cfs from hour 35 to hour 47; 100 cfs for hour 48

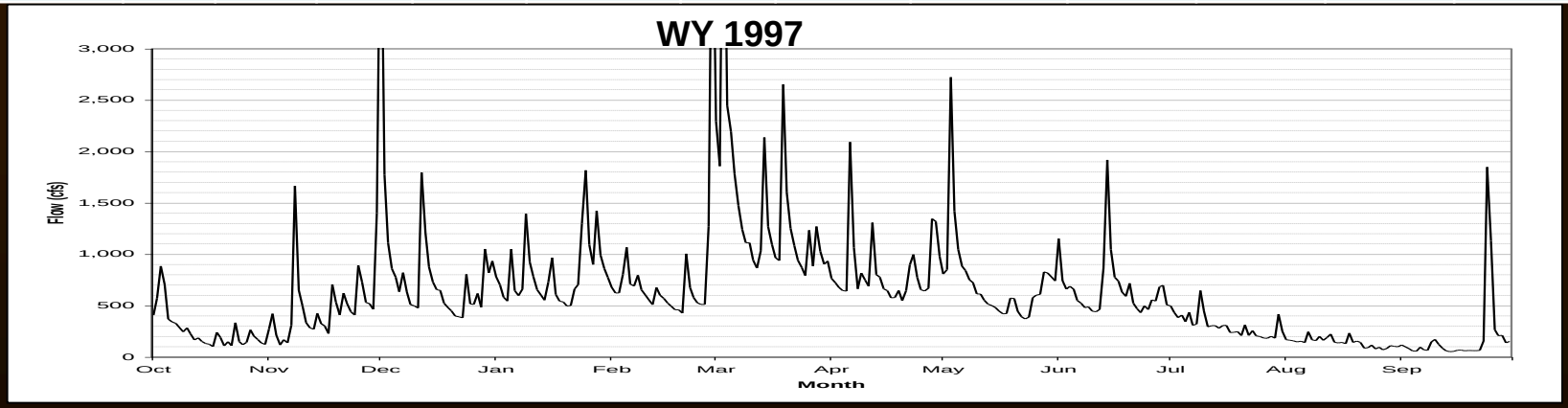
2 600 cfs from hour 16 to hour 36; 300 cfs from hour 37 to hour 48

3 12:00 a.m. (midnight) shall be the starting point for determining the appropriate time for initiating and changing flow releases

Generalized Life History Table

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Spawn												
Fry												
Salamander									Larvae			
Mussels							Egg layi			Glochidia discharged		

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
# Hi Q Days (events)	1 (1)	1 (1)	0	0	2 (1)	3 (1)	5-6 (2-3)	4-6 (2-3)	2 (1)	2 (1)	1 (1)	1 (1)



Settlement Agreement/Project License Conditions (cont)

- North Carolina Resource Enhancement Fund
  - $100,000 initial deposit
  - $25,000 per year (up to License term – 3) w/ escalation formula

Settlement Agreement/Project License Conditions (cont)

- Monitoring of biotic and abiotic parameters;
- Addition of large woody debris and gravel;
- Vegetation management below Santeetlah Dam; and

Settlement Agreement/Project License Conditions (cont)

Other natural resource stewardship activities, including, but not limited to:

a) threatened and endangered species recovery efforts;

b) control of exotic species and environmental outreach; and

c) education directly related to those Cheoah River and Little Tennessee River basin resources affected by ongoing Project operations, in particular the Santeetlah and Cheoah developments,

Questions?