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The Economic Cost of Unanticipated Water Supply Reductions for Agricultural Producers in the Humboldt River Region

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ABSTRACT

This article develops economic models for a cow-calf ranching operation and an alfalfa hay operation in the Humboldt River Region (HRR) that use surface water for irrigation. The models were built and parameterized through consultation with ranchers and farmers in the HRR in order to represent typical agricultural operations in the region. The models were used to calculate the economic value to an operation of an acre-foot of water not received due to an unanticipated supply reduction. This analysis was conducted to support the conjunctive management of surface and groundwater in the HRR by providing estimates of the economic value of the water that surface water users expect but do not receive due to interference from upstream groundwater pumping.

For the cow-calf ranch model, reduced water deliveries impact ranch profits by reducing the amount of low-cost feed grown on the ranch. The increase in average feed costs forces the ranch to reduce its herd size, which lowers the number of new calf births and, as a result, lowers future profits from livestock sales. The cow-calf ranching model predicts an economic value of an acre-foot of water for the cow-calf ranch in the range of $215 per acre-foot for unanticipated supply interruptions that occur in normal water years, and upwards of $290 per acre-foot for supply interruptions that occur during drought. Model results do not provide evidence that the economic value of an acre-foot of water increases with the length of the unanticipated supply reduction.

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For the alfalfa hay farm model, results indicate that unanticipated reduced water deliveries impact farm profits by first preventing the farm from planting a cover crop during fallow years and then, for more significant interruptions, reducing its acreage of alfalfa hay. The alfalfa hay model predicts that the economic value of an acre-foot of water increases with both the volume of water not received and the length of the unanticipated supply reduction. The economic value of water per-acre-foot predicted by the alfalfa hay model ranges from less than $10 per acre-foot for unanticipated supply interruptions that occur in normal water years, in the range of $100-$200 per acre-foot for single-year supply interruptions that occur during a below average water year, and over $300 per-acre-foot for supply interruptions that occur in successive below average water years.

Keywords: Water economics, water policy, alfalfa hay, livestock ranching, agriculture, conjunctive management, Humboldt River

INTRODUCTION

In August 2015, the Pershing County Water Conservation District (PCWCD), which holds approximately 140,000 acre feet (1 acre foot = 1233.48 cubic meters) of decree rights for Humboldt River water, filed a petition in District Court asserting that groundwater pumping by junior water rights holders is depleting surface flows in the Humboldt River and conflicting with their senior water rights. In the 20 years preceding this petition, the Lovelock Valley in PCWCD asserts that they had 10 years where senior surface water rights holders received less than 50% of their full allotment due to low Humboldt River flows, while at the same time junior groundwater rights holders elsewhere in the Humboldt River Region (HRR) received their full allotment (PCWCD, 2016). The PCWCD petitioned the court to require the Nevada State Engineer use statutory available tools to (i) bring all over-appropriated basins surrounding the Humboldt River back to their perennial yield; (ii) eliminate all cones of depression related to groundwater pumping that cause interference with Humboldt River surface flows; and (iii) regulate water used for mining and milling pursuant to Nevada statutory code.

The PCWCD's petition, which was dismissed in October 2020, would have required substantially reduced groundwater pumping across the HRR. This would have impacted agricultural producers, municipal providers, and mining operations that rely on groundwater pumping, and could have led to significant economic disruption. Further, it has been postulated that even with a substantial curtailment of pumping across the HRR, it could take decades of reduced groundwater pumping for surface flows in the Humboldt River to approach historical pre-pumping conditions (Allander, 2021). Given the significant economic costs associated with management by curtailment, as inferred by PCWCD's petition, and the long time lag before senior surface rights holders may see benefits, the Nevada State Engineer proposed an alternative approach prior to the petitions dismissal where junior groundwater users provide mitigation to senior surface rights holders for the water they do not receive due to groundwater pumping. The State Engineer has asserted that the mitigation approach would address the harm suffered by senior surface rights holders while optimizing the beneficial use of the limited water resources in the HRR.

The State Engineer's mitigation approach, as proposed in 2018 as preliminary draft regulations, set forth a framework for groundwater users to pay financial compensation, based on the volume of Humboldt River flow captured by their pumping (hereafter *capture*), to surface water users for the volume of water they do not receive due to conflict caused by upstream groundwater pumping (hereafter *conflict*) (Nevada Division of Water Resources, 2018). This compensation scheme required calculating (i) the amount of capture caused by every up-stream groundwater user; (ii) the amount of conflict affecting every down-stream surface rights holder; and (iii) the economic value of an acre-foot of water not received due to conflict. The Desert Research Institute (DRI) and the U.S. Geological Survey (USGS) are working to develop a numerical model to quantify capture and better characterize conflict between groundwater and surface water users in the HRR. This article describes an approach to estimate the economic value of an acre-foot of water in the HRR that can be used to set financial compensation and/or establish assessment fees to account for water lost due to conflict to surface rights holders that is caused by groundwater pumping.

In October 2020, PCWCD and the Nevada State Engineer stipulated and agreed that PCWCD's petition be dismissed because they had reached a final settlement agreement resolving all disputes raised. Under that settlement agreement the State Engineer agreed to develop a Draft Order that is intended to provide clear procedures and standards for review of groundwater applications within the HRR. As of October 2021, the draft order has been issued and made available to the public but a final order has yet to be issued.

Given the recent agreement between PCWCD and the Nevada State Engineer, it unlikely that the State Engineer's mitigation approach will be implemented in the HRR in the near term. However, alternative approaches have been suggested where groundwater users in parts of the HRR pay into a mitigation fund based on the volume of Humboldt River flow they capture. This fund could then be used to finance on-the-ground projects in the HRR designed to prevent or offset capture impacts and increase the availability of water to senior surface water rights holders. While this alternative approach would not provide financial compensation to downstream surface water users for water lost due to conflict, its implementation would still require credible estimates of the economic value of an acre-foot of water in the HRR in order to establish groundwater-user assessment fees that would be paid into the mitigation fund. Irrespective of whether or not a financial-based approach is used to facilitate conjunctive management in the HRR, the economic value of water will likely be a key factor in how the State Engineer balances its efforts to prevent conflict while at the same time seeking to optimize the beneficial use of a limited water resource.

This article describes the development and application of economic models for alfalfa hay and ranching operations in the HRR that use surface water for irrigation. These models are used to calculate the economic value of an acre-foot of water not received, due to conflict, for these two operations under different assumptions about the magnitude (volume of water not received) and duration (the number of consecutive years) of conflict.

The remainder of this article is structured as follows. The methods section describes the structure and parameterization of the cow-calf ranch and alfalfa hay farm linear programming models. The results section presents and discusses the results for medium sized (defined below) cow-calf ranch and alfalfa hay farm and presents sensitivity analysis results. The appendix includes results for four different sizes of the cow-calf ranch and alfalfa hay farm.

METHODS

This article presents results from two multi-period linear programming (LP) models that depict production processes on a cow-calf ranch and an alfalfa hay farm. The models were developed and parameterized through consultation with farmers and ranchers in the HRR in order to represent typical cow-calf ranching and alfalfa hay operations for that region. This section explains the structure and parametrization of these two LP models. The LP models used in this study were adapted from a model developed in Torell et al. (2002), which has been used in many ranch planning and policy projects. Such projects include quantifying the impact of federal land policies in Idaho, Nevada, Oregon, New Mexico, and Wyoming (Rimbey et al., 2003; Taylor et al., 2004, 2005), studying management strategies under various drought conditions (Torell et al., 2010; Ritten et al., 2010), comparing the effectiveness of grazing management and distribution methods (Stillings et al., 2003; Tanaka et al. 2007), analyzing the impacts and treatment options of invasive plants with regards to wildfires (Satyal, 2006; Maher et al. 2013), and calculating the economic costs and benefits of various juniper management practices (Aldrich et al. 2005).

Linear Programming

LP is a technique used to obtain the optimal solution in a mathematical model whose objective function and constraints are represented by linear relationships (Gass ,2003). The LP algorithm used in this study was set up to find the management plan for the ranch/farm (e.g., when to sell/purchase cattle, how many acres to plant) that maximizes ranch/farm profits while satisfying all of the constraints on production (e.g., available land, available water, grazing season constraints on public land). The two models include linkages between years related to herd expansion (in the case of the cow-calf ranch) and alfalfa planting and fallowing (in the case of the alfalfa hay farm).

The advantage of the LP approach for this study is that the models can be used to analyze how the economic costs of water delivery interruptions depend on the intensity (volume of water not received) and duration (the number of consecutive years) of interruption, as well on the characteristics of the operation (i.e., size, forage availability, herd size and composition). This flexibility allows the model to tailor its predictions of the financial cost of an unanticipated reduction of water supply, such as conflict, to the specific circumstances of different agricultural operations in the HRR.

Cow-Calf Ranch Model

The multi-period LP model was set up so that the representative cow-calf rancher maximizes the net present value of discounted annual profits (net annual revenues) over a 40-year planning horizon by choosing the numbers of livestock to purchase and sell each year and by selecting a mix of forage sources to sustain their herd at minimum cost. The LP model was constrained by five factors: (i) available land, (ii) available water, (iii) livestock feed requirements, (iv) cattle reproduction and mortality, and (v) cash-flow through the inclusion of a minimum cash reserve requirement.

Land availability impacts rancher decision-making and ranch profits by changing the amount of forage that can be grown on the ranch and, hence, the cost of feeding a herd of a given size. Land availability constrains the model because the cost of forage depends on the ranch's land holdings. As described in Table 1, the model assumed the ranch has access to two low-cost sources of forage: (i) a Bureau of Land Management (BLM) public lands allotment and (ii) private land that can be irrigated to support grazed meadows or grow meadow hay. Meadow hay can be consumed by cattle on the ranch but cannot be sold. Meadow hay land allows for three months of "aftermath" grazing post-harvest. In addition to forage raised on the ranch, the ranch operation has the option to purchase up to 1,000 tons of meadow hay and up to 1,000 tons of alfalfa hay.

Table 1. Land, Forage, and Water Constraints*

Element	Value
Small Ranch	5,000 BLM Acres
	625 Private Land Acres**
	937.5 Expected Water Deliveries (acre-feet)
Medium Ranch	10,000 BLM Acres
	1,250 Private Land Acres
	1,875 Expected Water Deliveries (acre-feet)
Large Ranch	15,000 BLM Acres
	1,875 Private Land Acres
	2,812.5 Expected Water Deliveries (acre-feet)
Extra Large Ranch	20,000 BLM Acres
	2,500 Private Land Acres
	3,750 Expected Water Deliveries (acre-feet)
Conversion (AUM/acre)	1 BLM
	5.7 Grazed Meadow
	3.0 Raised Meadow Hay Aftermath
Purchased Feed Constraints (tons)	1,000 Purchased Meadow Hay
	1,000 Purchased Alfalfa
Yield (tons/acre)	1.5 Raised Meadow Hay
Conversion Rate (AUMs/ton)	2.42 Meadow Hay
	2.42 Alfalfa
Water Requirements (acre-feet/acre)	1.5 Grazed Meadow
	1.5 Raised Meadow Hay

BLM = Bureau of Land Management, AUM = animal unit months

*The parameter values reported in this table were arrived at through consultation with producers in the study area and the published literature (Torell et al. 2014). The water requirements are the typical entitlements that the Humboldt River decrees allocate for grazed meadow and raised meadow hay irrigation.

**Private land can be irrigated to support grazed meadows or grow meadow hay.

The land and forage constraints are captured by equations for each land type in each year. These equations require that total annual land use by land type are at or below total available land. Forage requirements in the model are based on animal unit months (AUMs), where an AUM is defined as the forage necessary to feed a 1,000-pound cow and her suckling calf for a month. Table 1 describes the conversion rates for different land types in acres (1 acre = 4046.86 square meters) and purchased feed in tons (1 ton = 0.907 metric tonnes) to AUMs.

Inter-annual forage use is constrained by seasonal grazing restrictions on public land allotments and limited grazing potential on rangeland in winter months. The LP model assumes that cattle have access to meadow hay year-round but only have access to federal rangeland from April to September and to grazed meadows from April to December. These assumptions were arrived at through consultation with ranchers in the study area and are typical of western rangelands. Further, the model assumes aftermath grazing on meadow hay fields from October to December, where aftermath grazing is defined as grazing on hay fields after the hay has been harvested. These restrictions are captured by dividing each model year into 12 months and including a constraint that the herd's forage requirements must be met in each month given the restrictions on seasonal availability. Table 2 describes the availability of different forage types over the course of a year.

Table 2. Seasonal Forage Availability Constraints*

Forage	**Month****											
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
BLM	*	*	*	*	*	*						
Grazed Meadow	*	*	*	*	*	*	*	*	*			
Raised Meadow							*	*	*	*	*	*
Alfalfa Hay	*	*	*	*	*	*	*	*	*	*	*	*
Meadow Hay	*	*	*	*	*	*	*	*	*	*	*	*

BLM = Bureau of Land Management
* Seasonal forage availability determined through consultation with producers in the study area.
**A "*" indicates that the forage source is available in the month.

Table 3 describes the production costs per acre for the different land types and the cost per ton for different feed sources. Table 3 shows that forage from the ranch's public land allotment ($10.00/AUM), irrigated grazed meadows ($11.40/AUM), and irrigated meadow hay plus aftermath grazing ($13.12/AUM) has a substantial cost advantage compared to purchased meadow hay ($61.98/AUM) or alfalfa hay ($76.45/AUM). The production costs of $10/AUM reported in Table 3 for the ranch's public land allotment includes both the $1.35/AUM BLM grazing fee and the ranch's various herd management costs.

Water availability impacts rancher decision-making by changing the costs of forage. As reported in Table 1, the model assumes that grazed meadows and raised meadow hay both require 1.5 acre-feet per acre of irrigated water per year, which is the typical duty that the Nevada Division of Water Resources gives for grazed meadow and raised meadow hay irrigation. A reduction in the volume of irrigation water available to the ranch forces the ranch to restrict the number of acres of grazed meadows or raised meadow hay grown on the ranch and, as a result, increases the costs associated with feeding a herd of a given size. Table 3 shows that an additional acre-foot of water used to support grazed meadows reduces feed costs by $144.15 compared to purchasing meadow hay. The same water used to grow meadow hay reduces feed costs $159.60 compared to purchasing meadow hay. The higher costs savings for meadow hay is because an acre-foot of water produces 3.32 AUM of feed compared to 2.85 AUM per acre-foot for grazed meadow. This fact implies that, as modelled, the ranch will always choose to use available land and water resources to grow meadow hay rather than grazed meadow if they are able, given season availability restrictions.

Table 3. Forage and Purchased Hay Costs*

Element	Value
Production Cost ($/acre)	$10 Public Land Allotment (BLM)
	$65 Grazed Meadow
	$87 Raised Meadow Hay
Purchase Price of Hay ($/ton)	$150 Purchased Meadow Hay
	$185 Alfalfa Hay
Forage Costs ($/AUM)**	$10 BLM
	$11.40 Grazed Meadow
	$13.12 Raised Meadow Hay + Aftermath
	$61.98 Purchased Meadow Hay
	$76.45 Alfalfa Hay
Water-Forage Conversion (AUM/acre-foot)***	3.80 Grazed Meadow
	4.23 Raised Meadow Hay + Aftermath
Grazed Meadow Savings ($/acre-foot)****	$192.20 v. Purchased Meadow Hay
	$185.39 v. Alfalfa Hay
Raised Meadow Hay + Aftermath Savings ($/acre-foot)*****	$216.29 v. Purchased Meadow Hay
	$280.35 v. Alfalfa Hay

BLM = Bureau of Land Management, AUM = animal unit months
* Forage costs determined through consultation with producers in the study area.
** Public Land Allotment (BLM): 10 ($/acre) / 1 (AUM/acre) = 10.00 ($/AUM); Raised Meadow Hay: 87 ($/acre) / [1.5 (tons/acre) x 2.42 (AUM/ton) + 3(AUM/acre)] = 13.12 ($/AUM); Grazed Meadow: 65 ($/acre) / 5.7 (AUM/acre) = $11.40 ($/AUM); Purchased Meadow Hay: 150 ($/ton) / 2.42 (AUM/ton) = $61.98 ($/AUM); Alfalfa Hay: 185 ($/ton) / 2.42 (AUM/ton) = $76.45 ($/AUM).
*** Grazed Meadow: 5.7 (AUM/acre) / 1.5 (acre-feet/acre) = 3.80 (AUM/acre-foot); Raised Meadow Hay: (1.5 (tons/acre) x 2.42 (AUM/ton) + 3 (AUM/acre)) / 1.5 (acre-feet/acre) = 4.23 (AUM/acre-foot).
**** Cost-savings vs. Purchased Meadow Hay: ($61.98 - $11.40) ($/AUM) x 3.80 (AUM/acre-foot) = $192.20; Cost-savings vs. Alfalfa Hay: ($76.45 - $11.40) ($/AUM) x 4.23 (AUM/acre-foot) = $247.19.
***** Cost-savings vs. Purchased Meadow Hay: ($61.98 - $13.12) ($/AUM) x 3.80 (AUM/acre-foot) = $216.29; Cost-savings vs. Alfalfa Hay: ($76.45 - $13.12) ($/AUM) x 4.23 (AUM/acre-foot) = $280.35.

The model of the representative cow-calf ranch is analyzed under a range of assumptions on its expected water delivery. A ranch's expected water delivery is assumed to equal their typical water deliveries in an average water year given their portfolio of water rights. The expected water delivery will be less than or equal to the ranch's full duty with the more senior water rights being more fully served than junior rights in any given year. The range of expected water deliveries considered are based on interviews with stakeholders and water managers in the HRR.

There are seven classes of animals in the model: 1-2. heifer and steer calves (less than a year old) born on the ranch; 3. purchased heifer calves; 4. heifer yearlings (one-year-olds); 5. cull cows, which must be sold each year because they would not be suitable for breeding in subsequent years; 6. brood cows, which may be sold or retained for breeding in subsequent years; and 7. horses. The model assumes that the ranch maintains a 20-to-1 cow-to-bull ratio. Given this assumption, the costs of bulls are included in the model by increasing the costs of purchasing, feeding, and maintaining a cow by 1/20 the corresponding cost for a bull.

The LP model is set up so that forage demand and supply are balanced each month on an AUM basis for each animal class. Table 4 reports feed requirements in AUM equivalencies for each animal class over the course of a year. (AUM equivalencies express the feed requirements for different animal classes as a percentage of an AUM, which, as mentioned above, is defined as the forage necessary to feed a 1,000-pound cow and her suckling calf for a month.) Table 4 shows that calves' feed requirements change over the course of a year. Calving is assumed to take place in the late winter and calves are assumed to be weaned upon return to the base property in October. Table 4 also shows that the model assumes that yearlings and cows are purchased in April and that cows are sold in November.

In addition to forage requirements, the model imposes a restriction that a minimum percentage of each animal's forage requirements over the course of a year be met through alfalfa hay consumption. Table 5 reports the minimum alfalfa hay requirements for each class of animal in the model.

Table 4. Feed Requirement for Livestock in Animal Unit Month Equivalencies*

Livestock	**Month**											
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
Steer Calves – Sold	-	-	-	-	-	-	0.50	-	-	-	-	-
Heifer Calves – Sold	-	-	-	-	-	-	0.50	-	-	-	-	-
Heifer Calves – Purchased or Retained	-	-	-	-	-	-	0.56	0.56	0.56	0.56	0.56	0.56
Heifer Yearlings	0.75	0.75	0.75	0.75	0.75	0.75	1.00	1.00	1.00	1.00	1.00	1.00
Sold Cows (Cull or Brood)	1.06	1.06	1.06	1.06	1.06	1.06	1.06	-	-	-	-	-
Retained Cows	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
Horse	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25	1.25

*Feed requirements were taken from Torell et al. (2014).

Table 5. Minimum Alfalfa Hay Requirements as a Percentage of Total Forage by Animal Class*

Element	**Value**
Steer Calf	40%
Heifer Calf	40%
Purchased Heifer Calves	45%
Heifer Yearling	40%
Cow (Brood or Cull)	0%
Horse	0%

*Minimum alfalfa hay requirements taken from Torell et al. (2014).

The dynamic linkages in the model related to livestock reproduction, which are taken from Torell et al. (2014), are as follows:

1. Calves (Heifer and Steer) – The model assumes that 83% of bred cows can have either a heifer or steer calf each year. Half of calves are heifers and half are steers. Steer and heifer calf death losses are 3% per year; 4% for purchased heifer calves.

2. Heifer Yearlings – The model assumes that 90% of heifer calves become heifer yearlings. The 90% replacement rate reflects the fact that not all heifer calves are satisfactory breeding stock. Heifer yearling death losses are 0% per year.

3. Cows – The model assumes that a minimum of 10% of the cow herd must be replaced each year by retained yearlings or through the purchase of replacement heifers. The model further assumes that 10% of cows are cull cows that must be sold each year. Brood cows can also be purchased in April of each year. Brood and cull cow death losses are 2% per year.

Table 6 reports the purchase price of livestock, the annual maintenance (non-feed) costs, the average sale weight, and the sale prices associated with different classes of livestock. The model assumes that input and output prices and fixed costs remain constant across all years.

Table 6. Livestock Costs, Purchase and Sale Prices, and Sale Weight

Element	Value
Purchase Price of Livestock	$870.39 Brood Cow
Annual Maintenance Cost	$5 Steer Calf
	$5 Heifer Calf
	$74 Heifer Yearling
	$89.09 Brood Cow
	$74 Cull Cow
Average Sale Weight (100 lbs)	4.75 Steer Calf
	4.35 Heifer Calf
	9.50 Cow (Brood or Cull)
Sale Prices of Livestock (per 100 lbs)	$160 Steer Calf
	$150 Heifer Calf
	$67 Cow (Brood or Cull)

The parameter values reported in this table were arrived at through consultation with producers in the study area and the published literature (Torell et al., 2014).

Livestock sales are modeled as the ranch's sole source of income. The cash constraint is that at the end of every year the ranch must have $10,000 cash reserved in the bank after all variable and fixed production costs, loan obligations, and the family living expenses have been paid. The model assumes that excess cash in one year is transferred to the next year. The model also allows for annual borrowing, with all debt obligations paid in full by the end of the 40-year planning horizon. Table 7 reports the financial assumption for the ranch. Table 8 provides the initial herd size for the medium size (1,250 acre) cow-calf ranch, which is a major portion of the ranch's initial wealth.

Table 7. Ranch Financial Assumptions

Element	Value
Fixed Ranch Expenses	$20,000 for Small Ranch
	$40,000 for Medium Ranch
	$60,000 for Large Ranch
	$80,000 for Extra Large Ranch
Family Living Allowance	$35,000
Initial Wealth	$0
Off-Ranch Income	$0
Minimum Balance in Savings	$10,000
Discount Rate*	7%
Short Term Borrowing Rate	10%
Interest Returned on Savings	3%

*The model assumes the rancher discounts future profits at 7% per year relative to current year profits when formulating their optimal production plan.

Table 8. Medium Size Cow-Calf Ranch: Initial Herd Size Assumptions*

Element	Head of Cattle
Steer Calf	468
Heifer Calf	328
Purchased Heifer Calves	140
Heifer Yearlings	135
Cows	993
Culled Cows	113
Horses	30

* Initial herd size assumptions were chosen through consultation with producers in the study area.

Alfalfa Hay Farm Model

The multi-period LP model was set up so that the representative alfalfa hay farm maximizes the net present value of discounted annual profits over a 40-year planning horizon by choosing the number of acres of alfalfa hay to plant each year, whether to continue to irrigate established fields, and whether to plant winter wheat or let the field sit fallow in years when crop rotation dictates that alfalfa cannot be planted. The alfalfa LP model was constrained by available land, available water, and cash-flow through the inclusion of a minimum cash reserve requirement.

The farm grows two crops: alfalfa hay and winter wheat. Both crops are assumed to require 3 acre-feet/acre of irrigation water annually, which are the typical duties that the Nevada Division of Water Resources gives for irrigated alfalfa hay. The model assumes that the farm has enough land suitable for production that in years when it receives its expected water delivery, all of its irrigable land gets 3 acre-feet per acre of water. The model requires that 4 acre-feet/acre of water is used to plant a new field of alfalfa. The additional acre-foot of water is required to wet the soil prior to planting. This additional water requirement for planting is typical for operations in the study region and other regions in the arid West. In years when the farm receives less than its expected water delivery, irrigated acreage is constrained by water availability. Table 9 gives the model assumptions on total acreage and expected water deliveries for the four farm size categories analyzed in this article.

Table 9. Land and Water Constraints

Element	Value
Small Farm	1,250 Irrigated Acres
	3,750 (acre-feet) Expected Water Deliveries
Medium Farm	2,500 Irrigated Acres
	7,500 (acre-feet) Expected Water Deliveries
Large Farm	3,750 Irrigated Acres
	11,250 (acre-feet) Expected Water Deliveries
Extra Large Farm	5,000 Irrigated Acres
	15,000 (acre-feet) Expected Water Deliveries
Water Requirements	3 (acre-feet/acre) Alfalfa*
	3 (acre-feet/acre) Winter Wheat
Crop Rotation & Fallowing	6 Years of Alfalfa Hay Harvests must be followed by 1 year of Fallow or Winter Wheat Planting

*The model requires that 4 acre-feet/acre of water is used to plant a new field of alfalfa after 3 or more years of less than 20% of expected water deliveries. The additional acre-foot of water is required to wet the soil prior to planting.

Table 10. Production Yields, Costs, and Output Prices

Element	Value
Yields (tons/acre)	6.4 Alfalfa Hay Years 1&2
	6.0 Alfalfa Hay Years 3–6
	1.0 Winter Wheat
Production Cost ($/acre)	$325.00 Alfalfa Hay in Year 1
	$150.00 in Alfalfa Hay in Years 2–6
	$120.00 Winter Wheat
Output Prices ($/ton)	$199.25 Alfalfa Hay
	$130.00 Winter Wheat
Profits per Acre ($/acre)*	$950.20 Alfalfa Hay in Year 1
	$1,125.20 Alfalfa Hay in Year 2
	$1,045.50 Alfalfa Hay in Years 3–6
	$10.00 Winter Wheat
Profits per Acre-Foot of Water ($/acre)	$316.73 Alfalfa Hay in Year 1
	$375.07 Alfalfa Hay in Year 2
	$348.50 Alfalfa Hay in Years 3–6
	$3.33 Winter Wheat

**Alfalfa hay (Year 1)*: 199.25 ($/ton) sales price x 6.4 (ton/acre) yield – 325.00 ($/acre) production costs = 920.20 ($/acre) net return. *Alfalfa hay (Year 2)*: 199.25 ($/ton) sales price x 6.4 (ton/acre) yield – 150.00 ($/acre) production costs = 1,125.20 ($/acre) net return. *Alfalfa hay (Years 3-6)*: 199.25 ($/ton) sales price x 6.0 (ton/acre) yield – 150.00 ($/acre) production costs = 1,045.50 ($/acre) net return. *Winter wheat*: 120.00 ($/ton) sales price x 1 (ton/acre) yield – 110.00 ($/acre) production costs = 10.00 ($/acre) net return.

The model assumes that alfalfa hay can only be grown on the same plot for six consecutive years. In the seventh year, the plot can be planted with winter wheat or left fallow. This seven year crop-rotation cycle is typical for alfalfa hay operations in the study region and throughout the western United States. This crop-rotation assumption means that the farm will be land constrained in years when the alfalfa hay planted in previous years takes up a significant portion of the available acreage and the farm is not water constrained. In these years, the lack of available land will force the farm to use its water to plant winter wheat as a cover crop on fallowed land for an annual net return of $10 per acre rather than plant alfalfa hay for an annual net return of $920 per acre.

Table 10 gives the assumptions concerning crop yields, production costs, and output prices. The values reported in Table 10 come from our interviews with stakeholders, as well from the published literature (Torell et al., 2014). Table 10 shows that the linkages between years in the model are related to the fact that after an alfalfa field is established, it can be continued to be harvested for six years at lower production costs before it must be left fallow for a year.

The model assumes that the farmer has three decisions to make in each year:

1. *Planting* – The farmer must choose how many new acres of alfalfa hay to plant given their land and water availability constraints.

2. *Irrigating Established Alfalfa Fields* – The farmer must choose whether to continue to irrigate and harvest established alfalfa hay fields or to rip them out and let them sit fallow. The farmer will only stop irrigating established alfalfa fields due to water availability constraints.

3. *Winter Wheat versus Fallow* – Whether or not to plant winter wheat after six years of alfalfa harvest or let the field sit fallow. The farmer will only plant winter wheat in years when they have water available to establish new alfalfa fields but cannot do so due to land constraints.

Table 11 shows the net present value of profits for an acre currently in different vintages of alfalfa hay, winter, and fallow assuming the farm receives its expected water deliveries for all 40 years in its planning horizon. These net present value figures follow directly from the assumptions on prices, water requirements, and yields reported in Tables 9 and 10. Table 11 shows that the newer vintages of alfalfa hay have higher net present values of profits than older vintages, with newly planted alfalfa hay having the highest net present value. This fact implies that the farm will respond to water shortages by first ripping out the older vintages of alfalfa hay before they stop planting new fields.

Alfalfa hay and winter wheat sales are the farm's two sources of income. The cash constraint is that at the end of every year the farm must have $10,000 cash reserved in the bank after all variable and fixed production costs, loan obligations, and family living expenses have been paid. The model assumes that excess cash in one year is transferred to the next year. The model also allows for annual borrowing, with all debt obligations paid in full by the end of the 40-year planning horizon. Table 12 reports the financial assumptions for the alfalfa hay farm.

The model assumes that at the start of year 1 the farm has established fields of alfalfa hay carried over from previous years. Table 13 gives the initial conditions for the farm in terms of total acres of established alfalfa hay of different vintages, the number of acres available for planting, and the number of acres that must be fallowed the first year of the analysis.

Table 11. Net Present Value per Acre: Land Use in Year 1

Element	Net Present Value ($/Acre)
Alfalfa Hay 1st Year	$12,844.26
Alfalfa Hay 2nd Year	$12,817.00
Alfalfa Hay 3rd Year	$12,617.21
Alfalfa Hay 4th Year	$12,481.15
Alfalfa Hay 5th Year	$12,335.56
Alfalfa Hay 6th Year	$12,179.78
Winter Wheat	$12,013.09
Fallow	$11,988.94

Table 12. Alfalfa Farm Financial Assumptions

Element	Value
Fixed Farm Expenses*	$300,000 for Small Farm
	$600,000 for Medium Farm
	$900,000 for Large Farm
	$1,200,000 for Extra Large Farm
Family Living Allowance	$35,000
Initial Saving Balance	$0
Off Ranch Income	$0
Minimum Balance in Savings	$10,000
Discount Rate	7%
Short-Term Borrowing Rate	10%
Interest Returned on Savings	3%

*The model assumes that the fixed costs are reduced by 25% after two or more years of less than 20% of expected water deliveries. The lower fixed costs after two or more years of lower than expected water deliveries capture the reduction in employment and other inputs on the farm when acres planted are reduced due to lack of water.

Table 13. Initial Conditions: Land Use at the Start of Year 1

Element	Value
Land Available for New Planting	1/7 Total Acreage
Alfalfa Hay 2nd Year	1/7 Total Acreage
Alfalfa Hay 3rd Year	1/7 Total Acreage
Alfalfa Hay 4th Year	1/7 Total Acreage
Alfalfa Hay 5th Year	1/7 Total Acreage
Alfalfa Hay 6th Year	1/7 Total Acreage
Must be left Fallow or Winter Wheat	1/7 Total Acreage

Economic Cost of Unanticipated Water Supply Reductions

The two LP models in this article were used to calculate the loss in profits that an operation will sustain in the current year, as well as in subsequent years, from not receiving a portion of their water allocation due to an unanticipated reduction water supply such as can occur as a result of conflict or drought. To calculate the loss in profits from a single year of unanticipated water reduction, each model is run twice: once when the operation receives its expected water delivery each year over the 40-year planning horizon and once when the operation receives less than their expected water delivery in the first year of the 40-year planning horizon and then receives their expected water delivery in all subsequent years. The economic value of the water not received is then calculated as the difference in the discounted present value of profits between the two model runs.

More formally, let us define $\pi_t(w_t^c)$ as the profits the operation receives in year *t* assuming that the operation (i) received its expected water deliveries in all years leading up to year *t*; (ii) receives reduced water deliveries, w_t^c, in year *t*; and (iii) anticipates receiving its expected water deliveries in all subsequent years, $\widehat{w}_s$, $s = t + 1, \ldots, 40$. We define $\pi_{t+s}(w_t^c)$ as the operations profits in year *t*+*s* (i.e., *s* years after unexpected water supply reduction in year *t*) assuming that the operation experienced a water supply reduction in year *t* and received its expected water deliveries in all other years. This notation can be expanded to two or more years of water supply reduction. For example, for a two-year reduction of water supply, $\pi_{t+1}(w_t^c, w_{t+1}^c)$ are profits in the second year of water reduction (year $t + 1$) and $\pi_{t+1+s}(w_t^c, w_{t+1}^c)$ are profits *s* years after the end of the water supply reduction period.

Using this notation, the present value of the operation's profits assuming reduced water deliveries, w_t^c, in year *t* is

$$V_t(w_t^c) = \sum_{s=1}^{\infty} \frac{1}{(1+r)^{s-1}} \pi_{t+s-1}(w_t^c) = \sum_{s=1}^{\infty} \delta^{s-1} \pi_{t+s-1}(w_t^c) \qquad (1)$$

where *r* is the discount rate used by the operation and δ is the discount factor. The loss in profits from a water supply reduction lasting a single year when the operation receives w_1^c rather than its expected water deliveries, $\widehat{w}_1$, is given by

$$\begin{aligned} V_1(\widehat{w}_s) - V_1(w_1^c) &= \pi_1(\widehat{w}_s) + \delta V_2(\widehat{w}_2) - [\pi_1(w_1^c) + \delta V_2(w_1^c, \widehat{w}_2)] \\ &= [\pi_1(\widehat{w}_s) - \pi_1(w_1^c)] + \delta[V_2(\widehat{w}_2) - V_2(w_1^c, \widehat{w}_2)]. \end{aligned} \qquad (2)$$

The first term in the equation is the loss in profits in the year that water supply reduction occurs; the second term is the change in profits in years after the one-year water supply reduction has ended related to adjustments the operation made in response to the reduced water deliveries.

The results section will show that this second term in Equation (2) is positive for the cow-calf ranch. This is because the years of reduced water cause the ranch to sell breeding cows, which reduces new calf births in future years and, thereby, future profits from livestock sales. As such, the loss in present value of profits for the cow-calf ranch from a one-year reduction in water supply will be greater than the loss in profits in the year water reduction is experienced. In contrast, the results show that the second term in Equation (2) is negative for the alfalfa hay farm. This is because the reduction in acres of alfalfa planted in reduced water supply years relaxes the farm's land constraint and allows the farm to plant more new alfalfa in years after the water supply reduction has ended.

This procedure for calculating the economic costs of unexpected water supply reductions assumes that the operation (i) knows the current year's water deliveries when making herd-management and/or planting decisions (perfect foresight over an irrigation season) and (ii) will receive its expected water delivery in all subsequent years. Hence, the model is not forward-looking and does not consider the possibility that low current water deliveries will change the rancher's expectations about the volume of future deliveries.

For multi-year reductions in water deliveries, two model runs must be performed for each additional year of reduced water supply. For example, to calculate the economic value of water not received due to the second year of reduced water supply, the first model run assumes that the operation receives it expected water delivery in the second year and in all subsequent years. The second model run assumes that the operation receives less than their expected water delivery in the second year and then receives their expected water delivery in all subsequent years. In both runs, the initial conditions in the second year are based on the operation having received less than its expected water delivery in the first year. The economic value of the water not received in the second year is then calculated as the difference in the present value of profits between the two model runs. This procedure implies that the economic cost of water supply reductions in the second year is net of the economic cost of water supply reductions experienced in the first year.

Equation (2) can be generalized to express the present value of the loss in profits from a two-year water supply reduction. When the operation experiences two years of water supply reduction, w_1^c and w_2^c, rather than its expected water deliveries, $\widehat{w}_1$ and $\widehat{w}_2$, the present value of the loss in profits (expressed in Year 1 dollars) is given by

$$
\begin{aligned}
&V_1(\widehat{w}_1) - V_1(w_1^c) + \delta[V_2(w_1^c, \widehat{w}_2) - V_2(w_1^c, w_2^c)] \\
&\quad = [\pi_1(\widehat{w}_1) - \pi_1(w_1^c)] + \delta[V_2(\widehat{w}_2) - V_2(w_1^c, \widehat{w}_2)] + \delta[V_2(w_1^c, \widehat{w}_2) - V_2(w_1^c, w_2^c)] \\
&\quad = [\pi_1(\widehat{w}_1) - \pi_1(w_1^c)] + \delta[V_2(\widehat{w}_2) - V_2(w_1^c, w_2^c)] \\
&\quad = [\pi_1(\widehat{w}_1) - \pi_1(w_1^c)] + \delta\big[\pi_2(\widehat{w}_2) - \pi_1(w_1^c, w_2^c) + \delta[V_3(\widehat{w}_3) - V_3(w_1^c, w_2^c, \widehat{w}_3)]\big] \\
&\quad = [\pi_1(\widehat{w}_1) - \pi_1(w_1^c)] + \delta[\pi_2(\widehat{w}_2) - \pi_1(w_1^c, w_2^c)] \\
&\qquad\qquad + \delta^2[V_3(\widehat{w}_3) - V_3(w_1^c, w_2^c, \widehat{w}_3)],
\end{aligned} \tag{3}
$$

where $V_1(\widehat{w}_1) - V_1(w_1^c)$ is the present value of the loss of profits in year 1 and $V_2(w_1^c, \widehat{w}_2) - V_2(w_1^c, w_2^c)$ is the present value of the additional loss in profits in year 2 given water supply reduction in year 1, both calculated according to the procedure described above. Similar to Equation (2), the first two terms in Equation (3) are the loss in profits that occur in the two years that water supply reduction occurs; the third term is change in profits in years after the two-year water supply reduction has ended related to adjustments the operation made in response to the reduced water deliveries.

Following from Equation (3), the present value of the loss in profits from a water supply reduction lasting T years defined by $w_1^c, w_2^c, \dots, w_1^T$, is given by

$$\sum_{t=1}^{T} \delta^{t-1} [\pi_t(\widehat{w}_t) - \pi_t(w_1^c, \ldots, w_t^c)] + \delta^{T+1}[V_{T+1}(\widehat{w}_{T+1}) - V_{T+1}(w_1^c, \ldots, w_T^c, \widehat{w}_{T+1})]. \tag{4}$$

Equation (4) illustrates that the insight from Equations (2) and (3) holds for multi-year water supply reductions. The first term in Equation (4) captures the loss in profits that occur over the water supply reduction period and the second term captures the change in profits in the post-reduction years related to adjustments the operation made in response to the reduced water deliveries during the water supply reduction period.

RESULTS

This section presents the results from the multi-period LP models of representative cow-calf ranches and alfalfa hay farms in the middle and lower HRR. The two LP models are used to estimate the economic value of an acre-foot of water not received based on the reduction in the present value of the operation's profits from not receiving the water. The results focus on how the economic value of an acre-foot of water not received varies with (i) the *intensity* of the water supply reduction (volume of water not received); (ii) the *duration* of water supply reduction (number of consecutive years of lower than expected deliveries); and (iii) whether the water supply reduction occurs during a period of lower than expected water supply (i.e., *drought)*.

The results in this section focus on the medium size cow-calf ranch (1,250 irrigated acres) and the medium size alfalfa hay farm (2,500 irrigated acres). We limit our focus to the 1,250-acre ranch and the 2,500-acre farm because our assumption of constant returns-to-scale production technology means that, in most water supply reduction scenarios, the loss of ranch/farm profits from a given percentage reduction in water deliveries scales linearly with ranch/farm size.

In the ranch/farm models presented in this article, ranch/farm size only impacts profitability through the relationship between size and fixed costs. Tables 7 and 12 show that while fixed costs associated with production increase linearly with ranch/farm size, family living allowance is independent of size. This assumption means that, all else equal, fixed costs will be a higher portion of total costs for smaller ranches/farms. Fixed costs only impact the model results in scenarios where the ranch/farm earns negative profits in one or more years and must incur debt. When these conditions are reached, the per-acre-foot cost of water not received is higher for smaller ranches/farms due to their proportionately higher fixed costs and, hence, their proportionately greater debt burden. Model results (not reported) show that negative profits only occur when the cow-calf ranch receives 50% or less of its expected water deliveries for one or more year and when the alfalfa hay farm receives 20% or less of its expected water deliveries for one or more years. It is only in these extreme scenarios where the per-acre-foot cost of water supply reduction predicted by the model differs between ranches/farms of different sizes.

The appendix presents results for the small, large, and extra-large cow-calf ranches (625, 1,875, and 2,500 irrigated acres) and for the small, large, and extra-large alfalfa hay farms (1,250, 3,750, and 5,000 irrigated acres).

Cow-Calf Ranch: Results

Table 14 reports the annual values for herd size, forage use, revenues, and costs for the medium-sized cow-calf ranch (1,250 irrigated acres) assuming expected water deliveries are 1,875 acre-feet per year. Table 14 also reports annual values for these variables when the ranch's expected water deliveries are reduced by 20% for 2, 4, 6, 8, and 10 years.

Table 14 illustrates how the ranch's production and livestock marketing activities adjust to deal with a reduction in water deliveries. Table 14 illustrates that reduced water deliveries impact ranch profits through two channels. First, when the ranch is water constrained, it is forced to reduce acres irrigated of raised meadow hay. This, in turn, forces the ranch to purchase meadow hay at a higher per AUM price ($61.98) than meadow hay raised on the ranch ($13.12), thereby increasing average feed costs. Second, the increase in feed costs forces the rancher to reduce their herd size in order to avoid accumulating debt in water supply reduction years. This reduction in herd size limits the number of calves born in years following the water supply reduction years, which further reduces the present value ranch profits.

Table 14. Medium Size Cow-Calf Ranch: Annual Forage Use and Herd Size under Expected Water Deliveries and with 20% Reduction (375 Acre-Foot) in Water Deliveries

Element	Baseline	2nd Year	4th Year	6th Year	8th Year	10th Year
Water Delivered (AF)						
Total	1,875	1,500	1,500	1,500	1,500	1,500
Forage Use (AUYs)						
BLM	4,748	4,514	4,423	4,331	4,305	4,189
Grazed Meadow	0	0	0	0	0	0
Raised Meadow Hay: Aftermath Grazing	2,250	1,800	1,800	1,800	1,800	1,800
Raised Meadow Hay	2,723	2,178	2,178	2,178	2,178	2,178
Purchased Meadow Hay	0	940	829	711	522	353
Alfalfa Hay	272	249	242	229	211	206
Total	9,993	9,681	9,472	9,249	9,016	8,726
*Livestock (AUYs)**						
Steer Calves	141	141	137	134	128	122
Heifer Calves	99	100	98	100	97	88
Purchased Heifer Calves	247	239	234	201	182	196
Heifer Yearlings	1,105	799	783	771	839	839
Brood Cows	7,455	7,471	7,300	7,133	6,872	6,599
Cull Cows	496	481	470	460	448	432
Horses	450	450	450	450	450	450
Total	9,993	9,681	9,472	9,249	9,016	8,726

An animal unit year (AUY) is defined as the forage necessary to feed a 1,000-pound cow and her suckling calf for a year. As such, an AUY = 12*AUM.
*AUYs of forage for cows includes the forage required to maintain bulls at a 20-to-1 bull-to-cow ratio.

Table 15 reports the annual values for variable costs, fixed costs, and revenues for the medium size cow-calf ranch assuming the ranch receives its expected annual water deliveries, as well as 20% reduction in water deliveries for 2, 4, 6, 8, and 10 years. Table 15 shows that water reductions, by provoking reductions in herd size, reduce revenues from sales of steer and heifer calves and mature cows. Table 15 also illustrates that despite higher average feed costs, the 20% reduction in water deliveries leads to lower total variable costs because of the smaller herd size.

Table 15. Medium Size Cow-Calf Ranch: Annual Financials under Expected Water Deliveries and with 20% Reduction (375 Acre-Foot) in Water Deliveries

Element	Baseline	2nd Year	4th Year	6th Year	8th Year	10th Year
Variable Costs ($)						
BLM*	100,000	100,000	100,000	100,000	100,000	100,000
Grazed Meadow	0	0	0	0	0	0
Raised Meadow Hay (aftermath grazing)	65,250	52,200	52,200	52,200	52,200	52,200
Purchased Meadow Hay	0	58,235	51,425	44,090	32,360	21,861
Alfalfa Hay	20,784	19,042	18,535	17,512	16,134	15,719
Livestock Maintenance Costs**	65,223	63,591	62,151	60,809	59,136	56,929
Brood Cow Purchases	0	0	0	0	0	0
Total	251,257	293,068	284,310	274,610	259,830	246,709
Fixed Costs ($)						
Total	40,000	40,000	40,000	40,000	40,000	40,000
Revenues ($)						
Steer Calves Sold	203,328	203,484	198,637	194,094	184,605	176,178
Heifer Calves Sold	122,372	124,139	121,133	124,172	120,063	109,745
Cows Sold (Brood and Cull)	41,421	40,146	39,239	38,368	37,397	36,059
Total	367,120	367,768	359,009	356,633	342,065	321,982
Balance Sheet ($)						
Profits* **	75,863	34,700	34,699	42,023	42,235	35,273
Family Living Allowance	35,000	35,000	35,000	35,000	35,000	35,000

BLM = Bureau of Land Managment

*The ranch costs for their 10,000-acre public land allotment (grazing fees plus management costs) are assumed to not vary with changes in herd size.

**Includes annual maintenance costs from all six classes of animals in the model: heifer and steer calves; heifer yearlings; mature cows and bulls; and horses

*** Profits = Total Revenues – Total Variable Costs – Fixed Costs.

Figure 1 reports the present value of annual profits over a 40-year planning horizon for a 1,250-acre cow-calf ranch under a range of assumptions about the intensity and duration of an unanticipated water supply reduction. In Figure 1, the colored dots represent the intensity of water supply reduction and the x-axis represents the duration of water supply reduction. As explained in the methods section, the present value of profits are calculated assuming the farm encounters one or more years of unanticipated reductions in water deliveries followed by receiving its expected water deliveries in subsequent years. Further, the present value of profits reported in Figure 1 are net of the family's $35,000 per year family living allowance and are discounted to Year 1.

Figure 1 shows that the cow-calf ranch is profitable when it receives its expected water deliveries. The present value of profits predicted by the model when the operation receives its expected water deliveries are $2,566,592. This level of profits means that the ranch can sustain reduced water deliveries of significant intensity and duration without being forced to shut down. Figure 1 shows when the increase in average feed costs leads the present value of profits to be negative if it receives 20% of its expected water deliveries (375 acre feet) for a period of 7 years or more. When the net present value of farm profits is negative, the operation would not be able to earn enough profits over the 40-year planning horizon to pay the debts that it incurred over the water supply reduction period and will be forced to shut down. Water supply reduction of an intensity of greater than 80% are not depicted in Figure 1.

When the ranch is forced to shut down, the total cost of the water supply reduction should be calculated as the present value of profits under expected water deliveries ($2,566,592 in the case of the 1,250-acre ranch) minus the sale value of remaining livestock, heavy equipment and other ranch capital, as well as the value of the land, residence, and other structures on the ranch property. In the case of shutdown, the value of water not received should be made on the basis of these quantities and should not be calculated only on the basis of acre-foot of water not received. This article recommends that the cost of water supply reduction where the operation shuts down should be analyzed on an operation-by-operation basis. The analysis in this article is designed to calculate the value of the water not received assuming that the operation is able to remain in operation.

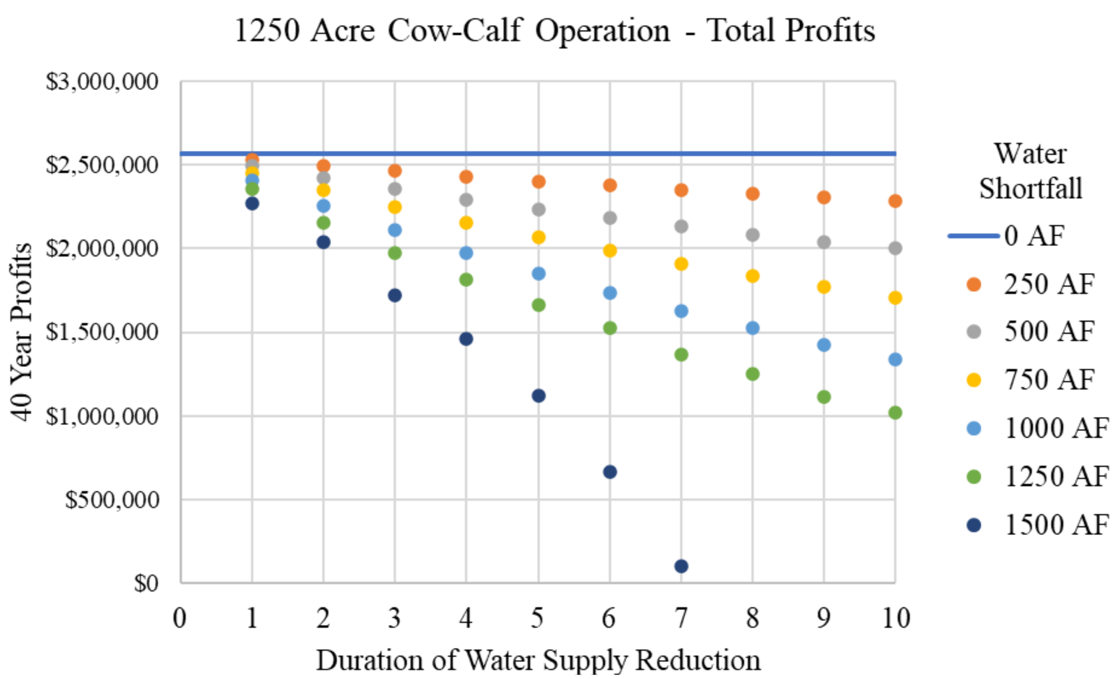

Figure 1. Medium Size Cow-Calf Ranch: Present Value of Farm Profits

Table 16 reports the *per-acre-foot* compensation for water not received due to conflict for the 1,250-acre cow-calf ranch. Table 17 reports the *total* value of water for the 1,250-acre cow-calf ranch assuming an unanticipated 10% reduction in water deliveries (187.5 acre feet). For multi-year unanticipated reductions in water supply, each cell in Tables 16 and 17 report results for the *additional* value of water not received in each year of reduction. The procedure for calculating the additional value of water not received in each year of water supply reduction is described in the Economic Cost of Unanticipated Water Supply Reductions section. Also from this section, the present value of the loss in profits (expressed in Year 1 dollars) from, for example, five years of 20% water losses requires summing the first five cells in the 20% "percent shortfall" row in Table 17 using a discount rate of 7%.

Table 16 shows that the per-acre-foot costs of water not received is higher than the $216.29 additional per-acre-foot feed cost of purchasing meadow hay rather than growing it on the ranch from Table 3. The reason for this result is that, as illustrated above in Tables 14 and 15, the reduction in water leads to the ranch selling breeding cows to avoid accumulating new debt. The sale of breeding cows limits its profits in future years by reducing new calf births and, thereby, future livestock sales. The difference in the value of an acre-foot of water and the cost of additional feed grows as the water shortage increases in magnitude and duration. The results in Table 16 suggest that the compensation for water not received for a cow-calf ranch should be set at a price slightly greater than the increase in feed costs.

Table 16 shows that the per-acre-foot costs of water not received increase significantly when the ranch receives less than 50% of its water. In these scenarios, the ranch is losing money in water shortage years and, as a result, must assume debt in order to remain in operation. These results indicate that while the cost of water supply reductions is driven by cattle production costs and herd dynamics when the ranch remains profitable; in years where the ranch loses money, the cost of water supply reductions also depends critically on the interest rate on the debt assumed by the ranch. The model predicts that the ranch will have accumulated significant debt in extreme water supply reduction years because the ranch is assumed to make decisions with the expectation it will receive its expected water deliveries, and, hence, return to profitability in the next year.

Table 16. Medium Size Cow-Calf Ranch: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent	Water	Duration of Water Supply Reduction									
Shortfall	Shortfall	1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$215	$214	$215	$216	$216	$216	$216	$216	$216	$216
10%	187.5 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
20%	375 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
30%	562.5 AF	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280
40%	750 AF	$288	$282	$286	$285	$286	$286	$287	$287	$288	$288
50%	937.5 AF	$292	$292	$475	$292	$583	$605	$811	$960	$1,217	$1,524
60%	1125 AF	$1,058	$291	$662	$1,084	$1,494	$1,857	$2,516	**Shutdown**	**Shutdown**	**Shutdown**

Table 17. Medium Size Cow-Calf Ranch: Total Cost of a 10% (187.5 Acre-Foot) Reduction in Water Deliveries on Top of Existing Shortfalls in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$40,313	$40,125	$40,313	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500
10%	187.5 AF	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500
20%	375 AF	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500
30%	562.5 AF	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500
40%	750 AF	$54,000	$52,875	$53,625	$53,438	$53,625	$53,625	$53,813	$53,813	$54,000	$54,000
50%	937.5 AF	$54,750	$54,750	$89,063	$54,750	$109,313	$113,438	$152,063	$180,000	$228,188	$285,750
60%	1125 AF	$198,375	$54,563	$124,125	$203,250	$280,125	$348,188	$471,750	**Shutdown**	**Shutdown**	**Shutdown**

The results in Table 16 do not suggest, however, that the per-acre-foot compensation for a water supply shortage should be increased in high shortage years where the ranch loses money. This is because the additional cost of water shortage is due to the ranch accumulating debt. The compensation payments would, in principle, allow the rancher to remain in operation without incurring new debts so that the appropriate per-acre-foot compensation would correspond to the case where the ranch remains profitable in water supply reduction years.

Alfalfa Hay Farm: Results

Table 18 reports the annual values for acres planted of alfalfa hay of different vintages and winter wheat on the medium size alfalfa hay farm (2,500 irrigated acres) assuming the farm receives its expected annual water deliveries in the current year. Table 18 also reports values of acres planted if the farm's water deliveries are reduced by 30% for 2, 4, 6, 8, and 10 years.

Table 18 shows that when the farm is water constrained, the farmer will first stop planting winter wheat as a cover crop and then, for more significant water shortages, will rip out alfalfa fields starting with the oldest vintage (6th year) and continuing in decreasing order of vintage until the water availability constraint is satisfied. The last thing the farmer will do when facing a water shortfall is pull back on planting new alfalfa fields. The reason for this, as shown on Table 11, is that newly planted alfalfa hay has the highest net present value of profits per acre. Appendix Tables A13 and A14 present how the adjustments the alfalfa hay farm makes to reduced water deliveries changes if alfalfa planting costs. The increased planning cost makes it so that the farm does not prioritize planting new alfalfa over maintaining existing fields.

Table 18 illustrates that reduced water deliveries impact farm profits through two channels. First, when the farm is water constrained, the farmer plants fewer acres of winter wheat and alfalfa hay, which reduces profits. Table 10 reports the per acre profits for winter wheat and different vintages of alfalfa hay. Second, the reduction in acres planted means that more land is fallowed in water supply reduction years. The increase in acres fallowed means that the farmer will be able to plant more alfalfa hay in years after the water supply reduction than they would had the reduction not occurred (put differently, water supply reduction relaxes the farms land constraint). Given that newly planted alfalfa hay has the highest net present value of profits per acre (Table 11), the increase in land available for planting means that the present value of profits for the farm are higher post-reduction than they would be if the water supply reduction never occurred.

Table 18. 2,500-Acre Alfalfa Hay Farm: Acres Planted under Expected Water Deliveries and with 30% Reduction (3,000 Acre-Foot) in Water Deliveries

Element	Baseline	2nd Year	4th Year	6th Year	8th Year	10th Year
Alfalfa Hay 1st Year	357	750	750	750	750	750
Alfalfa Hay 2nd Year	357	357	750	750	750	750
Alfalfa Hay 3rd Year	357	357	250	250	250	250
Alfalfa Hay 4th Year	357	286	0	0	0	0
Alfalfa Hay 5th Year	357	0	0	0	0	0
Alfalfa Hay 6th Year	357	0	0	0	0	0
Winter Wheat	357	0	0	0	0	0
Total Crops	2,500	1,750	1,750	1,750	1,750	1,750
Fallow	0	750	750	750	750	750
Total	2,500	2,500	2,500	2,500	2,500	2,500

Table 19 reports the annual values for variable costs, fixed costs, and revenues for representative alfalfa hay farm assuming the farm receives its expected annual water deliveries in the current year, as well as assuming the farm's water deliveries are reduced by 30% for 2, 4, 6, 8, and 10 years. Table 19 shows that water shortages reduce revenues from alfalfa hay, eliminate revenues from winter wheat, and reduce annual profits.

Table 19. Alfalfa Hay Farm: Annual Financials under Expected Water Deliveries and with 30% Reduction (3,000 Acre-Foot) in Water Deliveries

Element	Baseline	2nd Year	4th Year	6th Year	8th Year	10th Year
Variable Costs ($)						
Alfalfa Hay 1st Year	116,071	243,750	243,750	243,750	243,750	243,750
Alfalfa Hay Years 2-6	267,857	150,000	150,000	150,000	150,000	150,000
Winter Wheat	42,857	0	0	0	0	0
Total	426,786	393,750	393,750	393,750	393,750	393,750
Fixed Costs ($)						
Total	600,000	600,000	600,000	600,000	600,000	600,000
Revenues ($)						
Alfalfa Hay Sold	2,618,714	2,180,364	2,211,675	2,211,675	2,211,675	2,211,675
Winter Wheat Sold	46,429	0	0	0	0	0
Total	2,665,143	2,180,364	2,211,675	2,211,675	2,211,675	2,211,675
Balance Sheet ($)						
Profits*	1,638,357	1,186,614	1,217,925	1,217,925	1,217,925	1,217,925
Family Living Allowance	35,000	35,000	35,000	35,000	35,000	35,000

* Profits = Total Revenues – Total Variable Costs – Fixed Costs.

Figure 2 reports the present value of annual profits over a 40-year planning horizon for a 2,500-acre alfalfa hay farm under a range of assumptions about the intensity and duration of unanticipated water supply reduction. In Figure 2, the colored dots represent the intensity of water supply reduction and the x-axis represents the duration of water supply reduction. The present value of profits is net of the family's $35,000 per year family living allowance and is discounted to Year 1.

Figure 2 shows that the alfalfa hay farm is profitable when it receives its expected water deliveries. The present value of profits predicted by the model when the operation receives its expected water deliveries are $21,375,481. This level of profits means that the farm can sustain reduced water deliveries of significant intensity and duration without being forced to shut down. Figure 2 show that the farm only reaches the point where present value of profits is negative if it does not receive any water for a period of 7 years or more. When the net present value of farm profits is negative, the operation does not earn enough profits over the 40-year planning horizon to pay the debts that it incurs over the water supply reduction period and shuts down.

As considered for the case of the cow-calf ranch, when the alfalfa hay farm is forced to shut down, the total cost of the water supply reduction is the present value of profits under expected water deliveries ($21,375,481 in the case of the 2,500-acre farm) minus the sale value of heavy equipment on the farm, as well as the value of the land, residence, and other structures on the property. Like for the cow-calf operation, this article recommends the cost of water supply reduction where the alfalfa hay operation shuts down be analyzed on an operation-by-operation basis.

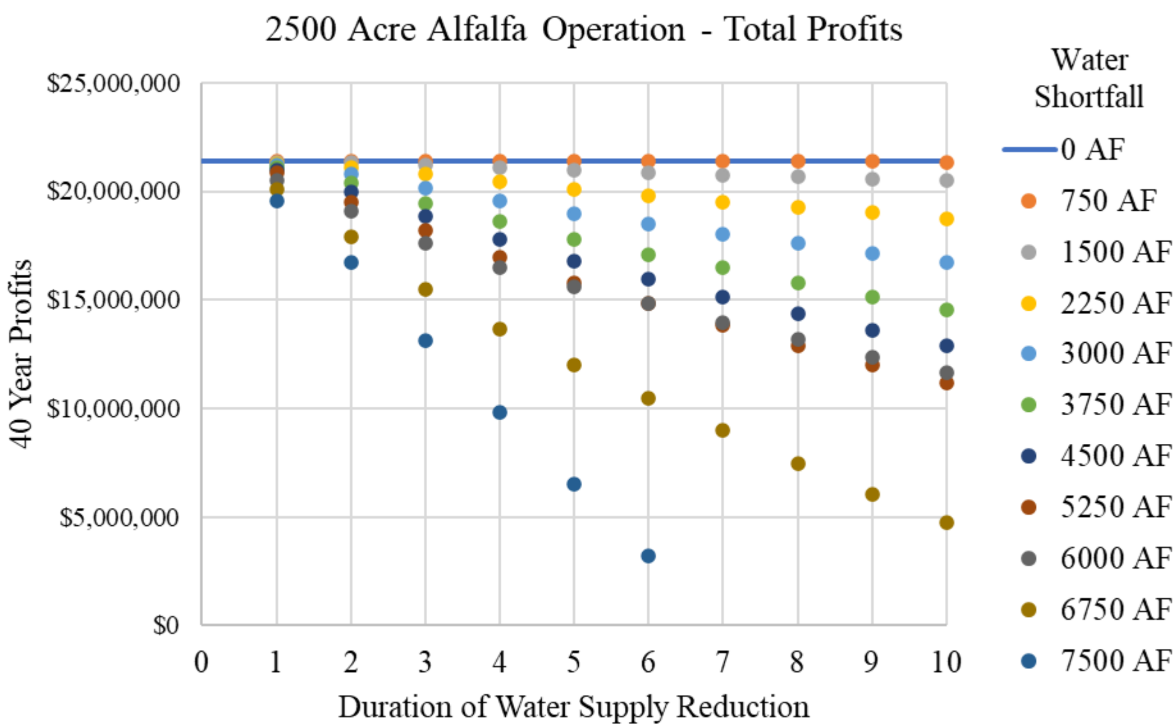

Figure 2. Present Value of Profits: 2,500-Acre Alfalfa Hay Farm

Table 20 reports the *per-acre-foot* compensation for water not received due to conflict for the 2,500-acre farm. Table 21 reports the *total* value of water not received for the 2,500-acre farm assuming an unanticipated 10% reduction in water deliveries. For multi-year reduction in water supply, each cell in Table 20 and 21 reports results for the *additional* value of water not received in each year of reduction. The procedure for calculating the additional value of water not received in each year of water reduction supply is described in the Economic Cost of Unanticipated Water Supply Reductions section.

Table 20 shows that in most water supply reduction scenarios, the per-acre-foot costs of water not received is lower than the annual per-acre-foot profits from planting alfalfa hay reported in Table 10. As explained above, the reason for this result is that while water supply reduction imposes a cost from lost profits from not planting winter wheat and/or ripping out older vintage alfalfa fields, it also has a benefit by alleviating the farm's land constraint thereby allowing the farm to plant more acres of new alfalfa in post water reduction years.

Two results on Tables 20 and 21 are worth emphasizing. First, Table 20 shows that small magnitude water supply reductions have a relatively little impact on the present value of farm profits even if they have a long duration. For example, a 10% reduction in expected water deliveries leads to a $3 per-acre-foot loss the present value of profits even if it lasts for ten years. The reason for this result is that crop rotation requires that alfalfa hay fields sit fallow or be planted with a cover crop (winter wheat) every seventh year. Given this requirement, small magnitude water supply reductions lead the farmer to stop planting winter wheat as a cover crop on fallowed land for an annual net return of $10 per acre but does not have a significant impact on total acres of alfalfa planted. We recommend that the small magnitude water supply reduction results be ignored because the low per-acre-foot costs of water not received in this case is due to the land constraint in the model, which limit new alfalfa plantings even if the farm has water available to plant new alfalfa, rather than to the value of water in production.

Second, Table 20 shows that short-lived but intense interruptions in water deliveries (i.e., one or two years) can have significant costs. For example, a single year of the farm receiving 50% of its expected water deliveries results in a marginal value of water of $163 per-acre-foot. The reason that short-lived but intense water supply reductions have significant costs is because reductions of 20% intensity or greater lead the farm to rip out alfalfa hay fields, which, from Table 10, have high profits per acre. Table 20 also shows that the relationship between the magnitude of water supply shortage and the reduction in present value of profits is non-linear, with a year of 20% reduction in deliveries leading to a marginal value of $61 per-acre-foot, a year of 40% reduction in deliveries leading to a marginal value of $114 per-acre-foot, and a year of 60% reduction in deliveries leading to a marginal value of $212 per-acre-foot.

Table 20. 2,500-Acre Alfalfa Hay Farm: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
10%	750 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
20%	1500 AF	$61	$61	$115	$145	$191	$159	$159	$156	$159	$202
30%	2250 AF	$114	$165	$237	$239	$236	$204	$201	$204	$244	$244
40%	3000 AF	$114	$237	$305	$307	$305	$270	$273	$310	$310	$310
50%	3750 AF	$163	$311	$311	$313	$308	$279	$314	$314	$314	$314
60%	4500 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314
70%	5250 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314

Table 21. 2,500-Acre Alfalfa Hay Farm: Total Cost of 10% (750 Acre-Foot) Reduction in Water Deliveries on Top of Existing Shortfalls in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250
10%	750 AF	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500
20%	1500 AF	$45,750	$45,750	$86,250	$108,750	$143,250	$119,250	$119,250	$117,000	$119,250	$151,500
30%	2250 AF	$85,500	$123,750	$177,750	$179,250	$177,000	$153,000	$150,750	$153,000	$183,000	$183,000
40%	3000 AF	$85,500	$177,750	$228,750	$230,250	$228,750	$202,500	$204,750	$232,500	$232,500	$232,500
50%	3750 AF	$122,250	$233,250	$233,250	$234,750	$231,000	$209,250	$235,500	$235,500	$235,500	$235,500
60%	4500 AF	$159,000	$233,250	$233,250	$234,750	$231,000	$209,250	$235,500	$235,500	$235,500	$235,500
70%	5250 AF	$159,000	$233,250	$233,250	$234,750	$231,000	$209,250	$235,500	$235,500	$235,500	$235,500

DISCUSSION AND CONCLUSIONS

The cow-calf ranching model predicts that unanticipated reduced water deliveries impact ranch profits by reducing the amount of low-cost feed grown on the ranch. The increase in average feed costs impacts profits in the current year and also forces the ranch to reduce its herd size, which lowers the number new calf births and, as a result, lowers future profits from livestock sales. The cow-calf model predicts an economic value of an acre-foot of water for the cow-calf ranch in the range of $215 per acre-foot for unanticipated supply interruptions that occur in normal water years, and upwards of $290 per acre-foot for supply interruptions that occur during periods of below average water deliveries, such as during a drought. The cow-calf model does not find evidence that the economic value of an acre-foot of water increases with the length of the unanticipated supply reduction.

The alfalfa hay farm model predicts that unanticipated reduced water deliveries impact farm profits by first preventing the farm from planting a cover crop during fallow years and then, for more significant interruptions, reducing its acreage of alfalfa hay. The alfalfa hay model predicts that the economic value of an acre-foot of water increases with both the volume of water not received and the length of the unanticipated supply reduction. The economic value of water per-acre-foot predicted by the alfalfa hay model ranges from less than $10 per acre-foot for unanticipated supply interruptions that occur in normal water years, in the range of $100-$200 per acre-foot for single-year supply interruptions that occur during drought, and over $300 per-acre-foot for supply interruptions successive years during a drought.

The economics values of an acre foot of water predicted by the models are in line with previous studies. For example, a recent study by West Water Research that combines U.S. Geological Survey data with data from the U.S. Department of Agriculture's Census of Agricultural estimates the agricultural production value of irrigation water in Nevada in 2015 to be $206 per acre foot (West Water Research, 2020). Data on permanent water right sales in Nevada collected by the authors show sale values in the Humboldt River basin of between $400 and $5200 per acre foot from 2006-2019. This corresponds to a range of annualized value between $26 and $340 per acre-foot if future profits are discounted at 7%.

A limitation of the cow-calf ranching model is that it does not capture the significant heterogeneity in how ranchers in the HRR use public land. The cow-calf model assumes that the ranch can access their public land allotment for the six-month period from April to September. While this grazing period is common for ranches in the HRR, many ranches, particularly in the lower parts of the basin, operate under grazing contracts that allow them to access public land in winter months. Given that water deliveries impact ranch profits by increasing feed costs, the assumptions on grazing access on public land will impact the value of an acre foot of water to the operation that is predicted by the model. The assumptions on public land access limit the ability of the results from this study to generalize to other regions of the county where ranchers have different seasonal access to their public land allotments or are less reliant on public land for forage. In addition, the model fails to account for the fact that the ranchers are likely to face a higher cost of purchased hay in periods of below average water deliveries.

A limitation of the alfalfa hay farm model is its inability to capture how the water supply interruptions due to groundwater capture will impact the seasonal water availability for a farm. The alfalfa hay model assumes that an acre foot of water not received reduces water availability equally throughout the growing season. It is likely that groundwater capture will have a more significant effect on farm-level water availability later in the irrigation season when surface water flows are at their lowest. Expanding the alfalfa hay model to allow for water availability to vary over the irrigation season would provide a more accurate depiction of the cost of groundwater capture for alfalfa hay producers.

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APPENDIX

Cow-Calf Ranch: Present Value of Profits

Table A1. Small (625-Acre) Cow-Calf Ranch: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	93.75 AF	$942,803	$925,206	$908,711	$893,277	$878,845	$865,355	$852,747	$840,964	$829,951	$819,658
20%	187.5 AF	$923,880	$888,600	$855,577	$824,696	$795,829	$768,848	$743,631	$720,063	$698,037	$677,452
30%	281.25 AF	$904,558	$851,242	$801,325	$754,641	$711,000	$670,209	$632,086	$596,456	$563,156	$532,035
40%	375 AF	$879,040	$804,166	$734,639	$673,175	$613,394	$560,953	$508,076	$463,867	$421,144	$381,869
50%	468.75 AF	$853,066	$756,718	$625,632	$508,119	$327,475	$75,483	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**
60%	562.5 AF	$791,348	$655,161	$412,166	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**

Profits for 625-acre operation receiving 100% of its water: $961,662

Table A2. Medium (1,250-Acre) Cow-Calf Ranch: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	187.5 AF	$2,528,878	$2,493,699	$2,460,714	$2,429,846	$2,400,984	$2,374,005	$2,348,788	$2,325,221	$2,303,195	$2,282,610
20%	375 AF	$2,491,033	$2,420,486	$2,354,445	$2,292,685	$2,234,951	$2,180,989	$2,130,556	$2,083,421	$2,039,369	$1,998,199
30%	562.5 AF	$2,452,392	$2,345,783	$2,245,958	$2,152,594	$2,065,312	$1,983,732	$1,907,485	$1,836,224	$1,769,626	$1,707,384
40%	750 AF	$2,403,346	$2,250,899	$2,108,234	$1,974,834	$1,850,135	$1,733,584	$1,624,655	$1,522,852	$1,427,707	$1,338,787
50%	937.5 AF	$2,352,538	$2,156,367	$1,975,782	$1,814,197	$1,659,929	$1,523,407	$1,368,224	$1,248,470	$1,117,457	$1,016,944
60%	1125 AF	$2,267,086	$2,034,717	$1,716,799	$1,462,510	$1,117,845	$669,378	$100,427	**Shutdown**	**Shutdown**	**Shutdown**

Profits for 1,250-acre operation receiving 100% of its water: $2,566,592

Table A3. Large (1,875-Acre) Cow-Calf Ranch: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	281.25 AF	$4,114,964	$4,062,202	$4,012,726	$3,966,426	$3,923,133	$3,882,664	$3,844,839	$3,809,488	$3,776,450	$3,745,572
20%	562.5 AF	$4,058,197	$3,952,382	$3,853,323	$3,760,684	$3,674,084	$3,593,141	$3,517,490	$3,446,787	$3,380,710	$3,318,955
30%	843.75 AF	$4,000,236	$3,840,332	$3,690,598	$3,550,554	$3,419,632	$3,297,261	$3,182,891	$3,076,000	$2,976,102	$2,882,739
40%	1125 AF	$3,926,666	$3,698,005	$3,484,013	$3,283,913	$3,096,865	$2,922,040	$2,758,647	$2,605,941	$2,463,225	$2,329,845
50%	1406.25 AF	$3,851,603	$3,556,024	$3,288,676	$3,038,873	$2,810,142	$2,596,832	$2,399,748	$2,216,590	$2,046,696	$1,888,789
60%	1687.5 AF	$3,721,992	$3,375,502	$2,904,259	$2,557,372	$2,147,881	$1,629,637	$1,016,638	$278,741	**Shutdown**	**Shutdown**

Profits for 1,875-acre operation receiving 100% of its water: $4,171,536

Table A4. Extra Large (2,500-Acre) Cow-Calf Ranch: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	375 AF	$5,701,051	$5,630,705	$5,564,738	$5,503,005	$5,445,281	$5,391,323	$5,340,890	$5,293,755	$5,249,704	$5,208,534
20%	750 AF	$5,625,361	$5,484,278	$5,352,201	$5,228,683	$5,113,216	$5,005,292	$4,904,424	$4,810,154	$4,722,051	$4,639,711
30%	1125 AF	$5,548,079	$5,334,881	$5,135,239	$4,948,513	$4,773,952	$4,610,790	$4,458,297	$4,315,776	$4,182,579	$4,058,095
40%	1500 AF	$5,449,986	$5,145,112	$4,859,791	$4,592,993	$4,343,596	$4,110,496	$3,892,638	$3,689,031	$3,498,742	$3,320,902
50%	1875 AF	$5,350,669	$4,955,680	$4,594,429	$4,255,686	$3,942,255	$3,650,082	$3,378,557	$3,125,648	$2,890,202	$2,670,827
60%	2250 AF	$5,176,898	$4,715,016	$4,131,992	$3,720,392	$3,243,124	$2,720,044	$2,073,380	$1,341,877	$489,222	**Shutdown**

Profits for 2,500-acre operation receiving 100% of its water: $5,776,479

Cow-Calf Ranch: Per-Acre-Foot Value of Water

Table A5. Small (625-Acre) Cow-Calf Ranch: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$215	$215	$216	$216	$216	$216	$216	$216	$216	$216
10%	93.75 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
20%	187.5 AF	$225	$224	$223	$224	$225	$225	$225	$225	$225	$225
30%	281.25 AF	$291	$279	$274	$254	$334	$246	$255	$237	$245	$245
40%	375 AF	$297	$291	$587	$708	$1,121	$1,573	$2,139	$2,792	$3,742	$5,353
50%	468.75 AF	$738	$521	$1,127	$1,830	$2,765	$4,259	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**
60%	562.5 AF	$1,312	$1,425	$2,356	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**

Table A6. Medium (1,250-Acre) Cow-Calf Ranch: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$215	$214	$215	$216	$216	$216	$216	$216	$216	$216
10%	187.5 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
20%	375 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
30%	562.5 AF	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280
40%	750 AF	$288	$282	$286	$285	$286	$286	$287	$287	$288	$288
50%	937.5 AF	$292	$292	$475	$292	$583	$605	$811	$960	$1,217	$1,524
60%	1125 AF	$1,058	$291	$662	$1,084	$1,494	$1,857	$2,516	**Shutdown**	**Shutdown**	**Shutdown**

Table A7. Large (1,875-Acre) Cow-Calf Ranch: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$214	$213	$215	$215	$216	$216	$216	$216	$216	$216
10%	281.25 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
20%	562.5 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
30%	843.75 AF	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280
40%	1125 AF	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280
50%	1406.25 AF	$292	$292	$292	$292	$292	$292	$568	$291	$568	$291
60%	1687.5 AF	$954	$291	$577	$605	$894	$1,134	$1,497	$1,844	**Shutdown**	**Shutdown**

Table A8. Extra Large (2,500-Acre) Cow-Calf Ranch: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$213	$211	$214	$215	$216	$216	$216	$216	$216	$216
10%	375 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
20%	750 AF	$216	$216	$216	$216	$216	$216	$216	$216	$216	$216
30%	1125 AF	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280
40%	1500 AF	$280	$280	$280	$280	$280	$280	$280	$280	$280	$280
50%	1875 AF	$292	$292	$292	$292	$292	$292	$292	$292	$292	$292
60%	2250 AF	$954	$292	$568	$605	$732	$902	$1,207	$1,521	$1,844	**Shutdown**

Cow-Calf Ranch: Total Cost of Water Delivery Reduction

Table A9. Small (625-Acre) Cow-Calf Ranch: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$20,156	$20,156	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250
10%	93.75 AF	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250	$20,250
20%	187.5 AF	$21,094	$21,000	$20,906	$21,000	$21,094	$21,094	$21,094	$21,094	$21,094	$21,094
30%	281.25 AF	$27,281	$26,156	$25,688	$23,813	$31,313	$23,063	$23,906	$22,219	$22,969	$22,969
40%	375 AF	$27,844	$27,281	$55,031	$66,375	$105,094	$147,469	$200,531	$261,750	$350,813	$501,844
50%	468.75 AF	$69,188	$48,844	$105,656	$171,563	$259,219	$399,281	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**
60%	562.5 AF	$123,000	$133,594	$220,875	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**	**Shutdown**

Table A10. Medium (1,250-Acre) Cow-Calf Ranch: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$40,313	$40,125	$40,313	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500
10%	187.5 AF	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500
20%	375 AF	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500	$40,500
30%	562.5 AF	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500	$52,500
40%	750 AF	$54,000	$52,875	$53,625	$53,438	$53,625	$53,625	$53,813	$53,813	$54,000	$54,000
50%	937.5 AF	$54,750	$54,750	$89,063	$54,750	$109,313	$113,438	$152,063	$180,000	$228,188	$285,750
60%	1125 AF	$198,375	$54,563	$124,125	$203,250	$280,125	$348,188	$471,750	**Shutdown**	**Shutdown**	**Shutdown**

Table A11. Large (1,875-Acre) Cow-Calf Ranch: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$60,188	$59,906	$60,469	$60,469	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750
10%	281.25 AF	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750
20%	562.5 AF	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750	$60,750
30%	843.75 AF	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750
40%	1125 AF	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750	$78,750
50%	1406.25 AF	$82,125	$82,125	$82,125	$82,125	$82,125	$82,125	$159,750	$81,844	$159,750	$81,844
60%	1687.5 AF	$268,313	$81,844	$162,281	$170,156	$251,438	$318,938	$421,031	$518,625	**Shutdown**	**Shutdown**

Table A12. Extra Large (2,500-Acre) Cow-Calf Ranch: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$79,875	$79,125	$80,250	$80,625	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000
10%	375 AF	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000
20%	750 AF	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000	$81,000
30%	1125 AF	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000
40%	1500 AF	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000	$105,000
50%	1875 AF	$109,500	$109,500	$109,500	$109,500	$109,500	$109,500	$109,500	$109,500	$109,500	$109,500
60%	2250 AF	$357,750	$109,500	$213,000	$226,875	$274,500	$338,250	$452,625	$570,375	$691,500	**Shutdown**

Alfalfa Hay Farm: Higher Planting Cost

These tables report annual results for the 2,500-acre alfalfa hay ranch assuming that the costs of planting one new acre of alfalfa is $3,000. Under this assumption, the model will maintain existing alfalfa fields rather than plant new fields even when land is available for planting.

Table A13. 2,500-Acre Alfalfa Hay Farm: Acres Planted under Expected Water Deliveries and with 30% Reduction in Water Deliveries

Element	Baseline	2nd Year	4th Year	6th Year	8th Year	10th Year
Alfalfa Hay 1st Year	357	0	357	357	0	357
Alfalfa Hay 2nd Year	357	0	179	357	0	179
Alfalfa Hay 3rd Year	357	357	0	357	357	0
Alfalfa Hay 4th Year	357	357	0	179	357	0
Alfalfa Hay 5th Year	357	357	357	0	357	357
Alfalfa Hay 6th Year	357	179	357	0	179	357
Winter Wheat	357	0	0	0	0	0
Total Crops	2,500	1,750	1,750	1,750	1,750	1,750
Fallow	0	1,250	1,250	1,250	1,250	1,250
Total	2,500	2,500	2,500	2,500	2,500	2,500

Table A14. 2,500-Acre Alfalfa Hay Farm: Annual Financials under Expected Water Deliveries and with 30% Reduction in Water Deliveries

Element	Baseline	2nd Year	4th Year	6th Year	8th Year	10th Year
Variable Costs ($)						
Alfalfa Hay 1st Year	116,071	0	1,071,420	1,071,420	0	1,071,420
Alfalfa Hay Years 2-6	267,857	187,500	133,929	133,929	187,500	133,929
Winter Wheat	42,857	0	0	0	0	0
Total	426,786	187,500	1,205,349	1,205,349	187,500	1,205,349
Fixed Costs ($)						
Total	600,000	600,000	600,000	600,000	600,000	600,000
Revenues ($)						
Alfalfa Hay Sold	2,618,714	1,494,375	1,537,072	1,551,303	1,494,375	1,537,072
Winter Wheat Sold	46,428.57	0	0	0	0	0
Total	2,665,143	1,494,375	1,537,072	1,551,303	1,494,375	1,537,072
Balance Sheet ($)						
Profits*	1,638,357	706,875	-268,277	-254,046	706,875	-268,277
Family Living Allowance	35,000	35,000	35,000	35,000	35,000	35,000

* Profits = Total Revenues – Total Variable Costs – Fixed Costs.

Alfalfa Hay Farm: Present Value of Profits

Table A15. Small (1,250-Acre) Alfalfa Hay Farm: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	375 AF	$10,453,268	$10,452,176	$10,451,155	$10,450,202	$10,449,311	$10,448,478	$10,447,699	$10,446,972	$10,446,292	$10,445,656
20%	750 AF	$10,440,601	$10,416,922	$10,380,897	$10,324,490	$10,256,135	$10,201,034	$10,149,537	$10,101,409	$10,057,674	$10,015,312
30%	1125 AF	$10,416,621	$10,322,935	$10,167,952	$9,975,944	$9,798,727	$9,657,339	$9,526,445	$9,403,248	$9,271,211	$9,139,733
40%	1500 AF	$10,376,519	$10,174,519	$9,850,647	$9,538,100	$9,248,974	$9,012,320	$8,790,905	$8,566,331	$8,340,292	$8,129,040
50%	1875 AF	$10,324,306	$9,967,176	$9,499,872	$9,060,031	$8,652,681	$8,315,482	$7,996,625	$7,658,235	$7,341,984	$7,046,421
60%	2250 AF	$10,262,330	$9,743,102	$9,178,724	$8,647,538	$8,156,806	$7,747,649	$7,346,128	$6,938,562	$6,557,659	$6,201,674
70%	2625 AF	$10,188,058	$9,519,028	$8,857,576	$8,235,045	$7,660,931	$7,179,816	$6,695,632	$6,218,888	$5,773,333	$5,356,927

* Profits for 1250-acre operation receiving 100% of its water: $10,454,436

Table A16. Medium (2,500-Acre) Alfalfa Hay Farm: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	750 AF	$21,373,145	$21,370,961	$21,368,921	$21,367,013	$21,365,231	$21,363,565	$21,362,008	$21,360,553	$21,359,193	$21,357,922
20%	1500 AF	$21,347,811	$21,300,454	$21,228,404	$21,115,590	$20,978,881	$20,868,678	$20,765,684	$20,669,429	$20,581,957	$20,497,234
30%	2250 AF	$21,299,852	$21,112,479	$20,802,514	$20,418,497	$20,064,064	$19,781,288	$19,519,499	$19,273,106	$19,009,031	$18,746,076
40%	3000 AF	$21,219,647	$20,815,648	$20,167,904	$19,542,810	$18,964,558	$18,491,250	$18,048,419	$17,599,271	$17,147,193	$16,724,690
50%	3750 AF	$21,115,221	$20,400,962	$19,466,354	$18,586,671	$17,771,972	$17,097,573	$16,459,859	$15,783,080	$15,150,577	$14,559,453
60%	4500 AF	$20,991,269	$19,952,814	$18,824,058	$17,761,685	$16,780,222	$15,961,907	$15,158,866	$14,343,733	$13,581,927	$12,869,958
70%	5250 AF	$20,842,726	$19,504,666	$18,181,762	$16,936,699	$15,788,471	$14,826,242	$13,857,874	$12,904,386	$12,013,277	$11,180,464

* Profits for 2500-acre operation receiving 100% of its water: $21,375,481

Table A17. Large (3,750-Acre) Alfalfa Hay Farm: Present Value of Profits

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	1125 AF	$32,293,022	$32,289,747	$32,286,686	$32,283,825	$32,281,151	$32,278,653	$32,276,317	$32,274,135	$32,272,095	$32,270,189
20%	2250 AF	$32,255,021	$32,183,987	$32,075,910	$31,906,689	$31,701,626	$31,536,322	$31,381,831	$31,237,448	$31,106,241	$30,979,156
30%	3375 AF	$32,183,083	$31,902,024	$31,437,076	$30,861,051	$30,329,401	$29,905,238	$29,512,554	$29,142,964	$28,746,852	$28,352,419
40%	4500 AF	$32,062,776	$31,456,778	$30,485,161	$29,547,521	$28,680,143	$27,970,180	$27,305,934	$26,632,212	$25,954,094	$25,320,340
50%	5625 AF	$31,906,136	$30,834,747	$29,432,836	$28,113,311	$26,891,263	$25,879,665	$24,923,094	$23,907,926	$22,959,171	$22,072,484
60%	6750 AF	$31,720,208	$30,162,526	$28,469,392	$26,875,832	$25,403,638	$24,176,166	$22,971,604	$21,748,905	$20,606,195	$19,538,242
70%	7875 AF	$31,497,395	$29,490,304	$27,505,948	$25,638,353	$23,916,012	$22,472,667	$21,020,115	$19,589,884	$18,253,220	$17,004,001

*Profits for 3750-acre operation receiving 100% of its water: $32,296,527

Table A18. Extra Large (5,000-Acre) Alfalfa Hay Farm: Present Value of Profits: 5,000-Acre Alfalfa Hay Farm

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
10%	1500 AF	$43,212,932	$43,208,565	$43,204,483	$43,200,669	$43,197,104	$43,193,772	$43,190,658	$43,187,748	$43,185,029	$43,182,487
20%	3000 AF	$43,162,254	$43,067,534	$42,923,422	$42,697,791	$42,424,372	$42,203,966	$41,997,979	$41,805,468	$41,630,525	$41,461,079
30%	4500 AF	$43,066,329	$42,691,574	$42,071,638	$41,303,605	$40,594,738	$40,029,187	$39,505,609	$39,012,822	$38,484,673	$37,958,762
40%	6000 AF	$42,905,920	$42,097,908	$40,802,419	$39,552,231	$38,395,727	$37,449,111	$36,563,449	$35,665,153	$34,760,996	$33,915,990
50%	7500 AF	$42,697,061	$41,268,533	$39,399,318	$37,639,952	$36,010,554	$34,661,756	$33,386,328	$32,032,771	$30,767,764	$29,585,515
60%	9000 AF	$42,449,153	$40,372,237	$38,114,726	$35,989,980	$34,027,053	$32,390,425	$30,784,342	$29,154,076	$27,630,464	$26,206,526
70%	10500 AF	$42,152,068	$39,475,942	$36,830,134	$34,340,008	$32,043,552	$30,119,093	$28,182,357	$26,275,382	$24,493,163	$22,827,538

* Profits for 5000-acre operation receiving 100% of its water: $43,217,605

Alfalfa Hay Farm: Per-Acre-Foot Value of Water

Table A19. Small (1,250-Acre) Alfalfa Hay Farm: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
10%	375 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
20%	750 AF	$61	$109	$115	$194	$191	$159	$159	$156	$159	$202
30%	1125 AF	$114	$165	$237	$239	$236	$204	$201	$204	$244	$244
40%	1500 AF	$114	$237	$305	$307	$305	$270	$273	$310	$310	$310
50%	1875 AF	$163	$311	$311	$313	$308	$279	$314	$314	$314	$314
60%	2250 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314
70%	2625 AF	$255	$313	$321	$324	$314	$295	$383	$319	$319	$319

Table A20. Medium (2,500-Acre) Alfalfa Hay Farm: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
10%	750 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
20%	1500 AF	$61	$61	$115	$145	$191	$159	$159	$156	$159	$202
30%	2250 AF	$114	$165	$237	$239	$236	$204	$201	$204	$244	$244
40%	3000 AF	$114	$237	$305	$307	$305	$270	$273	$310	$310	$310
50%	3750 AF	$163	$311	$311	$313	$308	$279	$314	$314	$314	$314
60%	4500 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314
70%	5250 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314

Table A21. Large (3,750-Acre) Alfalfa Hay Farm: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
10%	1125 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
20%	2250 AF	$61	$61	$115	$145	$191	$159	$159	$156	$159	$202
30%	3375 AF	$114	$165	$237	$239	$236	$204	$201	$204	$244	$244
40%	4500 AF	$114	$237	$305	$307	$305	$270	$273	$310	$310	$310
50%	5625 AF	$163	$311	$311	$313	$308	$279	$314	$314	$314	$314
60%	6750 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314
70%	7875 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314

Table A22. Extra Large (5,000-Acre) Alfalfa Hay Farm: Per-Acre-Foot Value of Water ($/Acre-Foot)

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
10%	1500 AF	$3	$3	$3	$3	$3	$3	$3	$3	$3	$3
20%	3000 AF	$61	$61	$115	$145	$191	$159	$159	$156	$159	$202
30%	4500 AF	$114	$165	$237	$239	$236	$204	$201	$204	$244	$244
40%	6000 AF	$114	$237	$305	$307	$305	$270	$273	$310	$310	$310
50%	7500 AF	$163	$311	$311	$313	$308	$279	$314	$314	$314	$314
60%	9000 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314
70%	10500 AF	$212	$311	$311	$313	$308	$279	$314	$314	$314	$314

Alfalfa Hay Farm: Total Cost of Water Delivery Reduction

Table A23. Small (1,250-Acre) Alfalfa Hay Farm: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125
10%	375 AF	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125	$1,125
20%	750 AF	$22,875	$40,875	$43,125	$72,750	$71,625	$59,625	$59,625	$58,500	$59,625	$75,750
30%	1125 AF	$42,750	$61,875	$88,875	$89,625	$88,500	$76,500	$75,375	$76,500	$91,500	$91,500
40%	1500 AF	$42,750	$88,875	$114,375	$115,125	$114,375	$101,250	$102,375	$116,250	$116,250	$116,250
50%	1875 AF	$61,125	$116,625	$116,625	$117,375	$115,500	$104,625	$117,750	$117,750	$117,750	$117,750
60%	2250 AF	$79,500	$116,625	$116,625	$117,375	$115,500	$104,625	$117,750	$117,750	$117,750	$117,750
70%	2625 AF	$95,625	$117,375	$120,375	$121,500	$117,750	$110,625	$143,625	$119,625	$119,625	$119,625

Table A24. Medium (2,500-Acre) Alfalfa Hay Farm: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250
10%	750 AF	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250	$2,250
20%	1500 AF	$45,750	$45,750	$86,250	$108,750	$143,250	$119,250	$119,250	$117,000	$119,250	$151,500
30%	2250 AF	$85,500	$123,750	$177,750	$179,250	$177,000	$153,000	$150,750	$153,000	$183,000	$183,000
40%	3000 AF	$85,500	$177,750	$228,750	$230,250	$228,750	$202,500	$204,750	$232,500	$232,500	$232,500
50%	3750 AF	$122,250	$233,250	$233,250	$234,750	$231,000	$209,250	$235,500	$235,500	$235,500	$235,500
60%	4500 AF	$159,000	$233,250	$233,250	$234,750	$231,000	$209,250	$235,500	$235,500	$235,500	$235,500
70%	5250 AF	$159,000	$233,250	$233,250	$234,750	$231,000	$209,250	$235,500	$235,500	$235,500	$235,500

Table A25. Large (3,750-Acre) Alfalfa Hay Farm: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375
10%	1125 AF	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375	$3,375
20%	2250 AF	$68,625	$68,625	$129,375	$163,125	$214,875	$178,875	$178,875	$175,500	$178,875	$227,250
30%	3375 AF	$128,250	$185,625	$266,625	$268,875	$265,500	$229,500	$226,125	$229,500	$274,500	$274,500
40%	4500 AF	$128,250	$266,625	$343,125	$345,375	$343,125	$303,750	$307,125	$348,750	$348,750	$348,750
50%	5625 AF	$183,375	$349,875	$349,875	$352,125	$346,500	$313,875	$353,250	$353,250	$353,250	$353,250
60%	6750 AF	$238,500	$349,875	$349,875	$352,125	$346,500	$313,875	$353,250	$353,250	$353,250	$353,250
70%	7875 AF	$238,500	$349,875	$349,875	$352,125	$346,500	$313,875	$353,250	$353,250	$353,250	$353,250

Table A26. Extra Large (5,000-Acre) Alfalfa Hay Farm: Total Cost of a 10% Reduction in Water Deliveries

Percent Shortfall	Water Shortfall	Duration of Water Supply Reduction									
		1 Year	2 Years	3 Years	4 Years	5 Years	6 Years	7 Years	8 Years	9 Years	10 Years
0%	0 AF	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500
10%	1500 AF	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500	$4,500
20%	3000 AF	$91,500	$91,500	$172,500	$217,500	$286,500	$238,500	$238,500	$234,000	$238,500	$303,000
30%	4500 AF	$171,000	$247,500	$355,500	$358,500	$354,000	$306,000	$301,500	$306,000	$366,000	$366,000
40%	6000 AF	$171,000	$355,500	$457,500	$460,500	$457,500	$405,000	$409,500	$465,000	$465,000	$465,000
50%	7500 AF	$244,500	$466,500	$466,500	$469,500	$462,000	$418,500	$471,000	$471,000	$471,000	$471,000
60%	9000 AF	$318,000	$466,500	$466,500	$469,500	$462,000	$418,500	$471,000	$471,000	$471,000	$471,000
70%	10500 AF	$318,000	$466,500	$466,500	$469,500	$462,000	$418,500	$471,000	$471,000	$471,000	$471,000