

Glen Canyon Dam Adaptive Management Work Group

Ad Hoc Committee on Strategic Planning

Report to AMWG, January 2001 Addendum

This report is intended to augment the materials sent to Adaptive Management Work Group (AMWG) members in preparation for your meeting January 11-12, 2001.

In the weeks since the packet for this meeting was sent out, the AMWG Ad Hoc Committee on Strategic Planning (AHC) has continued refining the Strategic Planning document. Small groups of TWG members and outside scientists, chaired by AHC members, have made numerous recommendations for changes and refinements to the Management Objectives (MOs). The Technical Work Group members have reviewed those recommendations and made suggestions of their own. The attached document shows how the MOs, and particularly the qualitative targets, have changed based on that input since the version of the document you saw at your last meeting. The AHC felt that because the AMWG will be asked to approve the qualitative targets at the meeting, it was important for members to use the most recent version. Note that the AHC has reviewed in detail the small group recommendations for Goals 1 through 7 only.

Current and target levels and the comments column have been deleted from this version, as they are not the subject of approval by the AMWG at this meeting. The vision and mission are not included because no changes are proposed for them.

In addition to changes to the MOs, several of the Goals and Principle 8 have been modified, as well. Those changes, like the changes to the MOs, are on the agenda for your approval at the upcoming meeting, and all are redlined for your convenience.

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.
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.
8. ~~Protect the presence of Southwest willow flycatcher in a manner consistent with 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	Qualitative Target
1.1 (1 and 3)	Maintain or attain	Primary producers: algae on hard substrates, rooted macrophytes on soft substrates, and diatoms Algae and periphyton	Biomass Composition Production	Mainstem from Glen Canyon Dam to the Paria River in both pools and on cobble bars identified by specific sampling sites	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.
1.2 (2)	Maintain or attain	Benthic invertebrates	Biomass Composition Production	Mainstem from Glen Canyon Dam to Paria River	
3	Maintain or attain	Aquatic macrophytes	Biomass Composition Production	Mainstem from Glen Canyon Dam to Paria River	
1.3 (4 and 6)	Maintain or attain	Primary producers: algae on hard substrates, rooted macrophytes on soft substrates, and diatoms Algae and periphyton	Biomass Composition Production	Mainstem below the Paria River on cobble bars identified by specific sampling sites	
1.4 (5)	Maintain or attain	Benthic invertebrates	Biomass Composition Production Distribution	Mainstem below the Paria River	

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	Qualitative Target
6	Maintain or attain	Aquatic macrophytes	Biomass Composition Production Distribution	Mainstem below the Paria River	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.
1.5 (7)	Maintain or attain	Foodbase drift: <u>Diptera</u> <u>Gammarus</u> <u>Other Bugs</u> <u>CPOM^(a)</u> <u>FPOM^(b)</u> <u>DOC</u>	Abundance Composition	Mainstem below GCD	

^(a) Coarse particulate organic matter

^(b) Fine particulate organic matter

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	Qualitative Target
2.1 (8)	Maintain or attain	Humpback chub (150 mm and larger) [Length is based on the size at which a HBC is able to be pit-tagged.]	Abundance	LCR aggregation ^(a) LCR and mainstem within 3 miles of LCR Eight mainstem aggregations Mainstem except within 3 miles of the LCR	The target is viable populations and removal of jeopardy.
2.2 (9)	Maintain or attain	Humpback chub (51 mm to 150 mm)	Year class strength Abundance	LCR aggregation LCR and mainstem within 3 miles of LCR Eight mainstem aggregations Mainstem except within 3 miles of the LCR	The target is viable populations and removal of jeopardy.
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 Eight mainstem aggregations	The target is viable populations and removal of jeopardy.
2.4 (10)	Establish	Humpback chub	Spawning aggregation Populations	CRE downstream of GCD	The target is viable populations and removal of jeopardy.

^(a) [The definition of the LCR aggregation will be resolved following completion of the stock assessment workshop and the PEP review.](#)

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	Qualitative Target
2.5 (11)	Attain	Humpback chub	Condition	LCR aggregation LCR and mainstem within 3 miles of LCR	The target is viable populations and removal of jeopardy.
				Eight mainstem aggregations Mainstem except within 3 miles of the LCR	
			Disease and other parasites Health	LCR aggregation LCR and mainstem within 3 miles of LCR	
				Eight mainstem aggregations Mainstem except within 3 miles of the LCR	
(12)	Maintain or attain	Humpback chub	Spawning	LCR and mainstem within 3 miles of LCR	
				Mainstem except within 3 miles of the LCR	
2.6 (13)	Reduce	Native Non native fish	Mortality due to non-native fish predation as a % of overall mortality Predation on native fish	LCR CRE below GCD	The target is reduction of non-native fish predation and competition so it does not impinge on native fish viability.
				Mainstem	
			Competition with native fish	CRE below GCD	
2.7 (14)	Attain	Razorback sucker	Abundance Populations	CRE below GCD	Target is derived from the capability of the habitat to support the species.

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	Qualitative Target
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2.8 (15)	Maintain	Flannemouth sucker	Abundance	CRE below GCD	The target is viable populations and removal of jeopardy.
			Distribution		
		Bluehead sucker	Abundance		
			Distribution		
Speckled dace	Abundance				
	Distribution				

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

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
3.1 (16)	Restore	Colorado pikeminnow Bonytail Roundtail Chub River otter	Abundance	CRE downstream of GCD	See goal.

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.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
4.1 (17)	Maintain or attain	Rainbow trout	Abundance	Mainstem from Glen Canyon Dam to Paria River	Target is the level at which trout do not impinge on native fish.
			Proportional stock density (see below)		
			Length at age		
			Growth rate		
			Condition		
			Whirling disease and other parasitic infections		
Health	See goal.				
Spawning habitat					
Natural recruitment					
4.2 new	Limit	Lees Ferry Rainbow trout	Distribution	CRE below the Paria River	The target is minimal competitive or predator / prey effect on downstream native fish.

[Proportional Stock Density is the ratio that results by dividing the number of fish great 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 7.5. Establish water temperature, quality, and flow dynamics to achieve GCDAMP ecosystem goals.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
7.1 (18)	Attain	Water	Temperature range	Mainstem	<p>The target 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 targeted featured 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.</p>
			Seasonal variability of temperature		
7.2 (19)	Maintain	Water	Quality	Mainstem	<p>The target is water quality based on the range of natural variability, the range of operational flexibility of the dam, the range of legal flexibility, the legally-defined state water quality standards, and the range that optimizes conditions for the targeted featured resources. The targeted resources are foodbase, native fish, trout, Southwestern willow flycatcher, riparian and spring communities, the recreational experience, and cultural resources.</p>
7.3 (20)	Maintain	Flow dynamics	Power plant operations	Mainstem	<p>See goal.</p>
			BHBF flows		
			Habitat maintenance flows		

Goal 86. ~~Increase fine-~~Maintain or attain levels of sediment storage within the main channel and along shorelines to achieve GCDAMP ecosystem goals.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
8.1 (21)	Maintain or attain	Fine S _s sediment	Abundance	Main channel up to power plant capacity	The target for Goal 8 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.
			Grain-size		
			Distribution		
8.2 (22)	Maintain or attain	Fine S _s sediment	Abundance	Eddies up to <u>25,000 cfs</u> power plant capacity	
			Grain-size		
			Distribution		
8.3 (23)	Maintain or attain	Fine S _s sediment	Abundance	Shorelines between <u>25,000 cfs</u> power plant capacity and maximum BHBF	
			Grain-size		
			Distribution		

Goal 57. Maintain or attain viable populations of Kanab ambersnail.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
5.1 (24)	Attain and maintain	Kanab ambersnail	Population	Vasey's Paradise	Target is a viable population.
5.2 (25)	Maintain	Kanab ambersnail	Habitat	Above some stage level at Vasey's Paradise (stage level is an 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.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
(26)	Maintain or increase	Southwest willow flycatcher	Abundance	CRE below GCD	The target is the number of breeding pairs that the habitat is capable of supporting.
			Distribution	CRE below GCD	The target is the distribution of breeding pairs that the habitat is capable of supporting.
			Fledging success	CRE below GCD	
6.8 (27)	Maintain	Southwest willow flycatcher	Riparian Critical habitat	CRE below GCD, and especially from Separation to Lake Mead	The target is the capability of the habitat to support the species. The target is For 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.
(28)	Reduce	Brown-headed cowbird	Brood parasitism	CRE	

Goal 69. Protect or improve the biotic riparian and spring communities.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
6.1 (29)	Maintain	Marsh	Abundance	CRE below GCD	Target is no loss of native species.
			Composition		
			Area Distribution		
6.2 (30)	Maintain	New high water zone community	Patch number and distribution Abundance	CRE below GCD	In all river reaches where it was documented by aerial photography in 1984, the target is to allow for scouring of some NHWZ vegetation due to periodic high flows, and to allow its return through successional processes.
			Composition		Target is to allow no loss of native plant or animal species.
			Area Distribution		
6.3 (31)	Maintain	Old high water zone	Abundance	CRE below GCD	Target is no loss of area.
			Composition		
			Distribution		
6.4 (32)	Maintain	Sand beach	Abundance	CRE below GCD	
			Composition		
			Distribution		
6.5 (33)	Maintain	Culturally important species	Abundance	CRE below GCD	
			Distribution		
6.6 (34)	Reduce	Invasive non-native species	Abundance	CRE below GCD	The target is the level at which these species do not impinge on biological, recreational, and cultural resources.
			Distribution		The target is no spreading of invasive non-native species to areas where they do not already occur

The target [for the goal as a whole](#) is an achievable and appropriate mix of [four](#) these 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.

Goal 69. Protect or improve the biotic riparian and spring communities.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
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6.7 new	Maintain	Spring and wetland	Habitat occupied by rare and endemic species	CRE below GCD	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.
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Goal 9.10. Maintain or improve the quality of recreational experiences for users of the Colorado River ecosystem, within the framework of GCDAMP ecosystem goals.

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
9.1 (35)	Maintain	Visitor	Physical access and safety	Mainstem	The target level should be within the capacity of the CRE to absorb visitor impacts. The target level should consider GLCA and GRCA Management Plans. See Myers et al. ⁽²⁵⁾
9.2 (36)	Maintain or improve	Recreational spectrum	Quality and quantity	Glen Canyon	
9.3 (37)	Maintain or increase	Camping beaches	Size	Mainstem	
			Quality		
			Number		
		Distribution			
9.4 (38)	Maintain or improve	Rapids	Navigability	Mainstem	The target level is 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	Metric to include parameters for primitive character, unconfined experience, undeveloped natural and wild character, opportunities for solitude, sounds of nature and scenic beauty.

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

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
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10.1 (40)	Maintain or increase	Power	Generation flexibility	GCD	See goal.
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Goal ~~11.2~~. 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.~~

MO #	Perform some action	On some element	On some attribute	At some place	Qualitative Target
11.1 (41)	Preserve	Register-eligible properties	National Register integrity	APE	The 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	The 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	Management action	Consultation	CRE	The target is to achieve effective, legally mandated consultation.
11.4 (44)	Protect and maintain	Traditional cultural resources	Physical access	CRE	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.
11.5 (45)	Integrate	Information	Cultural and other resources	CRE	The 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	Qualitative Target
12.1 (46)	Maintain or attain	Socio-economic data	Hydropower	N/A	The target level is how much socioeconomic data is needed for adequate decision-making.
			Air quality	N/A	
			Wilderness	N/A	
			Recreation	N/A	
			Non-use values	N/A	
			Tribal & spiritual values	N/A	
12.2 (47)	Attain and maintain	Monitoring and research program	Natural, cultural, and recreational resources	CRE	See goal.
12.3 (48)	Attain and maintain	AMP composed of all stakeholders	That acknowledges uncertainty and uses experimentation, monitoring & research	N/A	See goal.
			Participation		
12.4 (49)	Attain and maintain	Funding	Tribal participation	AMP	The target is a level of funding adequate to meet each tribe's needs to participate in the Adaptive Management Program.
12.5 (50)	Conduct	Experimental flows	Flow dynamics	Main-stem	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	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	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	The target is adequate funding to meet the goal.
			Appropriated	N/A	
			State Agency	N/A	
			Power revenues	N/A	
12.9 (54)	Maintain or attain	Participation	Externally-funded investigators	CRE	The target is contributions to meeting Information Needs by externally funded investigators.

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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

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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).

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).

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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 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

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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 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.

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.