Economic Benefits of Forecast Informed Reservoir Operations at Lake Mendocino

Final Report

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Introduction

ERG estimated the benefits of Forecast Informed Reservoir Operations (FIRO) at Lake Mendocino for six benefit types:

- Agricultural water supply
- Municipal and industrial (M&I) water supply
- Hydropower
- Fisheries
- Recreation
- Reduced operation, maintenance, and replacement (OM&R) costs

For each benefit category, we provide background information, an overview of the methods, and details on the calculations performed.

Flood risk reduction benefits are not included here because they were considered as part of the hydrologic engineering management plan in accordance with accepted U.S. Army Corps of Engineers' (USACE's) Hydrologic Engineering Center (HEC) methods for estimating expected annual flood damages.

This assessment did not directly evaluate impacts to tribes nor estimate cultural values. Cultural significance is important but is outside this scope of work. Some benefits to local tribes, such as fisheries, may be captured indirectly in the benefits quantified, but our methods do not distinguish the beneficiary.

To develop the methods, ERG reviewed Bureau of Reclamation's (USBR's) prior work on these benefit categories, reviewed the 1983 Principles and Guidelines, assessed the scope of the project, assessed data availability, and held an all-day meeting with expert economists on March 11, 2020 to vet the methods. The National Economic Development (NED) procedures from the Principles and Guidelines provided useful guidance for developing our methodologies. These procedures outline the steps to estimate various benefits, using a variety of techniques such as benefit transfer, estimating demand curves, and least-cost alternatives. The NED procedures played a major role in developing the strategies for estimating each benefit. The 1983 Principles and Guidelines are discussed in more detail in the following section.

Benefits were quantified for two FIRO alternatives: The Modified Hybrid and the Ensemble Forecast Operations (EFO) alternatives. These two alternatives were chosen following the Hydrologic Engineering Management Plan (HEMP) analysis, which assessed the performance of all five alternatives (including existing operations, or baseline) in relation to 16 metrics including flood risk management, environmental concerns, water supply reliability, dam safety, recreation, hydropower production, and operational considerations. Based on the results from the HEMP analysis, the Modified Hybrid was selected for Lake Mendocino FIRO. The EFO alternative was recommended as a reach goal to provide a growth path for the water control plan as scientific and technological advancements are made.

FIRO's impacts on Lake Mendocino water levels were estimated using data from a 33-year hindcast from 1/1/1985 through 9/30/2017. This time period is sufficiently long to take into account a variety of water year types and ensure that the benefits reflect fluctuations in water supply. This is critical because the benefits of FIRO are very different in dry years than wet years. For each benefit, average annual benefits were calculated over these 33 years. However, because average benefits obscure the variability across water year types, for some benefits we present estimates for one wet and one dry year to demonstrate this variability.

We chose not to project impacts forward due to uncertainty in future weather and climate conditions. To do so would require significant additional hydrological analysis that is beyond the scope of this project. Instead, we have assumed future impacts of FIRO are represented based on the hindcast period. Climate change could alter the impacts of FIRO in multiple ways. For example, drier conditions could lead to larger benefits of preserving additional water in the flood pool. Conversely, a higher prevalence of multi-year droughts could result in smaller benefits of FIRO because the water level may never exceed the rule curve and allow for water conservation in the later years of the drought. Future conditions involve several uncertainties, and could be assessed if needed, in a follow-up assessment.

We did not calculate the net present value of the benefits because (1) there is no clear end date for the benefits associated with FIRO; (2) we are not comparing the benefits and costs; and (3) benefits are not expected to substantially increase or decrease with time.

All benefits are presented in 2019 dollars. When necessary, the Bureau of Labor Statistics' Consumer Price Index for All Urban Consumers (CPI-U) was used to convert figures to 2019 dollars.

Table 1 provides an overview of the estimated benefits. The Modified Hybrid alternative results in total estimated annual benefits of $9.4 million. The "reach" alternative, EFO, has estimated total annual benefits of $9.9 million.

Table 1: Summary of Average Annual FIRO Benefits (1,000s of 2019 Dollars)

Benefit Type	Modified Hybrid	EFO
Total	$9,361.4	$9,872.2
Agriculture water supply [a]	$114.1	$118.4
M&I water supply	$2,674.6	$2,778.9
Hydropower [b]	-$1.9	-$43.8
Fisheries [c]	$5,726.4	$5,726.4
Recreation	$802.7	$1,239.2
Reduced OM&R costs	$45.5	$53.0

[a] This is expected to underestimate total benefits because it only reflects the average marginal value and not the value of increased reliability.
[b] The negative annual benefit is due to a current rule in the water control manual that requires hydropower production to stop when reservoir elevations exceed 755 feet. If this rule were to change, we would expect FIRO alternatives to provide a positive benefit.
[c] Estimate using the cost to raise the height of Coyote Valley Dam as a proxy for benefits. The alternative method using water transaction prices results in larger values.

Federal Guidelines

Federal water resource projects are governed by the 1983 Economic and Environmental Principles and Guidelines For Water And Related Land Resources Implementation Studies (P&G) and the 2013 Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies (PR&G). This framework is used when evaluating major water projects in order to promote consistency and informed decision making. This section provides an overview of the guidance relevant to this analysis. Specific guidance for each benefit is included in the relevant section of the report. Our methods deviate from the P&G methods due to data availability or the scope of this project. The P&G methods are designed for an in-depth analysis to justify the costs of large-scale water projects. Evaluating the benefits of FIRO does not require such a detailed analysis.

The following outlines procedural steps to estimate various benefits, using a variety of techniques such as benefit transfer, estimating demand curves, and least cost alternatives. The above-referenced documents played a major role in helping develop the specific strategies for estimating each benefit, however, the methods used for this study were also shaped by Bureau of Reclamation's (USBR's) prior work, members of the project team, and the economists who attended the March 11, 2020 meeting.

Identifying the baseline: Any analysis of programmatic benefits must identify the relevant baseline against which the benefits will be assessed. At a minimum, this requires identifying the current levels of ecosystem services but also current trends and variability if resources permit. The baseline assessment should include both the targeted water resource and also other resources that may be affected by the program. The FIRO HEMP conducted a detailed analysis of the current hydrological conditions at Lake Mendocino. These water levels are used to identify our baseline conditions. Secondary data sources are also used such as recreational levels on and around Lake Mendocino provided by the USACE.

Projecting forward: The guidelines suggest projecting the future conditions of the study area. We agree this is preferable, however, it is beyond the scope of this project. We have used the 33-year hindcast period to assess benefits rather than projecting forward. Implications of this are discussed in the benefits introduction section.

Time periods: The guidance suggests using the same period of analysis for all alternative plans. All the benefits are based on the 33-year hindcast period mentioned above.

Discount rate: The guidance recommends using the discount rate determined and published annually.

NED accounting: The guidance outlines four accounts, (1) national economic development (NED), (2) environmental quality (EQ), (3) regional economic development (RED), and (4) other social effects (OSE). The NED account reflects effects on the national economy and is the basis for our benefit estimation. Benefits estimates therefore should reflect the benefit to the nation as a whole. Transfers between regions are not considered in a NED analysis.

Agricultural Water Supply

Background

Water used for frost protection for wine grapes and for crop irrigation, generally, can result in improved quality and quantity of agricultural goods, which leads to an economic benefit from avoided crop losses.[1] FIRO can help attain that economic benefit by utilizing better forecasting and allowing reservoir operations to change based on the predicted incoming flow. Agriculture output is significant in Mendocino and Sonoma Counties. In 2018, agricultural output was valued at $320.8 million in Mendocino and $1.1 billion in Sonoma according to the 2018 Mendocino and Sonoma County crop reports, respectively. The impact of FIRO on agriculture is expected to be small because agriculture generally can access sufficient quantities of water. Surface water diversions are "regulated" under water rights, but rarely enforced. Groundwater withdrawals are currently unregulated. Further complications in the Russian River Basin limit the effectiveness of the existing regulatory framework: (1) complicated system of water rights in the Russian River Watershed; (2) complex interaction of surface water and groundwater; (3) absence of groundwater regulation in the region; and (4) a need for greater collection and reporting of surface water and groundwater use in the region. Unlike many river systems in the western states, the Russian River has not been adjudicated, nor does it have a Water Master with the authority to strictly control and regulate surface water and groundwater use. The Sustainable Groundwater Management Act (SGMA), signed into law in 2014, provides a framework for sustainable groundwater management through regional groundwater sustainability plans. Steps are being taken to implement SGMA in the Russian River Basin in the coming years.

Summary of Findings

The value of water was estimated using the residual imputation method. Using the estimated average value of an AF of water, and assuming a hypothetical average increase in water for agriculture of 740 or 768 AF under the Modified Hybrid and EFO alternatives, respectively, we estimate an average annual benefits of $114,079 and $118,394. In a dry year, benefits may exceed $775,000

Despite this, we develop a framework to quantify the agricultural benefit because future changes in water availability and the regulatory framework may significantly impact the agricultural benefits provided by FIRO. Additionally, this benefit may be more prominent for other reservoirs that may use the DST, and it is important that the DST is transferable.

[1] The benefits of FIRO to agriculture include additional water for irrigation, heat suppression, and frost suppression. We collectively call these agricultural benefits in this report. Elsewhere researchers sometimes refer specifically to irrigation benefits. However, we are using broader terminology to ensure that heat and frost suppression are also included.

Methods and Results

Annual avoided losses were calculated from agricultural production due to the revised water management practices of the FIRO alternatives using a net income approach. Specifically, we use the residual imputation method (also known as the residual value method) which imputes the "shadow price of water." This method subtracts all known input costs from total revenue for a crop. The remainder is the value attributed to water. This remainder is then divided by the quantity of water used to generate a value per unit of water.

This methodology includes:

- Calculate net returns per acre for prevalent crops (revenue minus costs).
- Calculate the value of a unit of water by dividing net returns by water usage.
- Estimate the potential increase in water supply.
- Calculate the annual avoided losses by multiplying the estimated value of a unit of water by the increase in water supply.

The residual imputation method is a common technique used to value irrigation water. Young and Loomis (2008) provide a detailed overview of this method.

This methodology, however, assesses the average marginal value of water, which is only one of the benefits of the improved reliability of FIRO. FIRO will be especially beneficial in years with extreme water shortages. In these dry years, FIRO can provide additional water that may allow vineyards to continue operations without damage to crops, whereas without FIRO they may have had significant long-term damage that would impact their production for many years. This would provide a large agricultural benefit, however due to difficulties in estimation, these long-term impacts are not estimated. Instead, we present the benefit of FIRO in a dry year when this situation may occur for demonstration purposes.

Our approach assumes the number of acres of each crop planted is not impacted by FIRO. For example, FIRO would not lead to farmers switching crops or expanding acreage. There are some models, such as the Statewide Agricultural Production (SWAP) model, that include these decisions as part of the modeling process. We have chosen not to use these models because the additional water supply for agriculture from FIRO is relatively small and thus will likely not have a large impact on planting choices.

The 1983 P&G recommends using a farm budget analysis to estimate changes in net income. In particular, it recommends estimating revenues with and without the project and taking the difference to approximate the value. The residual imputation method uses a farm budget analysis to estimate net returns. However, we have not directly estimated revenues with the FIRO alternatives because of data availability.

Step 1: Calculate Net Returns for Chardonnay and Pinot Noir

This analysis focuses on wine grapes because they are the dominant crop in this region. According to the Sonoma and Mendocino county annual crop reports, wine grapes are 71 percent of the agricultural value in Sonoma County and 73 percent in Mendocino County (excluding timber from the total). University of California at Davis (UC Davis) has detailed sample cost data for Chardonnay and Pinot Noir grapes in the Russian River Valley of Sonoma county. These costs are for a hypothetical vineyard using typical production practices for the region. There are many assumptions used to develop these estimates which are detailed in their report. UC Davis reports that total costs per acre are $14,416 for Chardonnay and $15,673 for Pinot Noir (January 2017 dollars). Adjusting to 2019 dollars using the CPI-U results in costs of $15,036 and $16,347.

UC Davis calculates revenues using average annual yields and average prices from 2012-2016. However, we chose to use more recent price data for 2014-2018 as reported in the Sonoma Crop Reports (Table 2). Five-year average prices, adjusted to 2019 dollars, are $2,310 per ton for Chardonnay and $3,837 per ton for Pinot Noir. The P&G guidelines recommend using normalized crop prices issued by the Department of Agriculture. However, wine grapes are not included in this data series. When this is the case, the guidance suggests using statewide average prices over the three previous years. Local prices rather than statewide averages were used because the price of wine grapes is highly variable depending on region (even within a state).

We used the reported average yields from UC Davis (6.75 and 4 tons per acre for Chardonnay and Pinot Noir, respectively). These yields reflect the average annual yield over the life of the vines in a mature vineyard.

Net returns are estimated to be $554 for an acre of Chardonnay and -$998 for an acre of Pinot Noir. In our baseline estimates, we assume zero value for water for Pinot Noir grapes due to the negative net return. However, we provide an alternative estimate for Pinot Noir using price and yield data from only 2018, which was a very good year for Pinot Noir grapes in this region. In 2018, the net return for an acre of Pinot Noir grapes was $430.

According to economic theory, negative net revenues should not persist because a rational producer would exit the business. There are several reasons we may observe negative net revenue for Pinot Noir grapes. First, there may be errors in our values. Second, due to price and yield fluctuations, growers may experience negative returns in some years but remain profitable over a longer time horizon. Negative values have been found in other studies such as Speelman et al. (2008), Lange (2007), and OECD (n.d.).

Step 2: Estimate the Value of a Unit of Water

We used an estimated 0.87 AF per acre of water usage for wine grapes, a value determined from McGourty et al. (2008).[2] In their study, the authors estimated the total acreage of wine grapes in the upper Russian River and the total water usage for irrigation, heat protection, frost protection, and postharvest. Dividing the total water usage of 13,569 AF by 15,539 acres results in an estimate of 0.87 AF per acre per year. Dividing the net returns for Chardonnay by 0.87 AF results in a per AF value of $634 (Table 2). Dividing the net returns for Pinot Noir in 2018 by 0.87 AF results in a per AF value of $493.

Note that we have calculated the gross benefit of water including costs for water irrigation. Net and gross benefits are very similar in this instance because the cost of irrigation water is estimated to be only $33 per acre. Gross benefits are useful when estimating the societal benefit whereas net benefits are of relevance specifically to farmers.

Table 2: Calculation of the Value of an AF of Water ($2019)

Value	Source	Chardonnay	Pinot Noir
Total costs/acre	UC Davis	$15,036	$16,347
Yield (average)	UC Davis	6.75	4.00
Yield (2018 only)	Sonoma Crop Report 2018	5.56	4.33
Price per ton (2014-2018 average)	Sonoma Crop Reports 2014-2018	$2,310	$3,837
Price per ton (2018 only)	Sonoma Crop Report 2018	$2,410	$3,871
Net returns	Calculation	$554	-$998
Net returns (2018 only)	Calculation	-$1,638	$430
Water use per acre	McGourty et al. (2008)	0.87	0.87
Value per AF of water	Calculation	$634	-$1,143
Value per AF of water (2018 only)	Calculation	-$1,875	$493

Step 3: Estimate Additional Water Reliability

As noted above, the impact of FIRO on agriculture is expected to be small because agricultural users generally can access sufficient quantities of water. However, for illustrative purposes, we present benefit estimates with hypothetical increases in water availability. We used the same methodology to estimate increases in water reliability as we did for M&I consumers above. This method uses the volume below the target storage level as a proxy for water scarcity. The amount FIRO can reduce this deficit would then represent benefits of increased water reliability due to FIRO. See previous section for more details and Appendix Table A1 for the data used in these calculations. We calculate average annual increases in total water reliability of 1,480 and 1,536 AF for the Modified Hybrid and EFO alternatives, respectively. Of this amount, *we*

[2] We did not use data from UC Davis's sample costs because it only provides water usage during mid-June through September.

attribute half to agriculture (740 AF and 768 AF). If M&I reached a threshold for health and safety (we assumed 30 percent of total M&I consumptive demand), agriculture's share would go to zero. However, in our historical data this does not occur.

These 740 or 768 AF are then allocated across different commodities based on acreage. For example, Chardonnay grapes in Sonoma and Mendocino counties are 21 percent of total agricultural value in these counties and so 155 or 161 AF was allocated to Chardonnay grapes.

The crop reports for Sonoma and Mendocino county include livestock and timber but these were excluded from this analysis. The timber industry generally does not receive water from lake Mendocino. Young and Loomis (2008) suggest not including livestock because this is a secondary product and the value of water has already been incorporated into the value of the intermediary product, the feed.

Step 4: Extrapolate to Other Commodities

Next, we extrapolate to other wine varietals and other commodities

To extrapolate to other wine grapes we:

- Estimated cost per varietal as the average cost per acre for Chardonnay and Pinot Noir.
- Estimated revenue per varietal by multiplying average yields for 2017-2018 by average value per ton (both from the Sonoma County Crop Report).
- Took the difference between costs and revenues to estimate net returns, imposing a lower-bound of zero for each varietal.
- Took a weighted average of net returns across all varietals (excluding Chardonnay and Pinot Noir, weighting by value).
- Divided the average net returns of $29.05 by 0.87 AF to generate a value of water of $33.27.

Extrapolating to other commodities involved:

- Estimating total agricultural expenditures in Sonoma County of $870.6 million (USDA, 2018).
- Estimating total revenues in Sonoma county of $919.1 million (USDA, 2018).
- Estimating total farm acres in Sonoma county of 567,284 (USDA, 2018).[3]
- Using these values to estimate average net returns of $85.44 per acre.
- Calculating average water use per acre of 2.38 (Lewis et al. (2008), see Table 3).
- Dividing net returns by average water usage per acre.

Table 3: Calculation of Water Usage

	Water Usage	Acreage	Use per Acre

[3] Note that all the data from the USDA Census of Agriculture includes livestock production and so the acreage will not match the numbers provided elsewhere in this analysis.

	(AF/year)		(AF/year/acre)
Total	25,669	20,614	1.25
Wine grapes	13,569	15,539	0.87
Remainder	12,100	5,075	2.38

Step 5: Estimate Benefits of FIR0

Table 4 shows the benefit associated with an average annual increase of 740 or 768 AF of water for agriculture in Sonoma and Mendocino counties. An average annual benefit of $114,079 was estimated for the Modified Hybrid approach and $118,394 for EFO. However, as noted above, the estimated value of water can differ significantly across years for wine grapes due to price and yield fluctuations. Using 2018 values for Pinot Noir increases the estimated benefits by $60,505 and $62,793 under these two FIRO alternatives.

Table 4: Average Annual Agricultural Benefits

Commodity	Value per AF ($2019)	Acres (Bearing)	Share of Acreage	Additional AF		Benefit ($2019)	
				Modified Hybrid	EFO	Modified Hybrid	EFO
Chardonnay	$634.32	20,272.5	21%	155.0	160.9	$98,314	$102,033
Pinot Noir	$0.00	16,066.6	17%	122.8	127.5	$0	$0
TOTAL						*$98,314*	*$102,033*
Other wine grapes	$33.27	40,328.1	42%	308.3	320.0	$10,258	$10,646
TOTAL IMPUTING FOR OTHER WINE VARIETALS						*$108,572*	*$112,679*
Other crops	$35.83	20,099.8	21%	153.7	159.5	$5,507	$5,715
TOTAL IMPUTING FOR ALL CROPS						*$114,079*	*$118,394*

In addition to presenting the average annual benefit of FIRO to agriculture, we also present the benefit in an extremely dry year to demonstrate the potential benefits. These extremely dry years are when FIRO may be most beneficial.[4] To demonstrate the potential of FIRO, we use 2009 as an example. In 2009, FIRO would result in an estimated increase of 4,121 or 5,045 AF of water for agriculture, resulting in a benefit of $635,452 for the Modified Hybrid approach and $777,854 for EFO. This takes into account that the additional AF of water is higher in certain dry years. However, the marginal value of water may also be higher because the value of a unit of water is higher when there is scarcity. Additionally, this does not consider long-term damage to vines. Thus, this is likely still an underestimate of the value of FIRO in critically dry years.

[4] The exception would be a multi-year drought when FIRO often has limited impacts after the first year.

Caveats and Limitations

First, the residual imputation method has inherent assumptions and limitations. One limitation of this method is that the values are sensitive to measurement errors in costs or revenues, or the omission of any costs. For example, any costs omitted will bias the value of water upwards. Additionally, if output prices or yields vary significantly from one year to the next, as may occur for wine, then the value of water can vary significantly. For example, Table 4-B in the UC Davis sample costs report shows how the net returns for Pinot Noir can vary from -$8,661/acre to $5,973/acre depending on yield and price. Lastly, this method assumes that all net revenues can be attributed to the value of water (this hinges on the product exhaustion theorem).

Additional assumptions are:

1. Increased water reliability from FIRO will be distributed across crops based on agricultural acreage.
2. Crops without cost and revenue data can be represented well with the average calculated value of water.
3. The value of water to Pinot Noir grapes is zero.
4. The average marginal value of water reflects the value of FIRO. FIRO benefits may exceed this due to the peace of mind obtained from greater reliability or the avoidance of long-term damages of droughts.

Municipal and Industrial (M&I) Water Supply

Background

FIRO operations at Lake Mendocino may increase reliability of water supply to municipal, commercial, and industrial users. We present these benefits for all users together because the methodology is very similar and available data does not allow the impacts to be disaggregated.

Additional water storage at Lake Mendocino may result in a more reliable water supply for local businesses, resulting in avoided production losses. Providing a reliable water supply for M&I users could have a significant impact on avoiding lost economic output and jobs. An example of the potential impact can be seen from a study that estimated the economic impact of the water supply from the Colorado river, finding that the river contributed $657.45 billion towards gross state product in 2014, and contributed to over 7 million jobs in seven counties in Southern California alone (James et. al, 2014).

Improved forecasts and FIRO operations will also improve water reliability for households that rely on Lake Mendocino for water, especially in times of drought. In particular, FIRO will reduce the likelihood of water curtailments during droughts to residential users. Improved consumer water supply reliability would benefit all residents that rely on Lake Mendocino water for many purposes, including drinking water. Sonoma County Water Agency (now Sonoma Water) estimated in 2009 that "Lake Mendocino and Lake Sonoma water plays a significant role in providing drinking water to about 750,000 residents in portions of Mendocino, Sonoma and Marin counties." This analysis includes Sonoma and Mendocino counties.

Summary of Findings

Consumer surplus is the benefit consumers receive when they value a good or service more than the market price. The shift in the supply curve from FIRO, and the resulting decrease in price and increase in quantity, creates an increase in consumer surplus. The increase in

Methods and Results

The P&G provides general guidance for estimating M&I water supply benefits but does not discuss specific methodologies. For example, the NED procedures suggest that when the price of water reflects its marginal cost, that price should be used to reflect the willingness to pay. However, it does not provide details on how to define the relevant price (e.g., marginal or average) or how to evaluate changes in price. USBR's Technical Memorandum Number EC-2009-02 is used as the basis for this analysis. This memorandum "presents methods and provides specific guidance for estimating M&I water supply benefits under a wide range of conditions that is not included in the P&G's."

We estimate the demand curve for M&I water and use the price elasticity of demand to quantify changes in consumer surplus due to an increase in water reliability. The price elasticity of demand is a measure of the change in the quantity of a good or service demanded based on a change in the price of that good or service, in this case water. The elasticity is then used to generate a demand curve and calculate how price may change due to a change in water reliability. The old and new prices and quantities are then used to calculate change in consumer surplus.

The NED procedures from the 1983 guidelines suggest estimating the future water supply and the future water needs for M&I purposes for the given study area, for scenarios in which no project is implemented and for the project being implemented, in this case, FIRO. Then an economic benefit can be calculated by using water cost estimates in conjunction with the change in water usage from the project. Estimating future supply and demand is beyond the scope of this project. Therefore, we assume future supply (in a typical year) and demand is represented by current conditions.

If the impact on price is insignificant, the 1983 P&G acknowledge that the current market price can be used to estimate benefits. However, in this case, the additional supply is large enough that it may have a sizable impact on price. To account for this possibility, we have chosen to model the demand curve and the change in price attributable to FIRO. The alternative of using the current market price may overstate the benefit. However, because prices are not set in a competitive market, it is unclear how much prices may change as a result of FIRO. M&I water suppliers tend to set prices every few years at a level that is expected to cover their costs. By providing more water, FIRO may reduce the average cost of a unit of water (by spreading the fixed costs over a greater number of AF). Therefore, there is a theoretical basis for FIRO reducing the price. However, we also present the benefit as a function of only the market price and the change in quantity as a lower-bound.

Step 1: Estimate the Price Elasticity of Demand

The first step in this analysis is to identify the appropriate price elasticity of demand. After reviewing the literature, an elasticity of -0.4 was chosen. This can be interpreted to mean that a ten percent increase in the price of water will result in a reduction in demand of 4 percent. Young and Loomis (2014) believe a range from -0.3 to -0.6 is appropriate for municipalities. Dalhuisen et al. (2003) reviewed the literature and found a mean price elasticity of demand of -0.41 and a median of -0.35 for residential users. Worthington and Hoffman (2008) find that for residential demand, "Price elasticity estimates are generally found in the range of zero to 0.5 in the short-run and 0.5 to unity in the long-run."[5] There are fewer studies in the literature measuring the elasticity of demand for commercial and industrial usage because data tend to be unavailable, expensive, or time-consuming to acquire and because water tends to have a small role in the industrial cost structure (Young and Loomis (2008)). The literature indicates somewhat more elastic estimates for commercial and industrial users than municipalities, likely because water generally tends to be a small input for commercial and industrial users and thus a change in price has a small impact on production. We have assumed a perfectly inelastic supply curve.

As a sensitivity analysis, we also present benefit estimates using a range of elasticities from -0.1 to -1.

Step 2: Estimate the Increase in Water Supply Reliability

Lake Mendocino area users generally have access to adequate water supply, but during some years the reservoir is below the target storage level. We chose to use the volume below the target storage level as a proxy for water scarcity. The amount FIRO can reduce this deficit would then represent benefits of increased water reliability due to FIRO. Data are available from 1985 to 2017.

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[5] See also Espey et al. (1997) and Sebri (2014).

On average, storage levels on October 1st are below the target storage level of 40,000 by 1,536 AF under baseline operations (see Appendix Table A1). The target is, however, met 79 percent of the time. In years when the storage level is not met, there is an average deficit of 7,239 AF. In contrast to the storage deficit resulting from baseline operations, FIRO generally results in the target being met. The Modified Hybrid alternative results in the target being met in all but one year and the EFO alternative meets the target every year. We calculate average annual increases in water reliability of 1,480 and 1,536 AF for the Modified Hybrid and EFO alternatives, respectively.

We assume equal curtailment for agriculture and M&I unless M&I reaches a threshold where health and safety are impacted (we assumed 30 percent of total M&I consumptive demand). This threshold is not reached in the data considered. On average, 740 AF is attributable to M&I under the Modified Hybrid and 768 under EFO.

Step 3: Estimate the Demand Curve and Estimate the Average Change in Price

Next, the elasticity of demand, current price, and current quantity were used to develop demand curves for M&I users. The relevant values are summarized in Table 5.

Average quantity of water usage between 2009 and 2013 was provided by Sonoma Water for the Upper Russian Reach and averaged 12,041 AF per year. This is the summation of water usage for Calpella, Redwood Valley, Hopland, Cloverdale, and Healdsburg. These are the consumers who are assumed to receive project water.

Current price is from the City of Ukiah's Final Draft Water Rate Study.[6] Prices vary across the cities using project water, but Ukiah's prices tend to be in line with surrounding cities (see Exhibit I-2 in source). As of January 1, 2020, the price per CCF in Ukiah was $3.22 for municipal, commercial, and industrial users. Converting to price per AF by multiplying by 435.599 yields a price of $1,403 per AF.

Ukiah also charges a flat monthly rate per meter type. We chose to only use the marginal price because the average price, incorporating the monthly charge, would vary by consumer. Based on the elasticity literature, this elasticity is applicable to both a marginal price and an average price.

Table 5: Values for Water Demand Equations

Parameter	Modified Hybrid	EFO
Input Values		
Price elasticity of demand	-0.4	-0.4
Current water rate ($/AF)	$1,403	$1,403

[6] We used retail prices to reflect the total value to end-users. However, this includes any value-added due to purification or distribution. Elsewhere, wholesale prices are sometimes used.

Current water demand (AF)	12,041	12,041
Proposed change in supply (AF)	740	768
Derived Values		
New supply (AF)	12,781	12,809
β	-3.43	-3.43
α	16,857	16,857
p	$1,187	$1,179
Change in price	$216	$224

The demand for water can be written as $Q_D = \alpha + \beta P$, where:

Q_D is the quantity of water demanded in AF

α is a parameter reflecting the quantity of water demanded if the price was zero

β is a parameter reflecting the change in quantity given a change in price

P is the market price

Elasticity can be defined as $\varepsilon = \beta*(P/Q_D)$. Rearranging to solve for the unknown parameter of β gives the equation $b = \varepsilon * Q_D/P$. We calculate:

β= -0.4 *(12,041 AF/$1,403) = -3.43

Rearranging the demand equation to solve for α yields: $\alpha = Q_D - \beta P$, so

α = 12,041 AF - (-3.43 * $1,403) = 16,857

The estimated demand equations are:

$Q_D = 16{,}857 – 3.43P$

We can then estimate the new prices using the new demand and the demand curve rearranged to solve for p:

Modified Hybrid: p= (12,781-16,857)/-3.43 = $1,187/AF

EFO: p= (12,809-16,857)/-3.43 = $1,179/AF

Step 4: Estimate the Change in Consumer Surplus

Consumer surplus is the benefit consumers receive when they value a good or service more than the market price. In a supply and demand model it is represented as the area under the demand curve and above market price. In a supply and demand model it is represented as the area under the demand curve and above market price, as shown in Figure 1.

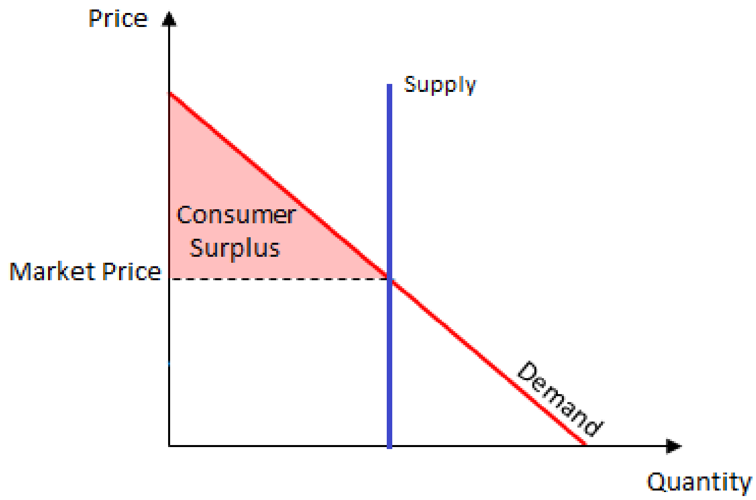

Figure 1. Consumer Surplus

The shift in the supply curve from FIRO creates an increase in consumer surplus. The increase in consumer surplus is calculated as:

Modified Hybrid: [(740 AF * $216/AF) / 2] + (12,041 AF * $216/AF) = $2,674,599

EFO: [(768 AF * $224/AF) / 2] + (12,041 AF * $224/AF) = $2,778,931

Similarly, producer surplus is the benefit producers receive from selling a good or service above the cost of production. The increase in producer surplus can be represented by the area above the supply curve and below market price. We have not quantified the change in producer surplus because (1) the elasticity of water supply is unknown and (2) many water suppliers set price so that revenues equal total costs and consequently producer surplus is zero.

Sensitivity Analyses

Two sensitivity analyses were conducted. The first assumes no change in price as a result of the increase in water reliability. Because pricing decisions are not decided in a competitive market, but instead is determined by the supplier based on a variety of factors, and because the availability of FIRO water is uncertain when pricing decisions must be made, the modeled change in price may not be accurate. Therefore, benefit was estimated as the product of the current price and the change in AF of water. This results in an annual benefit of $1.04 million under the Modified Hybrid and $1.08 under the EFO. For comparison, the benefits using the consumer surplus approach are $2.7 million and $2.8 million.

The second sensitivity analysis uses a range of elasticities to model the demand curve. Our preferred estimated elasticity is -0.4. Here we use a range from -0.1 to -1. Benefits associated with the Modified Hybrid range from $1.1 million to $10.7 million. Benefits associated with EFO range from $1.1 million to $11.1 million.

Caveats and Limitations

This model has several assumptions. First, it assumes that the prices observed in the data reflect market equilibrium prices. In other words, the prices are set based on supply and demand. Because water prices are often set based on suppliers' costs, this may not always hold. Second, it assumes that the elasticity of labor demand from the literature is appropriate for this region. We do not have any reason to believe this elasticity would not be appropriate.

Hydropower

Background

Lake Mendocino was created in 1958 following completion of the Coyote Valley Dam (CVD). In addition to providing flood control, water supply, recreation, and stream flow regulation, Lake Mendocino also generates hydroelectric power (hydropower) from the Dam's associated electrical power plant. The City of Ukiah is responsible for maintaining and operating the Lake Mendocino Hydroelectric Plant, while the USACE is responsible for maintaining and operating the dam in accordance with the Lake Mendocino Water Control Manual (WCM) (1959, revised in 1986).

Summary of Findings

The benefit from hydropower was calculated by multiplying the average wholesale electricity price ($/MWh) by the power generation (MWh) for each of the alternatives. The Modified Hybrid alternative generates $1,868 less in benefits annually compared to the Baseline and the EFO alternative generates $43,750 less annually. These results are highly dependent on the current WCM which, if updated, would result in FIRO alternatives providing greater

Hydropower is an important renewable, efficient, local energy source for communities in the surrounding area of Lake Mendocino. In 2017, the City of Ukiah received 11 percent of its energy from small hydroelectric power plants, one of which was the power plant at Lake Mendocino (Power Content Label, 2017). FIRO has the possibility to increase water storage at Lake Mendocino, and therefore has the potential to allow for more hydropower generation. Increasing the ability to produce hydropower at Lake Mendocino would provide a direct economic benefit to the supplier by increasing sales, with an indirect benefit to the businesses and individuals who would utilize the electricity production.

The hydroelectric plant operations are dependent on the water elevation in Lake Mendocino. Based on a rule in the WCP, the plant must shut down when the flood pool elevation exceeds a 755 ft threshold. The rationale for this rule is to ensure that the reservoir can be evacuated as quickly as possible when the pool elevation is very high. The flood control gates have the ability to release much more water than the power plant, and the power plant cannot operate when the flood control gates are open. With FIRO, however, rapid release of the reservoir when the pool elevation exceeds 755 ft may not always be necessary. As a result, although this rule is reasonable under the current WCM paradigm, this rule will likely be re-evaluated in the WCM update.[7]

The HEMP analysis determined hydropower generation in accordance with the current operating rules of the WCM. Based on the historical data for which the alternatives were assessed, the Modified Hybrid and EFO alternatives reached the 755 ft flood pool elevation more often than the Baseline scenario. As a result, there were more days when power generation was required to be shut off for the FIRO alternatives, and in turn more days for which the FIRO alternatives do not provide hydropower generation. If the WCM were updated with an increased flood pool elevation threshold to trigger power generation shutoff, the economic benefit of the FIRO alternatives would increase significantly. The current analysis presents findings based on the total economic benefit over the historical period of analysis, as well as specific years to showcase how the FIRO alternatives provide benefits in years when hydropower generation was not shut off due to a high flood pool elevation.

Methods and Results

The hydropower benefit was calculated by estimating the increased electricity generated under FIRO alternatives at Lake Mendocino and the value of a unit of electricity. The following steps were taken in order to calculate the economic benefit:

- Determine the wholesale cost of electricity in the Lake Mendocino region.
- Determine the hydropower generated based on baseline operations and the FIRO alternatives.
- Calculate the economic benefit by multiplying the average monthly price by the daily hydropower generation.

The NED guidelines present two methods to value hydropower. The first is the resource cost of the most likely alternative. This method is more appropriate when evaluating a hydropower construction project. This analysis instead assesses the value of additional hydropower from an existing plant with no construction modifications. Therefore, the resource cost of the most likely alternative is not appropriate. There are no alternatives to increase power generation being considered; the increased generation is a byproduct of FIRO. The alternative approach recommended by the NED guidelines, using market prices to reflect the benefit of additional supply, is thus more applicable here (referred to as the user-value method by some sources).

Unlike the water supply benefit assessed below, we do not calculate a change in price as a result of the change in quantity. This is because the additional power generation provided by FIRO is relatively small compared to the total electricity provided by the City of Ukiah, and thus

[7] This assessment is based on the discussion during the HEMP analysis results presentation on June 2, 2020.

it is unlikely to impact the price (i.e., the plant is a price taker). This is confirmed by the P&G which notes that little change in price would generally be expected.

Step 1: Obtain the Cost of Electricity

As recommended in the NED guidance, wholesale market price data were used to value the additional electricity generated. Historical wholesale price data were compiled for the Northern California hub, or NP-15. The weighted average daily price for NP15 EZ Gen DA LMP Peak was used. Data were downloaded from the U.S. Energy Information Administration's Wholesale Electricity and Natural Gas Market Data. We averaged daily values, across ten years of historical data (2010-2019), to estimate average monthly prices. All prices were converted to 2019 dollars using the CPI-U. Table 6 presents the monthly averages. Monthly prices were used to take into account seasonal price fluctuations. Future prices were not projected and so this analysis also assumes that future wholesale prices are reflected well by historical prices.

Table 6: Monthly Average Wholesale Electricity Rates for NP-15 (2010-2019)

Month	Average Price $/MWh
Jan	$43.87
Feb	$51.91
Mar	$40.79
Apr	$40.84
May	$41.54
Jun	$43.81
Jul	$53.33
Aug	$51.83
Sep	$45.56
Oct	$44.98
Nov	$44.92
Dec	$46.05

Step 2: Obtain Hydropower Generation Data

The daily hydroelectric power production, in MWh, for the Baseline, Modified Hybrid alternative, and EFO alternative were determined as part of the HEMP analysis. As previously mentioned, the HEMP analysis evaluated hydropower generation according to the existing WCM rule that requires the power plant to shut off when the flood pool elevation exceeds 755 ft. Based on this rule, there were 656, 1,348, and 2,285 days when the Baseline, Modified Hybrid, and EFO, respectively, have zero power generation during the 33-year evaluation period (see Table 7). Compared to days when Baseline was able to continue to generate power, Modified Hybrid and EFO alternatives were required to shut off power generation for 708 and

1,639 days, respectively. These correspond to a 6 percent and 14 percent increase. The daily data was aggregated to provide the monthly hydroelectric power production over the 33 years of record (1985-2017).

Step 3: Calculate Hydropower Economic Benefit

Using the data gathered in the previous two steps, the economic benefit from hydropower was calculated for baseline operations and the two FIRO alternatives (Modified Hybrid and EFO). The average annual value of hydropower production was calculated by multiplying the monthly averaged wholesale price of electricity ($/MWh) by the power generation (MWh) for each of the alternatives.[8] In aggregate, the Modified Hybrid alternative generates $1,868 less in benefits annually from the baseline and the EFO alternative generates $43,750 less annually. It is important to note that the Modified Hybrid and EFO alternatives generate less economic benefit than baseline operations due to the current WCM rule that does not allow power generation when the pool elevation is higher than 755 ft. If this rule were changed to increase the pool elevation threshold, we would expect that the Modified Hybrid and EFO alternatives would provide greater economic benefits than Baseline.

To demonstrate how the economic benefits of the alternatives differ depending on whether hydropower generation was shut off, the benefits are presented based on water year type classifications provided by Sonoma Water. These data provide the daily water supply condition, classified as a 1 (normal), 2 (dry), or 3 (critical), from 1985-2017. These daily classifications were averaged for each year and then rounded to the nearest whole number to provide a single classification (1, 2, or 3) for the entire year. For the 33-year period of record, 29 years were classified as a 1, and 4 years were classified as a 2. No years were classified as a 3, although some days did receive a value of 3. The Modified Hybrid and EFO alternatives generate $4,653 and $53,380 *less* in annual benefits than baseline operations for years classified as a 1. In drier years (years classified as a 2), however, the Modified Hybrid and EFO alternatives generate $18,318 and $26,064 *more* annually than baseline operations, respectively.

Figures 2 and 3 show the total economic benefit of hydropower for the baseline, Modified Hybrid alternative, and EFO alternatives during a dry year (2014) and a wet year (2017). These years were classified as a 2 and a 1, respectively, based on the water year type classifications. Table 7 shows the number of days with zero power generation, which provides context as to why the FIRO alternatives result in less economic benefit than Baseline in 2017. The Modified Hybrid and EFO alternatives generally provide greater economic benefits than baseline during dry years because they generally store more water in the reservoir during dry periods. This additional stored water can then be used for hydropower production. In wet years, however, the FIRO alternatives seem to provide less economic benefit than baseline operations. This is due to the WCM rule that requires the power plant to shut off when the pool elevation exceeds

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[8] To demonstrate, in January 1985, the overall value of hydropower at Coyote Dam, under the baseline scenario, was calculated as $43.87/MWh x 1061.99 MWh for a total value of $46,579.

755 ft, which often happens during wet years. If this WCM rule was not in place, we would expect that the Modified Hybrid and EFO alternatives would provide more economic benefit than baseline operations.

Figure 2: Hydropower Economic Benefit During a Dry Year

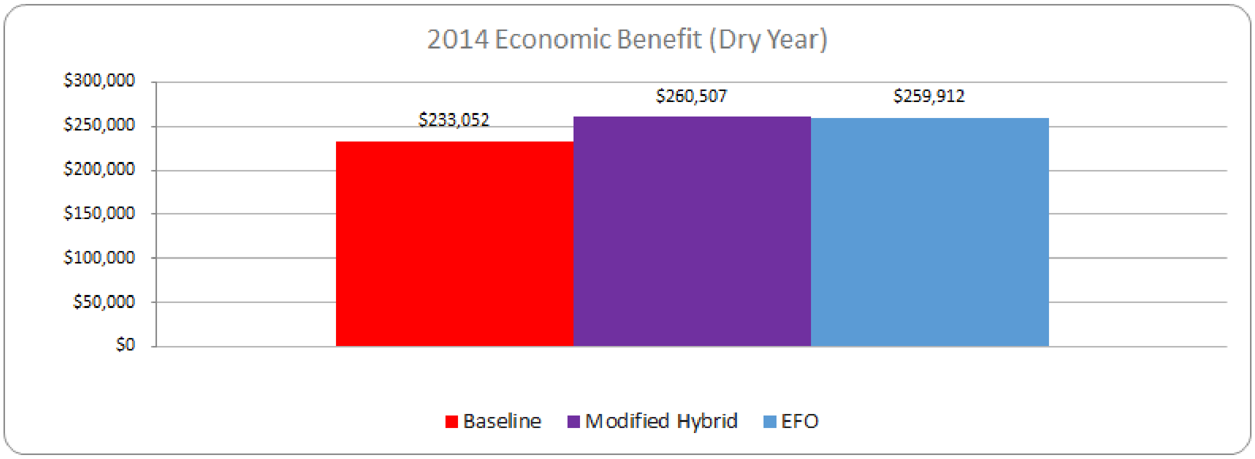

Figure 3: Hydropower Economic Benefit During a Wet Year

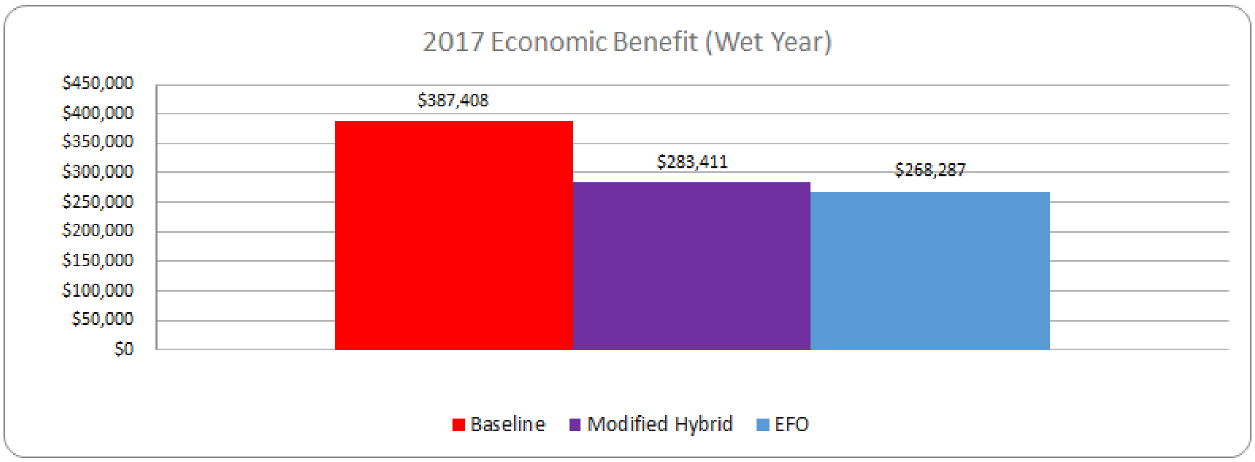

Table 7: Number of Days with Zero Power Generation

Year	Baseline	Modified Hybrid	EFO
All Years	656	1,348	2,285
2014	0	0	0
2017	2	109	112

Caveats and Limitations

The hydropower economic benefit analysis conducted for Lake Mendocino assumes that the safety mechanism that prevents production when elevations levels reach a certain height would remain during FIRO. Without this rule the benefits of FIRO may be markedly different. The analysis also assumes that historical wholesale prices reflect future prices.

Fisheries

Background

FIRO may benefit fish populations and habitat in the Russian River watershed. By increasing the water level stored in the reservoir, FIRO may improve stream flow and reduce water temperature. Additionally, it may allow better controlled releases from Lake Mendocino, which will reduce turbidity. There are three endangered or threatened salmonid species in the Russian River that would benefit: Coho salmon, Chinook salmon, and steelhead trout. In general, healthy habitats provide a benefit to society: "studies have shown that regardless of direct interaction with salmon populations, many Californians hold a positive willingness to pay (WTP) to ensure the long-term survival of salmon" (ECO Northwest, 2012). Additionally, improved habitats and salmonid populations will have direct benefits to the local community, local businesses, and the tourism industry.

Summary of Findings

The benefit to fisheries was estimated using two methods. One assumes that an alternative to achieving FIRO benefits could be accomplished by raising the height of Coyote Valley Dam by 6 feet. Annualizing this cost over 50 years results in an estimated annual benefit of $5.73 million. Alternatively, using water

Methods Overview

Estimating benefits to salmonid populations can be difficult because there is not a market price to reflect the value of healthy salmonid habitats to society. Economists therefore must use other methods to approximate this value. For example, surveys have been conducted to estimate the value placed on healthy fish populations (e.g., WTP). Another method is the least-cost alternative. This method considers alternative projects that would result in the same impact as the proposed project (e.g., a predetermined increase in fish populations or a specific change in temperature of the river beneficial to salmonids). The least-cost alternative that would achieve the same goal is then used as an estimate of the benefit. We use an abbreviated least-cost alternative approach, described in more detail below.

We also conduct a secondary analysis because of the uncertainty in the calculation of costs to raise CVD and the feasibility of this alternative. For this secondary analysis, we use water transaction prices as a proxy for value. The benefit of this method is that it is more easily applied to a DST than the least-cost method and therefore more transferable to other reservoirs. Lastly, we include a short section on using benefit transfer of WTP studies because this method is included in the DST.

The 1983 NED guidelines discuss quantifying benefits for commercial fishing, but not other benefits associated with improved fish populations or habitat. They suggest measuring the change in harvest and harvest cost as the basis for monetizing benefits. We have chosen not to use this methodology because it does not capture the full range of benefits associated with increased fish populations and improved habitats. Additionally, it would require inputs that are not available. The general guidance provided in the 1983 P&G (i.e., not specific to any one benefit type) mentions the least-cost alternative as a viable method. "The cost of the most likely alternative may be used to estimate NED benefits for a particular output if non-Federal entities are likely to provide a similar output in the absence of any of the alternative plans under consideration and if NED benefits cannot be estimated from market price or change in net income."

Abbreviated Least-Cost Alternative Method and Scoping of Alternatives

There are two direct ways in which FIRO can benefit threatened salmonids (e.g., Chinook salmon, steelhead trout) populations in the upper Russian River watershed:

1. By storing more water in the reservoir, there is more water available to be released in the fall to help migrating Chinook and more desirable flows for summer rearing juvenile steelhead trout.
2. By storing more water in the reservoir, a deeper pool results in more cold water at depth which, when released, reduces downstream temperatures and benefits juvenile steelhead trout in the summer months, and returning adult Chinook salmon in the fall, when water temperatures are critical for survival/production, early migration (before ambient temperature cool) and successful reproduction/spawning success.

A full least-cost alternative analysis would consider all feasible options that would achieve the same impact on fish populations, river flow, or river temperatures. Conducting a full least-cost alternative analysis to estimate the value to fisheries requires significant resources to consider the feasibility and costs of a wide range of possible alternatives, each of which has variables that are difficult to quantify. That analysis is beyond the scope of this project. Therefore, after consultation with local fisheries experts, we have selected an alternative that has been previously considered, and for which at least some basic cost information is readily available. We use that cost as an estimate of the avoided costs from FIRO.

In consultation with fisheries experts, we identified temperature and flow as the key salmonid fisheries metrics that can be correlated with FIRO operations. Raising Coyote Valley Dam (CVD) would also achieve similar impacts to temperature and flow, and consequently similar benefits to salmonid populations below Lake Mendocino. Raising CVD has been considered in the past, although this option has stagnated due to funding and safety concerns. However, this is an appropriate alternative to consider for the purposes of this report. Additionally, there is evidence from USACE that this is the least-cost alternative: "Based on draft preliminary economic analysis, costs for the full dam raise could increase to $560 million before non-CVD alternatives for water supply would challenge the dam raise as the least costly alternative per acre feet per year" (USACE (2018)).

The project team also researched and discussed other alternatives. A review of the literature to identify alternative possibilities in the region did not identify any alternatives besides raising the height of the dam that have been seriously considered or that have had costs estimated.

Three other alternatives we considered were planting trees (to reduce water temperature), buying water rights (to reduce water withdrawals), and expanding hatchery operations. However, the feasibility of these alternatives is not known and would likely be determined to be infeasible; thus, a full-scale evaluation of these alternatives was not possible within the timeframe of this study. These options are discussed briefly here as they may be pertinent to other localities.

Planting trees could provide a canopy over parts of the river, potentially decreasing temperatures and benefiting juvenile steelhead trout in the summer. However, tree plantings may not be sufficient to achieve the same benefits as FIRO because there is only so much land available for trees, therefore capping their potential impact. Additionally, it would be expensive to plant trees because this land is very valuable and easements would need to be secured, involving lengthy and costly litigation. To complicate things further, the benefits would be uncertain and unintended negative impacts would need to be factored in (e.g. increased water uptake, leaf litter, evapotranspiration by the trees, etc.).

Buying water rights or purchasing water transfers: Purchasing water has the potential to increase the flow of water in the Russian River and benefit salmonid populations. However, water rights in the Russian River Valley are very complicated and it may be extremely difficult and take a very long time to obtain the necessary amount of water to accomplish the benefits needed. Although purchasing water was deemed difficult under the current landscape, and hence not a feasible alternative that would qualify for the least-cost alternative methodology, transaction costs are a good proxy for value and are used for the secondary analysis conducted below.

Expanding hatchery operations: The Coyote Valley Fish Facility (CVFF) is located just below the Coyote Dam and Lake Mendocino. Eggs are retrieved and fertilized at the facility and then transported to Warm Springs Hatchery (WSH) to be incubated, hatched and raised to a yearling stage. The yearling steelhead are then transported back to CVFF and eventually released into the East Branch of the Russian River (California Department of Fish and Wildlife, 2020). Although theoretically these operations could be expanded to increase steelhead populations, increasing hatchery production will not enhance the natural stock in the same way that improved habitat conditions would.[9]

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[9] There are several ways hatcheries tend to have deleterious effects on the viability of wild salmonid populations including: (1) increasing risk of negative interactions (predation, competition) among hatchery and wild fish; (2)

Avoided Cost of Raising the Dam Height

Both flow and temperature benefits could be achieved by raising the height of CVD at Lake Mendocino. Therefore, we estimate the cost of raising the dam to a height that would achieve the equivalent flow and temperature benefits as FIRO. This is based on very simplified assumptions.

Step 1: Estimate the Necessary Height Increase of the Dam

Based on guidance from Sonoma Water (personal communication), we assume that raising the dam six feet would result in roughly equivalent flow and temperature benefits for fisheries as FIRO alternatives. We assumed the maximum water supply benefit produced by the Modified Hybrid alternative is approximately 12,000 AF, which is due to the maximum allowable winter water supply pool storage being 80,050 AF with FIRO and 68,400 AF under the current Water Control Manual. We assumed that raising the dam would be done without FIRO so the flood pool space would need to remain the same as the current Water Control Manual and we would simply be increasing the water supply volume. The height of the spillway is currently at 765 ft which corresponds to a total reservoir volume of approximately 117,000 AF. We used the current storage-elevation curve and found that to add an additional 12,000 AF of storage, the spillway and the dam height would need to be raised by a little more than 6 feet. This would result in the spillway being at an elevation of about 771 feet and the dam height would change from 784 feet to 790 feet.

Step 2: Estimate the Cost to Raise the Dam Six Feet

The cost to raise the dam by 6 feet has not been calculated in an engineering study. To estimate that cost, we use the estimated cost to raise the dam by 36 feet and apply certain assumptions to approximate the cost for a 6-foot increase. In 2015, the estimated cost to raise the dam by 36 feet was at least $320 million (USACE (2018)). "This rough estimate is based on a 2015 update to 1974 cost estimate and does not account for potential dam safety issues." We increase this estimate to $350 million to include some of these costs, and then adjust for inflation using the CPI-U. This results in a cost estimate of $377.5 million in 2019 dollars. This includes both fixed costs and incremental costs related to the height increase of the dam.

Estimated cost is highly dependent on the share of the cost that is fixed. Additionally, there is little information in the literature from which to derive the fixed component and the two relevant sources identified have very different implications. We therefore averaged two estimates.

The first method assumes that $10 million is a fixed cost that occurs regardless of whether the dam is raised by six feet or 36 feet. This figure is based roughly on a USBR report that identified the lowest total costs associated with increasing the height of a dam similar to CVD was $6

selective breeding causing decreased genetic diversity which leads to the loss of traits important to survival in the wild; and (3) increasing risk of disease transmission.

million (USBR (2014)).[10] This cost includes raising the dam and adding a new auxiliary spillway to be 3 feet higher than the existing spillway.[11] We round up to $10 million to take into account inflation and to provide a conservative cost estimate. If the fixed cost is larger, then the cost to raise the dam by 6 feet would also be larger. We then impute a $10.2 million per foot cost ([$375 million - $10 million]/36 feet). This results in an estimated construction cost of $71.3 million for a 6-foot increase in the height of the dam ($10 million + $10.2 million x 6 feet).

The second approach uses cost estimates of raising the Shasta Dam to determine the fixed, incremental, and ultimately the total cost of raising the CVD by 6ft. First, the average per-foot incremental cost from the Shasta Dam study was calculated to be $24 million per foot (see Table A2 in Appendix A). Using this incremental cost, we determine the average fixed cost of raising Shasta Dam to be $925.4 million (see Table A2 in Appendix A). The incremental and fixed costs calculated for Shasta Dam are based on total capital cost estimates of raising the dam by 6.5ft, 12.5ft, and 18.5ft. We then use the incremental and fixed cost estimates to estimate the total cost of raising Shasta Dam by 36ft (the equivalent height as the CVD cost appraisal), which we find to be $1,775 million ($925.4 million + (36ft * $24 million/ft)). The share of the total cost that is fixed is therefore 52.1% ($925.4 million / $1,775 million). We then apply this ratio to the total cost estimate of $377.5 million for a 36ft increase at CVD to get a fixed cost of $196.8 million for any dam raise construction at CVD. The incremental cost of dam construction at CVD was then imputed to be $5 million per foot (($377.5 million - $196.8 million) / 36ft). Finally, the total cost of raising CVD by 6-ft was calculated to be $226.9 million ($196.8 million + (6ft * $5 million/ft)).

We then averaged $71.3 million and $226.9 million to estimate a cost of $149.1 million. In addition to the direct costs to raise the dam, there are other costs such as pre-building planning and assessment costs and ongoing operating and maintenance (O&M) costs. The upfront research costs to determine the feasibility and costs of raising the dam are approximately $5.5 million (USACE (2018)). We add this cost to the estimated cost of $149.1 million to raise the dam by six feet, for a total cost of $154.6 million. We assume that the incremental O&M costs from the 6-foot increase are negligible. In other words, for the purposes of this estimate we assume that the O&M costs to maintain the current dam and the dam with the 6-foot increase are equivalent.

Step 3: Estimate the Average Annual Value

The benefit of FIRO could then be estimated as the $155 million avoided cost from not raising the height of the dam. This represents benefits over the life of the dam. For example, if the dam is expected to last 50 years, the annualized value, discounted at 2.75 percent, would be $5.73

[10] See Example No. 1 – Dam T Modification; Figure Comparative Costs - New Auxiliary Spillway + Dam Raise.

[11] The example dam that this cost is based on is an embankment dam that is 250ft high and has a crest length of 2,200ft. The CVD is structurally similar in that it is an earth-filled embankment dam that is roughly 160ft high and 3,500ft long.

million (this excludes incremental O&M costs associated with the additional six feet and assumes all construction costs occur in Year 1) (USBR (2019)).[12]

Ideally, the avoided cost estimate should reflect the costs of a project that would have occurred in the absence of the project being evaluated. Although raising the height of the dam has been considered in the past, this alternative has stagnated in recent years due to funding and safety concerns. Therefore, this methodology may overestimate benefits.

Valuation Using Water Transaction and Conveyance Prices

As noted above, we cannot assert that raising the height of the dam is the least-cost alternative without assessing all alternatives. Therefore, to provide an alternative estimate, we have chosen to use water transaction and conveyance prices as a proxy for the value of water. The transaction price is the market price at which users have purchased and sold water. The conveyance price is the cost to transport that water to the user. Together, these reflect the value placed on this resource by the user. It also reflects the avoided damages associated with a reduction in water usage (e.g., the price at which a farmer is willing to sell water reflects the marginal revenue product associated with using that water to irrigate crops).

Neither water transaction prices nor conveyance prices were available specific to the Russian River. Therefore, we used data from the Nasdaq Veles California Water Index (NQH2O) which tracks the price of water rights in the state of California, as determined by water entitlement transactions in the five largest markets in California.[13] These prices reflect the purchase price of water, and do not include additional transportation or transaction costs. The Index has tracked weekly prices since October 31, 2018. See the NQH20 methodology for additional details. The average weekly price for the most recent 12 months (August 2019 through July 2020) is $346.63 per AF. Adjusting to 2019 dollars, the average weekly price is $344.34 per AF.[14]

We applied the approximate average ratio of conveyance costs to market prices from USBR's Shasta Lake Water Resources Investigation. USBR estimated both State Water Project (SWP) and non-SWP conveyance costs but chose to use non-SWP costs because they are more "reflective of the opportunity cost for use of the resource." They also estimated conveyance costs for ten regions (North Bay Aqueduct, South Bay Aqueduct, etc.).[15] We took the average

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[12] The relevant time horizon is unknown. The fisheries literature tends to use 50-years but dam projects often use 100-years. As a sensitivity check, we estimated avoided costs of $4.55 using a 100-year horizon.

[13] This includes the Central Basin, the Chino Basin, the Main San Gabriel Basin, the Mojave Basin (Alto Subarea), and surface water.

[14] If we use only prices during the summer rearing and fall migration months (July-October), the average price is slightly lower at $318.68.

[15] WTP for water is reflected by the total price, comprising both the market price and the conveyance costs. Therefore, market prices are dependent on conveyance costs, and hence conveyance costs should be for the same vicinity as the water market prices used. There is some, but imperfect overlap between the area used to derive market prices and conveyance prices.

conveyance cost from Table 3-9 in the Economic Valuation Appendix of the USBR investigation and inflated the values to 2019 dollars using the CPI-U. This results in an average conveyance cost of $291 per AF.[16] Lastly, the report applied either a 10 percent of a 25 percent conveyance loss depending on the region. We have incorporated the average of 17.5 percent loss. Together, this results in a price of $695.23 per AF.

On average over the 33-year evaluation period, FIRO is expected to increase lake levels by 11,018 AF under the Modified Hybrid approach and by 16,459 AF under the EFO approach. Multiplying these values results in an estimated annual benefit to fisheries of $7.7 million under the Modified Hybrid Approach and $11.4 million under the EFO. For comparison, we estimated benefits as $5.73 million using the dam height raise method.

Valuation Using WTP Benefit Transfer

We include here a short section explaining how one would use benefit transfer of WTP studies to estimate the fisheries benefit. We did not use this method for Lake Mendocino, but have included this short methodology section because this method is included in the DST.

Benefit transfer is the process of finding values from previous studies in areas with similar local conditions (e.g., geography, type of fish, socio-economic conditions) and applying those values to your area. Benefit transfer can be a reasonable and cost-effective approach, as it does not require primary data collection. WTP values can be derived from a variety of survey techniques, such as contingent valuation or choice modeling. To use this method, the user would conduct a review of the literature and find a study with similar conditions. The WTP value would then be applied to the current project. For example, a hypothetical study on the value of salmon in Oregon *may* be appropriate to apply to a project in Washington that would improve salmon habitat because these states are both in the Pacific Northwest and have similar perspectives on the importance of salmon.

Next, the values reported from the study must be applied to the current project. This requires a similar metric be measured in both. For example, if the WTP is per fish and the current project has an estimate of the change in fish populations, then the WTP can be directly applied by multiplying it by the change in fish. In other instances calculations may be necessary to get the WTP value in a metric that can be applied.

Caveats and Limitations

The estimate using the cost of raising the dam as the alternative, avoided cost, includes some assumptions:

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[16] Ideally, this analysis would identify the party(parties) that would sell their water diversions to maintain in-stream flows and where they would purchase water from to offset the reduction from Lake Mendocino. From this, we would identify the conveyance costs specific to that route. However, lacking this information, we believe using an average from existing estimates is appropriate.

- This estimate assumes that in the absence of FIRO, raising the height of the dam is a realistic alternative that could be considered.
- This assumes the cost to raise the dam is appropriate. This estimate is based on a very rough approximation. The true cost could be somewhat higher or lower.
- This method assumes that the dam would be raised solely for the purpose of improving fish habitats. If the dam raise would be enacted for multiple purposes, then this may be an overestimate of the value to fish. However, the least-cost alternative often provides a lower-bound on benefits because benefits would have to exceed costs for the project to be enacted.

The estimate using water transaction prices as a measure of value also includes some assumptions:

- This estimate assumes the transaction price is relevant to the Russian River Valley. This price is based on five large markets in California where demand for water may differ from this locality.
- This estimate assumes the demand for water, as reflected by prices in 2019 and 2020, is representative of future prices. If the real price of water increases, then the benefit of FIRO would be higher (for example, due to increases in population or climate change).
- This estimate assumes that the value of water can adequately be captured in the market. This assumes perfect competition.

Recreation

Background

FIRO can lead to increases in quantity and quality of recreation at Lake Mendocino and on the Russian River. FIRO operations would affect recreational participation by increasing reservoir water surface elevations, decreasing reservoir drawdown during the peak recreation season (May to September), and increasing average annual reservoir surface area over existing reservoir operation conditions. The additional surface area will provide more space for water-based activities. Additionally, the higher elevations will sometimes improve lake access because the boat launches are only accessible above certain elevations. Land-based activities may also benefit from improved aesthetics; low water levels often result in unsightly mud flats or reservoir rings.

Summary of Findings

We estimate the value to recreation as the product of increased recreation and daily use values. Benefits under the Modified Hybrid alternative total $802,700 per year and benefits

There is a large market for recreational activities at Lake Mendocino and along the Russian River. In FY2016 there were 809,764 visitors to Lake Mendocino (USACE, 2019). In Sonoma county alone, outdoor recreation is valued at $731 million per year (Sonoma EDB, 2018). Ward et al. (1996) estimated that at Lake Mendocino in the 1980s, an additional acre-foot (AF)[17] was worth between $12.28 and $244.91 in recreational value, depending on lake levels (adjusted to 2019 dollars using the CPI-U). Analyses for other areas show the potential for economic benefits from recreation stemming from increased water supply. A study on the Colorado River showed that a 100,000 AF increase in water over a year would result in over 18,000 visits to nearby lakes, and over $350,000 in spending from tourism related activities (Neher, 2013).

Additional recreational opportunities will have several beneficiaries. First, those who enjoy recreation will benefit directly. Second, the additional recreation will also benefit businesses directly involved with recreation, as well as those indirectly involved (e.g., gas stations and local restaurants). For this analysis, we focus on the direct benefits to recreationalists. Additionally, we only estimate benefits associated with increased recreation at and around Lake Mendocino, not along the Russian River.

Methods and Results

The NED guidelines suggest using willingness-to-pay estimates from either a travel cost method or a contingent valuation method, if applicable. If these methods are either not feasible or not justified for the particular project, then the unit day value (UDV) method should be used. We chose to apply UDVs in a benefit transfer analysis because the time and resources were not available to conduct a survey.

ERG estimated the increased level of recreational activity due to increased water levels at Lake Mendocino using multivariable regression analysis, and then applied UDVs to those increased recreation levels. Our preliminary estimates do not consider recreation along the river increased quality for current visitors. This analysis includes several steps:

- Obtain recreational use data for Lake Mendocino.
- Estimate the relationship between recreational usage and water levels at Lake Mendocino.
- Apply this relationship to the change in water levels attributable to FIRO.
- Identify an estimate of the UDV for each recreation type.
- Estimate the value of increased recreation as the product of the increased levels of recreation and daily use values.

Step 1: Obtain Recreational Use Data for Lake Mendocino

The Lake Mendocino Master Plan and the Fish Habitat Flows and Water Rights Project Draft Environmental Impact Report (DEIR) both include information on the different types of recreation that occur on and around the Lake. The map in Figure 1, replicated from the DEIR,

[17] An acre-foot is defined as an acre of water one foot deep, equivalent to 325,851 gallons.

shows the locations of the campgrounds, day use areas, boat ramps, and other recreational facilities.

To estimate usage, we use the USACE's VERS (Visitation Estimation & Reporting System).[18] The VERS system primarily uses vehicle meters to track entrances to recreation areas managed by USACE. The number of vehicles is then adjusted using load factors to estimate the number of visitors. The VERS data measures visits, where a visit can be as short as 15 minutes or as long as 14 days.[19] We have assumed each visit lasts for one day. Data was provided from 1984 to 2019 but ultimately only data for FY2014-FY2017 were used due to data consistency over time.[20]

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[18] These data were generously provided by Taylor Baughn and Poppy Lozoff at the USACE.

[19] USACE also has data on camping reservations in recent years from the NRRS (National Recreation Reservation System) which can measure the number of recreation days; however, these data are not in a format that can be easily applied to our analysis.

[20] Data for CY1984-CY1999 is limited to total annual recreational days or visits (i.e., no monthly or site-specific data available). Data for FY2018 and FY2019 are excluded because water level data are not available. Data reporting methods changed significantly in FY2014 and began including more locations; prior to FY2014 data was only available for camping and Pomo area day-use.

Figure 4: Map of Lake Mendocino Recreational Sites

Step 2: Estimate the Relationship between Recreational Usage and Water Levels

We developed a use estimating model (UEM) to evaluate how usage would change under FIRO operations. We used ordinary least squares regressions to determine the relationship between water levels and monthly recreation. The UEM model was developed after reviewing the relevant literature, including Bowker et al. (2010), Neher et al . (2013), Platt (1999), Platt (2001), and Ward et al. (1996).

We considered several variables as indicators of water levels:

- Monthly average AF, elevation, and surface area.
- The above variables transformed to a percent full measure (e.g., AF divided by total storage) (Ward et al., 1996).
- Start of the season water levels or seasonal drawdown of water levels (e.g., from May till September) (Bowker et al., 1994). These measures were rejected as inappropriate for use with monthly data.

Surface area was ultimately chosen because, conceptually, surface area is more appropriate than elevation or AF. The surface area is directly related to the amount of water available for recreation, whereas elevation and storage are only indirectly related. Methodological Appendix B shows the results for percent of full AF and percent of full elevation.

A log-log model was chosen to ensure predicted visitation is positive. An additional aspect of a log-log model is the coefficients can be interpreted as a 1 percent change in visitation as a result of a 1 percent change in the explanatory variable.

Several control variables were considered in the regressions, including:

- Median real household income in Mendocino county (annual values from the Census Bureau’s Small Area Income and Poverty Estimates).
- Population in Mendocino county (annual values from Census Bureau’s population estimates).
- Monthly precipitation and average monthly temperature for Ukiah Airport (from National Oceanic and Atmospheric Administration’s (NOAA's) Global Summary of the Month data).
- Season dummies (“summer” equals one during the summer months of May through August and otherwise equals zero; “shoulder” equals one during the spring and fall months of March, April, September, and October and otherwise equals zero).

We ultimately decided against including median household income or population in the regressions because our short time period did not show much variation in these variables. We also excluded seasonal dummies as is explained in further detail below.

All months were included in the model to estimate both peak and non-peak recreation. We included temperature and precipitation variables to capture seasonal variation. The use of a log-log model takes into account that a change in surface area may have a larger impact on recreation visits during the peak season because it measures the *percent change* in recreation. In other words, it assumes that the percent change is similar across seasons. And, since recreational use is larger in the peak season, the change in visitation is also larger. An alternative way to account for seasonal variation in recreation is to directly include monthly or seasonal dummy variables (to capture level differences) and interaction terms between the surface area and the month/season (to capture differences in how recreation responds to surface area by season). This alternative is included in the methodological appendix.

The relationship between recreation and water levels will likely differ by recreation type. Visitation data was aggregated for several locations with similar activities:

- Camping (includes Kyen, and Chekaka campgrounds; FY2014-2017).
- Boating and fishing (North Boat Ramp only; FY2014-FY2017)
- General recreation (includes Inlet Road and Pomo Visitor Center; FY2014-FY2017)

The years used vary based on data availability. Some months with incomplete data are excluded. Recreation at some locations are excluded entirely due to data missing regularly (e.g., Bushay campground and South Boat Ramp). Removal of these sites will underestimate total benefits because we are excluding any change in recreation at these sites from the benefit calculation.

Some locations are inaccessible above or below certain reservoir levels. When the monthly average elevation levels are outside these ranges, we exclude the data from the model (i.e., greater than 750 feet for the general model and less than 728 feet for the boating and fishing model). We also replace predicted recreation with zero.

The third model is a catch-all for other recreation not covered by camping, boating, or fishing. Identifying the relevant locations for inclusion was not straight-forward. The first consideration was missing data; data is missing for many locations in certain months or years. There are very few months with data for all localities. The second consideration was double-counting. For example, visitation to Inlet Road and Mesa day-use area may overlap. However, since most people visiting Mesa have to travel along Inlet Road, including both numbers would overestimate visitation. We ultimately chose to limit the analysis to Inlet Road and Pomo Visitor Center. We believe most people visiting Lake Mendocino for purposes other than camping, boating, or fishing, will visit at least one of these sites. This choice minimizes months with incomplete data and the risk of double-counting.

Regression results are shown in Table 8. The coefficients on “Ln Surface Area” (i.e., the natural log of surface area) are the primary parameters of interest. The coefficients for the camping and boating models are positive and significant; however, the coefficient for the general model is not significant. The interpretation of the camping coefficient of 1.5 is that for a 1 percent increase in surface area, recreation would increase by 1.5 percent per month. Assessed at the means of 11,712 monthly visits and 1,544 acres this implies that for an increase of roughly 15.4 acres, there will be 117 more campers per month. Because the coefficient for general recreation is not statistically significant, we assume no change in general recreation as a result of FIRO. A non-significant coefficient indicates that we cannot say that it differs from zero (i.e., no impact on recreation).

A few other things to note here. First, the sample sizes are small due to our short time period. This is unfortunate because it limits our statistical precision; however, as noted above, it is not advisable to combine earlier data collected using different collection techniques due to inconsistencies over time (e.g., there is a large drop in the number of camping visits once the methodology changed). Fortunately, the relationship is strong enough that significant coefficients for surface area in two of the three models can be obtained.

Second, the amount of variation in visitation explained, as measured by the R^2, ranges from 0.14 to 0.68. The variation explained in the camping model is especially small. The R^2 values for the other two models are generally considered acceptable. Third, the appropriateness of the signs on the coefficients for control variables, and their statistical significance, vary. We expected a negative sign for precipitation because rainy weather reduces recreation and because recreation is higher during the dry summer period. The coefficients on precipitation are not statistically significant. We expected a positive sign for temperature which is observed, and it is significant in two of the three models.

Table 8: Recreational Regression Results

	(1)	**(2)**	**(3)**
	Camp	**Boat**	**General**
VARIABLES	**Ln Camping**	**Ln Boating**	**Ln General**
Ln Surface Area	1.532*	8.338***	1.000
	(0.810)	(2.425)	(0.586)
Ln Precipitation	-0.00155	0.102	0.0159
	(0.0865)	(0.0751)	(0.0575)
Ln Temperature	0.801	3.122*	2.369**
	(1.392)	(1.450)	(0.933)
Constant	6.080	-4.276	-0.427
	(5.662)	(5.978)	(3.817)
Observations	43	15	25
R-squared	0.142	0.682	0.555

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Step 3: Apply this Relationship to the Change in Water Levels Attributable to FIRO

The coefficients from Table 8 are applied to the estimated daily storage levels at Lake Mendocino from 10/2001 till 9/2017 under the baseline and FIRO alternatives. For each day, we estimate the monthly visitation levels under the three scenarios for each activity type. We used camping under the baseline scenario on September 29, 2017 to demonstrate. Plugging in the relevant values results in the following:

$$e\text{^} \, [(\text{constant}) + (\beta1*\ln(\text{S.A.})) + (\beta2*\ln(\text{Prec.})) + (\beta3*\ln(\text{Temp.}))$$

$$e\text{^} \, [-5.390 + (1.532*\ln(1{,}700)) + (-0.00155*\ln(0.03)) + (0.801*\ln(69.6))] = 12{,}205 \text{ camping trips}$$

These monthly predictions are averaged over the 16-year period and then multiplied by 12 months to reflect the annual average. FIRO's impact on recreation is the difference between the predicted recreational levels under the baseline and the two FIRO alternatives. Average annual visitation increases by 18,154 under the Modified Hybrid alternative and 27,229 under the EFO alternative. Average annual findings are shown in Table 9, under step 4, below. Monthly averages are shown in Appendix B.

Some locations are inaccessible above or below certain reservoir levels. When the daily elevation levels exceed these thresholds predictions are adjusted to be zero visitation. These thresholds include greater than 750 feet for the general model (because many sites become inundated at this threshold) and less than 728 feet for the boating and fishing model (because the boat launch becomes unusable). The Kyen Lower campground is inundated at 756 feet but other portions of the campground remain open and so we did not impose a restriction in the camping model. Additionally, recall that Bushay, which does become inaccessible beginning around 750 feet, is not included in the camping model due to lack of data.

Step 4: Obtain UDVs

Next, a dollar value needs to be placed on the increased recreational usage. Some types of recreation have market values that can be observed. For example, the rental price for a campsite is observed and is a lower-bound on the value of a day of camping for that party. However, the true value derived will generally exceed the price paid. For other forms of recreation, there are often no market values observed, for example hiking on many public lands. To value recreational usage when market values are either unknown or expected to underestimate the true value, economists tend to use surveys and stated preference methodologies to derive values. Common examples include contingent valuation and travel cost methodology. Conducting such a study tends to be expensive and time intensive. A benefit transfer analysis was chosen to estimate values for this project.

We considered using values from USACE's Economic Guidance Memorandum, 20-03, Unit Day Values for Recreation for Fiscal Year 2020 (as recommended by the 1983 NED guidance). However, these values are generally believed to underestimate the true value of recreation (USDA, 2019). We also considered using averages from the USGS Benefit Transfer and Use Estimating Model Toolkit which has compiled many studies estimating daily use values into a searchable database. However, using specific values from the literature that are appropriate to this location results in more defensible estimates.

USGS's Toolkit and Oregon State University's Recreational Use Values Database were reviewed to identify appropriate values. Ultimately, daily use values from Bowker et al. (2009) were chosen. In this study a recreation demand model was developed for visitors to National Forests using on-site survey data and travel cost estimates. The model was used to estimate willingness-to-pay (WTP) for fourteen recreation activities regionally.

Use values from this paper were preferred because the analysis is rigorous and the study was relatively recent. Additionally, this paper provided values for many different types of recreation which allows us to compile all recreational values from one paper, rather than compiling values across sources. However, there are a few drawbacks to this study. First, it is not limited to the Lake Mendocino area; it covers the entire Pacific region. Second, it is not limited to recreation on or around a lake. Some of the data are from non-water areas and some are from riverine areas. Notwithstanding these limitations, these values are the most appropriate for the purposes of this project.

Table 9 includes the relevant unit values taken from Bowker et al. (2010) and their values updated to 2019 dollars.[21] UDVs are the total value derived from an activity. Using these values assumes the value derived from the activity one would otherwise have partaken in is zero. Researchers sometimes adjust UDVs to reflect the marginal benefit from this activity over second preference.

Table 9: Unit Day Values

Activity	Reported Values (2004$)	Adjusted Values (2019$)
Camping or resort stay at the forest	$17.57	$23.78
Driving, motor-boating, site seeing, and other motorized activities	$27.88	$37.73

[21] The report includes several estimates using different assumptions. We chose to use their estimates from the trimmed sample that excludes the top five percent of distances traveled to report conservative estimates. We also chose to use the values that incorporate opportunity cost, estimated as one-third of the imputed wage rate.

Fishing	$67.92	$91.92
Swimming and non-specific forest recreation	$43.46	$58.82
Hiking	$62.80	$84.99
Nature based activities (special forest product gathering, historical site visit, nature center visit, nature study)	$23.45	$31.74
Off-Highway Vehicle activities	$52.61	$71.20
Picnicking	$23.45	$31.74
Trail use (bicycling, horseback riding, and non-motorized water activities)	$56.23	$76.10
Viewing activities (nature viewing, and off-site viewing, wildlife viewing)	$30.26	$40.95
Source: Bowker et al. (2009). Table 15 Consumer Surplus Results TOP5 Data.		

Step 4: Calculate the Economic Benefit

The last step is to estimate the value of increased recreation as the product of the increased levels of recreation and UDVs. In some instances, several day use values would be applicable to a model. For example, the North Boat Ramp is associated with both boating and fishing recreation. In these instances, a simple average of the relevant activities' values was used.

As shown in Table 10, benefits under the Modified Hybrid alternative total $802,743 per year and benefits under the EFO alternative total $1.2 million per year.

Table 10: Recreational Benefit of FIRO at Lake Mendocino

Model	Primary Types of Recreation	Average Unit Day Value	Average Annual Visitation	Average Annual Change in Visitation		Benefit (1,000s)	
				Modified Hybrid	EFO	Modified Hybrid	EFO
Camping	Camping	$23.78	140,542	9,115	12,814	$216.7	$304.7
Boating and fishing	Boating and fishing	$64.83	29,945	9,039	14,415	$586.0	$934.5
General recreation	Hiking, picnicking, beach use, swimming, nature viewing	$38.22	137,394	0	0	$0	$0
Total	N/A	N/A	307,881	18,154	27,229	$802.7	$1,239.2

Alternative Estimates And Validity Assessment

For comparison, Ward et al. (1996) estimated that at Lake Mendocino in the 1980s the value of an additional AF of water to recreation was between $12.28 and $244.91, depending on current lake levels (adjusted to 2019 dollars using the CPI-U).[22] On average, FIRO is expected to increase lake levels by 11,018 AF under the Modified Hybrid approach and by 16,459 AF under the EFO approach. Dividing our total benefits of $0.8 million and $1.2 million by these levels results in per AF values of $73 and $75, respectively. This shows that our estimates are in line with the previous findings from Ward et al. ($12.28 - $244.91).

Alternatively, the values from Ward et al. (1996) could be directly used to estimate recreational benefits. This analysis is conducted as a sensitivity analysis and to demonstrate the type of calculation that could be performed if a demand curve for recreation cannot be calculated for a location in the DST.

This analysis assumes visitation levels are similar today to the 1980s and the value of a visit is similar (measured in real dollars). Ward et al. report 230,000 campers per year and 121,000 day visitors per year (351,000 total). We estimate 307,900 visitors, a comparable number.

Post-cast data from 1985-2017 for the FIRO alternatives was applied to Ward et al.'s findings. For each day in our sample, we estimated the additional AF of water under the two alternatives and the fullness of the pool levels. Fullness was calculated by dividing the surface area under the baseline by the full surface area of 1,785. This generates a distribution of "fullness" days. These values were mapped to the deciles used by Ward et al. For example, 47 percent of days in our sample have a "percent full" between 85 percent and 95 percent full, and hence are classified in the 90 percent full category.

The daily additional AF values in a decile category were then averaged to generate an average annual increase in AF. When averaging, values are weighted by the average share of annual visitors in that month. This is because the additional value of an AF is higher during the peak recreation season than the non-peak season.

The additional AF were then multiplied by the marginal recreational value of an AF to calculate total benefits. Estimated annual recreational benefits are $0.9 and $1.3 million under the Modified Hybrid and EFO alternatives, respectively (Table 11). These values are very similar to our baseline estimates of $0.8 and $1.2 million.

Table 11: Benefits Calculated Using Ward et al. (1996) Parameters

Percent Full	Marginal Value of 1 AF		Average Additional AF (Weighted by Visitation)		Average Additional Value	
	1994 Dollars	2019 Dollars	Modified Hybrid	EFO	Modified Hybrid	EFO
100	$44.99	$76.23	3,047	3,687	$232,292	$281,075
90	$46.73	$79.18	5,899	9,672	$467,111	$765,809

[22] The authors used data on visitors before and during the early part of the 1985-1991 California drought to estimate the relationship between water levels and visitation. They also conducted a travel cost model with water level as a visit predictor to compute marginal values of water in recreation.

80	$50.41	$85.41	1,184	1,891	$101,142	$161,507
70	$57.58	$97.56	676	893	$65,911	$87,171
60	$71.62	$121.35	266	351	$32,318	$42,648
50	$100.00	$169.44	26	34	$4,479	$5,821
40	$144.54	$244.91	0	0	$0	$0
30	$112.55	$190.70	0	0	$0	$0
20	$34.42	$58.32	0	0	$0	$0
10	$7.25	$12.28	0	0	$0	$0
Total	N/A	N/A	11,099	16,529	$903,252	$1,344,030

Caveats and Limitations

The VERS system measures visits, where a visit can be as short as 15 minutes or as long as 14 days. Because this is combined with values based on daily use, it introduces some error into our estimates. On the one hand, if a visitor stays several days without leaving, their use value will be underestimated. Or, if a visitor visits several locations around Lake Mendocino in a day, their value may be overestimated because each activity will have a day value applied. Because the magnitude of these two biases is unknown, the estimates have not been adjusted to reflect them.

The benefit estimate may also be underestimated if visitors do not visit one of these areas, for example if only Overlook day use area is visited. An adjustment was considered to add estimated use of the South Boat Ramp to the analysis: take a ratio of use at the South Boat Ramp to the North Boat Ramp in months when both are available and use this to adjust upward the estimate of boating and fishing recreational benefits. However, there are only five months with data for both localities, which would require an extrapolation that introduces unacceptable error.

Reduced Operation, Maintenance, and Replacement (OM&R) Costs

FIRO may result in a reduction in the cost of environmental reviews because there may be fewer Temporary Urgency Change Petitions (TUCPs). Each of these petitions costs approximately $250,000 (personal communication). Using data from 1985 to 2017 we identified instances where FIRO may have avoided these TUCPs. We estimate that the Modified Hybrid approach would reduce the prevalence of these by 18.2 percent and the EFO alternative would reduce the prevalence by 21.2 percent. Therefore, we estimate an annual average savings of $45,455 for Modified Hybrid and $53,030 for EFO. We have not incorporated this benefit into the DST because it is unique to this situation.

Appendix A: Additional Tables

Table A1: Target Storage Level Deficits

Year	October 1st Lake Mendocino Storage (AF)			Volume below Target Storage Level of 40,000 AF			Difference	
	Baseline	Modified Hybrid	EFO	Baseline	Modified Hybrid	EFO	Modified Hybrid	EFO
1985	46,535	61,766	62,947	0	0	0	0	0
1986	53,569	67,214	69,047	0	0	0	0	0
1987	31,411	44,660	46,489	8,589	0	0	8,589	8,589
1988	31,151	45,450	49,778	8,849	0	0	8,849	8,849
1989	62,431	72,447	78,024	0	0	0	0	0
1990	49,839	59,618	65,139	0	0	0	0	0
1991	47,040	56,662	62,165	0	0	0	0	0
1992	46,301	55,355	58,057	0	0	0	0	0
1993	65,958	81,228	81,583	0	0	0	0	0
1994	40,463	56,921	66,181	0	0	0	0	0
1995	87,526	89,215	87,976	0	0	0	0	0
1996	63,997	77,729	79,432	0	0	0	0	0
1997	53,863	60,833	72,354	0	0	0	0	0
1998	98,853	101,303	99,127	0	0	0	0	0
1999	69,816	81,116	84,182	0	0	0	0	0
2000	48,532	62,863	64,413	0	0	0	0	0
2001	32,103	45,311	46,814	7,897	0	0	7,897	7,897
2002	44,254	60,311	69,119	0	0	0	0	0
2003	85,145	85,157	84,782	0	0	0	0	0
2004	42,755	58,758	74,693	0	0	0	0	0
2005	90,367	90,290	90,280	0	0	0	0	0
2006	83,693	87,404	87,558	0	0	0	0	0
2007	48,782	55,870	73,611	0	0	0	0	0
2008	38,599	54,234	67,024	1,401	0	0	1,401	1,401
2009	29,911	38,153	41,200	10,089	1,847	0	8,242	10,089
2010	84,413	86,780	85,966	0	0	0	0	0
2011	70,220	81,418	84,925	0	0	0	0	0
2012	65,611	74,143	69,828	0	0	0	0	0
2013	42,699	56,458	68,501	0	0	0	0	0
2014	31,860	45,144	45,030	8,140	0	0	8,140	8,140
2015	34,290	47,169	49,719	5,710	0	0	5,710	5,710
2016	58,381	68,799	76,526	0	0	0	0	0
2017	73,415	83,316	81,552	0	0	0	0	0
Average				1,536			1,480	1,536
Share zero				79%			79%	79%
Average if >0				7,239			6,975	7,239

Table A2: Imputed Incremental Dam Raise Construction Cost

Option	Total Capital Cost ($ millions)	Crest Raise (feet)	Imputed Incremental Cost per Foot ($ millions) [a]	Fixed Cost ($ millions) [b]

CP1	$1,073	6.5	N/A	$920
CP2	$1,180	12.5	$18	$885
CP3	$1,362	18.5	$24	$925
CP4	$1,370	18.5	$25	$933
CP4A	$1,371	18.5	$25	$934
CP5	$1,391	18.5	$27	$954
Average			*$24*	*$925*

Source: U.S. Bureau of Reclamation. (2015). Shasta Lake Water Resources Investigation. Table ES-3. Summary of Potential Benefits and Costs of Comprehensive Plans.

[a] Calculated as the difference in capital costs between the relevant option and CP1 divided by the difference in height.

[b] Calculated as: Capital Cost - (Crest Raise * Incremental Cost).

Appendix B: Recreation Methodological Appendix

Table B1: Summary Statistics (FY2014-FY2017)

Variable	Obs	Mean	Std. Dev.	Min	Max
Elevation (ft)	45	732	13	707	754
Acre-feet	45	60,170	20,014	25,709	97,645
Surface area (acres)	45	1,544	212	1,019	1,781
Camping visits	43	11,712	6,574	1,040	24,382
Boating visits	27	2,495	1,287	1,361	5,652
General recreation visits	24	11,449	7,812	4,643	35,063
Median real household income	45	48,151	2,384	46,264	52,622
Population	45	87,280	164	87,107	87,576
Precipitation (in)	45	2.9	4.1	0.0	14.9
Temperature (avg degrees F)	45	61.7	10.1	44.2	77.3

Figure B1: Visitation Counts by Month-Camping

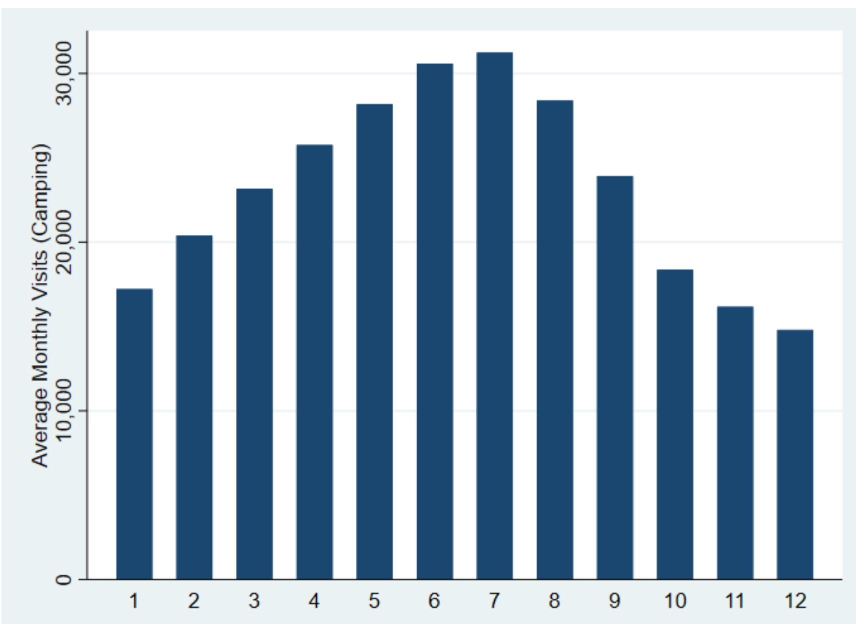

Figure B2: Visitation Counts by Month-Boating

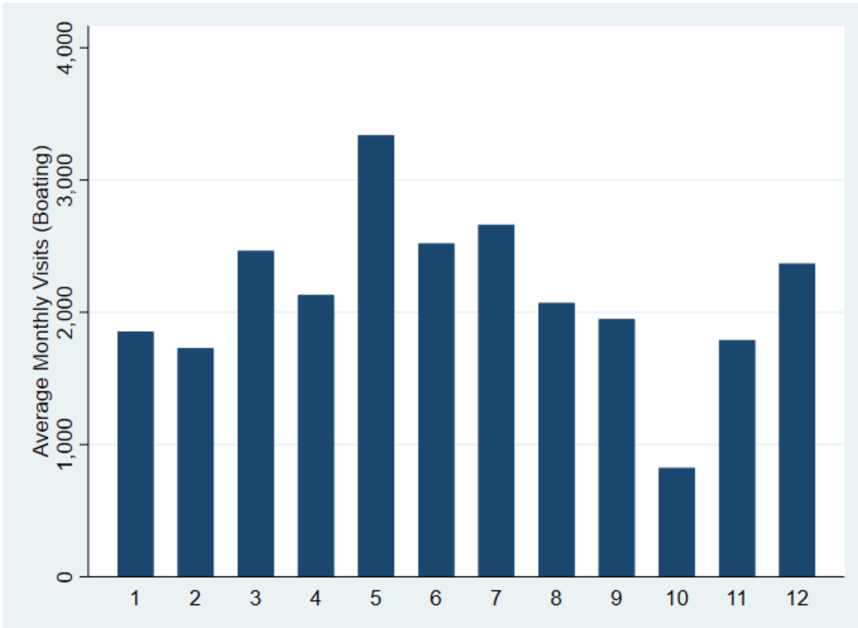

Figure B3: Visitation Counts by Month-General Recreation

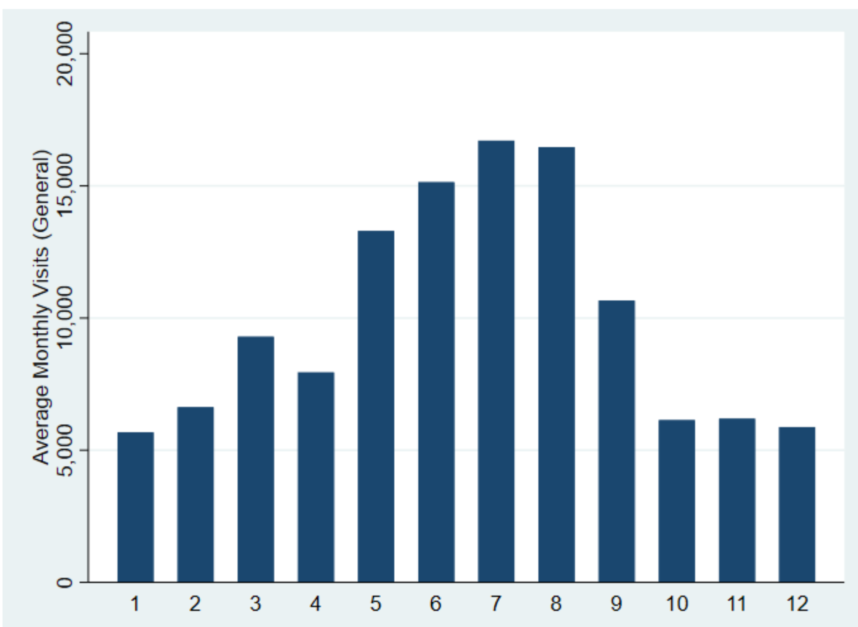

Table B2: Alternative Regression Specifications for Camping Model

	(1)	(2)	(3)	(4)	(5)	(6)
	Preferred	AllYears	Pre2013	Seasons	AF	Elevation
VARIABLES	Ln Camping	Ln Camping	Ln Camping	Ln Camping	Ln Camping	Ln Camping
Ln Surface Area	1.532*	1.213***	-0.216	0.768		
	(0.810)	(0.389)	(0.219)	(1.096)		
Ln Acre-Feet					0.615*	
					(0.332)	
Ln Elevation						12.73*
						(6.955)
Ln Precipitation	-0.00155	-0.0207	0.00873		0.00308	0.00488
	(0.0865)	(0.0388)	(0.0220)		(0.0869)	(0.0871)
Ln Temperature	0.801	0.399	1.289***		0.900	0.919
	(1.392)	(0.596)	(0.337)		(1.391)	(1.393)
Summer				1.105		
				(21.06)		
Ln Summer*SA				-0.0908		
				(2.855)		
Shoulder				-16.06		
				(14.18)		
Ln Shoulder*SA				2.217		
				(1.940)		
Constant	-5.390	-0.689	6.546***	3.284	-1.285	-78.62*
	(7.884)	(3.411)	(1.879)	(7.956)	(6.597)	(46.04)
Observations	43	172	126	43	43	43
R-squared	0.142	0.100	0.298	0.174	0.139	0.138

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table B3: Alternative Regression Specifications for Boating Model

	(1)	(2)	(3)	(4)
	Preferred	Seasons	AF	Elevation
VARIABLES	Ln Boating	Ln Boating	Ln Boating	Ln Boating
Ln Surface Area	8.338***	-1.054		
	(2.425)	(12.80)		
Ln Acre-Feet			2.232***	
			(0.631)	
Ln Elevation				39.79***
				(11.26)
Ln Precipitation	0.102		0.0868	0.0824
	(0.0751)		(0.0755)	(0.0761)
Ln Temperature	3.122*		2.840*	2.740*
	(1.450)		(1.454)	(1.465)
Summer		-71.73		
		(96.51)		
Ln Summer*SA		9.741		
		(13.03)		
Shoulder		-97.11		
		(98.40)		
Ln Shoulder*SA		13.09		
		(13.29)		
Constant	-66.70***	15.47	-28.58***	-266.1***
	(17.08)	(94.76)	(7.395)	(72.33)
Observations	15	15	15	15
R-squared	0.682	0.792	0.691	0.691
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table B4: Alternative Regression Specifications for General Model

	(1)	(2)	(3)	(4)
	Preferred	Seasons	AF	Elevation
VARIABLES	Ln General	Ln General	Ln General	Ln General
Ln Surface Area	1.000	0.134		
	(0.586)	(0.730)		
Ln Acre-Feet			0.438*	
			(0.236)	
Ln Elevation				9.283*
				(5.017)
Ln Precipitation	0.0159		0.0100	0.00829
	(0.0575)		(0.0573)	(0.0575)
Ln Temperature	2.369**		2.307**	2.288**
	(0.933)		(0.927)	(0.931)
Summer		-11.69		
		(13.39)		
Ln Summer*SA		1.717		
		(1.815)		
Shoulder		-8.522		
		(7.746)		
Ln Shoulder*SA		1.199		
		(1.061)		
Constant	-7.913	7.730	-5.129	-61.48*
	(4.815)	(5.308)	(3.847)	(32.08)
Observations	25	25	25	25
R-squared	0.555	0.705	0.565	0.564
Standard errors in parentheses				
*** p<0.01, ** p<0.05, * p<0.1				

Table B5: Monthly Average Change in Recreation

Month	Camping		Boating and Fishing	
	Modified Hybrid	EFO	Modified Hybrid	EFO
1	617	930	343	639
2	627	961	512	904
3	533	775	784	1,187
4	474	708	757	1,155
5	526	768	900	1,357
6	600	850	987	1,432
7	723	1,008	1,326	1,934
8	830	1,161	1,180	1,678
9	924	1,299	992	1,544
10	1,145	1,534	578	1,095
11	1,260	1,638	334	856
12	853	1,178	326	615

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