GCDAMP FY 2017 Knowledge Assessment: Final Report from the Executive Coordinator for the Science Advisors Program

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Contents

Executive Summary

This document reviews the purposes, methods, and results of the Knowledge Assessment (KA) carried out in FY 2017 for the Glen Canyon Dam Adaptive Management Program (GCDAMP) Technical Work Group (TWG), with advice and support from the Grand Canyon Monitoring and Research Center (GCMRC) and the GCDAMP Science Advisors Program Executive Coordinator (SAP-EC), and offers recommendations for improving the KA process.

The FY 2017 KA had three objectives, to (1) summarize what is known about the priority resources of the GCDAMP, (2) assess needs for monitoring to sustain crucial knowledge, and (3) identify critical knowledge gaps and weaknesses that require attention. The resulting information provides crucial guidance for work planning and budgeting. The TWG also conceived the FY 2017 KA as a trial with two additional objectives, (4) to test a standardized process for conducting the KA and compiling its findings that can be repeated with minimal effort and high consistency, and (5) to test the utility of presenting the KA findings in the form of a set of simple tables and graphical symbols to facilitate communication. Such tools and graphics are sometimes termed a "scorecard."

The FY 2017 KA focused on eleven priority resource topics derived from the 2016 GCDAMP Long-Term Experimental and Management Plan, Final Environmental Impact Statement (LTEMP FEIS) and Record of Decision:

- Aquatic food base
- Archaeological and cultural resources
- Humpback chub
- Hydropower and energy
- Invasive fish species
- Other native fish species
- Rainbow trout fishery
- Recreational experience
- Riparian vegetation
- Sediment
- Water quality

The FY 2017 KA addressed three broad spheres of knowledge for each of these eleven focal resource topics:

- Status and Trend: How closely does the condition of the resource currently approach management objectives and, if the current condition shows any trend, is this a trend toward or away from management objectives?
- Drivers and Constraints: What environmental factors, including human actions and basic dam operations, most strongly affect resource status and trend, how strong are these effects, and do these effects constrain or drive resource condition toward or away from management objectives?
- LTEMP Experimental and Management Actions: Which LTEMP experimental and management actions are expected to affect resource condition and trend, how strong are these effects expected to be, and are these effects expected to drive resource condition toward or away from management objectives?

The assessment combined and expanded on methods developed for similar knowledge assessments by the National Park Service (NPS), Natural Resources Condition Assessment Program (http://www.nature.nps.gov/water/nrca/), and the Sacramento-San Joaquin Delta Ecosystem Restoration Program (https://www.dfg.ca.gov/ERP/ conceptual_models.asp). Each resource topic for the GCDAMP FY 2017 KA was assessed by a team of experts from the GCMRC, cooperating institutions, and stakeholders. The experts recorded their information using a spreadsheet tool developed by the SAP-EC, based on the NPS and Delta methods.

The team for "Other Native Species" could not complete its assessment due to scheduling conflicts. The experts for the other ten resources assessed the current status of seven overall as meeting the criteria for "Moderate Concern," and assessed two, aquatic food base and recreational experience, as meeting the criteria for "Significant Concern" overall. Only one resource, invasive fish species (nonnative invasive species), received an overall rating of "Good Condition." Since this last resource topic focuses on a threat, its status indicates that, non-natives, invasive fish species overall currently pose only a limited threat to other species in the system. However, the expert teams consider six of the ten assessed resources currently to be experiencing either no net trend in status, and four – aquatic food base, archaeological and cultural resources, hydropower and energy, and the recreational experience – to be experiencing deteriorating trends in status. The experts did not identify any resource as currently experiencing a net improving trend in status.

The assessment of drivers and constraints identified numerous factors that influence the status of the ten assessed focal resources. These factors fall into thirteen proposed overarching categories: aquatic food base dynamics (primary and secondary production), aquatic invasive species, archaeological site disturbance, boat and aircraft launches, dam design and operational constraints, humpback chub dynamics, Lake Powell conditions, rainbow trout dynamics, riparian vegetation dynamics, river flow variation, river water quality, river water temperature, and sediment dynamics (above and below baseflow stage).

The assessments of status and trend, drivers and constraints, and the potential effects of LTEMP experimental and management actions for the ten assessed resources also identified numerous gaps and areas of uncertainty in critical knowledge. The resources with the highest frequencies of such gaps and uncertainties were (in descending order of frequency): water quality, riparian vegetation, the rainbow trout fishery, the aquatic food base, humpback chub, invasive fish species, and sediment. The raw spreadsheet entries indicate that the expert teams reported these gaps and uncertainties because of difficulties with unclear or undefined management objectives for individual resource characteristics; temporal or spatial gaps in the available data; insufficient numbers of suitable data points; or high temporal or spatial variability in the available data. These findings highlight topics that could benefit from improved management objectives, continuing and/or improved monitoring, and/or research to address critical gaps and uncertainties.

The concluding recommendations identify needs and opportunities for the TWG and GCMRC to improve the assessment methods and their implementation under five headings: What to assess and when, assessment structure and process, the spreadsheet tool, the scorecard display system, and the default method used to average together the findings across multiple lines of evidence for each resource topic.

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Introduction

This document reviews the purposes, methods, and results of the Knowledge Assessment (KA) carried out in FY 2017 for the Glen Canyon Dam Adaptive Management Program (GCDAMP) Technical Work Group (TWG), and offers recommendations for improving the KA process.

The GCDAMP advises the Secretary of the Interior (Secretary) on the adaptive management of Glen Canyon Dam operations and other management and experimental actions subject to the provisions of the Grand Canyon Protection Act of 1992 (GCPA) and other Federal laws. The GCDAMP provides advice on the status of resources and the results of studies undertaken to increase knowledge of the effects of dam operations, other management actions, and environmental factors on key resource values. The GCDAMP oversees a substantial program of monitoring and research, and manages large bodies of data and knowledge, in order to advise the Secretary on these topics.

The GCDAMP periodically reviews the knowledge on which it bases its advice to the Secretary. This knowledge and advice crucially help inform decisions of the Secretary concerning adaptive management of dam operations and their impacts, as well as decisions on monitoring and research priorities. The review – here termed a 'knowledge assessment' – assesses the knowledge and the reliability or certainty of the knowledge, to address three broad objectives, to: (1) summarize what is known; (2) assess ongoing needs for monitoring to sustain crucial knowledge; and (3) identify crucial gaps and weaknesses in this knowledge that require attention.

The FY 2017 KA was overseen by the TWG Steering Committee Ad Hoc Group (SCAHG), with the content provided by teams of experts from the Grand Canyon Monitoring and Research Center (GCMRC), monitoring and research cooperators, and stakeholder representatives. The Executive Coordinator for the GCDAMP Science Advisors Program (SAP-EC) provided recommendations to the SCAHG on methods, prepared written guidance and spreadsheet tools for the expert teams, implemented quality assessment/quality control procedures for the expert team spreadsheet contributions, and compiled and analyzed the results. Craig Ellsworth, Western Area Power Authority, and manager of the GCDAMP WIKI site, provided a site from which members of the AMP community can access the KA documents.

The present document contains five sections, which (1) review the objectives of the FY 2017 KA, (2) review the structure of the KA, (3) review the assessment methods, including the graphic methods used to communicate KA results, (4) summarize and discuss the KA results, and (5) identify ways in which the KA process could be improved. Appendixes present the methods in detail and provide copies of all summary tabular results. The raw data entries are available at the GCDAMP WIKI site; Appendix E below provides a list of these raw data tables.

Assessment Objectives

The FY 2017 KA had three objectives:

- Summarize what is known.
- Assess needs for monitoring to sustain crucial knowledge.
- Identify critical knowledge gaps and weaknesses that require attention.

The resulting information provides crucial guidance for work planning and budgeting. The TWG also conceived the FY 2017 KA as a trial with two additional objectives:

- Test a standardized process for conducting the KA and compiling its findings that can be repeated with minimal effort and high consistency.
- Test the utility of presenting the KA findings in the form of a set of simple tables and graphical symbols to facilitate communication. Such tools and graphics are sometimes termed a "scorecard."

The FY 2017 KA focused on eleven priority resource topics identified in the GCDAMP Long-Term Experimental and Management Plan, Final Environmental Impact Statement (LTEMP FEIS) and Record of Decision (ROD) of the Secretary (2016). These topics and their associated management objectives under the LTEMP are as follows (as listed in the ROD):

1. *Archaeological and Cultural Resources.* Maintain the integrity of potentially affected NRHP[1]-eligible or listed historic properties in place, where possible, with preservation methods employed on a site-specific basis.

2. *Natural Processes.* Restore, to the extent practicable, ecological patterns and processes within their range of natural variability, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems.

3. *Humpback Chub.* Meet humpback chub recovery goals, including maintaining a self-sustaining population, spawning habitat, and aggregations in the Colorado River and its tributaries below the Glen Canyon Dam.

4. *Hydropower and Energy.* Maintain or increase Glen Canyon Dam electric energy generation, load following capability, and ramp rate capability, and minimize emissions and costs to the greatest extent practicable, consistent with improvement and long-term sustainability of downstream resources.

5. *Other Native Fish*. Maintain self-sustaining native fish species populations and their habitats in their natural ranges on the Colorado River and its tributaries.

6. *Recreational Experience*. Maintain and improve the quality of recreational experiences for the users of the Colorado River Ecosystem. Recreation includes, but is not limited to, flatwater and whitewater boating, river corridor camping, and angling in Glen Canyon.

[1] NRHP: National Register of Historic Places

7. *Sediment*. Increase and retain fine sediment volume, area, and distribution in the Glen, Marble, and Grand Canyon reaches above the elevation of the average base flow for ecological, cultural, and recreational purposes.

8. *Tribal Resources*. Maintain the diverse values and resources of traditionally associated Tribes along the Colorado River corridor through Glen, Marble, and Grand Canyons.

9. *Rainbow Trout Fishery*. Achieve a healthy high-quality recreational rainbow trout fishery in GCNRA and reduce or eliminate downstream trout migration consistent with NPS fish management and ESA compliance.

10. *Nonnative Invasive Species*. Minimize or reduce the presence and expansion of aquatic nonnative invasive species.

11. *Riparian Vegetation*. Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate.

The FY 2017 formally considered two specific resource topics under the general category of Natural Processes: the aquatic food base, and water quality. At the same time, the tribes represented on the TWG, and the TWG SCAHG, recognized that the GCDAMP has no history of formally assessing the state of knowledge concerning tribal resources other than NRHP-eligible or listed historic places under the provisions of the National Historic Preservation Act. Consequently, it will take time to develop methods and knowledge categories appropriate to the topic of "Tribal Resources." The FY 2017 KA therefore was not able to address this topic.

The FY 2017 KA thus focused on the following eleven topics (listed in alphabetical order):

- Aquatic food base
- Archaeological and cultural resources
- Humpback chub
- Hydropower and energy
- Invasive fish species
- Other native fish species
- Rainbow trout fishery
- Recreational experience
- Riparian vegetation
- Sediment
- Water quality

Assessment Structure

The FY 2017 KA sought to address three broad spheres of knowledge for each of these eleven focal resource topics:

- Status and Trend: How closely does the condition of the resource currently approach management objectives and, if the current condition shows any trend, is this a trend toward or away from management objectives?

- Drivers and Constraints: What environmental factors, including human actions and basic dam operations, most strongly affect resource status and trend, how strong are these effects, and do these effects constrain or drive resource condition toward or away from management objectives?
- LTEMP Experimental and Management Actions: Which LTEMP experimental and management actions are expected to affect resource condition and trend, how strong are these effects expected to be, and are these effects expected to drive resource condition toward or away from management objectives?

More specifically, the FY 2017 KA posed three sets of core questions for each of the eleven focal resource topics:

1. **Status and Trend**
   a. What is the present understanding of the status of the condition(s) addressed by the topic?
   b. What is the present understanding of the direction of any trend(s) in these conditions?
   c. How certain or uncertain is this understanding?
2. **Drivers and Constraints**
   a. What is the present understanding of the drivers and constraints that most significantly shape the status and trends in these conditions?
   b. What is the present understanding of the strength and direction of these effects?
   c. How certain or uncertain is this understanding?
3. **Effects of Experimental and Management Actions**
   a. What is the present understanding of the ways in which each type of LTEMP experimental or management action could affect the status and trends in these conditions?
   b. What is the present understanding of the likely strength and direction of these effects?
   c. How certain or uncertain is this understanding?

The last of these three sets of questions focused on eleven specific experimental management actions identified in the LTEMP FEIS and ROD as features of the Preferred Alternative:

- Fall High-Flow Experiments [HFEs] > 96-hr duration but ≤ 45,000 cfs in October or November
- Fall HFEs < 96-hr duration but ≤ 45,000 cfs in October or November
- Humpback chub translocation
- Larval humpback chub head-start program
- Macroinvertebrate production flows
- Mechanical removal of invasive fish species
- Mechanical removal of rainbow trout from the Little Colorado River [LCR] reach
- Proactive Spring HFEs ≤ 45,000 cfs in April, May, or June
- Riparian vegetation restoration
- Spring HFEs ≤ 45,000 cfs in March or April
- Trout management flows

The Preferred Alternative in the LTEMP FEIS and ROD also includes summer low flow experiments. However, these will not be attempted until during the second 10 years of

implementation of the LTEMP. The FY 2017 Knowledge Assessment focused on topics that might bear on the GCDAMP Triennial Work Plan for FY 2018-2020 and therefore did not address the potential effects of summer low-flow experiments.

Through its answers to the three sets of core questions presented above, the FY 2017 Knowledge Assessment sought to:

- Summarize information on status, trends, and the state of knowledge for the eleven focal resource topics.
- Document the state of knowledge of how antecedent conditions (external drivers and constraints) may affect the outcomes of different management actions.
- Identify potential needs for continuing, increasing, reducing, revising, or adding monitoring, research, and other information-gathering efforts to address potentially crucial gaps in knowledge.

Why Assess Status/Trend and Drivers/Constraints and LTEMP Actions?

The inclusion of three elements in the FY 2017 KA – status and trends, the effects of drivers and constraints, and the potential effects of LTEMP experimental and management actions – requires a brief explanation.

- The core purpose of the GCDAMP is to provide advice to the Secretary on the status and trends among the focal resources of the program and the effects of experimental and management actions on these resources, to help the Secretary better manage these resources to meet the requirements of the GCPA and other federal laws.
- The assessment of drivers and constraints provides additional guidance to programs of adaptive management. Status and trends in focal resources depend not only on the effects of recognized experimental or management actions, but also on the effects of potentially numerous other factors – drivers and constraints – that also affect these resources. Without reliable information on these other factors and the ways in which they affect the Colorado River ecosystem, the GCDAMP cannot distinguish the effects of experimental or management actions from the effects of other factors on the focal resources of the program. As is the case with all adaptive management programs on rivers, the GCDAMP has no opportunity to carry out controlled experiments on the river as a whole that follow the so-called gold-standard for experimental design known by the acronym, "BACI." In a BACI design, experimenters study conditions ***B***efore versus ***A***fter some experimental action, and do so simultaneously both at a sample of ***I***mpacted sites and at a sample of ***C***ontrol sites. Control sites, by definition, are sites that resemble the impacted sites as closely as possible (based on an understanding of the relevant factors) *except* for the occurrence or imposition of the experimental action of interest. Given that it cannot carry out controlled experiments on the river as a whole, the GCDAMP instead must monitor and understand the mechanisms of all factors that could potentially significantly affect the ecosystem and the effects of experimental and management actions.
- The FY 2017 KA element focused on the potential effects of the LTEMP experimental and management actions closely resembles the element focused on drivers and constraints. In effect, this third element assessed the strength of understanding of how the LTEMP actions will most likely affect the focal resources of the program. However, the purpose of this element was not to revisit the detailed analyses of potential effects carried

out for the LTEMP EIS. Those analyses used formal modeling tools to compare the potential impacts of the different Alternative federal actions considered in the FEIS. The purpose of the third element of the FY 2017 KA instead was to identify and prioritize the kinds of information the GCDAMP will need, in order to be able to conduct and evaluate the effects of the listed experimental and management actions, including evaluating how much was truly learned through these actions.

Assessment Methods

Assessment Teams

The FY 2017 KA established an expert team for each of the eleven focal resource topics. Each team was responsible for answering the core questions for their focal resource topic, with the understanding that stakeholders would have the opportunity to participate in team deliberations as well. Table 1 lists the members of the eleven teams of experts, including stakeholders, with the names of team leaders shown in **boldface**:

Table 1. FY 2017 Knowledge Assessment Expert Teams

Topic	Team
Aquatic food base	**Ted Kennedy**, Jeff Muehlbauer, Chris Budwig, Shane Capron, Bill Davis, and Craig Ellsworth
Archaeological and cultural resources	**Jan Balsom** and Jen Dierker
Humpback chub	**Charles Yackulic**, Randy Van Haverbeke, and Kirk Young
Hydropower and energy	WAPA: **Craig Ellsworth**, Shane Capron, Clayton Palmer, Dave Welker, Chrystal Dean; Reclamation: Paul Davidson and Nick Williams; GCMRC: Lucas Bair; CREDA: Leslie James; UAMPS: Cliff Barrett; SRP: Jenika Raub; SEAHG chair: Ben Reeder; CRC: Peggy Roefer; and NTUA: Arash Moelemi
Invasive fish species	**David Rogowski** and Ken Hyde
Other native fish species	**Brian Healy** (*not completed due to scheduling conflicts*)
Rainbow trout	**Mike Yard**, Clay Nelson, Michael Dodrill, and Kimberly Dibble, with additions by Chris Budwig, John Jordan, John Hamill, and Joe Miller
Recreational experience	**Lucas Bair**, Ben Reeder, Chris Budwig, Kevin Dahl, and David Rogowski
Riparian vegetation	**Emily Palmquist**, Barbara Ralston, Joel Sankey, John Spence, and Larry Stevens
Sediment	**Paul Grams**, David Topping, Joel Sankey, Helen Fairley with panel including Lucas Bair, Daniel Buscombe, Joseph Hazel, Erich Mueller, and Jack Schmidt
Water quality	Reclamation: **Robert Radtke**, Marianne Crawford, Katrina Grantz; USGS: Bridget Deemer, Charles Yackulic, Nicholas Voichick: CRC: **Peggy Roefer**; SNWA: Todd Tietjen; and NPS: Mark Anderson

Assessment Process

Each team was asked to first "break down" its assigned resource topic into a set of discrete "resource characteristics" for separate consideration. Resource characteristics consist of features or properties of the resource that may vary at least partially independently of each other over time and space in response to different drivers and constraints. For example, investigations of sediment focus on sandbar area, sediment storage overall as well as separately in sandbars and

within-channel deposits, and sediment transport as both suspended sediment and bedload. Similarly, investigations of the aquatic food base focus on overall invertebrate biomass productivity, invertebrate species diversity, the relative proportions of particular species of both algae and aquatic macroinvertebrates, and how these vary over time and space.

Additionally, each team was asked to identify the "technical" (*aka* "specific") measures used to assess the condition of each resource characteristic. These technical measures often are defined in existing investigative protocols. For example, the assessment of sediment storage described in the current (FY15-17) Triennial Work Plan relies on a battery of technical measures, including yearly conventional topographic surveys of volume and area at 47 high-elevation sandbar sites, estimates of area based on daily imagery from remotely deployed digital cameras at 42 high-elevation sandbar sites, remote sensing of area at > 1000 high-elevation sandbar sites every four years, conventional topographic surveys of volume and area at high-elevation sandbars in 30 to 80-mile segments every 3 to 10 years, and combined bathymetric and topographic surveys of low-elevation fine-sediment storage volume in in 30 to 80-mile segments every 3 to 10 years. Whenever appropriate, assessments of knowledge should refer to the specific types of evidence used to carry out the assessment.

Each team entered its information about resource characteristics and, as appropriate, their technical measures, using a spreadsheet tool. This tool provides standard tables for addressing the questions about status and trend, drivers and constraints, and the LTEMP experimental and management actions. The tool includes standard definitions for all common terms and standard terms for categorizing (rating) status and trend, the strength and direction of effects, and expert confidence in the certainty/uncertainty of the ratings. The tool also provides text fields in which the teams can record their rationale for each set of ratings and present recommendations for addressing concerns raised by each set of entries. Each entry (row) in the table for status and trend addresses a single resource characteristic and a single technical measure for that characteristic. Each row in the table for drivers and constraints addresses a single resource characteristic and a single driver or constraint affecting that characteristic. Each entry (row) in the table for status and trend addresses a single LTEMP experimental or management action, and a single technical measure for a single resource characteristic that may be affected by that action. Appendix A presents the spreadsheet tool and the guidance provided to the expert teams for entering information into each standard table.

Each team submitted a draft spreadsheet to the SAP-EC for review, for quality assessment and quality control (QA/QC). The QA/QC review checked for the following:

- Missing entries for status, trend, strength of effect, direction of effect, or confidence. Without entries for these data fields, it is not possible to integrate the results of the KA within and across resource topics.
- Entries for status, trend, strength of effect, direction of effect, or confidence that did not appear to align with information provided in the rationale statements.
- Non-standard entries for status, trend, strength of effect, direction of effect, or confidence. The spreadsheet uses the built-in Data Validation function to ensure that these entries are limited to fixed set of possible entry values. Data Validation ensures consistency and makes it possible to integrate the results of the KA within and across

resource topics. Experienced users of Microsoft Excel can find ways to override Data Validation controls, but any resulting non-standard entries needed to be corrected.

- Non-standard entries for resource topic and LTEMP experimental and management action labels. The spreadsheet also uses the built-in Data Validation function to ensure that these labels are limited to fixed set of possible entry values. As noted above, Data Validation ensures consistency and makes it possible to integrate the results of the KA within and across resource topics. As also noted above, sophisticated users of Microsoft Excel can find ways to override Data Validation controls, but any resulting non-standard entries needed to be corrected.
- Missing label repetition. Any given table for status/trend, drivers/constraints, or LTEMP experimental and management actions might contain multiple entries (rows) for the same resource characteristic, with the rows differing only in addressing different technical measures. Each such table needed to be checked, to ensure that the label for the resource characteristic was repeated for every such row. In some tables, labels for drivers or constraints, or the standard names for LTEMP experimental and management actions also might need to be repeated.
- Misplaced text information. The tables for status and trend, drivers and constraints, and LTEMP experimental and management actions contain one specific field for text on the rationales for the ratings of status/trend and strength/direction of effect, a second specific field for text on the rationales for the ratings of confidence, and a third specific field for text on recommendations. Text placed in the wrong field needed to be moved to the correct field.
- Missing text repetition. Some teams found that they needed to indicate the same rationale text for multiple rows in their tables on status and trend, drivers and constraints, or LTEMP experimental and management actions. However, some teams accomplished this by recording the complete rationale in only a single row, and entering notes in the subsequent rows referring the reader back to the complete row. Because all tables are subject to analysis and sorting, such back-references needed to be replaced with complete copies of the repeated information.
- Text entered into Review Comments instead of into provided text fields. Microsoft Excel provides a Review function that allows the user to insert commentary concerning individual cells in the form of a background Comment. The information in such Comment fields is not available for analysis and sorting, and therefore needed to be copied and pasted into all text fields relevant to the inserted Comment.
- Typographic and spelling errors. Analyses of labeled and text information require correct spelling and capitalization.

Four expert teams required additional input and interactions with the SAP-EC:

- The sediment team submitted its draft spreadsheet with many empty rating fields and a statement of concerns about the objectivity of the rating methods. These concerns arose for several apparent reasons: (1) Uncertainty in the estimates of sediment storage increase over time, because of the way that these estimates are based on initial benchmark values combined with estimates of accumulation, in which the effects of uncertainty become compounded. (2) The objectives for sediment stated in the LTEMP ROD (see above, Assessment Objectives) focus on relative rather than absolute conditions and the availability of sediment for redistribution by high flows. Further, (3) these relative

objectives focus on what is needed "for ecological, cultural, and recreational purposes" rather than for specific sediment endpoints. Finally, (4) the ultimate purpose of the sediment program is to provide crucial information for triggering (or postponing) high-flow experiments, each of which redistributes stored sediment, further clouding the potential meaning of "status" or "trend." Guidance from the SAP-EC enabled the sediment team leader to revise the draft spreadsheet, using "Low Confidence" ratings to indicate the impact of data uncertainties, "Unknown" ratings for status and trend to indicate the ambiguity of objectives, and the rationale fields to explain concerns. The team also provided suggestions on how some rating categories could be improved (see below, Recommendations).

- The rainbow trout fishery core team – all scientists from the GCMRC and cooperators – also submitted its draft spreadsheet with empty rating fields and a statement of concerns about the objectivity of the status/trend and other rating methods. However, the team leader also stated that the draft provided ample information in the rationale text fields to make it possible to fill in the missing rating fields, but that he had run out of time to do so. At the request of the TWG Chair, several TWG representatives of the angler community stepped up to translate the scientists' narrative information into rating values, providing additional text to explain their decisions where appropriate. A difficulty for the scientists and stakeholders was the presence of *two conflicting objectives* within the overall LTEMP ROD objective for this resource: (1) "Achieve a healthy high-quality recreational rainbow trout fishery in GCNRA" and (2)"… reduce or eliminate downstream trout migration consistent with NPS fish management and ESA compliance." The team of scientists addressed this tension by including separate resource characteristics and technical measures sensitive to each of the two included objectives.
- The nonnative invasive species team confronted the fact that nonnative invasive species – specifically *aquatic* nonnative invasive species – are in fact not "resources" along the Colorado River below Glen Canyon Dam, but threats to actual GCDAMP resources. Aquatic invasive species may prey on native aquatic species, compete with them for habitat space and food resources, and/or transmit diseases to the native species. Any increase in the abundance of aquatic nonnative invasive species therefore constitutes a "detrimental" trend from the standpoint of the native aquatic species even as it constitutes a "beneficial" trend for the invading species themselves. The SAP-EC worked with the team to clarify the somewhat different rules that would apply to threats, as follows: (1) Status would be rated based on the status of the valued resources affected by the threat, e.g., "Good Condition" status (see below) would indicate a low level of impact to valued resources from nonnative invasive species. (2) Trend would be rated based on the trend in impacts to valued resources, e.g., an "Improving" trend (see below) would indicate a declining level of impact to valued resources from nonnative invasive species. (3) For the effects of drivers and constraints and the potential effects of LTEMP experimental and management actions, the logic of the ratings for strength and direction of effect would parallel the logic of the ratings for status and trend.
- The riparian vegetation team submitted a draft with numerous rating entries of "Unknown" for status, trend, and the strength and direction of effects. The team stated, "[t]his is because the ratings for each characteristic are value judgments, as in, 'Total vegetation cover is improving.' There isn't a consensus on whether or not increasing vegetation is good or bad, so we are unable to say that it is improving or declining. In

those cases, we have given an explanation of what we know in the 'Rationale' portion, as in 'total vegetation cover is increasing.'" The SAP-EC determined that some of this abundance of "Unknown" ratings could be reduced by focusing the assessment only on the objectives for riparian vegetation stated in the LTEMP ROD: "Maintain native vegetation and wildlife habitat, in various stages of maturity, such that they are diverse, healthy, productive, self-sustaining, and ecologically appropriate." This objective does not include consideration of potential needs to reduce riparian vegetation encroachment on campsite areas or to manage the impacts of riparian vegetation on archaeological sites and their wind-blown sediment overburdens. In the interests of time, the SAP-EC changed several rating values in the spreadsheet based on the narrower ROD-based objective, guided by the precise explanations provided by the team in its rationale narratives. The original team subsequently only had time for a quick review of the edits.

Rating Categories and Definitions

The KA incorporated the following definitions for categorizing status and trend, the strength and direction of effects, and expert confidence in the certainty/uncertainty of the ratings (see Appendix A for information about the sources of these categories and definitions):

Status Rating Categories and Definitions

- Resource is in Good Condition: The resource characteristic, or its specific technical measure, lies within an acceptable range of condition. This range may be a reference range, or a target specified in some management policy or guidance such as the LTEMP resource objectives.
- Condition Warrants Moderate Concern: The resource characteristic, or its specific technical measure, lies outside its acceptable range of condition but could be improved through the application of existing management methods without significant changes in management policies or expenditures.
- Condition Warrants Significant Concern: The resource characteristic, or its specific technical measure, lies outside its acceptable range of condition and cannot be improved through the application of existing management methods without significant changes in management policies or expenditures.
- Unknown: (1) There is not sufficient information about the resource characteristic or its specific technical measure, to assess for evidence of status. This rating typically calls for ratings of "Unknown" for trend and "Low" for confidence. However, in some cases it may be possible to assess trend but not status. In such cases the user must explain why it is possible to assess trend but not status. Or (2) the acceptable range of condition has not yet been defined for the resource characteristic or its specific technical measure.

Trend Rating Categories and Definitions

- Condition is Improving: The resource characteristic, or its specific technical measure, shows a trend toward or further into its acceptable range of condition. This range may be a reference range, or a target specified in some management policy or guidance such as the LTEMP resource objectives.
- Condition is Unchanging: The resource characteristic, or its specific technical measure, shows no trend of either improvement or deterioration in condition.
- Condition is Deteriorating: The resource characteristic, or its specific technical measure, shows a trend away or departing from its acceptable range of condition.

- Unknown: There is not sufficient information about the resource characteristic or its specific technical measure, to assess for evidence of any trend.

Strength of Effect Rating Categories and Definitions

- Strong: Even a relatively small change in the driver or constraint of interest will result in a relatively large change in the affected condition, and this cause-effect relationship is not significantly subject to random variation or affected by variability in other factors.
- Moderate: The driver or constraint of interest must undergo a relatively large change in order to cause a relatively large change in the affected condition; and/or this cause-effect relationship is subject to moderate random variation or is moderately affected by variability in other factors.
- Weak: Even a relatively large change in the driver or constraint of interest will result in only a relatively small change in the affected condition; and/or this cause-effect relationship is subject to significant random variation or is strongly affected by variability in other factors.
- Unknown: There is not sufficient information, with which to evaluate the strength of the cause-effect relationship, even though there is sufficient information to support a hypothesis that at least some type of cause-effect relationship may exist. This rating typically would call for ratings of "Unknown" for the direction of effect and "Low" for confidence. However, in some cases it may be possible to estimate the direction but not the strength of an effect. In such cases the user must explain why it is possible to assess the direction but not the strength of the effect.

Direction of Effect Rating Categories and Definitions

- Positive Effect: An increase in the magnitude, duration, frequency, or spatial extent of the driver or constraint consistently results in an increase in quality, abundance, and/or spatial and temporal distributions of the affected condition. Conversely, a decrease in the magnitude, duration, or spatial extent of the driver or constraint consistently results in a decrease in quality, abundance, and/or spatial and temporal distributions of the affected condition.
- Negative Effect: An increase in the magnitude, duration, frequency, or spatial extent of the driver or constraint consistently results in a decrease in quality, abundance, and/or spatial and temporal distributions of the affected condition. Conversely, a decrease in the magnitude, duration, or spatial extent of the driver or constraint consistently results in an increase in quality, abundance, and/or spatial and temporal distributions of the affected condition.
- No Effect: An increase or decrease in the magnitude, duration, frequency, or spatial extent of the driver or constraint does not consistently result in an increase or decrease in quality, abundance, and/or spatial and temporal distributions of the affected condition.
- Unknown: There is not sufficient information, with which to evaluate the direction of effect.

Confidence Rating Categories and Definitions

- High: Current understanding of status and trend *or* strength and direction is subject to little or no disagreement or uncertainty among investigators and in peer-reviewed studies; is supported by substantial, high-quality, documented expert knowledge and/or evidence and, where appropriate, by well-accepted statistical analyses; and is consistent with well-

accepted principles in the relevant fields of knowledge and/or with studies in highly analogous systems.

- Medium: Current understanding of status and trend *or* strength and direction is subject to moderate disagreement or uncertainty among investigators and among peer-reviewed studies; and is supported by some documented expert knowledge and/or evidence and analyses. The expert knowledge and/or evidence and analyses may be limited or subject to methodological weaknesses, but nevertheless may be consistent with well-accepted principles in the relevant fields of knowledge and/or with studies in highly analogous systems.
- Low: Current understanding of status and trend *or* strength and direction is subject to substantial disagreement or uncertainty among investigators and among peer-reviewed studies; is supported by only limited or undocumented expert knowledge and/or evidence and analyses that may also be subject to methodological weaknesses; and may be inconsistent with well-accepted principles in the relevant fields of knowledge and/or with studies in highly analogous systems. Ratings of "Unknown" for status and/or trend typically but not always receive ratings of "Low" for confidence.

Roll-Up Method

The tabular, hierarchical structure of the information assembled for the KA – by intention – makes it possible to "roll up" the results to look at the average ratings for status, trend, strength and direction of effects, and confidence for groups of table entries. For example, the structure makes it possible to look at the average rating for status and trend for each resource, across all resource characteristics and their individual technical measures, or simply the average rating for each resource characteristics across all of its individual technical measures, and so forth.

Rolling up results to larger, more inclusive groupings requires decisions about whether to weight all data entries equally. The expert teams conceivably might want to treat some individual technical measures as more sensitive or significant than others, or give less weight to technical measures with "Low" confidence or "Unknown" status, trend, strength, or direction ratings.

The FY 2017 KA took a four-step approach to rolling up results, as follows:

1. A simple spreadsheet algorithm assigned an alphanumerical value to each rating, following the assignment rules shown in Table 2.
2. A second set of spreadsheet algorithms calculated the average for each of the three components of the overall rating system: Status/Strength, Trend/Direction, and Confidence. This averaging, by default, weighted all entries equally. The averaging ignored "U" values unless a grouping contained nothing other than "U" values for a given component, in which case the entire group was assigned the average of "U" for that component.
3. A third spreadsheet algorithm then compiled (concatenated) the results into a three-digit code indicating the "default" average ratings for Status/Strength, Trend/Direction, and Confidence. This result was used to summarize the average for each grouping and select the appropriate visual symbol (graphic) for communicating the results (see below).
4. These default results were distributed to the expert teams, with the request that they identify any that they would like to change based on an alternative weighting of the raw entries. All of the expert teams accepted the default results for purposes of this first trial

with the KA methods. Members of the TWG also suggested alternative default rules that might be tested in future knowledge assessments (see Recommendations, below).

Table 2. Alphanumerical Values Assigned for Averaging Results

Status	Trend	Strength	Direction	Confidence	Value
Good Condition	Improving	Strong	Positive Effect	High	1
Moderate Concern	Unchanging	Moderate	No Effect	Medium	2
Significant Concern	Deteriorating	Weak	Negative Effect	Low	3
Unknown	Unknown	Unknown	Unknown	(n/a)	U

Not all potential groupings of data were suitable for averaging. It is meaningful to calculate the average status of all resource characteristics for a given resource, the average status of each individual resource characteristic for a given resource, or the average potential impact of each LTEMP experimental or management action on a given resource, or the average potential impact of each LTEMP experimental or management action on each individual resource characteristic for a given resource. However, it is not meaningful to calculate the average strength or direction of effect of all drivers or constraints for an entire resource, or even for any single characteristic of that resource. Drivers and constraints necessarily push and pull resource characteristics in different directions. For example, increasing abundance of aquatic prey invertebrates may promote growth and reproductive success among rainbow trout, while increasing water temperatures may have the opposite effect. When averaged together, such conflicting effects will appear to cancel each other out. As a result, averaging the ratings for large suites of both conflicting and compounding effects does not provide useful guidance for adaptive management. (However, as a tool for QA/QC, averaged ratings for drivers and constraints may indicate to an expert team whether they have considered, for example, too many drivers with only positive or only negative effects, potentially misrepresenting the complexity of the ecosystem.)

Assessment Graphics

The FY 2017 KA incorporated a set of standardized graphics to communicate the results. The graphics are modified from those used in the National Park Service, Natural Resource Condition Assessment (NRCA) program (see Recommendations, below, for additional information). In principle, these graphics could be used to summarize the information in each individual row in one of the spreadsheet tables (e.g., for each individual technical measure). However, the graphics are more useful for summarizing the results after they have been aggregated:

- Information on status and trend for a given resource topic can be presented for each resource overall as well as for each of its individual resource characteristics, aggregated (averaged) across all technical measures
- Information on the strength and direction of the drivers and constraints acting on a given resource topic can be presented for each driver and constraint, aggregated (averaged) across all resource characteristics
- Information on the likely strength and direction of impact of each LTEMP experimental and management action on a given resource can be presented for each resource overall as well as for each of its individual resource characteristics, aggregated (averaged) across all technical measures.

The FY 2017 KA graphic system "works" by presenting information in a hierarchical visual system.

- All symbols have the same size and shape – a standardized circle. As a result, symbol size and shape do not convey any information.
- The most noticeable property of each circle is its color. The system uses one set of colors to indicate status, for the assessment of status and trend, and a different set of colors to indicate strength of effect, both for the assessment of drivers and constraints and for the assessment of the potential impacts of LTEMP experimental and management actions.
- The second most-noticeable property of each circle is the orientation of an enclosed arrow: up, down, or left-right (indicating "neither up nor down"). The shape occurs as a silhouette imposed on top of the colored field. The system uses the orientation of the arrow to indicate trend, for the assessment of status and trend, and to indicate direction of effect, both for the assessment of drivers and constraints and for the assessment of the potential impacts of LTEMP experimental and management actions.
- The third variable property of each circle consists of a circling border that varies in its texture (style): thick, thin, or intermittent. The system uses the border texture to indicate the level of confidence in the ratings of status/trend or strength/direction reported by the expert team.

Table 3 shows the symbol sets used in the GCDAMP FY17 knowledge assessment, in the assessment of present knowledge of the status and trend in a resource. Table 4 shows the symbol sets used in the assessment of both (a) the effects of specific drivers and constraints on the resource, and (b) the anticipated effects of specific LTEMP experimental and management actions on the resource.

Table 3. "Status and Trend" Symbol Set

Resource Status		Trend in Status		Confidence in Status & Trend Assessments	
	Resource is in Good Condition	⇧	Condition is Improving		High
	Condition Warrants Moderate Concern	⇔	Condition is Unchanging		Medium
	Condition Warrants Significant Concern	⇩	Condition is Deteriorating		Low
	Status Unknown	--------	Trend Unknown	(n/a)	

Table 4. "Strength and Direction of Effect" Symbol Set

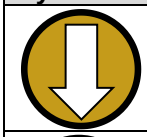
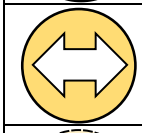
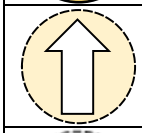
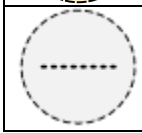
Strength of Effect		Direction of Effect		Confidence in Strength & Direction Assessments	
	Strong Effect		Positive (Beneficial) Effect		High
	Moderate Effect		No Effect		Medium
	Weak Effect		Negative (Detrimental) Effect		Low
	Strength of Effect Unknown	--------	Direction of Effect Unknown	(n/a)	

Table 5 and Table 6 provide examples to illustrate the application of the graphics system used for communicating the results of the FY 2017 KA.

Table 5. Status and Trend Symbol Set Examples

Symbol	Meaning
	Condition good; trend improving; confidence high
	Condition of moderate concern; no trend; confidence medium
	Condition of significant concern; trend deteriorating; confidence low
--------	Condition unknown; trend unknown; confidence low

Table 6. Strength and Direction of Effect Symbol Set Examples

Symbol	Meaning
	Strength of effect high; direction of effect negative; confidence high
	Strength of effect moderate; no effect direction; confidence medium
	Strength of effect weak; direction of effect positive; confidence low
	Strength of effect unknown; direction of effect unknown; confidence low

Results

Table 7 summarizes the amount of information that the expert teams assembled and entered into the spreadsheet tool for each resource topic. For each resource topic, the teams addressed 2 to 28 individual resource characteristics, 2 to 28 technical measures, 6 to 11 drivers and constraints, and 5 to all 11 of the LTEMP experimental and management actions. The resulting tabular data support a wide range of analyses.

Table 7. Spreadsheet Entry Frequencies by Resource

Resource Topic	Resource Characteristics	Technical Measures	Drivers & Constraints	LTEMP Actions
Aquatic food base	2	5	11	11
Archaeological and cultural resources	2	2	8	11
Humpback chub	4	4	11	9
Hydropower and energy	7	8	9	11
Invasive fish species	28	28	9	9
Rainbow trout	18	18	10	5
Recreational experience	21	25	8	11
Riparian vegetation	8	8	8	7
Sediment	11	16	6	7
Water quality	7	7	8	6

Status and Trends

Table 8 presents the average results for status and trend for each of the ten resource topics assessed, averaged across all resource characteristics and their individual technical measures. As noted above (see Assessment Methods, Assessment Teams), the "Other Native Fishes" expert team was not able to complete its assessment because of other responsibilities. Appendix B presents the complete set of graphic results for the individual resource characteristics for each resource topic, averaged across all technical measures for each characteristic. The tables in Appendix B also indicate the number of technical measures tabulated for each characteristic.

Table 8. Status and Trend Results by Resource

Resource Topic	Status & Trend
Aquatic Food Base	↓
Archaeological & Cultural Resources	↓
Humpback Chub	↔
Hydropower & Energy	↓
Invasive Fish Species	↔
Rainbow Trout	↔
Recreational Experience	↓
Riparian Vegetation	↔
Sediment	↔
Water Quality	↔

The results in Table 8 indicate that the expert teams considered most of the resources to have statuses of "Moderate Concern" (7 of 10), with two having statuses of "Significant Concern" and only one having a status of "Good Condition." Further, the expert teams consider most of the

resources to be experiencing either no trend (6 of 10) or a deteriorating trend (4 of 10) in status. The average level of confidence in these results is "High" for four resource topics and "Medium" for the other six.

The averaged results for trend should be viewed with caution. As explained below (see Recommendations, Scorecard Display), averaging together information about trends across multiple resource characteristics can result in the averaging together of trends that may point in opposite directions. The averaging of such information results in an estimate of the *net* direction of the trend interest. In some instances, the value of the average may correspond to a rating of "Unchanging" for trend (see above, Assessment Methods, Rating Categories and Definitions). However, it is more correct to state that the result indicates "No Net Trend."

A different type of integrated analysis provides further insights into these results. As noted above (see Roll-Up Method), the averaging process ignored "Unknown" ratings unless all entries for a resource characteristic or for an entire resource contained nothing but "Unknown" values for status or trend, in which case the entire resource characteristic or entire resource was assigned the average of "Unknown" for its status or trend. Alternatively, one can tabulate the relative incidence of "Unknown" entries for status or trend, and the relative incidence of ratings of "Low" for confidence, as shown in Table 9. The relative incidence of these types of results indicates the extent of gaps and uncertainties recognized by each expert team.

Table 9. Unknown and Uncertain Results for Status and Trend

Resource	Unknown Status AND Unknown Trend AND Low Confidence	Unknown Status OR Unknown Trend AND Low Confidence	Known Status AND Known Trend BUT Low Confidence	Unknown Status OR Unknown Trend BUT NOT Low Confidence	Unknown Status OR Unknown Trend OR Low Confidence
Aquatic food base	0.0%	0.0%	0.0%	20.0%	20.0%
Archaeological and cultural resources	0.0%	0.0%	0.0%	0.0%	0.0%
Humpback chub	0.0%	0.0%	25.0%	0.0%	25.0%
Hydropower and energy	0.0%	0.0%	12.5%	0.0%	12.5%
Invasive fish species	0.0%	3.6%	14.3%	3.6%	21.4%
Rainbow trout fishery	0.0%	5.3%	0.0%	52.6%	57.9%
Recreational experience	16.0%	0.0%	0.0%	0.0%	16.0%
Riparian vegetation	37.5%	0.0%	25.0%	12.5%	75.0%
Sediment	0.0%	0.0%	31.3%	6.3%	37.5%
Water quality	28.6%	28.6%	0.0%	42.9%	100.0%

The first column in Table 9 identifies the individual resource topics. The second column indicates the percentage of all individual raw data entries (individual technical measure entries) for status and trend contained a rating of "Unknown" for *both* status and trend, and "Low" for confidence. The third column indicates the percentage of entries with "Unknown" for *either* status or trend, and "Low" for confidence. The fourth column indicates the percentage of entries with ratings of "Low" for confidence but *without* ratings of "Unknown" for either status or trend. The fifth column indicates the percentage of entries with ratings of "Unknown" for *either* status or trend, but with "Medium" or "High" rather than "Low" confidence. The last column combines

all of this information to indicate the percentage of entries rated “Unknown” for status, and/or “Unknown” for trend, and/or “Low” for confidence. The last column thus summarizes the extent of gaps (“unknowns”) and uncertainties (“low confidence”) recognized by each expert team.

Table 9 indicates that every raw data entry for status and trend for water quality (100%) contained a rating of “Unknown” for status, and/or of “Unknown” for trend, and/or of “Low” for confidence. Other resources with high incidences of gaps and uncertainties about status and trend include riparian vegetation (75%), the rainbow trout fishery (57.9%), and sediment (37.5%). A review of the rationale fields for these raw data entries shows that the expert teams reported these gaps and uncertainties because of difficulties with unclear or undefined management objectives for individual resource characteristics; temporal or spatial gaps in the available data; insufficient numbers of suitable data points; or high temporal or spatial variability in the available data. For example, the rainbow trout results highlight difficulties with distinguishing trends against a background of “boom-bust” cycling as well as high year-to-year variance in trout abundance. These kinds of results suggest topics that could benefit from improved management objectives and/or improved monitoring.

Drivers and Constraints

Appendix C presents the complete set of graphic results for the drivers and constraints identified for each resource topic, averaged for each resource characteristic. Unfortunately, there is no simple way to summarize these results. As explained earlier (see Roll-Up Method, above), it is not meaningful to average the rating values for the drivers and constraints affecting an entire resource topic across all associated resource characteristics. In addition, each expert team independently developed its own list of drivers and constraints. This produced a total of 88 different driver and constraint names, with no two expert teams using the same names for any drivers and constraints. As a result, it is not possible to directly compare the ratings for individual drivers across resource topics.

However, it is possible to organize the 88 drivers and constraints into a smaller number of categories. Table 10 identifies 13 categories or types of drivers and constraints, incorporating all 88 original “raw” types identified by the ten expert teams (see Appendix C). Other groupings are possible (see Recommendations, below). Table 10 also shows the numbers of individual drivers and constraints in each category, both overall and for each affected resource. Table 10 lists the proposed driver/constraint categories in order based on their overall frequency of identification across all resource topics.

The most frequently reported category of drivers and constraints, “River Flow Variation,” includes high-flows, low-flows, and the overall range of variation in flows. The second most frequently reported category, “Lake Powell Conditions,” includes lake hydrologic conditions (e.g., water surface elevation), thermal conditions (temperature distributions, stratification), water quality (dissolved oxygen, nutrient, and turbidity distributions), and biological conditions (biological oxygen demand and the distributions of nonnative biota within the lake). These conditions directly affect dam operations and/or the temperature, water quality, and biological inclusions in the water released from the dam. The third most frequently reported category, “River Water Temperature,” highlights the pervasive effects of water temperature in the river ecosystem, affecting the aquatic food base, humpback chub, nonnative invasive species, and rainbow trout.

Further, seven of the thirteen proposed categories of drivers and constraints – aquatic food base, aquatic invasive species, humpback chub, rainbow trout, riparian vegetation, sediment, and water quality – directly refer to priority resource topics. These cross-references highlight the close interactions among resource conditions in the ecosystem. For example, riparian vegetation dynamics directly affect the aquatic food base, through the generation of plant litter that constitutes allochthonous inputs to the aquatic food web, and also affect archaeological site conditions, recreational experience, and sediment dynamics. Similarly, aquatic food base dynamics directly affect humpback chub and rainbow trout dynamics, and also affect themselves through causal relationships within the food web, such as the effects of primary production on macroinvertebrate production.

Table 10. Proposed Categories of Drivers and Constraints versus Affected Resources

Resource Topic ➔ / Proposed Driver and Constraint Categories 🡻	Aquatic food base	Archaeological and cultural resources	Humpback chub	Hydropower and energy	Invasive fish species	Rainbow trout fishery	Recreational experience	Riparian vegetation	Sediment	Water quality	Total
River Flow Variation	4		2	3	1	4	3	3	4		24
Lake Powell Conditions				1	2					8	11
River Water Temperature	1		4		4	1					10
Riparian Vegetation Dynamics	1	1					1	3	2		8
Aquatic Food Base (Primary and Secondary Production)	1		1			4					6
Sediment Dynamics (Above and Below Baseflow Stage)	1	3						2			6
Dam Design and Operational Constraints				5							5
Archaeological Site Disturbance		4									4
Rainbow Trout Dynamics			1			1	2				4
River Water Quality	3		1								4
Aquatic Invasive Species					2						2
Boat and Aircraft Launches							2				2
Humpback Chub Dynamics			2								2

One can also tabulate the relative incidence of "Unknown" entries for the strength and direction of effect for drivers and constraints, and the relative incidence of ratings of "Low" for confidence (Table 11). The relative incidence of these types of results provides guidance on the extent of gaps and uncertainties in knowledge about drivers and uncertainties recognized by the expert team for each resource topic.

Table 11 is similar to Table 9, above. The first column again identifies the individual resource topics. The second column indicates the percentage of all individual raw data entries that contain a rating of "Unknown" for *both* the strength and the direction of effect for an individual driver or constraint, and "Low" for confidence. The third column indicates the percentage of entries with

"Unknown" for *either* the strength or the direction of effect of an individual driver or constraint, and "Low" for confidence. The fourth column indicates the percentage of entries with ratings of "Low" for confidence but *without* ratings of "Unknown" for either the strength or the direction of effect of an individual driver or constraint. The fifth column indicates the percentage of entries with ratings of "Unknown" for *either* the strength or the direction of effect of an individual driver or constraint, but with "Medium" or "High" rather than "Low" confidence. The last column combines all of this information to indicate the percentage of entries rated "Unknown" for the strength and/or the direction of effect of an individual driver or constraint, and/or "Low" for confidence. This last column thus again summarizes the extent of gaps ("unknowns") and uncertainties ("low confidence") recognized by the expert team for each resource.

Table 11. Unknown and Uncertain Results for Driver and Constraint Strength and Direction of Effect

Resource	Unknown Strength AND Unknown Direction AND Low Confidence	Unknown Strength OR Unknown Direction AND Low Confidence	Known Strength AND Known Direction BUT Low Confidence	Unknown Strength OR Unknown Direction BUT NOT Low Confidence	Unknown Strength OR Unknown Direction OR Low Confidence
Aquatic food base	0.0%	13.6%	50.0%	0.0%	63.6%
Archaeological and cultural resources	0.0%	0.0%	0.0%	0.0%	0.0%
Humpback chub	0.0%	21.4%	7.1%	7.1%	35.7%
Hydropower and energy	0.0%	0.0%	0.0%	23.6%	23.6%
Invasive fish species	0.0%	0.0%	0.0%	0.0%	0.0%
Rainbow trout fishery	0.0%	0.0%	64.3%	0.0%	64.3%
Recreational experience	0.0%	0.0%	0.0%	0.0%	0.0%
Riparian vegetation	0.0%	12.5%	37.5%	45.8%	95.8%
Sediment	0.0%	0.0%	0.0%	12.5%	12.5%
Water quality	16.7%	20.8%	8.3%	33.3%	79.2%

Table 11 indicates that nearly every raw data entry for the strength or the direction of effect of an individual driver or constraint on riparian vegetation (95.8%) contained a rating of "Unknown" for strength of effect and/or "Unknown" for direction of effect and/or "Low" for confidence. Other resources with high incidences of gaps and uncertainties about the strength or the direction of effect of individual drivers or constraints include water quality (79.2%), the rainbow trout fishery (64.3%), the aquatic food base (63.6%), and humpback chub (35.7%). A review of the raw data entries shows that the expert teams reported these gaps and uncertainties because of difficulties with unclear or undefined management objectives for individual resource characteristics, and gaps in direct evidence of how hypothesized drivers and constraints affect each resource or its individual characteristics. These kinds of results again suggest topics that could benefit from improved management objectives and/or improved monitoring and focused research to evaluate the hypothesized cause-effect relationships.

LTEMP Experimental and Management Actions

Table 12 presents the average results for the potential effects of the eleven LTEMP experimental and management actions.

Table 12. Results for Potential Effects of LTEMP Experimental and Management Actions by Resource

Resource Topics → / Experimental & Management Actions ↓	Aquatic food base	Archaeological and cultural resources	Humpback chub	Hydropower and energy	Invasive fish species	Other native fish species	Rainbow trout fishery	Recreational experience	Riparian vegetation	Sediment	Water quality
Fall HFEs > 96-hr duration	↓	↔	↑	↓	↓			↔	↓	↑	--------
Fall HFEs ≤ 45,000 cfs in October or November	↓	↔	↑	↓	↓			↔	↓	↑	--------
Humpback chub translocation	↔	↔	↑	↔	↔			↔			
Larval humpback chub head-start program	↔	↔	↑	↔	↔			↔			
Macroinvertebrate production flows	↑	↓	--------	↑	↓		↑	↔	↑	↑	--------
Mechanical removal of invasive fish species	↔	↔		↔				↔			
Mechanical removal of rainbow trout from LCR reach	↔	↔	↑	↔	↓		↑	↔			
Proactive Spring HFEs ≤ 45,000 cfs in April, May, or June	↑	↔	↑	↓	--------		--------	↔	↑	↑	--------
Riparian vegetation restoration	↑	--------		↔				↔	↑	↑	
Spring HFEs ≤ 45,000 cfs in March or April	↑	↔	↑	↓	--------		↑	↔	↑	↑	--------
Trout management flows	↓	↓	↑	↔	↑		↓	↔	↑	↓	--------

Specifically, Table 12 presents the average results for each resource topic across all resource characteristics and all their technical measures. As noted above (see Assessment Methods, Assessment Teams), the "Other Native Fishes" expert team was not able to complete its assessment because of other priorities. Appendix D presents the complete set of graphic results for the individual resource characteristics for each resource topic, averaged across all technical measures for each characteristic. Note that Table 12 appears on a custom-sized page to accommodate the large size of the table.

The results in Table 12 indicate that the expert teams expect the net effects of the various LTEMP experimental and management actions (across all resource characteristics for the ten resources) to be a "mixed bag." Each action is expected to have a mixture of net positive to negative and net strong to weak effects on each of the ten resources, on average across all the individual resource characteristics for each resource. No single action is expected to consistently provide a net benefit to all resources. Similarly, with the exception of recreational experience, no single resource is expected to be affected consistently by all actions. In the case of recreational experience, the results indicate that the expert team expects the net effects of all actions on all resource characteristics to be neutral (neither positive nor negative). However, the tables in Appendix D show that these average effects mask a range of variation in effects across individual resource characteristics.

One can also tabulate the relative incidence of "Unknown" entries for the expected strength and direction of effect of LTEMP experimental and management actions, and the relative incidence of ratings of "Low" for confidence (Table 13). The relative incidence of these types of results provides guidance on the extent of gaps and uncertainties concerning these expected effects recognized by the expert team for each resource topic.

Table 13. Unknown and Uncertain Results for the Potential Strength and Direction of Effect of LTEMP Experimental and Management Actions

Resource	Unknown Strength AND Unknown Direction AND Low Confidence	Unknown Strength OR Unknown Direction AND Low Confidence	Known Strength AND Known Direction BUT Low Confidence	Unknown Strength OR Unknown Direction BUT NOT Low Confidence	Unknown Strength OR Unknown Direction OR Low Confidence
Aquatic food base	0.0%	0.0%	54.5%	0.0%	54.5%
Archaeological and cultural resources	0.0%	0.0%	0.0%	7.7%	7.7%
Humpback chub	25.0%	33.3%	16.7%	0.0%	75.0%
Hydropower and energy	4.5%	0.0%	0.0%	3.4%	8.0%
Invasive fish species	71.8%	0.0%	10.3%	5.1%	87.2%
Rainbow trout fishery	0.0%	70.0%	10.0%	0.0%	80.0%
Recreational experience	2.4%	2.4%	23.7%	0.4%	28.9%
Riparian vegetation	28.6%	26.8%	16.1%	10.7%	82.1%
Sediment	0.0%	7.1%	17.9%	21.4%	46.4%
Water quality	89.7%	0.0%	0.0%	10.3%	100.0%

Table 13 is similar to both Table 9 and Table 11, above. The first column again identifies the individual resource topics. The second column indicates the percentage of all individual raw data entries that contain a rating of "Unknown" for *both* the potential strength and the potential direction of effect of an LTEMP experimental and management action, and "Low" for confidence. The third column indicates the percentage of entries with "Unknown" for *either* the potential strength or the potential direction of effect of an LTEMP experimental and management action, and "Low" for confidence. The fourth column indicates the percentage of entries with ratings of "Low" for confidence but *without* ratings of "Unknown" for either the potential strength or the potential direction of effect of an LTEMP experimental and management action. The fifth column indicates the percentage of entries with ratings of "Unknown" for *either* the potential strength or the potential direction of effect of an LTEMP experimental and management action, but with "Medium" or "High" rather than "Low" confidence. The last column combines all of this information to indicate the percentage of entries rated "Unknown" for the potential strength and/or the potential direction of effect of an LTEMP experimental and management action, and/or "Low" for confidence. This last column thus again summarizes the extent of gaps ("unknowns") and uncertainties ("low confidence") recognized by the expert team for each resource.

Table 13 indicates that every raw data entry for the potential strength and/or the potential direction of effect of an LTEMP experimental and management action on water quality (100%) contained a rating of "Unknown" for the potential strength of effect and/or "Unknown" for the potential direction of effect and/or "Low" for confidence. Other resources with high incidences of gaps and uncertainties about the potential strength or direction of effect of the LTEMP experimental and management actions include invasive fish species (87.2%), riparian vegetation (82.1%), the rainbow trout fishery (80%), humpback chub (75%), the aquatic food base (54.5%), and sediment (46.4%). A review of the raw data entries shows that the expert teams reported these gaps and uncertainties because of difficulties with unclear or undefined management objectives for individual resource characteristics; gaps in direct evidence of how the LTEMP actions may act as drivers that affect each resource or its individual characteristics; and/or high temporal or spatial variability or other weaknesses in the data available to support hypotheses about possible effects. These kinds of results again suggest topics that could benefit from improved management objectives and/or improved monitoring and focused research to better understand the hypothesized cause-effect relationships.

Results Summary

The results of the FY 2017 KA indicate that the expert teams considered most of the resources to have current statuses of "Moderate Concern," with two – aquatic food base and recreational experience – having current statuses of "Significant Concern" and only one – invasive fish species (nonnative invasive species) – having a current status of "Good Condition." As noted above, the "Good" rating for the current status of invasive fish species refers to the level of threat posed by these species. The results for this one resource indicate that, overall across all invasive fish species of interest, the net threat currently posed by these species is not a matter of concern. At the same time, however, the expert teams consider most of the resources currently to be experiencing either no trend or a deteriorating trend in status. No resource was recognized as experiencing an improving trend. The four resources identified as experiencing deteriorating trends are the aquatic food base, archaeological and cultural resources, hydropower and energy, and the recreational experience.

The results also identify a distinct suite of drivers and constraints that affect a large proportion of the resources. In some cases these effects are direct; in other cases the effects are indirect, resulting from the ways that the focal resources affect each other. For example, Lake Powell thermal conditions affect the temperature of the river below the dam, which in turn affects the aquatic food base, which in turn affects humpback chub, rainbow trout, and aquatic invasive species population dynamics. These results thus document a complex web of causal relationships or "causal chains," particularly ones that arise from conditions in Lake Powell. That is, conditions in Lake Powell, both in general and immediately antecedent to individual experimental flow releases, have a wide range of significant impacts on the focal resources of the GCDAMP. The KA assessment results in turn document that the conditions in Lake Powell are shaped by the hydrologic, thermal, and water quality characteristics of its inflows as well as by internal lake dynamics.

Finally, the results evince a high degree of uncertainty about the state of knowledge concerning several focal resources and/or a significant concern about gaps in that knowledge. Table 14 brings together the rightmost columns from Tables 8, 10, and 12 to identify those resources with the greatest frequencies of "Unknown" for status or strength and/or "Unknown" for trend or direction and/or "Low" for confidence. The last column in Table 14 summarizes the extent of gaps ("unknowns") and uncertainties ("low confidence") recognized by the expert team for each resource across all three elements of the KA.

Table 14. Unknown and Uncertain Results across All Assessment Elements

Resource	Status & Trend	Drivers & Constraints	LTEMP Experimental & Management Actions	Average Percentage of Entries
Water quality	100.0%	79.2%	100.0%	93.1%
Riparian vegetation	75.0%	95.8%	82.1%	84.3%
Rainbow trout fishery	57.9%	64.3%	80.0%	67.4%
Aquatic food base	20.0%	63.6%	54.5%	46.1%
Humpback chub	25.0%	35.7%	75.0%	45.2%
Invasive fish species	21.4%	0.0%	87.2%	36.2%
Sediment	37.5%	12.5%	46.4%	32.1%
Recreational experience	16.0%	0.0%	28.9%	15.0%
Hydropower and energy	12.5%	23.6%	8.0%	14.7%
Archaeological and cultural resources	0.0%	0.0%	7.7%	2.6%

Table 14 shows that expert teams reported significant gaps ("Unknowns") in knowledge and/or low confidence in that knowledge in roughly a third or more of the KA spreadsheet entries concerning water quality, riparian vegetation, the rainbow trout fishery, the aquatic food base, humpback chub, invasive fish species, and sediment. In the worst cases, the expert teams reported significant gaps in knowledge and/or low confidence in that knowledge in nearly all of the KA spreadsheet entries concerning water quality and riparian vegetation. Reviews of the raw data indicate that the expert teams reported these gaps and uncertainties because of difficulties

with unclear or undefined management objectives for individual resource characteristics; temporal or spatial gaps in the available data; insufficient numbers of suitable data points; or high temporal or spatial variability in the available data. As noted throughout this report, these findings highlight resource topics that could benefit from improved management objectives, continuing and/or improved monitoring, and/or research to address critical gaps and uncertainties.

Recommendations

The TWG and GCMRC carry the responsibility for deciding whether to conduct similar knowledge assessments in subsequent years, presumably with improvements in the process. As noted above (see Assessment Objectives), the FY 2017 KA had three primary objectives, to: (1) summarize what is known, (2) assess needs for monitoring to sustain crucial knowledge and (3) identify critical knowledge gaps and weaknesses that require attention. In addition, the FY 2017 KA sought to test a standardized process for conducting the KA and compiling its findings that can be repeated with minimal effort and high consistency, and test the utility of presenting the KA findings in the form of a set of simple tables and graphical symbols – sometimes called a "scorecard" – to facilitate communication.

The SAP-EC offers the following recommendations for improving the KA process, based on this FY 2017 test.

What to Assess and When

The FY 2017 KA had three elements, focused on the state of knowledge concerning (1) status and trends in the focal resources of the GCDAMP, (2) key drivers and constraints affecting these focal resources, and (3) the expected (potential) effects of eleven experimental and management actions mandated for the first ten years of implementation of the LTEMP. All three elements provided useful information in FY 2017. However, it is useful to consider whether the TWG and GCMRC need to repeat all three elements – and if so, when.

<u>Recommendations:</u>

- The TWG and GCMRC should establish a regular schedule of knowledge assessments, integrated with the development of at least the triennial work plans and the cumulative findings of the Annual Reporting cycle. Regularizing these assessments will make it easier to incorporate its findings into GCMRC and TWG annual and triennial work and planning cycles, and help make the assessments a recognized tool for guiding GCDAMP efforts and communicating results. The FY 2017 KA encountered difficulties, for example, because the assessment was added onto the existing workloads of the expert team members after the start of the annual work cycle.

- The TWG and GCMRC need not repeat the assessment of knowledge about the potential effects of the LTEMP experimental and management actions. With the implementation of the LTEMP and its ROD, information on the *actual* effects of LTEMP actions will now begin to accumulate. The TWG and GCMRC will need to review this information on *actual* effects as it accumulates, at the very least in time for the ten-year review included in the LTEMP design. The TWG and GCMRC also need to be on the alert for any "long-term unacceptable adverse impacts" of LTEMP actions on any resources, as called for in

the ROD. The TWG and GCMRC need to establish a schedule for reviewing the accumulating knowledge about the actual effects of LTEMP actions.

- Every effort should be made to include the assessment of "Other Native Fishes" in all future KAs. This is a resource of high importance to the GCDAMP. All ten of the other focal resources assessed in FY 2017 should be assessed on the same schedule.

- Every effort should be made to ensure that future KAs include the assessment of "Tribal Resources," however these come to be defined. The GCDAMP has no history of formally assessing the status of conditions along the river corridor that relate to the traditional ways in which the individual tribes associated with the GCDAMP value and find meaning in the Glen-Marble-Grand Canyon landscape overall, specific features and places in the landscape, the life-forms and natural processes present, the activities tribal members may need to carry out in the landscape, and the ways that all people use and move through the landscape. Consequently, it will take some time to identify sets of "resource characteristics" and indicators appropriate to this resource topic. However, the LTEMP calls for the assessment of the impacts of its actions on such resources, as have guidance documents from two previous Secretary's Designees, Assistant Secretary Castle in 2014 and Assistant Secretary Gimbel in 2016. These calls make it urgent that the tribes and partners – e.g., the National Park Service and the GCMRC – develop some trial methods for moving this effort forward.

- The TWG and GCMRC should consider expanding the assessment of the "Natural Processes" resource topic to include processes other than the two included in the FY 2017 KA. Other possibilities include the effects of the river on canyon wildlife, including insects, reptiles and amphibians, birds, bats, and other mammals; and the upstream effects of Lake Mead.

- The LTEMP and its ROD limit the "Nonnative Invasive Species" resource topic to invasive aquatic organisms, but do not limit it to fishes. The TWG and GCMRC should consider expanding the assessment of this topic to include other aquatic invasive species if ecologically appropriate.

Assessment Structure and Process

Recommendations

- The TWG should make clear from the outset precisely what objectives the expert teams should to use for each resource topic, against which to assess status and trend. This will require clearing up all ambiguities that could significantly affect the rating outcomes or that could result in further concerns about 'subjectivity.' Further, the guidance should be revised to make clear that the expert teams should assess each focal resource independently, without taking into account the ways in which the resources affect each other. This may require addressing rainbow trout under two separate objectives – one for the rainbow trout in the Lees Ferry Reach, and one for the rainbow trout downstream in the LCR Reach.

- The process and its guidance need to be improved to encourage the expert teams to address a smaller number of truly "key" resource characteristics for each focal resource.

The SAP-EC team could provide draft guidance for the TWG to consider, to help the expert teams better constrain their efforts.

- The expert teams need to be encouraged to read and follow the formal guidance for the KA – and conversely to provide feedback on how the guidance could be improved. Some difficulties in the FY 2017 KA arose because the expert teams did not closely follow the available guidance – for example to distinguish when it was appropriate to rate a condition as "unknown" versus simply uncertain ("low" confidence). Conversely, the TWG and GCMRC should encourage the FY 2017 KA expert teams – or at least their leaders – to provide feedback on the rating categories used in the assessment process. Several GCMRC scientists have experience with the formal elicitation of expert knowledge, for example, and would likely provide useful feedback.

- Integration of the work of the individual expert teams could be improved by developing a standard, master list of drivers and constraints. The use of such a standardized list would make it possible to compare and "roll up" results about drivers and constraints across all of the focal resources together, and to maintain consistency across repeated KAs. Such a master list might best be organized hierarchically, with a relatively small number of major categories (e.g., see above, Results, Drivers and Constraints) and sub-categories. In effect, the resulting list would provide a standard vocabulary for conceptual models of the system. This need not be inflexible: Terms could be added or their use discontinued over repeated KA cycles, but such changes would require documentation to ensure continuity in the process.

- The FY 2017 KA did not address or could have better addressed some environmental factors that recent Annual Reporting Meetings, past KAs, and GCMRC publications have identified as potentially relevant to the GCDAMP. Including such factors in the master list of drivers and constraints would encourage the expert teams to at least consider them during future KAs. These factors concern, for example:

    1. The ways in which conditions in the Paria and Little Colorado Rivers and their watershed affect the timing, magnitude, and composition of the sediment they deliver to the Colorado River.
    2. The presence of aquatic parasites and other pathogens that may affect native and nonnative fishes.
    3. The ways in which the composition of the aquatic macrophyte and phytoplankton assemblages affect the feeding opportunities and behaviors of aquatic macroinvertebrates and fishes.
    4. The meso- and micro-habitat structure of the river channel and backwaters in relation to channel sediment dynamics.
    5. The presence of chemical contaminants in the river that may affect native fishes and/or bio-accumulate in ways that also could affect the non-aquatic ecosystem of the river corridor.
    6. The upstream effects of hydrologic and biological conditions in the western Grand Canyon and Lake Mead.

- Integration of the results from repeated KAs would also benefit from the development of standardized lists of resource characteristics for each focal resource topic, the

examination of which could be repeated in successive KAs. Again, terms could be added or their use discontinued over repeated KA cycles, but it would be best if such changes were always documented to ensure continuity in the process. It might also be possible to develop standard lists of specific (technical) measures for each resource characteristic, although we might expect more fluidity in such lists as monitoring and research methods evolve.

- The KA process would benefit from the formal inclusion of the effort in annual or triennial work plans, so that all participating experts know this will be an expected matter of attention (see above, Recommendations, What to Assess and When). The TWG, GCMRC, and cooperators could line up the expert teams well in advance, to help the experts incorporate the effort into their understandably already busy work schedules.

- The schedule for each KA should include a more formally recognized period or opportunity for all stakeholders to provide feedback to the expert teams. However, it is not clear how this might be coordinated. The Annual Reporting Meeting schedule already provides the experts with an opportunity to summarize knowledge of status, trends, drivers, and constraints, and for the stakeholders to respond to that information. Formally incorporating KAs into that schedule may be a challenge, but all other alternatives would impose additional burdens on both the experts and the stakeholders.

- The TWG has proposed, and Reclamation and the SAP-EC have requested in the draft FY 2018-2020 Triennial Work Plan and Budget, that the GCDAMP re-establish a "Standing Panel" as part of the SAP, to provide routine review services to the GCDAMP. Such services would include reviewing KA findings as well as providing recommendations on how best to maintain and further strengthen the KA process itself. The schedule for each KA should include a formal cycle of review by the SAP-EC or the proposed SAP Standing Panel. Again, it would be best to schedule this review to align with the Annual Reporting cycle, but such a schedule would pose other challenges.

Spreadsheet Tool

The spreadsheet tool for the FY 2017 KA adequately served its primary purposes, (1) to collect, and make it easy for the expert teams to provide, specific types of information on status, trends, drivers, constraints, and LTEMP actions; (2) to ensure consistency in this information; (3) make it easy to analyze the resulting information in a variety of tabular formats; and (4) make it easy to generate the information needed for standard "scorecard" reporting. However, the tool could be improved.

<u>Recommendations:</u>

- The FY 2017 KA expert teams – or at least the team leaders – should be polled for feedback on the spreadsheet tool, on ways in which the tool or its associated guidance might be improved. Feedback from the teams during the FY 2017 KA already suggests some improvements, recommended below. However, there may be no substitute for including a cycle of independent QA/QC for all spreadsheets, e.g., by the SAP-EC, to ensure consistency.

- The spreadsheet should include places where the expert teams can or record or find several additional pieces of information, including:

    1. Explicit documentation of the objectives and benchmarks used for assessing status and trend
    2. The definitions of all resource characteristics and technical measures addressed in the KA
    3. The definitions of all drivers and constraints addressed in the KA (see recommendations above on Knowledge Assessment Structure and Process)
    4. Citations for important reference works relevant to ratings and considered in rationale narratives.

- The "Unknown" category for status, trend, strength, and direction could be split into two variants to recognize two possibilities: there may not be enough evidence with which to even attempt an assessment, or the available evidence, while perhaps nominally sufficiently plentiful, may be too "noisy" to support any firm conclusion. This is a matter for consideration by the expert teams involved in the FY 2017 KA.

- The guidance provided with the spreadsheet tool, and the Data Validation functions incorporated into the tool, should be improved to promote greater consistency in how the expert teams fill in the tables in the tool. As noted above (see Assessment Process), the raw FY 2017 KA spreadsheets required QA/QC processing by the SAP-EC to eliminate several kinds of inconsistencies, including misplaced information and the overriding of Data Validation settings. However, some of these challenges reflected insights by the expert teams that the existing tool did not fully fit or accommodate the ways in which they thought about their assigned resource topics. Other instances simply reflected a lack of attention to the original guidance.

Scorecard Display

The FY 2017 KA implemented a system of graphic representation of the results of the KA based on the National Park Service, Natural Resources Condition Assessment (NRCA) methodology (https://www.nature.nps.gov/water/nrca/). This implementation faced some challenges. For example, the colors of the NRCA symbols proved inadequate for representing the strength of effects of drivers or the expected strength of effect of LTEMP actions. This resulted in much discussion that eventually led to a change – somewhat late in the KA process – to a different type of "color ramp" for these latter purposes. Some TWG members have suggested alternative color ramps to represent effect "strength" for future consideration.

It is important to note, however, that the cumulative experiences of the NPS with its NRCA methodology have prompted the NPS to begin considering ways to improve its processes, including the NRCA graphic system. Jeff Albright, the Coordinator of the NPS NRCA Program, has communicated to the SAP-EC and to Rob Billerbeck, the National Park Service Colorado River Coordinator, about these latter efforts. In particular, the NRCA program is looking at ways to reduce the potential for subjectivity and to improve the way it communicates NRCA results, based on an alternative methodology developed by the National Oceanic and Atmospheric Administration, Marine Sanctuaries Program (http://sanctuaries.noaa.gov/science/condition/pdfs/guidance-2016.pdf). The TWG, GCMRC, and SAP-EC should look into this potential alternative and also maintain communications with

Jeff Albright, to determine whether any aspects of the KA methodology and its graphical summarization might be improved.

Further, the results of averaging information about trends and directions of effects – and the associated summary graphics – need to be explained carefully. Averaging together information about trends or directions of effects across multiple resource characteristics can result in the averaging together of trends or effects that do not all point in the same direction. Some may in fact point in opposite directions. The averaging of such "vector" information results in an estimate of the *net* direction of the trend or effect of interest. In some instances, the value of the average may correspond to a rating of "Unchanging" for trend or "No Effect" for direction (see above, Assessment Methods, Rating Categories and Definitions). However, it is more correct to state that the result indicates "No Net Trend" or "No Net Effect." This relationship should be kept clear in the presentation of results for future KAs.

Roll-Up Default Method

The FY 2017 KA incorporated a default method for averaging the raw KA results to generate summary results (see above, Roll-Up Method). For example, the results for status and trend were "rolled up" into averages for each resource characteristic of a resource topic, across all individual specific (technical) measures for each resource characteristic; and then further averaged for each entire resource topic across all resource characteristics and their individual technical measures. The default method gives equal weight to all entries including in a given average, and ignores values of "Unknown" for any given rating component when other values are present for that component among the other entries included in a given calculation.

The purpose of the default method was not to impose a rigid system on the raw data from the expert teams, but rather to give the expert teams a set of tangible results to which they could react. The teams then had the option to request a change in the weights given to different resource characteristics or technical measures, and/or a change in how the calculation addressed "Unknown" values. For example, entries with "Low" confidence could be weighted less than entries to which an expert team assigned a higher level of confidence; and a set of entries with simply a majority frequency of "Unknown" values for a given component could be assigned an "Unknown" value for its average. In all cases, however, the methodology should prohibit subjective averaging; all roll-ups should be completely reproducible based on the provided evidence and an explicit set of rules for handling the raw information. The TWG, GCMRC, and SAP-EC should review the default method during the next KA cycle, to consider alternatives.

Appendixes

All Appendixes are archived as separate documents on the Knowledge Assessment page of the GCDAMP WIKI website, http://gcdamp.com/index.php?title=2017_Knowledge_Assessment.

Appendix A: Knowledge Assessment Guidance

- See document, GCDAMP FY 2017 Knowledge Assessment Guidance Final 2016-11-10.pdf

Appendix B: Status & Trend Summary Results

- See document, GCDAMP FY 2017 Knowledge Assessment Status & Trend Summary Results Final 2017-04-07.pdf

Appendix C: Drivers and Constraints Summary Results

- See document, GCDAMP FY 2017 Knowledge Assessment Drivers & Constraints Summary Results Final 2017-04-24.pdf

Appendix D: LTEMP Experimental and Management Actions Summary Results

- See document, GCDAMP FY 2017 Knowledge Assessment LTEMP E&M Actions Summary Results Final 2017-04-24.pdf

Appendix E: Spreadsheet Tabular Data by Resource Topic

- GCDAMP 2017 KA Aquatic Food Base Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Aquatic Food Base LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Aquatic Food Base Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Archaeological & Cultural Resources Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Archaeological & Cultural Resources LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Archaeological & Cultural Resources Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Humpback Chub Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Humpback Chub LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Humpback Chub Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Hydropower & Energy Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Hydropower & Energy LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Hydropower & Energy Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Invasive Fish Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Invasive Fish LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Invasive Fish Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Rainbow Trout Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Rainbow Trout LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Rainbow Trout Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Recreational Experience Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Recreational Experience LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Recreational Experience Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Riparian Vegetation Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Riparian Vegetation LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Riparian Vegetation Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Sediment Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Sediment LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Sediment Status & Trend FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Water Quality Drivers & Constraints FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Water Quality LTEMP Actions FINAL 2017-04-07.pdf
- GCDAMP 2017 KA Water Quality Status & Trend FINAL 2017-04-07.pdf