NORTH COAST RESOURCE PARTNERSHIP

Local Planning for the North Coast Resource Partnership:

TRINITY COUNTY FOREST ECOLOGY AND WATERSHED HYDROLOGY & ECONOMIC VALUATION OF NATURAL CAPITAL AND ECONOMIC ANALYSIS FOR TRINITY RIVER WATER

Northwest California Resource Conservation & Development Council's
Five Counties Salmonid Conservation Program (5C)

31 March 2017

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INTRODUCTION

The North Coast Resource Partnership (NCRP) has been working on updating the regional integrated strategy that is the framework for the various resource management strategies the region undertakes in its quest to balance environmental stewardship with its communities' critical water and resource needs. This latest effort to update the region's planning strategy was funded by the Strategic Growth Council. On behalf of Trinity County, an NCRP member County, the Northwest California Resource Conservation & Development Council's Five Counties Salmonid Conservation Program (5C) undertook a project to address two technical sections of the NCRP plan: 4. Forest ecology and watershed hydrology & 9. Economic valuation of natural capital and regional economic analysis. The Trinity River watershed, specifically will be studied from two perspectives: forest ecology as it relates to water yield and the use of Trinity River water, with attention to the current out of basin export of the majority of the water.

In regards to forest ecology and watershed hydrology, the 5C project developed a model based on a combination of natural forest mortality, wildfire occurrence, harvest management options, climate trends, and other factors that was used to estimate changes in forest composition and project changes in water yield along with a gross estimate of the cumulative effects of these changes. This information will be used by local and regional leaders and stakeholders to evaluate different forest management approaches and water management efforts.

For the concept of economic valuation of natural capital and economic analysis for Trinity River water, existing studies on the value of goods and services produced within and outside of the Trinity River basin that are directly supported by Trinity River water were compiled and synthesized. The intent is to provide local decision makers with information that can facilitate discussions about local resource management. Local leaders have long expressed an interest in exploring the concept of assessing the value of the various benefits derived from the Trinity River. What has been lacking is a sense of even the gross magnitude and scope of these benefits.

The Northwest California Resource Conservation & Development Council is a non-profit organization whose mission is to conserve natural resources and promote resource based economic development that improves the standards of living for current and future generations in Trinity, Humboldt and Del Norte Counties by working collaboratively with Council partners to promote projects for the benefit of all communities. The 5C Program is the largest under the Council's umbrella and has long participated in the North Coast Resource Partnership. More information on the 5C is available at www.5counties.org.

BACKGROUND AND SETTING

The focus of this study is the Trinity River, which is located within the Trinity River Watershed Management Area (TRWMA) in Trinity County. The TRWMA is approximately 2,900 square miles of high elevation largely steep mountain terrain, which is predominantly under federal landownership. The Trinity River is the largest tributary to the Klamath River system. Trinity County is made up of a geographically dispersed group of rural communities, which are entirely disadvantaged, that are surrounded by a large wealth of natural resources including threatened coho and other anadromous species. Local policy makers have expressed concern that federal management of this wealth is often done without their input. Water is a key resource of the county. A significant amount of the Trinity River flow (approximately 50% or more) is diverted just upstream of Lewiston to the east and south to the federal Central Valley Project administered by the U.S. Bureau of Reclamation. This is one of the state's largest out-of-basin water transfers. It has been speculated that the cool, clean water from the Trinity River is an important element in maintaining habitat and water temperatures for Delta smelt and salmonids in the Sacramento River watershed. The diversion is also used to generate electrical power at several hydroelectric facilities along its course, including powerplants at Trinity Dam, Lewiston Dam, Whiskeytown (Judge Francis Carr), Spring Creek and Keswick Dam.

Due to its Mediterranean climate, Trinity County receives most of its precipitation in the late fall through spring and then enters into a drought for several months. Surface water flows are dependent on a series of factors including but not limited to: watershed size, soils and geology, topography (aspect, slope, and elevation), vegetation, hydrography, and other factors. High elevation watersheds, which are found throughout the County, tend to store more water in the form of snow with percolation into soils. This natural storage is vital to help maintain consistent streamflows in the drier months. In recent years, the region has experienced several very dry years and very low, sometimes negligible, snowpack. In the county seat of Weaverville, the main water provider – Weaverville Community Services District – has been near or at maximum capacity of water supply during the summer in the many of the last several years. The dry climate also does not bode well for salmon, particularly threatened coho, which rely on high winter flows to migrate upstream to spawn.

Numerous management measures, plans, and regulatory strategies on the federal, state, and local levels have been developed that affect water management, fisheries, and water quality in the Trinity River and the North Coast region. Over the past 20 years, major state and federal actions or plans have identified impacts to water and aquatic resources in the Trinity River: Northwest Forest Plan (US Forest Service, 1994); Federal and State listings of coho salmon as a Threatened Species (National Marine Fisheries Service (NMFS), 1998 & CA Fish and Game Commission, 2002); Trinity River Record of Decision (ROD) (Bureau of Reclamation, U.S. Fish and Wildlife Service, and Hoopa Valley Tribe, 2000); Trinity River Total Maximum Daily Load (TMDL) allocation for sediment (US Environmental Protection Agency, 2000). However, several conservation groups are actively working to restore and enhance watershed conditions. The Bureau of Reclamation's Trinity River Restoration Program has targeted sediment reduction, habitat creation, and fish passage over the past several years in its long-term effort to address the adverse impacts to the Trinity River salmonid populations created by the construction of the dams and diversion of water to the Central Valley. It is estimated that the salmon and steelhead populations declined by about 80 to 90% after construction of the dams (Stene, 1996 from Study Summaries and http://www.trrp.net/background/impacts/ Trinity River Restoration Program. Retrieved 2017.03.31). For more information on the TRWMA basic statistics and information pertinent to water resources management, including complete references, please refer to the NCRP Phase III Plan (North Coast Integrated Regional Water Management Plan Phase III, August 2014). Of particular relevance is Section 6.3 Local Water Related Issues for North Coast Watershed Management Areas; Trinity River Watershed Management Area (p133 NCRP Plan Phase III).

FOREST ECOLOGY AND WATERSHED HYDROLOGY

SUMMARY

This assessment examines watershed level GIS fire history, forest stand data, and aerial photography of the Trinity River Watershed within Trinity County to assess stand conditions. By overlaying fire histories, topography and elevation factors with existing research on snow water yield, climatic patterns, and stand management, this assessment estimates potential increases in spring and summer snow melt water yields from thinning dense conifer stands with specific characteristics. Strategic forest stand thinning can reduce sublimation, open canopies to extend the length of the spring/summer snowmelt and modify forest fuels to reduce fire intensity without triggering adverse watershed effects.

Declining snow packs, unreliable precipitation patterns, and climatic changes over the past 50+ years have impacted water reliability for communities and habitat for endangered species. Additionally, the explosive growth of wildfire since 1987 has caused concerns and opportunities for forest management that must be considered in any effort to influence water yield. Between 2006 and 2015, wildfires burned 468,467 acres, subsequently changing conifer forest stand composition sufficiently to produce an estimated short-term water yield increase of 134,000 acre feet per year (equivalent to approximately 6% of the storage capacity of Trinity Lake).

Based on GIS analysis, 267,534 acres in Trinity County are both between 4,000 feet and 6,000 feet elevation and are on northwest to northeast aspects. Of this total, 118,278 acres are outside of Wilderness areas, SPI ownership, and have not burned in the past decade. Within this aspect and elevation band, thinning of some stands can improve snow depth and contribute to longer spring and summer runoff. However, thinning is not suggested throughout the watershed as the past 30 years of wildland fires have created risks of negative cumulative watershed impacts.

A 10,715 acre subset of the stands selected under these criteria were analyzed to estimate the water yield changes from a hypothetical thinning. Under two sets of assumptions on water yields this area would yield an additional 1,079 to 3,159 acre feet of runoff per year from thinning. Expanding that analysis to all 118,278 acres of potentially treatable lands would result in a theoretical maximum increase of 17,580 acre feet to 34,870 acre feet (~0.7% to1.5%) of the capacity of Trinity Lake. Active management could be used to increase snow water equivalent and snow melt in late spring and summer. More detail is found in the report titled ***Trinity County Forest Ecology and Watershed Hydrology: Assessment to Improve Late Spring/Summer Stream Flows, Reduce Fire Intensity and Fire Related Carbon Emissions in the Trinity River Watershed***. The report is accompanied by Appendix A, which is a photo log of Fire Affected Stands in the Trinity River Basin.

DISCUSSION & CONCLUSION

This project developed a new model for assessing forest stand conditions and various physical factors to estimate the effect of thinning practices on water yield. Accordingly, there were several basic assumptions made and methods used to arrive at model results and predictions. These are described in detail in the report in Deliverable A.1, along with detailed interpretation of the results.

We recommend that policy makers look at forest thinning of stands at sufficient elevation and favorable aspect to improve late spring and summer water yield.

Based on the assumptions in the model, low and high water yield estimates were generated over the 16 year period of effect. Thinning of dense conifer stands by 20% of basal area (20–40 ft2.acre) and light thinning 10% of conifer basal area within mixed Hardwood-Conifer stands will yield an average of 0.22 acre feet of additional water per year per acre based on the aggregate stands of the three assessment areas examined.

Thinning can create the right balance of stand openings and ground shade to maximize snow accumulation on the forest floor. At the same time thinning combined with pruning and fuels reduction can create shaded fuel break conditions. While this treatment can be used at all elevations and aspects, to increase summer water yield it is most effective between 4,000 feet and 6,000 feet elevation on northwest to east facing aspects.

ECONOMIC VALUATION OF NATURAL CAPITAL AND ECONOMIC ANALYSIS: TRINITY RIVER WATER

SUMMARY

To complete a coarse, initial economic valuation of natural capital and economic analysis for Trinity River water, existing studies on the value of goods and services produced within and outside of the Trinity River basin that are directly supported by Trinity River water were compiled and synthesized, along with other non-local studies of similar uses. Earth Economics was retained to perform the economic analysis of these studies. In a perfect assessment, recent and exclusively local studies of several ecosystem services would be available to be used for a larger assessment of overall values for Trinity River water. That is impractical primarily due to a lack of comprehensive local data.

Instead, economic values assessed on a regional level, such as biological beneficial uses, that resulted from Earth Economics' parallel efforts with the NCRP were applied based on the Trinity River watershed area. For that larger regional effort, Earth Economics used its vast database to capture a wide array of relevant values and applied it using the benefit transfer method to the North Coast region based on land cover types. For this project, the values derived from Earth Economics' database were applied based on land cover type found within the Trinity River watershed. These initial results are shown in Earth Economics' Study Summaries Table 2 "Annual Valuation Results for the Trinity River Watershed". This is what will be referred to in this introductory narrative as the Earth Economics base framework. 5C staff provided Earth Economics with several local and regional studies and reports on various beneficial uses of Trinity River water. Earth Economics then reviewed, and substituted where appropriate, data from these local studies into the overall valuation summary, if they met various criteria. These criteria addressed the degree of transferability, soundness of methodology, and fundamental similarities in terms of types of goods and services, land cover types, and gross cultural and demographic qualities. As Earth Economics explains, cultural and demographic similarities are more difficult to compare, but for a rough similarity, only domestic studies were used. The Value Summary table lists each ecosystem good and service analyzed from the local studies and indicates which ones were incorporated into the Earth Economics' base framework. A reference and synopsis of each study from which each local valuation was derived is included in the Earth Economics' report "Study Summaries". As described therein, the unit for the Earth Economics base framework is dollar per acre per year ($/ac/yr). The values in the individual studies have varying units. In some cases, studies were largely a snapshot from a specific year. However, for the purposes of this broad level assessment, those were interpreted as an annual value. A description of the methodology and criteria applied in bringing together the Earth Economics base framework and values from local studies is explained in Earth Economics' Study Summaries document.

Once valuations from local studies were added to the base framework, overall valuations were derived for Trinity River water. This end result is a gross estimate of the range of values of the water produced from the basin. These are described and included in Earth Economics' Study Summaries as Table 3 "Asset Value over 100 Years of the Trinity River WMA Using a 3% Discount Rate", which is shown below.

Total Asset Value over 100 Years of the Trinity River WMA Using a 3% Discount Rate

Low	Average	High
347,885,735,423	423,964,337,026	716,916,714,923

The approach used here allowed as complete a picture as possible of overall valuations for Trinity River water while at the same time retained a high degree of compatibility with the regional data. The results indicate a $4.3 Billion annual value on average.

It should be noted that the resulting valuations of ecosystem services in the Trinity River Watershed Management Area are thought to be conservative estimates and, given the gaps identified by Earth Economics, represent an incomplete picture of actual overall values. To understand these valuations as well as the Discussion and Conclusion narratives that follows, it is necessary to read both the Study Summaries document and the Value Summary spreadsheet.

DISCUSSION

The methodologies used to assess and evaluate the data and arrive at estimated ecosystem service values for the Trinity River Watershed's natural areas are well described in Earth Economics' Study Summaries. The challenges of assessing such a wide array of factors from more straight-forward water supply benefits to more subjective recreational benefits and cultural values are many and varied. To translate estimated values into compatible units and adjust for inflation would be daunting if attempted using exclusively local data. For the purposes of this gross initial assessment, the goal was to obtain a sense of the overall value of Trinity River water. This would serve as a starting point to begin to understand the more complete magnitude and scope of these values. The benefits of Trinity River water to the state and agricultural industry has long been documented by well resourced interests. What has been lacking is a more balanced picture that includes ecosystem services. That is one of the goals of this project.

The Earth Economics' base framework served as a starting point for this study. More details on that methodology are described in Trinity River WMA Ecosystem Services Valuation below. Oftentimes a range of values are used to represent low, medium, and high estimates, as described in Earth Economics' Study Summaries. Local studies were identified by Council's 5C staff in coordination with project partners - notably Tom Stokely. He has been described as a "living encyclopedia" of the Trinity River's water issues. His long career both as a County Natural Resources Division Planner (23 years) and his role as Chairman and member of the Trinity Adaptive Management Working Group (TAMWG), the federal advisory committee for the Trinity River Restoration Program, makes him well qualified to speak on these issues. Furthermore, his time as a Policy Review Panel representative for Trinity County on the North Coast Integrated Regional Water Management Group (original name of the NCRP) makes him particularly suited for this project. The Council and 5C thank Tom profusely for his willingness to volunteer to provide input and advice on this project. Several pertinent local studies containing market and non-market based values were identified and provided to Earth Economics' review. It is important to understand that Earth Economics' assessment of these local studies was objective and governed by their method and criteria. The decision of whether to include local studies was governed by that process and made by Earth Economics. The base criteria for the selection of studies is found in the Earth Economics' Study Summaries report in the "Selecting Valuation Literature" section just prior to the overall results and valuations. Sometimes their decision on whether to include a local study was not necessarily formulaic. For instance, the preference is generally to rely on recent data and studies that have primary valuations (original data). However, sometimes a primary valuation study is preferable to a more recent one that contains secondary valuations. The similarity of the geographic region of the studies also comes into play when assessing suitability. In some studies, the methodology wasn't as detailed and may not have appeared as suitable as others, yet was still used because after being analyzed, they were found to have valuations very similar to other studies with more detailed and strong methodologies. It is clear that the specific application of the economic criteria described in the Study Summaries is not necessarily straightforward and simple because so many factors have to be considered along with the specific context and attributes of each dataset and study. Earth Economics summarizes caveats, limitations, and cites specific references towards the end of the Study Summaries document.

There are studies that were evaluated by Earth Economics and found to not meet the strict economic analysis standards outlined here and were not recommended for inclusion in an overall set of valuations. However, for resource managers, these studies may still be valuable to help illustrate certain relationships or gross senses of value for various uses of water. For example, the Shires study, which was very recent and focused on food production within the Westlands Water District (WWD) was not initially going to be incorporated into the resulting crop valuations for Trinity River water despite the fact that Trinity River water is crucial to WWD operations and the obvious correlation between that water and crop values within the WWD. This is because the WWD study lacked specific details on the size of the overall operations and the degree of reliance on Trinity River water (as opposed to groundwater). Another reason is the lack of data on how much of the Trinity River diversion overall is used to irrigate crops, regardless of specific farm location. However, other crop values existed that were more strongly tied and applicable to use of Trinity River water, which were consistent with the more recent WWD crop values. Therefore multiple datasets were included. Regardless of the initial reservations, absent the specific quantities and information needed to confidently meet Earth Economics' criteria outlined in the Study Summaries on its own, local resource managers can still review the WWD study values as stand-alone data and get a sense of the current impact of the diversion on agriculture in the WWD. This is a reasonable interpretation of that data because local resource managers know that without Trinity River water, WWD would likely be a small operation that would not be prominent in the broader landscape of

California agriculture. The Hanak study on water supply and irrigation values was somewhat recent compared to other data sources, but ultimately was not used. Values from the Trinity River EIS/EIR better addressed Earth Economics' criteria and were used instead. In other words, the fact that specific studies were not included in the overall valuation of the Trinity River water presented here does not mean that the studies should not be used for analyzing valuations of Trinity River water or similar studies. Their exclusion speaks more to the fact that the studies excluded here were not the best fit for the objectives of this study. Studies described here can also be used for purposes other than analyzing the overall economic impact of Trinity River water. For example, resource managers can look at the Shires and other local studies overall in their quest to evaluate and assess possible funding mechanisms where end users reimburse watersheds of origin for use of Trinity River water.

Following a review of the local studies, a lack of data for several ecosystem service values was identified based on land cover type. They are shown in Earth Economics' Study Summaries Table 4 "Gaps in Ecosystem Service Values for the Trinity River Watershed". Local resource managers should find this useful in pursuing a more complete assessment of the value of Trinity River water. Perhaps some of the project metrics and data reported by NCRP projects can be compiled and analyzed to help fill in some of these gaps over time.

As described in Earth Economics' Study Summaries, the results are admittedly an underestimate of the actual values. However, Earth Economics assertion bears repeating "The presentation of our study results clearly displays the range of values and their distribution. The final estimates are not precise; however, it is better to provide estimates than to assume that ecosystem services have zero value or even infinite value. Pragmatically, in estimating the value of ecosystem services, it is better to be approximately right than precisely wrong."

There are several caveats to this work that are of a larger scale than those described by Earth Economics in the Study Summaries. Notable among these include: 1) the receipt of subsidies for irrigation water, crops, and electricity by WWD along with other unique challenges to that farmland (http://www.ewg.org/research/california-water-subsidies/findings Retrieved 2017.03.31); 2) the financial viability of the hydropower produced by the Central Valley Project diversion as it begins to become uncompetitive with renewable sources of energy that are gaining a foothold in the state's energy market; 3) other factors that make maintaining the dams and water delivery infrastructure cost-prohibitive; 4) the absence of valuations for local cannabis cultivation; and 5) unique values and uses likely not captured through the use of Earth Economics' database.

The subsidies provided to WWD represent complexities in the process by which the true economic benefits of Trinity River water to agricultural production are calculated. The subsidies make it possible for the crops to be as profitable as they are to WWD. Without them, it is unclear what would be the actual profit margins. There are salinity drainage problems and selenium contamination in WWD farms (https://www.usbr.gov/mp/nepa/documentShow.cfm?Doc_ID=2240 Retrieved 2017.03.31) that present theoretical issues including a possible future cost of having to remediate these lands and whether such costs should be deducted from the overall economic benefits of the agriculture produced. The cost competitiveness of the hydropower produced by the diversion at four powerplants has complexities beyond calculating economic benefits of power. The revenue from the sale of the hydropower currently funds restoration activities in the Trinity River watershed and subsidizes agricultural water deliveries. Therefore, if the hydropower becomes too costly to produce, that ecosystem service ceases to exist along with revenue that facilitates a significant portion of watershed restoration and water deliveries. Similarly, if the cost to maintain the infrastructure of the aging dams and other infrastructure becomes too high for the primary purpose of delivering water to heavily subsidized and remote agriculture, then that would have an indirect impact on some of the agricultural economic benefits of the water. The recent failure of the Oroville Dam spillway highlights the need to consider maintenance costs when discussing the economic benefits that dams currently facilitate (http://www.sacbee.com/news/state/california/water-and-drought/article142028574.html Retrieved 2017.03.31). In the larger context that the Bureau of Reclamation (BoR) has struggled to recoup the federal dollars invested in the Central Valley Project ("Central Valley Project, California: Repayment Status and Payoff" Report No, WR-EV-BOR-0003-2012. Office of Inspector General. US Department of the Interior. 2013. Available https://www.doioig.gov/sites/doioig.gov/files/WR-EV-BOR-0003-2012Public.pdf Retrieved 2017.03.31), these considerations could lead the BoR to evaluate whether continuing to operate the diversion in the same manner and for the same end uses is advisable. If the way the diversion is managed were to change, it would have broad repercussions in terms of the water's out of basin economic benefits. These caveats present challenges that currently cannot be nor should necessarily be factored into this type of economic analysis because they are too speculative to practically evaluate. But such caveats should enter into the discussions of how these results should be considered and how to weigh the benefits of the water and consider its future management.

Although these caveats are worth mentioning, it is important to remember that the economic estimates of ecosystem services from natural lands within the Trinity River watershed presented here are based strictly on current uses and management of Trinity River water.

The issue of cannabis cultivation within the basin warrants some discussion. In recent years, Trinity County has experienced a boom of marijuana cultivation that has resulted in large scale changes primarily on its undeveloped land with many adverse impacts on surface water. This has exacerbated water crises in certain subwatersheds. Specifically, residents of several watersheds have had to import water during the dry season to an ever-increasing degree. This places greater pressure on local water districts to expand service areas. A long-time suggestion that the Weaverville Community Services District, the district serving the largest population in the Trinity River watershed, should petition to increase its water right from the Trinity River is being revisited and heavily promoted by many local resource professionals. Another facet of the cannabis issue is that some local water districts, including the WCSD, have inadvertently supported the industry by selling water directly to water truck operators in an attempt to provide households struggling to meet domestic needs during the dry periods. It is known that many of the water trucks are servicing cannabis operations. But it is difficult and impractical to restrict those users from those sales. There is insufficient data from which to estimate the percentage of these sales from the overall total volume of water sold. The economic value of Trinity River water to cannabis cultivation is not captured in these valuations. Given the exponentially greater profit margin of this crop (by acre or plant) than that of the traditional food crops that are represented in these valuations, this omission may be significant.

The Council acknowledges that there are other instances of both missing and undervalued components. One example is the importance that local tribes place on ceremonial rather than consumptive uses of the water such as the flows required for the Hoopa and Yurok "Boat Dance" ceremonies (http://www.trrp.net/restore/flows/flow-faq/ Retrieved 2017.03.31). These are likely not well represented in the overall cultural valuations. Another likely underestimated value is the important role of Trinity River water in temperature regulation of the lower Klamath River system. Also, the potential economic benefits specific to the upper Trinity River communities of having the lake full more often isn't really captured in this initial assessment because such considerations would be largely speculative in the absence of specific data. Earth Economics did acknowledge that additional economic benefits were implied in numerous studies but could not be directly extrapolated or translated into actual dollar amounts within the parameters of this study.

CONCLUSION

As presented in the results table in the Summary above, the Trinity River WMA overall ecosystem services are estimated to be worth 4.2 Billion on average per year based on a limited set of values and uses assessed. Given the data gaps described in Table 4 of Earth Economics' Study Summaries and in the Discussion above, this is a conservative estimate. It is anticipated that this initial assessment of ecosystem services will likely be utilized beyond specific economic benefit characterizations. It can inform a wide variety of resource management strategies as well as policy discussions. As noted above, the intent is to provide local decision makers with information that can facilitate discussions about local resource management. Local leaders have been curious about assessing the value of the various benefits derived from the Trinity River, particularly given the fact that the majority of the water from the river is exported to the Central Valley Project. They have expressed frustration about the lack of representation that they have in the various agencies' management processes and decisions in regards to the Trinity River Division of the Central Valley Project. The County's interests, and opinions have been formally expressed through various letters sent by the Board of Supervisors to various agencies that oversee relevant projects such as the Central Valley Project and Delta Plan. They have consistently requested to be included in discussions regarding management of Trinity River water. The County's interests in investigating the economic benefits are especially motivated by the fact that it is not compensated for any of the exported water, though does receive reduced electric rates for its sparse population. These preliminary economic valuations are expected to help them navigate and better understand the benefits of the various uses of the water. They are also a tool with which the County can better evaluate its resource management concerns. This may include, as County leaders have previously expressed an interest in exploring, the concept of recovering some revenue from this large water export, particularly given the local impacts of the diversion. Perhaps an understanding with the agencies managing the water projects can be reached that will recognize the need to maintain the source watershed healthy via some economic reimbursement obtained from the economic profits of the largely agricultural end users. There are many ways to achieve this such as a direct fee paid by end users or negotiation with the federal agencies on increased in lieu of tax payments such that a small percentage of the estimated natural capital value is captured for investing in Trinity River watershed health. This concept of investing in natural ecosystems to preserve their services is not without precedent and has become more popular over the last several years (http://www.ecosystemmarketplace.com/articles/?category=water Retrieved 2017.03.31). To complete a more complete picture, the County may choose to further develop this initial valuation. The gaps identified in the Study Summaries will serve as a roadmap for such future work.

TRINITY RIVER WATERSHED MANAGEMENT AREA ECOSYSTEM SERVICES VALUATION

Earth Economics previously conducted an ecosystem services valuation (ESV) for the North Coast of California under contract with the West Coast Watershed, which includes the Trinity River. This section reviews this previous work and assesses how values from the literature review may be included in the current ecosystem services valuation to fill data gaps and improve the estimation of ecosystem service benefits from the Trinity River.

The goal of this analysis is to provide ecosystem service values for the natural areas of the Trinity River Watershed Management Area (WMA). The following sections will describe the steps taken in the valuation analysis. The first step was to assess the extent of natural areas in the Trinity River Watershed by determining the spatial extent of land cover types using Geographic Information System (GIS) software. Next, the benefit transfer method (BTM) was used to determine dollar-per-acre values for ecosystem services. Last, these two datasets were combined to estimate the total value of economic benefits provided by the Trinity River Watershed. These methods are described in detail in the following sections.

LAND COVER ANALYSIS

Land cover acreage for the Trinity River Watershed was derived from the U.S. Forest Service's CALVEG spatial data using GIS software.[1] The acreage was calculated for every regional description category in the CALVEG data and summarized along the entire outer coast study area, by county, and by water management area (WMA). The regional description categories were grouped into 17 different land cover categories for the ecosystem services valuation.

The GIS data was modified in several ways to enable a more detailed description of the natural capital of the study area. "Spatial attributes" were constructed to describe unique locations of ecosystems within the landscape. These locations often influence the economic values of ecosystem services, and thus are important to account for when determining ecosystem service values. For example, riparian borders often have a large positive effect on nearby waters and are more ecologically productive. In this analysis, we considered four spatial attributes that affect ecosystem service values: proximity to agricultural areas, and the location of land covers within coastal, riparian, or urban zones. Identifying the spatial attributes of land cover data allows the application of more granular study values and increases accuracy as each attribute provides information that narrows the scope of values and mitigates uncertainty. Valuations tend to be more accurate when the spatial distribution of values is taken into account, as this can help control for the variation in valuation literature.[2]

VALUATION METHODOLOGY

With land cover acreage and spatial attributes defined, the next step in the analysis involved employing the benefit transfer method (BTM) to identify ecosystem service values.

The Benefit Transfer Method

The benefit transfer method (BTM), broadly defined as "…the use of existing data or information in settings other than for what it was originally collected", is frequently used to indirectly estimate the value of ecological goods or services.[3] BTM is often the most practical option available to quickly generate reasonable estimates at a fraction of the cost of conducting local, primary studies. This methodology is commonly used in ecosystem services valuation.[4]

The BTM process is similar to a home appraisal in which the value and features of comparable, neighboring homes (e.g. two bedrooms, a garage, one acre, recently remodeled) are used to estimate the value of the home in question. In our analysis, the BTM process identifies previously published ecosystem service values from comparable ecosystems and transfers them to our study site, the Trinity River Watershed. As with home appraisals, BTM results can be somewhat rough, but they quickly yield values appropriate for policy work and analysis.

The process begins by finding primary studies with land cover types (wetland, forest, grassland, etc.) comparable to those within the study area. Any primary studies deemed to have incompatible assumptions or land cover types are excluded. Individual primary study values are adjusted and standardized for units of measure, inflation, and land cover type to generate an "apples-to-apples" comparison.

Selecting Valuation Literature

Valuation literature was selected from Earth Economics' Ecosystem Service Toolkit (EVT) for the BTM analysis. The EVT is one of the largest repositories of published, peer-reviewed primary valuation studies, reports, and gray literature on the value of ecosystem services. Before transferring a value from the literature to the Trinity River Watershed, we examined the degree of correspondence, or the similarity between the context of the literature's values and that of the Trinity River Watershed.[5] Conducting a defensible benefit transfer requires careful thought, research, and choices, particularly as regards the degree of correspondence. The following criteria were used to assess the correspondence of literature values from the EVT to the Trinity River Watershed:

Criteria 1: Similarity of ecosystem goods and services

At the most basic level, the commodity being valued in the literature and the one we wish to value in the Trinity River Watershed should be the same. The similarity of uses, goods, and services at the two sites is critical for a valid transfer.[6] Studies that valued services that do not exist in the Trinity River Watershed were not included in the dataset. For example, a value for protection from hurricane damage on the East Coast of the United States is not an appropriate service to transfer to the Trinity River.

Criteria 2: Similarity of land cover types

Like Criteria 1, the similarity between land cover types at both sites is important. Benefit transfers are more accurate as the similarities between the study sites and the Trinity River increase.[7] Land cover types in the literature which did not exist in the GIS data were excluded. For example, tropical rainforests do not exist in the Trinity River Watershed and are therefore inappropriate land cover types for BTM.

Criteria 3: Literature is of sound methodology

Earth Economics ensures that values for this analysis were drawn from credible sources with the latest methods. Studies had to meet data quality conditions, including the use of correct economic methodologies.[8] There are common best practice methods for valuing ecosystem goods and services, with certain valuation methods best suited to specific ecosystem services.

Criteria 4: Transferability of ecosystem services

Some ecosystem services lend themselves to a BTM approach better than others. Services with large or even global benefits, such as carbon sequestration, are highly transferable between two sites. Other services with more local effects, like habitat for a specific species or aesthetic views, are less transferable. Regardless of transferability, ecosystem services from study sites along the Trinity River were prioritized. However, there were many gaps in this literature, in which case values from throughout California and nearby states were utilized. Services which had no Trinity River or California data and also had high transferability were derived from areas in the greater United States. No studies were used from outside the U.S.

Criteria 5: Similar demographics and cultural attitudes

Benefit transfers are more accurate when the demographic characteristics, attitudes, and beliefs of consumers in the literature sites and the Trinity River Watershed are similar.[9] Although it is difficult to determine cultural attitudes of sites from published literature, to partially address these effects, only valuation studies from the United States were considered for the dataset.

Calculating Ecosystem Service Values

All ecosystem service values were standardized to account for differences in units and for inflation. The unit of measure for this analysis is dollars per acre per year, adjusted to 2014 United States dollars using Bureau of Labor Statistics Consumer Price Index inflation factors.

Values for ecosystem services can vary due to factors such as scarcity, income, and uniqueness of habitat, among others. The values provided in this analysis include an array of different contexts for ecosystem services. By extracting values from a large pool of studies and contexts, we ensure a well-informed value approximation. The analysis presents high, low, and average dollar-per-acre values that reflect the variability and uncertainty in the data, with the average value representing a measure of central tendency.

An important point to note about this analysis is that an ecosystem service-land cover combination not included in the analysis does not necessarily mean that the ecosystem does not produce that service or that the service is not valuable, but rather shows a lack of data for that service. For example, shrubland provides highly valuable services such as recreation, habitat, and carbon sequestration, yet there are few valuation studies of this land cover type. Caution should be exercised when comparing total ecosystem service values across land covers, as the difference in values could stem from an information gap rather than true differences in ecosystem service value.

Using the previously outlined criteria, total per-acre-per-year values for each land cover, ecosystem service, and spatial attribute combination were selected from the literature. These were then summed to provide a total dollar-per-acre-per-year value for each land cover type (i.e. forest). These per-acre-per-year values were multiplied by the number of acres of that land cover type. The result was an annual value representing the flow of ecosystem service value provided for each land type in question. These flows were then summed across all land cover types in the Trinity River to produce a total ecosystem service value for the entire study area.

ASSET VALUATION METHODOLOGY

Provided the natural capital of the Trinity River Watershed is not degraded or depleted, the annual flow of ecosystem services will continue into the future. Just as with traditional economic analyses, we can calculate the asset value of natural land in the Trinity River Watershed.

Asset values provide a measure of the expected benefits flowing from natural capital over time. The net present value allows a comparison of benefits that are produced at various points in time. We estimate asset values with a constant 3% discount rate over 100 years. Asset values can be calculated over different timeframes depending on the purpose of the analysis and the nature of the project. In the case of natural capital valuations, ecosystems are self-maintaining, stable over long periods, and continuously productive as long as they remain unimpaired, thus a low discount rate is appropriate. It is, however, also worth noting that, if kept healthy, the natural capital of the Trinity River will continue to provide benefits well beyond 100 years into the future.

RESULTS: ANNUAL VALUE

Table 1 shows the extent of land cover types in the Trinity River Watershed. Note that the Barren and Urban land cover types are not included in the valuation tables below, but are shown in Table 1 to provide a complete account of land cover types in the study area.

Table 1. Land Cover Acreage within the Trinity River Watershed

Land cover Type	Acres	Percent of WMA
Barren	30,184	1.59%
Coniferous Forest	1,564,335	82.30%
Cropland	865	0.05%
Deciduous Forest	129,136	6.79%
Grassland	19,797	1.04%
Lake	17,379	0.91%
Pasture	735	0.04%
Reservoir	25	0.00%
River	2,337	0.12%
Shrubland	131,845	6.94%
Urban	1,721	0.09%
Mixed Forest	116	0.01%
Fresh Herbaceous Wetland	2,282	0.12%
Total	1,900,760	100.00%

The results of the previous work with WCW is shown in Table 2. Each combination of land cover and spatial attribute that could be valued in this analysis is represented by a single row in Table 2. Each asterisk indicates the presence of the spatial attribute in that column. The results in Table 2 do not include the studies in the literature review shown above.

Table 2. Annual Valuation Results for the Trinity River Watershed

	Attribute									
Land Cover	Agriculture	Riparian	Urban	Acres	$/acre/year (Minimum)	$/acre/year (Average)	$/acre/year (Maximum)	$/year (Minimum)	$/year (Average)	$/year (Maximum)
Coniferous Forest				1,507,787	1,503	2,628	4,339	2,266,638,587	3,962,102,947	6,542,159,226
			*	1,216	1,827	5,372	10,016	2,222,219	6,533,392	12,181,659
		*		55,020	1,503	2,628	4,339	82,711,341	144,580,107	238,728,295
		*	*	8	1,827	5,372	10,016	14,628	43,006	80,186
	*			292	1,504	2,628	4,340	439,513	768,114	1,268,159
	*	*		12	1,504	2,628	4,340	17,728	30,982	51,151
Cropland	*			770	175	366	557	134,373	281,423	428,473
	*		*	70	175	366	557	12,149	25,443	38,738
	*	*		25	175	366	557	4,425	9,267	14,109
Deciduous Forest				121,662	1,481	2,625	4,190	180,159,277	319,371,134	509,803,667
			*	1,563	1,805	3,953	6,529	2,819,755	6,176,011	10,201,960
		*		4,524	1,481	2,625	4,190	6,698,473	11,874,486	18,954,927
		*	*	119	1,805	3,953	6,529	215,515	472,035	779,740
	*			1,262	1,482	2,626	4,191	1,869,833	3,313,976	5,289,468
	*	*		6	1,482	2,626	4,191	9,555	16,935	27,030
Fresh Herbaceous Wetland				1,988	240	10,649	24,395	476,820	21,172,483	48,501,810
		*		294	18,025	29,509	44,330	5,295,503	8,669,388	13,023,482
Grassland				18,685	66	168	264	1,228,933	3,137,244	4,927,921
			*	145	509	611	707	73,612	88,376	102,229
		*		944	66	168	264	62,106	158,544	249,038
		*	*	0.4	509	611	707	226	272	315
	*			22	66	168	264	1,433	3,659	5,748
	*	*		1	66	168	264	59	149	235
Lake		*		17,364	100	6,735	13,369	1,735,349	116,941,015	232,146,681
		*	*	7	100	6,735	13,369	733	49,425	98,117
	*	*		7	100	6,735	13,369	733	49,425	98,117
Mixed Forest				58	1,414	2,484	3,674	82,732	145,282	214,905
			*	36	1,659	3,983	7,487	60,511	145,286	273,067
		*		1	1,414	2,484	3,674	1,573	2,762	4,086
		*	*	0.4	1,659	3,983	7,487	738	1,772	3,330
	*			20	1,415	2,485	3,675	28,011	49,178	72,739
Pasture	*			728	218	253	289	158,966	184,512	210,058
	*	*		8	1,823	1,858	1,893	13,786	14,051	14,316
Reservoir		*		25	865	12,506	40,284	21,922	317,061	1,021,318
River		*		2,266	5	6	6	11,345	12,606	13,867
		*	*	68	5	6	6	340	377	415
	*	*		3	5	6	6	17	19	20
Shrubland				128,882	146	146	146	18,834,565	18,834,565	18,834,565
			*	14	146	146	146	1,983	1,983	1,983
		*		2,938	224	413	767	656,886	1,212,532	2,251,907
	*			12	146	146	146	1,788	1,788	1,788
Total				1,868,855				2,572,718,037	4,626,793,013	7,662,078,845

Addition of Studies from the Literature Review

The values in Table 2 can be refined with the studies analyzed in the literature review. To refine the analysis for the Trinity River Watershed, value estimates from the literature review were standardized to 2015 USD. We categorized every value recorded from the literature review by land cover type and ecosystem service. This process allowed us to compare these new values with the values already included in the ESV and identify and exclude land cover and ecosystem service combinations that would result in double counting. When choosing additional studies to enhance the ESV, we followed the previously criteria outlined and lent preference to primary valuations. The following sections describe the values added to the ESV.

Cultural Value

Douglas and Taylor (1999) estimated the economic benefits of the existence of a healthy Trinity River. Their results show that non-recreation users gain benefits of $12/person/year to $93/person/year from this service, and recreation users gain benefits of $15/person/year to $418/person/year. In total, the existence of a healthy Trinity River amounts to benefits of $170 million to $1,286 million for non-recreation users and $2 million to $297 million for recreation users. When combined, these benefits total between $172 million and $1,583 million.

Recreation Value

The U.S. Fish and Wildlife Service (1999) estimated the value of water-related recreation activities on the Trinity River. Boating, fishing, and swimming were valued at $10,104,886; $5,136,920; and $6,474,269; respectively. In total, river recreation on the Trinity River may be valued at $21,716,075 annually.

Water Supply

The U.S. Fish and Wildlife Service (1999) also estimated the benefits of Trinity River water as a source of irrigation for agricultural lands. These benefits range from $47 million to $5,397 million.

Food

Stene (1996) estimated the value of crops in California. We replaced the food ecosystem service value in the existing ESV with these more site-specific values. The total ecosystem service value for cropland thus increased to $105,192 to $1,957,353 per year.

Energy

The Trinity River house 4 power plants at hydroelectric dams: Lewiston, Trinity, Judge Francis Carr, and Spring Creek. These hydroelectric plants are all fed by Trinity River water. The Bureau of Reclamation estimates that, on average, these dams together produce a total of 1,518 GWh of power annually.[10] Electricity rates in Trinity county range from 5 cents to 7 cents.[11] This means that Trinity River water produces between $75 million and $106 million in electricity annually.

Adjusted Annual Value

The total ecosystem service value provided by the Trinity River Watershed was previously estimated at $2.6 billion to $7.7 billion. The previously described additions increase this total to $11.0 billion to $22.7 billion, with an average of $13.4 billion. This amounts to an increase of about $8.8 billion on average. Yet, this can still be considered an underestimate in ecosystem service value, as gaps still remain in the valuation data.

RESULTS: ASSET VALUE

The asset value calculated in this report is based on a snapshot of the current land cover, consumer preferences, population base, and productive capacities. As such, it does not consider the possibility of future environmental degradation or change in value due to scarcity. Rather, it assumes that the ecosystems of the North Coast region will remain the same over 100 years. For more information on the caveats of this analysis, see the section titled "BTM and ESV Limitations." Table 3 presents the asset value of both the range of values and average value of ecosystem services in the entire Trinity River WMA, including previous ESV work as well as values from the literature review presented in this document.

Table 3. Total Asset Value over 100 Years of the Trinity River WMA Using a 3% Discount Rate

Low	Average	High
347,885,735,423	423,964,337,026	716,916,714,923

REMAINING GAPS

The literature review identified many studies valuing existence and recreation benefits in the Trinity River, but values for many ecosystem services are still missing. Studies in the literature review focused on market and non-market values of commercial and recreational fishing, irrigation water supply, and existence value to beneficiaries. Table 4 presents the ecosystem services valued and not valued in the Trinity River watershed, including those from the literature review and the previous ESV. A land cover and ecosystem service combination marked with an asterisk shows where values exist in the ESV; blank combinations show where no applicable data exists. There are large gaps in knowledge of the non-market benefits of regulating services; habitat for species including, but not limited to, salmon; and aesthetic values provided by the river. Additional primary valuations conducted in these areas would greatly benefit ecosystem service estimates for the Trinity River.

Table 4. Gaps in Ecosystem Service Values for the Trinity River Watershed

Ecosystem Service	Coniferous Forest	Cropland	Deciduous Forest	Fresh Herbaceous Wetland	Grassland	Lake	Mixed Forest	Pasture	Reservoir	River	Saline Herbaceous Wetland	Shrubland
Aesthetic Information	*		*				*					
Air Quality	*		*	*	*		*					*
Biological Control	*	*	*		*		*	*				*
Climate Stability	*	*	*	*	*		*	*			*	*
Cultural Value										*		
Disaster Risk Reduction				*	*		*				*	*
Energy & Raw Materials										*		
Food	*	*	*	*	*	*	*	*				
Habitat				*				*			*	*
Navigation												
Pollination & Seed Dispersal	*	*	*		*		*					
Recreation & Tourism	*		*	*	*	*	*		*	*	*	*
Soil Formation	*	*	*		*		*					
Soil Quality	*	*	*				*					
Soil Retention	*	*	*		*		*					*
Water Capture, Conveyance, & Supply	*		*	*	*		*			*	*	
Water Quality	*		*	*	*		*				*	
Water Storage						*				*		

NON-ECOSYSTEM SERVICE ECONOMIC BENEFITS

The Trinity River provides economic benefits beyond ecosystem services values. The Trinity River watershed also stimulates and supports local economic development. Ecosystem-related manufacturing, sales, tourism, and events inject cash into local economies. This investment in turn supports jobs, businesses, and tax revenue, and creates ripple effects throughout multiple other economic sectors. Compared with other economic sectors, ecosystem-related expenditures are likely to stay within the local economy for longer, and result in less "leakage." Several studies from the literature review estimate the number of jobs and the amount of economic activity that are dependent on natural ecosystems.

For example, Hawks and Bowker (1994) estimated that reservoir recreation at Lake Shasta can support from 465 to 711 jobs and $106 million to $162 million in local economic activity. We were unable to determine recreation visitation levels at Trinity Lake, but as Lake Shasta is less than 30 miles from Trinity Lake, it is reasonable to assume recreation on Trinity Lake provides a similar level of economic benefits.

Shires (2016) estimated jobs and economic activity from irrigation-dependent agriculture in California. We were unable to relate this information to the Trinity River, but Trinity River irrigation certainly must support jobs and local economies related to agriculture.

Niemi et al. (2001) estimated the jobs based on salmon runs in the Klamath Basin, finding that every 1,000 fish support 1.5 commercial fishing jobs and 4 recreation jobs. According to a recent report in the Trinity River, Chinook, Coho, and Steelhead runs may total around 30,000 fish annually.[12] This means Trinity River fish support about 46 commercial fishing jobs and 122 recreation jobs.

These results show that, in addition to providing valuable ecosystem service benefits, the Trinity River also directly supports local economies. This initial analysis shows that the Trinity River could support millions in local economic activities and hundreds of local jobs. Again, these estimates should be regarded as underestimates as the Trinity River likely provides inputs into other economic sectors besides commercial fishing and recreation.

BTM AND ESV LIMITATIONS

Valuation exercises have limitations that must be noted, yet these limitations should not detract from the core finding that ecosystems produce significant economic value for society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

- Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.
- Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).
- To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates and not exchange values. These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates (see below).

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. The size and landscape complexity of most ecosystems makes this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows:

- While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts, such as in the development of economic statistics such as Gross Domestic or Gross State Product.
- As employed here, the prior studies upon which we based our calculations encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Also, only limited sensitivity analyses were performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels ("comps"): even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.
- The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. of the value of all of the world's ecosystems.13 Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all or a large portion of a watershed might be sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose that is more analogous to national income accounting than to estimating exchange values.[6]

The presentation of our study results clearly displays the range of values and their distribution. The final estimates are not precise; however, it is better to provide estimates than to assume that ecosystem services have zero value or even infinite value. Pragmatically, in estimating the value of ecosystem services, it is better to be approximately right than precisely wrong.

General Limitations

- Static Analysis. This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.
- Increases in Scarcity. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce.[14] If ecosystem services are scarcer than assumed, their value has been

underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed; climate change may also adversely affect the ecosystems, although the precise impacts are difficult to predict.

- Asset Values. The asset value calculated in this report is based on a snapshot of the current land cover, consumer preferences, population base, and productive capacities. As such, it does not consider the possibility of future environmental degradation or change in value due to scarcity. Rather, it assumes that the ecosystems of the Trinity River Watershed will remain the same over 100 years.

GIS Limitations

- GIS Data. Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on the context of their surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy.
- Scale and Resolution. Developers of Land Cover data typically rely on several data types and sources in its efforts to map and monitor resources over broad landscapes. Hierarchically, these data range in scale from coarse to fine, with widely varying spatial and spectral resolutions. Lower resolution source data may result in inadequate data for high value ecosystem units (i.e., wetland, beach, riparian vegetation).
- Ecosystem Health. There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they deliver higher values than those assumed in the original primary studies. This situation would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation overestimates current value.
- Spatial Effects. This ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e. that every acre of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Resolving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values, as changes in ecosystem service levels cascade throughout the economy.[8]

Benefit Transfer/Database Limitations

- Incomplete coverage. That not all ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of ecosystem services. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of zero or less for an ecosystem service.
- Selection Bias. Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of ranges partially mitigates this problem.

Primary Study Limitations

- Price Distortions. Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.
- Non-linear/Threshold Effects. The valuations assume smooth and/or linear responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services. Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, such as an endangered species listing.
- Sustainable Use Levels. The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced. If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

LITERATURE REVIEW

1. ***Center for Environmental Economic Development. 2005. Restoration Benefits: Overview of Concepts & Principles. Center for Environmental Economic Development, Arcata, CA.***

Summary: This brief report provides an overview of restoration options for the Klamath River and the potential economic benefits and costs that could result from restoration. The authors cite several economic values for fisheries from a study conducted by ECONorthwest in 2001[1] and also cite a study conducted by USGS, which estimated an increase in recreation due to restoration of the Klamath.[2]

Study Site: Klamath River, OR and CA

Ecosystem Services: Salmon protection, commercially and recreationally caught salmon, general recreation

Methodology Used: The authors used the benefit transfer method, which involves taking ecosystem service values from published articles or reports and applying them to a study site. The data used in this type of approach is referred to as secondary data because it is collected by someone other than the user. Additionally, the values produced in this report are non-market benefits, meaning that the goods or services are not traded in markets and must be valued by means other than market prices.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Salmon protection	US 2001$ 30-97/household	$52-169/household
Commercially caught salmon	US 2001$ 5-70/fish	$7-102/fish
Recreationally caught salmon	US 2001$ 200/fish	$291/fish
Recreation	US 2003$ 3,000,000,000	$3,865,979,381

Recommendation: Little detail is given for the values cited, such as the dollar year (here we assume the dollar year is the publication year), or in the case of (4) above, the units associated with the value. The authors themselves question the reliability of (4). Research into the original studies cited in this paper is needed to determine the applicability of these value estimates, and are also reviewed in this document. However, as this study is a secondary reference to the data presented, it should not be used to cite the data presented. The original sources should be cited if this data is to be used.

1 Coping with Competition for Water: Irrigation, Economic Growth, and the Ecosystem in the Upper Klamath Basin. Ernie Niemi, Anne Fifield, and Ed Whitelaw, ECONorthwest. 2001.

2 Making Unbiased TCM Benefits Estimates with Klamath River Basin TCM and Contingent Use Data. Aaron Douglas, USGS and Andrew Sleeper, Successful Statistics LLC. 2003.

2. ***Hawks, L.J., Bowker, J.M. 1994. Estimating the Local Economic Impact of Lake Recreation in Northern California. In: Proceedings, 1993 Southeastern Recreation Research Conference, Vol. 15. General Technical Report SE-90. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station, 29-35.***

Summary: The goal of this study was to assess the influence of water levels in Shasta Lake on local non-resident recreational spending. Visitation estimates were combined with expenditure profiles and IMPLAN, a type of input/output model, to estimate the economic impacts to the local economy.

Study Site: Shasta Lake

Ecosystem Services: Recreation-related (boating, camping, and fishing) values include:

- Final Demand: The value of goods and services produced and sold to final users. This includes direct sale or margins of sales associated with the initial expenditures on goods and services.
- Total Industrial Output: The total output of industries or establishments which produce goods.
- Total Income: Wages earned by workers in the recreation industry.
- Value Added: The gross output, equal to the difference between the total output and the cost of its intermediate inputs. Value added includes employee compensation, taxes on production, gross operating surplus, etc.
- Employment: The number of jobs supported by recreational expenditures.

Methodology Used: The authors used an input/output model, a quantitative technique which analyzes the interdependencies between different sectors in an economy. Input/output models simulate economic interdependencies and trade flows (economic activity) in terms of how industries obtain inputs and provide outputs to other industries. They determine total economic impacts and contributions made throughout economies by market demands. For example, expenditures made by recreation users allow the recreation industry to pay workers, who then spend their income in other industries, creating a ripple effect through economies. The values produced with this method are market impacts, meaning the values estimated enter into the local markets and economy of the study area.

Values:

Value Type	Value as stated in study	Value in 2015 USD
Final Demand	16.7 million to 25.6 million	28 million to 43 million

Total Industrial Output	20.3 million to 31 million	34 million to 52 million
Total Income	11.8 million to 18 million	20 million to 30 million
Value Added	13.9 million to 21.3 million	23 million to 36 million
Employment	465 -711 jobs	n/a

Recommendation: The majority of the panel used to vet the visitation model assert that the visitation model performed sufficiently for most scenarios. The panel also felt the results from the drought models underestimated effects of water levels on recreation. It is important to note that these values are only market benefits due to non-local spending in the two counties assessed. This introduces two important points: (1) this does not reflect the non-market benefits people get from recreation, and (2) local visitors to Lake Shasta accrue these non-market benefits as well as non-local visitors and also input expenditures into the local economy.

3. Douglas, A.J., Taylor, J.G. 1999. The Economic Value of Trinity River Water. Water Resources Development 15(3): 309-322.

Summary: The goal of this study was to estimate the non-market benefits provided by sending more water down the Trinity River. The value of additional streamflow, which results in a higher amount of fish runs, is presented for five different streamflow and fish run scenarios determined from expert scientific opinion. Two surveys were administered – one survey to on-site users of the Trinity River, and one survey to households in California, Nevada, Oregon, and Washington. Finally, the authors compared the consumer surplus estimated from the study to the costs and benefits of increasing stream flows in the Trinity River.

Study Site: Trinity River

Ecosystem Service(s): Existence Benefit (Improved streamflow)

Methodology Used: This study used contingent valuation, a process in which a population is surveyed to determine their willingness to pay for an environmental good or service. The benefits of improved streamflow are non-market values; this service does not involve market purchases or direct participation. Since the value of this service cannot be determined through a market, people's willingness to pay for this service establishes the economic benefit the population receives from this service.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Aggregate existence value to households in CA, NV, OR, WA; 120,000 acre-feet/year & 9,000 fish	US 1994$ 106,698,000/year	$170,716,800
Aggregate existence value to households in CA, NV, OR, WA; 240,000 acre-feet/year & 35,000 fish	US 1994$ 128,613,000/year	$205,780,800
Aggregate existence value to households in CA, NV, OR, WA; 360,000 acre-feet/year & 75,000 fish	US 1994$ 249,265,000/year	$398,824,000
Aggregate existence value to households in CA, NV, OR, WA; 600,000 acre-feet/year & 85,000 fish	US 1994$ 514,812,000/year	$823,699,200
Aggregate existence value to households in CA, NV, OR, WA; 840,000 acre-feet/year & 105,000 fish	US 1994$ 803,638,000/year	$1,285,820,800
Aggregate existence value to users; 120,000 acre-feet/year & 9,000 fish	US 1994$ 1,346,400/ year – $6,732,000/year	$1.3 million to $6.7 million
Aggregate existence value to users; 240,000 acre-feet/year & 35,000 fish	US 1994$ 3,615,500/year – US 1994$ 18,077,300/year	$3.6 million to $18 million
Aggregate existence value to users; 360,000 acre-feet/year & 75,000 fish	US 1994$ 11,455,200/ year – US 1994$ 57,275,900/year	$11.5 million to $57 million
Aggregate existence value to users; 600,000 acre-feet/year & 85,000 fish	US 1994$ 23,423,700/ year to US 1994$ 117,118,400/year	$23 million to $117 million
Aggregate existence value to users; 840,000 acre-feet/year & 105,000 fish	US 1994$ 37,155,600/ year – US 1994$ 185,778,000/year	$37 million to $186 million
Per capita existence value to households in CA, NV, OR, WA; 120,000 acre-feet/year & 9,000 fish	US 1994$ 7.719/ person/year	$12
Per capita existence value to households in CA, NV, OR, WA; 240,000 acre-feet/year & 35,000 fish	US 1994$ 9.304/ person/year	$15
Per capita existence value to households in CA, NV, OR, WA; 360,000 acre-feet/year & 75,000 fish	US 1994$ 18.032/ person/year	$29
Per capita existence value to households in CA, NV, OR, WA; 600,000 acre-feet/year & 85,000 fish	US 1994$ 37.243/ person/year	$60
Per capita existence value to households in CA, NV, OR, WA; 840,000 acre-feet/year & 105,000 fish	US 1994$ 58.137/ person/year	$93
Per capita existence value to users; 120,000 acre-feet/year & 9,000 fish	US 1994$ 9.461/ person/year	$15
Per capita existence value to users; 240,000 acre-feet/year & 35,000 fish	US 1994$ 25.404/ person/year	$41
Per capita existence value to users; 360,000 acre-feet/year & 75,000 fish	US 1994$ 80.491/ person/year	$129

Ecosystem Service	Value as stated in study	Value in 2015 USD
Per capita existence value to users; 600,000 acre-feet/year & 85,000 fish	US 1994$ 164.588/ person/year	$263
Per capita existence value to users; 840,000 acre-feet/year & 105,000 fish	US 1994$ 261.076/ person/year	$418

Recommendation: One important point to note about this study is that the authors presented a range based on setting the non-respondents willingness-to-pay to zero or the mean of the usable sample. Either method is a valid way to deal with non-respondents, as survey-takers may elect not to respond for a variety of reasons. The lower bound may underestimate the willingness-to-pay, while the upper bound may overestimate the willingness-to-pay. The authors take the average of these two bounds to estimate existence benefits. We recommend choosing either the values from the user survey or the values from the household survey, but not both. Using values from both surveys may result in double counting, as households from CA, NV, OR, and WA may also be recreational users of the Trinity River.

4. *Douglas, A.J., Sleeper, A. 2003. Making Unbiased TCM Benefits Estimates with Klamath River Basin TCM and Contingent Use Data. Manuscript (December).*

Summary: This study focuses on development of a new approach to defining TCM consumer surplus, intended to correct for overestimation of consumer spending (leading to an underestimation of consumer surplus). Survey respondents were also asked to estimate increased trip frequency assuming improved water quality, and/or increased recreational fishing harvest (contingent use). The study closes with a simple benefit-cost estimate for restoring the Lower Klamath.

Study Site: Lower Klamath River Basin (below Iron Gate dam), all tributaries of the Klamath (including the Trinity) and streams flowing into its tributaries.

Ecosystem Services: Recreational benefits, water quality (45% marginal improvement), food provisioning (recreational fishing)

Methodology Used: This study used the travel cost method, based on consumer spending and travel surveys. This approach use the cost of travel required to consume or enjoy ecosystem services as the implicit value of the service – the value of recreational areas must be at least the price visitors are willing to pay to travel to it. A survey was used to gauge respondents' willingness-to-pay for hypothetical water quality and/or recreational fishing harvests expected from various resource management strategies (known as "contingent use" analysis).

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Recreational benefits	1997$ 9,156,356,211 (based on 1997 populations of NV, CA, OR, WA)	$13,524,898,391
Improved water quality (45% marginal improvement)	1997$ 270,817,529	$400,025,892
Food provision (50% marginal increase in recreational fishing harvests)	1997$ 305,589,074	$451,387,111
Food provision (100% marginal increase in recreational fishing harvests)	1997$ 452,400,978	$668,243,690

Recommendation: This appears to be an early draft with sentence fragments, multiple proofreading errors, and often thinly described analytical processes. While the analysis seems defensible, it appears never to have passed through peer review. We caution against relying heavily on these results, although the study may be a useful benchmark of other valuation studies of the region.

5. *English, D.B.K., Bowker, J.M., Bergstrom, J.C., and Cordell, H.K. 1995. Estimating the Economic Impacts of Recreation Response to Resource Management Alternatives. General Technical Report SE-91. Asheville, NC: USDA Forest Service, Southern Forest Experiment Station.*

Summary: This study describes a method for estimating the regional economic impacts of proposed water-level management policies on the marginal recreational demand expected to follow from increasing the appeal of local/regional recreational amenities. Spending data comes from expenditure surveys (May-September 1992), stratified to focus on house boating, other boating, developed camping, dispersed camping, fishing, and scenic driving. Visitation levels were based on a separate, on-site random sampling. An expert panel concluded that visitation levels are more likely to be driven by natural conditions (e.g., drought) than water-level management impacts. Drought estimates are based on what was considered a "relatively extreme drought" at the time (i.e., conservative estimates for most years).

Study Site: Shasta and Trinity lakes in Northern California (impacts within Shasta and Trinity counties); Chatuge, Fontana, Hiwasee, and Santeetlah lakes in Western North Carolina (omitted here).

Ecosystem Services: Recreational demand (regional economic contribution)

Methodology Used: To estimate regional economic impacts, an IMPLAN input-output (I/O) model was used, which simulates economic interdependencies and trade flows in terms of how regional industries obtain inputs and provide outputs to other industries; this includes how business income and wages are spent and re-spent regionally.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Trinity Lake recreational demand profile (drought)	House boating (21%), Other boating (25%), Developed camping (18%), Scenic driving (10%), Fishing (27%)	N/A
Trinity Lake recreational demand profile (non-drought)	House boating (20%), Other boating (26%), Developed camping (31%), Scenic driving (5%), Fishing (18%)	N/A
Recreation, total regional (Shasta and Trinity counties) contribution (drought)	1990$ 31,170,000	$56,569,873
Recreational total regional (Shasta and Trinity counties) contribution (non-drought)	1990$ 54,480,000	$98,874,773
Recreational spending regional (Shasta and Trinity counties) employment impact (drought)	721.5 FTE (full-time job equivalent)	N/A
Recreational spending regional (Shasta and Trinity counties) employment impact (non-drought)	1,258.2 FTE	N/A

Recommendation: This report provides detailed information on spending patterns associated with lake-centric outdoor recreation, including spending by activity (e.g., boating, fishing) in categories of lodging, food, transportation, miscellaneous activities, equipment and "other." These data are calculated to aggregate spending, as well as per 1,000 visitors across each activity. Details on the water management policies are thin, so those estimates were not summarized here. This report would likely provide an excellent basis for estimating regional economic contributions of lake-based recreation in Shasta and Trinity counties, given updated visitation patterns and levels.

6. *Niemi, E., Fifield, A., Whitelaw, E. 2001. Coping with Competition for Water: Irrigation, Economic Growth, and the Ecosystem in the Upper Klamath Basin. ECONorthwest, Eugene, Oregon.*

Summary: This report investigates water use in the Upper Klamath Basin, discussing competing water demand, strategic options for accommodating competition for water, and specific beneficial case studies. The authors review the literature for benefit estimates of different water uses.

Study Site: Upper Klamath River Basin

Ecosystem Services: Water Supply, Commercial Fisheries, Recreation, Energy, Existence Value

Methodology Used: This report uses the benefit transfer method to estimate the value of various ecosystem services. The results contain both market and non-market values. Examples of market values include jobs created and recreation expenditures. Non-market values included in the report include salmon protection and consumer surplus, or the amount people are willing to pay above and beyond what they already pay, for recreation opportunities.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Water Supply for Irrigation	$147 per acre foot to $729 per acre foot	$229 to $1,134/ acre-foot
Commercially caught salmon due to salmon population increase	US 5-70/fish	$7 to $102/fish
Recreationally caught salmon due to salmon population increase	US 200/fish	$291/fish
Commercial fishing jobs due to salmon population increase	1.5 jobs per 1,000 fish	n/a
Recreational fishing jobs due to salmon population increase	4 jobs per 1,000 fish	n/a
Recreational fishing Expenditure due to salmon population increase	US 1998$ 79,510 per 1,000 fish	$115,552 per 1,000 fish
Recreational fishing consumer surplus due to salmon population increase	US 1998$ 108,900 per 1,000 fish	$158,285 per 1,000 fish
Recreational fishing	$55/person/day	$81 /person/day
Electricity generation from hydropower	$0.75 per acre-foot to $2.5 per acre foot	$1 to $3/acre-foot
Salmon protection	$30-97/household/year	$52 to $169 / household/year

Recommendation: This report has no primary research of its own, and the majority of the studies cited cannot be accessed. In some cases, the dollar year of the value is not stated, so we assume it is the publication year of the study.

7. Faux, J., Perry, G.M. 1999. Estimating Irrigation Water Value Using Hedonic Price Analysis: A Case Study in Malheur County, Oregon. Land Economics 75(3): 440-452.

Summary: The authors investigate irrigation water use in order to reveal an implicit market price for water used in irrigation. Farm property sales in Treasure Valley in northeastern Malheur County were collected and included in the hedonic price model.

Study Site: Malheur River, Owyhee River

Ecosystem Services: Water Supply

Methodology Used: The hedonic pricing method is used to estimate values for ecosystem services that directly affect market prices. In this paper, farm property sales are related to irrigation water use on those farms. These relationships are used to analyze how the price people are willing to pay for farmland changes when irrigation water use changes and to produce a range of market values for irrigation water.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Water Supply for Irrigation	USD 1995$ 147 per acre-foot per year to $729 per acre-foot per year	$229 to $1,134 per acre-foot per year

Recommendation: This study was referenced several times by the other reviewed studies, despite the study site being outside of the Klamath River Basin. Malheur County borders Idaho and has a dry and arid climate, unlike the Trinity River Basin, which is temperate. This study may overestimate water used for irrigation from the Trinity River.

8. US Fish and Wildlife Service, US Bureau of Reclamation, Hoopa Valley Tribe, Trinity County. 1999. Environmental Impact Statement / Environmental Impact Report.

Summary: This is an environmental impact statement/report on various alternatives for restoring anadromous fish runs along the mainstem Trinity River. The alternatives: ***Preferred Alternative*** (400 to 600 thousand acre-feet *carryover storage*, continued water exports as this allows, flood control, various watershed protection efforts); ***No Action*** (340 thousand acre-feet average annual release, dredging, annual replacement of 3.4 thousand yd^3 spawning gravel); ***Maximum Flow*** (1,225 thousand acre-feet average annual release, annual replacement of 16.4 thousand yd^3 spawning gravel); ***Flow Study/Evaluation*** (595 thousand acre-feet average annual release, adaptive management); ***Percent Inflow*** (release 40% of previous week's inflow – 500 thousand acre-feet average per year); ***Mechanical Restoration*** (340 thousand acre-feet average annual release, rehabilitation of 47 channels, annual replacement of 3.4 thousand yd^3 spawning gravel); ***State Permit*** (Minimum flow under the existing permit, 120.5 to 250 thousand acre-feet per year, no dredging, 3.7 thousand yd^3 spawning gravel replaced each year). The Preferred Alternative is supported by the US Fish and Wildlife Service, Bureau of Reclamation, Hoopa Valley Tribe, and Trinity County.

Study Site: Mainstem of the Trinity River, downstream of the Lewiston dam.

Ecosystem Services: Recreation (ocean sportsfishing); Food Provisioning (commercial salmon fishing); Hydroelectricity (total, and increase per average user); Irrigation Water; Recreation (river canoeing, camping, drift-boat fishing, drift-raft fishing, white-water kayaking and rafting, recreational mining, swimming and inner tubing); Non-use (existence) Values (restoration of the river and salmon populations)

Methodology Used:

Trip days per recreationist (by type: boating, swimming, fishing, off-river) were estimated from the Trinity River User Study (USGS Biological Resources Division 1993-94). Total visit-days were estimated by regressing values from single-destination trips against river flow and fish population data; the expected impact of each management alternative on river flow and fish populations were then used to estimate visitation rates by recreation type. Per-trip expenditures were drawn from a 1992 meta-study of 250 estimates of recreational spending (Walsh et al.), and aggregate spending levels developed by combining the estimated visitation rates with per-trip expenditures.

Non-use (existence) values of restoring the river and salmon populations were based on a 1993-94 random survey of households in NV, CA, OR, and WA by the National Biological Service. Survey data was used to estimate the willingness to pay (WTP) of people for Trinity River habitat and salmon.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Ocean sportsfishing	$59,080,000 (2020)	$53,273,219
San Joaquin Valley irrigation to dry periods	$5,974,208,000 (2020)	$5,387,022,543
San Joaquin Valley irrigation to long-term avg	$6,005,420,000 (2020)	$5,415,166,817
Tulare Basin irrigation to dry period	$5,343,392,000 (2020)	$4,818,207,394
Tulare Basin irrigation to long-term avg	$5,368,146,000 (2020)	$4,840,528,404
San Felipe Unit irrigation to dry period	$52,668,000 (2020)	$47,491,434
San Felipe Unit irrigation to long-term avg	$88,396,000 (2020)	$79,707,845
Recreation, boating to Trinity River, avg water year	$6,841,008 (1997)	$10,104,886

Recreation, fishing to Trinity River, avg water year	$3,477,695 (1997)	$5,136,920
Recreation, swimming to Trinity River, avg water year	$4,383,080 (1997)	$6,474,269
Recreation, off-river activities to Trinity River, avg water year	$3,082,167 (1997)	$4,552,684
Recreation (all) to Trinity River, avg water year	$17,783,950 (1997)	$26,268,759
Recreation to Trinity Lake, avg water year	$8,750,520 (1997)	$12,925,436
Recreation to Trinity Lake, dry year	$6,593,410 (1997)	$9,739,158
Willingness to Pay per household – Trinity River habitat and salmon populations: 90% streamflow diverted, 9K returning adult salmon	$7.72 to $17.01 (1994)	$12.35 to $27.22
Willingness to Pay per household – Trinity River habitat and salmon populations: 80% streamflow diverted, 35K returning adult salmon	$9.30 to $24.83 (1994)	$14.88 to $39.73
Willingness to Pay per household – Trinity River habitat and salmon populations: 70% streamflow diverted, 75K returning adult salmon	$18.03 to $31.34 (1994)	$28.85 to $50.14
Willingness to Pay per household – Trinity River habitat and salmon populations: 50% streamflow diverted, 85K returning adult salmon	$37.24 to $41.75 (1994)	$59.58 to $66.80
Willingness to Pay per household – Trinity River habitat and salmon populations: 30% streamflow diverted, 105K returning adult salmon	$40.70 to $58.14 (1994)	$65.12 to $93.02

Recommendation: While the full report includes a vast array of environmental values, the Executive Summary is necessarily brief, omitting important information, such as the methodologies used to derive value estimates as well as many of the estimates. Accordingly, we reviewed Chapters 2 and 3, Appendix D, and Appendix E from the original draft for more detailed information on these estimates.

9. Stene, E.A., 1996. Trinity Division - Central Valley Project (No. RTD-105). Bureau of Reclamation.

Summary: This report describes the history and project details of the Trinity River Division expansion of the Central Valley Project (CVP). The main body of the report describes the context for the project expansion, the pre- and post-construction history, population by community (e.g., Weaverville, Anderson, Cottonwood) and county, and a description of how water from the Division is used (primarily Clair Engle Lake and Keswick Reservoir, but also a number of hydroelectric dams, as well as irrigation for Shasta and Tehama counties. Table 2 presents the total crop value of 25 crops and family gardens in the Division.[3] These are the only economic values presented, aside from construction contract details. Table 1 does present electrical generation capacity along the river as of 1981, but no actual generation data, nor market rates for any electricity produced.[4]

Study Site: Trinity River Division, Trinity County, CA

Ecosystem Services: Provisioning: Food

Methodology Used: The author does not calculate any values, but instead reports only the crops, planted acreage, and total crop values from the Bureau of Reclamation's 1990 Crop Production Report. The source of these values is not stated, but they were presumably based on a field survey within the 5,796 acres (the term in the report is "full and supplemental service") irrigated by the Trinity River Division. Because the original values were aggregated by crop acreage, the per-acre values below were calculated from those values.

Values:

Ecosystem Service	Value as stated in study ($1990 per acre)	Value in 2015 USD (per acre)
Provisioning: Food (Oats)	$123	$223
Provisioning: Food (Alfalfa Hay)	$709	$1,287
Provisioning: Food (Other Hay)	$371	$673
Provisioning: Food (Irrigated Pasture)	$189	$343
Provisioning: Food (Corn, Sweet (Processing))	$108	$196
Provisioning: Food (Corn, Sweet (Fr. Market))	$3,200	$5,808
Provisioning: Food (Melons, Cantaloupe, Etc.)	$1,400	$2,541
Provisioning: Food (Honeydew, Honey Ball, Etc.)	$1,400	$2,541
Provisioning: Food (Watermelon)	$1,400	$2,541
Provisioning: Food (Squash)	$2,400	$4,356
Provisioning: Food (Tomatoes (Fr. Market))	$4,400	$7,985
Provisioning: Food (Nursery)	$4,956	$8,995
Provisioning: Food (Apples)	$373	$677
Provisioning: Food (Apricots)	$300	$544
Provisioning: Food (Grapes, Table)	$2,275	$4,129
Provisioning: Food (Olives)	$680	$1,234
Provisioning: Food (Peaches)	$550	$998
Provisioning: Food (Pears)	$432	$784
Provisioning: Food (Prunes and Plums)	$300	$544
Provisioning: Food (Other Fruits)	$1,371	$2,488

3 Cited source: Bureau of Reclamation, 1990. Crop Production Report. Bureau of Reclamation.

4 Cited source: Water and Power Resources Service, 1981. Project Data. Government Printing Office, Denver, CO.

Ecosystem Service	Value as stated in study ($1990 per acre)	Value in 2015 USD (per acre)
Provisioning: Food (Almonds)	$1,408	$2,555
Provisioning: Food (Pecans)	$2,279	$4,136
Provisioning: Food (Walnuts)	$5,400	$9,800
Provisioning: Food (Other Nuts)	$3,070	$5,572
Provisioning: Food (Family Gardens and Orchards)	$500	$907

Recommendation: These data – planted acreages, crop prices, and crop yields – are several years old. Agricultural yields and crop prices fluctuate widely by year – for instance, from 2002 to 2006, table grape yields in Fresno County, CA[5] ranged from 7.6 to 11.34 tons per acre ($11,200 to $16,716 per acre, based on a grower-reported average of $1,473/ton). More recent crop reports could be gathered from public agencies. Still, when compared to the results in Shires (2016), a much more up-to-date study, the values tend to be within the same ballpark.

10. Shires, M.A., 2016. The Economic Impact of the Westlands Water District on the Local and Regional Economy. Westlands Water District.

Summary: This report describes the local and regional economic contributions of the Westlands Water (irrigation) District (hereafter referred to as "the District") to Fresno and Kings Counties, CA. As part of the Central Valley Project (CVP), the District receives a share of available water each year. That volume varies considerably year-to-year: In 2006, the District received nearly 1.1 million acre-feet of water from the CVP, but in 2015, that amount was under 100,000 acre-feet. Local consumers (agriculture, industry, and municipal) have responded by increasing groundwater withdrawals and, in the case of agriculture, shifting production to less water-intensive perennial crops. Overall, in 2015 the District was directly responsible for over 21,000 jobs and $2.6 billion in economic activity in these two counties. Accounting for indirect and induced economic activity, the contribution was $3.6 billion and nearly 29,000 jobs. This value stems from the District's water provisioning to two customer bases: municipal and commercial water consumers, and agriculture.

Study Site: Westlands Water District (part of the Central Valley Project), Fresno and Kings Counties, CA

Ecosystem Services: Water supply, Provisioning (food)

Methodology Used: The report identifies three categories of economic contributions which the District's water supports: crop production, crop distribution, and water supply support services and infrastructure. Crop production and distribution are reported by crop, planted acreage, and total crop values from the District's internal data and the 2014 Crop Report produced by the Fresno Farm Bureau. The means by which these values were derived is not stated, but they were presumably based on field surveys within the 351,893 acres irrigated by the District. Because the original values were aggregated by crop acreage, the per-acre values below were calculated from those values.

Other data provided in the report (summarized above) are the collective impact on secondary markets – those distributing crops from producers to consumers, and goods and services associated with supplying water, including infrastructure costs. These were estimated using IMPLAN, the standard Input-Output platform for estimating primary, secondary, and induced economic effects across a wide range of economic sectors.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Provisioning: Food (Grain)	$763.37/ac	$763.37/ac
Provisioning: Food (Vegetables and melons)	$5,212.85/ac	$5,212.85/ac
Provisioning: Food (Fruit)	$5,919.22/ac	$5,919.22/ac
Provisioning: Food (Tree nuts)	$5,820.70/ac	$5,820.70/ac
Provisioning: Food (other)	$4,100.49/ac	$4,100.49/ac
Direct employment: agriculture (farm labor)	21,444 jobs	N/A
Indirect employment: agriculture (agricultural inputs)	1,396 jobs	N/A
Induced employment: agriculture (spending by farm employees)	6,011 jobs	N/A
Direct contribution: agriculture	$2,611,528,840	$2,611,528,840
Indirect contribution: agriculture	$188,568,049	$188,568,049
Induced contribution: agriculture	$795,875,686	$795,875,686
Direct District employment: water supply services and infrastructure	484 jobs	N/A
Direct District spending: water supply services and infrastructure	$95,448,369	$95,448,369

Recommendation: This study does not isolate the value of irrigation water to the agricultural sector (and accordingly, indirect and induced employment and spending associated with agriculture). While this is not necessarily problematic, the overall size of the District is not reported; projecting these figures to other locations should be approached with caution.

5 Peacock, W.L., Vasquez, S.J., Hashim-Buckey, J., Klonsky, K.M., De Moura, R.L., 2007. Sample Costs to Establish and Produce Table Grapes - San Joaquin Valley-South (No. GR-VS-07-2). Cooperative Extension - UC Davis, Davis, CA.

11. Hanak, E., Lund, J., Dinar, A., Gray, B., Howitt, R., Mount, J., Moyle, P., Thompson, B., 2011. Managing California's Water: From Conflict to Reconciliation. Public Policy Institute of California, San Francisco, CA.

Summary: This report attempts to describe the context for water policy and water management within the State of California, including a fairly detailed history of water in the state, the current distribution and economic importance of water to agricultural and urban consumers, and key factors with which current and future policymakers must contend. The report suggests multiple reforms to improve water management in the state.

Study Site: California

Ecosystem Services: Regulating (water supply)

Methodology Used: The report estimates the additional value of products due to water, calculated as farm revenues minus the cost of purchased inputs – in this instance, irrigation water. A distinction is made between gross and net water use, presumably to allow for some portion of water used for irrigation to be re-used. The additional value is expressed as a ratio of gross farm income (by crop or farm type) divided by net water use.

The value of household water (single-family households) was based on a survey of 443 water service and 560 wastewater service areas. The results were grouped by region (SF Bay area, Central Coast, South Coast, Inland Empire, Sacramento area, San Joaquin Valley, and "Rest of State"). "Rest of State" is defined as rural counties in the Sacramento River region, the North Coast, and the North Lahontan regions. While this does not appear to include the Trinity River Watershed, we believe it is likely the closest match offered.

Values:

Ecosystem Service	Value as stated in study	Value in 2015 USD
Regulating: Water Supply (Irrigated pasture)	$47/acre-ft	$57/acre-ft
Regulating: Water Supply (Rice)	$223/acre-ft	$271/acre-ft
Regulating: Water Supply (Corn)	$258/acre-ft	$313/acre-ft
Regulating: Water Supply (Alfalfa)	$287/acre-ft	$348/acre-ft
Regulating: Water Supply (Cotton)	$551/acre-ft	$669/acre-ft
Regulating: Water Supply (Other field crops)	$573/acre-ft	$695/acre-ft
Regulating: Water Supply (Fruits and nuts)	$1,875/acre-ft	$2,275/acre-ft
Regulating: Water Supply (Truck farming and horticulture)	$5,363/acre-ft	$6,508/acre-ft
Regulating: Water Supply (Municipal use) (Rest of state)	$886/acre-ft	$1,075/acre-ft

Recommendation: As a statewide study, these data (as presented) have limited applicability to the Trinity River Watershed. Figure 2.10 (page 94) does show a statewide map of agricultural revenues per acre, suggesting that Trinity River area farms earn $320-$1,499 per acre ($2008), but those data do not isolate the contribution of irrigation water to those revenues. Moreover, the authors explain that water prices are strongly affected by scarcity – shortages of just 5 percent cause significant losses for agricultural producers, and 25 percent reductions in irrigation water may mean losses up to ten times as great. That said, the impact of scarcity varies widely, as some producers retain their own water rights, and others may switch to less water-intensive (or higher margin) crops. Since these responses are likely to vary widely by location, their applicability to the Trinity River Watershed is unknown.

ENDNOTES

1 Existing Vegetation - CALVEG, "EvegTile03B 99 04 v2. 2009." (McClellan, CA: USDA-Forest Service, Pacific Southwest Region, 2004).

2 Randall S. Rosenberger and R Johnston, "Benefit Transfer," in *Encyclopedia of Energy, Natural Resource, and Environmental Economics*, vol. 3 (Amsterdam: Elsevier, 2013), 327–33.

3 Randall S. Rosenberger and John B. Loomis, "Benefit Transfer," in *A Primer on Nonmarket Valuation*, ed. Patricia A. Champ, Kevin J. Boyle, and Thomas C. Brown, The Economics of Non-Market Goods and Resources 3 (Netherlands: Springer, 2003), 445–82, doi:10.1007/978-94-007-0826-6_12.

4 Leslie Richardson et al., "The Role of Benefit Transfer in Ecosystem Service Valuation," *Ecological Economics*, Ecosystem Services Science, Practice, and Policy: Perspectives from ACES, A Community on Ecosystem Services, 115 (July 2015): 51–58, doi:10.1016/j.ecolecon.2014.02.018.

5 Mark L. Plummer, "Assessing Benefit Transfer for the Valuation of Ecosystem Services," *Frontiers in Ecology and the Environment* 7, no. 1 (2009): 38–45.

6 Ibid.; Kevin J. Boyle and John C. Bergstrom, "Benefit Transfer Studies: Myths, Pragmatism, and Idealism," *Water Resources Research* 28, no. 3 (1992): 657–663; Roy Brouwer, "Environmental Value Transfer: State of the Art and Future Prospects," *Ecological Economics* 32, no. 1 (2000): 137–152; Clive L. Spash and Arild Vatn, "Transferring Environmental Value Estimates: Issues and Alternatives," *Ecological Economics* 60, no. 2 (2006): 379–388.

7 Plummer, "Assessing Benefit Transfer for the Valuation of Ecosystem Services"; Randall S. Rosenberger and Tom D. Stanley, "Measurement, Generalization, and Publication: Sources of Error in Benefit Transfers and Their Management," *Ecological Economics* 60, no. 2 (2006): 372–378; Rosenberger and Johnston, "Benefit Transfer."

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9 John B. Loomis and Randall S. Rosenberger, "Reducing Barriers in Future Benefit Transfers: Needed Improvements in Primary Study Design and Reporting," *Ecological Economics* 60, no. 2 (2006): 343–350; Boyle and Bergstrom, "Benefit Transfer Studies"; Timothy P. VandenBerg, Gregory L. Poe, and John R. Powell, "Assessing the Accuracy of Benefits Transfers: Evidence from a Multi-State Contigent Valuation Study of Groundwater Quality," Working Papers (Ithaca: Cornell University Department of Applied Economics and Management, 1995), http://ageconsearch.umn.edu/handle/127936.

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