

Glen Canyon Dam
Adaptive Management Work Group
Ad Hoc Committee on Strategic Planning

Report to AMWG, January 2001

Strategic Plan Update

This document consists of the following components, which should be viewed as an integrated whole. Together, they guide the work of the Glen Canyon Dam Adaptive Management Work Group.

- Vision and Mission
- Principles
- Goals
- Objectives
- Glossary

Vision and Mission

The Grand Canyon is a homeland for some, sacred to many, and a national treasure for all. In honor of past generations, and on behalf of those of the present and future, we envision an ecosystem where the resources and natural processes are in harmony under a stewardship worthy of the Grand Canyon.

We advise the Secretary of the Interior on how best to protect, mitigate adverse impacts to, and improve the integrity of the Colorado River ecosystem affected by Glen Canyon Dam, including natural biological diversity (emphasizing native biodiversity), traditional cultural properties, spiritual values, and cultural, physical, and recreational resources through the operation of Glen Canyon Dam and other means.

We do so in keeping with the federal trust responsibilities to Indian tribes, in compliance with applicable federal, state, and tribal laws, including the water delivery obligations of the Law of the River, and with due consideration to the economic value of power resources.

This will be accomplished through our long-term partnership utilizing the best available scientific and other information through an adaptive ecosystem management process.

Principles

The Glen Canyon Dam Adaptive Management Work Group embraces the following Principles. They guided development of the Goals and Objectives for the Glen Canyon Dam Adaptive Management Program (GCDAMP). These Principles are:

1. The Goals represent a set of desired outcomes that together will accomplish our Vision and achieve the purpose of the Grand Canyon Protection Act. Some of the Objectives and actions that fall under these Goals may not be the responsibility of the GCDAMP, and may be funded by other sources, but are included here for completeness.
 2. The construction of Glen Canyon Dam and the introduction of non-native species have irreversibly changed the Colorado River ecosystem.
 3. Much remains unknown about the Colorado River ecosystem below Glen Canyon Dam and how to achieve GCDAMP ecosystem Goals.
 4. The Colorado River ecosystem is a managed ecosystem. An ecosystem management approach, in lieu of an issues, species, or resources approach, will guide our efforts. Management efforts will prevent any further human-induced extirpation or extinction of native species.
 5. An adaptive management approach will be used to achieve GCDAMP ecosystem Goals, through experimentation and monitoring, to meet the intent of the Grand Canyon Protection Act, the Environmental Impact Statement, and the Record of Decision.
 6. Management actions, [including changes in dam operations](#), will be tried that attempt to return ecosystem patterns and processes to their range of natural variability. When this is not appropriate, [or beyond the range of operational flexibility of the dam](#), experiments will be conducted to test other approaches.
 7. Because management actions to achieve a Goal may benefit one resource or value and adversely affect another, those action alternatives that benefit all resources and values will be pursued first. When this is not possible, actions that have a neutral impact, or as a last resort, actions that minimize negative impacts on other resources will be pursued, consistent with the final Glen Canyon Dam EIS and the Record of Decision.
 8. [If the target of a management objective proves to be inappropriate, unrealistic, or unattainable, the AMP will reevaluate that target and the methods used to attain it.](#)
- ~~8.9.~~ 8.9. Recognizing the diverse perspectives and spiritual values of the stakeholders, the unique aesthetic value of the Grand Canyon will be respected and enhanced.

Goals

1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.
2. Maintain or attain viable populations of existing native fish and remove jeopardy from humpback chub and razorback sucker.
3. Restore populations of extirpated species, as feasible and advisable.
4. Maintain a wild reproducing population of rainbow trout above Lees Ferry the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.
5. Maintain or attain viable populations of Kanab ambersnail.
6. Protect or improve the biotic riparian and spring communities.
7. Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.
8. ~~Increase fine~~ Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

~~Goal 8. Protect the presence of southwestern willow flycatcher in a manner consistent with riparian ecosystem goals~~

9. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.
10. Maintain ~~or increase power capacity~~ and energy generation, and increase where feasible and advisable, within the framework of GCDAMP ecosystem goals.
11. Preserve, protect, manage, and treat cCultural resources ~~within the river corridor shall be preserved, protected, managed and treated~~ for the inspiration and benefit of past, present and future generations.
12. Maintain a high-quality monitoring, research, and adaptive management program. (These goals are now part of Goal 12: Build a broad, effective, outreach program. Broaden the funding base to achieve GCDAMP goals and objectives.)

Goal 1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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The target for all the Management Objectives in Goal 1 is adequate food availability to support trout and native fish above the Paria River, and native fish below the Paria River. <u>Linkages</u> : See the numbers of fish desired under Goals 2, 3, and 4.																																		
1.1 (1 and 3)	Maintain or attain	<u>Algae and periphyton</u> <u>Primary producers: algae on hard substrates, rooted macrophytes on soft substrates, and diatoms</u>	Biomass	Mainstem from Glen Canyon Dam to <u>the Paria River in both pools and on cobble bars identified by specific sampling sites</u>	$17.5x \pm y$ g/m ² (Cobble) ⁽²⁷⁾ $2.7 a \pm b$ g/m ² (Pool) ⁽²⁷⁾ (To be provided from Shannon et al.)		150 g/m ² ⁽²⁷⁾ $x \pm y$ g/m ² (Cobble) $a \pm b$ g/m ² (Pool) (Need to resolve differences between data from Shannon et al. and AGFD.)	Also see McKinney et al. 1999 ⁽²²⁾ <u>The small group suggested the target should be the average of 1996 and 1997 data which they believe represents the best biomass estimates for the period in which data is available, and because they appeared to be good years to support the desired species.</u>																										
			Composition		49.60% <u>Cladophora</u> 33.10% <u>Chlorophyta</u> -9.10% <u>Fontinalis</u> -3.35% <u>Chromophyta</u> -2.40% <u>Rhodophyta</u> -2.50% <u>Cyanobacteria</u> (27)	Obtain from literature <u>Information Need</u>	<u>Metric is % of algal species that support upright diatoms.</u> <u>Given the change in composition, the idea of Cladophora as a keystone species has been called into question. Scientists have said composition is an Information Need and should not be broken down below algae and macrophytes at this point in time.</u>																											
					<table border="1"> <thead> <tr> <th>River Mile</th> <th>% Algae</th> <th>% Macrophytes</th> </tr> </thead> <tbody> <tr> <td colspan="3" style="text-align: center;"><u>POOLS</u></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>IN</u></td> <td style="text-align: center;"><u>IN</u></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>IN</u></td> <td style="text-align: center;"><u>IN</u></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>IN</u></td> <td style="text-align: center;"><u>IN</u></td> </tr> <tr> <td colspan="3" style="text-align: center;"><u>COBBLES</u></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>IN</u></td> <td style="text-align: center;"><u>IN</u></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>IN</u></td> <td style="text-align: center;"><u>IN</u></td> </tr> <tr> <td></td> <td style="text-align: center;"><u>IN</u></td> <td style="text-align: center;"><u>IN</u></td> </tr> </tbody> </table>	River Mile	% Algae	% Macrophytes	<u>POOLS</u>				<u>IN</u>	<u>IN</u>		<u>IN</u>	<u>IN</u>		<u>IN</u>	<u>IN</u>	<u>COBBLES</u>				<u>IN</u>	<u>IN</u>		<u>IN</u>	<u>IN</u>		<u>IN</u>	<u>IN</u>		
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Production	Information Need	Information Need	<u>Metric is g/m²/time of Cladophora</u>																															

Goal 1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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The target for all the Management Objectives in Goal 1 is adequate food availability to support trout and native fish above the Paria River, and native fish below the Paria River. <u>Linkages</u> : See the numbers of fish desired under Goals 2, 3, and 4.							
1.2 (2)	Maintain or attain	Benthic invertebrates	Biomass	Mainstem from Glen Canyon Dam to Paria River	5.0 x +/- y g/m² (Cobble)⁽²⁷⁾ 1.0a +/- b g/m² (Pool)⁽²⁷⁾	5000 g/m²(27) x +/- y g/m² (Cobble) a +/- b g/m² (Pool)	Also see McKinney et al. 1999 ⁽²²⁾
			Composition		-0.4% Worms -3.6% Gammarus -5.5% Oligochaetes -0.1% Simulium 28.8% Midges -3.8% Miscellaneous 57.7% Gastropoda (Cobble)⁽²⁷⁾ 9999 -1.0% Worms -0.9% Gammarus 35.7% Oligochaete 22.3% Midges (Pool)⁽²⁷⁾ <u>Cobble:</u> % Tubificids % Gammarus % Chironomids % Gastropods % Other <u>Pool:</u> % Tubificids % Gammarus % Chironomids % Gastropods % Other (Data to be filled in by Joe Shannon and AGFD.)	Information Need	Metric is relative % of species.
			Production		Information Need	Information Need	Metric is g/m ² /time

Goal 1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.

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1.3 (3)	Maintain or attain	Aquatic macrophytes	Biomass	Mainstem from Glen Canyon Dam to Paria River	Information Need		Information Need			
			Composition		Information Need		Information Need			
			Production		Information Need		Information Need	Metric is g/m ² /time		
1.34 (4 and 6)	Maintain or attain	Primary producers: algae on hard substrates <u>and</u> , rooted macrophytes on soft substrates, <u>and diatoms</u>	Biomass	Mainstem below the Paria River on cobble bars identified by specific sampling sites	<u>RM River Mile</u>	g/m ²	50 g/m ² (27)			
					COBBLE					
					2					
					61					
					68					
					127					
			205							
			Composition		<u>RM River Mile</u>	% Algae	% Macro-phytes		Information Need	Metric is relative % of algal species. MAMB is for miscellaneous algae, macrophytes, and bryophytes
					POOLS					
					2					
					61					
					68					
					127					
					205					
					COBBLE					
2										
61										
68										
127										
205										

Goal 1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.

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1.45 (5)	Maintain or attain	Benthic invertebrates	Biomass	Mainstem below the Paria River	0.960 g/m ² (Cobble) ⁽²⁷⁾ 0.054 g/m ² (Pool) ⁽²⁷⁾	Obtain from literature <u>To be provided based on 1996-97 data.</u>	
			Composition		-0.4% Worm -7.1% Gammarus -8.2% Oligochaete -4.3% Simulium 55.4% Chironomid -3.6% Miscellaneous 21.0% Gastropod (Cobble)⁽²⁷⁾ -0.4% Worm -1.1% Gammarus 30.1% Oligochaete 14.3% Simulium 48.9% Chironomid -1.2% Miscellaneous -4.0% Gastropod (Pool)⁽²⁷⁾ <u>Cobble:</u> % Tubificids % Gammarus % Chironomids % Gastropods % Other <u>Pool:</u> % Tubificids % Gammarus % Chironomids % Gastropods % Other	Obtain from literature	Metric is relative % of species.
			Production		Information Need	Information Need	Metric is g/m ² /time

Goal 1. Protect or improve the aquatic foodbase so that it will support viable populations of desired species at higher trophic levels.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments												
			Distribution		—20 Worms —500 Gammarus —120 Oligochaetes —10 Simulium 2150 Midges —20 Miscellaneous 1580 Gastropod (Cobble at Mile 2) ⁽²⁷⁾	Information Need													
1.56 (7)	Maintain or attain	Foodbase drift: <u>Diptera</u> <u>Gammarus</u> <u>Other Bugs</u> <u>CPOM</u> <u>FPOM</u> <u>DOC</u>	Abundance	Mainstem below GCD	0.024 g/m ³ /s (Plants) 0.056 g/m ³ /s (Detritus) 0.001 g/m ³ /s (Inverts)	Obtain from literature To be provided based on 1996-97 data.)													
					<table border="1"> <tr> <td><u>River Mile</u></td> <td><u>AFDW</u></td> </tr> <tr> <td><u>2</u></td> <td></td> </tr> <tr> <td><u>61</u></td> <td></td> </tr> <tr> <td><u>68</u></td> <td></td> </tr> <tr> <td><u>127</u></td> <td></td> </tr> <tr> <td><u>205</u></td> <td></td> </tr> </table>		<u>River Mile</u>	<u>AFDW</u>	<u>2</u>		<u>61</u>		<u>68</u>		<u>127</u>		<u>205</u>		
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<u>127</u>																			
<u>205</u>																			
			Composition		29.2% (Plants) 69.3% (Detritus) —1.1% (CPOM inverts) —0.4% (FPOM inverts)	Obtain from literature													

Goal 2. Maintain or attain viable populations of existing native fish and remove jeopardy from humpback chub and razorback sucker.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
2.1 (8)	Maintain or attain	Humpback chub (150 mm and larger) <u>(Length is based on the size at which a HBC is able to be pit-tagged.)</u>	Abundance	<u>LCR and mainstem within 3 miles of LCR aggregation (The definition of the LCR aggregation will be resolved following completion of the stock assessment workshop and the PEP review.)</u>	<u>8096-4330-4811 individuals⁽³⁻³⁶⁾ with a mean of 4508 individuals</u>	Information Need	The target is viable populations and removal of jeopardy. Target to be based on 91-96 population estimate, PVA, & N _e .
				<u>Mainstem except within 3 miles of the LCR Eight mainstem aggregations</u>	<u>225 individuals⁽³⁻³⁶⁾ Information Need</u> <u>?? Confidence interval with a mean of 225 individuals??</u>	Information Need	
2.2 (9)	Maintain or attain	Humpback chub (51 mm to 150 mm)	<u>Abundance Year class strength</u>	<u>LCR aggregation LCR and mainstem within 3 miles of LCR</u>	<u>Obtain from literature Information Need. Consider using a CPUE index for different year classes, at some place in the LCR at some time during the year.</u>	<u>Information Need. Intended to be an index that will indicate spawning success.</u>	The target is viable populations and removal of jeopardy. Metric is “catch per unit effort” (CPUE). See Gorman and Bramblett. ⁽⁹⁾ See synthesis by Coggins.
				<u>Eight mainstem aggregations Mainstem except within 3 miles of the LCR</u>	<u>0-74 captures/trip⁽⁹⁾ Information Need</u>	Information Need	

Goal 2. Maintain or attain viable populations of existing native fish and remove jeopardy from humpback chub and razorback sucker.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments	
2.3 (new)	Maintain or attain	Humpback chub (> 200 mm) (This is the length at which 50% of the fish are thought to be sexually mature.)	Recruitment	LCR aggregation	Information Need	Information Need	Target is viable populations and removal of jeopardy.	
				8 mainstem aggregations	Information Need	Information Need		
2.4 3 (10)	Establish	Humpback chub	PopulationsSpawning aggregation	CRE downstream of GCD	One self-sustaining populationspawning aggregation in the LCR	One additional self-sustaining populationA second spawning aggregation	The target is viable populations and removal of jeopardy.	
2.5 4 (11)	Attain	Humpback chub	Condition	LCR aggregationLCR and mainstem within 3 miles of LCR	Information Need	Information Need. There should be a minimum threshold.	The target is viable populations and removal of jeopardy. PEP should be asked to evaluate the method that would be used to calculate condition and the value to be established as the threshold.	
				8 mainstem aggregationsMai nstem except within 3 miles of the LCR	Information Need	Information Need		
				HealthDisease and other parasites	LCR aggregationLCR and mainstem within 3 miles of LCR	Information Need		Information Need
				8 mainstem aggregationsMai nstem except within 3 miles of the LCR	Information Need	Information Need		

Goal 2. Maintain or attain viable populations of existing native fish and remove jeopardy from humpback chub and razorback sucker.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
2.5 (12)	Maintain or attain	Humpback chub	Spawning	LCR and mainstem within 3 miles of LCR	Information Need	Information Need	See Gorman and Bramblett. ⁽⁹⁾ The target is viable populations and removal of jeopardy.
				Mainstem except within 3 miles of the LCR	Information Need	Information Need	
2.6 (13)	Reduce	Non-native Native fish	Predation on native fish	CRE below GCD LCR	Information Need	Information Need	Metric for 'predation on native fish' is rate of predation. See Gorman and Bramblett. ⁽⁹⁾ The target is reduction of non-native fish predation and competition so they it does not impinge on native fish viability. Suggested metrics for this MO are stomach content analysis, abundance, and distribution. Linkages: The native fish MOs in Goal 2 and Goal 3.
			Mortality due to non-native fish predation as a % of overall mortality	Mainstem	Information Need	Information Need	
			Competition with native fish	CRE below GCD	Information Need	Information Need	
2.7 (14)	Attain	Razorback sucker	Populations Abundance	CRE below GCD	0 individuals ⁽⁹⁾	Information Need	Target is <u>derived from the</u> capability of the habitat to support the species.
2.8 (15)	Maintain	Flannelmouth sucker	Abundance and distribution	CRE below GCD	?? AGFD to provide ⁽⁹⁾	Information Need	Appropriate metric to be determined. The target is viable populations and removal of jeopardy.
			Distribution		?? AGFD to provide ⁽⁹⁾	Information Need	
		Bluehead sucker	Abundance		?? AGFD to provide ⁽⁹⁾	Information Need	
			Distribution		?? AGFD to provide ⁽⁹⁾	Information Need	
		Speckled dace	Abundance		?? AGFD to provide ⁽⁹⁾	Information Need	
			Distribution		?? AGFD to provide ⁽⁹⁾	Information Need	

Goal 3. Restore populations of extirpated species, as feasible and advisable.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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3.1 (16)	Restore	Colorado pikeminnow	Abundance	CRE downstream of GCD	0 individuals ⁽⁹⁾	Information Need	
		Bonytail			0 individuals ⁽⁹⁾	Information Need	
		Roundtail Chub			0 individuals ⁽⁹⁾	Information Need	
		River otter			0 individuals ⁽¹⁰⁾	Information Need	

Goal 4. Maintain a wild reproducing population of rainbow trout above Lees Ferry the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.

NOTE ON GOAL 4: The purpose of this goal is recreation. It is limited by MO 13.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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<p>This goal is self-explanatory and does not need a separate qualitative target. Linkages: See Issue Paper B (trout).</p>									
4.1 (17)	Maintain or attain	Rainbow trout (RBT)	Abundance	Mainstem from Glen Canyon Dam to Paria River	260,000 +/- 30,000 Age II+ individuals ⁽²³⁾	100,000 250,000 Age II+ individuals	<p>An upper threshold level of population abundance should be developed that triggers some action to reduce abundance so population densities do not drive the other suite of RBT indicators below acceptable levels. Target is the level at which trout do not impinge on native fish.</p>		
					<u>Electrofishing CPUE</u>	<u>Information Need</u>			
					<u>Information Need</u>	<u>Information Need</u>			
					Proportional Stock Density (see below)	15%		Information Need	Might replace measure of “length at age” in the future. Value of metric needs to be assessed.
					Length at age	15” by Age III ⁽²³⁾		15 – 18” by Age III	
					Condition	$W_r = 0.82^{(23)}$		$W_r = 0.90$	
					Whirling disease and other parasitic infections	Absence		Absence	
Spawning habitat	Information Need	Information Need	Metric is quality and abundance of habitat.						
4.2 new	Maintain or attain	Rainbow trout	Natural recruitment		100%	100%	<u>This MO restates and measures the goal.</u>		

Goal 4. Maintain a wild reproducing population of rainbow trout above Lees Ferry the Paria River, to the extent practicable and consistent with the maintenance of viable populations of native fish.

NOTE ON GOAL 4: The purpose of this goal is recreation. It is limited by MO 13.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
4.23 new	Maintain or attain Limit	Lees Ferry RBT	Distribution	CRE b Below the Paria River	Information Need	Information Need. Some number that suggests minimal competitive or predator / prey effect on downstream native fish. Need research and data that demonstrate predator / prey and competitive effect.	Target is some number that suggests minimal competitive or predator / prey effect on downstream native fish.

Proportional Stock Density is the ratio that results by dividing the number of fish greater than 16” by the number of all fish greater than 12”. This provides a measure of the abundance of fish at a certain size, which should translate into a target for both abundance and length at age.

Goal 5. Maintain or attain viable populations of Kanab ambersnail.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
5.1 (24)	Attain and maintain	Kanab ambersnail	Population	Vasey's Paradise	7100 (April 1999) 6400 (May 1999) 20,000 (July 1999) 35,000 (Sept/Oct 1999) (Individuals below 70,000 cfs stage) ⁽²⁴⁾	Information Need (to be measured in the spring and before any Management Action that may affect the population)	The metric is the population parameter(s) that indicate viability. Target is a viable population. "Viable" includes the entire population, not just those below 70,000 cfs. Management Action: monitor the KAS populations at Keyhole, Elves, and Deer Creek
5.2 (25)	Maintain	Kanab ambersnail	Habitat	Above some stage level at Vasey's Paradise (stage level is an Information Need)	82-99 m ² monkeyflower and 36.6 m ² watercress below 70,000 cfs stage. Information Need (for above new stage level when it is determined)	Information Need. A n ten -year running average greater than or equal to 50 y% of the total area of occupied habitat measured at Vasey's in March 1996, with a minimal level TBD.	Target is level needed to sustain a viable population. Purpose is to limit human impact, by intentional flooding or other actions, to habitats occupied by Kanab ambersnail.

Goal 6. Protect or improve the biotic riparian and spring communities.

NOTE ON GOAL 6: This goal is intended to help achieve the biological, cultural, and recreational goals.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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The target is an achievable and appropriate mix of ~~these four~~ types of communities: marsh, open sand beach, old high water zone (OHWZ), and new high water zone (NHWZ). All four communities are important for maintaining the diversity of wildlife. The Old High Water Zone is a high priority because of the threat of losing it. One way of maintaining it is through high flows, which may have a negative effect on marshes and New High Water Zones.

Considering the legal and regulatory mandates of the NPS to protect natural landscapes and native species and communities, considering regenerative capabilities, and recognizing the dynamic and successional nature of these communities, the other three zones would be a lower priority.

6.1 (29)	Maintain	Marsh	Abundance	CRE below GCD	1215 patches (4.6 ha) ⁽⁷⁾	For a 40x -year running average of 1000y or more marsh patches $\geq 10 \text{ m}^2$, as determined by standard criteria for wetland species, soil type, and wetted area.	See Kearsley ⁽¹⁵⁾ and Stevens et al. ⁽²⁹⁾ .
			Composition		Information Need	No loss of native species. Species are assumed still to be present when they have been detected by monitoring within the last 10 years.	
			Area		Information Need	For a 40x -year running average area equal to +/- 50y % of the area defined by aerial imaging in 2000.	

Goal 6. Protect or improve the biotic riparian and spring communities.

NOTE ON GOAL 6: This goal is intended to help achieve the biological, cultural, and recreational goals.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
6.2 (30)	Maintain	New high water zone <u>community</u>	Patch number and distribution	CRE below GCD	Information Need	Information Need	<u>Target is to ensure that NHWZ vegetation is not eliminated from any reaches where it already occurs. Metric is number of miles per reach.</u> In all river reaches where it was documented by aerial <u>imaging</u> photography in <u>2000</u> 1984, <u>the target is to allow for scouring of some NHWZ vegetation due to periodic high flows, and to allow its return through successional processes.</u>
			Composition		Information Need	<u>For no loss of native plant or animal species.</u> Species are assumed still to be present when they have been detected by monitoring within the last 10 years.	<u>Target is to allow no loss of native plant or animal species.</u>
			Area		Information Need	For a <u>40x</u> -year running average area equal to +/- <u>50y</u> % of the area defined by aerial imaging in 2000. <u>In any given year, the vegetated area should not be less than the area measured in 1983 or 25% of the area measured in 2000 (whichever is less).</u>	NHWZ vegetation & sand beaches occur in the same strip of land. An increase to NHWZ vegetation will reduce the amount of open sand, and vice versa. These objectives are therefore closely linked to each other, as well as to the beach-building effects of BHBFs.

Goal 6. Protect or improve the biotic riparian and spring communities.

NOTE ON GOAL 6: This goal is intended to help achieve the biological, cultural, and recreational goals.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
6.3 (31)	Maintain	Old high water zone	Abundance	CRE below GCD	Information Need In 1992, there was an estimated 1,870 acres of OHWZ vegetation (cite: Stevens 1992).	Information Need	Target is no loss of area.
			Composition		Information Need	Information Need	
			Distribution		Information Need	Information Need	
6.4 (32)	Maintain	Sand Beach	Abundance	CRE below GCD	Information Need	Information Need	See Kearsley⁽¹⁵⁾ and Stevens et al.⁽²⁹⁾
			Composition		Information Need	Information Need	
			Distribution		Information Need	Information Need	
6.54 (33)	Maintain	Culturally important species	Abundance	CRE below GCD	157 species (Plants) ^(21;30)	Information Need	
			Distribution		Information Need	Information Need	
6.65 (34)	Reduce	Invasive non-native species	Abundance (Abundance refers to number of individuals within the species. These species should be limited to invasive ones, not just non-natives.)	CRE below GCD	95+ species (Plants) ⁽²⁸⁾ 3 species (Birds) ⁽²⁸⁾	Range to be determined. No new non-native species. Invasive non-native species cover </= x% of total riparian area. Targets are species-specific. (Information Need)	The target for abundance is the level at which these species do not impinge on biological, recreational, and cultural resources.
			Distribution		Information Need	No new non-native species. Invasive non-native species cover </= x% of total riparian area or less. Information Need	The target for distribution is no spreading of invasive non-native species to areas where they do not already occur.

Goal 6. Protect or improve the biotic riparian and spring communities.

NOTE ON GOAL 6: This goal is intended to help achieve the biological, cultural, and recreational goals.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
6.7 new	Maintain	Spring and wetland	Habitat occupied by rare and endemic species	CRE below GCD at some stage level (Information Need)	Information Need	Information Need	<u>The target is to maintain the capability of these habitats to support the rare and endemic species known to live there. The targets should recognize the dynamic nature of these habitats as influenced by flow events.</u>
6.86 (27)	Maintain	Southwest willow flycatcher	Riparian habitat	CRE below GCD, and especially from Separation to Lake Mead	Information Need	For a dynamic mosaic of NHWZ, OHWZ, and marsh vegetation, the NHWZ being dominated primarily by willows and/or tamarisk at least 4 meters high and in patches at least 20 meters wide. Information Need	The target is the capability of the habitat to support the species. <u>The target is a dynamic mosaic of NHWZ, OHWZ, and marsh vegetation. The NHWZ should be dominated primarily by willows and/or tamarisk at least 4 meters high and in patches at least 20 meters wide. This MO provides specificity for other MOs under this goal. Lake Mead water levels are an important factor, but are outside the control of the AMP.</u> Definitions of critical habitat will change as we learn more about the species' needs.

Goal 7. Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

NOTE FOR GOAL 7: The phrase, “to achieve GCDAMP ecosystem goals,” indicates that this goal is a method to achieve certain other goals. In this case, “ecosystem goals” includes biological goals, recreational goals, and the cultural goal.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
7.1 (18)	Attain	Water	Temperature range	Mainstem	6.93-18.56° C ⁽¹⁷⁾	Use decision process <u>Information Need</u>	Target may include several stations in the mainstem.
			Seasonal variability of temperature		Information Need	Use decision process <u>Information Need</u>	
<p>The target for MO 7.1 is a temperature range and pattern of seasonal variability based on the range of natural variability, the range of operational flexibility of the dam, the range of legal flexibility, and the range that optimizes conditions for the featured-targeted resources. Targeted resources are foodbase, native fish, trout, and people (human health and safety – microorganisms and hypothermia).</p> <p>Temperature patterns should have as their first priority the improvement of conditions for native biological resources, including native fish, and including foodbase and trout interactions. This is based on the special status of native fish. <u>Linkages:</u> MO 13; Principles 4, 6, and 7; and the Vision-Mission statement.</p>							
7.2 (19)	Maintain	Water	Quality	Mainstem	Information Need (for the specific water quality parameters to use).	Obtain from literature and use decision process <u>Information Need</u>	Parameters may include nutrients, salinity, pH, DO, nitrogen, phosphorus, microbes, and others. Data available from NASQWAN. ⁽³⁵⁾
<p>The target for MO 7.2 is water quality based on the range of natural variability, the range of operational flexibility of the dam, the range of legal flexibility, <u>the legally-defined state water quality standards</u>, and the range that optimizes conditions for the featured-targeted resources. The targeted resources are foodbase, native fish, trout, Southwestern willow flycatcher, riparian and spring communities, the recreational experience, and cultural resources. <u>Linkages:</u> Goals 1-3, 8-10, and 12.</p>							
7.3 (20)	Maintain	Flow dynamics	Power plant operations	Mainstem	ROD operating criteria	Current ROD Dam operating criteria <u>then in effect</u>	See MO 50 for experimental flows.
			BHBF flows		Maximum 45,000 cfs (March to April)	Current ROD Dam operating criteria <u>then in effect</u>	
			Habitat maintenance flows		ROD operating criteria	Current ROD Dam operating criteria <u>then in effect</u>	

Goal 8. ~~Increase fine sediment~~ Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

NOTE FOR GOAL 8: The phrase, “to achieve GCDAMP ecosystem goals,” indicates that this goal is a method to achieve certain other goals. In this case, “ecosystem goals” includes biological goals, recreational goals, and the cultural goal.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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<p>The target for Goal 68 is enough sediment to achieve the biological, recreational, and cultural goals. Given limited sediment inputs, we need to retain enough sediment in the system to achieve ecosystem patterns in these goals). For the biological goals, the purposes are habitat and nutrient storage. For the cultural goal, the purposes are plant habitat and preserving sites through filling in arroyos <u>and replenishing the terraces with sediment</u>. For recreational goals, the purposes are camping beaches and trout spawning habitat. <u>Linkages</u>: Recreational, biological, and cultural goals: 1-4, 7-10, and 12.</p>							
8.1 (21)	Maintain or attain	Fine S sediment	Abundance	Main channel up to power plant capacity	329,000 m ³ (35 sites) ^(12;31)	Current volumes or higher, including some timeframe based on tributary inputs and high flows timing (Information Need).	Metric is area (m ²) and volume (m ³) as a rolling average. Target level should consider spawning habitat for trout in Glen Canyon.
			Grain-size		0.3-0.4 mm ^(12;31)	Current volumes or higher, including some timeframe based on tributary inputs and high flows timing (Information Need).	Also, see Kondolf. ⁽¹⁶⁾ Target level should consider spawning habitat for trout in Glen Canyon.
			Distribution		Information Need	Current volumes or higher, including some timeframe based on tributary inputs and high flows timing (Information Need).	Metric is # sandbars by reach. Target level should consider spawning habitat for trout in Glen Canyon.
8.2 (22)	Maintain or attain	Fine sediment	Abundance	Eddies up to 25,000 cfs	289,120 m ³ (35 sites) ^(12;31)	Information Need	Metric is area (m ²) and volume (m ³) as a rolling average
			Grain-size		0.15-0.18 mm ^(12; 31)	Information Need	
			Distribution		Information Need	Information Need	Metric is # of sandbars by reach
8.3 (23)	Maintain or attain	Fine S sediment	Abundance	Shorelines between 25,000 cfs and maximum BHBF	0.37m (Glen Canyon) 0.60m (Marble Canyon) 0.80m (Grand Canyon) ⁽¹²⁾	Information Need	Metric is area (m ²) and volume (m ³) as a rolling average
			Grain-size		0.15 -- 0.18 mm ⁽³¹⁾	Information Need	
			Distribution		Information Need	Information Need	Metric is # sandbars by reach

Goal 9. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

NOTE ON GOAL 9: The phrase, “within the framework of GCDAMP ecosystem goals,” is intended to indicate a hierarchy or order of precedence. That is, the accomplishment of this goal should be undertaken in such a way that the likelihood of achieving the biological goals and the cultural goal is not impaired.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
9.1 (35)	Maintain	Visitor	Physical access	Mainstem	Information Need. Obtain from current GLCA and GRCA management plans. Use 10-year average distributed by season of user-days, number of people, and distribution.	Information Need (subject to GLCA and GRCA river management plans in progress)	Target level should be within the capacity of the CRE to absorb visitor impacts. Target level should consider GLCA and GRCA Management Plans. See Myers et al. ⁽²⁵⁾
			Physical safety		Information Need. Use average of NPS incident reports from Myers et al. for period 1988-92.	No more river-related deaths. Minimum flows 10,000 cfs. Maximum flows 35,000 cfs. BHBFB flows OK with adequate warning time (Stewart et al. 2000)	
9.2 (36)	Maintain or improve	Recreational opportunities spectrum	Quality and quantity	Glen Canyon	Information Need GLCA data: number and variety of recreational activities.	GLCA Management Plan (in progress)	NPS studies underway. Target level should be within the capacity of the CRE to absorb visitor impacts. Target level should consider GLCA and GRCA Management Plans. See Myers et al. ⁽²⁵⁾
				Grand Canyon	Information Need. GRCA data: number and variety of recreational activities.	GRCA Management Plan (in progress – temporarily suspended)	
9.3 (37)	Increase	Camping beaches	Size	Mainstem in critical reaches (where there are only very few, very small, or very high use campsites)	Information Need From Kaplinski et al. in prep.	800 m ² (Stewart et al. 2000)	Target level should be within the capacity of the CRE to absorb visitor impacts. Target level should consider GLCA and GRCA Management Plans. See Myers et al. ⁽²⁵⁾ Metric for Quality includes parameters for vegetation, sanitation, and shade. Metric for Distribution is number of campsites required per identified reach.
			Quality		Information Need	Information Need	
			Distribution		21 +/- 5 beaches per critical reach above 10,000 cfs capable of accommodating 16-36 people (after Kearsley et al. 1999)	Minimum 21 +/- 5 beaches per critical reach above maximum ROD flows (25,000 cfs) capable of accommodating 16-36 people (after Kearsley et al. 1999)	

Goal 9. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

NOTE ON GOAL 9: The phrase, “within the framework of GCDAMP ecosystem goals,” is intended to indicate a hierarchy or order of precedence. That is, the accomplishment of this goal should be undertaken in such a way that the likelihood of achieving the biological goals and the cultural goal is not impaired.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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9.4 (38)	Improve	Rapids	Navigability	Mainstem	Information Need	Information Need See incident rates/flow level during the late 1980s and Interim Flow period. Also use Haberline study for a reference.	Target level to be developed from NPS on-river accident rates. See Myers et al. ⁽²⁵⁾ The target should address navigability across the range of flows allowed within the ROD. The metric is the number of accidents per rapid at each flow.
9.5 (39)	Maintain or enhance	Experience	Wilderness	Grand Canyon	Information Need	Information Need	Metric to include parameters for primitive character, unconfined experience, undeveloped natural and wild character, opportunities for solitude, sounds of nature and scenic beauty. The NPS is probably responsible for monitoring this MO.

Goal 10. Maintain ~~or increase power capacity~~ and energy generation, and increase where feasible and advisable, within the framework of GCDAMP ecosystem goals.

NOTE ON GOAL 10: The phrase, “within the framework of GCDAMP ecosystem goals,” is intended to indicate a hierarchy or order of precedence. That is, the accomplishment of this goal should be undertaken in such a way that the likelihood of achieving the biological goals, the recreational goals, and the cultural goal is not impaired.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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10.1 (40)	Maintain or increase	Power	Generation flexibility	GCD	ROD and current operating practices ⁽³³⁾	Information Need	
<p>Target is to maintain current practices, as constrained by the ROD, for</p> <ul style="list-style-type: none"> ▪ marketable capacity and energy, ▪ existing emergency criteria for the WAPA and WSCC systems, and ▪ regulation for WALC and WACM; <p>and to determine feasibility and advisability for</p> <ul style="list-style-type: none"> ▪ financial exception criteria for the WAPA system, and ▪ regulation for other systems. 							

Goal 11. Preserve, protect, manage, and treat ~~Cultural resources within the river corridor shall be preserved, protected, managed and treated~~ for the inspiration and benefit of past, present and future generations.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
11.1 (41)	Preserve	Register-eligible properties	National Register integrity	APE	Information Need	100% of extant historic properties	Target level should consider recreational impacts. See USBR ⁽³²⁾ and Leap et al. ⁽¹⁹⁾ Target is to preserve register-eligible properties via protection, management, and/or treatment (data recovery) for the purpose of federal agency compliance with NHPA, and AMP and AMWG compliance with GCPA.
11.2 (42)	Preserve	Other cultural resources	Cultural values	CRE	Information Need	Information Need	Target level should consider recreational impacts. Target is to preserve (stabilize or improve based on current cultural values) other traditionally important resources that are not sufficiently addressed under other MOs.
11.3 (43)	Attain and maintain	AMP resource monitoring and management actions	Effective government-to-government consultation	CRE	Existing level: TWG, AMWG, and PA meetings. \$75,000 appropriated and \$400,000 power revenues.	100% of AMP actions	See USBR ⁽³²⁾ Target is to achieve effective, legally mandated consultation.

Goal 11. Preserve, protect, manage, and treat ~~Cultural resources within the river corridor shall be preserved, protected, managed and treated~~ for the inspiration and benefit of past, present and future generations.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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11.4 (44)	Protect and maintain	Traditional cultural resources	Physical access	CRE	Information Need	Information Need	See USBR ⁽³⁴⁾ The target is designed to prevent AMWG from undertaking events that might restrict or block physical access by Native American religious practitioners, without meaningful consultation. See AIRFA and EO 13007.
11.5 (45)	Integrate	Information	Cultural and other resources	CRE	Synthesis report ⁽³⁰⁾	Information Need	Target is to ensure that data is able to be used both for increased understanding of the past and for ongoing interactions of humans within the CRE.

Goal 12. Maintain a high-quality monitoring, research, and adaptive management program.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
12.1 (46)	Maintain or attain	Socio-economic data	Hydropower	N/A	Information Need	Information Need	The current level is how much socioeconomic data we have on the attributes. The target level is how much socioeconomic data is needed for adequate decision-making.
			Air quality	N/A	Information Need	Information Need	
			Wilderness	N/A	Information Need	Information Need	
			Recreation	N/A	Information Need	Information Need	
			Non-use values	N/A	Information Need	Information Need	
			Tribal & spiritual values	N/A	Information Need	Information Need	
12.2 (47)	Attain and maintain	Monitoring and research program	Natural, cultural, and recreational resources	CRE	GCMRC Strategic Plan	Updated GCMRC Strategic Plan	Current and target levels should include a planning document and an outside peer review document.
12.3 (48)	Attain and maintain	AMP composed of all stakeholders	That acknowledges uncertainty and uses experimentation, monitoring & research	N/A	Information Need	Updated AMP Strategic Plan that describes the processes for science-based collaborative resources management.	
			Participation		See meeting records.	100% attendance by all representatives at AMWG and TWG meetings plus active participation in Ad Hoc Committees.	
12.4 (49)	Attain and maintain	Funding	Tribal participation	AMP	\$75,000 (Appropriated) \$400,000 (Power revenues)	Information need	The target is a level of funding adequate to meet each tribe's needs to participate in the Adaptive Management Program. <u>Linkage:</u> Vision/Mission statement, particularly the mention of federal trust responsibilities.

Goal 12. Maintain a high-quality monitoring, research, and adaptive management program.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
12.5 (50)	Conduct	Experimental flows	Flow dynamics	Mainstem	Information Need	Information Need	See GCMRC, ⁽⁶⁾ Webb et al. ⁽³⁷⁾ and Topping et al. ⁽³¹⁾ Target level is the experiments needed to gain critical understanding of ecosystem function under different dam operations.
12.6 (51)	Conduct	Management experiments	Other management actions	CRE	Information Need	Information Need	Target level is the experiments needed to gain critical understanding of ecosystem function under different management alternatives outside of dam operations.
12.7 (52)	Build	AMP	Public support	N/A	Information Need	Information Need A public outreach plan adopted by the AMWG. Propose to have BOR, NPS, and USGS public affairs people develop the plan.	Metric should include GCMRC and BOR web pages; GCD programs and tours; AMWG Outreach Committee; publications; various AMWG member activities. The target is adequate public support for AMP experiments and adaptive management, and a diverse funding base.
12.8 (53)	Maintain or attain	Funding	Foundation and Corporate	N/A	\$0	Information Need	The target is adequate funding to meet the goal. Develop a plan identifying sources for obtaining foundation and corporate funding.
			Appropriated		\$75,000 (FY 2000)	\$1,010,000 USGS \$475,000 Tribal participation	
			State Agency		Information Need (obtain from AGFD)	Information Need	
			Power revenues		\$6.22M (for GCMRC) \$1.443M (for BOR)	\$7,850,000 indexed for CPI	

Goal 12. Maintain a high-quality monitoring, research, and adaptive management program.

MO #	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
12.9 (54)	Maintain or attain	Participation	Externally-funded investigators	CRE	Information Need (obtain from NPS)	<p>Information Need</p> <p>MAs:</p> <ol style="list-style-type: none"> 1. Develop a brochure that indicates support that would be provided by GCMRC and NPS to researchers who bring their own funding to address issues related to AMP MOs and INs. 2. Get outside researchers engaged and obtain their data. 	<p>Current and target levels should include small and cost-shared projects in NPS, AGFD, etc.</p> <p>The target is contributions to meeting Information Needs by externally funded investigators.</p> <p>NOTE: Incentives could include donated office space, partial funding, letters of support, facilitated access, and logistical support.</p>

Glossary

ADAPTIVE MANAGEMENT

Adaptive management is an iterative process, designed to experimentally compare selected management actions by evaluating alternative hypotheses about the ecosystem being managed. It consists of three parts: management actions, monitoring, and adaptation. Management actions are treated as experiments subject to modification. Monitoring is conducted to detect the effects of the management actions. Finally, management actions are refined based on the enhanced understanding about how the ecosystem responds.

AREA OF POTENTIAL EFFECT

BIODIVERSITY

Biodiversity is “the variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels [including] ... the variety of ecosystems...”⁽³⁸⁾

BIOLOGICAL GOALS

Biological goals include Goal 1 (foodbase), Goal 2 (native fish), Goal 3 (extirpated species), Goal 5 (Kanab ambersnail), and Goal 6 (riparian and spring communities).

BIOTIC COMMUNITY

A biotic community is a “group of organisms ... that co-occur in the same habitat or area and interact through trophic and spatial relationships...”⁽²⁰⁾

CAPACITY (GENERATING)

Generating capacity is a measure of the ability to generate electric power, usually expressed in MW (megawatts). The capacity of a hydropower plant is a function of head (reservoir elevation) and maximum water flow through the turbines.

COLORADO RIVER ECOSYSTEM

The Colorado River ecosystem is the Colorado River mainstem corridor and interacting resources in associated riparian and terrace zones, located primarily from the forebay of Glen Canyon Dam to the western boundary of Grand Canyon National Park. It includes the downstream inundation level to which dam operations impact physical, biological, recreational, cultural, and other resources. The scope of GCDAMP activities may include limited investigations into some tributaries (e.g., the Little Colorado and Paria Rivers).

CONCEPTUAL MODEL

A conceptual model is an “assessment of the dynamics of the more important compartments and fluxes of material or energy in a system [*i.e.*, patterns and processes], or of changes in a population.”⁽²⁰⁾ A conceptual model is a heuristic tool to provide a framework for thinking about how an ecosystem functions and to discover gaps in our knowledge.

CULTURAL GOAL

Cultural goal refers to Goal 11.

CULTURAL RESOURCES

Cultural resources includes, but is not necessarily limited to, any prehistoric or historic district, site, building, structure, landscape, or object included in, or eligible for inclusion in the National Register, including artifacts, records, and material remains related to such a property or resource. Properties of traditional religious and cultural importance to an Indian tribe are included in this definition under Section 101(d)(6)(A) of NHPA.

ECOSYSTEM

An ecosystem is “a community of organisms and their physical environment interacting as an ecological unit.”⁽²⁰⁾ An ecosystem consists of patterns and processes that are dynamic and occur within a particular range of temporal and spatial variability.

Glossary

ECOSYSTEM INTEGRITY

Ecosystem integrity is “the ability to support and maintain a balanced, integrated, adaptive biological system having the full range of elements (genes, species, and assemblages) and processes (mutation, demography, biotic interactions, nutrient and energy dynamics, and metapopulation processes) expected in the natural habitat of a region.”⁽¹³⁾ Ecosystem integrity is related to ecosystem resilience (*i.e.*, the capacity to maintain characteristic patterns and processes) following a disturbance.

ECOSYSTEM MANAGEMENT

An ecosystem management approach differs from an issue-, species-, or resource-specific approach. Ecosystem management is a method for sustaining or restoring ecosystems and their functions and values. “It is goal driven, and it is based on a collaboratively developed vision of desired future conditions that integrates ecological, economic, and social factors. It is applied within a geographic framework defined primarily by ecological boundaries.”⁽¹¹⁾ Ecosystem management is a process that attempts to mimic appropriate ecosystem patterns (abundance and distribution of species and habitats) and ecosystem processes (drivers of ecosystem patterns). It includes managing for viable populations of all native species.

ECOSYSTEM PATTERNS

Ecosystem pattern is the abundance of species, biotic communities, and physical habitats, as well as their spatial and temporal distribution. This is a broader concept than “composition and structure.” Composition usually refers only to species presence or absence, and structure usually refers to the distribution of biotic communities.

ECOSYSTEM PROCESSES

Ecosystem processes are the abiotic (*i.e.*, non-living) and biotic (*i.e.*, living) functions, disturbances, or events that shape ecosystem patterns. There are physical processes (*e.g.*, fire, hydrologic, geomorphic, and climatic regimes; air chemistry, nutrient cycling), biological processes (*e.g.*, competition, predation, herbivory, parasitism, disease, migration, dispersal, gene flow, succession, recruitment, maturation), and anthropogenic processes (*e.g.*, habitat conversion, novel toxins, vandalism).

ELECTRICAL ENERGY

Electrical energy is the generation or use of electrical power over a period, usually expressed in megawatt-hours (MWh), kilowatt-hours (kWh), or gigawatt-hours (GWh).

EXTIRPATED SPECIES

An extirpated species is one that no longer occurs (*i.e.*, has become extinct) in a particular area. Examples from the CRE include river otter and razorback sucker.

INVASIVE SPECIES

An invasive species is one that has invaded an area following changes in one or more ecosystem processes and has become dominant. Examples from the CRE include non-native species (*e.g.*, tamarisk) and native species (*e.g.*, willow).

LEGAL FLEXIBILITY

Legal flexibility is that which is allowed by the [legal sideboards, statutes, judicial decrees, compacts, and treaties](#) controlling operation of the dam.

MONITORING

Monitoring is the “collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective.”⁽⁴⁾ Monitoring needs to produce data of sufficient statistical power to detect a trend if in fact it is occurring.⁽⁸⁾ Monitoring differs from inventorying, which is the measurement of environmental attributes at a given point in time to determine what is there. It also differs from research, which is the measurement of environmental attributes to test a specific hypothesis.

NATIVE SPECIES

A native species is one that occurred in an area prior to anthropogenic alterations to ecosystem patterns and/or processes. Examples from the CRE include humpback chub, razorback sucker, flannelmouth sucker, bluehead

Glossary

sucker, speckled dace, Colorado pikeminnow, bonytail, roundtail chub, river otter, Kanab ambersnail, Southwest willow flycatcher, brown-headed cowbird, netleaf hackberry, honey mesquite & catclaw acacia.

NATURALIZED SPECIES

A naturalized species is ~~one-a non-native species~~ that has become established in an area. See examples in the CRE listed under non-native species.

NON-NATIVE SPECIES

A non-native species is one that did not occur in an area prior to anthropogenic alterations to ecosystem patterns and/or processes. Non-natives are also known as introduced, exotic, or alien species. Many, but not all, non-native species can be categorized as an invasive species. Examples of non-native species in the CRE include *Gammarus*, rainbow trout, brown trout, common carp, red shiner, channel catfish, tamarisk, and camelthorn.

OPERATIONAL FLEXIBILITY

Operational flexibility is the physical capability of the dam to release water.

QUALITATIVE TARGET

An articulation of the purpose of one or more Management Objectives, in order to give a description in words of what the numerical target levels are intended to accomplish, ~~and to give direction and guidance to the persons who developed the quantitative targets.~~

RANGE OF NATURAL VARIABILITY

The Range of Natural Variability is the spatial and temporal variation in ecosystem patterns and ecosystem processes under which the ecosystem has evolved. The range of natural variability for ecological processes is usually defined by their frequency (e.g., number/year), intensity (e.g., cubic feet per second), duration (e.g., number of days), magnitude (e.g., acres), seasonally, and rate of change. See Landres⁽¹⁸⁾ for a full discussion.

REASONABLE AND PRUDENT ALTERNATIVE

“Reasonable and prudent alternatives refer to alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that the Director believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat.”⁽⁵⁾

REASONABLE AND PRUDENT MEASURE

“Reasonable and prudent measures refer to those actions the Director believes necessary or appropriate to minimize the impacts, i.e., amount or extent of incidental take.”⁽⁵⁾

RECOVERY

Recovery is improvement in the status of a listed species to the point at which listing is no longer appropriate, under the criteria set out in section 4(a)(1) of the Endangered Species Act⁽⁵⁾.

~~RECREATIONAL OPPORTUNITY SPECTRUM~~

RECREATIONAL GOALS

Recreational goals include Goal 4 (trout) and Goal 9 (recreation).

REMOVAL OF JEOPARDY

To “jeopardize the continued existence of [a listed species] means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species.”⁽⁵⁾ Removing (or avoiding) jeopardy is intended to be accomplished through the implementation of reasonable and prudent alternatives.

Glossary

RIPARIAN ECOSYSTEM

The riparian ecosystem is the streamside zone that is influenced by riverine processes, e.g., flood regime and distance to subsurface water.

RIVERINE ECOSYSTEM

The riverine ecosystem is any area typically inundated by the river.

VIABLE POPULATION

A population is considered viable when there is a high chance of persistence over a long timeframe without demographic or genetic augmentation. Population viability is not the same as “recovery” or “removal of jeopardy” for a species. However, the concept of population viability is an important consideration in determining recovery and removal of jeopardy.

Abbreviations

AFDW	ash-free dry weight
AGFD	Arizona Game and Fish Department
AIRFA	American Indian Religious Freedom Act
AMP	adaptive management program
AMWG	Glen Canyon Dam Adaptive Management Work Group
APE	Area of Potential Effect
BHBF	beach/habitat building flow
BO	biological opinion
cfs	cubic feet per second
CPOM	coarse particulate organic matter
CPUE	catch per unit effort
CRE	Colorado River ecosystem
D50	median grain size
DO	dissolved oxygen
EO	Executive Order
FPOM	fine particulate organic matter
GCD	Glen Canyon Dam
GCMRC	Grand Canyon Monitoring and Research Center
GCPA	Grand Canyon Protection Act
GLCA	Glen Canyon National Recreation Area
GRCA	Grand Canyon National Park
HBC	Humpback chub
KAS	Kanab ambersnail
LCR	Little Colorado River
MA	management action
MO	management objective
Ne	effective population size
NHPA	National Historic Properties Act
NHWZ	new high water zone
NPS	National Park Service
OHWZ	old high water zone
popn	population
PVA	population viability analysis
RBT	Rainbow trout
Register	National Historic Register
RNV	range of natural variability
ROD	record of decision
RPA	reasonable and prudent alternative
SWWF	Southwestern willow flycatcher
TBD	to be determined
WACM	Western Area - Colorado Montrose
WALC	Western Area - Lower Colorado
WAPA	Western Area Power Administration, Department of Energy
Wr	mean annual relative weight
WSCC	Western Systems Coordinating Council

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