Glen Canyon Dam
Adaptive Management Work Group

Ad Hoc Committee on Strategic Planning

Report to AMWG, ~~June 2000~~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. Recognizing the diverse perspectives and spiritual values of the stakeholders, the unique aesthetic value of the Grand Canyon will be respected and enhanced.

G. *Protect or improve the aquatic foodbase so that it will sup[illegible] iable populations of desired species at higher trophic level.*

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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. Linkages: See the numbers of fish desired under Goals 2, 3, and 4.							
1	Maintain or attain	Algae and periphyton	Biomass	Mainstem from Glen Canyon Dam to Paria River	17.5 g/m^2 (Cobble)[27] 2.7 g/m^2 (Pool)[27]	150 g/m^2[27]	Also see McKinney et al. 1999[22]
			Composition		49.60% *Cladophora* 33.10% Chlorophyta 9.10% *Fontinalis* 3.35% Chromophyta 2.40% Rhodophyta 2.50% Cyanobacteria[27]	Obtain from literature	Metric is % of algal species that support upright diatoms
			Production		Information Need	Information Need	Metric is g/m^2/time of *Cladophora*
2	Maintain or attain	Benthic invertebrates	Biomass	Mainstem from Glen Canyon Dam to Paria River	5.0 g/m^2 (Cobble)[27] 1.0 g/m^2 (Pool)[27]	5000 g/m^2[27]	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] 1.0% Worms 0.9% Gammarus 35.7% Oligochaete 22.3% Midges (Pool)[27]	Information Need	Metric is relative % of species.
			Production		Information Need	Information Need	Metric is g/m^2/time
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

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
4	Maintain or attain	Algae and periphyton	Biomass	Mainstem below the Paria River	12.21 g/m^2 (Cobble)[27] 0.35 g/m^2 (Pool)[27]	50 g/m^2[27]	
			Composition		29.9% *Cladophora* 23.7% MAMB 46.6% *Oscillatoria* (Cobble)[27] 51.0% *Cladophora* 48.9% MAMB 0.1% *Oscillatoria* (Pool)[27]	Obtain from literature	Metric is relative % of algal species. MAMB is for miscellaneous algae, macrophytes, and bryophytes
			Production		Information Need	Information Need	Metric is g/m^2/time
	Maintain or attain	Algae and periphyton	Distribution	Mainstem below the Paria River		Information Need	

Mile	% *Cladophora*	% MAMB	% *Oscillatoria*
Cobble[27]			
2	49.3	43.3	7.4
61	22.4	43.1	34.5
68	8.7	7.2	84.1
127	5.6	12.4	82.0
205	63.7	12.4	23.9
Pool[27]			
2	60.0	40.0	0.0
61	28.6	71.4	0.0
68	80.0	20.0	0.0
127	15.2	84.8	0.0
205	71.2	28.5	0.3

Go. Protect or improve the aquatic foodbase so that it will supp. iable populations of <u>desired</u> species at higher trophic level.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	
			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]	Obtain from literature	Metric is relative % of species.
			Production		Information Need	Information Need	Metric is g/m^2/time
			Distribution		20 Worms 500 *Gammarus* 120 Oligochaetes 10 Simulium 2150 Midges 20 Miscellaneous 1580 Gastropod (Cobble at Mile 2)[27]	Information Need	
6	Maintain or attain	Aquatic macrophytes	Biomass	Mainstem below the Paria River	Obtain from literature	Information Need	
			Composition		Obtain from literature	Information Need	
			Production		Obtain from literature	Information Need	
			Distribution		Obtain from literature	Information Need	

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
7	Maintain or attain	Foodbase drift	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	
			Composition		29.2% (Plants) 69.3% (Detritus) 1.1% (CPOM inverts) 0.4% (FPOM inverts)	Obtain from literature	CPOM is coarse particulate organic matter. FPOM is fine particulate OM.

Goa Maintain or attain viable populations of existing native fis a remove jeopardy from humpback chub and razorback su .

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
8	Maintain or attain	Humpback chub (150 mm and larger)	Abundance	LCR and mainstem within 3 miles of LCR	8096 individuals[3; 36]	Information Need	The target is viable populations and removal of jeopardy. Target to be based on 91-96 population estimate, PVA, & N_e.
				Mainstem except within 3 miles of the LCR	225 individuals[3; 36]	Information Need	
9	Maintain or attain	Humpback chub (51 mm to 150 mm)	Abundance	LCR and mainstem within 3 miles of LCR	Obtain from literature	Information Need	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.
				Mainstem except within 3 miles of the LCR	0-74 captures/trip[9]	Information Need	
10	Establish	Humpback chub	Populations	CRE downstream of GCD	One self-sustaining population in the LCR	One additional self-sustaining population	The target is viable populations and removal of jeopardy.
11	Attain	Humpback chub	Condition	LCR and mainstem within 3 miles of LCR	Information Need	Information Need	The target is viable populations and removal of jeopardy.
				Mainstem except within 3 miles of the LCR	Information Need	Information Need	
			Health	LCR and mainstem within 3 miles of LCR	Information Need	Information Need	
				Mainstem 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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	
13	Reduce	Non-native fish	Predation on native fish	CRE below GCD	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 do 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.
			Competition with native fish	CRE below GCD	Information Need	Information Need	
14	Attain	Razorback sucker	Populations	CRE below GCD	0 individuals[9]	Information Need	Target is capability of the habitat to support the species.
15	Maintain	Flannelmouth sucker	Abundance	CRE below GCD	113 captures (5.3%)[9]	Information Need	Appropriate metric to be determined. The target is viable populations and removal of jeopardy.
		Bluehead sucker			41 captures (1.9%)[9]	Information Need	
		Speckled dace			391 captures (18.2%)[9]	Information Need	

Goal 3. Restore populations o, rpated species, as feasible.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
This goal is self-explanatory and does not need a separate qualitative target. Linkages: See Issue Paper B (trout).							
17	Maintain or attain	Rainbow trout	Abundance	Mainstem from Glen Canyon Dam to Paria River	262,000 Age II+ individuals[23]	100,000 Age II+ individuals	
			Growth rate		15" by Age III[23]	18" by Age III	
			Condition		$W_r = 0.82$[23]	$W_r = 0.90$	
			Health		Information Need	Information Need	Metric is level of disease and parasite infections
			Spawning		Information Need	Information Need	

Goal 5. Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

NOTE FOR GOAL 5: 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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
18	Attain	Water	Temperature range	Mainstem	6.93-18.56°C[17]	Use decision process	Target may include several stations in the mainstem.
			Seasonal variability of temperature		Information Need	Use decision process	
The target for MO 18 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 resources. Targeted resources are foodbase, native fish, trout, and people (human health and safety – microorganisms and hypothermia). 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. Linkages: MO 13; Principles 4, 6, and 7; and the Vision-Mission statement.							
19	Maintain	Water	Quality	Mainstem	Information Need (for the specific water quality parameters to use).	Obtain from literature and use decision process	Parameters may include nutrients, salinity, pH, DO, nitrogen, phosphorus, microbes, and others. Data available from NASQWAN[35]
The target for MO 19 is water quality 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 resources. The targeted resources are foodbase, native fish, trout, Southwestern willow flycatcher, riparian and spring communities, the recreational experience, and cultural resources. Linkages: Goals 1-3, 8-10, and 12.							
20	Maintain	Flow dynamics	Power plant operations	Mainstem	ROD operating criteria	Current ROD operating criteria	See MO 50 for experimental flows.
			BHBF flows		Maximum 45,000 cfs (March to April)	Current ROD operating criteria~~Use decision process~~	
			Habitat maintenance flows		ROD operating criteria	Current ROD operating criteria~~Use decision process~~	

Goal 6. ~~Increase fine sediment storage~~Maintain or attain levels of sediment within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

NOTE FOR GOAL 6: 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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
The target for Goal 6 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. For recreational goals, the purposes are camping beaches and trout spawning habitat. Linkages: Recreational, biological, and cultural goals: 1-4, 7-10, and 12.							
21	Maintain or attain	Sediment	Abundance	Main channel ~~below~~ up to power plant capacity	329,000 m^3 (35 sites)[12; 31]	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]	Information Need	Also see Kondolf.[16] Target level should consider spawning habitat for trout in Glen Canyon.
			Distribution		Information Need	Information Need	Metric is # sandbars by reach. Target level should consider spawning habitat for trout in Glen Canyon.
22	Maintain or attain	Sediment	Abundance	Eddies up to power plant capacity	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 # sandbars by reach
23	Maintain or attain	Sediment	Abundance	Shorelines between power plant capacity 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		0.15-0.18mm[31]	Information Need	
			Distribution		Information Need	Information Need	Metric is # sandbars by reach

Goal 7. Maintain or attain viable ... ulations of Kanab ambersnail.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	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.
				AZ (except Vasey's Paradise)	3 individuals (Keyhole) 21 individuals (Elves) 0 individuals (Deer Creek)[1]	Information Need	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.
25	Maintain	Kanab ambersnail	Habitat	Vasey's Paradise	82-99m^2 (monkeyflower) 36.6 m^2 (watercress) (area below 70,000 cfs stage)[24]	Information Need	Target is level needed to sustain a viable population. "Viable" includes the entire population, not just those below 70,000 cfs.

Goal 8. Protect the presence of southwestern willow flycatcher and its critical habitat in a manner consistent with riparian ecosystem goals.

NOTE ON GOAL 8: The phrase, "in a manner consistent with riparian 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 Goal 9 is not impaired.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
26	Maintain or increase	Southwest willow flycatcher	Abundance	CRE below GCD	12 breeding pairs[26]	Information Need	Target is the ~~capability of the habitat to support the species~~number of breeding pairs that the habitat is capable of supporting.
			Distribution	CRE below GCD	Information Need	Information Need	Target is the ~~capability of the habitat to support the species~~distribution of breeding pairs that the habitat is capable of supporting.
			Fledging success	CRE below GCD	Information Need	Information Need	See GCMRC.[7] The target is the level needed to maintain the target level in the Abundance attribute of MO 26.
27	Maintain	Southwest willow flycatcher	Critical ~~H~~habitat	CRE below GCD	Information Need	Information Need	The target is the capability of the habitat to support the species.
28	Reduce	Brown-headed cowbird	Brood parasitism	CRE	50% of nests parasitized[2]	Information Need	The target is the level needed to maintain the target level of Southwestern willow flycatcher in MO 26.

Goal 9. Protect or improve the bio[illegible]arian and spring communities.

NOTE ON GOAL 9: This goal is intended to help achieve the biological, cultural, and recreational goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
29	Maintain	Marsh	Abundance	CRE below GCD	1215 patches (4.6 ha)[7]	Information Need	See Kearsley[15] and Stevens et al.[29] The target is an achievable and appropriate mix of these types of communities. 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.
			Composition		Information Need	Information Need	
			Distribution		Information Need	Information Need	
30	Maintain	New high water zone	Abundance	CRE below GCD	Information Need	Information Need	
			Composition		Information Need	Information Need	
			Distribution		Information Need	Information Need	
31	Maintain	Old high water zone	Abundance	CRE below GCD	Information Need	Information Need	
			Composition		Information Need	Information Need	
			Distribution		Information Need	Information Need	
32	Maintain	Sand beach	Abundance	CRE below GCD	Information Need	Information Need	
			Composition		Information Need	Information Need	
			Distribution		Information Need	Information Need	

Goal 9. Protect or improve the biotic riparian and spring communities.

NOTE ON GOAL 9: This goal is intended to help achieve the biological, cultural, and recreational goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
33	Maintain	Culturally important species	Abundance	CRE below GCD	157 species (Plants)[21; 30]	Information Need	
			Distribution		Information Need	Information Need	
34	Reduce	Invasive non-native species	Abundance	CRE below GCD	95+ species (Plants)[28] 3 species (Birds)[28]	Information Need	The target is the level at which these species do not impinge on biological, recreational, and cultural resources. Abundance refers to number of individuals within the species. These species should be limited to invasive ones, not just non-natives.
			Distribution		Information Need	Information Need	

Goa. Maintain or improve the quality of recreational experienc. / users of the Colorado River ecosystem, within the frame. 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 and the cultural goal is not impaired.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
35	Maintain	Visitor	Physical access and safety	Mainstem	Information Need	Information Need	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]
36	Maintain or improve	Recreational spectrum	Quality and quantity	Glen Canyon	Information Need	~~GLCA Management Plan levels~~	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]
37	Maintain or increase	Camping beaches	Size	Mainstem	Information Need	Information Need	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	
			Number		262 campsites[14]	Information Need	
			Distribution		37% of campsites in critical reaches[14]	Information Need	

Goal 10. 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 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 and the cultural goal is not impaired.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
38	Maintain or improve	Rapids	Navigability	Mainstem	Information Need	Information Need ~~and Decision Process~~	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.
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 11. Maintain or increase power and energy gener.. within the framework of GCDAMP ecosystem goals.

NOTE ON GOAL 11: 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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
40	Maintain or increase	Power	Generation flexibility	GCD	ROD and current operating practices[33]	Information Need	

Goal 12. <u>Preserve, protect, manage, and treat</u> ~~C~~cultural resources ~~within the river corridor shall be preserved, protected, managed and treated~~ for the inspiration and benefit of past, present and future generations.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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]
42	Preserve	Other cultural resources	Cultural values	CRE	Information Need	Information Need	Target level should consider recreational impacts.
43	Attain and maintain	Management action	Consultation	CRE	Information Need	100% of management actions	See USBR[32]
44	Protect and maintain	Traditional cultural resources	Physical access	CRE	Information Need	Information Need	See USBR[34]
45	Integrate	Information	Cultural and other resources	CRE	Synthesis report[30]	Information Need	

Goal 13. Maintain a high-quality monitoring, research, and adaptive management program.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	
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.
48	Attain and maintain	AMP composed of all stakeholders	That acknowledges uncertainty and uses experimentation, monitoring & research	N/A	Information Need	Information Need	
			Participation	N/A	See meeting records.	Information Need	The target is representation of all stakeholders at every AMWG and TWG meeting and other subcommittee meetings to which the stakeholders have committed, and review by all stakeholders of relevant program documents.

Goal 13. Maintain a high-quality monitoring, research, and adaptive management program.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
49	Attain and maintain	~~Full tribal participation~~ Funding	~~Funding~~ Tribal participation	AMP	$75,000 (Appropriated) $400,000 (Power revenues)	~~$475,000 (Appropriated in FY2002)~~Information need	The target is a level of funding adequate to meet each tribe's needs to participate in the Adaptive Management Program. Linkage: Vision/Mission statement, particularly the mention of federal trust responsibilities.
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.
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.

Goal 13. Maintain a high-quality monitoring arch, and adaptive management program.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
52	Build	AMP	Public support	N/A	Information Need	Information Need	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.
53	Maintain or attain	Funding	Foundation and Corporate	N/A	$0	Information Need	The target is adequate funding to meet the goal.
			Appropriated	N/A	$75,000 (FY 2000)	$1,485,000 (FY 2002)	
			State Agency	N/A	Obtain from literature	Information Need	
			Power revenues	N/A	$6.22M (for GCMRC) $1.443M (for BOR)	Information Need	
54	Maintain or attain	Participation	Externally-funded investigators	CRE	Information Need	Information Need	Current and target levels should include small and cost-shared projects in NPS, AGFD, etc. The target is contributions to meeting Information Needs by externally funded investigators. NOTE: Incentives could include donated office space, partial funding, letters of support, facilitated access, and logistical support.

~~***Goal 14: Build a broad, effective outreach program.***~~
~~***Goal 15: Broaden the funding base to achieve GCDAMP Goals and Objectives.***~~

NOTE ON GOALS 14 AND 15: These goals are now part of Goal 13.

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.

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 7 (Kanab ambersnail), Goal 8 (Southwestern willow flycatcher), and Goal 9 (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]

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 12.

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.

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).

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.

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 GOALS
Recreational goals include Goal 4 (trout) and Goal 10 (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.

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.

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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:

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.

The construction of Glen Canyon Dam and the introduction of non-native species have irreversibly changed the Colorado River ecosystem.

Much remains unknown about the Colorado River ecosystem below Glen Canyon Dam and how to achieve GCDAMP ecosystem Goals.

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.

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.

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.

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.

Recognizing the diverse perspectives and spiritual values of the stakeholders, the unique aesthetic value of the Grand Canyon will be respected and enhanced.

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
1	Maintain or attain	Algae and periphyton	Biomass	Mainstem from Glen Canyon Dam to Paria River	17.5 g/m^2 (Cobble)[27] 2.7 g/m^2 (Pool)[27]	150 g/m^2[27]	Also see McKinney et al. 1999[22]
			Composition		49.60% Cladophora 33.10% Chlorophyta 9.10% Fontinalis 3.35% Chromophyta 2.40% Rhodophyta 2.50% Cyanobacteria[27]	Obtain from literature	Metric is % of algal species that support upright diatoms
			Production		Information Need	Information Need	Metric is g/m^2/time of *Cladophora*
2	Maintain or attain	Benthic invertebrates	Biomass	Mainstem from Glen Canyon Dam to Paria River	5.0 g/m^2 (Cobble)[27] 1.0 g/m^2 (Pool)[27]	5000 g/m^2[27]	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] 1.0% Worms 0.9% Gammarus 35.7% Oligochaete 22.3% Midges (Pool)[27]	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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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
4	Maintain or attain	Algae and periphyton	Biomass	Mainstem below the Paria River	12.21 g/m^2 (Cobble)[27] 0.35 g/m^2 (Pool)[27]	50 g/m^2[27]	
			Composition		29.9% Cladophora 23.7% MAMB 46.6% *Oscillatoria* (Cobble)[27] 51.0% Cladophora 48.9% MAMB 0.1% Oscillatoria (Pool)[27]	Obtain from literature	Metric is relative % of algal species. MAMB is for miscellaneous algae, macrophytes, and bryophytes
			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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
4 (continued)	Maintain or attain	Algae and periphyton	Distribution	Mainstem below the Paria River		Information Need	

Mile	% *Cladophora*	% MAMB	% *Oscillatoria*
Cobble[27]			
2	49.3	43.3	7.4
61	22.4	43.1	34.5
68	8.7	7.2	84.1
127	5.6	12.4	82.0
205	63.7	12.4	23.9
Pool[27]			
2	60.0	40.0	0.0
61	28.6	71.4	0.0
68	80.0	20.0	0.0
127	15.2	84.8	0.0
205	71.2	28.5	0.3

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	
			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]	Obtain from literature	Metric is relative % of species.
			Production		Information Need	Information Need	Metric is g/m^2/time
			Distribution		20 Worms 500 Gammarus 120 Oligochaetes 10 Simulium 2150 Midges 20 Miscellaneous 1580 Gastropod (Cobble at Mile 2)[27]	Information Need	

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
6	Maintain or attain	Aquatic macrophytes	Biomass	Mainstem below the Paria River	Obtain from literature	Information Need	
			Composition		Obtain from literature	Information Need	
			Production		Obtain from literature	Information Need	
			Distribution		Obtain from literature	Information Need	
7	Maintain or attain	Foodbase drift	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	
			Composition		29.2% (Plants) 69.3% (Detritus) 1.1% (CPOM inverts) 0.4% (FPOM inverts)	Obtain from literature	CPOM is coarse particulate organic matter. FPOM is fine particulate OM.

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
8	Maintain or attain	Humpback chub (150 mm and larger)	Abundance	LCR and mainstem within 3 miles of LCR	8096 individuals[3; 36]	Information Need	Target to be based on 91-96 population estimate, PVA, & N_e
				Mainstem except within 3 miles of the LCR	225 individuals[3; 36]	Information Need	Target to be based on 91-96 population estimate, PVA, & N_e
9	Maintain or attain	Humpback chub (51 mm to 150 mm)	Abundance	LCR and mainstem within 3 miles of LCR	Obtain from literature	Information Need	Metric is "catch per unit effort" (CPUE). See Gorman and Bramblett.[9] See synthesis by Coggins.
				Mainstem except within 3 miles of the LCR	0-74 captures/trip[9]	Information Need	
10	Establish	Humpback chub	Populations	CRE downstream of GCD	One self-sustaining population in the LCR	One additional self-sustaining population	

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
11	Attain	Humpback chub	Condition	LCR and mainstem within 3 miles of LCR	Information Need	Information Need	
				Mainstem except within 3 miles of the LCR	Information Need	Information Need	
			Health	LCR and mainstem within 3 miles of LCR	Information Need	Information Need	
				Mainstem except within 3 miles of the LCR	Information Need	Information Need	
12	Maintain or attain	Humpback chub	Spawning	LCR and mainstem within 3 miles of LCR	Information Need	Information Need	See Gorman and Bramblett.(9)
				Mainstem except within 3 miles of the LCR	Information Need	Information Need	See Gorman and Bramblett.(9)

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
13	Reduce	Non-native fish	Predation on native fish	CRE below GCD	Information Need	Information Need	Metric is rate of predation. See Gorman and Bramblett.[9]
			Competition with native fish	CRE below GCD	Information Need	Information Need	
14	Attain	Razorback sucker	Populations	CRE below GCD	0 individuals[9]	Information Need	Target is capability of the habitat to support the species
15	Maintain	Flannelmouth sucker	Abundance	CRE below GCD	113 captures (5.3%)[9]	Information Need	Appropriate metric to be determined
		Bluehead sucker			41 captures (1.9%)[9]	Information Need	Appropriate metric to be determined
		Speckled dace			391 captures (18.2%)[9]	Information Need	Appropriate metric to be determined

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

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
17	Maintain or attain	Rainbow trout	Abundance	Mainstem from Glen Canyon Dam to Paria River	262,000 Age II+ individuals[23]	100,000 Age II+ individuals	
			Growth rate		15" by Age III[23]	18" by Age III	
			Condition		$W_r = 0.82$[23]	$W_r = 0.90$	
			Health		Information Need	Information Need	Metric is level of disease and parasite infections
			Spawning		Information Need	Information Need	

Goal 5. Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
18	Attain	Water	Temperature range	Mainstem	6.93-18.56 °C[17]	Use decision process	Target may include several stations in the mainstem.
			Seasonal variability of temperature		Information Need	Use decision process	
19	Maintain	Water	Quality	Mainstem	Information Need (for the specific water quality parameters to use).	Obtain from literature and use decision process	Parameters may include nutrients, salinity, pH, DO, nitrogen, phosphorus, microbes, and others. Data available from NASQWAN[35]
20	Maintain	Flow dynamics	Power plant operations	Mainstem	ROD operating criteria	Current ROD operating criteria	See MO 50 for experimental flows
			BHBF flows		Maximum 45,000 cfs (March to April)		
			Habitat maintenance flows		ROD operating criteria		

Goal 6. ~~Increase fine sediment storage~~Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
21	Maintain or attain	Sediment	Abundance	Main channel up to power plant capacity	329,000 m^3 (35 sites)[12; 31]	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]	Information Need	Also see Kondolf.[16] Target level should consider spawning habitat for trout in Glen Canyon.
			Distribution		Information Need	Information Need	Metric is # sandbars by reach. Target level should consider spawning habitat for trout in Glen Canyon.
22	Maintain or attain	Sediment	Abundance	Eddies up to power plant capacity	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 # sandbars by reach

Goal 6. ~~Increase fine sediment storage~~Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
23	Maintain or attain	Sediment	Abundance	Shorelines between power plant capacity 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		0.15-0.18mm (31)	Information Need	
			Distribution		Information Need	Information Need	Metric is # sandbars by reach

Goal 7. Maintain or attain viable populations of Kanab ambersnail.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	The metric is the population parameter(s) that indicate viability. Target is a viable population.
				AZ (except Vasey's Paradise)	3 individuals (Keyhole) 21 individuals (Elves) 0 individuals (Deer Creek)[1]	Information Need	The metric is the population parameter(s) that indicate viability. Target is a viable population.
25	Maintain	Kanab ambersnail	Habitat	Vasey's Paradise	82-99m^2 (monkeyflower) 36.6 m^2 (watercress) (area below 70,000 cfs stage)[24]	Information Need	Target is level needed to sustain a viable population.

Goal 8. Protect the presence of southwestern willow flycatcher and its critical habitat in a manner consistent with riparian ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
26	Maintain or increase	Southwest willow flycatcher	Abundance	CRE below GCD	12 breeding pairs[26]	Information Need	The target is the number of breeding pairs that the habitat is capable of supporting.
			Distribution	CRE below GCD	Information Need	Information Need	The target is the distribution of breeding pairs that the habitat is capable of supporting.
			Fledging success	CRE below GCD	Information Need	Information Need	See GCMRC[7]
27	Maintain	Southwest willow flycatcher	Critical habitat	CRE below GCD	Information Need	Information Need	
28	Reduce	Brown-headed cowbird	Brood parasitism	CRE	50% of nests parasitized[2]	Information Need	

Goal 9. Protect or improve the biotic riparian and spring communities.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
29	Maintain	Marsh	Abundance	CRE below GCD	1215 patches (4.6 ha)[7]	Information Need	See Kearsley[15] and Stevens et al.[29]
			Composition		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
			Distribution		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
30	Maintain	New high water zone	Abundance	CRE below GCD	Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
			Composition		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
			Distribution		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
31	Maintain	Old high water zone	Abundance	CRE below GCD	Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
			Composition		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
			Distribution		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]
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	See Kearsley[15] and Stevens et al.[29]
			Distribution		Information Need	Information Need	See Kearsley[15] and Stevens et al.[29]

Goal 9. Protect or improve the biotic riparian and spring communities.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
33	Preserve: stabilize or improve	Culturally important species	Abundance Composition	CRE below GCD	157 species (Plants)[21; 30]	Information Need	See MO 42 – MO 33 may be redundant
			Distribution		Information Need	Information Need	
34	Reduce	Invasive non-native species	Abundance	CRE below GCD	95+ species (Plants)[28] 3 species (Birds)[28]	Information Need	
			Distribution		Information Need	Information Need	

Goal 10. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
35	Maintain	Visitor	Physical access and safety	Mainstem	Information Need	Information Need	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]
36	Maintain or improve	Recreational spectrum	Quality and quantity	Glen Canyon	Information Need	GLCA Management Plan levels	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]
37	Maintain or increase	Camping beaches	Size	Mainstem	Information Need	Information Need	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]
			Quality		Information Need	Information Need	Metric includes parameters for vegetation, sanitation, and shade

Goal 10. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
			Number		262 campsites[14]	Information Need	
			Distribution		37% of campsites in critical reaches[14]	Information Need	
38	Maintain or improve	Rapids	Navigability	Mainstem	Information Need	Information Need	Target level to be developed from NPS on-river accident rates. See Myers et al.[25]

Goal 10. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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.

Goal 11. Maintain or increase power and energy generation within the framework of GCDAMP ecosystem goals.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
40	Maintain or increase	Power	Generation flexibility	GCD	ROD and current operating practices[33]	Information Need	

Goal 12. Preserve, protect, manage, and treat ~~C~~cultural resources ~~within the river corridor shall be preserved, protected, managed and treated~~ for the inspiration and benefit of past, present and future generations.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
41	Preserve	Register-eligible properties	National Register integrity	APE	Information Need (> 265 historic properties)	100% of extant historic properties	Preserve via protection, management, and/or treatment for the purpose of federal agency compliance with the NHPA and AMP/AMWG compliance with GCPA.
42	Preserve	Traditionally important resources	Resource integrity	CRE	Information Need (obtained through ethnographic studies, polls, interviews, surveys, and literature)	Stable or improving for each identified resource	Purpose is to preserve (stabilize or improve based on current cultural values) other traditionally important resources that are not sufficiently addressed under other Mos.
43	Attain and maintain	AMP resource monitoring and management actions	Government to Government Consultation	CRE	Existing Level: TWG, AMWG, and PA meetings. $75,000 (appropriated) & $400,000 (power revenues)	100% of AMP actions	Attain and maintain a government to government consultative relationship regarding all AMP activities.
44	Protect and maintain	Traditional cultural resources	Physical access	CRE	Information Need	Information Need	AMP won't knowingly restrict or block physical access by Native American religious practitioners. SEE AIRFA & EO

Goal 12. 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.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
							13007; meaningful consultation issue.
45	Integrate & synthesize	Cultural & environmental data	Increased interdisciplinary understanding of the ecosystem and its history	CRE	Not readily available and not synthesized or integrated	Readily accessible by georeferencing using GIS, databases, etc.	See cultural resources PEP report.

Goal 13. Maintain a high-quality monitoring, research, and adaptive management program.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
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	
47	Attain and maintain	Monitoring and research program	Natural, cultural, and recreational resources	CRE	GCMRC Strategic Plan	Updated GCMRC Strategic Plan	
48	Attain and maintain	AMP composed of all stakeholders	That acknowledges uncertainty and uses experimentation, monitoring & research	N/A	Information Need	Information Need	
			Participation		See meeting records	Information Need	
49	Attain and maintain	Management, research, and monitoring activities	Tribal AMP Participation (need to define tribal participation)	CRE	0	Information Need	

Goal 13. Maintain a high-quality monitoring, research, and adaptive management program.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
50	Conduct	Experimental flows	Flow dynamics	Mainstem	Information Need	Information Need	Target level is the experiments needed to gain critical understanding of ecosystem function under different dam operations.
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.
52	Build	AMP	Public support	N/A	Information Need	Information Need	Metric should include GCMRC and BOR web pages; GCD programs and tours; AMWG Outreach Committee; publications; various AMWG member activities.
53	Maintain or attain	Funding	Foundation and Corporate	N/A	$0	Information Need	
			Appropriated	N/A	$75,000 (FY2000)	$1,485,000 (FY2002)	
			State Agency	N/A	Obtain from literature	Information Need	
			Power revenues	N/A	$6.22M (for GCMRC) $1.443M (for BOR)	Information Need	

Goal 13. Maintain a high-quality monitoring, research, and adaptive management program.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments
54	Maintain or attain	Participation	Externally-funded investigators	CRE	Information Need	Information Need	Current and target levels should include small and cost-shared projects in NPS, AGFD, etc.

~~Goal 14. Build a broad, effective outreach program~~.. NOTE: This goal is now part of Goal 13.

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments

~~*Goal 15. Broaden the funding base to achieve GCDAMP Goals and Objectives.*~~ *NOTE: This goal is now part of Goal 13.*

ID#	Perform some action	On some element	On some attribute	At some place	From the current level	To the target level	Comments

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.

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]

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]

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 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.

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).

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.

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].

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.

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.

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