GCDAMP Knowledge Assessment: Status & Trend

Resource Topic:	Water quality
Preparer(s):	Reclamation: Robert Radtke, Marianne Crawford, Katrina Grantz; USGS: Bridget Deemer, Charles Yackulic, Nicholas Voichick: CRC: Peggy Roefer; SNWA: Todd Tietjen; NPS: Mark Anderson
Version Date:	2/13/2017

Resource Characteristic	Specific Measure	Status	Trend	Confidence	Rationale: Status/Trend	Rationale: Confidence	Recommendations
GCD outflow temperature	degrees C	Significant Concern	Unknown	Medium	Data are for status of water quality at outflow of GCD, as assessed from data for several locations, specifically the dam forebay: monthly data, at 0.5 m increments; throughout Lake Powell: ~26 locations, quarterly, at 0.5 m increments; at tailrace: 15 min increments, downloaded ~monthly, static elevation. Data indicate that lake elevations have been declining allowing warmer water to be released through the dam due to the distance of the intake to the surface water in the lake. If lake elevations increase, the water will become colder (deleterious for native fish, good for trout) and if lake elevations decrease the water will become warmer (generally good for native, but also increases risk of increase in warm-water non-natives). CE-QUAL model can predict reservoir temperatures with an absolute mean error of 1/2 deg C. Status/Trend is different for different resources. Temperature varies seasonally as well and interannually.	Temperature of the outflow of GCD is dependent on the elevation and stratification of Lake Powell. Lake elevation is dependent on the inflow volume from rain and snow in the watershed. General mixing dynamics in Lake Powell are well understood, however, the exact temperature being released at the penstock isn't well predicted.	Reinstall temperature string on the Lake Powell side of GCD. Monitor forebay of GCD on a monthly basis to determine trends and analyze data collected in the past. It is difficult to assess a status and trend without identifying specific scenarios of concern. Gather data necessary to determine lake hydrodynamics including temperature data at the inflows (Colorado River and San Juan River). Utilize the results of an Protocols Evaluation Panel or Science Advisors Panel to determine location and frequency.

GCD outflow concentrations of dissolved oxygen	concentration, percent saturation	Moderate Concern	Unknown	Medium	Data are for status of water quality at outflow of GCD, as assessed from data for several locations, specifically the dam forebay: monthly data, at 0.5 m increments; throughout Lake Powell: ~26 locations, quarterly, at 0.5 m increments; at tailrace: 15 min increments, downloaded ~monthly, static elevation. The data indicate that water with lower DO concentrations has been released from GCD and impacted the trout fishery downstream. These conditions have been linked to the oxygen demand of spring runoff events consuming the oxygen in the metalimnion. This water then moves toward GCD and impacts the outflow DO. Deep hypolimnetic waters are also normally undersaturated in Lake Powell. The current CE-QUAL model for Lake Powell is able to predict dissolved oxygen at the Lake Powell outlet with an absolute mean error of 1.15 mg/L. This degree of error is quite good for predicting the vertical distribution of oxygen, but can result in quite large errors in the DO concentrations predicted to pass downstream (sometimes there is >3 mg/L differences between the predicted and observed oxygen concentration at the penstock). This could mean the difference between acceptable and unacceptable levels for downstream fish populations.	Seasonal spring runoff and water column mixing dynamics is fairly well predicted understood, however interannual runoff and mixing is not well predicted. Data analysis correlating inflow volumes, lake elevations, and general dissolved oxygen concentrations at GCD has been performed. (Reclamation has this data and analysis, however, it is not currently available on the web.) The model was built and calibrated using data from 1990 to 2005, but it is unknown how well the model would work for lake elevations/inflows outside of those experienced in that time frame. Analysis of unusual events (e.g., 2005) is fairly well predicted by the model several months out. The precision of modeled DO at the penstock may not be sufficient to guard against deleterious effects on the trout population. DO is not a threat to native fish lower in the system because of aeration (rapids).	Monitor forebay of GCD on a monthly basis to determine trends. Monitor Lake Powell at an interval determined by the results of an Protocols Evaluation Panel or Science Advisors Panel, analyze data collected in the past with special emphasis on metalimnetic oxygen minima and CBOD. More thoroughly monitor DO concentrations in Lake Powell during HFE (e.g., twice daily data, coupled with profile at dam)-- jet tubes significantly increase the DO in the river, would be good to understand the combination of DO from penstock and DO from jet tubes.
GCD outflow salinity, TDS, specific conductance	concentration	Unknown	Unknown	Low	Data are for status of water quality at outflow of GCD, as assessed from data for several locations, specifically the dam forebay: monthly data, at 0.5 m increments; throughout Lake Powell: ~26 locations, quarterly, at 0.5 m increments; at tailrace: 15 min increments, downloaded ~monthly, static elevation. The data indicate that the conductivity of the water discharged from GCD changes with lake elevation and inflow volumes. Lake Powell not only has a thermocline, but also a chemocline, which is a vertical salinity gradient. The thermocline and chemocline serve as impediments to mixing when destratification occurs. The dissolved oxygen concentration at the bottom is regenerated when lakes destratify. This does not occur in Lake Powell.	In most years Lake Powell does not destratify. Destratification allows oxygen and salts to mix throughout the water column. In Lake Powell, oxygen and salt is brought into the lake by the spring runoff. It is difficult to predict the amount of spring runoff and associated mixing from year to year to determine impacts.	Monitor Lake Powell at an interval determined by the results of an Protocols Evaluation Panel or Science Advisors Panel, analyze data collected in the past. Measure conductivity of inflow of Lake Powell at Colorado River and San Juan River.

GCD outflow concentrations of nutrients (e.g., phosphorous, nitrogen)	concentration of various species of nitrogen and phosphorus as well as various micronutrients (Fe, SiO2, K, Ca, etc.)	Moderate Concern	Unknown	Low	Data are for status of water quality at outflow of GCD, as assessed from data for several locations, specifically the dam forebay: monthly samples at surface (1m), penstock (+-40m) elevation and bottom (+-120 m). Both unfiltered and filtered samples. Throughout reservoir quarterly at 12 historical sites, surface and bottom sample, unless other water layers are found, then sampled. Nutrient data are also available below the dam at Lees Ferry through GCMRC (collected at same time as monthly Wahweap trips) as well as through the Arizona Water Science Center. There are also nutrient data from Lees Ferry available via NASQAN (site 09380000) but the degree to which these samples overlap with GCMRC and AZ Water Science Center has not yet been investigated. The resulting long term monitoring data for nitrogen and phosphorus species in Lake Powell show high interannual and intra-annual variability in the concentration of bioavailable nutrients exiting the penstocks (e.g. four-fold variation in soluble reactive phosphorus within a single season) although the mechanisms driving this variation are not well understood. Redfield ratios suggest the river is likely phosphorus limited, but there is very little work that has aimed to confirm this. The N:P ratio was high and stable in the early 2000s, but has been on a downward trend since roughly 2007, however the biological implication of this shifting stoichiometry are not known.	Analysis of historical nutrient Data have been quite limited and is insufficient to determine mechanisms driving patterns in nutrient concentrations at the Lake Powell penstock. While we assume that nutrient concentrations measured at the Lake Powell Wahweap station penstock depth are representative of nutrients exiting the Lake, this assumption hasn't been thoroughly examined with available data. Samples are collected routinely (scheduled monthly) at GCD and Lees Ferry. Some preliminary work suggests that nutrients are an important regulator on river food webs, suggesting that more attention should be paid to the trends in Lake Powell nutrient dynamics and their downstream implications	Analyses for nutrients should be routinely collected monthly (as scheduled) above and below GCD (forebay and Lees Ferry.. and further downstream). Timing of riverine nutrient sampling should be standardized. Given the extremely low concentrations of phosphorus in this system, the contract laboratory should be consulted to see if a new method might be able to lower the detection limits. More time should be spent analyzing the historical nutrient data collected in Lake Powell. Some protocol should also be developed to establish the representativeness of the Lake Powell-Wahweap station penstock depth sample in reflecting the water chemistry and biology exiting Lake Powell. Follow PEP recommended targeted sampling to better understand the drivers of nutrient patterns in the lake and the nutrient limitation regime below GCD.
GCD outflow concentrations of phytoplankton, zooplankton, chlorophyll a	concentration and counts	Unknown	Unknown	Low	Data are for status of water quality at outflow of GCD, as assessed from data for several locations, specifically for phytoplankton and chlorophyll, monthly at forebay and ~26 sites throughout reservoir quarterly, sampled at 1 meter depth. Zooplankton sampled monthly at forebay, 0-30 and 30-60m depth. Quarterly throughout reservoir 12 historic stations 0-30m depth. However, phytoplankton and zooplankton counts and chlorophyll concentration samples have not been collected and analyzed at an adequate frequency to determine impacts on the foodbase downstream of GCD. Quagga mussel veligers are counted as part of the zooplankton analysis and the trend in quagga mussels is also not available.	Some data analysis has been performed to determine the status and trend of phytoplankton, zooplankton, and chlorophyll below GCD, however, this analysis is not readily available so it is unknown if it is sufficient.	Samples for phytoplankton, zooplankton, and chlorophyll should be collected monthly above and below GCD. Monitor Lake Powell at an interval determined by the results of an Protocols Evaluation Panel or Science Advisors Panel, analyze data collected in the past at key locations to determine the impact of quagga mussels on the reservoir and other trends. There is a need to determine whether the data collected in Lake Powell is correlated to the data at Lees Ferry.

GCD outflow concentrations of metals (e.g., selenium, mercury, uranium, etc.)	concentration	Moderate Concern	Unknown	Low	Data are for status of water quality at outflow of GCD, as assessed samples taken annually at 26 historical stations 1 m off bottom , filtered. Selenium and mercury have been identified in concentrations of concern below GCD. The Gold King Mine spill and its associated contaminants entered Lake Powell. USGS Utah has collected some samples specific to the Gold King mine spill to determine the source and fate of these metals-- additional sampling is likely needed (e.g., core sampling).	Insufficient Data exist to be able to determine the status and trend of metals below GCD.	Data should be collected above and below GCD and in Lake Powell at an adequate frequency to determine status and trends as determined by the results of an Protocols Evaluation Panel or Science Advisors Panel. Analyze data collected in the past. Explore work conducted by other researchers on mercury in Lake Powell.
GCD outflow turbidity/sediment load	concentration, NTU	Unknown	Unchanging	High	Data are for status of water quality at outflow of GCD, as assessed from data for several locations, specifically the dam forebay: monthly data, at 0.5 m increments; throughout Lake Powell: ~26 locations, quarterly, at 0.5 m increments; at tailrace: 15 min increments, downloaded ~monthly, static elevation. Most sediment settles out at the inflow areas resulting in high water clarity at the outflow of GCD. The sediment from the inflows can impact the DO concentrations in the water column. See DO above. The amount of sediment entering Lake Powell can vary over time based on the amount of runoff. The amount of sediment cannot be predicted. Also, the goal for sediment has not been established. The goal for native fish and beaches is different than the goal for trout and therefore the status is unknown.	There is sufficient data to show that sediment does not exit GCD in high concentrations. The data for the inflow areas is lacking, see DO above. The goal for sediment has not been established. The goal for native fish and beaches is different than the goal for trout.	Monitor Lake Powell at an interval determined by the results of an Protocols Evaluation Panel or Science Advisors Panel, analyze data collected in the past at key locations to determine trends.