Summary of Results from GCDAMP TWG Multi-Attribute Evaluation Workshop

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1.0 Background and Purpose

This project was initiated as a result of a desire by the Glen Canyon Dam Adaptive Management Program (GCDAMP) to develop quantitative targets for key resources against which the success of management actions and experiments could be evaluated. After preliminary scoping, the project team[1] concluded that the existence of trade-offs among key resource endpoints meant that a single-attribute approach to target setting would be inappropriate. The project team proposed that GCDAMP develop instead a multi-attribute trade-off analysis (MATA) that would serve as a framework for evaluating management options. In February 2003, the Technical Working Group (TWG) of the GCDAMP agreed to participate in a workshop to develop and test a multi-attribute evaluation framework. The objectives of the workshop were:

- Gain an understanding of interactions among key resource endpoints
- Expose key trade-offs and uncertainties
- Gain experience with some structured methods for exposing values and preferences
- Identify refinements to endpoints, attributes, options and modeling/estimation methods
- Identify preliminary areas of agreement and disagreement

In preparation for the workshop, the project team developed a draft evaluation framework, consisting of a small set of **endpoints** (resource outcomes of concern) and **attributes** (quantitative metrics for assessing the impact of the management options on the endpoints). A preliminary set of management options was defined. A consequence table summarizing the expected impact of the options on the endpoints was prepared using existing information, models and expert judgment.

2.0 Endpoints and Attributes

The draft endpoints and attributes were refined with input from participating TWG members (Table 1). Additions or changes included:

- combining sand deposition for camping beaches and archaeological sites into a single attribute (previously separated)
- addition of long term beach sustainability as an attribute
- removal of attribute for rainbow trout below Lees Ferry
- addition of boating safety and accessibility (as affected by water level fluctuations)
- modification of the calculation of the power/financial attribute so that power impacts include both revenue implications and the cost of purchasing capacity.

Due to time limitations, the latter two changes were not incorporated into the pilot, but are noted for future analysis.

[1] The project team is headed by Ecometric Research from Vancouver, British Columbia. Team members include Josh Korman of Ecometric, Dr. Carl Walters of University of British Columbia, and Lee Failing of Compass Resource Management.

Table 1 Endpoints and Attributes

Endpoint	Attribute	Description
NATIVE FISH – Humpback Chub: LCR	Abundance (# fish relative to 2003)	Reports the incremental effect of management options on the expected abundance of humpback chub in the Little Colorado River. Number reported is a loss or gain relative to 2003 abundance. This attribute may be viewed as a surrogate for other native fish species.
	Probability of Extinction (%)	In some cases, a management option may have a higher expected value for chub abundance, but also a higher risk of a negative outcome. This attribute reports the probability of extinction of humpback chub in the Little Colorado River by 2030. This attribute may be viewed as a surrogate for other native fish species.
NATIVE FISH - HBC: Mainstem	Probability of Establishing (%)	Reports the probability of establishing a viable population of humpback chub in the mainstem Colorado River.
SPORT FISH – RBT	Abundance (thousands)	Reports expected abundance of fish > 150 mm in reach above Lees Ferry.
	Size (% of 2003)	Reports expected size relative to 2003 above Lees Ferry
	Probability of Major Decline (%)	Reports the probability that the abundance of rainbow trout above Lees Ferry will decline by 50% or more.
SAND DEPOSITION	Beaches and Arch Sites (% of 1984 area)	Reports the expected area of sand bars in Marble Canyon. Increased sand deposition will improve the availability and quality of camping beaches and increase protection of archaeological sites from erosion.
	Sustainability of Sand Sources (%)	Reports the probability that the estimated sand deposition can be maintained indefinitely.
RIPARIAN / WILDLIFE	Peregrine Falcon Abundance (% of 2003)	Reports the expected incremental effect on peregrine falcon abundance as a result of management options. Can be used as a surrogate for other avifauna that depend on the cold clear aquatic ecosystem above Lees Ferry.
BOATING ACCESS / SAFETY	Magnitude of fluctuation	Reports the magnitude of the daily or weekly water level fluctuation. Indicates the relative degree of safety and/or convenience for boaters.
POWER / FINANCIAL	Annual Cost (million $ / year)	Reports the average annual cost of a management option. For dam operation options, this involves an estimate of annual power costs relative to unconstrained operation; for non-power options, it involves estimating the levelized annual cost associated with construction and operation of non-power works.
	SPA Issue? (Yes/No)	Reports whether or not a management options creates issues with respect to the Colorado River Storage Project Act. It was argued that issues associated with other Acts (e.g. Grand Canyon Wilderness Protection Act) should also be included, or that this attributed be dropped.

3.0 Management Options and Consequences

Management options that were evaluated included:

POWER — Flows optimized for power production, without regard to impacts of diurnal fluctuation

MLFF — Continuation of current water operations and restrictions on flow variation

TCD — Construction of temperature control device to warm the river, in conjunction with MLLF flow option

SED PIPE — Augmentation of sediment inputs at Lee's Ferry

FLOW OPTION A — Steady flows in fall, with a January spike flow intended to conserve sediment

FLOW OPTION B — Like OPTION A, but longer steady flow period (summer and fall) to benefit native fishes as well as conserve sediment

FLOW OPTION C — Steady summer flow, fluctuating flow for rest of year (including fall), spike flow in January

FLOW OPTION D — Like OPTION C, but bigger spike flow in January to deposit sand on eroding cultural sites

TWG members reviewed and provided input on the preliminary management options. The draft consequence table was updated with input from TWG members (Table 2). It summarizes the estimated impacts of each option on each attribute.

Table 2 Estimated Impacts of the Management Options on the Attributes

Attribute	Units	What's Good	MLFF	TCD w MLFF	Sed Pipe - Sand	Flow A	Flow B	Flow C	Flow D	POWER - No Action	Sed Pipe - Turbidity
NATIVE FISH - HBC - LCR											
Abundance	# fish relative to 2003	more	-1000	1000	-500	-1000	-200	-1000	-1000	200	1000
Probability of Extinction	%	less	10%	50%	10%	10%	20%	10%	10%	5%	5%
NATIVE FISH - HBC - MAINSTEM											
Probability of Establishing	%	more	0%	50%	0%	0%	20%	0%	0%	0%	0%
SPORT FISH - RAINBOW TROUT											
Abundance	thousand fish > 1500 mm	more	100	80	100	100	150	100	100	10	100
Size	% 2003 condition	more	100%	120%	100%	100%	50%	100%	100%	200%	100%
Probability of Major Decline	%	less	0%	30%	0%	0%	0%	0%	0%	100%	0%
SAND DEPOSITION											
Beaches and Arch Sites	% 1984 sand coverage	more	50%	50%	90%	75%	80%	60%	80%	60%	50%
Probability of Sustainability	%	more	0%	0%	100%	50%	60%	10%	60%	0%	0%
RIPARIAN / WILDLIFE											
Peregrine Falcon	% 2003 Abundance	more	100%	80%	60%	110%	120%	100%	100%	80%	60%
POWER / FINANCIAL											
Levelized Annual Cost	Million $/year	less	7.5	12.3	14.5	8.6	15.3	10.0	9.5	0.0	14.5
SPA Issue	Yes =1; No = 0	less	0	0	1	0	0	0	1	0	0

4.0 Ranking and Weighting Exercises

After a review of the consequence table, stakeholders participated in a structured values elicitation process. There are three main reasons to use structured methods to elicit stakeholder values and preferences:

- to increase the accuracy and consistency of individual stakeholder judgments
- to increase the accountability and transparency of decisions by making the trade-offs made by stakeholders explicit
- to provide focus for constructive deliberations and refinement of the options.

There are many ways to elicit values. Different methods usually produce different results; no method is necessarily right. The use of multiple methods provides insight to the decision by thinking about it in different ways. By examining choices from different perspectives, stakeholders will have more confidence that their choices reflect their values, and are not the result of methodological bias.

The methods used in the workshop were selected because:

- They have a strong theoretical basis and are technically defensible;
- They are simple to understand and easy to process, with a quick turnaround time;
- They produce results in a format that support constructive deliberations;
- They have a strong track record of success, having been used in support of stakeholder deliberations at nearly 20 hydroelectric facilities in British Columbia, Canada.

For the GCDAMP pilot, stakeholders conducted two ranking and weighting exercises:

- Direct Ranking
- Swing Weighting

In Direct Ranking, stakeholders were asked to rank and then score each management option directly. In swing weighting, they were asked to rank and weight each attribute. The term "swing" weighting is used because decision makers are asked to say which attribute they would most want to "swing-up" from its worst to its best value. This is important because in some cases an attribute may be important in a general sense, but the actual change in the attribute value that results from the choice among management options may be relatively insignificant; this should affect the weight assigned to it.

Attribute weights were entered into the following equation that computed an overall score for each option:

$SCORE(a) = W_1(x_{1a}) + W_2(x_{2a}) + \ldots\ldots$

Where:

SCORE(a)	= the calculated score for a management option (e.g. 'a')
W_1, W_2…	= the weight of an attribute
x_1, x_2…	= the scaled impact of a given option on each attribute

Ranks for each management option for each stakeholder were then derived.

5.0 Results

This exercise was a pilot, and as a result, caution should be used in drawing any conclusions about selecting or rejecting management options. However, the following outlines the kinds of insights the analysis can provide to decision makers.

Figure 1 provides an example from a single stakeholder comparing their ranks assigned by the direct method and ranks assigned by the swing weighting method. Options ranked the same by both methods fall on or near the 45 degree line. Options that fall far from the 45 degree line should trigger a re-examination of that alternative by the stakeholder. For example, from Figure 1 we see that Stakeholder 2's ranks are quite consistent across the two methods except for Flow Option B. This option is ranked very low by the direct method, but is ranked number one by the weighted method. While this does not necessarily mean that the direct rank is wrong, it may indicate any of a number of problems, such as:

- mixing up the options in the direct ranking (common when there are many options);
- overlooking some elements of performance in the direct ranking (common when there are many attributes)
- overlooking options that are less controversial or less visible (reflecting a tendency to spend more discussion time on options with either vocal champions or vocal opponents).

Alternatively the direct ranking may be a more accurate reflection of the stakeholder's values if the attributes do not adequately capture all the important elements of performance. The intent of the multi-method approach is therefore not to say that one method is better than another, but to expose inconsistencies, clarify the rationale for choices, and improve the transparency and accountability of decisions.

Figure 1 Comparison of Ranks by Direct and by Swing Weighting Methods for Stakeholder 2

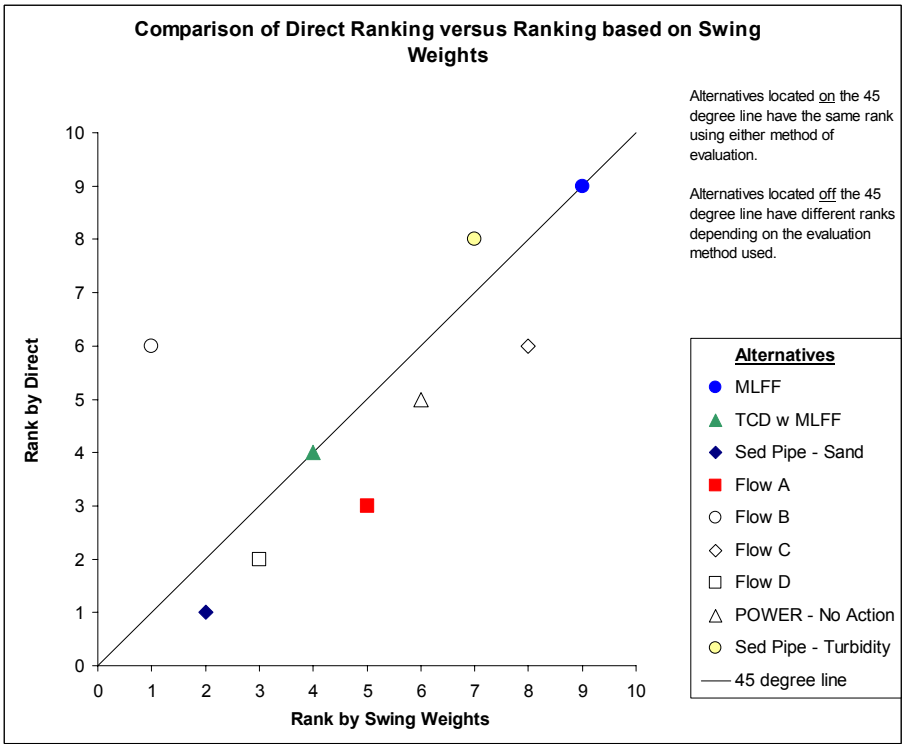

Figure 2 shows the range and distribution of weights assigned to each attribute by the group of stakeholders. Some clear groupings of weights can be seen in this figure, as well as significant outliers. All participants placed a similar and relatively high weight on humpback chub in the LCR, but one participant placed a much lower value on establishing a mainstem population. This highlights an area where further dialogue may be constructive. The low weight may reflect the participant's true values; however, it also may be a case where further dialogue among participants would increase understanding of the relative importance of a second population, and values may converge. In other cases, there is general agreement about relative values (for example, wildlife and boating access/safety are consistently weighted lower than chub, sand and Lees Ferry rainbow trout). Note first that this reflects the weight assigned given the swing across the range of possible outcomes, which according to the impact estimates do not include catastrophic outcomes for either of these attributes. This general agreement suggests that further debate about the relative value of these resources may not be necessary.

Figure 2 Range and Distribution of Weights Across Stakeholders

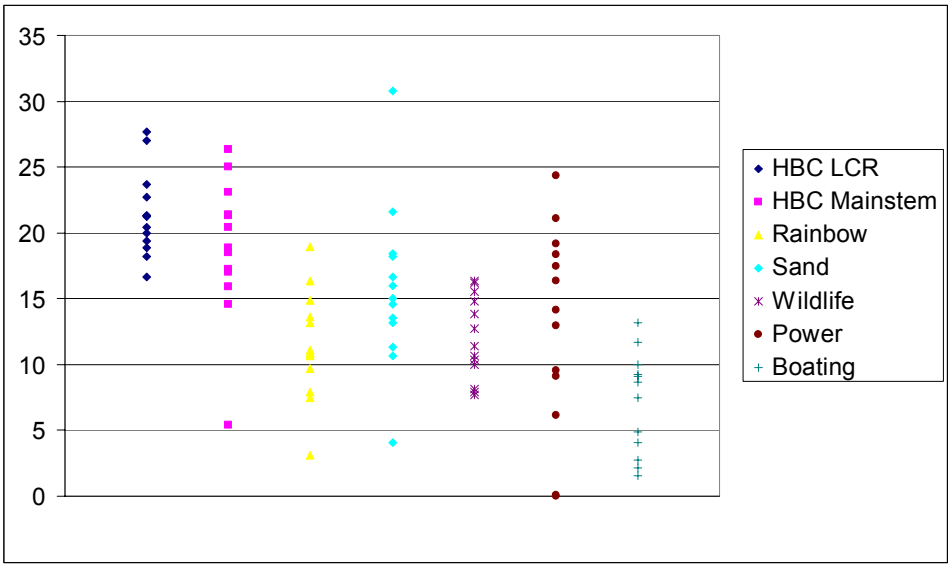

Figure 3 summarizes the ranks assigned by stakeholders to each option by each method. Options ranked 1 or 2 are colored green, 3 or 4 are yellow, 5, 6, or 7 are white and 8 or 9 are red. From this we could conclude that the TCD option received a lot of support, both by direct and weighted methods and may be a candidate for further exploration. Direct ranks for Flow Option B were variable, but this option was ranked either first or second by all stakeholders by the weighted method, suggesting it is also a candidate for further consideration. Flow Option A while receiving few first or second place ranks, did not elicit a high degree of opposition. The remaining options did not score well by either method, and, in a real rather than pilot evaluation, might be eliminated from further consideration.

Figure 3 Ranks Assigned to Alternatives by All Stakeholders by Direct and Swing Weighting Methods

Stakeholders	Method	MLFF	TCD w MLFF	Sed Pipe - Sand	Flow A	Flow B	Flow C	Flow D	POWER - No Action	Sed Pipe - Turbidity
1	Direct	8	1	3	5	5	5	9	3	1
	Swing	9	3	5	2	1	7	4	6	8
2	Direct	9	4	1	3	6	6	2	5	8
	Swing	9	4	2	5	1	8	3	6	7
3	Direct	6	2	9	6	6	5	4	2	1
	Swing	7	2	9	4	1	6	8	3	5
4	Direct	6	9	6	1	2	2	2	2	6
	Swing	7	4	8	2	1	6	5	3	9
5	Direct	9	1	2	6	5	7	7	3	3
	Swing	9	3	6	2	1	5	4	8	7
6	Direct	2	2	1	4	5	6	9	6	6
	Swing	8	2	7	3	1	6	4	5	9
7	Direct	2	1	8	5	4	6	7	2	8
	Swing	7	3	8	2	1	6	4	5	9
8	Direct	3	2	9	6	6	6	5	1	3
	Swing	5	2	9	4	1	6	8	3	7
9	Direct	7	6	4	3	2	5	1	9	8
	Swing	9	2	5	3	1	7	4	6	8
10	Direct	7	1	8	2	2	5	5	2	8
	Swing	6	2	8	3	1	7	5	4	9
11	Direct	4	1	3	2	4	7	8	8	6
	Swing	7	1	9	4	2	6	8	3	5
12	Direct	3	2	8	4	5	5	5	1	8
	Swing	8	4	7	2	3	9	5	1	6
13	Direct	9	3	8	7	2	3	6	5	1
	Swing	9	1	7	3	2	8	5	4	6
14	Direct	2	1	7	7	6	5	3	7	4
	Swing	7	3	8	2	1	6	5	4	9
15	Direct	6	1	2	5	3	4	7	8	8
	Swing	8	2	5	3	1	6	4	7	9

6.0 Conclusions and Next Steps

This MATA exercise was prepared and executed as a pilot exercise to explore the multi-attribute approach, test specific methods, and determine their usefulness for GCDAMP in future decision making. Limitations included:

- limited stakeholder participation, with the result that the full range of values of the TWG membership was unlikely captured;
- relatively short timeframe may not have allowed full discussion and understanding of the attributes and the significance of the impacts;
- set of attributes may be incomplete;
- set of management options was incomplete;
- some important aspects of uncertainty associated with some options were not fully represented or discussed.

The TWG should therefore use caution in drawing any conclusions about selecting or rejecting options on the basis of this analysis. However, as a test of methods, the pilot was quite useful. Participants expressed unanimous support for the MATA approach. Key benefits included:

- making values of all stakeholders explicit;

- facilitating constructive dialogue about value differences;
- distinguishing between disagreements caused by differences about facts and those caused by differences about values;
- exposing uncertainty and the role of risk tolerance in making decisions and trade-offs;
- focusing on the evaluation of management options, which some TWG members identified as the next step in the strategic planning process;
- facilitating constructive dialogue between stakeholders and scientists, with emphasis on the role of scientists in answering managers' questions about specific management options rather than in simply delivering technical presentations on their areas of expertise.

Important refinements identified included improved impact estimates (e.g., power), and a more detailed treatment of uncertainty (e.g., humpback chub).

Determination of next steps depends on a review by TWG and AMWG members. Some possible next steps that were suggested by workshop participants included:

1. Options and Attributes Workshop. One day working session (project team and GCMRC staff and/or small subgroup of TWG) to refine management options and attributes. The key is to develop a strategic set of options that expose major differences in approaches to management (e.g., flow options, TCD option, SED options, and techno-fix options) rather than a long list of every possible combination of management options.

2. Impact Estimation. Refined estimation of the impacts of the options on the attributes by the contractors. This will involve more accurate modeling or elicitation of expert judgments on attributes for which there is greater uncertainty or controversy. The uncertainty associated with each option must be better characterized. This will involve both a narrative and graphic summary of the range of possible outcomes (for holistic/direct ranking) and development of a summary statistic(s) to facilitate a weighting approach that accounts for uncertainty.

3. Multi-attribute Trade-off Analysis Workshop. 2-3 day workshop to conduct a full-scale multi-attribute evaluation of options with TWG and/or AMWG members.