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Operations and Tradeoffs of the Colorado River

This paper will cover the Bureau of Reclamations approach to managing the Colorado River over the next fifty years. It will be primarily a summary of the Colorado River Basin Water Supply and Demand Report. There will be a description of the various economic, cultural, and ecological aspects of management. It will focus on conflicts of interest and tradeoffs for reconciliation. Supplemental sources will be sited to provide a background

The Colorado River provides benefit by supplying water to over 40 million people, irrigating 5.5 million acres, generating 4,200 megawatts of hydropower annually, providing recreation, and sustaining a unique diversity of species (USBR). The management of the river seeks to maximize these benefits. The problem is that the management practices that may increase one benefit may affect another. In the optimization field this is termed a tradeoff. Various stakeholders seek to lobby management for operations that will benefit there particular interests. These stokeholds may include state, local, and tribal governments, environmentalist, power companies, and irrigators.

There are two major dams on the river. They are owned and operated by the United States Bureau of Reclamation. The operation of these dams dominates management decisions. Hoover Dam was created during the Great Depression and resulted in the creation of Lake Mead. It provides 28 million acre feet of storage. Glen Canyon Dam was created in 1966 and resulted in Lake Powell. It provides 24 million acre feet of storage. As a means to study how management decisions are made, we should examine how operations have been conducted in the past. Below is a graph showing the historical flow of the river below Glen Canyon Dam at Lees Ferry.

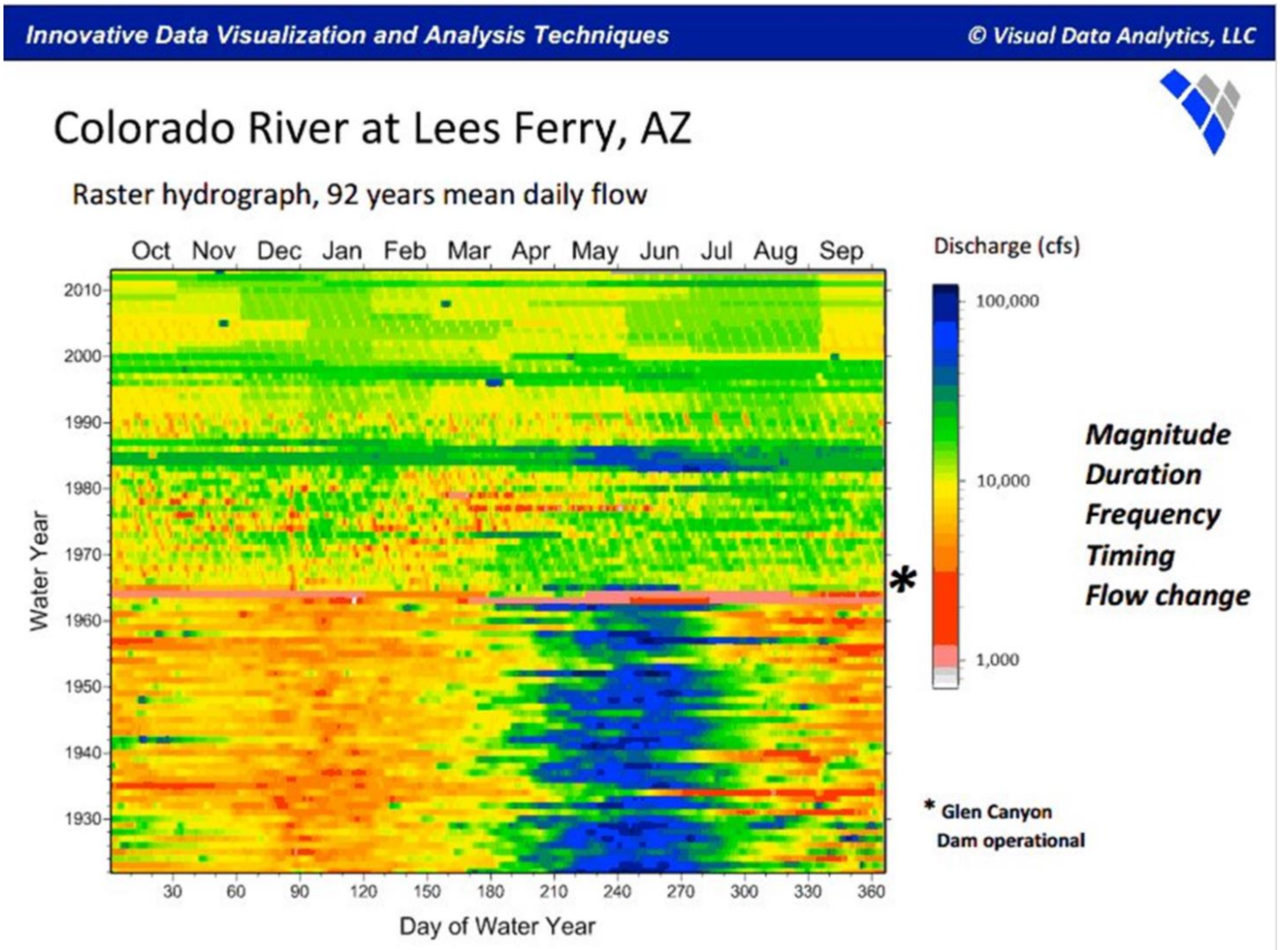

Figure 1: The Historical flow at Lees Ferry is shown above.

There appears to be three distinct periods. The first is the natural flow regime before the construction of the dam. The second two are different types of operation after construction of the dam.

The natural flow regime is shown from the start of the period of record up to 1966. There is wide various in the frequency, timing, duration, and magnitude of flow events. This is significant for two reasons. Firstly, the species living in the canyon have evolved to these condition and changes to this flow regime have had a negative effect on their survival. Secondly, the rate of sediment transport is dependent on large flow event. The large flow events will move sediment and deposit sandbars and other geomorphic features within the river. After the creation of the dams, sediment became trapped in the reservoirs and the river became sediment starved.

After Glen Canyon Dam was built the flow regime was drastically changed. There was a more homogenous flow. The very high flows in the late spring were lost and the spread out more evenly through the year. The only high flows can be seen in the late 1980's and were a result of flood control releases. The appears to be a second operational period after 1991.

After 1991 there appears to be a different mode of operations. The releases seem to follow month trends. This is likely a sign that their operations model has a monthly time step component. This can be seen in the hydrograph (Figure 2). There appears to be two release periods, one in the winter and the other in the summer. The release in the release in the winter is likely made to help fill up Lake Mead and to provide extra room in Lake Powell for the spring runoff. The releases in the summer are tide to increased irrigation and municipal use. There also appears to be several short high flow events during the last several years.

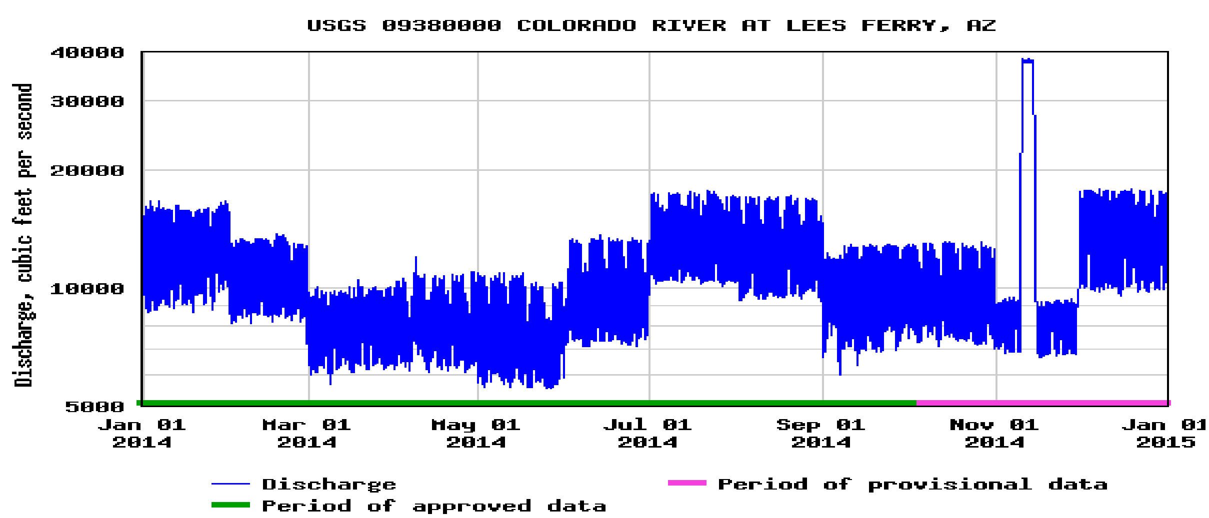

Figure 2: The month releases at Lees Ferry are shown here

In an effort to establish some degree of a natural flow regime, the Bureau as conducted high flow experiments. These are short periods lasting a week or so. The theory is that the high flow events will flush the canyon sediment and encourage a more natural deposition. This more natural deposition will help with habitat for native species. These high flow releases do not conflict with water supply interest because water released from Lake Powell is captured by Lake Mead. There is a conflict with Hydro power. Before the tradeoff involving high flow releases and hydropower is described in any detail it short background of hydropower will be provided.

Hydropower is generated by flowing water at high velocity through a turbine. The water spins the turbine and electricity is created. The power generated by the water can be calculated by the following equation (Eqn 1).

Eqn 1) $Power = Density\ of\ water \times Gravity \times Head \times Flow \times Turbine\ effcency$

This means that as the Flow is increased the power generated will be increased as well. There is another factor, the efficiency. The is a function of the geometry and materials of the turbine. Each turbine will have a point at which it produces a maximum efficiency. See below

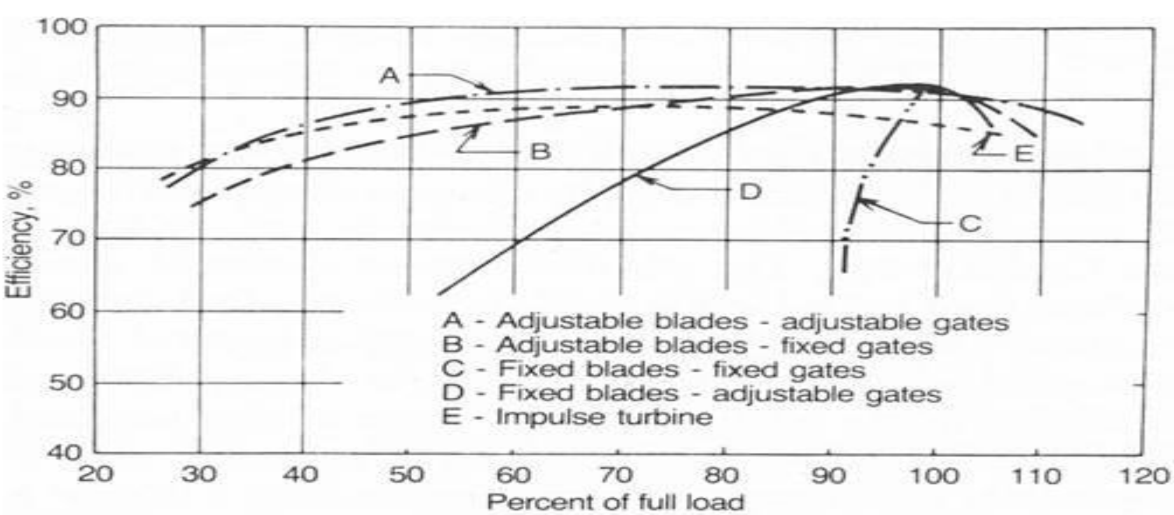

Figure 3: Notice that for each turbine type the point of highest efficiency is not at full load. (renewablesfirst)

When high flows are conducted the turbines are run at full capacity, 32,000 cfs (gcdamp). The turbines are not run at their best efficiency point when run a full capacity resulting in at least a ten percent loss in energy production.

When high flows are conducted the overflow tubes are utilized. These tubes have a capacity of 15,000 cfs (gcdamp). The overflow tubes do not produce hydropower. The use of the overflow tubes result in a further 30% reduction in power production. The amount of power production is not enough to determine the loss of revenue.

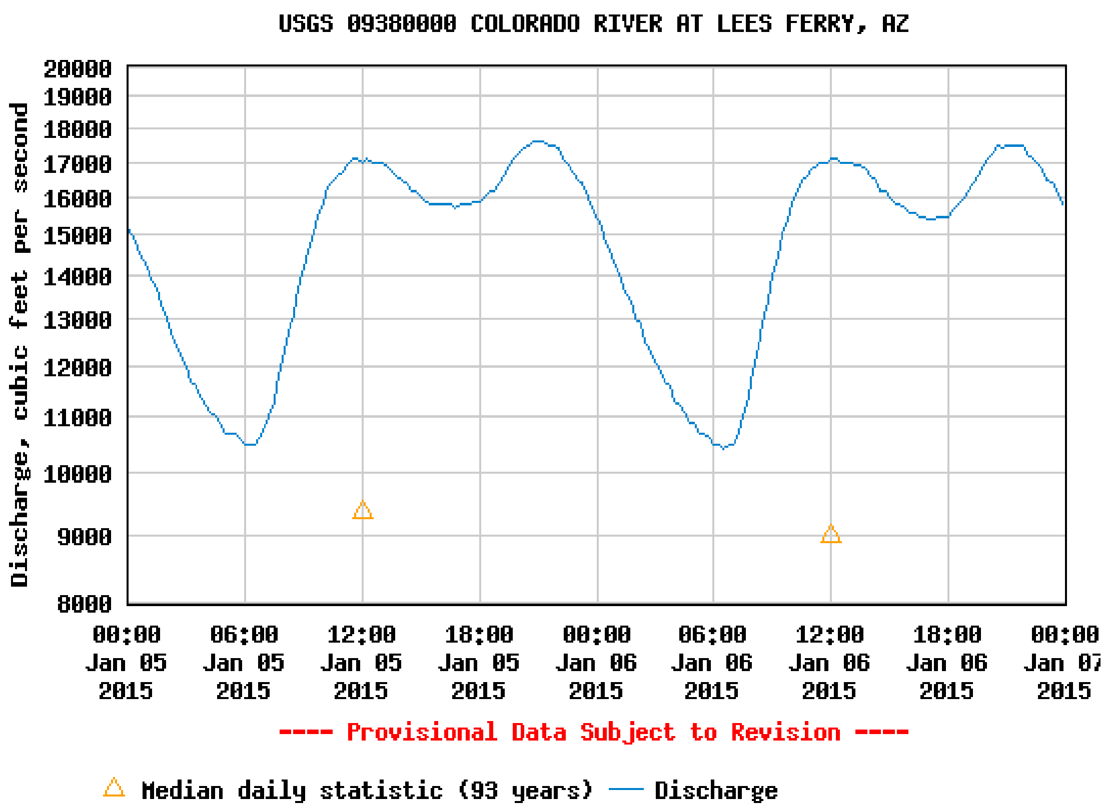

Figure 4: Daily changes in flows are directly tied to the price of electricity.

The amount of revenue generated not only depends on the amount of power created, but on the price of that power. The daily changes in flow are a direct result of changes in electrical prices. Notice how the flow declines in the overnight hours and increases as people get up for the day. This is due to the changes price of electricity as the demand changes through the day. Operators take advantage of the price change to maximize their revenue by generating hydropower when the price is high. During the experimental high flow events, electricity is constantly produced regardless of the price. This further reduces revenue by producing hydropower while the price is low.

The duration of the high flow events is also a significant factor in operation. The flow events appear to last a week and can generate flow on the order of 50,000 cfs. This is more than 4 times the average flow. Meaning that a single experimental high flow event can generate more flow then a average month of flow. The excess flow does not affect water supply because the extra flow can easily be absorbed by Lake Mead.

The experimental flow events can also provide benefit for tourism. The sand bars created by the experimental flows not only create fish and other aquatic species habitat, but it creates rafter habitat. The sand bars provide an outstanding camping location for the rafting outfitters.

The tourism within the canyon and the Colorado River in general provides a significant economic benefit. Dollars spent on tourism would likely benefit the local economy more than the revenue form hydropower. This is because revenue from tourism is spread out over more hands all of which need to pay for their basic expenses. Dollars spent in this fashion tend to be spent more often and therefore have a greater effect on GDP.

Tourism, hydropower, and Water supply do not tend to be in constant conflict. The timing of the daily flows benefit the rafters as it provides reliability. The timing of the summer water supply releases tends to increase the flow for rafting.

What does seem to be in conflict in term of tradeoffs is the experimental high flow events as part of the adaptive management plan. In order to maintain a balanced plan managers will need to determine priorities.

When determining the proper plan, the Bureau has several criteria. A summary is provided in the following table. One interesting thing about the approach is that they not only look and the end goals but the implementation process in terms of permitting, feasibility, risk, and viability.

Criteria	Summary Description of Criteria
Quantity of Yield	The estimated long-term quantity of water generated by the option—either an increase in supply or a reduction in demand
Timing	Estimated first year that the option could begin operation
Technical Feasibility	Technical feasibility of the option based on the extent of the underlying technology or practices
Cost	The annualized capital, operating, and replacement cost per af of option yield
Permitting	Level of anticipated permitting requirements and precedent of success for similar projects
Legal	Consistency with current legal frameworks and laws, or precedent with success in legal challenges
Policy Considerations	Extent of potential changes to existing federal, state, or local policies that concern water, water use, or land management
Implementation Risk	Risk of achieving implementation and operation of option based on factors such as funding mechanisms, competing demands for critical resources, challenging operations, or challenging mitigation requirements
Long-term Viability	Anticipated reliability of the option to meet the proposed objectives over the long term
Operational Flexibility	Flexibility of option to be idled from year to year with limited financial or other impacts
Energy Needs	Energy required to permit full operation of the option, including treatment, conveyance, and distribution
Energy Source	Anticipated energy source to be used to allow option to be operational
Hydropower	Anticipated increases or decreases in hydroelectric energy generation associated with implementation of the option
Water Quality	Anticipated improvements or degradation in water quality associated with implementation of the option
Recreation	Potential impacts to recreational activities including in-river and shoreline activities
Other Environmental Factors	Other environmental considerations, such as impacts to air quality, or aquatic, wetland, riparian, or terrestrial habitats
Socioeconomics	Potential impacts to socioeconomic conditions in regions within or outside of the Basin as a result of implementing the option

Figure 5: This Table was taken from the Colorado River Basin Water Supply and Demand Study

In summary the bureau is working on long term viability of the Colorado River Basin. To do this they are modifying operation as a means to balance the needs of all stakeholders. The general priorities of society will be displayed in the way in which the Bureau chooses to operate the system. The major questions that will need to be asked are: What is man's place in the environment? Are we here to be to watch over and care for the environment at all cost? Is the environment to be harnessed for our own good? Or something in between? The answer to those questions will determine the operation of the Colorado River Basin.

References:

http://www.gcdamp.gov/hfe.html (gcdamp)

http://www.renewablesfirst.co.uk/hydro-learning-centre/kaplan-turbines/ (renewablesfirst)

Reclamation, Managing Water in the West, Colorado River Basin Water Supply and Demand Study (USBR)