GCDAMP Knowledge Assessment: Drivers & Constraints

Resource Topic:	Water quality
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Resource Characteristic	Driver or Constraint	Strength	Direction	Confidence	Rationale: Strength & Direction	Rationale: Confidence	Recommendations
GCD outflow temperature	Lake Powell water surface elevation (high versus low)	Moderate	Unknown	High	Given the fixed height of the Lake Powell penstocks, reservoir water level is a dominant driver of outflow temperatures. Summertime stratification can lead to sharp temperature gradients wherein the variability in reservoir elevation can result in upwards of 7 degree differences in the temperature of water spilling downstream. This is reflected in the interannual variabilities of maximum temperature experienced within the Lees Ferry reach (and throughout the Grand Canyon). While we know that higher reservoir elevations lead to colder outflow temperatures, we have listed the direction of the effect as "unknown" since it is unclear what the targeted fish species would be for temperature management. For native fish the correlation of reservoir elevation and temperature would be considered "strong" because a small change in temperature could have a large impact on native fish.	A 50 year record of temperature data at the forebay of Lake Powell shows that the reservoir experiences strong thermal stratification each summer (generally >15 degrees C difference between top and bottom). While there is some variability in the depth of the metalimnion (and the associated degree of temperature change that would be expected with reservoir elevation change), in most summers the penstocks are drawing water from the metalimnion making for large outlet temperature changes with shifting lake elevation. While the relationship between lake elevation and temperature is most apparent in September-November, the relationship is somewhat weak and other variables (like stratification) would need to be considered to predict outflow temperature. The trending relationship between elevation and temperature of the outflow water from GCD is strong. The exact temperature cannot be predicted at a certain water surface elevation, but the general trend can be predicted.	Reinstall temperature string on the Lake Powell side of GCD for daily temperature data. Continue to 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) using the gage data from USGS in each of these tributaries. Consider adding temperature to the new gage at Hite. Utilize the results of an Protocols Evaluation Panel or Science Advisors Panel to determine location and frequency. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow temperature	Lake Powell thermal stratification regime	Moderate	Unknown	Medium	The thermal stratification Lake Powell experiences each summer determines the thickness of the epilimnion and metalimnion and the associated depth distribution of heat. While the duration and extent of stratification are relatively consistent from year to year, there is still some marked variability that could significantly change seasonal patterns in outflow temperatures during some years. However, the amount of temperature change in the outflow, even in the case of strong thermal stratification, would be fairly small. Storm events, water clarity, river inflows, and wind regime can all affect stratification patterns. It has also been posited that HFEs may serve to enhance mixing. There is also a chemocline in Lake Powell that increases the resistance to mixing of the water column. For native fish the correlation of reservoir elevation and stratification would be considered "strong" because a small change in temperature could have a large impact on native fish.	The role of different mixing processes in determining lake stratification are currently not well understood. The current version of the Lake Powell CE-QUAL model uses different mixing coefficients for each month of the year, but there is no mechanistic explanation for these terms. There has also been no quantitative attempt to link any index of stratification with the temperature of outflowing water from Lake Powell.	Reinstall temperature string on the Lake Powell side of GCD. Continue to 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) using the gage data from USGS in each of these tributaries. Consider adding temperature to the new gage at Hite. Utilize the results of an Protocols Evaluation Panel or Science Advisors Panel to determine location and frequency. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow temperature	Lake Powell inflow: spring runoff or baseflow	Weak	Unknown	High	The temperature of the inflow water is influenced by the time of year it is entering into the reservoir. Size and timing of the interflow impacts the temperature at GCD. As the water cools in the winter it becomes more dense and will mix with the water below, cooling the water to similar temperatures, so the outflow water will have a fairly well mixed water temperature. The strength of the effect is related to the reservoir depth. Interflow or overflow of spring runoff will also impact the outflow temperature.	Temperature has been studied in Lake Powell and the thermal dynamics of the water entering the lake in the spring (run off) and other times of the year have been described. Assessing these conditions under other scenarios will require additional knowledge/modeling.	Gather data necessary to determine lake hydrodynamics including temperature data at the inflows (Colorado River and San Juan River) using the gage data from USGS in each of these tributaries. Consider adding temperature to the new gage at Hite. Utilize the results of an Protocols Evaluation Panel or Science Advisors Panel to determine location and frequency. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of dissolved oxygen	Lake Powell inflow dynamics	Strong	Negative Effect	High	The amount of sediment and the associated nutrients that enters Lake Powell in high inflow years is much different than low inflow years. In some years, this sediment travels at the depth of the metalimnion and the oxygen demand from the sediment lowers the oxygen concentrations in this portion of the water column. As this water approaches the dam, depending upon lake elevation, it can lower the dissolved oxygen concentration in the water exiting Glen Canyon Dam.	The impact of interflow plume dynamics on the dissolved oxygen concentration of the inflow areas and downstream in Lake Powell has been described but predicting whether this water will be entrained in the outflow of Glen Canyon Dam is dependent on other factors.	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. More thoroughly monitor DO concentrations in Lake Powell during HFE. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of dissolved oxygen	Lake Powell chemical oxygen demand	Strong	Negative Effect	Medium	The amount of sediment that enters Lake Powell in high inflow years is much different than low inflow years. This sediment travels at the depth of the metalimnion and the oxygen demand from the sediment lowers the oxygen concentrations in this portion of the water column. As this water approaches the dam, depending upon lake elevation, it can lower the dissolved oxygen concentration in the water exiting Glen Canyon Dam.	The impact sediment on the dissolved oxygen concentration of the inflow areas and downstream in Lake Powell has been described but predicting whether this water will be entrained in the outflow of Glen Canyon Dam is uncertain. Additional work may be required to quantify the important difference between continued oxygen depletion versus transport of low dissolved oxygen waters.	Continue to 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. More thoroughly monitor DO concentrations in Lake Powell during HFE. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of dissolved oxygen	Lake Powell biological oxygen demand	Unknown	Negative Effect	Low	There is quite a bit of interannual variability in Lake Powell's nutrient availability, but the patterns and mechanisms of this variation have not been studied extensively. These nutrient can stimulate algal growth. As the algae is growing it is producing oxygen, but as the algae die and decompose they settle to the metalimnion. The oxygen demand from the decomposition lowers the oxygen concentrations in this portion of the water column. As this water approaches the dam, depending upon lake elevation, it can lower the dissolved oxygen concentration in the water exiting Glen Canyon Dam.	Biological oxygen dynamics have not been studied in Lake Powell.	Continue to 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. More thoroughly monitor DO concentrations in Lake Powell during HFE. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow concentrations of dissolved oxygen	Lake Powell water surface elevation (high versus low)	Moderate	Negative Effect	Medium	Given he fixed height of the Lake Powell penstocks, reservoir water levels can influence dissolved oxygen concentrations in the outflow. Summertime stratification can lead to sharp oxygen gradients. In general there is more oxygen above the thermocline than below the thermocline. This can possibly lead to higher outlet oxygen concentrations at low reservoir elevations. In contrast to this general pattern, low oxygen interflow plumes tend to occur higher up within the metalimnion such that higher lake elevations are better than lower elevations because the metalimnion depth (area of the water column with lower dissolved oxygen concentrations) is above the level of the intakes at Glen Canyon Dam. This lower dissolved oxygen region can move to the depth of the intakes at Glen Canyon Dam, lower the dissolved oxygen in the water exiting the dam and potentially kill the trout living below the dam if the concentrations are low enough. Low dissolved oxygen conditions have occurred in the past and it is unclear how large an impact these conditions had on the trout downstream of GCD.	Low dissolved oxygen concentrations have been seen below Glen Canyon Dam in the past (e.g., in 2005) when Lake Powell elevations were at their lowest but this phenomenon has not been studied extensively.	Continue to 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 More thoroughly monitor DO concentrations in Lake Powell during HFE. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of dissolved oxygen	Lake Powell thermal stratification regime	Moderate	Negative Effect	Medium	The stronger the stratification in Lake Powell the less likely it is to destratify in the winter. Lake Powell also has a chemocline which also impedes mixing. When lakes destratify in the winter, the oxygen from the surface is brought to the bottom water. In Lake Powell this occurs infrequently. Fortunately, the cold water that enters the lake in the winter flows in at the bottom and oxygenates the hypolimnion.	The stratification patterns in Lake Powell have been studied and in most years the lake does not destratify completely. As mentioned above, the current version of the Lake Powell CE-QUAL model uses different mixing coefficients for each month of the year, but there is no mechanistic explanation of these terms. There is also more that can be learned about the chemocline/thermocline interaction in Lake Powell.	Continue to 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 More thoroughly monitor DO concentrations in Lake Powell during HFE. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow salinity, TDS, specific conductance	Lake Powell inflow: spring runoff or baseflow	Strong	Unknown	High	The spring inflow is primarily driven by snow melt which is low in total dissolved solids. The base flow that enters the lake later in the year may have irrigation return flows or flows from ground water which contain more dissolved minerals. The spring inflows lower the salinity of the lake and the base flows can raise the salinity of the lake (hence the "unknown" in the direction category) . It is difficult to predict the amount/type of run off from year to year and so it is difficult to predict changes in salinity in at the outflow of the dam.	The processes that influence salinity concentrations are well understood in reservoirs. The original monitoring program for Lake Powell was established to monitor salinity.	Continue to 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. Measure conductivity of inflow of Lake Powell at Colorado River and San Juan River. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow salinity, TDS, specific conductance	Lake Powell water surface elevation (high versus low)	Weak	Negative Effect	Medium	Higher surface elevations in Lake Powell allow for more accumulation of higher salinity at the foot of Glen Canyon Dam because the water is withdrawn through the dam at a higher elevation. Generally, a increased inflow equals a higher surface water elevation and a freshening of the hypolimnion. Also, the existing chemocline will be strengthened which prevents mixing of the water column during destratification, lessening the likelihood the water column will be mixed.	The salinity trend at Glen Canyon Dam has been studied in the past, but these data were developed with spotty monthly data.	Continue to 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. Measure conductivity of inflow of Lake Powell at Colorado River and San Juan River. Develop/enhance model of salinity concentrations at Glen Canyon Dam. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow salinity, TDS, specific conductance	Lake Powell thermal stratification regime	Moderate	Unknown	High	The accumulation of salt in the hypolimnion is strengthened with stronger stratification. The strengthening of the chemocline provides an additional barrier to destratification, preventing mixing salinity from the hypolimnion into the upper layers of Lake Powell.	The processes that influence salinity concentrations are well understood in reservoirs.	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. Measure conductivity of inflow of Lake Powell at Colorado River and San Juan River. Develop model of salinity concentrations at Glen Canyon Dam. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of nutrients (e.g., phosphorous, nitrogen)	Lake Powell water surface elevation (high versus low)	Moderate	Positive Effect	Low	There is a significant relationship between nitrate concentration and reservoir elevation at the Lake Powell penstock, wherein as water levels drop there is less N being exported downstream. While redfield ratios suggest that P should be limiting to aquatic organisms, nutrient diffusing substrate assays done in Lees Ferry suggest that primary producers respond to N as well.	There has been relatively little work done to examine the historical nutrient dataset from Lake Powell. There has been a change in laboratory detection limits over time, with newer laboratory detection limits being much lower than in the past. In addition, our understanding of nutrient dynamics in Lees Ferry and downstream is quite limited. This makes it difficult to rate the strength of various drivers (since the relative role of N,P, and other micronutrients is not well established).	Samples for nutrients should continue to be collected monthly above and below GCD. 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 (1 or 2 ug/L for total and soluble phosphorus). 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 penstock depth sample in reflecting the water chemistry and biology exiting Lake Powell. Finally, targeted sampling should be designed to better understand the drivers of nutrient patterns in the lake and the nutrient limitation regime below GCD. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow concentrations of nutrients (e.g., phosphorous, nitrogen)	Lake Powell inflow dynamics	Strong	Positive Effect	Low	The inlet to Lake Powell and the sediment deltas therein are likely very important to system-wide phosphorus dynamics. The volume, conductivity, and temperature of inflows (as well as the lake elevation prior to large inflow events) likely determine P release and mixing within the reservoir. Most of the productivity in upper Lake Powell or in side canyons is due to the resuspension of nutrients. These nutrients are used before they travel to the lower sections of Lake Powell closer to the dam. This area of Lake Powell is considered oligotrophic.	Experimental work done on delta sediments characterize the capacity for P release in this zone (Wildman and Hering 2011), however the results of these laboratory-based assays have not been extended to the field (to quantify transport through Lake Powell under various inflow scenarios).	Samples for nutrients should continue to be collected monthly above and below GCD. 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 (1 or 2 ug/L for total and soluble phosphorus). 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 penstock depth sample in reflecting the water chemistry and biology exiting Lake Powell. It may also be instructive to examine satellite photos of the Lake Powell inflow deltas to see if there is a correlation between the area of exposed sediment and the phosphorus appearing at the outlet. Finally, targeted sampling should be designed to better understand the drivers of nutrient patterns in the lake and the nutrient limitation regime below GCD. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of nutrients (e.g., phosphorous, nitrogen)	Lake Powell thermal stratification regime	Unknown	Unknown	Low	Thermal stratification regulates mixing between the warmer epilimnion and the colder bottom waters of the lake. In doing so, it can affect the rate at which nutrients accumulate in the hypolimnion/metalimnion and the associated nutrient concentrations.	Stratification indices for Lake Powell have not been yet been compared to nutrient dynamics to look for relationships.	Samples for nutrients should continue to be collected monthly above and below GCD. 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 (1 or 2 ug/L for total and soluble phosphorus). 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 penstock depth sample in reflecting the water chemistry and biology exiting Lake Powell. Finally, targeted sampling should be designed to better understand the drivers of nutrient patterns in the lake and the nutrient limitation regime below GCD. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow concentrations of phytoplankton, zooplankton, chlorophyll a	Lake Powell thermal stratification regime	Weak	Unknown	Low	Depending upon the elevation of the stratification in Lake Powell, more or less phytoplankton and zooplankton will be entrained in the water exiting the dam. Also, the stronger the stratification less phytoplankton or zooplankton will be able to cross this energy barrier and make it through the dam.	Data have been collected for these three parameters, but few analyses have been performed to look for trends. There has also not been a comprehensive look at the impact of quagga mussels on these parameters. The presence of quagga mussels in Lake Powell is a recent occurrence and there has been insufficient time to make correlations between quagga mussel and phytoplankton concentrations.	Samples for phytoplankton, zooplankton, and chlorophyll should continue to be collected monthly above and below GCD. These samples should also be collected 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 any other trends. There is a need to determine whether the data collected in Lake Powell is correlated to the data at Lees Ferry. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of phytoplankton, zooplankton, chlorophyll a	Lake Powell nutrient concentrations (e.g., phosphorous, nitrogen)	Moderate	Unknown	Low	The increase of nutrients allows the phytoplankton to grow and reproduce, which then may stimulate an increase in zooplankton. Chlorophyll a is a measure of the amount of phytoplankton in the water. From a fish perspective a large number of zooplankton and phytoplankton are a positive because they are food for the fish. From a recreational perspective large amounts of phytoplankton are not conducive to a quality recreational experience. Extremely large amounts of phytoplankton, especially certain species of blue green algae, can produce toxins and be responsible for fish kills, dog deaths, and human health effects.	Data have been collected for these three parameters, but few analyses have been performed to look for trends. Determining if the goal is recreation or fish provides uncertainty in the confidence.	Samples for phytoplankton, zooplankton, and chlorophyll should continue to be collected monthly above and below GCD. These samples should also be collected 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. There is a need to determine whether the data collected in Lake Powell is correlated to the data at Lees Ferry. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of phytoplankton, zooplankton, chlorophyll a	Lake Powell water clarity/turbidity	Weak	Unknown	Low	Turbidity reduces light penetration into the water column and this reduces growth of phytoplankton since they can't photosynthesize without sunlight. At the outflow of GCD the turbidity rarely is found in concentrations high enough to impede algal growth. From a fish perspective a large number of zooplankton and phytoplankton are a positive because they are food for the fish. From a recreational perspective large amounts of phytoplankton are not conducive to a quality recreational experience. Extremely large amounts of phytoplankton, especially certain species of blue green algae, can produce toxins and be responsible for fish kills, dog deaths, and human health effects.	Data have been collected for these three parameters, but few analyses have been performed to look for trends. Determining if the goal is recreation or fish provides uncertainty in the confidence.	Samples for phytoplankton, zooplankton, and chlorophyll should continue to be collected monthly above and below GCD. These samples should also be collected 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. There is a need to determine whether the data collected in Lake Powell is correlated to the data at Lees Ferry. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow concentrations of phytoplankton, zooplankton, chlorophyll a	Lake Powell water surface elevation (high versus low)	Weak	Unknown	Low	Phytoplankton and zooplankton normally live in the upper waters of lakes. In the case of Lake Powell, the higher the elevation of the lake, the less likely phytoplankton and zooplankton will be entrained in the outflow of the dam because of the depth of the intakes. As the elevation decreases, the concentration of phytoplankton and zooplankton will increase.	Data have been collected for these three parameters, but few analyses have been performed to look for trends associated with lake elevation.	Samples for phytoplankton, zooplankton, and chlorophyll should continue to be collected monthly above and below GCD. These samples should also be collected 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. There is a need to determine whether the data collected in Lake Powell is correlated to the data at Lees Ferry. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of metals (e.g., selenium, mercury, uranium, etc.)	Lake Powell inflow dynamics	Unknown	Unknown	Low	Metals frequently are attached to sediment particles and will be found where the sediment is deposited, generally down lake not far from inflow zones. This sediment normally does not travel the distance of the lake to Glen Canyon Dam. In some cases soluble forms of metals can be released by the sediments, but due to the chemistry of Colorado River water soluble metals do not remain in solution in the epilimnion or metalimnion for an extended period of time and resettle back into the sediment. The State of Utah discontinued metal sampling in the water column due to these conditions as the samples were always non-detect.	Very little Data have been collected for these parameters.	Data should be collected above and below GCD and in Lake Powell at an adequate frequency to determine status and trends. Analyze data collected in the past. Explore work conducted by other researchers on mercury in Lake Powell. The interflow plume should be sampled for metals to discern whether the reducing conditions that develop in Lake Powell during the summer lead to metal dissolution and transport toward the dam. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow concentrations of metals (e.g., selenium, mercury, uranium, etc.)	Lake Powell thermal stratification regime	Unknown	Unknown	Low	Lack of oxygen in sediments tend to drive the metals into a more available chemical form (reduced). The lower the ORP the more available metals become. A low ORP is tied to low oxygen and low pH. Low ORP generally co-occurs with low oxygen and low pH. Generally metals are more bioavailable in acidic water (pH <7) than in basic water (pH >7). In the case of mercury, the process of methylation (which creates the more toxic bioavailable form of mercury, methylmercury) is often linked to sulfate reduction, which also occurs under low oxygen concentrations.	Very little Data have been collected for most of these parameters, with the most information available on mercury. FWS analyzed samples in the late 1990's on fish tissue and water for mercury. Also, independent university researchers are finding significant levels of methylmercury accumulating in fish tissue in Lake Powell. This data collection is ongoing and has yet to be published (personal communication with Mark Anderson at the Glen Canyon National Recreation Area).	Data should be collected above and below GCD and in Lake Powell at an adequate frequency to determine status and trends. Analyze data collected in the past. Explore work conducted by other researchers on mercury in Lake Powell. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.

GCD outflow concentrations of metals (e.g., selenium, mercury, uranium, etc.)	Lake Powell water surface elevation (high versus low)	Unknown	Unknown	Low	Higher concentrations of reduced metals are expected to occur in areas with low dissolved oxygen concentrations. See above for description of how reservoir elevation and dissolved oxygen concentrations relate. Most of the sources of uranium in the Hite area of Lake Powell have been buried under hundreds of feed of sediment and are sequestered by the sediment. This condition could change if reservoir elevations fall to such a level that the river begins to rework these sediments.	The metal sampling is conducted annually only at the bottom of the reservoir making it difficult to discern the vertical distribution of various metals (as well as any seasonal patterns in general).	Metal samples should be collected at an interval determined by the results of an Protocols Evaluation Panel or Science Advisors Panel. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow turbidity/sediment load	Lake Powell water surface elevation (high versus low)	Moderate	Unknown	High	Overall, higher reservoir levels will tend to have a lower turbidity, since there will be less scouring or erosion of the delta sediments in the inflow areas. In the case of Lake Powell, sediment is normally found at the metalimnion depth. At higher lake elevations, this water is above the intakes at Glen Canyon Dam and the sediment and associated metals are not entrained in the outflow of the dam. A dramatic drop in elevation and a large inflow event could allow sediment from the inflows to travel to GCD.	The lack of sediment in the water exiting Glen Canyon Dam has been well characterized and is the main driver for the need for High Flow Experiments. High Flow Experiments are the focus of the Long Term Experimental and Management Plan (LTEMP).	Sediment data should be collected 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. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow turbidity/sediment load	Lake Powell inflow dynamics	Unknown	Unknown	High	As Lake Powell elevations drop the impact of the inflow sediment concentrations will increase. The sediment could move farther into the reservoir, impacting more of the lake and potentially exiting Glen Canyon Dam. High inflows stir up and resuspend sediment in the inflow areas, while lower base flows tend to have a lower tendency to move sediment. It is difficult to predict from year to year the volume of the inflow. From a sediment perspective below Glen Canyon Dam, this would be a positive, but from a recreational perspective in Lake Powell, this would be a negative.	The sediment concentration of the water entering Lake Powell has been studied. Due to the variability of inflow volumes and reservoir elevations it is difficult to determine the impact on Lake Powell. The lack of sediment in the water exiting Glen Canyon Dam has been well characterized.	Sediment data should be collected 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. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.
GCD outflow turbidity/sediment load	Lake Powell thermal stratification regime	Weak	Unknown	High	The amount of sediment that enters Lake Powell in high inflow years is much different than low inflow years. This sediment travels at the depth of the metalimnion towards Glen Canyon Dam. In most cases the sediment settles out before reaching the dam.	The sediment concentration of the water entering Lake Powell has been studied. The lack of sediment in the water exiting Glen Canyon Dam has been well characterized.	Sediment data should be collected 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. The current monitoring plan for Lake Powell was developed by the 2000 Protocols Evaluation Panel.