EARTH ECONOMICS

The Economic Value of Land Conservation in Sonoma County:

A Case Study Focused on Upper Dry Creek and Cooley Ranch

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Chapter 1. Introduction

Study Context

1. The Upper Dry Creek Watershed is an 83,276-acre area of land that spans northern Sonoma County and southern Mendocino County. The watershed drains to Lake Sonoma, and is an economic asset that provides multiple benefits to Sonoma County residents and visitors.

2. Upper Dry Creek Watershed is an important part of Sonoma County's water supply system, particularly in the summer months, supporting water quality and reliability for 600,000 people in Sonoma and Marin Counties. Other benefits of the watershed include climate stability, habitat, aesthetic value, and recreational opportunities.

3. Approximately one quarter of the Upper Dry Creek Watershed is permanently protected from development by Cooley Ranch, a 19,132-acre easement that was purchased by the District in 2001. Had the easement not been acquired, a planned housing development would have been constructed, impairing some of the water quality benefits of the Cooley Ranch landscape, as well as impacting other benefits such as carbon sequestration, recreation and biodiversity.

4. Earth Economics and the District collaborated with local agency partners to identify, quantify, and – where possible – monetize the value of several benefits that can be attributed to actions that have protected Upper Dry Creek Watershed and Cooley Ranch.

Description of Study Sites

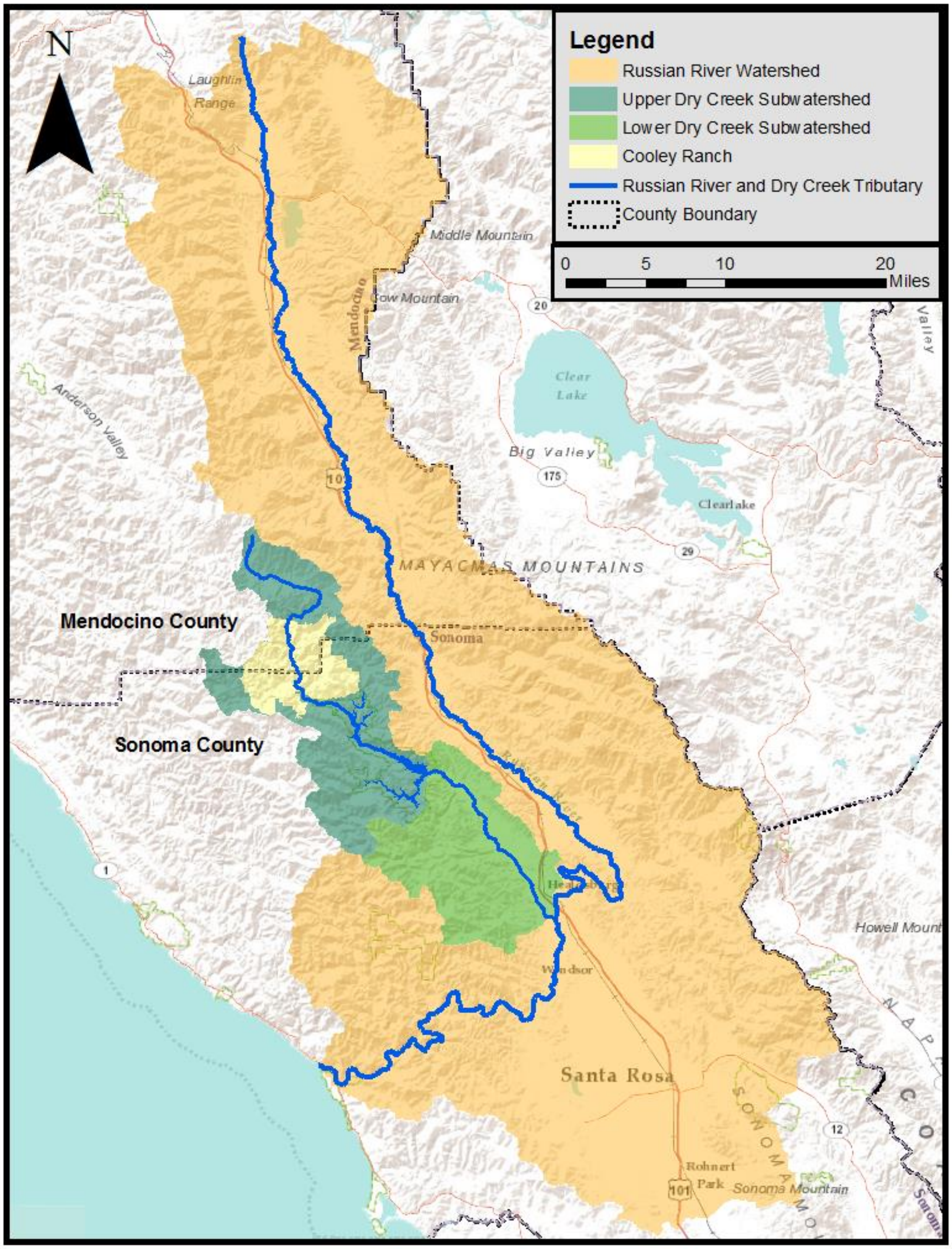
5. This analysis focused on the natural assets (oak woodlands, grasslands, wetlands, aquifers etc.) contained within the Upper Dry Creek Watershed and Cooley Ranch. These two study sites are defined as follows:

    a. **Upper Dry Creek Watershed**. An 83,276-acre watershed that drains into Lake Sonoma. The Lower Dry Creek Watershed, which begins immediately below the Warm Springs Dam and drains into the Russian River, was not included in this analysis.

    b. **Cooley Ranch**. A 19,132-acre property, protected from development by a District easement since 2001, which lies within the Upper Dry Creek Watershed. Cooley Ranch comprises approximately one quarter of the Upper Dry Creek Watershed and contains five tributaries that drain into Lake Sonoma.

6. Figure 1 provides a map showing the location and boundaries of the Upper Dry Creek Watershed and Cooley Ranch in relation to the Russian River Watershed and Sonoma County.

Figure 1 - Cooley Ranch and Upper Dry Creek Watershed



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Chapter 2. Key Concepts

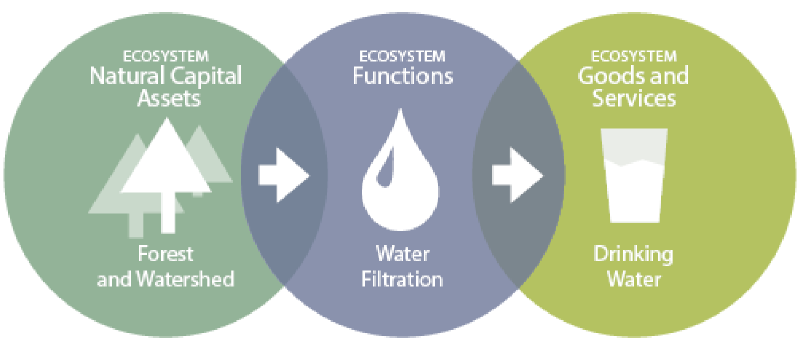
1. This chapter provides an overview of key concepts and the valuation framework used to analyze a subset of the ecosystem services known to be provided by the Upper Dry Creek Watershed and Cooley Ranch. The following chapters provide more detail on the methodology used to describe, quantify and monetize these ecosystem services.

Natural Capital and Ecosystem Services

2. Economies depend upon built, natural, and human capital. Natural capital consists of the "minerals, energy, plants, animals, ecosystems, [climatic processes, nutrient cycles and other natural structures and systems] found on Earth that provide a flow of natural goods and services."[1] Human capital consists of people, their education, health, skills, labor, knowledge, and talents.[*] Built capital consists of cars, houses, machinery, software, and the "tangible systems that humans design, build and use for productive purposes."[2] All built capital is created from a combination of human capital and energy and materials from nature (i.e. natural capital).

3. Natural capital provides a flow of goods and services, like other forms of capital. These ecosystem goods and services are the benefits people derive from nature.[3] For example, the natural capital assets of different ecosystems in the Upper Dry Creek Watershed (such as oak woodlands) perform critical functions (such as intercepting rainfall and filtering water) that support goods and services (such as drinking water). Figure 2 shows a simplified illustration of the relationship between natural capital, ecosystem functions, and ecosystem services, using drinking water as an example.

Figure 2 - The Link between Natural Capital and the Production of Ecosystem Goods and Services



[*] This report does not discuss the importance of human capital. However, people's health and well-being, as well as their work and enjoyment, are closely tied to the built and natural capital around them and are deeply intertwined with economic prosperity.

4. Upper Dry Creek Watershed and Cooley Ranch only represent the boundaries of where ecosystem services are produced on the landscape ("provisioning areas"). However, due to the physical nature of many ecosystem services, the people who benefit from them ("beneficiaries") are often in a different location altogether. The valuation boundary is therefore often broader than the study site itself. For example, many of the water quality benefits provided in the Upper Dry Creek Watershed are experienced downstream. Other benefits can be realized nearby (e.g. pollination) or even globally (e.g. carbon sequestration that supports climate regulation). The benefits of other services, such as recreation, are produced and experienced in a single location.

5. Natural capital also requires built, human, and social capital as important "complementary inputs" in the production of many ecosystem services. That is, all four capitals are required in combination in order to provide ecosystem services. For example, in order to enjoy a rafting trip along the Russian River, a vehicle is usually required to get there, along with a raft, paddles, lifejackets and other built capital inputs. In addition, the people on the trip need some knowledge of rafting technique (human capital) and there may be rules to follow while on the river (social capital).

6. In fact, built capital and human capital inputs have allowed society to utilize ecosystem services on a larger scale than ever before. The Sonoma County Water Agency for example delivers water to 600,000 people every day, a feat made possible by the Russian River Watershed and Upper Dry Creek Watershed in combination with the Agency's employees, its pipes, treatment facilities, institutional structure and other inputs.

7. Although man-made inputs are important, it is worth noting that ecosystem goods and services remain the basis of all economic activity (e.g. a clean water supply, breathable air, nourishing food, flood risk reduction, waste treatment, and stable atmospheric conditions). Without natural capital, many of the services and associated benefits that we often take for granted (and receive for free) could not exist, or would need to be replaced at a very high cost. Valuing and accounting for natural capital assets, and the ecosystem services they provide, can better inform our investments and help to advance our economy in the 21st century.

Water-Related Ecosystem Services

8. Water-related ecosystem services are those that are related to our direct consumption of water or that are largely supported by water ecosystems, and include water supply, water quality, and flood risk reduction. Due to their critical nature, water-related services were prioritized for quantification and valuation in this study. The Upper Dry Creek Watershed in particular provides important water-related ecosystem services for Sonoma County residents, such as the capture, treatment, and delivery of water for drinking, agriculture and industry.

9. As discussed above, natural capital (i.e. the landscape) is a key driver in the production of all ecosystem services. In the Upper Dry Creek Watershed, for example, the landscape's slope, soil, vegetative cover and other attributes play an important role in water-related ecosystem services.

These ecosystem services can be mapped to specific beneficiaries in Sonoma County and beyond, such as individuals, water utilities, and farmers.

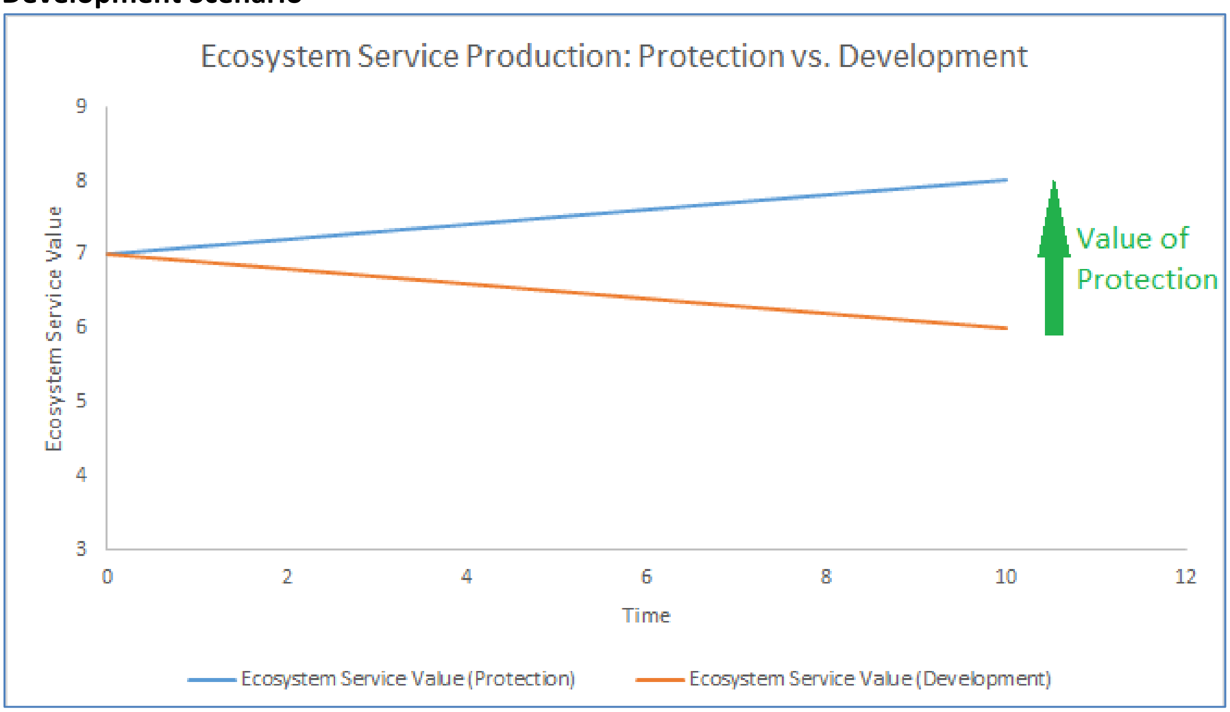
Counterfactual Analysis

10. This study relied on the use of counterfactual analysis to conduct valuations of both Upper Dry Creek Watershed and Cooley Ranch. Counterfactual analysis involves a comparison between what actually happened (baseline) and what would have happened in the absence of the intervention (counterfactual).

11. Figure 3 below illustrates the hypothetical difference in the value of ecosystem service production when a watershed such as Upper Dry Creek Watershed is protected vs. developed. The figure shows that in a hypothetical "Protection" scenario, ecosystem service production increases, while in a hypothetical "Development" scenario, ecosystem service production decreases. The difference between total ecosystem service production in the protected watershed vs. the developed watershed over time can be used to represent the added value of the policies and actions that support protection.

12. It should be noted that watershed protection can be achieved in a range of ways, and rarely means the watershed needs to be "fenced off". For example, today the Upper Dry Creek Watershed would be considered "protected" from a drinking water perspective, but also allows for recreation on Lake Sonoma, agriculture, and some residences.

Figure 3 - The Hypothetical Value of Upper Dry Creek Watershed under a Protection vs. Development Scenario



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Identification, Quantification and Valuation of Ecosystem Services

13. In order to value Upper Dry Creek Watershed and Cooley Ranch, we first identified a range of important ecosystem services that are provided by the sites to beneficiaries. The value of ecosystem services can be described in several ways, depending on the physical characteristics of the ecosystem service and data availability: Monetary Units, Physical Quantities, and/or Qualitative Descriptions.

14. A subset of these benefits were then selected for quantification. As discussed earlier, water-related services were prioritized for quantification and valuation. In addition, several criteria were used to determine whether an ecosystem service could be quantified:

    a. The ecosystem service is produced within Upper Dry Creek Watershed.

    b. The ecosystem service provides benefits to residents in Sonoma and Marin Counties.

    c. Local (or locally applicable) physical measures or models of the production function that produces the ecosystem service are available.

    d. Quantifying the ecosystem service will provide useful and objective information for decision making in Sonoma and Marin Counties.

    e. Quantifying the service would not be considered unethical or inappropriate by Sonoma County stakeholders.

15. Many services were not quantified due to a lack of local physical data. For other services, such as spiritual and historic value, quantification was not considered appropriate. Of those benefits selected for quantification, a subset were then monetized. The criteria for monetizing an ecosystem service were the same as those used for quantification, with the following additions:

    f. Quantification of the ecosystem service yields physical units that are amenable to monetization.

    g. Sufficient local economic data is available to produce a defensible estimate for the valuation.

    h. Valuing the ecosystem service will provide useful and objective information to decision making in Sonoma and Marin Counties.

    i. Valuing the service would not be considered unethical or inappropriate by Sonoma County stakeholders.

16. Not all ecosystem services that could be quantified were valued. And for those services that could be valued, often only a subset of their benefits were valued.

17. Finally, recreational ecosystem services that directly utilize Lake Sonoma, such as boating, fishing, and some tourism, were not considered in this analysis, although they clearly have economic value. These recreational activities were considered too dependent on the Warm Springs dam (i.e. built capital) to be quantified or valued as final ecosystem services. However, because the intended focus of this study was the Upper Dry Creek Watershed landscape, recreation around the lake such as hiking, biking and horse riding was not excluded from analysis.

18. Table 1 summarizes the ecosystem services that were identified in this study, and which of those were quantified and monetized. Of the ecosystem services that were monetized, the table shows examples of beneficiaries.

Table 1 - Ecosystem Services Identified, Quantified and Monetized for Upper Dry Creek Watershed and Cooley Ranch

Ecosystem Services or Benefits		Provisioning Assets or Investments (examples)	Beneficiaries (examples)	Damaging Activities (examples)	Analysis		
Benefit Category	**Benefit Sub-Category**				**Identification**	**Quantification**	**Valuation**
Water Quality	Nutrients (N, P) Retention	Vegetation (especially riparian buffers)	Water Agency, Fish, Recreation	Agriculture, Septic Systems	x	x	x
	Sediment Retention	Vegetation (especially riparian buffers)	Water Agency, Recreationists, Fish	Roads, Agriculture	x	x	x
	Temperature Reduction	Vegetation (especially riparian buffers)	Fish	Vegetation Removal	x		
	Pathogen Reduction	Soils	Water Agency, Recreationists	Human & Animal Waste	x		
Water Location	Water Capture & Conveyance	Watershed Vegetation and Groundwater	Water Agency	Impervious Surfaces (e.g. Pavement)	x		
Water Timing	Water Storage/Reliability	Aquifers and Recharge Areas	Water Agency	Impervious Surfaces (e.g. Pavement)	x		
Climate Stability	Carbon Sequestration	Vegetation	California, The World	Vegetation Removal, VMTs	x	x	x
Reduced Fire Risk		Vegetation Management	State of California, Water Agency	Increased Population Density	x		

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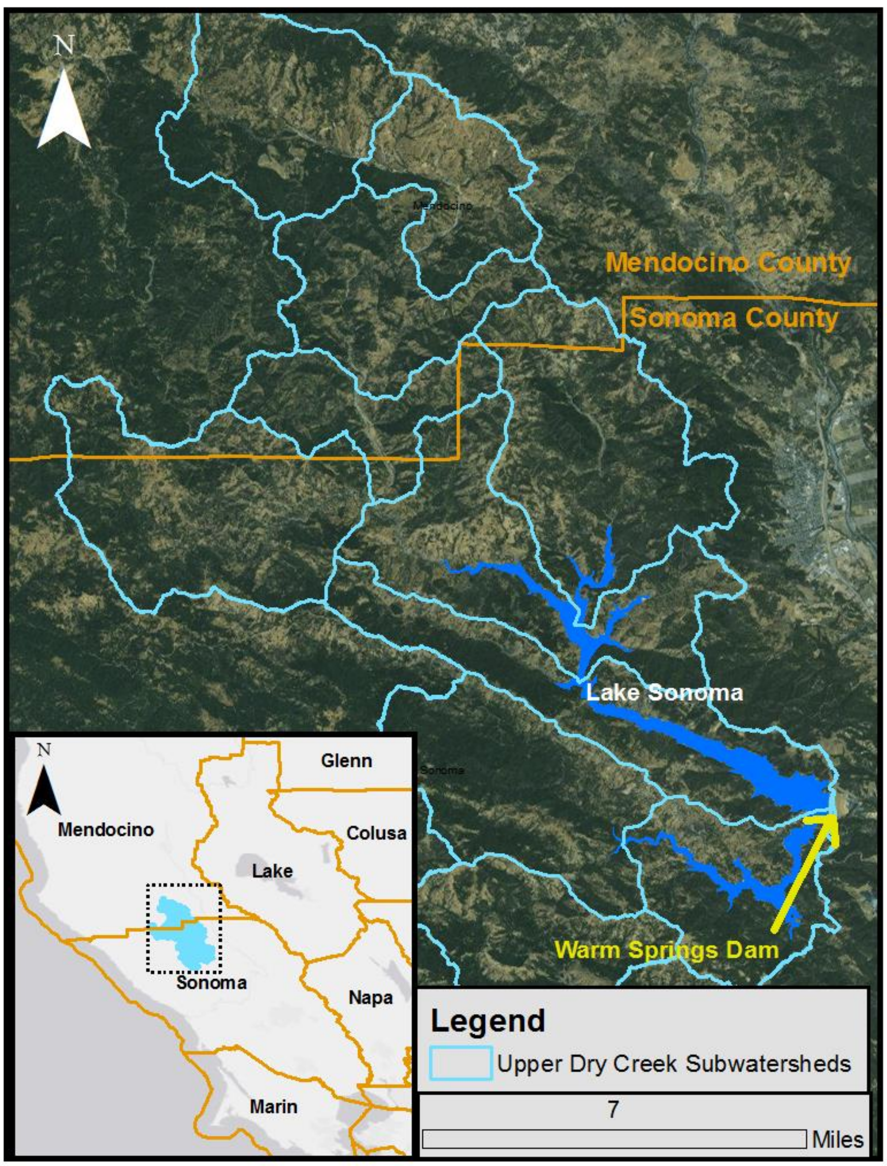
Chapter 3: The Benefits of Protecting Upper Dry Creek Watershed

Introduction

1. Upper Dry Creek Watershed ("The Watershed") is an approximately 83,000-acre basin that drains into Lake Sonoma. Water from Lake Sonoma flows through the Warm Springs Dam, into Lower Dry Creek, and then into the Russian River. Figure 4 shows The Watershed and its sub-watersheds in relation to Lake Sonoma.

Figure 4 - The Upper Dry Creek Watershed in Relation to Lake Sonoma



2. The Watershed spans northern Sonoma County and southern Mendocino County.

3. The purpose of this analysis is:

    a. To show how avoided development (via land use policies supported by voters) in The Watershed has resulted in clearly identifiable environmental benefits (or avoided costs).

    b. To monetize a subset of those environmental benefits (or avoided costs).

Defining a Baseline and Counterfactual Scenario

4. The economic value of ecosystem services enhanced and protected through avoided development was assessed by comparing the environmental benefits produced by land within The Watershed's boundary in its current state ("Protection") with a plausible counterfactual scenario, in which The Watershed is developed ("Development"), as described in Chapter 5. The two scenarios are described as follows:

    a. **Protection (Baseline).** This scenario represents the current condition of the watershed. The 83,276 acre Watershed remains relatively undeveloped. The 19,132-acre Cooley Ranch easement is purchased by the District in 2001, extinguishing development rights on one quarter of the Watershed, and allowing the existing (minimal) level of agriculture on that property. The 8,000-acre Lake Sonoma Wildlife Area is protected and managed by the California Department of Fish and Game. Several hobby farms are scattered throughout the Watershed.

    b. **Development (Counterfactual).** The Watershed is left relatively unprotected and development is allowed to occur. The Cooley Ranch easement is not purchased by the District. Approximately 23% of the 83,276 acres (18,400 acres) is converted to low intensity developed land.[†] Population in the watershed rises to approximately 11,883 people, including approximately 4,624 dwelling units (i.e. houses). Approximately half of these dwelling units (2,312) have septic systems. These assumptions were developed through the following steps:

        i. A Nature Conservancy report[4] on California's drinking water watersheds was used to identify a representative drinking water source that has experienced significant levels of development in California.

        ii. Big Bear Lake, the drinking water source for San Bernardino, was selected as a representative site.

[†] "Low intensity developed" refers to areas with a mixture of constructed materials (21-49% cover) and vegetation, such as single-family housing units.

iii. Big Bear Lake drains approximately 57,000 acres of watershed lands, 13,000 acres (23%) of which has been converted to "low intensity developed"[‡] land.

iv. Population density was calculated for the five census tracts (113, 112.06, 112.05, 112.03, 114.01) surrounding Big Bear Lake using the Social Explorer website.[5]

v. Figure 5 shows a map of Big Bear Watershed, and Figure 6 indicates the five census tracts used to estimate the population density in the Big Bear Lake Watershed.

vi. The weighted average population density for all five tracts, which includes one large undeveloped tract (113), is approximately 91 people per square mile (or 0.14 people per acre).

vii. The population density of Big Bear Lake Watershed was applied to Upper Dry Creek Watershed, resulting in a hypothetical population of 11,883 people.

viii. Assuming 2.57 people per dwelling unit,[§] this results in an estimate of 4,624 dwelling units.

[‡] "Low intensity developed" refers to areas with a mixture of constructed materials (21-49% cover) and vegetation, such as single-family housing units.

[§] This number represents the average number of people per household in Sonoma County in 2013. Available at: http://quickfacts.census.gov/qfd/states/06/06097.html

Figure 5 - Big Bear Lake Watershed[6]

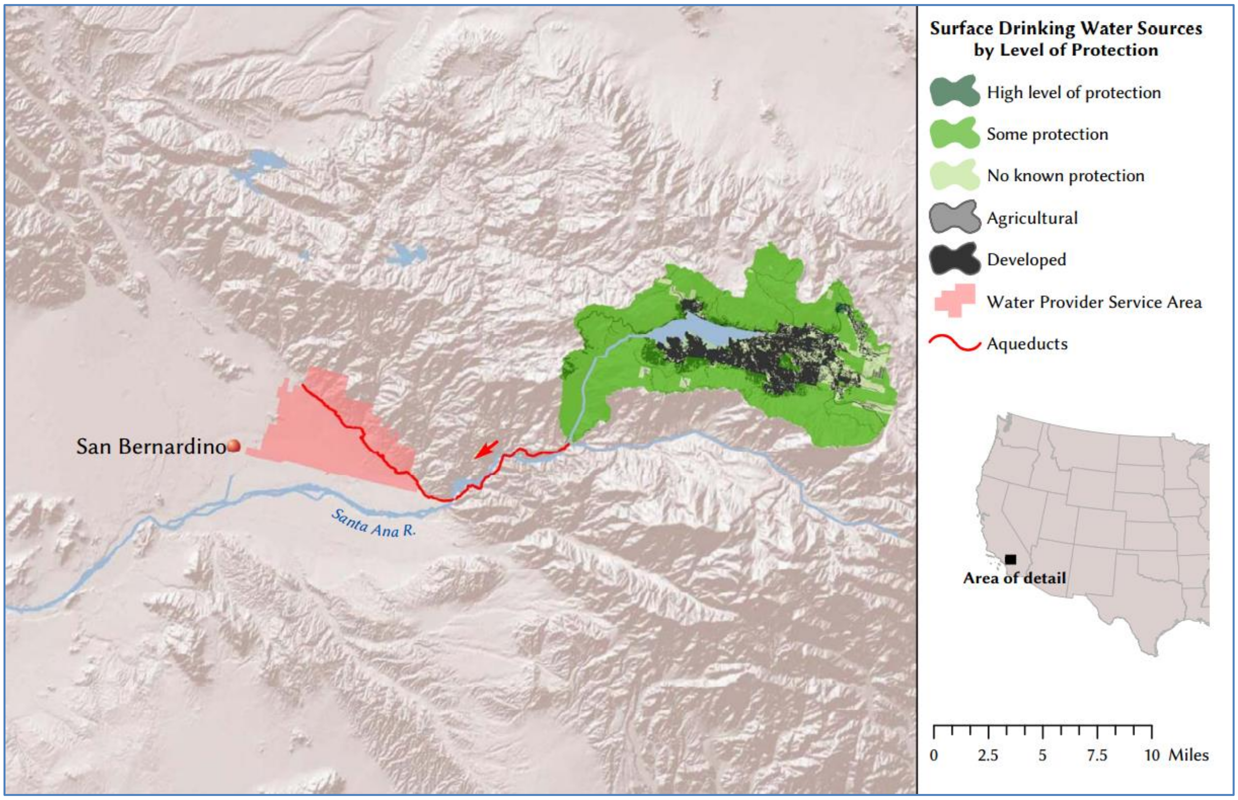
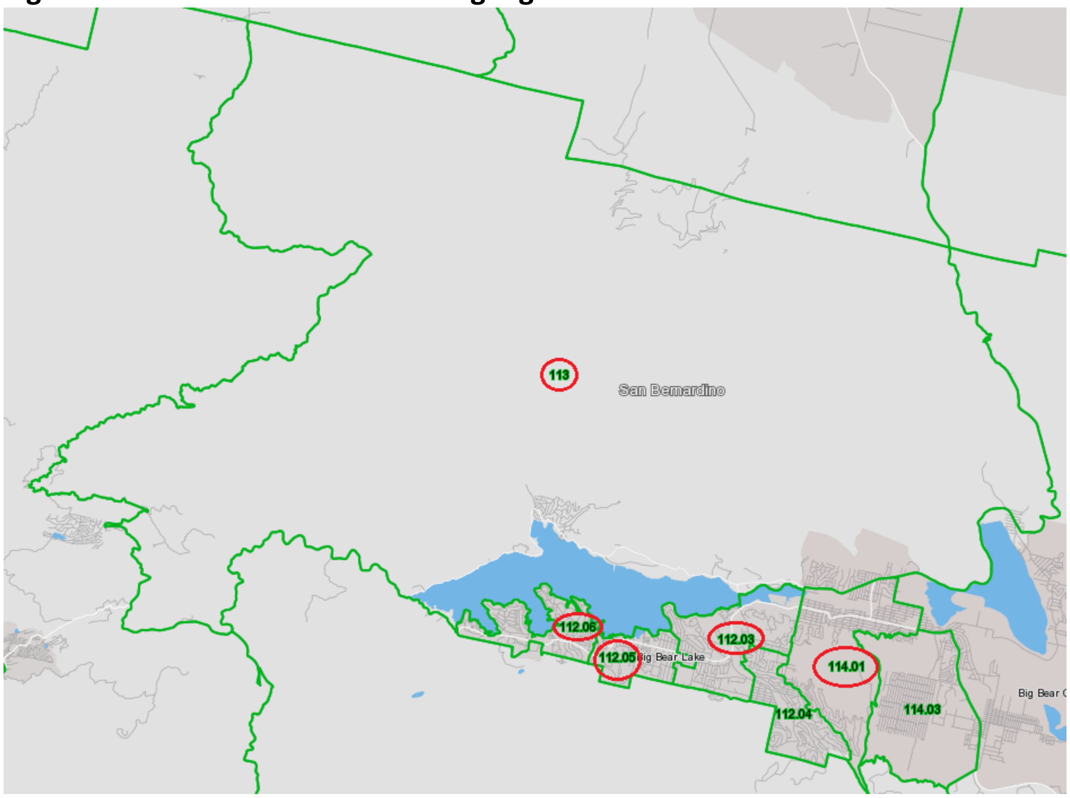


Figure 6 - Census Tracts Surrounding Big Bear Lake Watershed[**]



5. Table 2 shows the difference in the area of land cover types present in the Protection vs. the Development scenario for Upper Dry Creek Watershed. For simplicity, it was assumed that all land covers (except open water) would be converted in an equal amount (proportionate to their original extent) to the 18,400 acres of Low Intensity Developed land in the Development scenario.

Table 2 - Land Cover in Upper Dry Creek Watershed in a Protection and Development Scenario

NLCD Land Cover Class	Area in Protection Scenario (acres)	Area in Development Scenario (acres)	Change in Development vs. Protection (acres)
Open Water	2,273	2,273	0
Developed Open Space	1,625	1,255	(369)
Developed Low Intensity	69	18,469	18,400
Developed Medium Intensity	21	16	(5)
Developed, High Intensity	1	1	(0)
Barren Land(Rock/Sand Clay)	62	48	(14)
Deciduous Forest	2,397	1,852	(545)

[**] Census tracts used in analysis are circled in red.

Evergreen Forest	23,147	17,884	(5,262)
Mixed Forest	12,032	9,297	(2,736)
Shrub/Scrub	26,354	20,362	(5,991)
Grasslands/Herbaceous	15,286	11,811	(3,475)
Woody Wetlands	2	2	(1)
Emergent Herbaceous Wetlands	6	4	(1)
TOTAL	**83,275**	**83,275**	**0**

6. Table 3 summarizes several other key differences between the Protection and Development scenarios.

Table 3 – Upper Dry Creek Watershed Attributes in a Protection and Development Scenario

Attribute	Units	Scenario		Change in Development vs. Protection
		Protection	Development	
Area	Acres	83,276	83,276	0
Population	People/83,276 acres	100	11,883	11,783
Dwelling Units	Households/83,276 acres	34	4,624	4,589
Septic Systems	Septic Systems/83,276 acres	34	2,312	2,278
Population Density	People/acre	0.001	0.143	0.141

7. The environmental impacts in the Development scenario were compared with the impacts in the Protection scenario. Table 4 provides a summary of differences in key environmental impacts in the Development scenario, compared with the Protection scenario.

Table 4 - Environmental Impacts in the Upper Dry Creek Watershed under the Development scenario compared with Protection

Ecosystem Service Impacted	Cause	Change in Development vs. Protection	Monetized?
Water Quality	Septic Systems Release of Nutrients (N, P)	Increase	Yes
	Nutrient (N, P) Runoff due to Vineyards	Increase	Yes
	Sediment Runoff due to Roads	No Change	No
	Sediment Runoff due to Vineyards	Increase	Yes
Climate Stability	Emissions due to VMTs	Increase	Yes
	Vegetation Loss due to New Dwelling Units	Increase	No
Habitat & Biodiversity	Habitat Loss due to New Dwelling Units	Increase	No

8. Land cover changes in Table 2 were used as a proxy for estimating the value of some of the impacts listed in Table 4, while others were estimated based on different proxies (e.g. number of dwelling units).

9. The following sections further describes these (avoided) environmental impacts, and how they were monetized. The difference in environmental impacts in the Protection scenario vs. the Development scenario was used to represent the value of policies, actions and investments that have supported protection of the Watershed over time.

Water Quality

Water Quality: Nutrient (N, P) Runoff

1. Excessive nutrients are a leading cause of water quality impairments nationwide.

2. Nutrients are found in human and animal waste as well as in artificial fertilizers, soaps and detergents, and other industrial and municipal waste[7,8]

3. Nutrients can be directly discharged into surface water streams or run-off to streams bound to sediment when erosion occurs.

4. Nitrogen and phosphorus are nutrients naturally found in water bodies, but when found in excess they can cause algal blooms that lower oxygen levels in the water and produce toxins and bacterial growth harmful to humans and other organisms.[9]

5. Compton et al. (2011)[10] review the literature for economic studies that estimate costs associated with excess N, including impacts to drinking water, recreation, commercial fisheries, and human health impacts.

6. Based on several studies cited in the Compton et al. study, a total cost of $9.48 per kg of excess N was used for this analysis. While a number of additional costs could have been included, only the most plausible impacts were selected. For example, N runoff from the Upper Dry Creek Watershed will eventually reach the Russian River Estuary, therefore a study estimating N impacts to recreational use of estuaries was selected. Table 9 shows the cost estimates by impact type and study information.

Table 5 - Costs associated with excess N in the environment

Impact Type	**Impact Mechanism**	**Cost per kg N**	**Study Reference (as cited in Compton et al. 2011)**
Recreational use of lower Russian River and estuary	Nitrogen contributes to regional haze, and visibility damages decrease aesthetic enjoyment where people recreate.	$6.38	Birch et al. 2011
Anticipated damages of climate change	Nitrogen influences the production of many greenhouse gases (N_20, CO_2, CH_4), supporting a stable climate.	$3.10	Kusiima & Powers 2010
Total		**$9.48**	

7. Two causes of nutrient-related impacts were identified in the Watershed's Development Scenario: Agriculture and Septic Systems. Only water quality impacts due to septic systems were quantified and monetized:

   a. **Septic Systems.**

      i. According to the U.S. EPA, approximately 30% of U.S. households use on-site treatment systems.[11]

      ii. While not a major contributor of N runoff in California relative to farmland,[12] septic systems can still contribute significant N to streams, lakes and groundwater.

      iii. By estimating the annual N excretion rate for people, and the removal efficiency of an average septic system, the annual N runoff rate into Upper Dry Creek Watershed can be estimated.

      iv. Various estimates exist for the N excretion rate of people, and are generally quite consistent. Groffman et al. (2004)[13] estimates an average excretion rate of 12 g N per capita per day, or 4.38 kg per year. Gold et al. (1990)[14] observed losses of 9.5 kg per 3-person household per year. Hartner and Lund (2012) cite a paper by Crites and Tchobanoglous (1998) [15], which estimated that the daily nitrogen excretion per adult is 13.3 g, or approximately 4.85 kg per year. The Groffman et al. (2004) value of 4.38 kg per capita per year was adopted for this study.

v. Siegrist et al. (2000)[16] estimate that 80-90% of total N can be removed in conventional septic systems. Therefore an 85% removal efficiency rate was adopted. The rest of the N is assumed to reach surface water in Dry Creek through subsurface flows, though it is likely that additional N would be removed before it reaches surface water through sorption to soil particles, uptake by vegetation, etc.

vi. Assuming 2.57 persons per household, it is estimated that each household excretes (4.38*2.57 =) 11.26 kg N per year.

vii. Assuming an 85% removal efficiency, this results in (11.26*0.15 =) 1.69 kg N runoff per household per year.

viii. Assuming half of the households in the Watershed use a septic system, this means 2,278 septic systems.

ix. Over 2,278 new septic systems, this is equal to runoff of (2,278*1.69 =) 3,846 kg N per year.

x. Based on a cost of $9.48 per kg N, the total cost of this excess N runoff is (3,846*9.48 =) **$36,462 per year**.

8. Key Assumptions for this analysis include:

    a. It is assumed that in the Development scenario, half of all households rely on septic systems.

    b. For the purposes of this analysis, it is assumed that in the Protection scenario, people who would have lived in Upper Dry Creek in the Development scenario instead move to a more densely populated part of Sonoma County that does not require a septic system, such as one of the major urban areas served by the Regional Treatment Plant (operated by the City of Santa Rosa).

Water Quality: Sediment Removal

9. Sediment is the loose sand, clay, silt and other soil particles that travel in water bodies. Most often, sedimentation occurs due to eroded soils that flow into the river and affect downstream environments. While all watersheds produce a background level of sediment into water bodies, excess movement of sediment can affect water clarity, water bed elevations, and transports other pollutants such as nutrients.

10. For many utilities that draw their water from forested watersheds, increased sediment results in higher costs for water filtration, degraded fish and plant habitat, as well as disruptions to hydropower generation and navigation.[17]

11. However, most of the sediment produced by the Upper Dry Creek Watershed settles in Lake Sonoma and does not make is past the Warm Springs Dam. However, sediment that settles in Lake Sonoma does impact the Lake's storage capacity over time. In 2013, the Army Corps estimated that nationally, the average cost of dredging was approximately $5.82 per cubic yard.[18] However, avoided dredging costs were not considered in this analysis, because it is dredging is not technically feasible in Lake Sonoma.[19]

12. Two major causes of sediment-related impacts were identified in the Watershed's Development Scenario: Road Development and Agriculture. However, these impacts were not quantified or monetized.

Water Temperature

13. Temperature determines the kinds of organisms that can survive in a water body. It also affects the chemistry of the water. For example, warm water holds less oxygen than cold water (EPA 2012). Water temperature is important to fish species for enabling a habitat where they can grow and reproduce. Vegetation along water banks tends to cool the water by providing shade and regulating the climate.

14. Water temperature impacts were not quantified or monetized for this analysis.

Pathogens

15. Pathogens include bacteria, viruses, protozoan parasites and other micro-organisms. Some of

    Most often these pathogens originate in human or animal waste and spread when water is contaminated with sewage or other waste discharges. They can cause disease in people through exposure or

16. Pathogen impacts were not quantified or monetized for this analysis.

Climate Stability

Vehicle Miles Traveled

17. Vehicle Miles of Traveled (VMT) are the number of miles traveled nationally by vehicles for a period of 1 year.[21] In the Development scenario, it is assumed that VMTs will increase as more people move to the Upper Dry Creek Watershed and must commute to work and shop.

18. The following method was used to calculate the VMT avoided under the Protection scenario for the Cooley Ranch property.

19. The relationship between distance from a central business district (CBD) and vehicle miles of travel (.28% Δ VMT/Mile from CBD) was extracted from a study on built environment and travel behavior.[22]

20. Total VMT for California in 2014 (185.32 billion VMT) was divided by the 2014 population (38.5 million people) to give an average annual VMT per capita (8,553 VMT).[23,24]

21. It was assumed that a Californian that lived an average distance away from a CBD would drive the average per capita miles. No measurement of average distance from a CBD was available, so the average commute distance (11 miles) for Californians was used as a proxy for that value.[25]

22. In a Development scenario, it was assumed that 11,783 additional residents would live in the Watershed, which would increase their commute distance from the average of 11 miles to 32 miles (calculated as the average distance from the east and west shores of Upper Dry Creek to the midpoint between Healdsburg and Santa Rosa, the two main cities in the area).

23. The increased distance to the CBD would increase each person's annual commute by 499 miles per year each. Over 11,783 people, this results in approximately 5.8 million additional VMTs per year.

24. If a car of average fuel economy emits .00042 Tons CO_2e/VMT,[26] then 5.8 million VMTs results in approximately 2,472 additional tons CO_2e per year.

25. Using California CO_2 cap and trade prices at the time of this study ($12.61/ton CO_2e) the annual social cost of this carbon is $31,171.[27] Using a recent Stanford social cost study that valued global human health impacts, reduced agricultural yields and increased storm damages at $220/ton CO_2e [28], the annual social cost of this carbon is $543,825.

26. The average of this range, **$287,498** per year, was used as the annual benefit associated with avoiding the Development scenario.

Net Present Value of Protecting Upper Dry Creek Watershed

27. The net present value of the cumulative avoided impacts under the Protection scenario was calculated using a 3.375% discount rate over 50 years. While it is clear that many of the environmental benefits (i.e. avoided impacts) will extend beyond the period of analysis, 50 years was chosen as a cutoff point due to uncertainty.

28. It was assumed that under the Development scenario, the properties on Upper Dry Creek Watershed would be developed gradually and linearly over 10 years, beginning at 10% of potential in Year 1, increasing to 20% in Year 2 (and so on), reaching 100% in Year 10. Therefore

the impacts avoided through the Protection scenario were weighted according to this progression.

29. The net present value of environmental benefits associated with Protection vs. Development were calculated. Table 6 summarizes the results of this calculation.

Table 6 - Cumulative Annual Impacts Avoided and Net Present Value of Impacts Avoided over 50 Years under both Protection Scenario

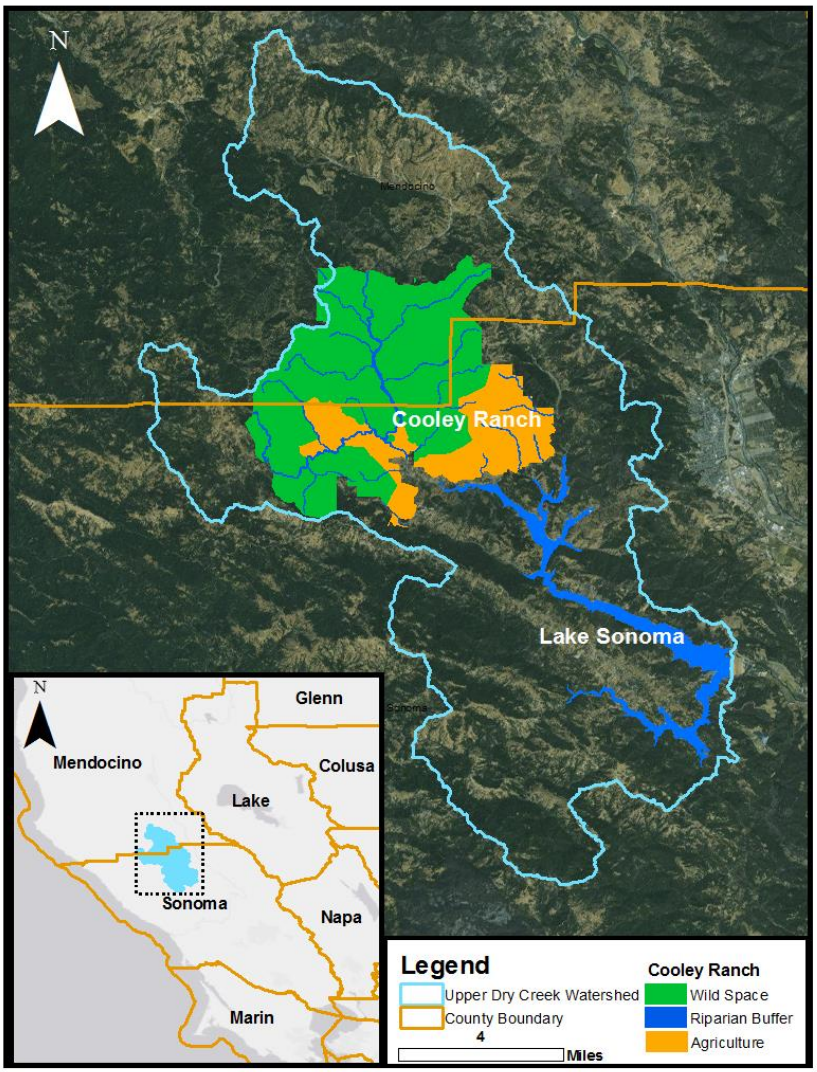
Ecosystem Service Impacted	Cause	Annual Benefits ($/year)
Water Quality	Septic Systems release of Nutrients (N, P)	$36,462
	Nutrient (N, P) Runoff due to Vineyards	Not Valued
	Sediment Runoff due to Roads	Not Valued
	Sediment Runoff due to Vineyards	Not Valued
Climate Stability	Emissions due to VMTs	$287,498
	Vegetation Loss due to New Dwelling Units	Not Valued
Habitat & Biodiversity	Habitat Loss due to New Dwelling Units	Not Valued
TOTAL		**$323,960**
Net Present Value of Benefits (50 years, 3.375% discount rate)		***$6,478,867***

Chapter 4: The Benefits of the Cooley Ranch Easement

Introduction

1. Cooley Ranch is a 19,132-acre easement located within the Upper Dry Creek Watershed that was purchased by the Sonoma County Agricultural Preservation and Open Space District ("The District") in 2001. Figure 7 shows Cooley Ranch in relation to the Upper Dry Creek and Lake Sonoma.

Figure 7 - Cooley Ranch in relation to Lake Sonoma and the Upper Dry Creek Watershed



2. The easement spans two counties: 10,677 acres are located in Sonoma County, and 8,454 acres are located in Mendocino County.

3. The District purchased the Sonoma County portion of the easement for approximately $6 million, while the Mendocino County portion of the easement was donated to The District by the Cooley Family.

4. The purpose of this analysis is:

    a. To show how The District's acquisition of the Cooley Ranch ("The Project") has resulted in clearly identifiable environmental benefits.

    b. To monetize a subset of those environmental benefits due to The Project.

Defining a Baseline and Counterfactual Scenario

5. The economic value added by The Project was assessed by comparing the environmental benefits produced by land within the Cooley Ranch boundary in its current state ("Protection") with a plausible counterfactual scenario, in which Cooley Ranch is subdivided and developed ("Development"). The two scenarios are described as follows:

    a. **Protection (Baseline).** The 19,132-acre Cooley Ranch easement is purchased by the District in 2001, extinguishing development rights on the property. The purpose of the easement is "to preserve the open space, natural, scenic and agricultural values of the Property…and to prevent any uses of the Property that will significantly impair or interfere with those values." (Brooks et al. 1999)[29] As such, the easement allows the ranch to be subdivided into four legal parcels, with one additional dwelling unit across the entire property, and further subdivision is prohibited. The existing level of agriculture, with 165 acres of vineyards, is allowed to continue.

    b. **Development (Counterfactual).** The Cooley Ranch easement is not purchased by the District. The 19,132-acre property is subdivided into 56 parcels of equal size, the maximum density that would be allowed under the county's zoning if there was no easement. A home site is developed on each parcel, which includes a septic system. New unpaved access roads are created for the homes, and many existing gravel roads on the Cooley Ranch property are converted to paved roads. It was assumed that each of the 56 parcels would be developed into a hobby farm, with vineyards covering approximately 12% of the parcel, which translates to approximately 41 acres of vineyards per parcel, or 2,296 acres of vineyard across the 56 parcels. This assumption of vineyard coverage was developed through the following steps:

        i. A selection of vineyards nearby Lake Sonoma were selected for analysis using the Draft Sonoma County Croplands Map, available at www.SonomaVegMap.org.

ii. The croplands map was overlaid with the Sonoma County parcel boundary GIS dataset, available at the County of Sonoma website (www.sonomacounty.ca.gov).

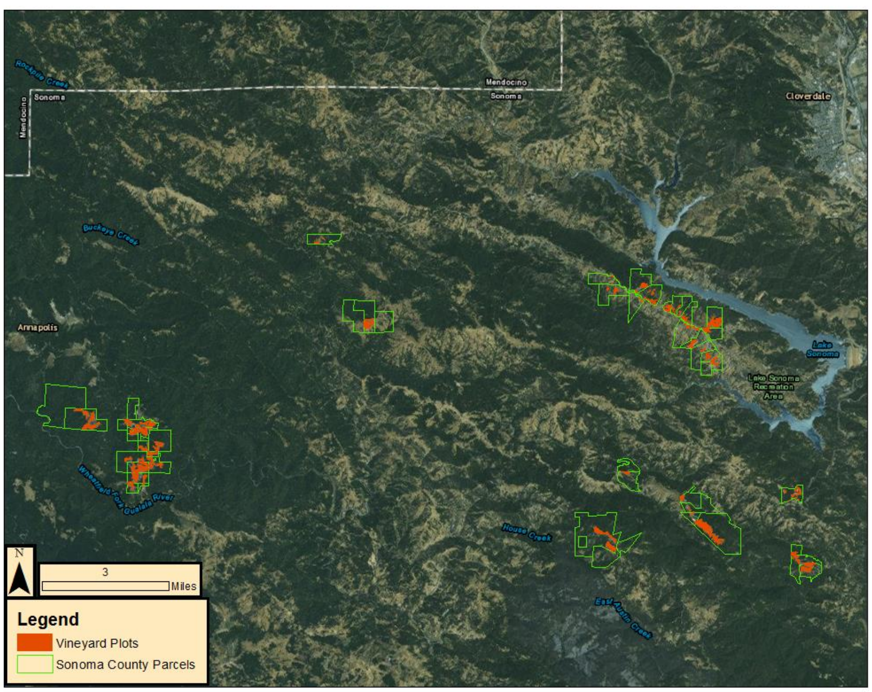
iii. A selection of parcels that contained vineyards identified in Step (i) above (a total of 56 parcels[††]) were chosen for analysis; all other parcels were ignored.

iv. For each of the parcels selected for analysis, the percentage of that parcel covered by vineyards was calculated. 20 of 56 parcels contained less than 5% vineyard; 21 of 56 parcels contained 5-20% vineyard; and the remaining 15 parcels contained 20-65% vineyard.

v. The weighted average of all the parcels covered by vineyard was calculated as 12%.

vi. Figure 8 shows a map of the parcels and vineyards used in this analysis, and Figure 9 provides a close up image of a representative parcel used in the analysis, containing approximately 12% vineyards.

Figure 8 - Parcels selected for analysis



[††] It is purely coincidence that 56 parcels were used for this land cover analysis, and that 56 was also the number of potential parcels that could be created through subdivision in the Development scenario. The numbers are not related.

Figure 9 - Representative parcel in Sonoma County containing vineyards

6. The environmental impacts in the Development scenario were compared with the impacts in the Protection scenario. Table 7 summarizes several other key differences between the Protection and Development scenarios. Table 8 provides a summary of differences in key environmental impacts in the Development scenario, compared with the Protection scenario.

Table 7 – Cooley Ranch Attributes in a Protection and Development Scenario

Attribute	Units	Scenario		Change
		Protection	Development	
Population	People/19,132 acres	10	144	134
Dwelling Units	Households/19,132 acres	0	56	56
Septic Systems	Septic Systems/19,132 acres	0	56	56
Vineyards	Acres	165	2,296	2,131

Table 8 - Environmental Impacts on Cooley Ranch under the Development scenario compared with Protection

Ecosystem Service Impacted	Cause	Change in Development vs. Protection	Monetized?
Water Quality	Septic Systems release of Nutrients (N, P)	Increase	Yes
	Nutrient (N, P) Runoff due to Vineyards	Increase	Yes
	Sediment Runoff due to Roads	No Change	No
	Sediment Runoff due to Vineyards	Increase	Yes
Climate Stability	Emissions due to VMTs	Increase	Yes
	Vegetation Loss due to New Dwelling Units	Increase	No
Habitat & Biodiversity	Habitat Loss due to New Dwelling Units	Increase	No

7. The following sections further describes these environmental impacts, and how they were monetized.

Water Quality: Nutrient (N, P) Runoff

8. Excessive nutrients are a leading cause of water quality impairments nationwide.

9. Nutrients are found in human and animal waste as well as in artificial fertilizers, soaps and detergents, and other industrial and municipal waste.[30,31]

10. Nutrients can be directly discharged into surface water streams or run-off to streams bound to sediment when erosion occurs.

11. Nitrogen and phosphorus are nutrients naturally found in water bodies, but when found in excess they can cause algal blooms that lower oxygen levels in the water and produce toxins and bacterial growth harmful to humans and other organisms. [32]

12. Compton et al. (2011) review the literature for economic studies that estimate costs associated with excess N, including impacts to drinking water, recreation, commercial fisheries, and human health impacts.

13. Based on several studies cited in the Compton et al. (2011) study, a total cost of $9.48 per kg of excess N was estimated. While a number of additional costs could have been included, only the most plausible impacts were selected. For example, N runoff from the Upper Dry Creek Watershed will eventually reach the lower Russian River and Estuary,

therefore a study estimating N impacts to recreational use of estuaries was selected. Table 9 shows the cost estimates by impact type and study information.

Table 9 - Costs associated with excess N in the environment

Impact Type	**Impact Mechanism**	**Cost per kg N**	**Study Reference (as cited in Compton et al. 2011)**
Recreational use of lower Russian River and estuary	Nitrogen contributes to regional haze, and visibility damages decrease aesthetic enjoyment where people recreate.	$6.38	Birch et al. 2011
Anticipated damages of climate change	Nitrogen influences the production of many greenhouse gases (N_20, CO_2, CH_4), supporting a stable climate.	$3.10	Kusiima & Powers 2010
Total		**$9.48**	

14. Two causes of nutrient-related impacts were identified in the Cooley Ranch Development Scenario: Agriculture and Septic Systems. Quantification and monetization of these impacts are described below:

    c. **Agriculture.**

      xi. Cropland is a major contributor of excess N in the environment.

      xii. As stated above, it is estimated that approximately 2,131 acres of new vineyards will be developed in the Development scenario.

      xiii. While grapes typically demand far less N inputs than most other crops (Hartner and Lund, 2012), they can still produce significant N runoff compared with other land uses.

      xiv. A study conducted in California by Viers et al. (2012) estimates that grape vineyards produce approximately 8.1 kg N per acre per year. Another study by Ramos and Martinez-Casasnovas (2005) estimated that vineyards produce 3.2 kg N runoff per acre per year. The estimate of 8.1 kg per acre per year in Viers et al. (2012) was used as the study was conducted in California.

xv. In the Development scenario, it is estimated that the 2,296 acres of vineyards will produce approximately (2,296*8.1 =) 18,598 kg N per year.

xvi. In the Protection scenario, it is estimated the current acreage of 165 acres of vineyards will produce approximately (165*8.1 =) 1,337 kg N per year.

xvii. The additional N runoff in the Development scenario compared with the Protection scenario is approximately (18,598-1,337 =) 17,261 kg N per year.

xviii. Based on a cost of $9.48 per kg N, the total cost of this excess N runoff is (17,261 *9.48 =) **$163,635 per year.**

d. **Septic Systems.**

xix. According to the U.S. EPA, approximately 30% of U.S. households use on-site treatment systems (EPA 1999).

xx. While not a major contributor of N runoff in California relative to farmland (Hartner and Lund, 2012), septic systems can still contribute significant N to streams, lakes and groundwater.

xxi. By estimating the annual N excretion rate for people, and the removal efficiency of an average septic system, the annual N runoff rate into Upper Dry Creek Watershed can be estimated.

xxii. Various estimates exist for the N excretion rate of people, and are generally quite consistent. Groffman et al. (2004) estimates an average excretion rate of 12 g N per capital per day, or 4.38 kg per year. Gold et al. (1990) observed losses of 9.5 kg per 3-person household per year. Hartner and Lund (2012) cite a paper by Crites and Tchobanoglous (1998), which estimated that the daily nitrogen excretion per adult is 13.3 g, or approximately 4.85 kg per year. The Groffman et al. (2004) value of 4.38 kg per capita per year was adopted for this study.

xxiii. Siegrist et al. (2000) estimate that 10-20% of N can be removed in conventional septic systems. Therefore a 15% removal efficiency rate was adopted.

xxiv. Assuming 2.57 persons per household, it is estimated that each household excretes (4.38*2.57 =) 11.26 kg N per year.

xxv. Assuming a 15% removal efficiency, this results in (11.26*0.15 =) 1.69 kg per household per year.

xxvi. Over 56 households, this is equal to runoff of (56*1.69 =) 95 kg N per year.

xxvii. Based on a cost of $9.48 per kg N, the total cost of this excess N runoff is (95*9.48 =) **$896 per year**.

15. Key Assumptions for this analysis include:

   e. For the purposes of this analysis, it is assumed that in the Protection scenario, people who would have lived on the 56 parcels in the Development scenario instead move to a more densely populated part of Sonoma County, served by the Sonoma County Water Agency.

Vehicle Miles Traveled

16. Vehicle Miles of Traveled (VMT) are the number of miles traveled nationally by vehicles for a period of 1 year.[33] The following method was used to calculate the VMT avoided under the easement scenario for the Cooley Ranch property.

17. The relationship between distance from a central business district (CBD) and vehicle miles of travel (.28% Δ VMT/Mile from CBD) was extracted from a study on built environment and travel behavior.[34]

18. In order to extract the actual change in VMT, it was necessary to find the average VMT per capita in California (8,553 VMTs). Total VMT for California in 2014 (185.32 billion VMTs) was divided by the 2014 population (38.5 million people).[35,36]

19. It was assumed that a Californian that lived an average distance away from a CBD would drive the average per capita miles. No measurement of average distance from a CBD was available, so the average commute distance (11 miles) for Californians was used as a proxy for that value.[37]

20. In a Development scenario, it was assumed that 133 additional residents would live in the Watershed, which would increase their commute distance from 11 miles to 37 miles (calculated as the average distance from the middle of Cooley Ranch to the midpoint between Healdsburg and Santa Rosa, the two main cities in the area).

21. The increased distance to the CBD would increase each person's annual commute by 499 miles per year each. Over 133 people, this results in approximately 66,892 additional VMTs per year.

22. If a car of average fuel economy emits .00042 Tons CO_2e/VMT,[38] then 66,892 VMTs results in approximately 28.09 additional tons CO_2e per year.

23. Using California CO_2 cap and trade prices ($12.61/ton CO_2e) the annual social cost of this carbon is $354.[39] Using a recent Stanford social cost study that valued global human health impacts, reduced agricultural yields and increased storm damages at $220/ton CO_2e [40] the annual social cost of this carbon is $6,237.

24. The average of this range, **$3,296 per year**, was used for this analysis.

Net Present Value of Impacts

30. The net present value of the cumulative avoided impacts under the protection scenario was calculated using a 3.375% discount rate over 50 years. While it is clear that many of the environmental benefits (i.e. avoided impacts) will extend beyond the period of analysis, 50 years was chosen as a cutoff point due to uncertainty.

31. It was assumed that under the Development scenario, the properties on Cooley Ranch would be developed gradually over 10 years, beginning at 10% of potential in Year 1, increasing to 20% in Year 2 (and so on), reaching 100% in Year 10. Therefore the impacts avoided through the Protection scenario were weighted according to this progression.

32. The net environmental benefits associated with The Project were calculated as the net present value of avoided impacts calculated above, representing the "asset value" of the Cooley Ranch policy intervention. Table 10 summarizes the results of this calculation.

Table 10 - Cumulative Annual Impacts Avoided and Net Present Value of Impacts Avoided over 50 Years under both Protection Scenario

Environmental Impact	Cause	Annual Impact ($/year)
Nutrient (N,P) runoff	Septic Systems	$896
	Vineyards	$163,635
Sediment runoff	Roads	Not Valued
	Vineyards	Not Valued
Vehicle Miles Traveled	New Dwelling Units	$3,296
Vegetation Removal	New Dwelling Units	Not Valued
Increased Fire Risk	New Dwelling Units	Not Valued
Habitat & Biodiversity Impacts	Subdivision/development	Not Valued
TOTAL		**$167,827**
Net Present Value of Benefits (50 years, 3.375% discount rate)		***$3,356,374***

Chapter 5: The Value of Water in Sonoma County

The previous sections estimated the value of a subset of the benefits of protecting Upper Dry Creek and Cooley Ranch. But what is the "value" of the drinking water itself? The purpose of this section is to provide a simple demonstration of one traditional economic approach to describing the value of water in Sonoma County.

The scope of this analysis is limited to water purchased by residential households in Sonoma County, which is delivered by Sonoma County Water Agency to consumers via cities and districts in Sonoma and Marin Counties (e.g. Santa Rosa Water). Other water users, such as the industrial, commercial, and agricultural sectors, were excluded from the analysis. As a result, this study may underestimate the full value of water provided in Sonoma County.

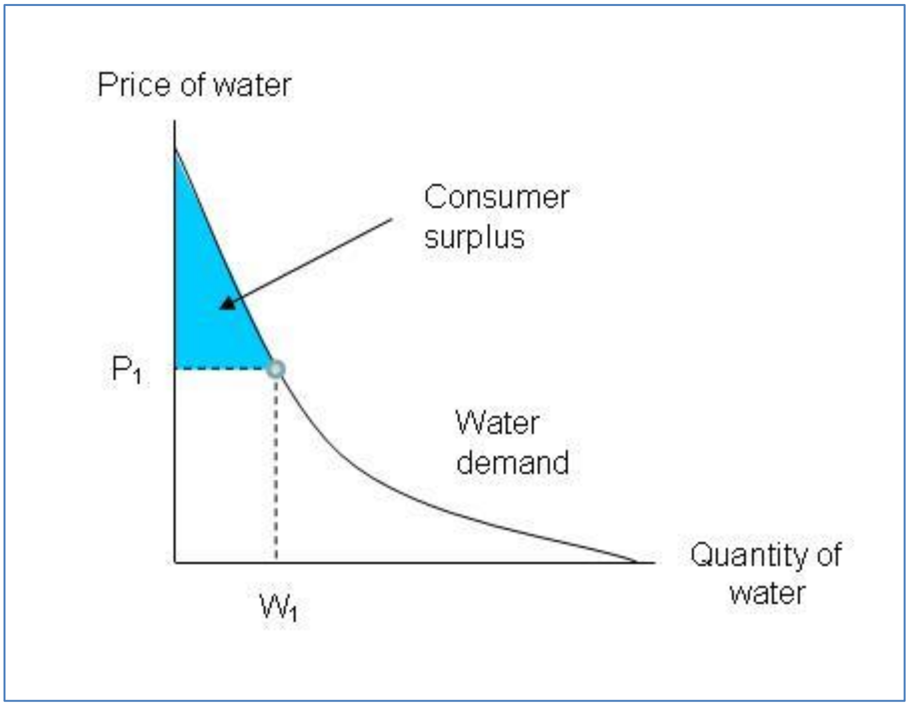
Price, Value and Consumer Surplus

In one sense, the economic value of water in Sonoma County is the price that households pay for the water, multiplied by the number of gallons sold over a given period. However, the *value* of a product is not always equal to the *price* consumers pay for it. Economists often measure the value of a good or service by consumers' willingness-to-pay (WTP) for it. The added value that consumers get from a good or service, over and above the price they pay, is referred to as "consumer surplus". For example, if a consumer – let's call her Sally – is willing to pay $4 for a smoothie, and finds a stall selling smoothies for $3, her consumer surplus for that first smoothie will be $1.

Sally's WTP for water depends on a number of factors, including her income level and preferences. In addition, Sally's WTP for water probably changes significantly depending on how much she has already consumed. The first few gallons of water she consumes each month, used for drinking and cooking, are critical to keeping her alive, and incredibly valuable to her. If she was lost in a desert with no access to water, she would be willing to pay a lot of money – perhaps her life savings – for a glass of water. The next few gallons, used for dishes, showering, and laundry, are still valuable to her but perhaps a bit less valuable. Finally, the water she uses to water her lawn is even less valuable, and in drought conditions she could likely go without watering it. We can calculate the total value Sally ascribes to the water by taking her WTP for each gallon, across every gallon she consumes.

Assuming Sally is a typical water user in Sonoma County, the price she pays for each gallon delivered to her house is probably about the same (the exact price depends on which utility supplies her water). Thus, the consumer surplus – or "added value" – Sally receives from the first few gallons of water is the highest, because her WTP for those first few gallons are higher compared to the price. As Sally purchases additional gallons of water and her WTP decreases, her consumer surplus also decreases with each additional gallon. Sally's WTP across different quantities of a good or service can be graphically represented as a "demand curve". According to economic theory, a consumer like Sally will purchase a good as long as their WTP is equal to or higher than the price of the good. Beyond that point, the consumer is not receiving any consumer surplus. Figure 1 shows a graphical representation of a hypothetical demand curve for water.

Figure 10 - Price and Consumer Surplus for Water



The line W1, on the X-axis, represents the maximum quantity of water that Sally is willing to purchase at the price labelled P1 on the Y-axis. Because Sally paid the same price for every gallon up to W1, and her WTP was higher for those earlier gallons, she received a consumer surplus, represented by the blue shaded area on the graph. A demand curve can also represent the average WTP of an entire group of people. In the methods section below, we create an "average" demand curve across the majority of residential water users in Sonoma County.

The steepness of the demand curve slope reflects the "price elasticity of demand". As Figure 1 shows, the first part of the demand curve is the steepest, which means that in theory, Sally would be less willing to give up consumption of her first few gallons of water, even if the price increased dramatically. In other words, Sally's demand for these gallons is relatively "inelastic", because it does not change much in response to price. This is because those first few gallons are critical to keeping her alive. As the quantity of water increases, Sally's demand becomes more elastic, and she would be more willing to give up consumption of those extra gallons if the price increased. Greater elasticity results is represented by a demand curve slope that is less steep. Sally would most likely use those gallons for less critical purposes, such as watering her lawn, or washing her car.

Elasticity is denoted by a number. For example, a value of "-0.5" means that for every 10% increase in price, Sally's demand for water decreases by 5%. Because water is so valuable to humans, our elasticity of demand tends to be very low. For example, one study conducted in the Western U.S., which is referenced below, found that people's elasticity of demand for indoor water (for drinking, cooking, toilets, showers etc.) was approximately -0.07, which means that for every 10% increase in price, people would only reduce their indoor water consumption by 0.7%.[41]

Methods

The goal of this exercise was to construct a demand curve for residential water in Sonoma County, and thereby estimate the economic value of this water. The following describes the data sources, methods, and assumptions used to develop this estimate. Because this is a cursory estimate and primarily for illustrative purposes, a number of assumptions were made that should be revisited in a more detailed analysis. These assumptions are included in the narrative to the extent possible.

Public water utilities operate on a "cost-recovery" basis, and do not aim to maximize profit, so the *price* of water reflects the approximate cost of the infrastructure (dams, transmission pipes, treatment plants) and labor (employees) required to deliver the water from its source to the consumers. For this reason and others, the price consumers have paid for water has been relatively low compared to incomes,[‡‡] and large price fluctuations have been uncommon. While the affordability and relative price stability is a good thing for consumers, it also makes it challenging for economists to estimate peoples' WTP for water across a range of prices and construct a full empirical demand curve for water.

Constructing a demand curve requires empirical data. In this case, the starting point was the current quantity of water consumed by residential households, and the average price paid for that quantity.

The City of Santa Rosa's water rates were used as a proxy for the price of residential water in Sonoma County.[§§] Santa Rosa Water has two types of rates for residential water users: 1) Single Family Residential and 2) Multi-Unit Residential. The 2015 volumetric rate for Single Family Residential is $5.39 per 1,000 gallons, and the volumetric rate for Multi-Unit Residential is $5.73 per 1,000 gallons.

[‡‡] In other words, the consumer surplus people get from water has been relatively high.

[§§] Rates differ between utilities in Sonoma County, and can also differ within utilities (e.g. if the utility uses tiered rates). A more detailed analysis should use the actual rate for each gallon of water sold at each utility.

The average of these volumetric rates, $5.56 per 1,000 gallons, was used for all water sold in Sonoma County.[***] Fixed monthly fees and other one-time fees were excluded from this analysis.[†††]

Next, the total quantity of water consumed by residential households was calculated for Sonoma County. California DWR collects information from water utilities on the different types of users that purchase their water.[42] User categories include Agriculture, Landscape, Multi-family, Other, and Single-Family. Data was compiled for each of the major retail water utilities in Sonoma County that report their water deliveries to DWR for 2015: City of Santa Rosa, City of Petaluma, City of Rohnert Park, Town of Windsor, City of Sonoma, and Valley of the Moon District.[‡‡‡] For each of these utilities, the total quantity of water delivered to Multi-family and Single-Family users was summed. Deliveries are reported in acre-feet of water, which was converted to 1,000 gallon units. Table 11 provides a summary of water deliveries and the total amount paid by consumers to purchase this water ($63.7 million).

Table 11 - Water Delivered to Single-Family and Multi-Family Users in 2015

Utility	Single-Family, Multi-Family Deliveries (AF)	Single-Family, Multi-Family Deliveries (1,000 G)	Average Rate per 1,000 G	Total Revenue
City of Santa Rosa	16,928	5,516,006	$5.56	$30,668,992
City of Petaluma	6,483	2,112,492	$5.56	$11,745,456
City of Rohnert Park	4,129	1,345,439	$5.56	$7,480,640
Town of Windsor	3,159	1,029,363	$5.56	$5,723,260
City of Sonoma	1,753	571,217	$5.56	$3,175,965
Valley of the Moon Dist.	2,724	887,618	$5.56	$4,935,157
TOTAL	**35,176**	**11,462,135**		**$63,729,469**

[***] Using an average of these two rates assumes there is an equal quantity of water sold at each rate. In reality, the quantity is likely to be different, and a weighted average would be more accurate. This should be considered in a future analysis.

[†††] Fixed fees make up a non-trivial portion of the monthly cost of water for most consumers, beginning at $11.32 per household per month for a standard residential 5/8 inch meter in Santa Rosa. Fixed fees affect the price of water, which in turn affects consumer behavior, and should therefore be factored into a future analysis.

[‡‡‡] This analysis excludes a number of residential water users who do not purchase water from these utilities.

Figure 11 provides a graphical representation of the amount paid for each gallon of water. The total area of the green shaded box is the average price multiplied by the total quantity, or approximately $63.7 million.

Figure 11 - Amount Spent by Residential Users to Purchase Water in Sonoma County

The next step was to sketch out the demand curve for residential users in Sonoma County. As discussed earlier, a demand curve represents the relationship between price and the amount of a good or service that a consumer demands. As the price increases, the quantity demanded by the consumer tends to decrease. This change in quantity demanded is determined by consumers' price elasticity of demand, which is denoted by a number.

Most studies calculate the price elasticity of demand for water based on changes in consumer demand in response to (usually increases) in price compared with the price they are currently paying. Thus, our starting point for this analysis is the current quantity of water purchased by consumers at the current price. The intersection of the last gallon of water (i.e. the 11,462,135-th gallon) and the average price at that gallon (i.e. 5.56) represents that point on the graph in Figure 11.

Studies on water demand indicate significantly different elasticities for indoor (-0.072) and outdoor (-0.6836) use of water.[43] The elasticity for outdoor water use indicates that a 10% increase in price will lead to a reduction of 6.8% in water use. The same increase in price would only lead to a .72% decrease for indoor water use, indicating that consumers are much less willing to reduce their indoor water use when faced with higher rates, likely because indoor water is used for more critical purposes (drinking, cooking, flushing toilets, showering etc.).

In order to use the differing elasticities, the relative proportion of indoor and outdoor water use in Sonoma County was first estimated based on water use statistics collected by California DWR.[44] Indoor use was estimated to make up 47% of total use, and outdoor use was estimated to make up 53% of total use.

Changes in demand in response to changes in price were then estimated for indoor and outdoor use separately, using their respective price elasticity values (-0.072 and -0.6836 respectively). The results were then combined into one curve, to represent the overall changes in water consumption with respect to changes in price.

Finally, a maximum WTP for water was estimated in order to set a reasonable limit on the demand curve. One study found that Californian consumers are willing to pay at least 142% more for water for a sustained period during severe droughts.[45] Based on this study, it was assumed that the current maximum rate that consumers would tolerate is 142% above the current rate. We believe this is a conservative estimate of maximum consumer WTP for water, especially for indoor water uses such as drinking, cooking and toilet related uses.

The "total value" of residential water in Sonoma County was estimated by calculating the total area beneath the demand curve. The consumer surplus – or "added value" was calculated by removing the area that corresponds to the total amount paid for the water. Figure 12 provides a visual representation of this calculation, and Table 12 provides a summary of total value and consumer surplus calculated for residential water in Sonoma County. Results indicate that total consumer surplus for residential water in Sonoma County is approximately $75 million per year. In other words, for every dollar that residential consumers spend on water in Sonoma County, they receive approximately $1.17 in consumer surplus, or "added value".

Figure 12 - Total Consumer Surplus of Water Purchases for Residential Users in Sonoma County

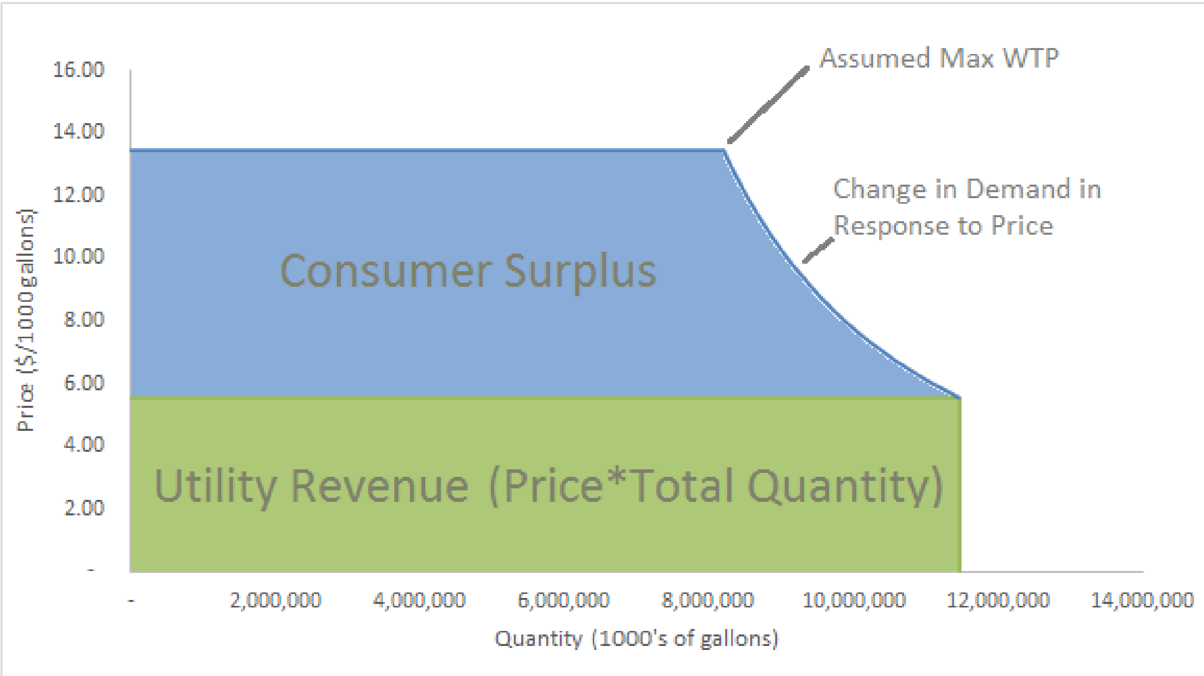


Table 12 - Summary of Consumer Surplus Calculations for Sonoma County

Category	Value
Amount Paid for Water (Utility Revenue)	$ 63,729,469
Consumer Surplus of Water ("Added Value")	$ 74,565,539
"Total Economic Value" of Water	$ 138,295,008

Chapter 6: The Potential Impacts and Costs Associated with a Wildfire in Upper Dry Creek Watershed

In its current state, the 83,276 acre Lake Sonoma Watershed represents a complex ecosystem that delivers many cost-effective benefits and services to a multitude of interests, as discussed in previous chapters. In many cases these benefits are not directly measured or even well understood, thus making it difficult to attach economic value to the watershed. Nonetheless, it is very clear that without the watershed, or if the watershed were to become degraded, the value of these services would diminish, or the costs of delivering these services would increase.

The purpose of this chapter is to examine the potential impacts and costs related to one significant risk that this watershed faces; the risk of a major wildfire. This chapter is not a definitive study assessing the likelihood of a wildfire but rather an assessment of the type and magnitude of damage and cost that a major wildfire would create. The hope is that by better understanding the scope and magnitude of the impact and potential cost of a wildfire, we can better prepare and even proactively take steps to lessen the risk of such an event.

Population Density and Wildfire Probability

A study by Syphard et al. (2007)[46] examined evidence for human influence on fire regimes in the State of California. Of all the variables the study looked at, population density was most closely related to the number of fires. Specifically, the study found that observed fire density across California (# fires/km^2) was highest when population density was between 35 and 45 people per km^2. For comparison, and somewhat by coincidence, the population density calculated for the Upper Dry Creek Watershed in the Development counterfactual in Chapter 6 (based on Big Bear Lake Watershed) was approximately 35 people per km^2. Assuming the Development scenario is plausible and accurate, this indicates that it would have a relatively high risk of wildfire.

Population and Wildfire Costs

Residential construction in wildland areas can increase the potential for future wildfires to impact life safety and property, and increases the burden on firefighting resources in the region. The area where residential development meets or intermingles in the midst of wildland areas is referred to as the "Wildland/Urban Interface" (WUI).[47] Fire in these areas often results in the greatest losses of property and life. Efforts to save lives and property can often divert and complicate firefighting efforts. WUI homes are frequently vulnerable to wildfires because fire departments are no longer just minutes away, and are, for the most part, unable to protect homes in outlying areas from wildfire disasters. Untreated wood shake and shingle roofs, narrow roads, limited access, steep terrain, lack of defensible space, and inadequate water supplies, all contribute to the potential for greater life loss and property damage in a wildland/urban interface wildfire.

Effects of Wildfires on a Watershed

A study by the Western Forestry Leadership Coalition estimated that the "hidden" cost of a wildfire is between 2 and 30 times the reported costs related to the actual firefighting and suppression costs.[48] Many of these costs will be borne locally by water utilities and ultimately water ratepayers. Below we discuss several of the major costs/issues that would arise from a major wildfire.

Water System Reliability

The Upper Dry Creek Watershed is part of a water system that delivers water to over 600,000 people. Lake Sonoma currently captures the majority of sediment that is produced in the watershed. Very little sediment makes its way past Warm Springs dam into Lower Dry Creek. However, sediment reduces the volume of Lake Sonoma, and each year a small percentage of the storage capacity of the lake is lost, ultimately reducing overall system reliability. From a water quality perspective, a major wildfire would create a wide range of negative impacts to a water utility and its ability to provide a clean and reliable source of drinking water. Impacts may include:

- **Increased Sediment and Siltation.** Wildfires dramatically increase the amount of sediment that is produced in the watershed. The high heat burns ground cover, roots, and surface litter as well as transforms the soil so that the area effectively becomes water repellent. Subsequent storm and heavy rain events no longer are held back or absorbed into the soil and depending on the terrain and slope can generate significant amounts of sediment.
    - Potential exists for sediment volumes to reduce water volume of Lake Sonoma by up to 5% per year. This loss of capacity may reduce the overall reliability of the water system over time.
- **Nutrients.** Currently the Lake Sonoma watershed serves as a very efficient filtration solution that removes significant amounts of nutrients (N and P) and allows the Water Agency to avoid significant water treatment costs. In the event of a wildfire, nutrients in the watershed would mineralize or volatize due to burning and high soil temperatures. Subsequently, these nutrients would become part of the increased run-off and sediment and likely reach Lower Dry Creek. In addition, within the watershed, the loss of nutrients makes it more difficult for revegetation to occur and it may require supplementation to promote new growth.
    - Increased nutrient levels may require additional water treatment and purification costs.
    - Increased nutrients may promote higher than desired levels of algae in Lake Sonoma and downstream and impact recreation and fish mortality.

Climate Stability

The Lake Sonoma watershed is a diverse and vibrant ecosystem with a wide and diverse range of forest type and land cover. These forests and vegetation all contribute to climate stability through their carbon sequestration and storage services. A wildfire would destroy significant portions of the forested watershed and release thousands of tons of greenhouse gasses and emissions. Impacts may include:

- **Loss of carbon storage capacity.** 20-50 years before meaningful natural revegetation can occur.
- **Reforestation and hillside stabilization costs** to replant and promote more rapid reforestation.

Wildlife

The Upper Dry Creek Watershed and shorelines of Lake Sonoma itself are home to hundreds of species of birds, mammals, reptiles, and fishes. These creatures rely on the ecosystem to provide habitat, food, shelter, and protection from other predators.

- Wildfires destroy wildlife both directly and indirectly. Many creatures are unable to escape the smoke and heat and perish. Others manage to escape but are left with a habitat that is barren of food or shelter.
- This is very difficult to produce a meaningful estimate for but there is no question this would be a loss to the ecosystem.

Recreation & Tourism

The Upper Dry Creek Watershed and Lake Sonoma are used by hikers, bird watchers, hunters, joggers, cyclists, boaters, fishermen, and other outdoor recreationists. The area has many trails, vistas, viewing areas, and activities.

- A wildfire would have detrimental impacts to most recreational activities. Access would be restricted; trails, roads, and structures could be destroyed.
- Visually and aesthetically the area would be scarred for many years.
- Tourism and recreational visits would be reduced or eliminated resulting in the loss of revenue to the region.

Reducing Fire Risk through Watershed Protection and Management

Mitigation

Proactive forest management can significantly modify fire behavior by reducing fire severity, size and rate of spread. A survey conducted in 2011 by the Nature Conservancy and the Watershed Association found that 82% of ratepayers were willing to pay a charge of 65 cents per month to protect the City's water supply from the risk of catastrophic wildfire. Using this data the local water utility implemented a program to proactively restore and maintain the watershed specifically to reduce the threat of major wildfires.

Buckley et al. (2014)[49] studied the potential avoided costs associated with fuel treatments in the Mokelumne Watershed, along the Sierra Nevada in California. They found that fuel treatments could significantly reduce the size and intensity of wildfires, and the economic benefits of treatments may be 3 to 4 times their costs. The study found that while fuel treatments primarily benefited the state and federal governments through avoided fire suppression and cleanup costs, water utilities relying on downstream intakes also experienced significant benefits through reduced sedimentation after a fire.

Sustainable forest management includes removing excess biomass, or small diameter trees, branches, and diseased wood, that act as fuel for a fire. Biomass represents a huge untapped resource for the generation of heat and power and its removal can improve forest health and reduce the risk of catastrophic wildfire. In fact, burning biomass in a controlled facility to generate power, as opposed to an open fire, can reduce carbon dioxide emissions and create jobs for rural economies.

Watershed Wildfire Impacts: Case Studies

Hayman Creek Fire (Colorado, 2002)

- The fire burned nearly 140,000 acres just South of Denver and had a severe impact on the watershed serving the greater Denver area.
- Deposited 1,000,000 cubic yards of sediment into reservoir. Removal costs were $75/cubic yard.
- Costs related to reservoir water storage decreases were estimated at $37 million dollars.[50]

Old, Grand Prix and Padua Complex Fire (California, 2003)

- 125,000 acre blaze in the mountainous Santa Ana watershed.
- Significant losses to structures and electrical infrastructure estimates at over $676,171,965.[51]
- Santa Ana Watershed Project Authority (SAWPA) estimated another $500,000,000 in costs related to future water quality issues and flood control mitigation.

Lost Creek Fire (Alberta, 2003)

- Burned 52,000 acres in the Oldman river basin which is an important drinking water source.
- Resulted in a 5.3X increase in nitrogen levels as compared to undamaged areas[52].
- Caused an 8X to 13X increase in sediment concentrations due to wildfire[53].

Rim Fire (California, 2013)

- 3rd largest wildfire on record in California, burning over 247,000 acres.
- Estimated to have released over 11,350,000 metric tons of greenhouse gasses and emissions.[54]
- Destroyed thousands of acres of habitat for multiple threatened species (great grey owl, pacific fishers).

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