Knowledge Assessment Workshop
Summary & Report Update

Originally Presented at SPG, Phoenix
Sept. 21, 2005

Presented Again for the TWG
November 30, 2005

Objectives of Knowledge Assessment

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

2. Develop strategic science questions that would need to be addressed to reduce uncertainties.

3. Identify modelling, research, monitoring and experimental designs required to answer the science questions.

4. Identify actions that are understood well enough to be treated as management actions if appropriate.

Definitions of Uncertainty

	Very Certain	Certain	Uncertain	Very Uncertain
Prediction	Direction and magnitude of response	Direction only	Direction only	Cannot predict direction
Supported by Data from Colorado River Ecosystem	Peer-reviewed, likely involving a model. Little debate on interpretation of predictions	Peer-reviewed results, no model	Limited data without peer-review and likely debatable inference	No or very limited data
Data from Other Reference Systems	Validated prediction in other system that is considered a good model for CRE	Validated prediction in other system that is a weaker model for CRE	Weaker prediction from other system that is a weak model for CRE	No or very limited data in other systems. Other systems are not good model of CRE
General Theory / Conventional Wisdom	Very Strong	Good	Moderate	Low
Probability that Predicted Direction is Correct	90-100%	70-90%	50-70%	<50%

Physical Resource Matrix

Performance Measure	Increase in GCD Release Water Temperature	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)
Fine- Sediment above 25 kcfs	+	-	+	+	0/+			+	-
Fine-Sediment between 8 and 25 kcfs	+	-	+	+	-	0/+	-	+	-
Fine-Sediment below 8 kcfs	+	-	+	+	-	-	-	+	-
Mainstem Water Temperature	+	-	+	-	-	-	-	+	-
Nearshore Water Temperature	+	-	+	-	-	-	-	+	-

Physical Resources Science Questions

1. Is there a “Flow-Only” (non sediment augmentation) operation that will restore and maintain sandbar habitats over decadal time scales?

2. Is there an optimal strategy for BHBF implementation to manage tributary inputs on an annual to inter-annual time scale?

3. What are the short-term responses of sandbars to BHBFs?

4. What is the rate of change in eddy storage (erosion) during time intervals between BHBFs?

5. How does the grain-size distribution of the deposits affect sandbar stability? Main channel turbidity?

6. What are the effects of ramping rates on sediment transport and sandbar stability?

Power Matrix

Performance Measure	Increase in GCD Release Water Temperature	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)
Hydro Power Load-Following Capacity	-	+	-	-	-	-	-	-	
Hydro Power Replacement Costs	-	+	-	-	-	-	-	-	

Power Science Questions

1. What are the hydropower replacements costs of the MLFF (annually, since 1996)?

2. What are the projected costs associated with the various alternative flow regimes being discussed for future experimental science (as defined in the next phase experimental design)?

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	+	-	+	-	-	-	-	-	-				

Food Base/Fish Matrix

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
Food base	Glen	+		+					-			
	Grand		-						-		+	
Mainstem spawning & incubation	HBC	+							+		+	+
	FMS	+	-						+		+	+
	RBT-Glen		-	+					+	+		
	RBT-Marble											
YOY/Juvenile nearshore rearing	HBC	+	-	+		-		-	+		+	+
	FMS	+	-	+		-		-	+		+	+
	RBT-Glen	+	-	+	-	-	-	-	+	+		
	RBT-Marble		-	+	-	-	-	-	+	+		

Food Base/Fish Matrix (con't)

Performance Measure	Location 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
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	+	-	+	-	-	-	-	-	-		

Food Base/Fish Matrix (con't)

Performance Measure	Location or Species	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		

Performance Measure	Location or Species	Supplementation from Hatchery	Translocation of HBC
Invasive Fish Species	Coldwater		
	Warmwater		
Disease	Asian Tapeworm		
	Whirling Disease		
Adult Population	HBC		+
	FMS		
	RBT #s - Glen		
	RBT Size - Glen		
	RBT #s- Marble		
Angling Opportunity and Quality	Glen		

Food Base Science Questions

1. What are the important pathways, and the rate of flux along them, that link lower trophic levels with fish?

2. How is invertebrate flux affected by water quality (e.g., temperature, nutrient concentrations, turbidity) and dam operations?

3. Are trends in the abundance of fish populations, or indicators from fish such as growth, condition, and body composition (e.g., lipids), correlated with patterns in invertebrate flux?

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?

Rainbow Trout (Glen Canyon) Science Questions

1. To what extent is the adult population of rainbow trout controlled by survival rates during incubation and YoY/juvenile rearing stages, or by changes in growth and maturation in the adult population influencing egg deposition?

2. To what extent is the size of rainbow trout in Glen Canyon controlled by density and food availability?

3. Does increased water temperature result in the occurrence of whirling disease in rainbow trout and if so, what affect will this have on population size and adult growth and condition?

4. Do rainbow trout migrate from Glen to Marble and eastern Grand Canyons? If yes to former, then to what extent do Glen Canyon immigrants support the population in Marble and eastern Grand Canyons?

Rainbow Trout (Marble and Eastern GC) Science Questions

1. Does a decrease in the abundance of rainbow trout in Marble and eastern Grand Canyons result in an improvement in the recruitment rate of juvenile humpback chub to the adult population?

2. Will a limited number of years of mechanical removal of rainbow trout in Marble and eastern Grand Canyons result in a long-term decrease in abundance, or will re-colonization require that mechanical removal be an ongoing management action?

Lees Ferry Angling Science Questions

1. Assuming a trade-off between trout density and size, what is the preferred combination for fishing guides?

2. What GCD flow constraints (ramping rates, daily flow range, etc.) maximize fishing opportunities and catchability?

Riparian Habitat Matrix

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
Fluctuation zone <25 kcfs	Glen & Grand Canyon		+		+	0/+	0/+	0/+	-	+		
Lower Riparian 25-45 kcfs			+		+	0/+	0/+	0/+	0/-	0/+		
Upper riparian zone 45-60 cfs												
> 60 kcfs												

Riparian Habitat Science Questions

1. How do processes occurring at a variety of spatial scales (i.e., population level to community to landscape scales) interface to influence riparian habitat?

2. What is the nature and timing of terrestrial—aquatic linkages, and what is their influence on the recipient habitat?

3. How do terrestrial habitat and cultural resources interface?

4. How do flows affect productivity and decomposition rates of riparian vegetation?

5. How do warmer releases affect viability and productivity of native/non-native vegetation?

6. To what extent and in what respects can BHBF's (magnitude and frequency) achieve reduction of exotic species?

7. How could monthly volumes be changed to beneficially affect riparian habitat?

Recreation Matrix

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
Campsites (available campable area)		+	-		+	+			+	-		
Access to attraction sites			-						+			
Rafting navigability					+	+			0/-	0/+		
qw and human health		-			+	+	+	+	-	+		
safety		+							+	-		
Recreational experience		+	-						0/-	+		

Recreation Science Questions

1. How do dam controlled flows affect visitors' recreational experiences, and what is/are the optimal flows for maintaining a high quality recreational experience in the CRE?

2. What are the drivers for recreational experience in the CRE, and how important are flows relative to other drivers in shaping recreational experience outcomes?

3. How do varying flows positively or negatively affect campsite attributes that are important to visitor experience?

4. What are the minimum size, quantity, distribution and quality of campsites to meet NPS goals for visitor experience?

5. Can changes in quality of recreational experience be quantified for single event opportunities (e.g., white water rafting, angling, camping) vs. multi-opportunity experiences (e.g. white water rafting with overnight camping)?

Recreation Science Questions (Con't)

6. How can safety & navigability be reliably measured relative to flows?

7. How do varying flows positively or negatively affect visitor safety, health, and navigability of the rapids?

8. How do varying flows positively or negatively affect group encounter rates, campsite competition, and other social parameters that are known to be important variables of visitor experience?

Historic Properties Matrix

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
Conservation> 45 kcfs stage	arch. sites	+	-		+	0/+			0/+	-		
Conservation <45 kcfs		+	-		+	0/+				-		
Conservation> 45 kcfs stage	TCPs										-	-
Conservation <45 kcfs											-	-

Cultural Resource Questions

1. Do dam controlled flows affect (increase or decrease) rates of erosion and vegetation growth at arch sites and Traditional Cultural Property (TCP) sites, and if so, how?

2. If dam controlled flows are contributing to (influencing rates of) arch site/TCP erosion, what are the optimal flows for minimizing future impacts to historic properties?

3. How do flows impact the sedimentary matrix of the higher terrace deposits, and what kinds of important historical/legacy information about the CRE ecosystem is being lost due to ongoing erosion of these older Holocene sedimentary deposits?

4. How effective are check dams in slowing rates of erosion at archaeological sites over the long term?

5. What are the TCPs in the CRE, and where are they located?

Cultural Resource Questions (Con't)

6. How can tribal values/data/analyses be appropriately incorporated into a western science-driven adaptive management process in order to evaluate the effects of flow operations and management actions on TCPs?

7. Are dam controlled flows affecting TCPs and other tribally-valued resources in the CRE, and if so, in what respects are they being affected, and are those effects considered positive or negative by the tribes who value these resources?

KAW Draft Report Update

- Comments solicited from workshop participants in September

- Ecometric Research & GCMRC currently revising draft report in response to comments

- Report is to be finalized by winter 2005-06

Approaches to Resolve Science Questions (Native Fish)

- Almost all questions require manipulations of flow and temperature from GCD and long-term data.
- Try approach for native fish as it is very important GCD AMP goal.
- First step is to make a relatively long-term decision on which strategies will be evaluated (next 5 yrs).
- After that, can look at smaller-scale manipulations that will not confound main treatments.

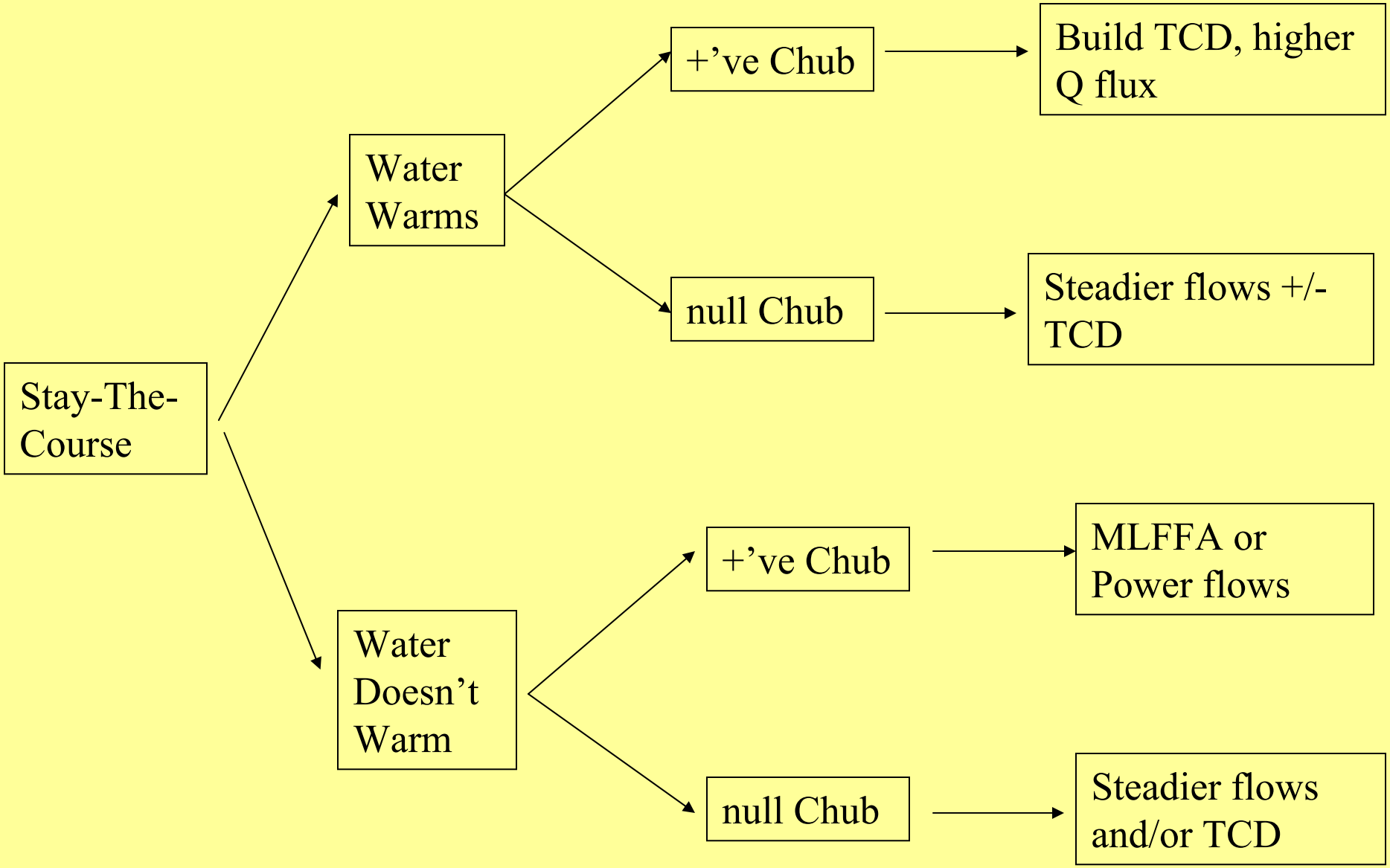
Treatments for Native Fish Restoration

Daily Flow Fluctuations	**Water Temperature**	**Non-Flow Options**
Maintain (MLFFA)	Natural pattern	Mechanical removal
Increase	TCD	Translocation
Decrease	Decrease monthly volumes in summer	Hatchery (juvenile production)

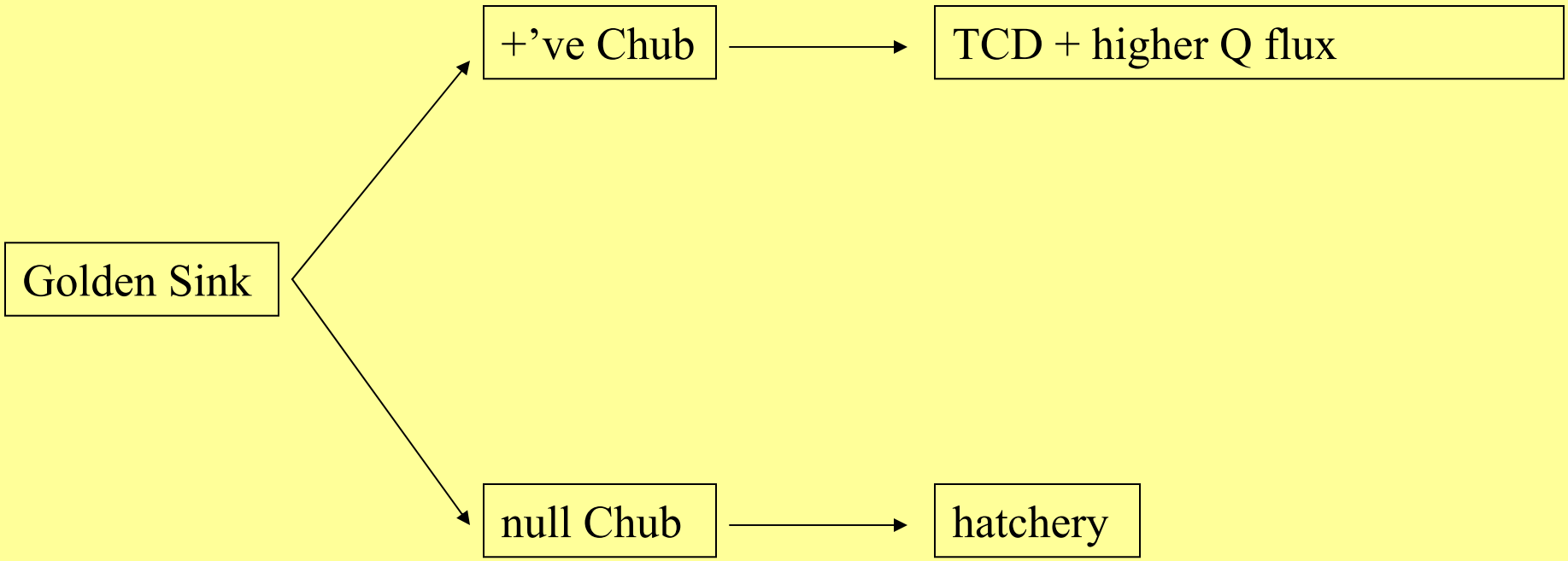
Major Experimental Options to Resolve Uncertainties in HBC Fish Response to GCD Operations

	Golden Sink	Stay-The-Course	Power
Benefits to Resources	Chub, sand storage, recreation, cultural		Power, Riparian
Daily Fluctuations	Decrease	Maintain (MLFFA)	Increase
Water Temperature	TCD or stabilize monthly volumes	Natural basin hydrology/ increased water removals	Natural basin hydrology/ increased water removals
Non-Flow	MR & Translocation	MR & Translocation	MR & Translocation
# of Treatments	3-4	1-2	2-3
Learning	Maximum but confounded (does RPA work?)	Least confounded but little learning about GCD if reservoir fills	Confounded if no chub response

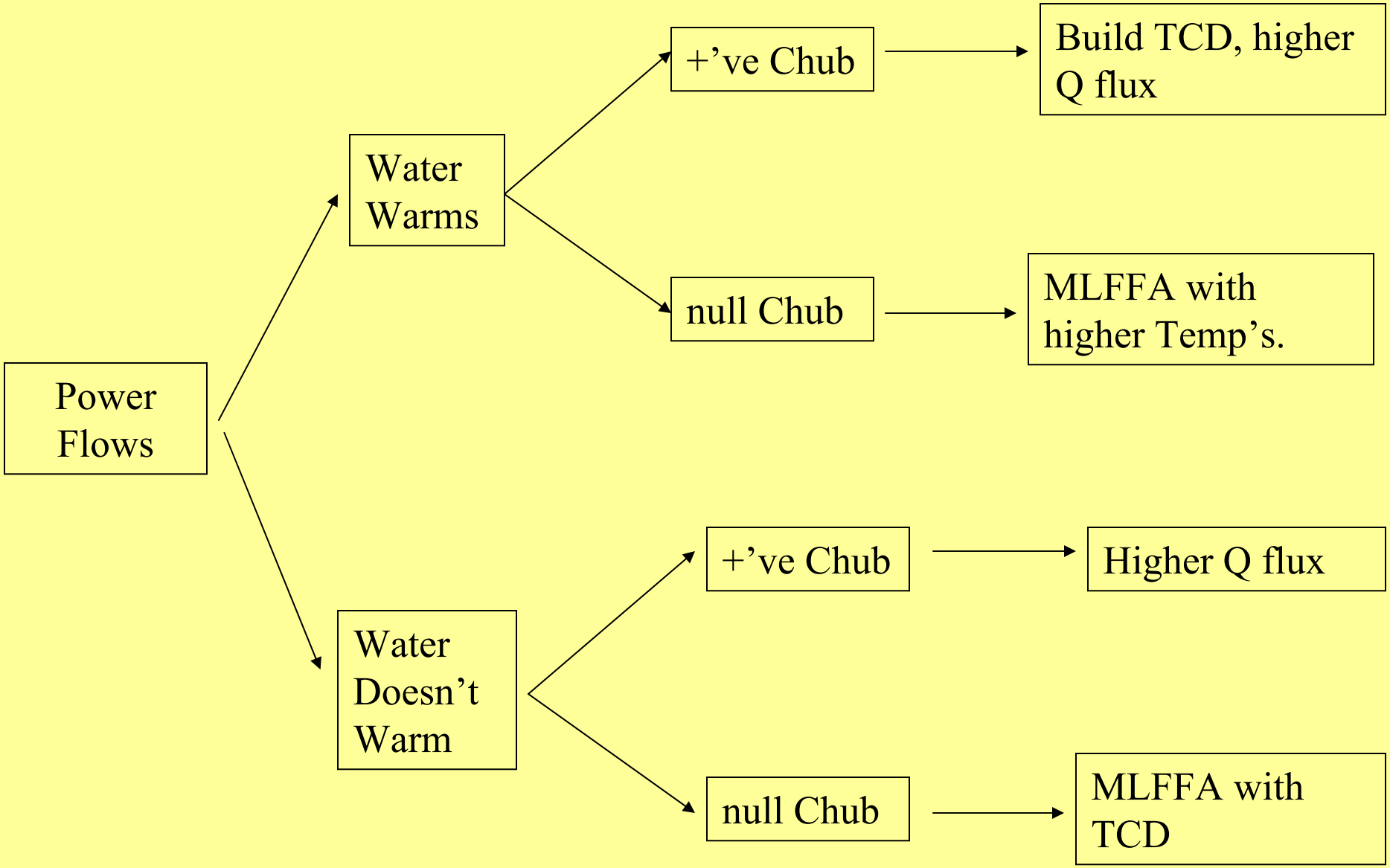
Stay-The-Course Experimental Sequence



Golden Sink Experimental Sequence



Power Flows Experimental Sequence



Food Base/Fish Matrix (Flow Flux Response)

Performance Measure	Location or Species	Overall Effect of Increased Fluctuations Relative to MLFFA	Increase Upramp Rate	Increase Downramp Rate	Increase and/or Lengthen Maximum Daily Flow	Increase Daily Variation in Flow	Decrease Minimum Daily Flow	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	-				-			

Food Base/Fish Matrix (Flow Flux Response, con't)

Performance Measure	Location or Species	Overall Effect of Increased Fluctuations Relative to MLFFA	Increase Upramp Rate	Increase Downramp Rate	Increase and/or Lengthen Maximum Daily Flow	Increase Daily Variation in Flow	Decrease Minimum Daily Flow	Supplementation from Hatchery	Translocation of HBC
Invasive Fish Species	Coldwater	-				-	+		
	Warmwater	-				-	+		
Disease	Asian Tapeworm								
	Whirling Disease								
Adult Population	HBC								+
	FMS								
	RBT #s - Glen	-				-	-		
	RBT Size - Glen	+				+	+		
	RBT #s- Marble	-				-	-		
Angling Opportunity and Quality	Glen	-	-		-	-	-		