A Natural Experiment in Reservoir Levels and Recreational Use: Modeling Visitation on Lake Mead and Lake Powell

Chris J. Neher[A,C], John W. Duffield[A], David A. Patterson[A]

[A]Department of Mathematical Sciences, University of Montana, Missoula, MT 59812,USA.

[C] Corresponding author. Email: bioecon@montana.com

Abstract

The Colorado River is one of the most highly developed watersheds in the United States and has relatively unique long term data sets for both recreational visitation and water levels on the two largest reservoirs in the United States—Lake Mead and Lake Powell. Previous efforts to model the relationship of recreation and reservoir water levels have primarily relied on survey-based estimates of visitor response to past actual or future hypothetical water levels. We provide the first major reservoir-recreation study based entirely on long-term observed data that also includes observed economic impacts. Models of volume and visitation had significant estimated parameters for lake volume explanatory variables and an R^2 of 0.97 for the Lake Powell model and 0.71 for Lake Mead. These models predict that 1,000 additional acre feet of water over a year are associated with 53 additional recreational visits to Lake Powell and 135 visits to Lake Mead. A second model of Lake Powell volume and local-area tourist spending also had a highly significant volume parameter and had an R^2 of 0.83 and predicts that a 1,000 acre foot increase in Lake Powell volume over a year is associated with $5,346 in additional visitor spending in tourism-related sectors in Coconino County, AZ. The Lake Powell volume-visitation and volume-spending models imply the average visitor to Lake Powell spends $102 in lodging, restaurant and bar, and amusement/recreation sectors in Coconino County. This estimate is consistent with independent estimates of visitor spending derived from prior National Park Service (NPS) visitor surveys.

Key words: Lake Powell, Recreational use, Reservoir levels, Visitor spending, National Park Service

Suggested Running Head: Colorado River Reservoir Levels and Recreational Use

This article presents the case study results of time-series models of Lake Powell and Lake Mead recreational visitation and visitor spending as a function of reservoir volume based on monthly data. The article makes 3 specific contributions to the literature. First, in the use of long-term visitation and water level data using month-level time steps to specifically identify season-level volume-visitation relationships. Second in directly modeling a reservoir volume-economic activity relationship using observed water volume and local area tax data. A final contribution lies in presenting 2 methods of model validation using both within-sample and out-of-sample prediction to assess the predictive power of the estimated models.

Reservoirs serve as popular recreational destinations throughout the U.S., providing recreational activities from swimming and boating to fishing and picnicking. Management decisions related to reservoir levels can have a large impact on the attractiveness of a water body for recreation, and predicted effects on water-based recreation are often considered in federal and state agency decisions related to reservoir management (Platt and Munger 1999). Reservoirs on the Colorado River, including Lake Powell and Lake Mead, receive millions of visitors every year, most attracted to water-based recreational activities. In recent years, however, a combination of low precipitation years and downstream water delivery obligations has led to reservoir levels at Powell and Mead significantly below historic levels. In the same period of declining reservoir levels, recreational visitation to the 2 National Park Service (NPS) National Recreation Areas (NRA) associated with the reservoirs (Lake Mead NRA, and Glen Canyon NRA for Lake Powell) has also been generally declining. This article explores the statistical relationship between water levels and recreational use at these 2 Colorado River reservoirs.

Many site-specific estimates of the relationship between recreational use and water levels within the literature are based on original visitor survey data (for example Bergstrom et al. 1996, Cameron et al. 1996, and Allen et al. 1996). User surveys have the advantage of flexibility of design, allowing researchers to estimate changes in both participation levels and trip quality associated with changing water levels (Duffield et al. 1992). Survey administration is, however, costly and time consuming. Additionally, survey-based models relating water levels to recreation are often based on stated preference responses to hypothetical or past water levels, alone or in combination with short-term actual visitation and water level data (Cameron et al. 1996). Eiswerth, Englin, and others (2000) used a repeat-contact mail survey of resource users to estimate recreation values for preventing a decline in water levels at a large western lake (Walker Lake, in NV) that was drying up. In contrast to most of the literature, Huszar and others (1999) did not directly survey visitors, but used detailed data collected over a 17 year period by resource managers on reservoir visitor numbers and visitor residency to develop and estimate a joint model of fish catch and recreation demand, both of which depend on water levels, to assess the losses and gains from water-level changes tied to events in the Humboldt River Basin of northern Nevada.

There is a generally assumed direct relationship between reservoir levels and recreational use levels (Cordell and Bergstrom 1993; Hanson et al. 2002; Daugherty et al. 2011). Within the Colorado River Basin, Booker and Colby (1995) noted that use of reservoirs is assumed to be a declining function of reservoir area or volume. In another study of reservoir levels in the southwestern U.S., Ward and Fiore (1987) estimated changes in visitation across New Mexico reservoir sites as a function of the square root of reservoir area.

Platt and Munger (1999) authored a report for the Bureau of Reclamation (BOR) reviewing a series of methods for evaluating the effect of changing reservoir water elevations on recreation use and value. Included in this review were suggestions for models based on observed visitation and lake level data. In a follow-on BOR study, Platt (2001) presented a series of use-estimation models developed to address recreational impacts from fluctuating water levels at two Kansas reservoirs using available visitation and water level data. The analysis included models of both water-based recreational activities such as boating, fishing, and swimming, and water-associated activities such as picnicking at reservoir sites.

This article utilizes a general structure for models to estimate monthly use suggested by Platt and Munger (1999). This modeling structure is applied to the case of 2 high-profile western reservoirs. The analysis uses monthly water volume and recreational use data to fit linear regression models and to assess the predictive power of the fitted models. Additionally, the study uses local area monthly tax data and reservoir levels to estimate a linear model explaining changes in tax receipts (visitor spending) as a function of varying reservoir levels. This use of previously collected water level, recreational use, and tax data allows for the efficient estimation of marginal effects of alternative reservoir levels on both reservoir visitation and visitor spending.

Study Sites

As noted, this analysis examines 2 national recreation areas administered by the National Park Service, Glen Canyon NRA (Lake Powell) and, 277 miles downstream, Lake Mead NRA. Since the relationships estimated in this paper are specific to changing reservoir levels and associated recreational use levels, where appropriate, NPS visitation data has been disaggregated to isolate only recreational visitation specific to the target reservoir areas (upstream of Glen Canyon Dam (for Lake Powell) and Hoover Dam (for Lake Mead)).

Lake Powell is the second largest man-made reservoir in the US, behind Lake Mead. On average, it stores about 16 million acre-feet of water, with a maximum capacity of about 27 million acre-feet. It covers about 13 percent of Glen Canyon National Recreation Area (NRA), or about 162,500 acres (254 square miles). The dam that holds it back, Glen Canyon Dam, was completed in 1963, though the lake did not fill completely until 1980. It is 720 feet high and the hydroelectric power plant within the dam has 1.296 gigawatts of generating capacity.

The Glen Canyon NRA was established by Congress in 1972, and is run by the National Park Service (NPS). It covers 1.25 million acres (or 1,953 square miles). In 2011 Glen Canyon NRA received 2.27 million recreational visits (NPS 2012). Approximately 175,000 visits were to the Colorado River downstream of Glen Canyon Dam and the remaining 2.08 million visits were to the Lake Powell Area upstream of the dam.

Located on the Arizona-Nevada State line, Lake Mead is the largest man-made reservoir in the United States. At 1,221 feet above sea level, Lake Mead has the ability to store over 28 million acre-feet of water. The reservoir covers 158,500 acres (248 square miles) or about 10 percent of the Lake Mead National Recreation Area (NRA). Lake Mead reaches 112 miles up the Colorado River and when full creates 550 miles of shoreline. Hoover Dam, which creates Lake Mead, was first named Boulder Dam, and then later renamed in 1947. The Boulder Canyon Project-Hoover Dam was completed in 1935 and was the first dam on the Colorado River. Hoover Dam is 726 feet high and 1,224 feet long at the crest. The hydroelectric power plant at Hoover Dam has 2.079 gigawatts of generating capacity and provides energy to a wide geographical area in the Southwest.

In 1964, Congress established the first and largest National Recreational Area, Lake Mead. It is administered by the National Park Service (NPS). The Lake Mead NRA covers 1.49 million acres (or 2,337 square miles) and also includes the smaller reservoir Lake Mohave. With year-round visitation, it received over 5 million recreational visits in 2011 (NPS 2012).

While Lakes Mead and Powell are located on the same river, and share many characteristics, there are key differences in the reservoirs and the recreational visitation they receive. Lake Powell at 3700 feet above sea level has a full pool elevation fully 2,500 feet above that of Lake Mead (Table 1). Accordingly, the mean daily high temperature for Lake Powell is 8 degrees cooler than for Lake Mead. These elevation and climatological differences also manifest themselves in the distribution of recreational reservoir use throughout the year. While the higher, cooler Lake Powell receives over half of its annual use in the summer months of June, July and August, Lake Mead receives only 30% of its use in these 3 months (Table 1; Figure 1). Equally importantly, Lake Mead is much closer to a large population center, Las Vegas. A greater share of visits to Lake Mead are one-day trips, and the proximity to Las Vegas also leads to a more stable use level over the year, while use at the colder, more remote, Lake Powell is more concentrated in the summer and shoulder seasons.

Lake Visitation and Visitor Expenditure Model Methods

The statistical relationship between recreational visitation levels and reservoir volume at the 2 Colorado River reservoirs was modeled through linear regression of time series data on lake use and water volume. The time-step modeled was monthly data, and the period examined was 1996-2011. In order to estimate participation effect functions for recreational use associated with the reservoirs, two primary data series are necessary: data on recreational visitation, and corresponding data on reservoir water levels. Recreational visitation data for the modeling came from NPS visitation statistics (NPS 2012). Water level data was drawn from Reclamation historical data (USBR 2012).

The volume-participation regression model uses time of year and reservoir volume to explain observed variation in recreational visitation. The base linear model was:

$$\hat{Y}_{\mathrm{i}} = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_K x_{iK} + e_i \qquad (1)$$

Where $\hat{Y}_i$ is estimated recreational visitation for month i, $x_{i1}, \ldots, x_{iK}$ are the time of year and reservoir volume for month i, $\beta_0, \beta_1, \ldots, \beta_K$ are unknown parameters ($K < N$) and the error terms, $e_1, \ldots, e_N$, are assumed to be independent $\mathrm{N}(0, \sigma_i^2)$.

Scatterplots of monthly visitation by average monthly reservoir contents were initially examined for indications of the functional form for the volume-visitation relationship at each reservoir. In the case of Lake Powell, the plot showed three distinct horizontal bands of data points (Figure 2). Examination of the underlying data showed the observations within the bands were divided into winter month observations (November-March) in the lowest band, shoulder month (April, May, September, and October) observations in the middle band, and summer month (June-August) observations in the upper band.

The Powell volume-visitation plot (Figure 2) also shows simple linear trendlines for the 3 horizontal data bands which suggest that summer visitation is more responsive to changing reservoir levels than shoulder season or winter season visitation. Based on this result, the model for Lake Powell was estimated by regressing monthly recreational visitation on indicator variables for the months March through November, average monthly reservoir volume (af), and interaction terms for volume in the core summer months (June-August) and in the shoulder season (April, May, September, and October). Table 2 shows the explanatory variables used and associated descriptive statistics.

In the case of Lake Powell, separate models were estimated for data from 1996-2006, and from 1996-2011 to check for stability in the estimated parameters. Additionally, the 1996-2006 model was used to predict out-of-sample visitation for the period 2007-2011, and these predictions were compared to actual observed visitation levels.

The volume-visitation plot for Lake Mead (1996-2011) is shown in Figure 3 along with a linear trendline. In the case of Mead, there is no obvious separation of seasonal use-volume relationships, as in the Powell plot. This result is consistent with Lake Mead visitation being much more evenly distributed across the year than in the case of Powell. For Lake Mead, monthly (1996-2011) recreational visitation was also regressed on month indicator variables (March through November), monthly volume, and summer and shoulder season interaction terms.

The Lake Powell volume-expenditure model uses time of year and volume along with explanatory variables for an annual trend and monthly unemployment rate (as a measure of general economic vitality) to explain observed variation in monthly gross sales in Coconino County, AZ for several key tourism-related sectors. The functional form of the estimated expenditure-volume relationship is identical to that specified in Equation 1, where $\hat{Y}_i$ is estimated visitor spending for month i, $x_{i1}, \ldots, x_{iK}$ are the time of year, reservoir volume, annual trend, and national unemployment rate for month i, $\beta_0, \beta_1, \ldots, \beta_K$ are unknown parameters ($K < N$) and the error terms, $e_1, \ldots, e_N$, are assumed to be independent $N(0, \sigma_i^2)$.

Results

Estimated Lake Visitation Model

Table 3 reports the estimated parameters for two linear regression models explaining Lake Powell monthly recreational visitation as a function of reservoir volume and monthly indicator and interaction variables. The models here utilize lake volume as the primary explanatory variable. Models were also estimated on lake elevation, with similar results. The advantage of modeling based on volume is that results are denominated in acre feet units, which is most convenient for policy and management applications. The estimated R^2 statistics show the Lake Powell models as specified explain approximately 97% to 99% of the variation in observed visitation. Models for the 1996-2006 period and the 1996-2011 period are shown to demonstrate the stability of the VOLUME parameters over time periods. All parameters in the two models remained significant in the extended dataset, and parameter values remained highly stable, and all variables have the expected sign. The key variables and coefficients for explaining the relationship between changing lake levels and changing visitation are the VOLUME, SUMMER*VOLUME interaction, and SHOULDER*VOLUME interaction variables. The interpretation of these coefficients is as follows. The coefficient on "Lake Powell Volume" (0.00116) indicates that throughout the year there is a positive statistically significant relationship between water volume and visitation. This coefficient indicates that for every 1000 af of additional water volume in Lake Powell there are an associated 1.16 additional recreational visits per month to the reservoir (Table 4).

The other water level variables, "summer-volume interaction" representing levels in the June-August months, and "shoulder-volume interaction" representing levels in April and May and September and October, are highly statistically significant (at the 99% level of confidence). The "shoulder-volume interaction" coefficient indicates that during the four "shoulder season" months 1,000 acre feet of storage is associated with an additional 3.0 visits per month. This effect is additive to the baseline effect relationship indicated by the VOLUME coefficient. The "summer interaction" coefficient shows that during the June through August period an additional 1,000 acre feet of Lake Powell storage is associated with an additional 8.95 recreational visitors per month (Table 4).

Overall, the Lake Powell model provides a statistically significant estimate of the marginal impact of varying lake levels on visits. As would be generally expected, the greatest impact is found in the high-use summer months. The shoulder season showed the next largest marginal impact and the winter-season a smaller marginal impact (Table 4). Within the range of data used in the explanatory model, it is predicted that an additional 1,000 acre feet of water in Lake Powell over an entire year would be associated with an increase in recreational visitation to Glen Canyon NRA of 54.5 visits.

In addition to the variables reported in Table 2, additional variables were modeled including monthly regional gasoline prices, and indicator variables for critical lake levels which impact visitor use (such as the lake level at which the Lake Powell "Castle Rock Cut" becomes passable or the level at which the Hite Marina access (now closed) was accessible). While models including only reservoir volume or only a critical-level indicator variable were individually significant, models including both variables were not. The two models can be viewed as alternative ways of modeling use. The model presented in Table 3 describes marginal changes in visitation throughout the full range of observed lake levels, while a model including only indicator variables for the critical lake levels describes a step function showing only two water level-dependent levels of visitation. The continuous model had more explanatory power, and general applicability. The additional variable, regional fuel price, was not statistically significant.

As noted, the observed volume-visitation plot for Lake Mead suggested that separate summer season and shoulder season relationships were not present in the data (as was the case for the Lake Powell observations). A specification for Lake Mead which included summer and shoulder season interaction terms showed the interaction terms were not statistically significant while the simple volume term was highly statistically significant (Table 3). A reduced specification of the Lake Mead model without the interaction terms showed a stable and significant volume term. This Lake Mead reduced model implies that an additional 1,000 acre feet of volume is associated with 11.25 additional recreational visits per month, or 135 visits over the entire year (Table 4).

Estimated Visitation Model Predictive Power

Two tests of the predictive power of the estimated volume-participation models were conducted. For both the Lake Powell and Lake Mead models, observed monthly recreational visitation was compared to the 95% prediction intervals for the individual monthly data points. For Lake Powell, only 5 of the 192 observations fell outside the 95% prediction interval. In the case of the Lake Mead model, 9 of 192 observations fell outside the prediction interval. A second predictive test, an out-of-sample test, was applied to the Lake Powell model. The model was estimated on only 2/3 of the available data (1996-2006) and this model was used to predict visitation using observed 2007-2011 reservoir levels. In 11 of the 60 out-of-sample months (18.3% of observations) the model predicted recreational use levels outside the 95% prediction interval. Figure 4 shows a plot of observed recreational visitation and out-of-sample predictions for 2007-2011. The variation in visitation levels across months in Figure 4 is dominated by seasonally driven changes in visits. Figure 5 shows an example of predictions vs. observations for the aggregated summer months (June-August). This figure is controlled for seasonal variation and thus all predicted changes in visitation in the graph are driven by changes in average lake volume for the three months. Clearly, the model predictions track closely to actual observed participation levels both within and out-of-sample.

Model of Lake Level Economic Impacts

Changes in recreational visitation to lakes and reservoirs do not occur in a social and economic vacuum in that they may have significant regional economic impacts. Visitors to lakes and reservoirs within National Park Service units spend money within the local economy which drives park-related effects on gateway communities (Stynes et al. 2000). Prior work on this issue has been largely based on survey methods used to measure visitor expenditures. We introduce to the literature an estimate of economic impact based on a direct link of water levels and visitor spending as measured through taxes on tourism-related spending.

The economic impact of varying Lake Powell water levels was estimated by comparing monthly gross tourism-related sales (Bradford 2012) reported in Coconino County, AZ from January 1997 to December 2011 (2011 $) to average monthly Lake Powell storage. Amusement, restaurant and bar, and hotel/motel sales as reported by the county from tax receipts were aggregated for this analysis. Table 5 shows the explanatory variables used in the regression. The regression results are shown in Table 6. The results show a highly significant estimated coefficient on Lake Powell Volume implying 1,000 acre foot increase in storage in Lake Powell leads to an increase in Coconino County sales of $447 (2011 $) per month, or $5,364 per year. The model further shows highly significant summer and shoulder season effects, a significant positive annual trend, and an expected negative (and highly significant) effect of the average monthly unemployment rate on gross sales. The model has an R^2 of 0.83. Figure 6 shows a scatter plot of observed and predicted Coconino County gross sales.

At the margin, a 1,000 acre foot increase in Lake Powell water levels would lead to an increase in recreational visitation to Lake Powell by 52.8 visits (Table 4). Based on the Table 6 model results, a 1,000 af increase over a year in Lake Powell would be associated with an additional $5,364 spent in Coconino County, AZ on lodging, restaurant and bar, and amusement and recreation spending. These models imply that an average visitor to Lake Powell spends $101.59 in these spending categories within Coconino County. In 2007 the NPS Visitor Services Program (Holmes et al. 2008) surveyed Glen Canyon NRA visitors. This study estimated that spring visitors spend about $102 (2011 $) per visitor for lodging, restaurant and bar, and recreation or amusement, and summer visitors spend an average of $118 in these categories. While the NPS survey estimate of $102-$118 per visitor included some spending that might occur outside of Coconino County, AZ, it was consistent with the lake-level model estimate of $102 per visitor spending.

Conclusions

Estimating the marginal impacts—both recreational and economic—of changing reservoir levels is more than an academic exercise. Agencies such as Bureau of Reclamation and Army Corps of Engineers have played a large role in dam building in the U.S., and routinely consider effects on recreation in reservoir management decisions (see for example Platt and Munger 1999, and Allen et al. 2010). Given that it is costly and sometimes infeasible given time constraints to conduct original visitor survey research for every reservoir management decision, the ability to obtain robust estimates of recreational impacts from data already collected and organized provides managers with an additional tool for analysis and decision making. Additionally, since our revealed preference models are based entirely on long-term observed data, they may have greater credibility with managers. A limitation of visitor survey data is that there may be non-response bias, given the impossibility of obtaining 100% response rates. Surveys are often also administered over a relatively short time period (weeks or months) and may not be entirely representative of a full year or of the long term.

The combination of Reclamation-managed reservoirs and Park Service-administered recreation areas provides a data-rich opportunity to estimate models of marginal effects of changing water levels in the cases of Lake Powell and Lake Mead. The BOR maintains daily data on reservoir contents and the NPS reports detailed monthly visitation estimates. All of this data is readily available online (USBR 2012, NPS 2012). The case studies of Lake Powell and Lake Mead were made even more interesting by large variation in reservoir levels over recent years. The combination of these factors facilitated the estimation of highly explanatory and statistically robust models of both recreational visitation and visitor spending as a function of reservoir levels at these the two largest man-made reservoirs in the U.S.

This analysis is presented as a case study demonstration of the feasibility of using existing data to estimate water level-participation models, or even water level-visitor expenditure models. The estimates presented in this article perform well in terms of statistical significance, both in and out-of-sample predictive power, as well as in terms of consistency with independent estimates derived from visitor surveys. These results provide encouragement for expanding and employing this method of analysis at other sites with similar data availability. The Colorado River corridor itself has a number of similar sites. Any site with consistent time series data associated with water levels and visitation or local-area tourism-related spending is a potential candidate. Where data allows, the models provide an extremely efficient alternative to costly and time-consuming visitor surveys for estimating key water level-related parameters.

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Table 1. Comparison of Characteristics of Lake Powell and Lake Mead.

Variable	Lake Powell	Lake Mead
Full Pool Elevation (feet above sea level)	3,700 ft.	1,229 ft.
Total 2011 Recreational Visits (reservoir areas above dams)	2,081,330	5,022,817
Average Annual Daily High Temperature	70.0 F. (Page, AZ)	77.8 F. (Boulder City, NV)
Percent of Annual Recreational Visits occurring in July	21.3%	9.3%
Percent of Annual Recreational Visits occurring in June-August	52%	30%
Percent of Annual Recreational Visits occurring in April-October	88%	68%

Figure 1. Monthly percentages of Lake Powell and Lake Mead National Recreation Areas 2011 Recreational Visitation

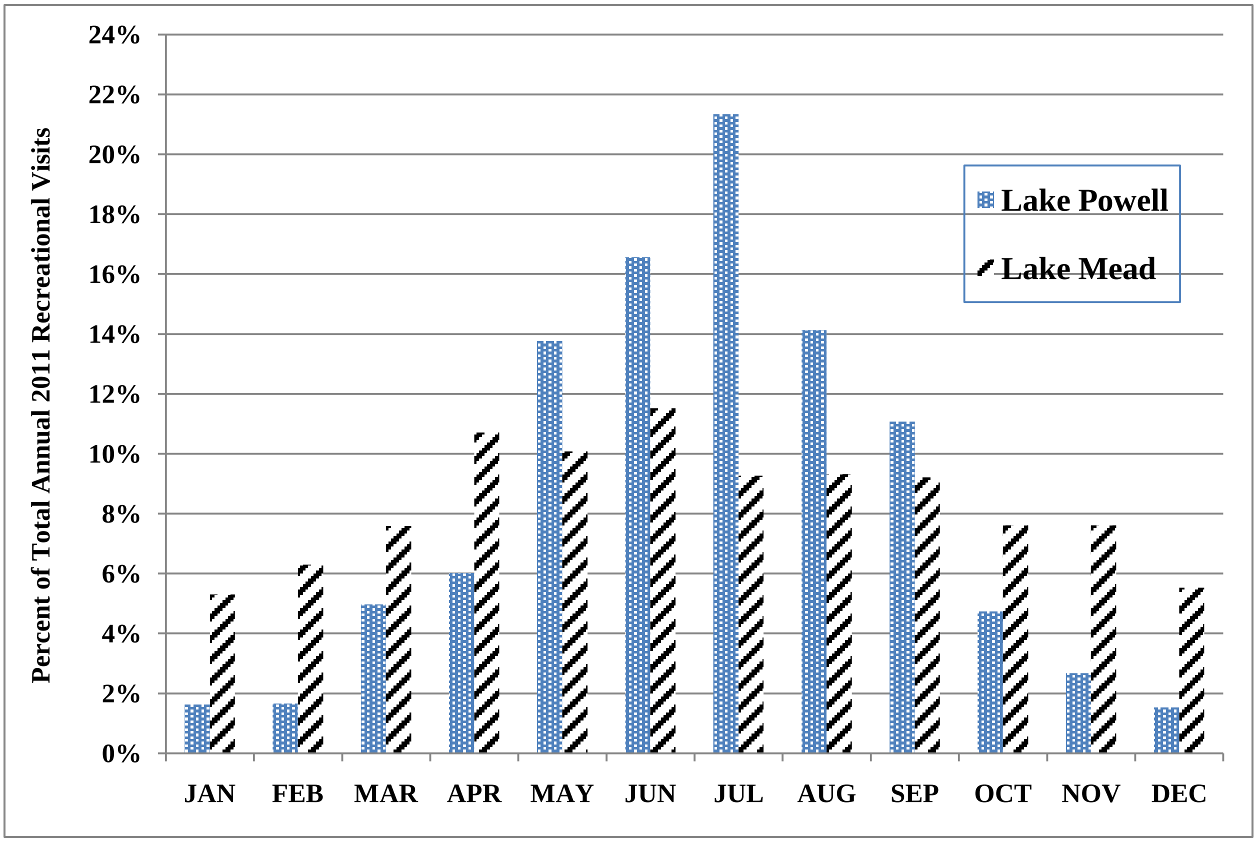

Figure 2. Plot of Glen Canyon NRA Visitation by Lake Powell Water Volume: Monthly data 1996-2011. (Simple linear trend lines shown for each series)

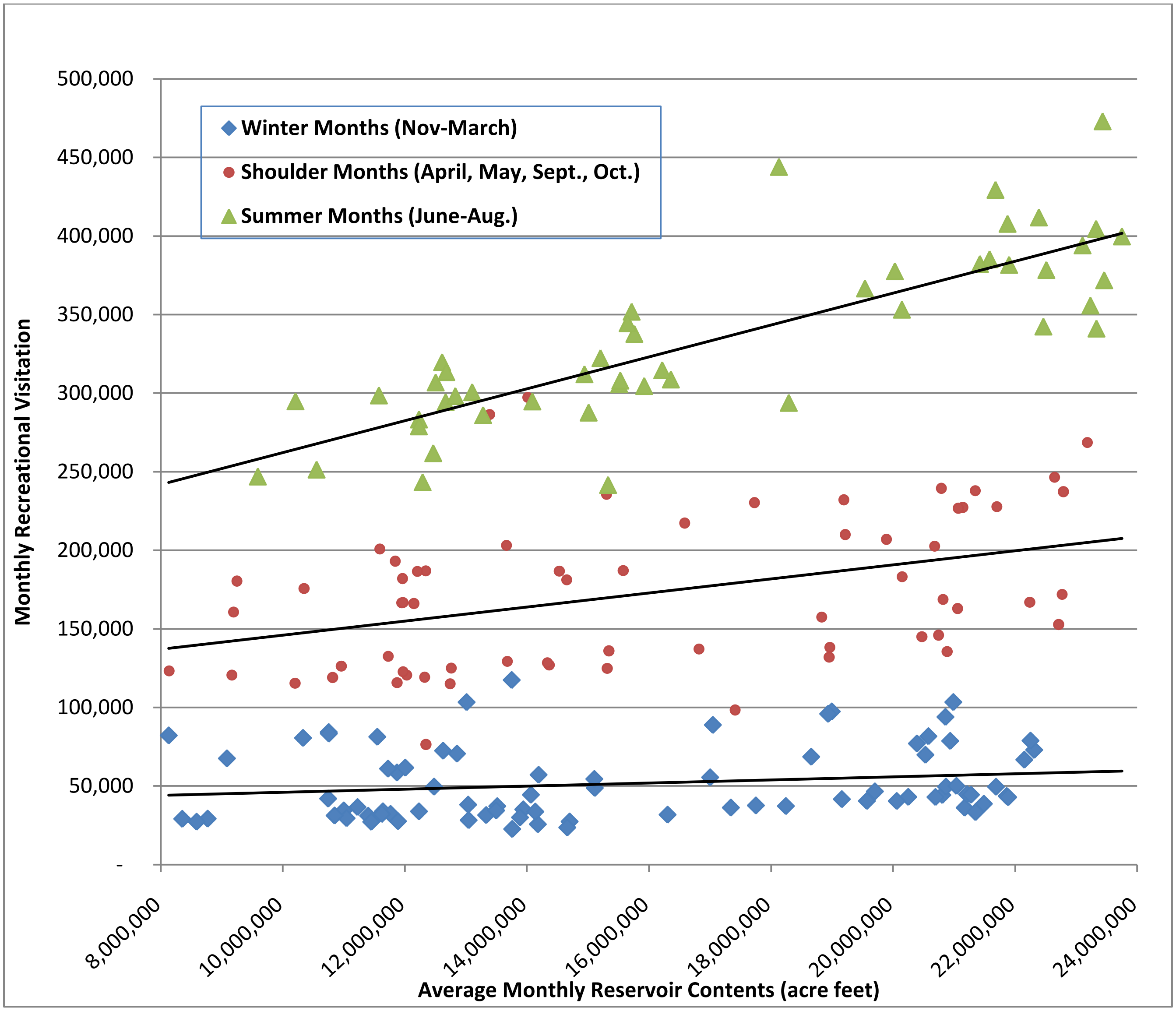

Figure 3. Plot of Lake Mead NRA Visitation by Lake Mead Water Volume: Monthly data 1996-2011. (Simple linear trend line shown)

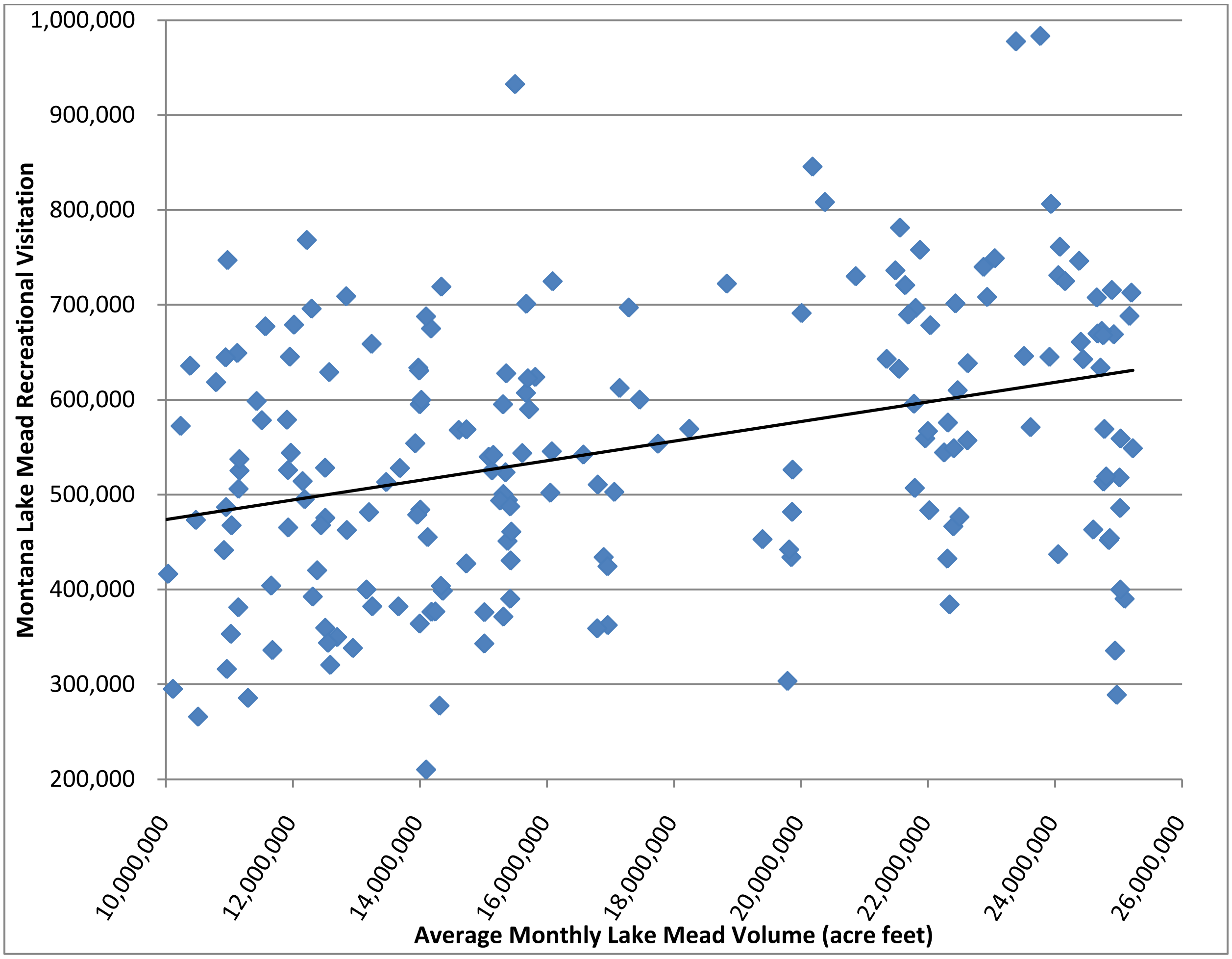

Table 2. Recreational Visitation to Lake Mead and Lake Powell National Recreation Areas-Volume of Lake Mead and Lake Powell Model Explanatory Variables. (1996-2011)

Variable	Description	Minimum	Median	Maximum
Lake Powell Visitation	Monthly recreational visitation	22,555	128,899	472,989
Lake Mead Visitation	Monthly recreational visitation	210,232	542,941	1,047,848
MARCH	Month Indicator Variables (0 or 1)	0	0	1
APRIL		0	0	1
MAY		0	0	1
JUNE		0	0	1
JULY		0	0	1
AUGUST		0	0	1
SEPTEMBER		0	0	1
OCTOBER		0	0	1
NOVEMBER		0	0	1
LAKE POWELL SUMMER*VOLUME	(JUNE+JULY+AUGUST) X VOLUME	0	0	23,748,777
LAKE MEAD SUMMER*VOLUME	(JUNE+JULY+AUGUST) X VOLUME	0	0	24,894,088
LAKE POWELL SHOULDER*VOLUME	(APRIL+MAY+SEPTEMBER+ OCTOBER) X VOLUME	0	0	23,182,862
LAKE MEAD SHOULDER*VOLUME	(APRIL+MAY+SEPTEMBER+ OCTOBER) X VOLUME	0	0	25,202,057
LAKE POWELL VOLUME	Average monthly water volume (af)	8,128,685	16,079,669	23,748,777
LAKE MEAD VOLUME	Average monthly water volume (af)	9,948,733	15,639,931	25,224,447
Sample Size	192			

Table 3. Recreational Visitation to Lake Powell and Lake Mead National Recreation Area-Volume of Lake Mead Estimated Models

Variable / Statistic	Lake Powell		Lake Mead 1996-2011 data	
	1996-2006 data	1996-2011 data	(Full Model)	(Reduced Model)
INTERCEPT	21,407 (7,438.1)***	17,623 (9,450.28)*	229,411 (34,206)***	217,311 (24,699)***
MARCH	48,714 (5,080.83)***	53,266 (6,327.06)***	80,956 (23,341)***	59,629 (23,834)***
APRIL	40,871 (11,369)***	54,231 (14,473)***	211,953 (53,826)***	197,601 (23,831)**
MAY	109,370 (11,510)***	139,635 (14,694)***	211,863 (53,321)***	211,259 (24,134)***
JUNE	135,956 (12,557)***	125,120 (16,305)***	243,479 (56,705)***	304,889 (24,140)***
JULY	171,602 (12,641)***	168,130 (16,543)***	205,152 (56,439)***	266,106 (24,147)***
AUGUST	144,709 (12,476)***	131,974 (16,346)***	196,871 (56,454)***	257,850 (24,146)***
SEPTEMBER	105,870 (11,690)***	119,114 (15,142)***	178,077 (52,820)***	177,743 (24,145)***
OCTOBER	36,852 (11,645)***	47,008 (15,072)***	128,532 (52,881)**	128,165 (24,143)***
NOVEMBER	27,350 (5,077.95)***	25,715 (6,326.55)***	49,006 (23,356)*	41,054 (24,141)**
SUMMER*VOLUME	0.00859 (0.00065895)***	0.00895 (0.00091599)***	0.004055 (0.002985)	--
SHOULDER*VOLUME	0.00364 (0.0006176)***	0.003 (0.00085064)***	0.000442 (0.002742)	--
VOLUME	0.00104 (0.00041677)**	0.00116 (0.00056857)**	0.010079 (0.001822)***	0.01125 (0.00123)***
R-Square	0.987	0.969	0.7126	0.686
Sample Size	132	192	192	192

* Coefficient is statistically significant at 90% level of confidence; ** Significant at 95% level; *** Significant at 99% level.

Table 4. Estimated Marginal Impact of Reservoir Elevation Changes, Lake Powell.

Season	**Months**	**Marginal impact of 1000 acre feet change in volume (recreational visits per month)**	
		Lake Powell	**Lake Mead**
Entire Year	January-December	--	11.25
Summer	June-August	8.95 + 1.16 = 10.11	--
Shoulder	April, May, September, October	3.0 + 1.16 = 4.16	--
Off-season	November-March	1.16	--
Effect of 1,000 af increase across entire year in additional predicted recreational visits		**52.8**	**135.0**

Figure 4. Out-of-Sample Predictions: Monthly Lake Powell Visitation: 2007-2011, based on Model Fitted to 1996-2006 data.

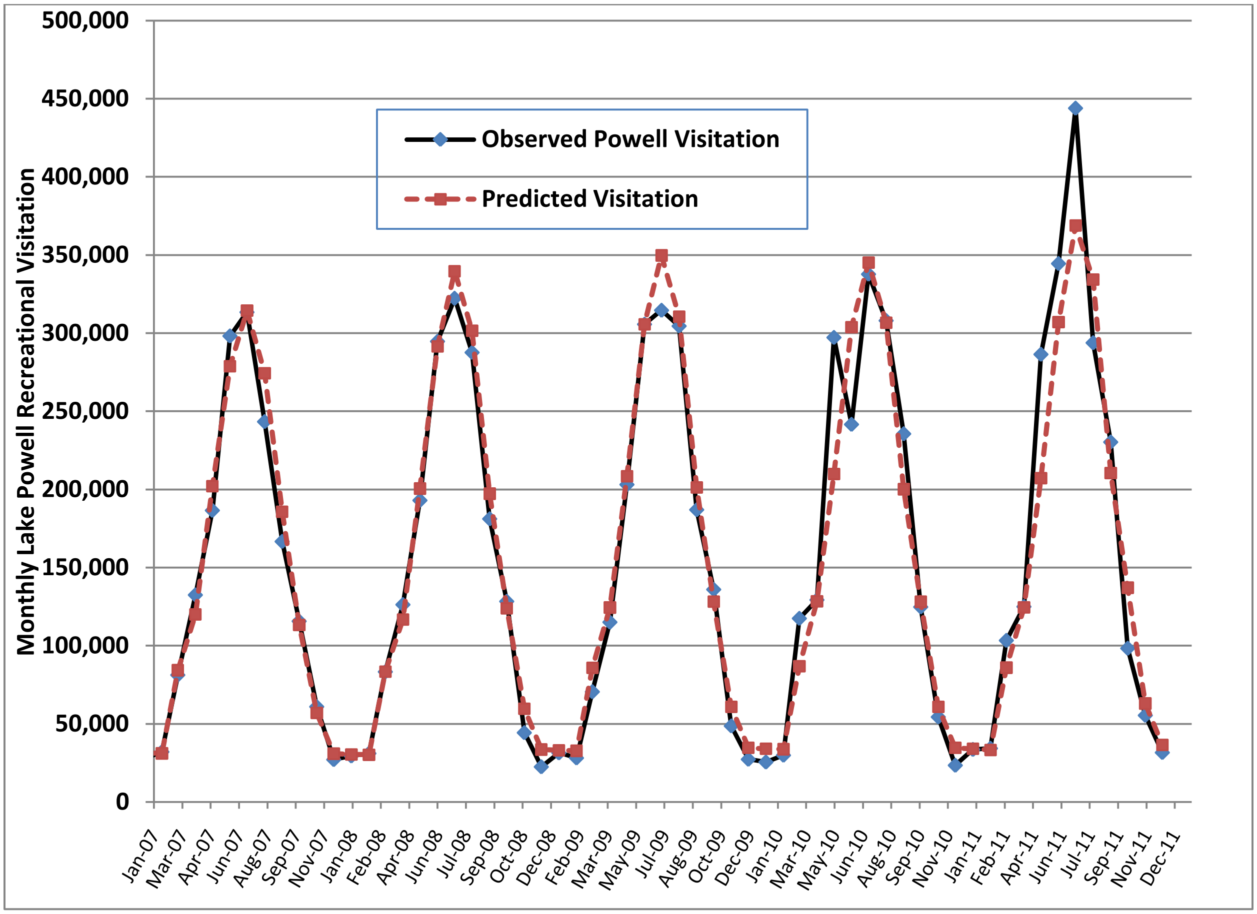

Figure 5. Lake Powell Summer Season Average Volume and Total Visitation: Within and Out-of-Sample Predictions v. Observed.

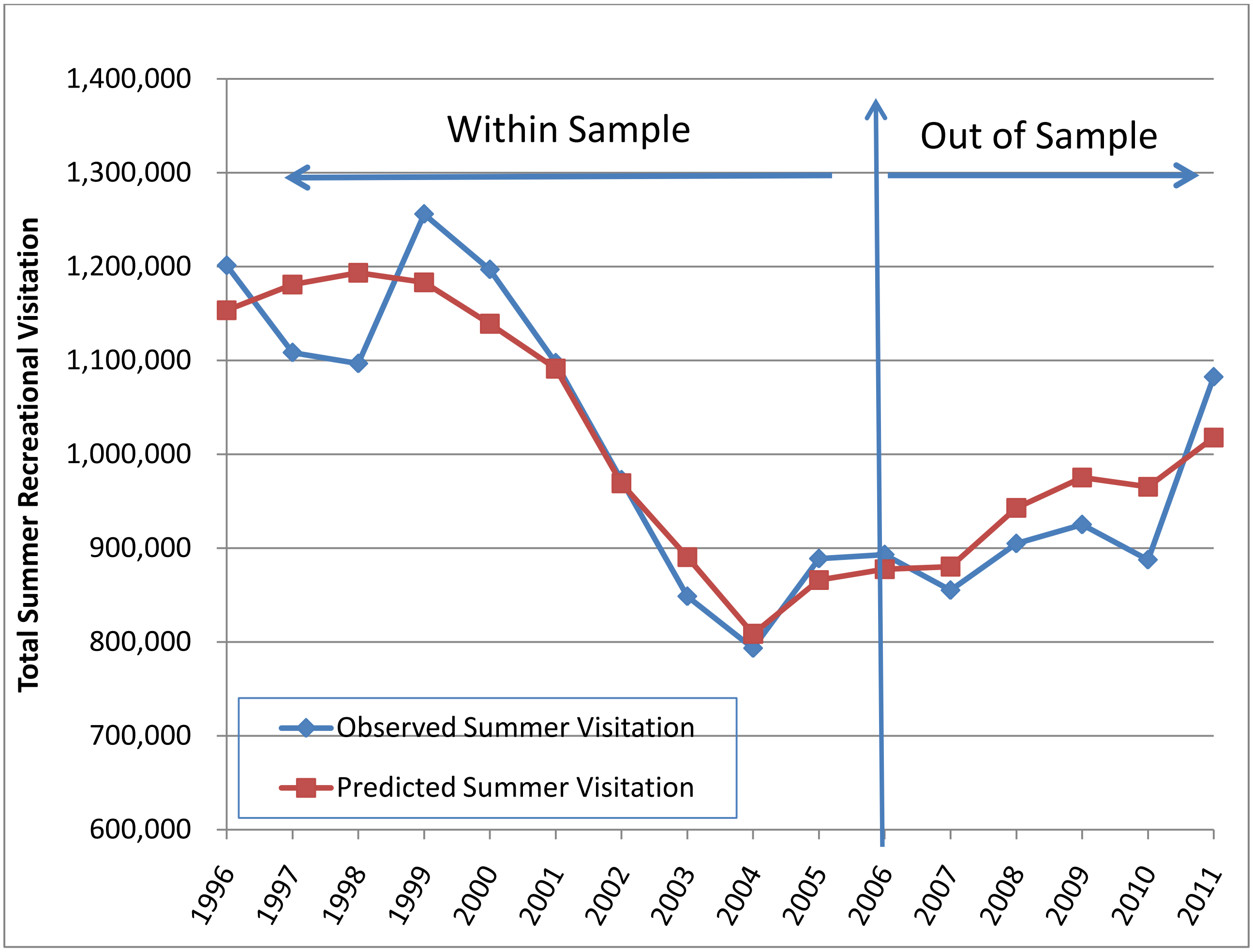

Table 5. Coconino County Gross Sales-Lake Powell Volume Model Explanatory Variables.

Variable	Description	Minimum	Median	Maximum
Coconino County Gross Sales	Amusement, Hotel/Motel, Restaurant/Bar (2011 $)	23,281,190	52,217,661	83,552,314
Lake Powell Volume	Monthly average water volume (af)	8,128,685	14,679,002	23,748,777
Summer Season	June, July, August	0	0	1
Shoulder Season	April, May, September, October	0	0	1
Annual Trend	Yearly Indicator Variables 0-14	0	7	14
Unemployment Rate	National Monthly Average	3.8%	5.15%	10.00%
Sample Size	180			

Table 6. Coconino County Gross Sales-Lake Powell Volume Estimated Models.

Variable	Coefficient (Standard Error)
INTERCEPT	28,324,040 (3,066,040)***
LAKE POWELL VOLUME	0.447 (0.163)***
SUMMER	28,919,054 (1,191,841)***
SHOULDER	19,776,035 (1,077,092)***
TREND YEAR	2,052,467 (230,537)***
UNEMPLOYMENT	(2,065,603) (417,108)***
R-Square	0.829
Sample Size	180

* Coefficient is statistically significant at 90% level of confidence; ** Significant at 95% level; *** Significant at 99% level.

Figure 6. Coconino County Predicted versus Observed Gross Sales based on Lake Powell Average Volume from 1997-2011.