Alternative Use Values within a Watershed under Transitory Supply Shocks

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Abstract

Western water laws have evolved under stochastic water supplies. First arrivals, generally agricultural producers, have rights granting preferential access to water over later claims on water supplies. Efficiency gains may be possible if institutional impediments did not preclude market forces from water allocations. This paper analyzes marginal water values to agricultural (senior) rights holders and water-based recreationists in the Humboldt Basin of Northern Nevada. Marginal values are currently being affected by increased water flows due to mining activities near the headwaters of the Basin. Transitory efficiency gains could be achieved by adjusting water use to these transitory supply shocks.

1. Introduction

In this manuscript we use programming techniques to assess the impact of dramatic changes in river flows which are related to activities of gold mines. Competition for scarce resources has characterized the economy of the Western United States since the mid-1850s. Conflicts over land (Lambert 1995), forest resources (Clawson 1975), minerals (Libecap 1989), and water (Cameron et al., 1996) have generally resulted in the development of institutions that more or less efficiently provide a more or less secure system of property rights in the region's resources (Libecap 1989). Conflicts continue and efficiency gains are often possible with redefinition of property rights, but existing institutions now generally protect established resource uses or foster marginal changes in allocations of the region's natural resources.

Existing institutions can fail when significant capture of property rights available in the public domain occurs due to new claims on previously unclaimed resources. Such an institutional failure has occurred with respect to the great expansion of gold mining activity in the state of Nevada since 1980. Nevada gold production has increased from under half a million troy ounces in 1980 to over 7 million troy ounces in 1996, and Nevada currently ranks as the world's third largest gold producer behind South Africa and Australia.

The Mining Act of 1872 and subsequent amendments specify conditions associated with obtaining rights to lands suspected of containing economically important precious metal deposits. Conditions for exploration, extraction, and subsequent restoration of disturbed areas are specified in various federal and state statutes and regulations. However, Nevada's gold mines use the heap-leaching process to extract gold from huge piles of ore dug from open pits. (Heap leaching is the primary technology employed in Nevada mining.) The pits that are excavated extend hundreds or thousands of feet below the surface and act as sinks for groundwater when the water table lies above the bottom of them. Mining naturally cannot occur in water-filled pits. Consequently, enormous pumping capacity must be installed to prevent the groundwater from seeping back into the pits during operations.

Prior to the start of mining, the area's groundwater was largely unappropriated. Unclaimed groundwater in Nevada is viewed as the property of all those who live in the state, and though there are currently no institutions to deal with massive claims in a systematic fashion, claims can be made by private parties and entities such as municipalities. A property right to the groundwater by the mining companies was therefore accomplished by filing a claim with the State Water Engineer. He granted the mines temporary and conditional use of the groundwater. Although other users of the state's surface and groundwater resources must provide evidence of water rights corresponding to withdrawals, as well as evidence of active beneficial use of the water, the mining industry was ruled exempt from these requirements.

The State water engineer's office has established four acceptable methods of disposing of this pumped water (reinjection, storage in infiltration ponds, irrigation for agricultural production, and discharge into surface channels), and the predominant form of disposal is discharge into nearby streams for eventual discharge into the Humboldt River.

Seven large open pit mines are now, or soon will be, operating within the Humboldt River watershed of northern Nevada and dewatering (other mines are in operation, but do not engage in the activity of dewatering). The combined impact of these mines represents pumping of approximately 445,000 a.f. each year over the 20-25 year anticipated period of continued mining operations. Approximately 65 percent of this pumped water, or 288,000 ac-ft per year at the peak of the mine dewatering, is discharged into the Humboldt River system (HCI), almost doubling the average annual flow of the river. At current market prices of about $3000 per a.f. to secure water rights in Reno, the nearest major city to the Humboldt basin, this discharge represents an annual value of approximately $864 million. This value may accrue over the two decades of anticipated gold production in the area. (Using rural water prices of about $300 to $500 per a.f. results in a much smaller value.) Following mine closure when gold extraction is no longer economically viable, seeping groundwater and surface flows will eventually fill the abandoned pits. The largest pit will contain 580,000 ac-ft of water and cover a surface area of 1,020 acres. The total combined volume of water in these pits will be approximately 1.36 million acre feet – more than in all of the natural surface waters in the state of Nevada, with the exceptions of Pyramid Lake and Lake Tahoe. Pit filling will be gradual, with estimates of several decades up to a hundred years for the pits to fill. Although not representing as great a change in flows as the change resulting from dewatering operations during mining activities, flows will decrease by a maximum of 2-3 percent over the pit filling period (HCI).

We use programming techniques below to model the economic impacts of changes in river flows due to disruptions resulting from mine dewatering and eventual filling of pit lakes. Impacts upon two significant downstream users are estimated: irrigated farms in the Pershing County Water Conservation District and recreators at Rye Patch Reservoir State Park. The estimated impacts of the mine dewatering are derived from an innovative approach to valuing trade-offs among alternative water users. Although other programming models of resource allocation are predicated upon post-optimality descriptions of model impacts on alternative resource users such as hydroelectric power (Hamilton et al.), coal mining (Keith et al.), or endangered spacies habitat (Keplinger et al.) resulting from water diversions to irrigated agriculture, this research incorporates non-market valuation methods using methods developed in Englin et al. to directly assess impacts on recreational use resulting from changes in stream flows due to mining activities and from demands by downstream irrigators.

The programming model developed here is used to assess the economic trade-offs stemming from several possible flow levels in the Humboldt River. We use the model to analyze several scenarios of potential interest to river basin modelers. First, the impacts of windfall gains resulting from mine dewatering and eventual losses from pit filling are examined. A second scenario addresses the development of strategies to avoid loss of the recreational asset at Rye Patch Reservoir due to draining of the reservoir to satisfy irrigators during drought periods (recreation aspects of this are addressed in Huszar et al.). This event occurred in 1992 and several years were required to restore the sport-fishery at the lake. Finally, alternative goal programming weights are placed on irrigator net farm incomes and recreator surplus to derive relative trade-offs resulting from reallocation of the water resource during different stages of mine operations. In the next section we provide a description of the area and institutions that support agricultural demands.

2. The Agricultural Sector

2a Background: The Pershing County Water Conservation District (PCWCD)

The PCWCD was formed in 1926 to consolidate water rights for farmers in the Lovelock, Nevada region. The birth of the district organization was part of the Humboldt Project, involving approximately 38,000 acres of farm land. The PCWCD managed to acquire these additional water rights by negotiating a contract with the US Bureau of

Reclamation. The project also led to construction of storage facilities to stabilize water supplies.

Agricultural production in this semi-arid region depends upon irrigation. Crops grown in the District lands include alfalfa hay, certified alfalfa seed and, to a lesser extent, wheat and barley. Summer high temperatures approach 40° C. Average annual precipitation is only 14.6 cm, and the area experiences some of the highest evapotranspiration rates in the United States. Water rights controlled by the District are sufficient for applying 3 acre feet of water to the areas' 37,504 irrigable acres in a normal water year. However, fluctuations in annual supplies are dramatic (Figure 1). Average annual runoff of the Humboldt river is about 200,000 acre feet (at the Imlay gauging station) but may vary between 5 and 370 percent of this average (State of Nevada). Consequently, the supplemental water sources provided by regional storage facilities, primarily Rye Patch Reservoir completed in 1936, are essential for continuation of traditional agricultural practices.

Within year variations are also important to irrigated agriculture. Crop water requirements are greatest in the summer months. Capacity at Rye Patch and two smaller storage reservoirs is 213,000 ac-ft. However, summer drawdowns of the reservoirs can be extreme. In July 1992, for example, in the middle of the most recent drought affecting the region, the reservoir was completely drained by the PCWCD to satisfy crop needs. The PCWCD states that the water was theirs to do with as they liked, but impact on recreation was quite severe (Huszar et al. 1998). These drought conditions adversely affect agricultural production, but have obvious implications on the sport-fishery maintained in Rye Patch Reservoir by the Nevada Department of Wildlife.

2b The Agricultural Sector and River Flows

To account for this within and across year variation, historical monthly flows into Rye Patch Reservoir are used in a programming model developed for the period of 1967 to 2026. Projected monthly flows resulted from estimation of a time series model assuming a gamma distribution underlies the predicted flows, thus eliminating the possibility of negative flows into the reservoir. The predicted flow model was estimated using the quasi-likelihood methods described in Gourieroux et al. (1984) (White's robust standard errors in parentheses):

$$
\begin{aligned}
(1)\quad Flow_t = &\underset{(0.1842)}{1.1743} + \underset{(0.0481)}{0.9145}\ ln(Flow_{t-1} + 1) - \underset{(0.0467)}{0.1369}\ ln(Flow_{t-2} + 1) \\
&+ \underset{(0.2375)}{0.7133}\ Jan + \underset{(0.1279)}{0.4211}\ Feb + \underset{(0.1562)}{0.8617}\ Mar + \underset{(0.1886)}{0.3527}\ Apr \\
&+ \underset{(0.1943)}{0.0982}\ May + \underset{(0.1629)}{0.5259}\ Jun - \underset{(0.1643)}{0.2644}\ Jul - \underset{(0.1587)}{1.1563}\ Aug \\
&- \underset{(0.1460)}{0.9370}\ Sep + \underset{(0.2470)}{0.3425}\ Oct + \underset{(0.1824)}{0.0419}\ Nov
\end{aligned}
$$

Historical observations were used over the 1967-1996 period. Simulated flows for the succeeding 30 years were derived for equation (1). Monthly storage levels in Rye Patch Reservoir are determined dynamically from past storage and net gains from inflows and releases from the reservoir:

(2) $$Volume_{mt} = Volume_{m-1,t} + Inflow_{mt} - Release_{mt}$$

Inflow is currently set equal to the generated *Flow* values at the Imlay gaging station.

Production activities in the PCWCD were constrained to historical major cropping patterns. Total acres planted to crop *c* of age *a* in year *t* were bounded by the total number of irrigated acres in the District:

(3) $$\sum_c \sum_a Crop_{cat} \leq \text{Irrland}$$

The age of the crop reflects the perennial nature of alfalfa seed and alfalfa hay production. Inter-year linkages are necessary to follow stands of advancing age of these crops:

(4) $$Crop_{cat} \leq Crop_{c,a-1,t-1}$$

The model was also constrained to limit reestablishment bounds on the perennial crops:

(5) $$Crop_{c,a=1,t} \leq \text{Replant}_c \sum_a Crop_{cat}$$

where Replant equaled 0.25 for alfalfa hay and 0.33 for alfalfa seed.

Monthly crop water requirements were derived from crop budget information compiled by the Idaho Cooperative Extension System for southwestern Idaho, a region similar to the study area, because no uniform set of crop budgets exist for the state of Nevada. Monthly (*m*) water requirements were specified as:

(6) $$\sum_c \sum_a \text{Wateruse}_{cam} Crop_{cat} \leq Agwater_{mt}$$

Annual water use was limited by the 3 ac-ft available for project lands over the production year, or

(7) $$\sum_{m} Agwater_{mt} \leq 3 \times \mathrm{Irrland}$$

Total monthly water use is related to releases from Rye Patch reservoir. The farmers' choice of crops drives monthly water requirements, which in turn drives storage and release decisions in the reservoir:

(8) $$Agwater_{mt} \leq \delta \ Release_{mt}$$

where δ is a loss coefficient between releases and actual field application of the irrigation water.

A potential problem in mathematical formulations of agricultural management decisions is crop portfolios that represent corner solutions, or in some other way do not accurately represent historical cropping patterns observed within a region. Several options exist for forcing decisions to positively reflect producer decisions (Howitt; McCarl). We adopt the procedures used in Keplinger et al. (1998). Several historical cropping patterns are available as activities in the model. Optimal decisions are then formed as convex combinations of these available production activities. The following two constraints determine the optimal composite cropping pattern for each year in the model:

(9) $$\sum_{a} Crop_{cat} \leq \sum_{mix} \lambda_{mix} \ \mathrm{Cropping}_{c,mix}$$

where λ_{mix} is the intensity variable of acres planted to cropping pattern *mix* and $Cropping_{c,mix}$ is acreage of crop *c* included in cropping pattern *mix*. Further,

$$(10) \quad \sum_c \sum_a Crop_{cat} \leq \sum_c \sum_{mix} \lambda_{mix} \, \mathrm{Cropping}_{c,mix}$$

which determines total acreage planted in year *t*.

Net farm income for the farmers in the PCWCD are determined from net farm returns to the different crops, determined from the Idaho enterprise budget sheets. Explicit consideration of water use is determined by the cost of water applications on a per acre-foot basis:

$$(11) \quad NFI_t \leq \sum_c \sum_a \mathrm{Returns}_{ca} \, Crops_{cat} - \mathrm{AppCost} \sum_m Agwater_{mt}$$

The value of growing crops at the end of the period are calculated as terminal values in the usual fashion:

$$(12) \quad Terminal \leq \sum_c \sum_a \mathrm{F}_{ca} \, Crop_{caT}$$

whre F_{ca} represent future discounted returns to crop *c* for the remaining years of its productive life.

3. The Recreational Sector

Consideration of non-market resource values has seldom been undertaken in mathematical programming models. Primal models have typically considered allocation decisions when markets exist. Dual solutions have consequently derived resource values based on their marginal contribution to various market activities. In one of the few programming studies we can find that incorporates nonmarket activities, Hurd et al. (1998) include a recreation sector in their model of the impacts of climate change on the Colorado River Basin, but they simply use user-day values. We incorporate recreation using a more systematic approach.

In a recent paper, Englin, Lambert and Shaw simultaneously estimated demand for one recreational activity, fishing. One of the major factors influencing an angler's demand is fishing success, most often measured using average catch rates at a recreation site. Englin, Lambert and Shaw are among the first to have let catch (a key explanatory variable in an angler's demand function) be the angler's *expected* catch (McConnell et al. also do this, and a recent, but different approach is in Jakus et al. 1998). Expected catch is endogenous to the angler, and reflects investments in accumulating fishing experience, effort expended on the fishing activity, as well as various policy variables influencing fish stocks. This model has been applied by Huszar et al. (1998) to fishing at Rye Patch using county-level time series data and an aggregate Poisson (or count data travel cost) model of demand for fishing (see Hellerstein, 1991). They use data collected at the only (easily accessible) entry point for the reservoir over the period from 1980 to 1996. In our programming model, the angler's expected catch rate was solved as a function of reservoir water characteristics, which simultaneously determined demand for fishing trips.

This approach is ideally suited to a mathematical programming model in which control variables, such as water levels at Rye Patch Reservoir, can influence expected catch rates and, consequently, demand for trips. The underlying presumption of such an approach is that water levels influence the anglers' expected fishing success, rather than water level itself being a determinant of trip demand. Expected catch was modeled as a nonlinear function of effort (*Days*), previous year's stocking by the Nevada Department of Wildlife (*Stock*), and minimum Rye Patch water levels over the year (*Mwater*). Trip demand was simultaneously estimated as a function of expected catch (*ECatch*), travel cost based on distance from county of origin plus an entrance fee (*Price*), and average annual water level in the Reservoir (*Awater*).

Maximum likelihood parameter estimates and White's (1980) standard errors are:

$$(13)\quad Ecatch = \exp\Big(\underset{(0.1542)}{-0.9675} + \underset{(0.0048)}{0.0812}\,Days - \underset{(0.3921)}{4.0615}\,Days^2 + \underset{(0.0011)}{0.0033}\,Stock + \underset{(0.0147)}{0.0080}\,Mwater\Big)$$

$$Trips = \underset{(0.3585)}{5.2245} - \underset{(0.4248)}{2.7691}\,Price + \underset{(0.0223)}{0.0567}\,Awater + \underset{(0.3034)}{0.9812}\,Ecatch - \underset{(0.1037)}{0.3269}\,Ecatch^2$$

Average values were used in the programming model for all independent variables except *Mwater* and *Awater* since these were the two control variables in the model. The resulting annual recreational demand model was thus used in our programming model:

$$(14)\quad Ecatch_t \le \exp\left(\alpha + 0.0080\, Volume_{mt}\right) \qquad \text{for all } m \text{ in year } t$$

$$(15)\quad Trips_t \le \beta + 0.0567 \sum_m Volume_{mt} / 12 + 0.9812\, Ecatch_t \; -$$

$0.3269\ Ecatch_t^2$

The constant terms α and β resulted from using mean values for the other independent variables in the econometric model (13).

The value of the trips taken to Rye Patch Reservoir is derived from the optimal quantity of $Trips_t$. Utilizing the Poisson specification underlying the expected catch and demand equations, consumers' surplus can be calculated by $CS_t = Trips_t / \gamma$, where γ is the coefficient on price in the estimated demand function. Following Hellerstein (1991), total consumers surplus for each county can be obtained in an aggregate recreation model, and we extrapolate this county-level CS_t to the state population in period t.

4. *The Overall Objective Function and Model Results*

The model is specified as a goal programming model, where differential weights are applied to farmer incomes and recreationists' surplus values. The discounted sum of the weighted values to the two user groups forms the objective function of the model:

$$(16) \quad \textit{Maximize} \quad \sum_t \left(W_{Farm}\, NFI_t + W_{Rec}\, TCS_t \right) / (1 + r)^t$$

$$+ W_{Farm} \left(Terminal / (1 + r)^T \right)$$

A discount factor of r = 4% was specified.

Modeling Results

The impacts of several alternative scenarios on agricultural incomes and recreational values were assessed. The first analysis focused on the impacts of current mine dewatering and subsequent reductions in Humboldt River flows due to pit filling following mine closures. We assume that the mines close in the year 2011, but the exact year of closure cannot be predicted (Netusil and Shaw). Releases of water into the Humboldt between 1997 and 2011 are predicted to increase flows at the Imlay gaging station by an average of 9.8 percent. The expected impact of this increase would be to increase and stabilize agricultural incomes over the period. Increased water supplies should also result in higher storage volumes in Rye Patch Reservoir, thus increasing the recreational benefits associated with the site. These conclusions are supported by the model results (table 1). Following closure of the mines in around 2011, mean flows are expected to fall from the 1967-96 levels by 2-3 percent, reflecting filling of the massive pits remaining from the mining operations.

Agricultural mean annual net farm income increases 11.8 percent between the pre-dewatering and dewatering periods. The more significant effect is the 84 percent reduction in the standard deviation of farm income. Due to the higher inflows, water storage levels can be sufficiently maintained over the irrigation period to support full utilization of the project's available irrigable lands. Following these windfall gains, the agricultural sector appears to suffer when pit filling diverts water from the Humboldt. Mean annual farm incomes fall 12 percent from the first, premining period. There is also an 18 percent increase in the standard deviation of farm income. The increased variability arises from an increased number of years of insufficient water to maintain agricultural production at the levels existing prior to the mining operations.

Consumers' surplus associated with recreational use of Rye Patch Reservoir continues to increase over all of the periods. However, the number of trips taken is expected to increase as the population of the state continues to grow (Clark County, which contains the city of Las Vegas, has been growing for several years at the fastest annual rate of any county in the United States.). Average population growth for the state of Nevada over the 1967-1996 period was 4.8 percent. Intuition suggests that few changes at Rye Patch would diminish recreational demand at a major State Park like this, especially since alternative fishing sites are far away for residents of the region. However, some effects from mine operations do appear to affect surplus. Specifically, the middle time period in which flows are augmented due to mine dewatering diminish the relative spread between minimum and maximum annual surplus and, related to this effect, decrease the coefficient of variation in the surplus measures.

Another interesting scenario is addressed in Huszar et al. (1998). During a drought event in July of 1992, Rye Patch Reservoir was completely drained by the PCWCD. As stated above, the PCWCD staff argue that they own rights to the water in the reservoir, but the drawdown killed millions of sport fish and raised concerns by recreators and environmental groups. There was significant opposition to future draining of the reservoir following this event. Safe minimum standards were sought to maintain a viable sport fishery in the reservoir. State biologists suggested that a minimum pool of 3,000 ac-ft be maintained at Rye Patch (Sevon, 1995). This volume represents a surface area of 566 acres, an area deemed sufficient to provide adequate cover for fry to escape predation from birds. Consequently, lower bound storage levels at Rye Patch were fixed at 3,000 ac-ft to assess the trade-offs between agricultural incomes and recreational values with a minimum pool standard in place.

Results are presented in table 2. Negative impacts on agricultural incomes are more pronounced in the first and third period. Mean net farm income falls approximately 0.2 percent in each of these periods. Mean income only falls $662, or 0.01 percent, over the middle, mine dewatering period. Recreational values increase when minimum pool volume is enforced. Mean annual recreational values increase 0.5, 0.6, and 0.3 percent in the three time periods.

The trade-offs between foregone agricultural income and recreationist surplus depends upon the quantity and variability of stream flows. The elasticity of farm incomes with respect to proportional changes in consumer surplus for the 1967-1996 period was -0.987. A one percent gain in surplus due to the minimum pool requirement was accompanied by a 0.987 percent loss in farm incomes. This suggests a viable opportunity for a water market between the two groups to safeguard the sportfishery during drought years. The elasticity was -0.012 over the 1997-2011 mine dewatering period. When water supplies are relatively more abundant and stable, there is less of a cost to farmers resulting from maintaining the 3,000 ac-ft pool minimum. The elasticity increases to -3.726 in the final period. As flow is diverted from the Humboldt River to fill the mine pits, maintenance of the 3,000 ac-ft minimum pool would have a greater cost on farm incomes in the Lovelock area.

The last scenario involves shifting social preferences to valuing the recreators' desires relatively more than the agricultural users, perhaps reflecting possible shifts in future claims to resources in the region. This is a purely speculative exercise, but one which is a concern of agricultural producers in the area because of a shift in property rights in a nearby area, the Truckee-Carson Irrigation District, away from farmers and to protection of endangered species and stable water supplies to a wildlife refuge managed by the United States Fish and Wildlife Service. Solutions resulted from shifting the weights on farm incomes and consumer surplus in the objective function (16) to greatly increase the sub-objective associated with recreators' surplus.

The results of this model are presented in table 3. Without legal title to water rights in Rye Patch on the part of the farmers, and with the weights associated with the maximization of net present values of farm incomes being greatly outweighed by recreational values associated with Rye Patch recreation, farm incomes fall significantly. Drops in mean annual farm income are -91.8, -97.0, and -94.3 percent for the first, second, and third periods, respectively. Consumer surplus values increase 30.7, 35.2, and 21.8 percent over the same three periods, as would be expected. Of course, we can attach no accurate weights to the relative preferences on the part of "society", as some have suggested is necessary in analysis of a true "social welfare" function, but our analysis here is suggestive of what could be done using indicators of social preferences from referendum voting or other data that might shed light on appropriate weights to assign each group.

5. Conclusions

The programming model developed for the basin allows consideration of various possible scenarios of interest in modeling river basin impacts. Perhaps of most interest is the mine dewatering scenario, because this is a situation that no one has thought to examine, but which gives legal rights to temporary discharges of groundwater, resulting in positive externalities to downstream parties. Also novel here, is integration of the programming model with a nonmarket valuation technique to evaluate potential benefits to recreation. The situation of trade-offs between recreation and agriculture is quite common in Western U.S. river basins. Our approach could be applied to analyze trade-offs between recreation and hydropower production, or any alternative allocation of water rights in a watershed.

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Table 1. Agricultural incomes andrecreationist consumer surplus at Rye Patch Reservoir before, during, and after upstream minedewatering.

	Agricultural Income			Recreationist Surplus		
	1967-1996	1997-2011	2012-2016	1967-1996	1997-2011	2012-2016
Maximum	7,556,099	6,893,080	7,013,292	1,726,530	2,752,934	4,268,896
Minimum	2,832,901	6,206,418	2,739,273	444,956	1,698,425	2,461,077
Mean	5,868,688	6,561,106	5,161,452	992,702	2,122,242	3,575,305
Std. Dev.	1,173,034	186,604	1,385,849	407,836	330,578	648,928
Coefficient of Variation	20.0	2.8	26.8	41.1	15.6	18.2

Table 2. Agricultural incomes andrecreationist consumer surplus at Rye Patch Reservoir with 3,000 ac-ft minimum pool maintained.

	Agricultural Income			Recreationist Surplus		
	1967-1996	1997-2011	2012-2016	1967-1996	1997-2011	2012-2016
Maximum	7,557,269	6,891,716	7,015,400	1,737,399	2,767,968	4,275,389
Minimum	2,813,746	6,202,026	2,723,128	445,628	1,709,550	2,477,009
Mean	5,855,528	6,560,444	5,152,652	997,460	2,135,314	3,587,214
Std. Dev.	1,176,347	186,241	1,393,328	409,826	331,900	646,838
Coefficient of Variation	20.1	2.8	27.0	41.1	15.5	18.0

Table 3. Agricultural incomes andrecreationist consumer surplus at Rye Patch Reservoir with maximizing consumers' surplus primary objective.

	Agricultural Income			Recreationist Surplus		
	1967-1996	1997-2011	2012-2016	1967-1996	1997-2011	2012-2016
Maximum	2,303,222	921,131	856,519	2,437,708	3,390,152	5,590,010
Minimum	0	0	0	456,284	2,475,598	3,424,189
Mean	481,005	199,994	292,849	1,297,128	2,868,668	4,354,714
Std. Dev.	315,312	306,706	338,167	555,515	298,431	694,456
Coefficient of Variation	65.6	153.4	115.5	42.8	10.4	15.9

Fig. 1. Annual flows at Imlay gaging station, 1964-1996