Update to the TWG on Experimental Planning

11/29/05

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"Ideas and Concepts Regarding Phase V Experimental Design"

Outline for Presentation

1. Overview on Knowledge Assessment 2005 (in pursuit of an experimental ***"hybrid design"***).

2. Supporting AEM Information Needs

3. Historical Context for the Record-of-Decision

4. Basis for GCMRC's Current Options for WY 2007-2011 EXP Design Recommendation

Part I:
Knowledge Assessment

1. Identify actions that are understood well enough to be treated as long-term management actions if appropriate (***"hybrid design"***).

2. Evaluate uncertainties about the effects of management actions on key resources in CRE.

3. Develop strategic science questions that would need to be addressed to reduce uncertainties (tied to SPG process).

4. Identify modelling, research, monitoring and best experimental science design required to answer the science questions (benefit resource & promote learning).

Highlights from Fish Matrix

Performance Measure	Species	Increase in GCD Release Water Temp.	Overall Effect of Increased Fluctuations Relative to MLFFA	BHBF with adequate sand supply	Sustained Low Steady Flow (summer-fall)	Mechanical Removal of Coldwater Exotics (Mainstem and Trib)
YOY/Juvenile nearshore rearing	HBC	+	-		+	+
	FMS	+	-		+	+
Invasive Fish Species	Coldwater	+	-	**NA**	+	-
	Warmwater	+	-		+	
Adult Population	HBC					
	FMS	+			+	

Performance Measure	Location and/or Species	Increase in GCD Release Water Temp.	Overall Effect of Increased Fluctuations Relative to MLFFA	Reduce Variation in Monthly Volume	BHBF with adequate sand supply	BHBF without adequate sand supply	HMF with adequate sand supply	HMF without adequate sand supply	Sustained Low Steady Flow (summer-fall)	High Sustained Flow (ponding-spring)	Mechanical Removal of Coldwater Exotics (Mainstem and Trib)	Mechanical Removal of Warmwater Exotics	Supplementation from Hatchery	Translocation of HBC
Food base	Glen	+		+					-					
	Grand		-						-		+			
Mainstem spawning & incubation	HBC	+							+		+	+		
	FMS	+	-						+		+	+		
	RBT-Glen		-	+					+	+				
	RBT-Marble													
YOY/Juvenile nearshore rearing	HBC	+	-	+		-		-	+		+	+		
	FMS	+	-	+		-		-	+		+	+		
	RBT-Glen	+	-	+	-	-	-	-	+	+				
	RBT-Marble		-	+	-	-	-	-	+	+				
Invasive Fish Species	Coldwater	+	-						+		-			
	Warmwater	+	-						+			-		
Disease	Asian Fish Tapeworm	+												
	Whirling Disease	+												
Adult Population	HBC													+
	FMS	+							+					
	RBT #s - Glen	+	-						+					
	RBT Size - Glen	+	+						+					
	RBT #s- Marble		-						+		-			
Angling Opportunity and Quality	Glen	+	-	+	-	-	-	-	-	-				

Native Fish Science Questions

1. What ultimately limits native fish populations:
   - production of young fish from tributaries
   - spawning and incubation in the mainstem
   - survival of YoY and juvenile stages in the mainstem
   - growth and maturation in the adult population as influenced by mainstem conditions?

2. What is the relative importance of increased water temperature, shoreline stability, food availability, and predators on the survival of early life stages of native fish?

3. How important are backwaters and vegetated shoreline habitats to the overall growth and survival of YoY and juvenile native fish?

4. Do the potential benefits of improved rearing habitat outweigh negative impacts owing to increases in non-native fish abundance or disease?

Grand Canyon Monitoring and Research Center

Part II: Revisiting Experimental Design for Water Year 2007 to 2011

Historical Perspective Behind **Phase V**?

When Do Experimental Treatments Become Management Actions?

What is the Distinction Between Experimentation and Management Action? All Efforts are Intended to Provide Resource Benefit?

Process of Ongoing Dialogue Between Managers & Scientists We know that stable flows that are "low" (less than 10,000 cfs range) are most effective at conserving sand, amplifying warming downstream and stabilizing near-shore habitats. Short-duration BHBF-type releases (2-4 days at 41,000-45,000 cfs)) can mobilize sand from the lower channel and deeper eddies and deposit this material to higher elevation shorelines relatively quickly when sand supply is enriched. The MLFF has likely improved recreational rafting and camping, as well as angling, but there no data on this (SCORE).

Clearly Identified Management Goals & Objectives Are the desired outcomes of the GCD-AMP both Measurable & Attainable? Example: Mechanical Removal - methods developed during 2003-2005 research are known to reduce the abundance and distribution of exotic, coldwater species within treatment reaches in Marble & Grand Canyons and the reduced abundance can apparently be maintained through continued implementation. Is this currently a stated Management Objective?

Environmental Compliance Beyond Experimentation? For experimental treatments to become management actions, decision makers would presumably need to modify the Record-of-Decision, but this is only an option following compliance requirements . . .

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Types of Experiments

Source: Mark McKinstry, BuRec

- True experiments vs. quasi experiments
  - True experiments
    - Quantify effect(s)
      - e.g., mechanical removal (560k/yr)
        - » Constant treatment vs. experimental
    - Partition variance
    - Develop cause/effect (but not an end in itself)
    - Statistical tests powerful
    - Inference is large depending on sampling units
    - Expensive, dedication to learning
  - Quasi experiments
    - "Natural" experiments
    - Develop correlations (Correlation ≠ Causation)
    - Infer effects
    - Inference is limited to sample
    - Statistical tests weaker (court??)
    - Relatively inexpensive, smaller emphasis on learning

Block Experiment

	Treatment 1	Treatment 2	Test
Time Step 1	Off	Off	Control
Time Step 2	On	Off	Treatment #1
Time Step 3	Off	On	Treatment #2
Time Step 4	On	ON	Interaction Term 1 * 2

Block Design

Year	Treatment 1	Treatment 2	Treatment 3	Treatment 4
1	on	off	off	off
2	off	on	off	off
3	off	off	on	off
4	off	off	off	on
5	on	on	off	off
6	on	off	on	off
7	on	off	off	on
8	off	on	on	off
9	off	on	off	on
10	off	off	on	on
11	on	on	on	off
12	on	off	on	on

Block Design

Pros

- Planned experiments
- Partitions variance
- Increases learning
- Cause and effect

Cons

- Long timeframe
- Emphasizes learning
- Long-term commitment

Hybrid Design

Year	Management 1	Management 2	Treatment 1	Treatment 2
1	on	on	on	off
2	on	on	on	off
3	on	on	on	off
4	on	on	off	on
5	on	on	off	on
6	on	on	off	on
7	on	on	on	on
8	on	on	on	on
9	on	on	on	on
10	on	on	off	off
11	on	on	off	off
12	on	on	off	off

Hybrid Design

Pros

- Planned experiments
- Partitions variance (some factors)
- Increases knowledge (some factors)
- Cause and effect (some factors)
- Implements management actions

Cons

- Long timeframe
- Long-term commitment
- Confounding effects
- Commitment to management actions
- Implies knowledge of effects of management actions

Forward Titration

Year	Treatment 1	Treatment 2	Treatment 3	Treatment 4
1	on	off	off	off
2	on	off	off	off
3	on	off	off	off
4	on	on	off	off
5	on	on	off	off
6	on	on	off	off
7	on	on	on	off
8	on	on	on	off
9	on	on	on	on
10	on	on	on	on
11	on	on	on	on
12	on	on	on	on

Reverse Titration

Year	Treatment 1	Treatment 2	Treatment 3	Treatment 4
1	on	on	on	on
2	on	on	on	on
3	on	on	on	on
4	off	on	on	on
5	off	on	on	on
6	off	on	on	on
7	off	off	on	on
8	off	off	on	on
9	off	off	on	on
10	off	off	off	on
11	off	off	off	on
12	off	off	off	on

Titration Design

Pros

- Implements management actions
- Improves some knowledge

Cons

- Decreased learning
- Cause and effect not identified (specific actions)
- Confounding factors
- Not a recognized “design”
- Analysis methods uncertain (e.g., main effects vs. interactions)

SBSC Quote of the Day:

"There is something fascinating about science. One gets such a wholesale return of conjecture out of a trifling investment of fact."

Mark Twain– 1874.

SBSC Quote of the Century:

"Adaptive Ecosystem Assessment & Management Is Not Just About Learning, It's about Comparing and Evaluating Agreed Upon Policies Intended to Benefit the Resources!"

C. Walters – 1874?

"The Original Proposed Approach of 2002, with Five Treatments"

IMPLEMENT TREATMENT DO NOT IMPLEMENT TREATMENT

The Design Did Not Build on History of Previous Work . . .

Though Useful as Starting Point, It Was Not Fully Adopted . . .

	Increased Fluctuations In Daily Flows	Mechanical Removal of Rainbow Trout in GC	Stable-Low Flows in Fall	TCD (Future)	Beach Habitat Building Flow
WY2002-03					
WY2003-04					
WY2004-05					
WY2005-06					
WY2006-07					
WY2007-08					
WY2008-09					
WY2009-10					
WY2010-11					
WY2011-12					
WY2012-13					
WY2013-14					
WY2014-15					
WY2015-16					
WY2016-17					
WY2017-18					

The 2002 Revised Design with Two Controlled and Two Randomized Treatments [May 2004]

IMPLEMENT TREATMENT **DO NOT IMPLEMENT TREATMENT**

Evolution in Design on Basis of Progress & Historical Perspective Continued

Water Year	MLFF + Designer Flow Treatments in Winter and Summer/Fall	Mechanical Removal of Rainbow Trout in GC (non-optimized)	Naturally Warmed owing to Low Reservoir	Beach Habitat Building Flow (Paria Trigger)
WY2003	MLFF + ExpFF	Remove Fish	Warming Event	Non-Trigger
WY2004	MLFF + ExpFF	Remove Fish	Warming Event	Non-Trigger
WY2005	Plus, Stable Fall	Remove Fish	Warming Event	Fall BHBF Test
WY2006	Plus, Stable Fall	Remove Fish	Warming Event	No Testing
WY2007	MLFF + ExpFF	Do Not Remove Fish	Warming Event	Event ???
WY2008	MLFF + ExpFF	Do Not Remove Fish	Random ???	Event ???
WY2009	Plus, Stable Fall	Do Not Remove Fish	Random ???	Event ???
WY2010	Plus, Stable Fall	Do Not Remove Fish	Random ???	Event ???
WY2011	MLFF + ExpFF	Remove Fish	Random ???	Event ???
WY2012	MLFF + ExpFF	Remove Fish	Random ???	Event ???
WY2013	Plus, Stable Fall	Remove Fish	Random ???	Event ???
WY2014	Plus, Stable Fall	Remove Fish	Random ???	Event ???
WY2015	MLFF + ExpFF	Do Not Remove Fish	Random ???	Event ???
WY2016	MLFF + ExpFF	Do Not Remove Fish	Random ???	Event ???
WY2017	Plus, Stable Fall	Do Not Remove Fish	Random ???	Event ???
WY2018	Plus, Stable Fall	Do Not Remove Fish	Random ???	Event ???

Update on Lake Powell

- Reservoir Level
  - Current Elevation - 3602.0 ft (98 ft from full)
    - low for 2005 – 3555.1 ft on 4/8/2005
    - lowest elevation since May 1969
  - Current Live Storage 12.0 MAF (49%)
  - Projected Low (March 2006) – 3593.0 ft
  - Projected High (July 2006) – 3625.7 ft
- Warmer GCD Releases
  - Maximum observed temperatures
    - 11/14/2003 – 13.2°C (56°F)
    - 10/5/2004 – 15.5°C (60°F)
    - 10/11/2005 – 15.8°C (61°F)
    - WY 2006 est. 12-13°C depending on hydrology

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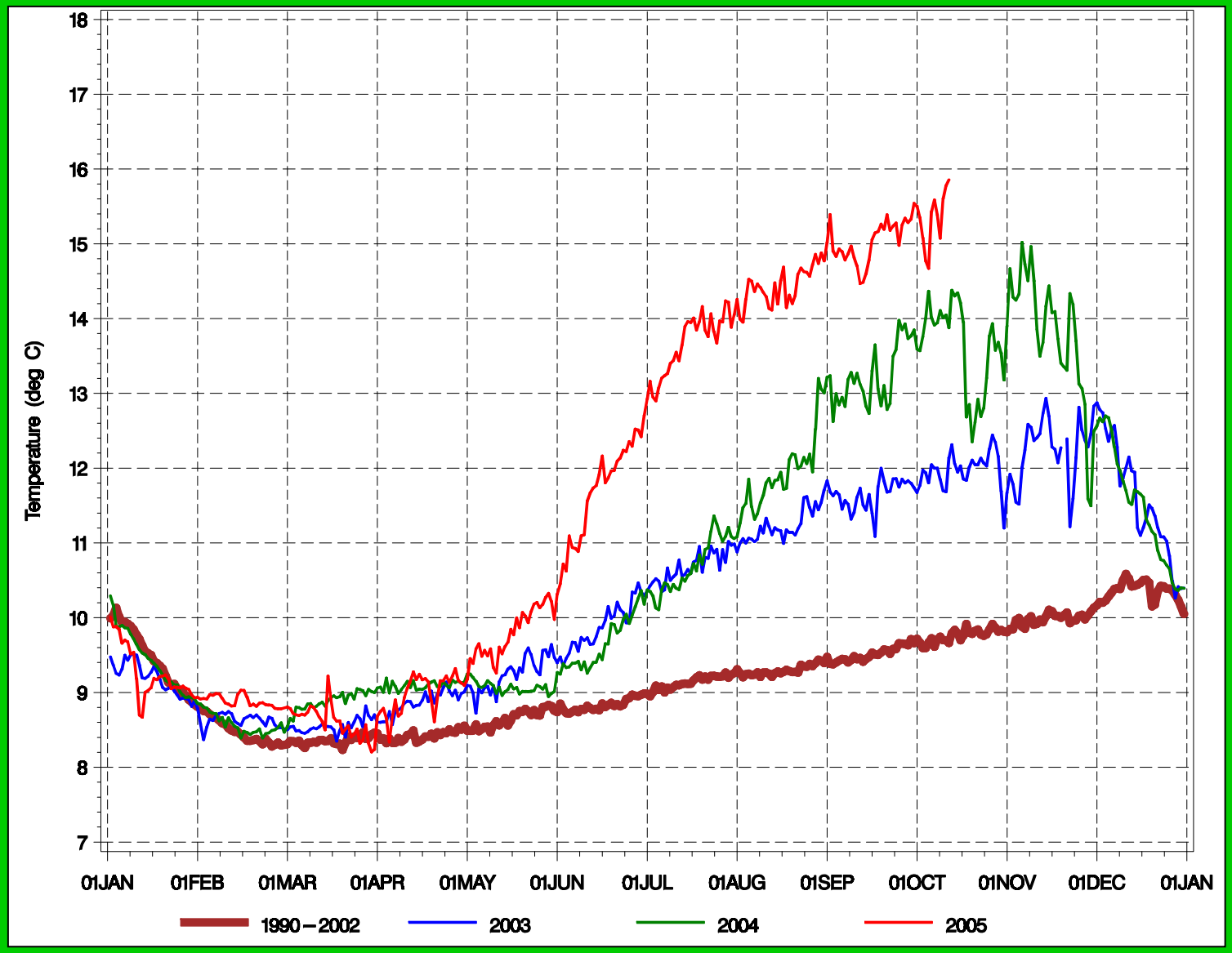
Mean Daily Temperature Patterns below Glen Canyon Dam



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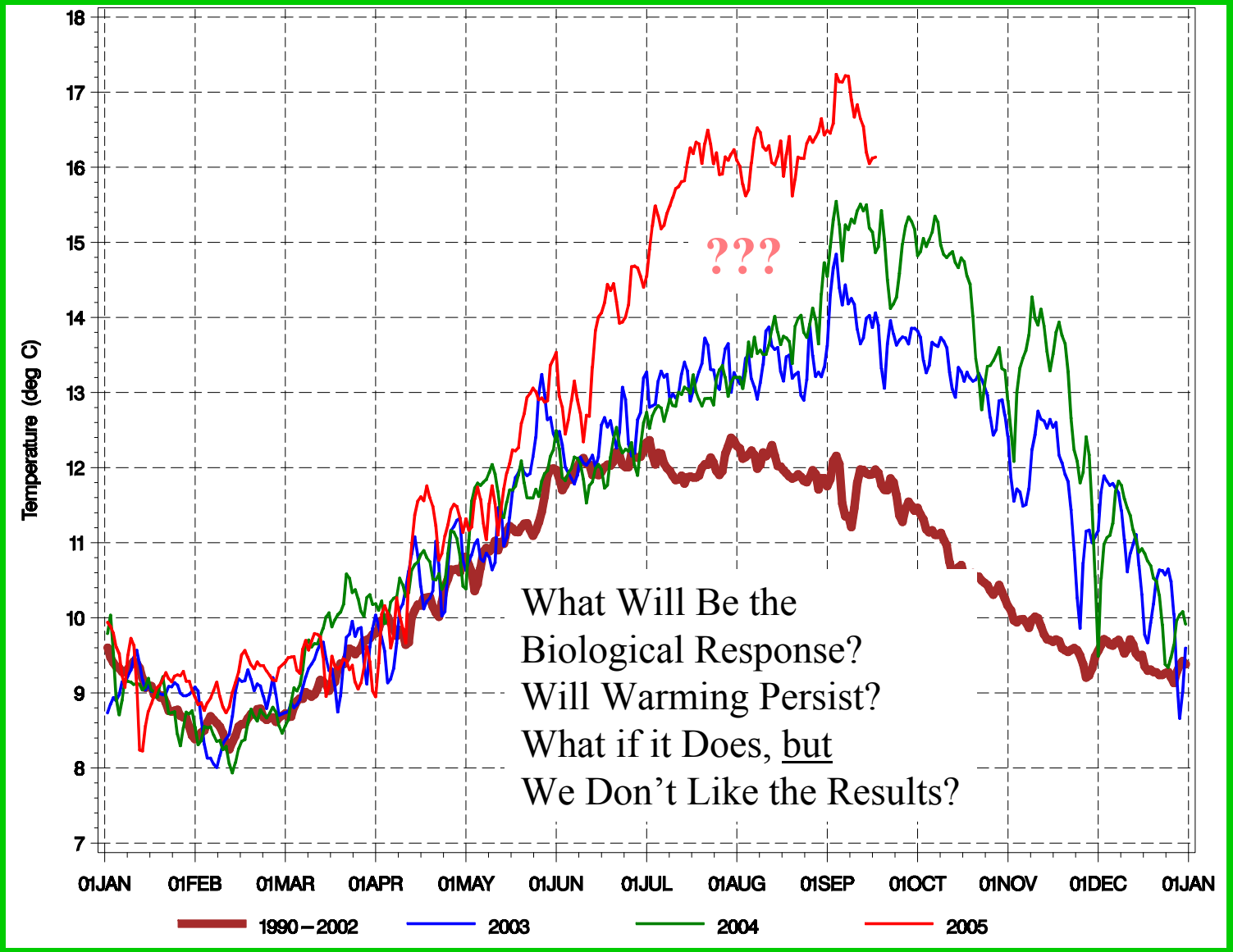
Mean Daily Temperature Patterns at Little Colorado River, RM 61



Mother Nature Got Involved in the Experiment in a Big Way!

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Historical Perspective on EXP

- Let's Step Back and Look
  - MLFF+BHBF is the approved Management Action (baseline)
  - EXP treatments include: reducing coldwater exotics, plus EXP trout suppression flows, and Fall BHBF test
  - Nature decided to add thermal element
  - Managers decided to add LCR Translocation (conservation)
- Comparing Policies: Stable Shoreline Habitat vs. Warmer River
  - "Fluctuating Flows" we decide???
  - "Temperature Control" nature's own device?

Warming was added to the MLFF operation after a decade of not being implemented!

Now What?

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Status of Evolved Design on Basis of Historical Perspective

IMPLEMENT TREATMENT **TREATMENT NOT IMPLEMENTED**

Water Year, w/ HBC & RBT Recruitment Success [+ or -]	Dominant Dam Operation (with Seasonal Variants Toward "Designer Flows," but All Within ROD)	Mechanical Removal of Rainbow Trout in GC (with Progressive Optimization)	Naturally Varied Temperature (Relative to August Average at GCD, RM61) [+, 0, -]	Beach/Habitat Building Flow (Paria, LCR River Sand Inputs Relative to Historic Mean) [+, 0, -]
WY1991, **[0,0]**	EXP Flows	No Exotic Control	**[0,nd]**	[-,-](No BHBF)
WY1992, **[-,+]**	Interim only	No Exotic Control	**[-,-]**	[+,-](No BHBF)
WY1993, **[-,+]**	Interim only	No Exotic Control	**[0,-]**	[+,+](No BHBF)
WY1994, **[-,+]**	Interim only	No Exotic Control	**[-,-]**	[-,-](No BHBF)
WY1995, **[-,+]**	Interim only	No Exotic Control	**[0,0]**	[0,0](No BHBF)
WY1996, **[0,+]**	Interim+BHBF	No Exotic Control	**[0,0]**	[-,-](W/ BHBF)
WY1997, **[0,+]**	MLFF only	No Exotic Control	**[0,0]**	[+,-](No BHBF)
WY1998, **[+,+]**	MLFF+HMF	No Exotic Control	**[0,0]**	[+,-](No BHBF)
WY1999, **[+,+]**	MLFF only	No Exotic Control	**[0,0]**	[+,- (No BHBF)
WY2000, **[+,+]**	MLFF+LSSF+HMF	No Exotic Control	**[0,+]**	[-,-](No BHBF)
WY2001, **[?,+]**	MLFF only	No Exotic Control	**[0,0]**	[+,-](No BHBF)
WY2002, **[?,-]**	MLFF only	No Exotic Control	**[0,0]**	[-,-](No BHBF)
WY2003, **[?,-]**	MLFF+EXP FF	Experimental Fish Removal	**[+,+]**	[-,-](No BHBF)
WY2004, **[?,0]**	MLFF+EXP FF	Experimental Fish Removal	**[+,+]**	[-,-](No BHBF)
WY2005, **[?,?]**	MLFF+EXP FF+Fall Testing	Experimental Fish Removal	**[++,++]**	[+,+](W/ BHBF)
***WY2006, decision [?,?]**	MLFF+Fall Testing	Experimental Fish Removal	**???**	**???**(No BHBF)

Considering Historical Perspective and Recent Results?

Let's Consider the Continued MLFF Options – Option #1

Forward Titration that Could Evolve to a Factorial Design In fact, we have 15 years of a Forward Titration design already behind us with pretty solid data for both sediment and fisheries! The MLFF (and its precursor, Interim operation) was implemented from 1991 through 2001 with no Mechanical Removal or persistent thermal warming event. Then, we continued mostly MLFF operations and implemented MR along with Nature's Own version of the Selective Withdrawal Structure since 2002! Hence, after an 11-year long "block" of MLFF with cold water and unconstrained RBT recruitment, we are now heading into the 4th year of a block of MR coupled with a warm main-channel "event." What to do?

Selective Withdrawal Structure might be a handy tool to have in our experimental kit right now. Pursue Mechanical Removal of Warm & Cold fish species?

MLFF Under the Range of Upper Basin Hydrologic Cycle If we continue monitoring the MLFF under the paired implementation of MR and warming, we have no way of ensuring that warming will continue. Perhaps we continue MR and let nature decide the end of the warm event, or try to manage the system to prolong warming (while building the SWS)?

Managers might choose to enhance the probability of a HBC recruitment signal by recommending stable Fall flows, but that could confound ability to discern MR & Temp from Habitat Stability?

Remember, Carl said "…it ain't just about learning . . . It's about comparing policies that managers are willing to commit to in order to benefit the resources!"

Considering Historical Perspective and Recent Results?

What About Option #2 (add Stable Fall Flows)

Evaluating Stable Flows vs. Mechanical Removal and Warming

What to do in the next 5-year phase (Phase V)?

MLFF Under the Range of Upper Basin Hydrologic Cycle **There is some chance that the Native Fishes response below GCD is dominated by Upper Basin Hydrology (cycles of wet/cold & dry/warm) once interactions with exotics are limited (through use of MR or other factors limiting their success). Perhaps flow stability should only be added to the Forward Titration (our most costly treatment) after a sustained monitoring period under MLFF+MR+Warm Event? If no recruitment occurs by 2011, then a combination of stable flows, MR and warming (with operation of a SWS) could be the next step in the Forward Titration turned Factorial.**

We Should Recognize that In 5 More Years, Our Experiment will be 20-years old!

SWS Could Allow Factorial Design w/ Decade Scale Blocks

IMPLEMENT TREATMENT **TREATMENT NOT IMPLEMENTED**

Water Year, w/ HBC & RBT Recruitment Success [+ or -]	Dominant Dam Operation (with Seasonal Variants Toward "Designer Flows," but All Within ROD)	Mechanical Removal of Rainbow Trout in GC (with Progressive Optimization)	Naturally Varied Temperature (Relative to August Average at GCD, RM61) [+, 0, -]	Beach/Habitat Building Flow (Paria, LCR River Sand Inputs Relative to Historic Mean) [+, 0, -]
WY1998, [+,+]	MLFF+HMF	No Exotic Control	**[0,0]**	[+,-] (No BHBF)
WY1999, [+,+]	MLFF only	No Exotic Control	**[0,0]**	[+,-] No BHBF)
WY2000, [+,+]	MLFF+LSSF+HMF	No Exotic Control	**[0,+]**	[-,-] (No BHBF)
WY2001, [?,+]	MLFF only	No Exotic Control	**[0,0]**	[+,-] (No BHBF)
WY2002, [?,-]	MLFF only	No Exotic Control	**[0,0]**	[-,-] (No BHBF)
WY2003, [?,-]	MLFF+EXP FF	Experimental Fish Removal	**[+,+]**	[-,-] (No BHBF)
WY2004, [?,0]	MLFF+EXP FF	Experimental Fish Removal	**[+,+]**	[-,-] (No BHBF)
WY2005, [?,?]	MLFF+EXP FF+Fall Testing	Experimental Fish Removal	**[++,++]**	[+,+] (W/ BHBF)
***WY2006, decision [?,?]**	MLFF+Fall Testing	Experimental Fish Removal	**[++,++]**	**???** (No BHBF)
WY2007, [?,?]	MLFF only **(Ramping**	Experimental Fish Removal	**SWS Built? [++,++]**	**???**
WY2008, [?,?]	MLFF only **Tests for**	Experimental Fish Removal	**Warm Thermal [++,++]**	**???**
WY2009, [?,?]	MLFF only **Sand Bars**	Experimental Fish Removal	**Regime [++,++]**	**???**
WY2010, [?,?]	MLFF only **Might be**	Experimental Fish Removal	**Extended [++,++]**	**???**
***WY2011, decision [?,?]**	MLFF ? **Added)**	Experimental Fish Removal	**Through [++,++]**	**???**
WY2012, [?,?]	Amended MLFF?	Experimental Fish Removal	**Management [++,++]**	**???**
WY2013, [?,?]	Amended MLFF?	Perhaps Stop EXP MR?	**Action [++,++]**	**???**

Other Options for Experimental Flows 2007-2011?

What About Stakeholder Suggested Modifications of the GCMRC's Recommended Options (#1 or #2) (add Relaxed Winter Fluctuating Flows, Stranding Flows, Altered Ramping Rates, etc.)

MINI EXPERIMENTS FOR CONSIDERATION –

Ramping & Daily Range versus Beach Stability, etc.

Alternative Operations for "Trout Suppression"

Influence of Expanded Daily Variability on Food Base and Associated Aquatic Resources, etc.

All Options are Being Discussed/Considered in SPG and Ongoing Conversations with SA's and Cooperating Scientists