ANL/DIS-14/9

Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Year 2013

Decision and Information Sciences Division

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by
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Work sponsored by the United States Department of Energy
and the Western Area Power Administration

June 2014

Foreword

This report was prepared by Argonne National Laboratory (Argonne) in support of a financial analysis of experimental releases from the Glen Canyon Dam (GCD) conducted for the U.S. Department of Energy's Western Area Power Administration (Western). Western markets electricity produced at hydroelectric facilities operated by the Bureau of Reclamation. The facilities known collectively as the Salt Lake City Area Integrated Projects include dams equipped for power generation on the Colorado, Green, Gunnison, and Rio Grande rivers and on Plateau Creek in the states of Arizona, Colorado, New Mexico, Utah, and Wyoming.

This report presents detailed findings of studies conducted by Argonne related to a financial analysis of experimental releases conducted at the GCD during water year 2013. Previous reports issued in January 2011 (ANL/DIS-11-1), August 2011 (ANL/DIS-11-4), June 2012 (ANL/DIS-12-4), and April 2013 (ANL/DIS-13-2) performed financial analyses of experimental releases conducted in water years 1997 to 2005, 2006 to 2010, 2011, and 2012, respectively. Staff members of Argonne's Decision and Information Sciences Division prepared this technical memorandum with assistance from staff members of Western's Colorado River Storage Project Management Center.

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Acronyms and Abbreviations

The following is a list of the acronyms and abbreviations (including units of measure) used in this document.

AHP	available hydropower
Argonne	Argonne National Laboratory
FSF	Fall Steady Flow
GCD	Glen Canyon Dam
GCDEIS	Glen Canyon Dam Environmental Impact Statement
GTMax	Generation and Transmission Maximization
HFE	High Flow Experiment
MSR	Minimum Schedule Requirement
PO&M-59	Power Operations and Maintenance, Form 59 (a Bureau of Reclamation form entitled, *Monthly Report of Power Operations – Powerplants*)
Reclamation	Bureau of Reclamation
ROD	Record of Decision
SHP	sustainable hydropower
SLCA/IP	Salt Lake City Area Integrated Projects
Western	Western Area Power Administration
WY	water year

Units of Measure

cfs	cubic feet per second
ft	feet
hr	hour
MW	megawatts
MWh	megawatt-hour(s)
pf	power factor
TAF	thousand acre-feet

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D.J. Graziano, L.A. Poch, T.D. Veselka, C.S. Palmer,* S. Loftin,* and B. Osiek*

Abstract

This report examines the financial implications of experimental flows conducted at the Glen Canyon Dam (GCD) in water year 2013. It is the fifth report in a series examining the financial implications of experimental flows conducted since the Record of Decision (ROD) was adopted in February 1997 (Reclamation 1996). A report released in January 2011 examined water years 1997 to 2005 (Veselka et al. 2011), a report released in August 2011 examined water years 2006 to 2010 (Poch et al. 2011), a report released June 2012 examined water year 2011 (Poch et al. 2012), and a report released April 2013 examined water year 2012 (Poch et al. 2013).

An experimental release may have either a positive or negative impact on the financial value of energy production. This study estimates the financial costs of experimental releases, identifies the main factors that contribute to these costs, and compares the interdependencies among these factors. An integrated set of tools was used to compute the financial impacts of the experimental releases by simulating the operation of the GCD under two scenarios, namely, (1) a baseline scenario that assumes both that operations comply with the ROD operating criteria and that the experimental releases actually took place during the study period, and (2) a "without experiments" scenario that is identical to the baseline scenario of operations that comply with the GCD ROD, except it assumes that experimental releases did not occur.

The Generation and Transmission Maximization (GTMax) model was the main simulation tool used to dispatch GCD and other hydropower plants that comprise the Salt Lake City Area Integrated Projects (SLCA/IP). Extensive data sets and historical information on SLCA/IP powerplant characteristics, hydrologic conditions, and Western Area Power Administration's (Western's) power purchase prices were used for the simulation. In addition to estimating the financial impact of experimental releases, the GTMax model was also used to gain insights into the interplay among ROD operating criteria, exceptions that were made to criteria to accommodate the experimental releases, and Western operating practices.

Experimental releases conducted in water year 2013 resulted in both positive and negative financial impacts, which totaled to a cost of about $1,918,000 for all experimental releases.

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1 Introduction

The Glen Canyon Dam's (GCD's) hydroelectric power plant, the Glen Canyon Powerplant (or the Powerplant), consists of eight generating units with a continuous operating capacity of 1,320 megawatts (MW) at unity power factor (pf). At the typical operating point of 0.99 pf, the capacity is slightly lower (Seitz 2004). Historically, the plant has operated at a 0.99 pf (Veselka et al. 2010). The Powerplant's electricity production serves the demand of 5.8 million consumers in 10 western states that are located in the Western Electricity Coordinating Council region of the North American Electric Reliability Corporation. Except for a minimum water release requirement at GCD, daily and hourly operations of the dam initially were restricted only by the physical limitations of the dam structures; the Powerplant; and its storage reservoir, Lake Powell. This approach—of adjusting the Powerplant's output principally in response to market price signals—often resulted in large fluctuations in the Powerplant's energy production and associated water releases.

Concerns about the impact of GCD operations on downstream ecosystems and endangered species, including those in Grand Canyon National Park, prompted the Bureau of Reclamation (Reclamation) to conduct a series of research releases from June 1990 to July 1991 as part of an environmental studies program. On the basis of an analysis of these releases, Reclamation imposed operational flow constraints on August 1, 1991 (Western 2010). These constraints were in effect until February 1997, when new operational rules and management goals specified in the Glen Canyon Dam Environmental Impact Statement (GCDEIS) Record of Decision (ROD) were adopted (Reclamation 1996). The ROD operational criteria limit the maximum and minimum amounts of water released from the dam during a one-hour period. The ROD criteria also constrain adjustments in water releases in consecutive hours and restrict the range of hourly releases on a rolling 24-hour basis.

The Glen Canyon Dam Adaptive Management Program, established by the GCDEIS ROD (Reclamation 1996), conducts scientific studies on the relationship between dam operations and downstream resources. Experimental water releases are performed periodically to monitor river conditions, conduct specific studies, enhance native fish habitat, and conserve fine sediment in the Colorado River corridor in Grand Canyon National Park.

Beginning in 1997, various types of experiments have been performed at GCD. The financial costs of experiments conducted from 1997 through 2005 were reported in the document, *Revised Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Years 1997 through 2005* (Veselka et al. 2011). The financial costs of experiments conducted from 2006 through 2010 were reported in the document, *Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Years 2006 through 2010* (Poch et al. 2011). The financial costs of experiments conducted in water year 2011 were reported in the document, *Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Year 2011* (Poch et al. 2012). The financial costs of experiments conducted in water year 2012 were reported in the document, *Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Year 2012* (Poch et al. 2013). Costs are assessed on the basis of a water year (WY). A WY is defined as a 12-month period from October 1 to September 30; for example, WY 2013 runs from October 1, 2012, to September 30, 2013.

This report discusses the financial costs of experiments in WY 2013. Two types of experiments were conducted in WY 2013, namely, (1) a fall steady flow (FSF), and (2) a high flow experiment (HFE). The fall steady flow experimental release is characterized by steady flows. In these experiments, release rates are set at a pre-defined rate of from 8,000 to more than 15,000 cubic feet per second (cfs). The pre-set release rates are set so that the same monthly volume of water is released as if no experiment occurred. The HFE can release a large amount of water. Water releases ramp up in a prescribed pattern and can exceed the Powerplant's maximum flow rate by up to 15,000 cfs for a specified number of hours during the release.

During normal operations, GCD is governed by stringent operating rules as specified in the ROD. Although these rules may have environmental benefits, they also have financial and economic effects on the value of the energy produced by the GCD Powerplant. These criteria reduce the flexibility of operations, diminish dispatchers' ability to respond to market price signals, and lower the economic and financial benefits of power production. Power benefits are affected by the ROD in two ways. First, the loss of operable capability must eventually be replaced by other power generation resources. Second, the hydropower energy cannot be used to its fullest extent during hours of peak electricity demand when the market price and economic benefits are relatively high.

During experimental releases, operational flexibility is essentially eliminated—water must be released according to a fixed and pre-specified schedule. Relative to the operational restrictions specified under the ROD, an experimental release may have either a positive or negative impact on the financial and economic value of GCD Powerplant energy production. The deviation in the value of power relative to ROD operations that can be directly attributed to an experimental release depends on several complex and interdependent factors. Work performed in this study estimates the financial costs of the experimental releases and identifies the main factors that contribute to these costs and the interdependencies among these factors.

Financial costs are estimated by Generation and Transmission Maximization (GTMax) model simulations of the Salt Lake City Area Integrated Projects (SLCA/IP). This tool uses an integrated systems modeling approach to dispatch power plants in the system while recognizing interactions among supply resources over time. Retrospective simulation for WY 2013 made use of extensive sets of data and historical information on SLCA/IP power plants' characteristics and hydrologic conditions and Western Area Power Administration's (Western's) power purchase prices. The GTMax model simulated two scenarios. The "Baseline" scenario assumes that operations comply with ROD operating criteria and experimental releases that actually took place, as documented by Western and Reclamation. The second scenario, "Without Experiments," is identical to the first one, except it assumes that experimental releases did not occur during the study period. Differences in the value of GCD energy production between the two scenarios are used to estimate the change in the value of power attributed to experimental releases. In addition to estimating the financial impact of experimental releases, the GTMax model was also used to gain insights into the interplay among ROD operating criteria, exceptions that are made to criteria to accommodate the experimental releases, and Western operating practices. Details on the methodology and data sources are fully explained in Section 4 of the report, *Revised Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Years 1997 through 2005* (Veselka et al. 2011).

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2 ROD Criteria and Western's Operating Practices

Important factors that explain the financial impacts of experimental releases include the following:

(1) ROD operating criteria,
(2) Exceptions to the ROD made to accommodate the experimental releases,
(3) Monthly and annual water release distribution of annual volumes, and
(4) Western's scheduling guidelines that were adapted in response to ROD restrictions.

This section provides background information on each of these factors.

2.1 ROD Operating Criteria and Exceptions

Operating criteria specified in the ROD are intended to temper water release variability. The criteria selected were based on the Modified Low Fluctuating Flow Alternative as described in the final GCDEIS. These criteria were put into practice by Western beginning in February 1997.

Flow restrictions under the ROD are shown in Table 2.1, along with operational limits in effect prior to June 1, 1991, for comparison. The ROD criteria require water release rates to be 8,000 cfs or greater between the hours of 7:00 a.m. and 7:00 p.m., and at least 5,000 cfs at night. The criteria also limit how quickly the release rate can increase and decrease in consecutive hours. The maximum hourly increase (i.e., the up-ramp rate) is 4,000 cfs/hour (hr), and the maximum hourly decrease (i.e., the down-ramp rate) is 1,500 cfs/hr. ROD operating criteria also restrict how much the releases can fluctuate during rolling 24-hour periods. This change constraint varies between 5,000 cfs and 8,000 cfs per day, depending on the monthly volume of water releases. Daily fluctuation is limited to 5,000 cfs in months when less than 600 thousand acre-feet (TAF) are released. The limit increases to 6,000 cfs when monthly release volumes are between 600 TAF and 800 TAF. When the monthly water release volume is 800 TAF or higher, the daily allowable fluctuation is 8,000 cfs.

The maximum flow rate is limited to 25,000 cfs under the ROD operating criteria. Maximum flow rate exceptions are allowed to avoid spills or flood releases during high runoff periods. Under very wet hydrological conditions, defined as when the average monthly release rate is greater than 25,000 cfs, the flow rate may be exceeded; however, water must be released at a constant rate. Exceptions to the operating criteria are also made to accommodate experimental releases. For the experiments discussed in this report, maximum flow rates above 25,000 cfs were allowed during the HFE conducted in November 2012.

Table 2.1: Operating Constraints Prior to 1991 and under the ROD (Post 1997)

Operational Constraint	Historic Flows (Pre 1991)	ROD Flows (Post 1997)
Minimum release (cfs)	3,000 during the summer 1,000 during the rest of the year	8,000 from 7:00 am–7:00 pm 5,000 at night
Maximum release (cfs)	31,500	25,000
Daily fluctuations (cfs/24 hr)	28,500 during the summer 30,500 during the rest of year	5,000; 6,000; or 8,000 depending on release volume[1]
Ramp rate (cfs/hr)	Unrestricted	4,000 up 1,500 down

[1] Limited to 5,000 cfs/day when monthly water release is less than 600 TAF; 6,000 cfs/day when monthly water release is 600 TAF to 800 TAF; and 8,000 cfs/day when monthly water release is greater than 800 TAF.
Source: Reclamation (1996).

Exceptions granted during some experimental releases can potentially increase the financial value of the GCD power resource relative to operations under ROD constraints. Scheduling guidelines adopted by Western's Energy Management and Marketing Office in Montrose, Colorado, can also influence the financial value. An experimental release yields higher financial value when power generation from a prescribed release is concentrated during periods when market prices are relatively high (and power is relatively expensive). This value may exceed the Without Experiments scenario because normal ROD operational criteria do not permit such high generation levels. In addition, experimental releases that are only a few days in length and have generation levels that are lower than the minimum value specified in the ROD during times of relatively low market prices (and relatively inexpensive power) may also yield higher financial value(s) than those found in the Without Experiments scenario. Releasing relatively small amounts of water during low-price hours allows for larger releases during higher-priced hours.

On the other hand, experimental releases that require high water flows during low-price hours typically yield financial values that are lower than those found in the Without Experiments scenario. The situation is exacerbated when an experimental release requires flow rates to exceed turbine capacity because water has to be released or spilled through bypass tubes, producing no energy. Spills also increase the tailwater elevation, thereby reducing the effective head and power conversion rates of water passing through the power plant's turbines.

2.2 Monthly Water Release Volumes

Monthly water releases in the Upper and Lower Colorado River Basin are set by Reclamation to be consistent with various operating rules and guidelines, acts, international water treaties, consumption use requirements, State agreements, and the "Law of the River" (Reclamation 2008a). In addition to power production, monthly release volumes are set considering other uses of the reservoirs, such as for flood control, river regulation, consumptive uses, water quality control, recreation, and fish and wildlife enhancement and to address other environmental factors.

Because future hydrologic conditions of the Colorado River Basin cannot be predicted with 100% accuracy, release decisions are made by using current runoff projections provided by the National Weather Service's Colorado Basin River Forecast Center. To be consistent with its annual operating plan, Reclamation adjusts its release decisions on a monthly basis to reflect projections made by rolling 24-month studies that are updated monthly.

For this study, historical SLCA/IP monthly water releases as recorded in Reclamation's Form PO&M-59 (Reclamation undated) were used for the Baseline scenario. These data were provided in a spreadsheet compiled by Western staff (Loftin 2014a). In addition, GCD hourly water release data obtained from Reclamation were used for experimental release periods.

To achieve flows required by some experiments, water might be reallocated among months from what it would have been had the experiments not occurred. The redistribution of monthly water releases made to accommodate an experimental release may either raise or lower the financial value of power produced by the GCD Powerplant. Water releases that were shifted to times of the year with higher power market prices, such as during July and August, tend to increase financial value. The opposite occurs when more water is shifted to months when power prices are lower.

A table with the monthly water releases and the elevations of the Lake Powell reservoir for each scenario during the study period is available in Appendix A of this report. The HFE conducted in November 2012 required water to be reallocated among months; specifically, flows were reduced in February and April (Loftin 2014b). This reallocation is seen in monthly water releases between the With (i.e., Baseline) and Without Experiments scenarios.

2.3 Montrose Scheduling Guidelines

The GCD restrictions shown in Table 2.1 describe operational boundaries; however, within these limitations are innumerable hourly release patterns and dispatch drivers that comply with a given set of operating criteria. Thus, although the operational range was significantly wider prior to the ROD, a wide range of ROD-compliant operational regimes still exists. But these operational constraints are not unique to the GCD: other SLCA/IP power plants must also comply with various operational limitations. For example, Flaming Gorge releases are patterned such that downstream flow rates are within Jensen Gauge flow limits. In addition, releases from the Wayne N. Aspinall Dams cannot result in reservoir elevations that are outside of (1) a specified range of forebay elevation levels, and (2) limits on changes in reservoir elevations over one- and three-day periods.

As operational constraints were imposed on SLCA/IP resources, including those at the GCD, power plant scheduling guidelines and goals shifted from a model driven primarily by market prices to a new model driven by customer loads. Within the boundaries of these operating constraints, SLCA/IP power resources are used to serve firm load. Western also places a high priority on purchasing power in 16-hour, on-peak blocks and 8-hour, off-peak blocks.

As illustrated in Figure 2.1, SLCA/IP generation resources are typically “stacked” on top of the block purchases as a means of following firm customer load. Because of operational limitations, Western staff may need either to purchase or sell varying amounts of energy on an hourly basis. The volumes of these variable market purchases are relatively small under the vast majority of conditions.

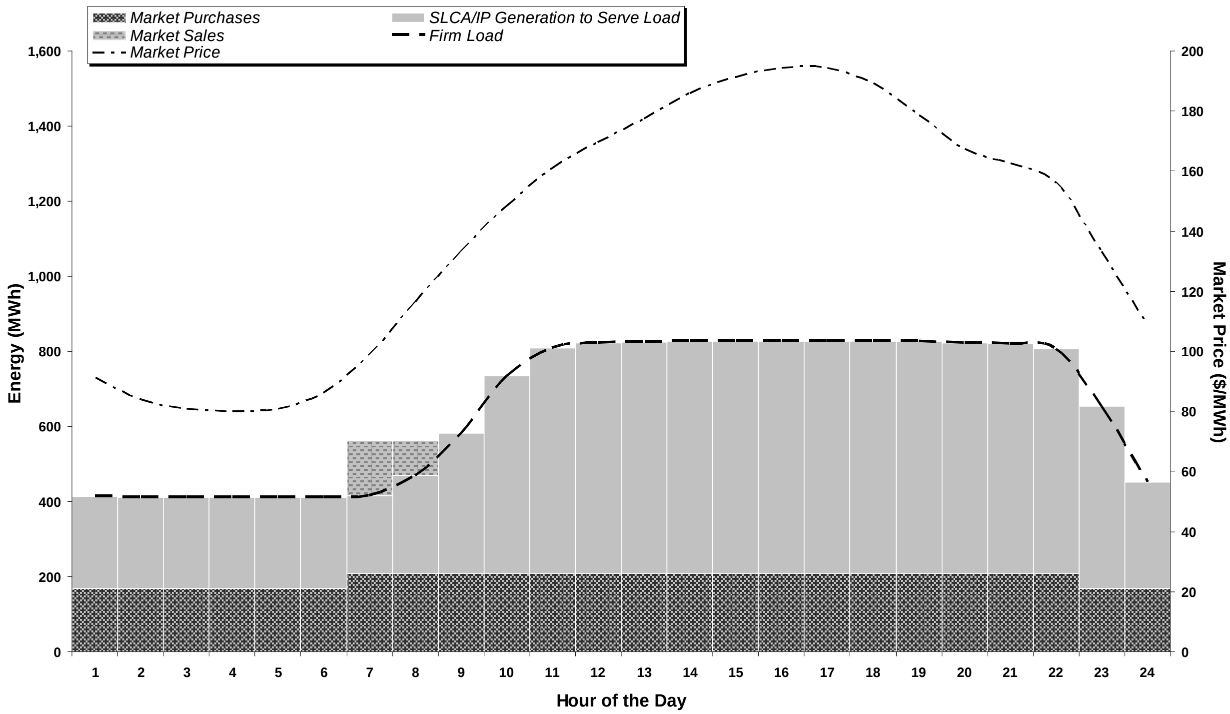

Figure 2.1: Illustration of the Firm-Load-Driven Dispatch Guideline under the 1996 ROD Operating Criteria When SLCA/IP Resources Are Short of Load

Market sales can be significant when SLCA/IP resources exceed firm load. Under load-following guidelines, excess hydropower generation is sold during hours with the highest price while complying with operational limits. On-peak sales are limited by maximum SLCA/IP generation levels that are constrained by limits on hourly ramp rates and daily change constraints. However, significant excess power generation rarely occurs, because projected power production in excess of sustainable hydropower (SHP) is sold to SLCA/IP customers on a short-term basis as available hydropower (AHP). SHP, which is based on an established risk level, is a fixed level of long-term capacity and energy available from SLCA/IP facilities during summer and winter seasons; this amount is the minimum commitment level for capacity that Western will provide to all SLCA/IP customers. AHP is the monthly capacity and energy that is actually available based on prevailing water release conditions; thus, it is the amount that Western offers to its customers above and beyond their SHP levels. These terms are explained in greater detail in Section 4.1 of Veselka et al. (2011).

The load-following scheduling objective facilitates a strong link between Western's contractual obligations and SLCA/IP operations, requiring dispatch among SLCA/IP power plants to be closely coordinated. This interdependency exists because loads and hydropower resources are balanced whenever feasible. Western is therefore able to affect SCLA/IP power plant operations and hourly reservoir releases indirectly via specifications in its contract amendments. Contract terms that indirectly affect power plant operations include SHP and AHP capacity and energy sales, as well as Minimum Schedule Requirement (MSR) specifications. The MSR is the minimum amount of energy that a customer must schedule from Western in each hour. The load-following dispatch philosophy minimizes scheduling problems and helps Western avoid noncompliant water releases.

In addition to load following, dispatchers follow other practices that are specific to GCD Powerplant operations. These practices fall within ROD operational boundaries but are not ROD requirements. Therefore, these institutional practices may be altered or abandoned by Western at any time. One practice involves reducing generation at Glen Canyon to the same minimum level every day during low-price, off-peak hours. Western also avoids drastic changes to total water volume releases when they occur over successive days. In this analysis, therefore, it was assumed that the same volume of water was released each weekday.

Another Western scheduling practice that was observed when examining water releases occurring on both Saturdays and Sundays is that weekend releases are generally not less than 85% of the average weekday release (Patno 2008). In addition, during the summer season, one cycle of raising and lowering GCD Powerplant output is recommended. This practice increases to a maximum of two cycles during other seasons of the year as dictated by the hourly load pattern.

Changes in Western's scheduling guidelines did not occur abruptly but subtly and over a period of months. These changes were not only the result of the operational constraints imposed by the ROD but also attributable to changing market conditions, such as persistent drought, electricity market disruptions in 2000 and 2001, and extended experimental releases that had large fluctuations in daily flow rate. Western found that by instituting load-following dispatch, it could better control its exposure and risk to market price fluctuations (Palmer 2010). New scheduling guidelines were implemented during WY 2001.

As in the case of operational constraints, the other SLCA/IP power plants (besides Glen Canyon) must also follow scheduling guidelines. For example, the Collbran Project's daily generation produced by the Upper and Lower Molina power plants is scheduled at or near power plant maximum capability for continuous blocks of time, the lengths of which are based on the amount of water that is available for release during a 24-hour period. Western also has scheduling guidelines for daily water releases from the Blue Mesa Reservoir. Water is released from Blue Mesa seven days a week to accommodate higher runoffs, except from November through February, when water is not released on Saturdays. The decision not to release water on

Saturdays was made for economic reasons so that more water could be released during higher-priced hours during the week.

3 Description of Experimental Releases

Two experimental releases were conducted during WY 2013: namely, a fall steady flow (FSF) that concluded in October 2012 and a high flow experiment (HFE) in November 2012. This section describes the experimental releases, their characteristics, and when they occurred. Table 3.1 summarizes the operational characteristics of the GCD Powerplant during the experimental releases, such as maximum and minimum flows, maximum daily fluctuation, and maximum and minimum ramp rates.

Table 3.1: Characteristics of GCD Powerplant Experimental Release Events, By Dates of Releases

Event	Date	Maximum Flow (cfs)	Minimum Flow (cfs)	Maximum Hourly Up-Ramp Rate (cfs/hr)	Maximum Hourly Down-Ramp Rate (cfs/hr)	Maximum Daily Fluctuation (cfs/day)	Water Reallocated within Year	Exception to ROD Criteria
FSF	9/1/2012–10/31/2012	8,869	7,409	680	670	1,150	No	No
HFE	11/18/2012–11/23/2012	43,565	7,087	2,081	2,232	33,663	Yes	Yes

3.1 Fall Steady Flow (FSF)

The purpose of initiating steady flows in the fall months of September and October is to create warmer water conditions to help young humpback chubs survive prior to the onset of winter. The FSF is also expected to create and improve the backwater rearing habitats of the humpback chub by increasing their spatial extent, promoting habitat stability, and improving habitat temperature and the availability of prey (Reclamation 2007). These flows began in September 2008 and were to continue for five years through September/October of 2012 (Reclamation 2008b). However, some fisheries' biologists recommend that Reclamation conduct steady flows during the summer months when the young chub first enter the main stem of the Colorado River from the tributary habitat where they hatch (Reese 2010).

The water release rate is determined such that the water volume released in a month is the same as what would have occurred in the absence of the experiment. The flow pattern for the FSF that occurred in WY 2013 is shown in Figure 3.1. The September/October 2012 FSF had a nominal constant flow of about 8,000 cfs, with a maximum flow of almost 8,900 cfs and a minimum flow of about 7,400 cfs.

It is of note that the FSF that occurred in the fall of 2012 spans two water years. Therefore, in terms of financial implications, it is the October portion of the 2012 FSF that is discussed in this report. The September 2012 portion of the FSF was discussed in the cost analysis report for WY 2012 (Poch et al. 2013).

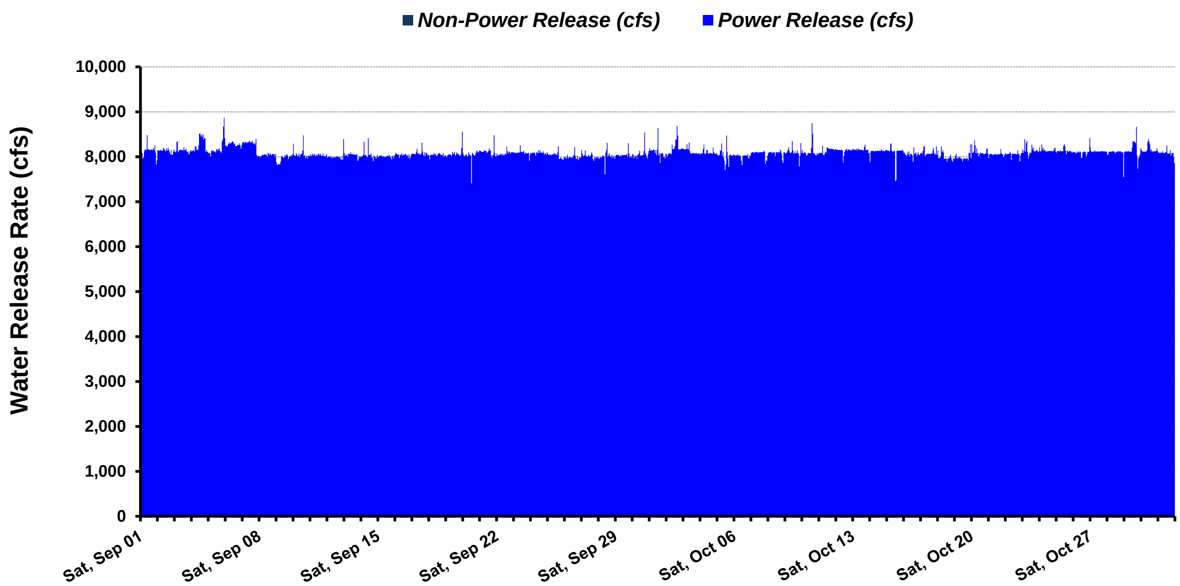

Figure 3.1: Release Pattern for the Fall Steady Flow Conducted in September/October 2012

3.2 High Flow Experiment (HFE)

The HFE that occurred in November 2012 was conducted per the 10-year (2011–2020) protocol for short-duration, high-volume controlled releases from GCD during sediment-enriched conditions (Reclamation 2011). The objective of this multi-year plan is to investigate how multiple events could be more effective in building sandbars and conserving sand over long periods. As a sediment conservation measure, HFEs rebuild sandbars and beaches; improve the riparian resources and protect archaeological resources by building up sandbars and redepositing sand at higher elevations; preserve and restore camping beaches; reduce near-shore vegetation; and rejuvenate backwaters, which can be important rearing habitat for native fish.

The November 2012 HFE ran from November 18 to 23. The total duration at high flow was 5 days, with 1 day at a nominal peak release of 43,600 cfs. The flow rate exceeded the capability of the turbines for 92 hours, with water released through the bypass tubes reaching 15,000 cfs. No electricity was generated by the water released through the bypass tubes. So that sufficient water was available to perform this experiment, water that would otherwise have been used in months after this experiment was redistributed for use during the HFE. Specifically, the redistribution for this HFE was imparted by reducing water releases in February and April of 2013 (Loftin 2014b). The flow pattern for the November 2012 HFE is shown graphically in Figure 3.2.

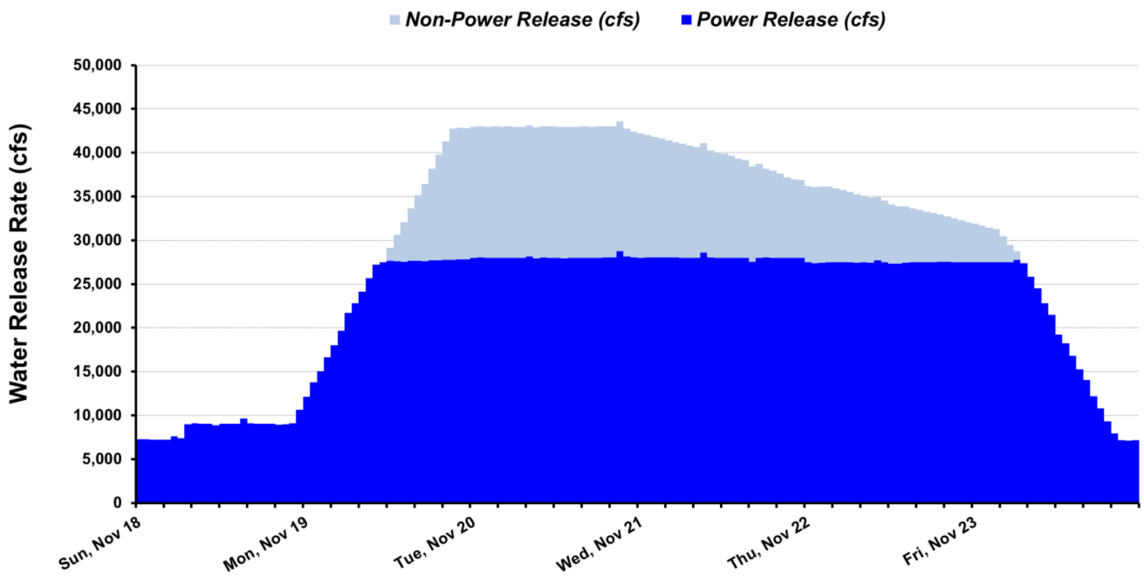

Figure 3.2: Release Pattern of the High Flow Experiment Conducted in November 2012

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4 Methods and Models

Financial impacts are computed as the difference in the values of GCD energy production between two simulated operating scenarios, as follows:

(1) The **Baseline scenario,** which assumes ROD operating criteria, the occurrence of experimental releases, exceptions to the ROD criteria to accommodate the experimental releases, and historical monthly release volumes; and

(2) The **Without Experiments scenario,** which assumes ROD operating criteria without exceptions, that no experimental releases took place, and monthly release volumes that may differ from historical levels.

The GTMax model is the main simulation tool used to dispatch SCLA/IP hydropower plants, including Glen Canyon. It not only simulates Glen Canyon operations, but it also provides insights into the interplay among the following: the ROD operating criteria, exceptions to the criteria to accommodate experimental releases, modifications to monthly water volumes, and Western's scheduling guidelines and goals. The GTMax model is supported by several other tools and databases. These support tools include: the SLCA/IP Contracts spreadsheet, Customer Scheduling algorithm, Market Price spreadsheet, Experimental Release spreadsheet, and a Financial Value Calculation spreadsheet.

The GTMax model is supported by an input spreadsheet that contains ROD operating criteria, historical hydropower operations data, and parameters for Western scheduling guidelines. The input spreadsheet also performs various computations and prepares input data for the model. GTMax results are transferred to another spreadsheet to summarize simulation results, perform cost calculations, extrapolate weekly results to a monthly total, and produce a variety of tables and graphs.

The methods, models, and data used in this analysis were discussed in detail in Section 4 of the earlier report, *Revised Financial Analysis of Experimental Releases Conducted at Glen Canyon Dam during Water Years 1997 through 2005* (Veselka et al. 2011). It is of note that the experiments conducted in WY 2013 required both exceptions to ROD criteria and modifications to monthly water releases when compared to the Without Experiments scenario.

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5 Cost of Experiments in WY 2013

This year had two types of experiments: namely, the second month of an FSF in October 2012 and an HFE in November 2012. The FSF in October 2012 had a nominal steady flow of 8,000 cfs, and the HFE in November 2012 had a peak flow of 43,600 cfs. The HFE in November 2012 required reallocation of water in the months of February and April in 2013.

Figure 5.1 shows the monthly water releases in WY 2013. The amounts of water released in the Baseline and Without Experiment scenarios differed in the months of November, February, and April. For November, water releases were higher in the Baseline scenario to accommodate the HFE. This higher water release was balanced with lower releases in February and April.

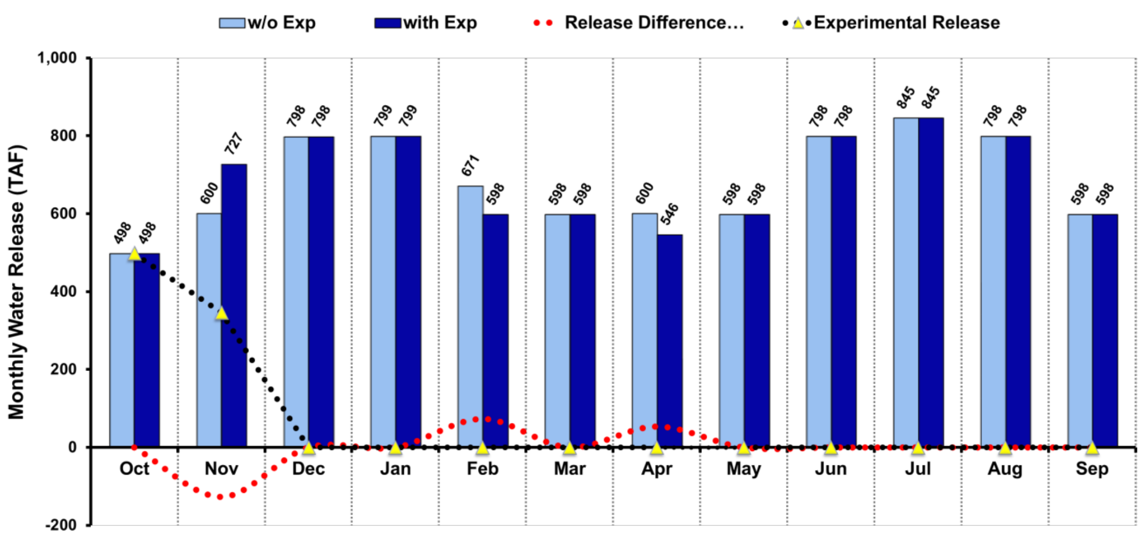

Figure 5.1: Monthly Water Releases in WY 2013

Figure 5.2 shows the costs associated with both the FSF and HFE that occurred in WY 2013. This figure also shows the monthly price spread between the on- and off-peak electricity prices Western paid to purchase AHP. The monthly on- and off-peak prices during WY 2013 are shown in Appendix B.

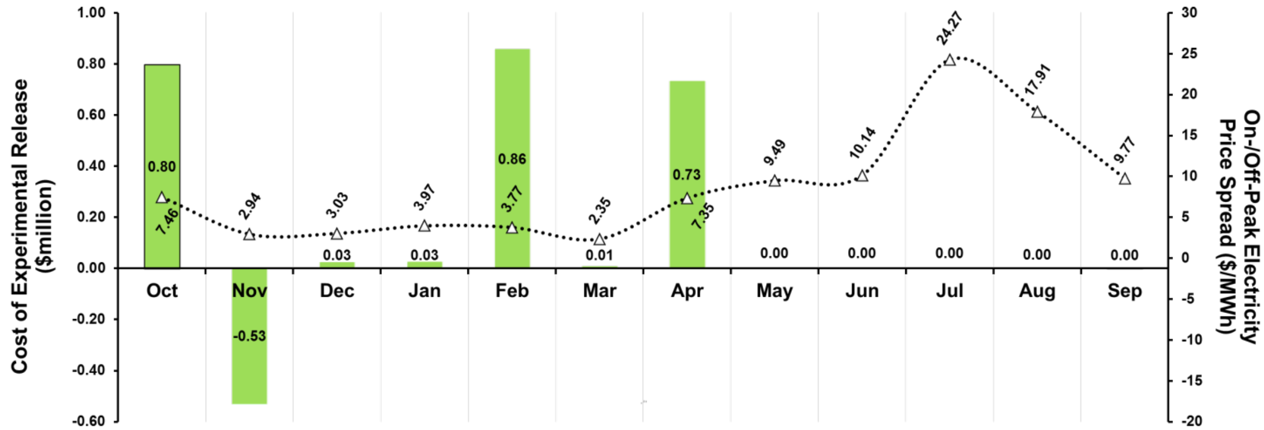

Figure 5.2: Cost of Experimental Releases in WY 2013

The FSF resulted in a cost of about $797,000. With steady flows the entire month of October, Western was unable to allocate water throughout the day to take advantage of the price spread between on- and off-peak hours, and hence incurred a financial loss.

The financial implications of the HFE occurred over several months, with a financial gain in November of about $529,000 and a financial loss in December through April of about $1,650,000, for a net cost of about $1,121,000. The financial gain in November resulted from the higher water released to accommodate the HFE. This gain, however, was tempered by costs incurred when water, totaling over 78 TAF, was spilled without generating power and associated income.

The largest financial losses from the HFE occurred in February (about $857,000) and April (about $733,000) because water was reallocated from these months to November. Although water releases in the months of December, January, and March were the same for both scenarios, these months had a combined financial loss of about $61,000. This loss was due to the difference in Lake Powell's elevation in the two scenarios as shown in Figure 5.3. The large HFE release in November lowered Lake Powell's forebay elevation, which reduced the GCD Powerplant's power conversion factor. Therefore, less energy is produced in the Baseline scenario for each unit of water passing through the turbines than is produced in the Without Experiments scenario, resulting in a cost of the experiments to Western.

The FSF and HFE conducted in WY 2013 had a combined annual cost of $1,918,000. The total cost of the FSF that occurred in fall 2012 was $992,000. This estimate is the sum of the cost in September 2012 (which was $195,000 [Poch et al. 2013]), which occurred in the previous water year (WY 2012), and the $797,000 cost incurred October 2012 (counted as part of WY 2013).

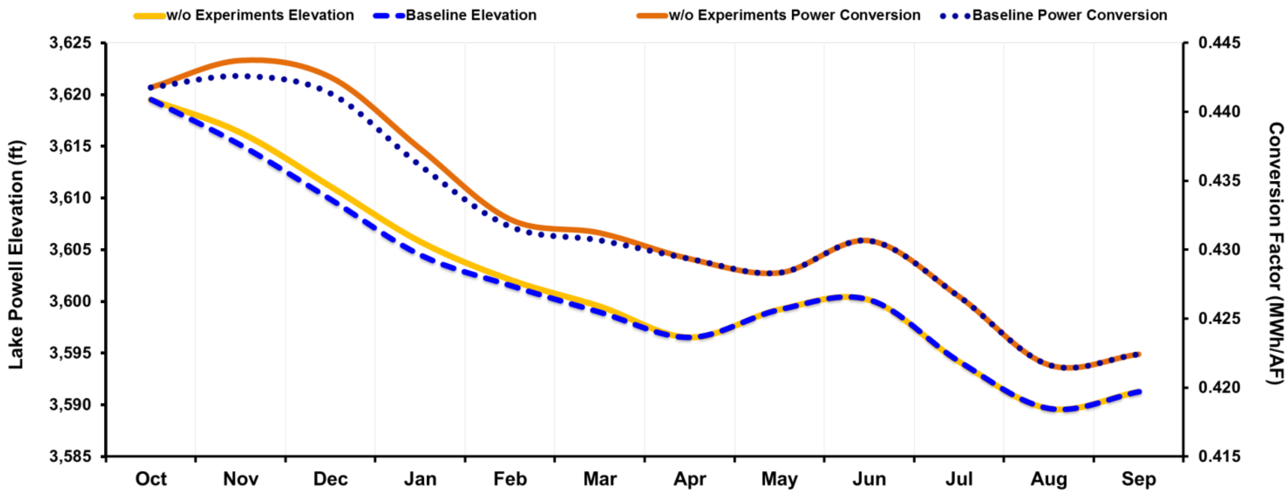

Figure 5.3: Comparison of Lake Powell Elevations and Power Conversion Factors in WY 2013

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Appendix A: Glen Canyon Dam Monthly Water Releases and Reservoir Elevations by Scenario during Water Year 2013

Table A.1 shows the monthly water releases and end-of-month elevations of Lake Powell by scenario during the study period.

Table A.1: Water Releases and Lake Powell Elevation by Scenario and Month in WY 2013

		Baseline (With Experiments)		Without Experiments	
Calendar Year	Month	Water Release (thousand acre-feet [TAF])	Lake Powell Elevation (feet [ft])	Water Release (TAF)	Lake Powell Elevation (ft)
2012	Oct.	498.1	3,619.5	498.1	3,619.5
2012	Nov.	727.0	3,615.1	600.0	3,616.3
2012	Dec.	797.7	3,609.9	797.7	3,611.1
2013	Jan.	798.7	3,604.5	798.7	3,605.8
2013	Feb.	598.1	3,601.5	671.5	3,602.1
2013	Mar.	597.8	3,598.9	597.8	3,599.5
2013	Apr.	546.3	3,596.5	600.0	3,596.5
2013	May	597.8	3,599.2	597.8	3,599.2
2013	June	797.8	3,600.1	797.8	3,600.1
2013	July	845.4	3,594.2	845.4	3,594.2
2013	Aug.	798.3	3,589.6	798.3	3,589.6
2013	Sept.	598.1	3,591.3	598.1	3,591.3

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Appendix B: Monthly On- and Off-Peak Electricity Prices in Water Year 2013

Table B.1 shows the weighted average monthly on- and off-peak electricity prices that Western paid to purchase available hydropower energy during the study period. Prices are based on total purchases in terms of dollars and megawatt-hours (MWh).

Table B.1: Weighted Average Monthly On- and Off-Peak Electricity Prices for Water Year 2013

Calendar Year	Month	Off-Peak ($/MWh)	On-Peak ($/MWh)	Experiment Conducted
2012	Oct.	24.64	32.11	Fall Steady Flow (FSF)
2012	Nov.	28.52	31.46	High Flow Experiment (HFE)
2012	Dec.	27.62	30.65	
2013	Jan.	27.00	30.97	
2013	Feb.	26.78	30.54	
2013	Mar.	30.50	32.86	
2013	Apr.	29.11	36.46	
2013	May	28.71	38.20	
2013	June	21.86	32.00	
2013	July	21.86	46.13	
2013	Aug.	28.15	46.06	
2013	Sept.	30.15	39.92	

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