Klamath County Commissioners

Tom Mallams, *Commissioner* Position One | **Dennis Linthicum**, *Commissioner* Position Two | **Jim Bellet**, *Commissioner* Position Three

U S Senate Committee on Energy and Natural Resources
Hearing on Klamath River Basin Water Resource Issues
Klamath County Commissioner Tom Mallams Testimony
June 20, 2013

First, I want to thank Oregon's Senator Ron Wyden for putting this Committee Hearing together. Bringing interested parties together can implement positive discussion seeking that illusive settlement on generational water conflicts.

In 2001, our community was united when water was shut off in the Reclamation Project. U. S. Congressman Walden, along with over 15,000 citizens, helped with buckets of water being pulled out of the Lake Ewauna, and poured into the "A" Canal, protesting this action.

As a Klamath County Commissioner, I watch in total frustration, as our community has been divided by the age old method of "divide and conquer." As far as the dam removal and KBRA is concerned, the great majority of the Klamath River Basin, has been very consistent in the direction they DO NOT want to go.

The areas elections in the last four years have proven this beyond any doubt. All three County Commissioners have been replaced, local State Senator Doug Whitsett and State Representative Bill Garrard retained their seats. Gail Whitsett is a newly elected State Representative. All these elections were won by a margin between 65-73%. The common denominator was that the winners opposed dam removal and the KBRA. Yes, there were other issues, but this was the most prominent issue that was the main focus. Siskiyou County Measure G also passed opposing dam removal by 80%.

As we speak, irrigators in the upper basin are now being denied the irrigation water needed to keep their crops and animals alive.

The Klamath River Basin is comprised of families of all shapes and sizes. Our communities are full of families that love our Basin. They want, more than anything else, to stay here, working and raising their families as the generations before have done.

Our communities have seen the devastation of the timber industry. Even with

305 Main Street, Klamath Falls, Oregon 97601
Phone: (541) 883-5100 | Fax: (541) 883-5163 | Email: bocc@klamathcounty.org

this loss, our citizens continued on, refusing to give in or giving up. Our sometimes harsh environment and numerous conflicts help create a very resilient people. The true spirit of the "American Way" still prevails in the Klamath River Basin. Often times, it seems as though the Klamath River Basin is "ground zero" for out of control regulation on our ability to use our Natural Resources. What ultimately happens here in the Klamath Basin will affect our entire nation.

So what is the next step?

In many ways, our Klamath River Basin is like a very large, extended family. We have many diverse members, with different strengths, weaknesses, life experiences, and desired outcomes for the issues facing all of us. Just because we may not agree with one another 100% of the time, does not mean that we cannot find common ground. Just like families do, we must focus on moving forward, finding that elusive balance.

The KBRA itself began as a noble cause. Numerous improved relationships came out of the KBRA process. Unfortunately, dam removal and the KBRA have obviously, failed to deliver what is ultimately necessary for a true, comprehensive settlement, embraced with Basin Wide and Congressional support. In its present form, it cannot go anywhere!

There are numerous options that can address the water issues in the Klamath Basin besides dam removal and the current KBRA. Unfortunately, all these viable options were systematically ignored. Being forced to accept dam removal and the KBRA as the absolute only option, ignoring all other directions is unacceptable. Deep, Off stream storage, dredging Klamath Lake, juniper removal and the list goes on and on.

We must regroup! We must keep striving ahead especially in these troubled times. We must follow the example of our "Founding Fathers" in never giving up.

AN ALTERNATIVE PLAN FOR BASIN

WATER AND SPECIES MANAGEMENT

Neither the removal of the Klamath River Dams nor the implementation of the KBRA will resolve Upper Basin conflicts because neither agreement addresses the actual causes of the conflicts.

The core causes of the conflicts are issues of water quality and water quantity. Neither water quantity nor water quality in the Upper Basin has changed significantly during the past century. Average precipitation has remained relatively constant. What have changed are the demands on water quantity and water quality.

According to historical journals water quality was equally as poor when European man first entered the area nearly 150 years ago. Virtually all of the water quality issues including temperature, phosphorous, nitrogen, organic solids and low oxygen levels have always been, and continue to be, the result of geologic conditions. Meaningful improvement in water quality cannot occur without changing the geological conditions that cause the poor water quality.

Water quantity issues are largely the result of new and expanded beneficial uses of a constant supply of available water. As each new and expanded use occurs, the amount of water available for previous beneficial uses is diminished. Western Juniper encroachment has become a major use of available water and a major contributor to reduction in water supply.

Control of Caspian Terns and Double Crested Cormorants that feast on juvenile sucker fish, would boost populations to acceptable levels.

CALIFORNIA - OREGON BI-STATE ALLIANCE

ALTERNATIVES
TO
KLAMATH RIVER HYDRO-ELECTRIC
DAM REMOVALS

SUBMITTED BY CAL/ORE BI-STATE ALLIANCE
C/O BSA

CALIFORNIA - OREGON BI-STATE ALLIANCE
GOALS AND OBJECTIVES

- **To Save** Taxpayers and Ratepayers **over one billion dollars** initial cost associated with the Klamath River Hydro-electric Dams and facilities scheduled for removals, and their replacement cost with green power under the proposed Klamath Basin Restoration Agreement (KBRA) and the Klamath Hydro-electric Settlement Agreements (KHSA). This does not include the additional long term Billions of dollar cost associated with the KBRA and KHSA agreements. The Bi-State Alliance hereby introduces alternatives to save taxpayers and ratepayers billions of dollars by preserving the green power hydro- electric dams on the Klamath River while achieving other environmental goals proposed by State and Federal Agencies.

- **To Achieve** the overriding environmental objectives set forth by the Federal Energy Regulatory Commission (FERC) to meet their mitigation recommendations for relicensing the four hydro-electric dams on the Klamath River in Oregon and California.
  a.) Provide anadromous fish passage around Iron Gate, Copco 1, and Copco 2 reservoirs to the pre dam 25 miles of native river habitat above Copco 1 Reservoir.
  B.) Improve Klamath River water quality between the Shasta and Scott Rivers.
  C.) Improve Klamath River water quality between Upper Klamath Lake and J.C.Boyle reservoir.

  Proposed Projects:

- Implement the Shasta Nation Tunnel Unassisted Anadromous Fish Passageway around Iron Gate, Copco 1 and Copco 2 Reservoirs at a cost of $1/6^{th}$ the cost estimated for installing fish ladders.

- Establish additional reliable storage facilities within the Upper Klamath Basin to satisfy the Klamath Project Water Users demands and to improve water quality in the Upper Klamath River. Provide project farmer's and rancher's irrigation water with poorer quality (high nutrient) Klamath R. Water and release a portion of the newly established stored better quality water to improve Klamath River water quality. This will preclude another 2001 Yr.

episode of Federal Agencies allocation of water for endangered species and depriving project irrigators their water which resulted in the loss of 1200 family farm homes.

- Establish additional reliable storage facilities within the Scott and Quartz Valleys, including increasing storage capacities of high-altitude lakes as recommended in the October 1991 Department of Water Resources Study entitled: SCOTT RIVER FLOW AUGMENTATION STUDY. These storage facilities will augment late summer and fall in stream flows and supplement agricultural irrigation water.

- Implement the 60,000 ac.ft. Klamath River/Shasta Valley Reserved Water Right (A0169580), transfer canal and storage facilities to supplement Montague Irrigation District's irrigation water with (poor quality high nutrient) Klamath R. water. This project augments current irrigation supplies, allows for additional land to become irrigable, and replaces naturally impaired upper Klamath R. water with higher quality water. A portion of the reduced water demands (good water quality) can be released by the District from Lake Shastina or from their wells into the Shasta River, improving the water quality in both the Shasta River and in the Klamath River below Iron Gate Reservoir per FERC recommended requirements for relicensing. Ref: (CDFG Project No. P0310329)

- Because PaciCorp is a signatory to the KBRA and KHSA, a **negative** one billion dollar 2020 yr. worth value has been established for the Klamath River Hydro-electric Dams scheduled for removals. The Bi-State Alliance proposes for the Siskiyou County Flood Control and Conservation District acquisition of Iron Gate, Copco 1, and Copco 2 Hydro-Electric Facilities. The sale of this 65 MW green energy to the PP&L grid would generate an estimated $50 Million per year to Siskiyou County which could be used for project financing and to reduce electricity cost to farming and ranching operations and to all ratepayers within the County.

- Similarly, it is hereby proposed for an Oregon based PUC acquisition of J.C.Boyle Hydro-Electric Facilities. The sale of this 98 MW green energy to the PP&L grid would generate an estimated $75 Million per year to the PUC which could be used for project financing and to reduce electricity cost to farming and ranching operations and to all ratepayers within the PUC District. Also, a Bi-State (PUC) could be formed to acquire all four hydro-electric facilities.

Other Benefits:

- Save Iron Gate Fish Hatchery which is dependent on cool low level water releases from Iron Gate Reservoir, and releases over six million salmon and steelhead fingerlings per year in to the Klamath River.
- Save future Klamath River water demands by State and Federal Agencies from the Scott and Shasta Rivers to satisfy requirements proposed in the KBRA for environmental waters.
- Save future Klamath River water demands by State and Federal Agencies from the Klamath basin diversions into the Rogue Valley to satisfy requirements proposed in the KBRA for environmental waters.
- Preserves the sacred Shasta Nation Villages and Burial Sites beneath the waters of Iron Gate and COPO Reservoirs.

THE VIABILITY OF DREDGING UPPER KLAMATH LAKE TO MITIGATE DROUGHT IMPACT: A COST-BENEFIT ANALYSIS

By

NICHOLAS SHEETS

A thesis submitted in partial fulfillment of

the requirements for the degree of

Masters of Science in Applied Economics

WASHINGTON STATE UNIVERSITY

School of Economic Sciences

MAY 2011

To the Faculty of Washington State University:

The members of the Committee appointed to examine the thesis of NICHOLAS SHEETS find it satisfactory and recommend that it be accepted.

Jonathan K. Yoder, Ph.D., Chair

Gregmar I. Galinato, Ph.D.

Hayley H. Chouinard, Ph.D.

Philip R. Wandschneider, Ph.D.

THE VIABILITY OF DREDGING UPPER KLAMATH LAKE TO MITIGATE DROUGHT IMPACT: A COST-BENEFIT ANALYSIS

Abstract

by Nicholas A. Sheets M.S. Applied Economics

Washington State University

May 2011

Chair: Jonathan K. Yoder

This thesis reviews the cost-benefit of dredging Upper Klamath Lake in Southern Oregon as a means to alleviate water stresses in the area. Currently, agricultural users must forego water use during low precipitation years and are compensated for losses by federal government transfers. Curtailments on water use are due to Environmental Protection Agency restrictions on minimum lake level and downstream flow requirements. There are two types of benefits assumed to arise from such a project; the first is that dredging the lake would provide additional water storage for agricultural users during low precipitation years making government transfers unnecessary. The second is an improvement to water quality as a result of increasing lake depth. Benefits to recreational users of the lake are estimated through use of benefits transfer techniques. Soil productivity rates and acreage totals are used to estimate the value of having available irrigation water for agricultural users. The result of this study is a cost-benefit analysis table. The table gives a range of potential estimates based on varying project sizes, interest rates, drought frequencies, and benefits transfer methods. The conclusion of the study is that the net benefit of dredging Upper Klamath Lake would be advantageous in some scenarios but not all.

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CHAPTER ONE

INTRODUCTION

Upper Klamath Lake is located in south central Oregon in an area known as the Klamath Basin. The lake has a surface area of 232 km^2 and an average depth of 2.8 m. (Wood, 2002, p 1). This size is large but relatively shallow compared to most western lakes. Among its many uses, Upper Klamath Lake provides approximately 250,000 acre-feet of water to the Klamath Irrigation Project. The Klamath Irrigation project supplies most of the Klamath Basin's agricultural producers with their irrigation water. The 250,000 acre-feet contributed represents 65% of the total water used in the project annually (Board, 2004, p 4).

The Upper Klamath Lake watershed is home to numerous indigenous species of fish and fowl. In 1988 the U.S. Fish and Wildlife Service listed two of these fish as endangered species, the Shortnose Sucker and the Lost River Sucker. In 1992, a drought year, the Fish and Wildlife Service recommended a minimum lake elevation for the first time. The elevation was set at 4,139 feet during summer months but allowed provisions for the lake to drop to 4,137 feet four times in a decade. The minimum elevation was set to help maintain stable habitats and protect fish populations as called for by the Endangered Species Act (ESA). This would mark the first time that curtailments were placed on the amount of water that could be used from the lake (Klamath Bucket Brigade, 2009).

In the summer of 2001, the Klamath Basin experienced a severe drought due to a decrease in overall snow-pack in the preceding winter. In response to the decline, the Bureau of Reclamation issued a halt to water use in the Klamath Irrigation Project. Minimum lake elevation was increased to 4,140 feet with no exceptions and downstream flow requirements were also set (Klamath Bucket Brigade, 2009). The Bureau cited the need to protect the Lost River Sucker Fish, Short Nose Sucker Fish and also the downstream Coho Salmon when making its decision. The result was a loss of available irrigation water that left many farmers without sufficient water to maintain their crop rotations. The loss in agricultural revenues was estimated in a study by William Jaeger at between $27 and $46 million for the year. In order to compensate agricultural producers for their loss, emergency government transfers were made totaling approximately $46 million (Jaeger, 2004, p 167). Curtailments were also seen in 2010 but are not yet quantified (Coba, 2011).

With requirements for lake levels and in-stream flows demanding large amounts of available water, it becomes important to develop contingency plans that will allow expectant agricultural producers to rely upon irrigation during their growing season. Continued research by Jaeger is being done to enable temporary transfers of water use rights between parties as a method to mitigate the losses accrued from droughts (Email communications with Prof. William Jaeger, 2009). However, the federal government's restrictions under the Endangered Species Act create the potential for a complete loss of irrigation use in the future (Klamath Bucket Brigade, 2009). Therefore investigation into alternative means of providing irrigation water in low precipitation years is prudent. This thesis explores the viability of a large scale dredging project on Upper Klamath Lake to increase storage capacity. There has been interest and discussion of a dredging project but no substantive research into the idea (Woodley, 2010).

One of the potential benefits from increasing lake depth is an increase in water quality. Upper Klamath Lake contains high levels of phosphorus loads and an extremely shallow average depth that provides the light, nutrients and mild temperatures algae need for heavy growth (Department of Environmental Quality, 2010). Due to these algal blooms, the lake is an undesirable site for water-sports such as swimming, water skiing or boating. Increasing the depth of Upper Klamath Lake would reduce temperature and light availability; dilute the overall nutrient availability and decrease phosphorus resuspension caused by wind gusts on a shallow lake (Kirke, 2001, p 1 and Laenen, 1996).

Water quality improvements and concomitant reduction in algal blooms on the lake would generate economic benefits in the form of increased visits and subsequent tourism dollars spent in the area (Gibbs, 1969, p 2). To accurately quantify the economic impact of dredging on recreation, a large scale hydrologic study would be required to assess the project's effect on algal growth. Such a study is beyond the scope of this thesis. Instead, moderate water quality improvements are assumed based on the introduction of algal growth limiting factors and the paper focuses on quantifying the recreational benefits from such a change. Benefits transfer techniques are used to determine the impact on recreational use. Values from a 1969 study by Kenneth Gibbs regarding Upper Klamath Lake are used in transfer estimates.

Society is faced with an ever increasing demand for limited natural resources. This fact makes it vital to determine efficient ways to use those resources. It is important to consider alternative solutions to a problem and understand which provides the most benefit at the least cost. This study considers the potential gains from eliminating the need for emergency transfers to agricultural users following curtailments. These gains are examined in conjunction with gains to outdoor recreation from water quality improvement. Two potential benefits that are not calculated but should be considered are: the gains to housing values from improved water quality and the non-use value of providing stable lake levels and downstream flows for endangered species.

Cost-benefit analysis is utilized and is appropriate in this scenario because of the need for government funding. To estimate the net benefits of dredging, several scenarios are projected. Alternate sizes, benefits transfer methods, discount rates and drought frequencies are assumed in order to increase the robustness and usefulness of the study. An alternative viewpoint might be the utilitarian perspective in examining whether the perpetuation of these fish species is worth the loss of human utilization of the water. In order to compare the benefits of each use the non-use or option value of the endangered species must be compared with the value from irrigation use of the water. Whichever value was greater would then be the appropriate use of the resource in utilitarian framework.

The primary concern before beginning dredging would be for the safety and ongoing maintenance of environmental factors important to the endangered species in the lake. It would need to be determined whether intermittent disturbance of lake-floor sediment would have a significant negative impact on the endangered species. The goal of such a project should be to cause no net harm to the species in question. No net harm should be emphasized because following completion of the project, increased water storage would help promote positive habitat conditions through stability of downstream flows. Flow stability should be considered a non-use benefit since large death tolls of Coho Salmon were believed to be the result of insufficient river flows in previous years (Klamath Bucket Brigade, 2009).

The lake has approximately 486,800 acre-feet capacity with average inflows of 1,350,000 acre-feet per year (Bureau of Reclamation, 2010, p 2). These water inflows create the potential for increased storage as a means to meeting the demand for irrigation water. The retention of water reserves would occur during periods of increased precipitation. This would allow for downstream flow requirements to be met without adversely affecting the ecology in those areas.

Downstream requirements are based upon temperature and dissolved load levels along with some other factors (Bureau of Reclamation, 2010, p 2). This suggests that the amount of water that will be storable will fluctuate based upon seasonal and yearly flows in order to comply with standards set by the Environmental Protection Agency, (Environmental Protection Agency, 2011).

In order to determine the viability of dredging Upper Klamath Lake as a solution to water shortages, a cost-benefit analysis will be used. The analysis will take into account minimum lake levels and in-stream flows as required by the ESA. Any methodology attempting to detail the costs and gains from such a project must first specify the parties to be considered. Agricultural producers rely on the Klamath Irrigation Project for their water needs and have been denied water during low precipitation years. Outdoor recreational users and businesses related to recreational use of the lake would stand to gain from an improvement to overall water quality. The Environmental Protection Agency (EPA) has an interest in the long term health of the endangered species residing in this watershed. Finally, governmental organizations paying emergency transfers to agricultural producers would be free of these payments if water storage were sufficiently increased.

Table 1.1 below depicts the timing of benefits and costs for each interested party. The methodology to quantify benefits and costs are also outlined below.

Table 1.1

Timing of Costs and Benefits to Stakeholders

Stakeholders	Benefits	Costs	Timing	Methodology
Agricultural Producers	Available irrigation water during low precipitation years improves: contract security with buyers, loan rates due to the reduction in uncertainty and a reduction in planning costs.	Possible adjudication costs from efforts to approve and implement a dredging project with legislators.	Fifty dredges would take five years to complete the project. Benefits would not occur until additional storage capacity is filled. Costs would occur before beginning the project.	Direct benefits of water via agricultural production. Indirect gains for agricultural users are not calculated.
Recreational Users	Improved water quality increases the value of the lake to recreational users.	No anticipated costs for recreational users.	Fifty dredges would take five years to complete the project. Benefits would not occur until algae levels are significantly reduced.	Functional or point benefits transfer techniques.
Federal Government	Benefits accrue from no longer making emergency transfers to agricultural producers due to water curtailments. If drought scenarios occur every 6 (9) years then benefits accrue every six (nine) years.	Government will be the responsible body for costs associated with the dredging project.	Fifty dredges would take five years to complete the project. Once the additional storage capacity was filled, these benefits would be available.	Direct multiplicative calculations were made using soil productivity and acreage to calculate benefits, cost estimates were provided by a contracting company.

As shown in table 1.1, agricultural producers would stand to gain from increased stability in the availability of irrigation water. This is true despite receiving emergency transfers in the event of drought. Loan rates, land values, contract negotiations with buyers and crop selection would all be positively impacted by increased certainty of irrigation water. Costs to agricultural producers would only be likely in the event of litigation fees. Individuals and businesses interested in recreational use of the lake would benefit from improved water quality. Costs would be negligible since recreational use would go uninterrupted during dredging due to the large size of the lake. Finally governmental organizations would benefit from no longer making emergency transfer payments and increasing downstream water flow stability for Coho Salmon. Costs of the dredging project would be paid with federal funding.

It is important to conceive the scale of such a project. Upper Klamath Lake is one of the largest lakes in the western United States. With a surface area of 232km^2 it is thirty miles long at times. Dredging a lake of this size to any real effect would be a massive undertaking. The size and cost of such a project make it critical to determine whether the anticipated results warrant action. The thesis accomplishes this task in four steps. First, the benefit from no longer making emergency transfers during drought is quantified using six year and nine year drought frequency intervals. Second, the expected benefit from improvements to water quality is calculated using point and functional benefits transfer methods. Third, the cost of dredging for project sizes of 250,000 and 350,000 acre-feet is calculated. Finally, these values are used to generate a net benefit calculation for a 36 year time horizon and the results are discussed. Before this however, the next section offers a preliminary overview of the benefits transfer methods used in later calculations.

CHAPTER TWO

BENEFITS TRANSFER LITERATURE REVIEW

A brief literature review follows to summarize important aspects of benefits transfer techniques that will be discussed throughout the thesis. In benefits transfer, the results of an existing study are adjusted to estimate the value of the target site. Benefits transfer method is used when time or money constraints do not allow for a full revealed or stated preference study. The following articles were consulted when selecting the type of benefits transfer method to use and an appropriate existing study.

The first article discussed is Rosenburger (2000). It focuses on outlining the body of literature on benefits transfer research. It describes how to conduct a variety of benefits transfer estimate types. The article discusses the potential limitations of benefits transfer methods. These limitations include the quality of existing studies, the consistency of statistical methods used to obtain data between studies, and the importance of site similarity.

Rather than recommending a specific transfer type, the article suggests that the appropriate method would be dependent upon the aims of the study and site specifications. The judgment of those conducting the study is purported to be very important to its accuracy. Rosenberger (2000) suggests that determining which benefits transfer method is best suited to site specific conditions contributes greatly to the overall validity of the value estimates produced.

The next article discussed is Colombo (2008) which explores methods to reduce errors in benefits transfer estimates. In order to examine the accuracy of benefits transfer estimates, the study generated benefits transfer estimates for the target site based on direct transfer, functional transfer and pooled data methods. Four sites were studied using choice experiments to determine revealed preference for each site. The revealed preference for a site was then used to generate benefits transfer estimates for each of the other three sites. These predictions were compared with the actual revealed preference values to determine the percentage error produced by the benefits transfer technique.

There are several types of benefits transfer techniques that can be used. The first examined by the study was the single point estimate transfer which uses a "unit" consumer surplus measure to predict the value for another site. The consumer surplus per individual that was found for a revealed preference site is adjusted for differences in the socio-economic characteristics between the two sites. This value is then multiplied by the expected change in use for a study site to provide a value change estimate. Simply put, willingness to pay at a target site is equal to the adjusted WTP from the study site (Colombo, 2008, p 130).

$$WTP_t = WTP_s$$

The next transfer type is a demand function transfer. This type uses a demand function that has been constructed and allows for the input of site specific values to account for changes in characteristics. In the example below, WTP(B^s, X^t) is equal to the willingness to pay at the target site estimated using the parameters of the benefit function of the study site (B^s) and the X values (site attributes, socio-economic characteristics, etc.) of the target site (Colombo, 2008, p 130).

$$WTP(B^s, X^t) = WTP_t$$

Finally, when several study site data sets are available meta-regression analysis can be applied (Rosenberger, 2000). In this method data is pooled across study sites to produce a benefits transfer model in such a way:

$$B_{t'} = B_{s+t} = B_s$$

Where B_s, B_t and B_{s+t} are the parameters of the study, target and pooled regression models respectively (Colombo, 2008, p 130).

The major implication of Columbo (2008) is the importance of site selection in reducing transfer errors. Characteristics such as landscape features, socio-demographics and historical usage directly influence the level of error received from a benefits transfer model. Utilizing a site that is very similar to the target site is preferable to producing a pooled model based on stacking information from several sites (Colombo, 2008, p 140). Adding site information in a pooled form does not always increase the accuracy of the model especially if the added study sites are dissimilar from the target site. Pooled models also increase the marginal costs of data collection. In addition benefits function transfers are not shown to be any more accurate than using a well-chosen point estimate (Colombo, 2008, p 146).

The last article considered is Johnston (2007). The article begins by expounding the importance of site similarity in the benefits transfer literature. Johnston states that the characteristics that are used to determine similarity between sites is critically important to minimizing transfer errors. Context similarity should be considered a better indicator than geographic proximity (Johnston, 2007, p 333).

The methodology of the study was to utilize choice experiment data from four communities in Rhode Island regarding proposed land use options. The four communities were selected specifically to stress similarities or dissimilarities in order to determine the effectiveness of site similarity in reducing benefits transfer errors. Geographical proximity and context similarity were the primary characteristics emphasized in site selection. The approach used was to compare the data from the revealed values found in the choice experiment surveys to determine the impact of site similarity characteristics on implicit price levels and utility measures. By measuring the impact of site characteristics on valuation inferences could be made regarding these factors in a benefits transfer setting.

The study's research supported site similarity as a method to reduce transfer error; with context similarity providing a more accurate predictor than geographical proximity. Johnston (2007) found that regardless of geographical proximity, those communities with similar populations and land use characteristics were more likely to approximate one another in their choice experiment values. Those two communities with the smallest degree of difference between their valuations were those that matched most closely in both characteristic and geographical terms (Johnston, 2007, p 349).

Based on this reading of the literature, the study selected for benefits transfer use for this thesis is Gibbs (1969). The advantages in characteristic similarity and geographic exactness gained by using a dated study are perceived to outweigh the drawbacks. Since data regarding the target lake was available this lent support for use of the point and functional transfer methods over that of the meta-analysis approach as detailed in Colombo (2008) and Johnston (2007). A point estimate adjusted for consumer price index levels and a demand function transfer adjusted for CPI and income changes were selected as the most appropriate benefits transfer methods. Once each approach was estimated the two were compared and then utilized to estimate a net present value change in recreational value for the next thirty-six years.

CHAPTER THREE

DATA AND METHODS

This thesis will consider two alternative project sizes for the dredging of Upper Klamath Lake. Current estimates suggest that the lake is responsible for approximately 250,000 acre-feet of the water supplied to the Klamath Irrigation Project annually. Therefore the first project size considered will be 250,000 acre-feet to increase lake capacity by the average amount of consumptive use by agriculture in a given year.

A proposed alternative to dredging the lake is the development of a reservoir site known as Long Lake, which has a capacity of 350,000 acre-feet of water (Board of Supervisors, 2004, p 3). In order to make a cost comparison with the reservoir, estimations for 350,000 acre-feet will also be made. With either project size, if a drought were to occur, sufficient water reserves would be available to maintain original lake levels and in-stream flows while providing uninterrupted irrigation use. It should be noted that this thesis does not calculate the recreational benefits of Long Lake Reservoir. In order to receive recreational benefits Long Lake would incur costs in infrastructure and access development not applicable to Upper Klamath Lake. Potential benefits would also be measured differently having no baseline for past Long Lake use to compare against. These points are made to show that the comparison is not a direct cost-effectiveness comparison.

Method of Estimating Lost Irrigation Value

The methods for estimating agricultural losses due to irrigation interruption are developed in this section. Data regarding the value from irrigation is developed in Jaeger (2004).

The Klamath Irrigation Project Areas were broken into distinct regions and each region was then broken down by soil class. The types of land found within the Klamath Irrigation Project were categorized into four distinct soil classes II through V. Estimates for the long-run value of irrigation water were then obtained by comparing the average productive values of irrigated and non-irrigated lands within similar categories of soil class (Jaeger, 2004, 176-179). Table 3.1 below depicts total acreage by soil type for Klamath Irrigation Project areas. Table 3.2 depicts the value of irrigation by soil type for Project areas. The values are the difference in crop productivity from an acre of land which is irrigated versus non-irrigated in the same soil class. These values were adjusted to 2010 levels from 2004 levels using a CPI index.

Table 3.1

Acreage by Irrigation Project Area and Soil Class

Klamath Irrigation Project Areas (acreage)	Soil Class II	Soil Class III	Soil Class IV	Soil Class V	Total
Merrill-Malin	2,030	13,965	6,205	0	22,200
Poe Valley	4,424	5,873	6,562	0	16,859
Midland-Henley-Olene	7,625	18,555	11,890	0	38,070
Bonanza-Dairy-Hildebrand	2,569	3,635	3,596	0	9,800
Langell Valley	3,315	6,969	5,491	565	16,340
Lower Klamath Lake	211	14,021	941	23	15,195
Malin Irrigation District	300	2,905	120	0	3,325
Shasta View District	1,000	3,100	1,100	0	5,200
West of 97 to Keno	387	1,487	1,843	32	3,730
Tule Lake/California	13,244	40,000	20,000	0	73,244

Source: William Jaeger (2004, p. 171)

Table 3.2

Increased Value of Production in Irrigated Versus Non-Irrigated Land (2010 Values)

Klamath Irrigation Project ($/acre/year)	Soil Class II	Soil Class III	Soil Class IV	Soil Class V	Average (weighted)
Merrill-Malin	$360	$268	$77	$43	$223
Poe Valley	$343	$182	$77	$43	$184
Midland-Henley-Olene	$343	$285	$77	$100	$232
Bonanza-Dairy-Hildebrand	$357	$300	$67	$40	$230
Langell Valley	$279	$122	$67	$40	$133
Lower Klamath Lake	$354	$184	$77	$29	$179
Malin Irrigation District	$341	$281	$84	$36	$279
Shasta View District	$345	$250	$244	$36	$268
West of 97 to Keno	$238	$155	$60	$43	$115
Tule Lake/California	$299	$244	$84	$29	$210

Source: William Jaeger (2004, p 175).

Table 3.1 shows the total number of acres broken down by soil type and district within the Klamath Irrigation Project. Table 3.2 shows the difference in productive value of an irrigated acre of land versus a non-irrigated acre of land for a given soil type and district. Put simply, table 3.2 shows how much more an acre of crops are worth with irrigation water. These two tables are used to estimate the cost of an emergency transfer in the event of a full curtailment. To make this calculation, the value of irrigation for each district and soil type (table 3.2 value) is multiplied by the corresponding total number of acres in that district and the products are summed (table 3.1 value). Table 3.2 has been adjusted to 2010 values as mentioned and both project sizes are assumed to provide sufficient irrigation water to avoid any losses.

To show an example, the acreage total for the Merrill-Malin area under soil class II as seen in table 3.1 is 2,030 acres. This figure is multiplied by an average loss of $360/acre/year, which is the corresponding amount as seen in table 3.2. The product is $730,800 of lost net profit that would be avoided under either dredging scenarios. These steps are repeated for each area and soil class and summing the results generates an estimated payment avoidance gain of $42,155,312 for a full curtailment scenario.

Once a value for agricultural losses in a curtailment scenario is established, the next step is to determine the frequency of curtailment scenarios. Two approaches are taken to estimating curtailment frequency. The first technique is to determine the average frequency of drought conditions. The second approach is to use existing curtailment patterns to assume a frequency level.

The data available for rainfall levels in Klamath Falls was examined and condensed to use years 1909 to 1997 for which data was most complete (Western Regional Climate Center, 2010). The average rainfall during this time was 13.48 inches with a standard deviation of 3.3. Therefore it is assumed that a precipitation level less than 10.18 should be considered a drought year. Under this assumption 14 years out of 89 would be considered drought years. Drought years do not seem to happen in any predictable pattern, as they are in consecutive years at times or could take as long as fifteen years between occurrences. Since there is need to establish the frequency at which low water years occur an average is taken. The average yields drought level rainfall with a frequency of 6.35 years. It is important to remember that this is a rough consideration of drought circumstances. Near drought rainfall levels could have a similar impact on agriculture. In addition, population growth and changes in water management due to endangered species law will continue to strain demand for Upper Klamath Lake as a water resource (USGS, 2009, p 1).

The next approach was to examine existing curtailment frequencies. Thus far curtailment years have occurred in 1992, 2001 and 2010, but seem unlikely for 2011(Klamath Basin Crisis Organization). Operating under this information, this thesis will calculate emergency transfer payment avoidance under two scenarios. The first scenario is that water will be curtailed every six years as suggested by the rainfall data (Western Regional Climate Center, 2010). The other scenario will suppose that curtailments occur every nine years reflecting the rate that curtailments have occurred thus far. Expected droughts every nine years will also provide sensitivity on the rates that potential costs and benefits might accrue.

Operating under the assumption that curtailments occur either every six or nine years as stated earlier, the net present value of avoided emergency transfer payments is calculated over a thirty-six year horizon. A thirty-six year horizon is used in order to allow for a significant time period with a common denominator between drought periods for ease of comparison. In addition to this reason, on-going sediment removal is anticipated to ensure continued benefits of the project. Sediment accumulation occurs at a relatively slow rate (.172 cm/year) and would only require occasional dredging for which thirty six years is a suitable horizon (Colman, 2004).

To determine the net present value of avoided agricultural losses an interest rate must be selected. For sensitivity the two interest rates of 4.375% and 8% were used when calculating present values. A 4.375% rate was used to be consistent with the Department of the Interior's discount rate for federal water resources in 2010 (Department of the Interior, 2011). An 8% rate was selected as consistent with the industry weighted average cost of capital (WACC) for agricultural staples (McClure, 2010). The smaller interest rate values the future more closely with the present. This results in higher net present values for avoided transfers for a 4.375% interest rate. Ordinary discounting techniques are sufficient as sustainability is not a major factor. In addition the Klamath Irrigation project is estimated to be 93% efficient in its use of water resources, recycling run off and returning unsaturated water to in-stream flows (Jaeger, 2006, p 180).

To use the interest rate in discounting, a discount rate is calculated by dividing one by one plus the interest rate. The discount rate for a 4.375% interest rate is calculated in equation 3.1 and the discount rate for 8% is calculated in equation 3.2.

3.1 $$1/(1+.04375) = .9581$$

3.2 $$1/(1+.08) = .9259$$

These rates are used in the net present value calculation of avoided emergency transfer payments over a 36 year time horizon as shown in equation 3.3 below.

3.3 $$\text{NPV avoided emergency transfers} = \sum discount\ rate^{d}\ (\$42{,}155{,}312)$$

Where d = (0, 6, 12, 18, 24, 30, 36) or (0, 9, 18, 27, 36) for the respective drought scenarios over a thirty-six year horizon. The first d set is used with the assumption of a six year drought interval as indicated by rainfall data. The second d set is used with the assumption of a nine year drought interval as evidenced by historical curtailment patterns. Using two sets for d and two sets of discount rates yields four net present values of the expected savings from no longer having to make emergency transfers to agricultural users. These net present values for the 36 year intervals are shown in table 3.3 below.

Table 3.3

NPV of Avoided Emergency Transfer Payments Due to Available Irrigation Water

Interest Rate	Interval	NPV
4.375%	6 Years	$155,255,424
4.375%	9 Years	$112,622,451
8%	6 Years	$109,487,195
8%	9 Years	$81,710,037

The table displays calculations of NPV for alternate curtailment frequencies and interest rates. The interest rates reflect society's time preference in regards to such a project. Alternate curtailment frequencies demonstrate a range of values to compensate for uncertainty in weather patterns. The highest value is for the most frequent curtailment interval at the lowest interest rate. This is intuitive because a low interest rate values the future more closely with the present and a shorter interval results in more frequently avoided transfers. Now that avoided transfer benefits have been enumerated, the subsequent section will lay out the methodology for recreational value estimates.

Procedures for Calculation of Recreational Value Estimates

The procedure for estimating recreational values is summarized in four steps. The first step is to identify an appropriate study, with similar site characteristics to Upper Klamath Lake, to transfer values from. The next step reviews the methodology used by the transfer study and outlines the functions and values needed for benefits transfer. The third step is to adapt the existing study's values to reflect the target site of Upper Klamath Lake in 2010. Finally, net present values are calculated based on the benefits transfer estimates found. These steps are explained below, beginning with the study site selection process.

The Gibbs (1969) paper was selected as the model to be used for benefits transfer. The paper studied potential recreational benefits from an improvement to water quality on several Oregon lakes including Upper Klamath Lake. The Gibbs paper was compared with three other studies for desired site similarity characteristics. These studies were: Bouwes (1979), Yaping (1997) and Soutukorva (1999). Each model was compared with the study site of Upper Klamath Lake in the year 2010 to determine which would provide the highest degree of accuracy. This was not a straightforward decision despite the location of the Gibbs model because of the amount of time that had passed since the study. Gibbs (1969) is dated and therefore certain parameters such as dollar values, had to be adjusted accordingly.

The most prominent site similarity issues are geographical and cultural traits that distinguish consumers. Geographical proximity between sites is one of the most important aspects of reducing benefits transfer error (Colombo, 2008, p 129). In this instance the Gibbs (1969) model was a study done on Upper Klamath Lake making it extremely useful in reducing error. The nearest alternative was the Bouwes study based in Wisconsin while the remaining two were from China, (Yaping 1997) and Sweden, (Soutukorva 1997). Therefore geographically and culturally speaking the Gibbs (1969) study is preferred over the alternative models.

It became apparent as each model was examined that time was an important factor to the accuracy of the benefits transfer. Having to make adjustments for time differences creates increased variability in a variety of ways. Statistical values will change due to the use of consumer price indexes and depending on the accuracy of the index used, can create a great deal of additional inaccuracy. Cultural tastes and trends influence the amount and types of recreational use over the years. For instance, in one decade it might have been much more popular to go swimming outdoors than in a following decade when municipal pools or water parks had gained popularity. The demographics of an area can also change over time affecting the types of recreation that are preferred. Keeping time limitations in mind the most recent of the models was the Soutukorva making it the most attractive resource in this aspect of comparisons.

Lake similarity is another factor linked with accuracy in the benefits transfer literature. Among the available studies the nearest approximation to Upper Klamath lake, other than the Gibbs model, was provided by the Yaping model that studied a lake with an average depth of 2.18m and a surface area of 73 km^2 (Yaping, 1997, p 2). The lake's poor water quality was due to issues with algae production and general pollution consistent with those problems facing Upper Klamath Lake. By contrast the Bouwes model studied Wisconsin lakes as an amalgam of all lakes sizes and locations compared against one another using a Lake Condition Index. The Soutukorva paper focused on an Archipelago that was considered the most distinctly different and employed visible depth as its quality component. It was concluded that the Gibbs and Yaping models are the most attractive choices with regards to lake similarity for these reasons.

The attitudes of recreational users at a study site should be similar to those of the transfer site. Therefore one of the conditions considered was the primary recreational use types at each site. In this instance, the Yaping lake was primarily used for swimming as was Soutukorva. Upper Klamath Lake is primarily used for boating and fishing activities. The Bouwes and Gibbs study sites were the most similar of the available choices in this regard.

Given the characteristics of each site and its method of study, the Gibbs (1969) study was selected as the most appropriate for benefits transfer modeling. Despite the shortcomings from the time difference between studies, the literature regarding benefits transfer criteria make this study the clear choice. The Gibbs (1969) study is a strong benefits transfer fit in many regards. It is common in benefits transfer studies to require adjustments to the models and time adjustments were considered relatively simple compared with the adjustments necessary to increase the accuracy of the other models. The next section outlines the methods used to generate estimates of recreational value in the Gibbs (1969) study.

Methodology of Gibbs (1969)

The methodology used in the Gibbs (1969) study is outlined below. The procedures used in this study are as follows. Gibbs collected survey information on recreational visits to several lakes in south central Oregon. From this information he constructed a model of recreational demand for each lake site. Gibbs adjusted the model for Upper Klamath Lake to reflect changes in demand from an increase in water quality. This adjustment was made by assuming a moderate increase in the recreational use intensity levels used to calculate demand. No assumptions were made about the method of water quality improvement. The increase in demand with improved water quality was compared to original demand levels to determine the value of water quality improvements. A detailed description of this process follows.

The parameters used in Gibbs (1969) are summarized in table 3.4. Two parameters needing further explanation are k which is the travel cost and p_l representing site expenditures. Travel cost (k) also includes the cost of food above what would have been spent at home (this can be a negative number), the cost of lodging or camping fees and any other expenses incurred while traveling to or from the lake. On-site expenditures (p_l) are the cost per day while visiting the site and includes lodging and camping, equipment rental, meal costs beyond those at home, and any other expenditure incurred during the visit. Each variable was considered at the individual level, therefore if a travel cost was obtained for a car of four people, the total cost would be divided by four to obtain the cost per person. Table 3.4 summarizes information for the relevant parameters from Gibbs (1969).

Table 3.4

Information Used in Recreational Value Calculations

Parameters	Parameter Descriptions	Values
q1	Number of recreation days per visit at Upper Klamath Lake	q1 = e^(.759 - .0064k* + .0064k + .0637p1* - .0637p1) 1969 General demand function q1 = e^(.801-.0637p1) 1969 Simplified demand, no water quality improvements q1 = e^(1.156 - .0637p1) 1969 Simplified demand with water quality improvements
k	Travel costs per visit/number of individuals traveling	Average travel cost 1969 = $6.80 Average travel cost 2010 = $40.40
p1	On-site costs	Average daily on-site costs 1969 = $1.84 Average daily on-site costs 2010 = $10.93
k*	Critical travel cost (maximum in travel costs an individual would pay to utilize the lake)	k* = k*(p1,p2,y,U) k* = 9.132 +.002y + 10.435p1 = $55 no water quality improvements 1969 k* = 60.426 + .002y + 10.435p1 = $106.65 Improved water quality 1969
p1*	Critical on-site cost (maximum in on-site costs a recreationist would pay to utilize the lake	p1* = p1*(k, y, p2, U) p1* = 3.531 + .269k - .004k2 + .000000017y2 = $5.54 Unimproved water quality 1969 p1* = 14.25 +.269k - .004k2 + .000000017y2 = $16.26 Improved water quality 1969

Information Used in Recreational Value Calculations

Y	Average annual family income after taxes per recreationist	$8,900 in 1969
V	Number of individual visits to the site per year (if a family of five comes to the lake once a year v=5	V = V(k, y, pop, Sw, Ws, B, F, C, Si) 146,491 visits to a non-improved lake 377,947 visits to an improved water quality lake
Si	Size of the lake in acres	98,560
F	Fishing intensity	Intensity levels were given discrete variables ranked 0 through 3, 0 meaning no use, 1 low use, 2 medium use and 3 high use Upper Klamath Lake estimates are: No water improvements = 1, Water quality improvements = 2
W	Intensity of water skiing, swimming and boating	No water improvements = 0, Water quality improvements = 2
B	Boating intensity	No water improvements = 1, Water quality improvements = 3
C	Camping intensity	No water improvements = 0, Water quality improvements = 0
Pop	Population of a county	49,600 in 1969

Source: Gibbs (1969).

The theoretical model for an individual is expressed in three structural equations which must be solved simultaneously. The parameter q_1 describes days of recreation per visit. The parameter k* represents the critical travel cost and p_1* is the critical on-site cost.

3.4
$$q_1 = q_1\left[(k^* - k), (p_1^* - p_1)\right] \text{ for } (k^* - k), (p_1^* - p_1) \geq 0$$

$$k^* = k^*(p_1, p_2, y, U)$$

$$p_1^* = p_1^*(k, y, p_2, U)$$

Equation 3.3 represents the individual demand equation. Now that the individual demand equation has been expressed, an aggregate model is obtained with the addition of the total estimated visits per year, V. The appropriate aggregate demand model is expressed in equation 3.5.

3.5

$$Vq_1 = f\left[(k^* - k), (p_1^* - p_1)\right] \text{ for } (k^* - k), (p_1^* - p_1) \geq 0$$

$$k^* = k^*(p_1, p_2, y, U)$$

$$p_1^* = p_1^*(k, y, p_2, U)$$

V is the total estimated visits per year. The value for V in equation 3.5, is a function of the factors shown in equation 3.6.

3.6

$$V = V(k, y, pop, Sw, Ws, B, F, C, Si)$$

Equations 3.4 through 3.6 are general representations of the functional structure used in Gibbs' individual demand equation. The unique site conditions at Upper Klamath Lake were utilized to construct a demand equation. Equation 3.7 expresses the individual demand for recreation before water quality improvement in 1969.

3.7

$$k^* = 9.132 + .002y + 10.435p_1$$

$$p_1^* = 3.531 + .269k - .004k^2 + .000000017y^2$$

$$q_1 = e^{.759 - .0064k* + .0064k + .0637p1* - .0637p1}$$

The Gibbs model used survey and existing statistics to determine values for the modeled variables. An average of 1.6 days per visit was estimated for Upper Klamath Lake. On-site daily expenses per recreationist were $1.84. Average annual family income after taxes was $8,900 per recreationist and $6.80 was allocated to travel costs on average. The critical travel cost, k*, was $55 and the critical on-site cost p_1* was $5.54.

In order to calculate the recreational value of the lake, the value per visit is multiplied by the estimated number of visits per year (V). The value per visit is calculated by taking the integral of the demand function from the average value of p_1 to the average value of p_1*. Equation 3.8 is the simplified demand equation for Upper Klamath Lake in 1969 before water quality improvements. Equation 3.9 is the value per visit calculation for Upper Klamath Lake in 1969 before water quality improvements.

3.8 $$q_1 = e^{.801 - .0637p1}$$

3.9 $$\text{Value per visit} = \int_{1.84}^{5.54} (e^{.801 - .0637p_1}) dp_1$$

The value per visit is calculated by taking the integral of the number of recreation days per visit (q_1) equation, from the values of p_1 ($1.84) to p_1* ($5.54). The value per visit was then calculated to be $6.37 in 1969 before water quality improvements. The value per visit was multiplied by the predicted number of visits (V) for the site to obtain a total value for the site. V was calculated using the function in equation 3.10.

3.10 $$V = -71,166.121 + 7,141.764W + 19,825.384F + .641Si - 379.786k$$

The result of equation 3.10 was an estimated 146,491 visits per year. Multiplying the number of visits by the value per visit resulted in a recreational value estimate of $933,148 for Upper Klamath Lake 1969.

Next Gibbs estimated economic benefits from an improvement to water quality. He anticipated two steps in improving the water quality and desirability of Upper Klamath Lake. His first step was to reduce the algae levels in the lake. The second step was to reduce the water temperature in order to maintain lowered algae levels. Each step was expected to impact his W (intensity of water skiing, swimming and boating) and F (fishing intensity) variables according to his consultations with FWPCA Pacific Northwest Laboratory. No specific method of improving water quality or lowering temperature was suggested by Gibbs (1969). This thesis will continue to operate under the assumption that the impact of dredging the lake would lower both water temperature and algae levels.

Because of improved water quality, the equations predicting critical values for travel and on-site costs are adjusted to reflect changes in recreational use intensities. The updated equations are shown in 3.11 below. Equation 3.11 is the updated Gibbs (1969) individual demand model for Upper Klamath Lake once water quality improvements have been made.

3.11 $$k^* = 60.426 + .002y + 10.435p_1$$

$$p_1^* = 14.25 + .269k - .004k^2 + .000000017y^2$$

$$q_1 = e^{.759 - .0064k^* + .0064k + .0637p1^* - .0637p1}$$

Solving these equations for the individual parameters gives the following values. Critical travel cost, k*, has an increased value of $106.65. The critical on-site cost p_1* is now $16.26. On-site costs p_1 remain at $1.84. The new k* and p_1* values are used to calculate the increased value per visit. First the q_1 equation is simplified as done before and the result is equation 3.12 below.

3.12 $$q_1 = e^{1.156 - .0637p1}$$

The simplified demand equation for recreation on Upper Klamath Lake in 1969 is shown in equation 3.12. Equation 3.12 is used in the calculation of a new value per visit as shown in 3.13 below. The value per visit calculated from the integral in equation 3.13 is $26.72. This value per visit reflects increased demand due to assumed water quality improvements.

3.13 $$\text{Value per visit} = \int_{1.84}^{16.26} (e^{\,1.156 - .0637p_1})dp_1$$

Expected visits (V) were increased to 377,947 per year due to increasing the recreational use intensities g used to calculate equation 3.10. The new value of V was multiplied by per visit value to obtain a total recreational value of the lake with water quality improvements of $10,098,744. Recall the original value of Upper Klamath Lake before water quality improvements was $933,148. The difference is an increase of $9,165,596. $9,165,596 represents the recreational value improvement from increased water quality in 1969 on Upper Klamath Lake.

Benefits Transfer Estimates of 2010 Recreational Values

The thesis will now utilize the Gibbs (1969) framework to make estimates for the 2010 value of water quality improvement on Upper Klamath Lake. Two benefits transfer estimates are calculated, point transfer and functional transfer. The point estimate is generated by adjusting the value of the original estimate for site specific differences (Colombo, 2008, p 130). Recreational intensity levels in the Gibbs (1969) study, suggested low intensity recreational use on Upper Klamath Lake. These estimates are consistent with 2010 recreational use therefore it is assumed that only the timeframe of the sites are different. The Gibbs (1969) estimate for an improvement in water quality is indexed to 2010 dollar values. The result is a 2010 water quality improvement estimate of $53,034,785 (Bureau of Labor and Statistics).

In addition to a point transfer, a functional benefits transfer is estimated. This method utilizes the existing Gibbs equations in 3.7 and 3.11 by indexing key values for inflation and recalculating the estimate. The 1969 values adjusted for inflation to 2010 are on-site cost (p_1), travel cost (k) and average annual family income after taxes per recreationist (y). The adjusted values of k, p_1 and y are $40.40, $10.93 and $52,880 respectively.

The adjusted values are inputted to equation 3.7 to solve for k* and p_1*. The resulting value for k* is $228.95 and for p_1* is $55.40. Once k, k*, p_1 and p_1* are known, all four are inputted into the q_1 equation in 3.7 to simplify q_1 into the form seen in 3.12. From there an integration equation similar to equation 3.13 is constructed with the adjusted values. This process is repeated to solve for the improved water quality values in equation 3.11. The value for k* following water quality improvements increases to $280.24; while p_1* is now $66.13.

Once k* and p_1* are found a new integration calculation is defined for value per visit in 2010 following water quality improvements (Colombo, 2008, p 130).

Equation 3.14 below shows the simplified q_1 (days per visit) equation for Upper Klamath Lake in 2010 before water quality improvements. The associated integration calculation is shown in equation 3.15. Equation 3.16 represents the simplified q_1 equation following water quality improvements. Equation 3.17 is the integration calculation for value per visit following water quality improvements.

3.14 $$q_1 = e^{3.08126 - .0637p1}$$

3.15 $$\text{Value per visit} = \int_{10.93}^{55.40} (e^{3.08126 - .0637p_1})dp_1$$

3.16 $$q_1 = e^{3.436505 - .0637p1}$$

3.17 $$\text{Value per visit} = \int_{10.93}^{66.13} (e^{3.436505 - .0637p_1})dp_1$$

The original value per visit estimate of $6.37 for an unimproved lake was increased to $160.44 in equation 3.15. The original value per visit of $26.72 for an improved lake was increased to $235.96 using equation 3.17. These estimates were then multiplied by their annual visit numbers to obtain a recreational value before and after water quality improvements. Annual visit numbers were not adjusted due to the nature of equation 3.10. Because use intensity characteristics are assumed to be alike for the lake in 1969 and 2010, the only number to adjust in equation 3.10 is travel cost. Without recalculating the model and adjusting the intercept accordingly this adjustment is not appropriate. Therefore, visitation estimates for 1969 will again be utilized in 2010.

Multiplying the appropriate value per visits with their visitation numbers yields \$23,503,016 as the current economic value without improvements to water quality and \$89,180,374 as the anticipated economic value after water quality improvements. Subtracting these values yields a functional estimate of recreational benefits for a 2010 increase in water quality of \$65,677,358. The functional estimate is reasonably similar to the point estimate value of \$53,034,785.

Some additional discussion for the selection of visitation numbers is warranted. The original estimate for the number of visits to Upper Klamath Lake before any water quality improvements in 1969 was 146,491. The estimated increase in visits to the lake following a water quality improvement led to a projection of 377,947 visits per year. Moderate growth has occurred in Klamath County with an increase in population from 49,600 to about 66,000 (U.S. Census Bureau, 2010). It is logical to believe that increased population leads to increased recreational visits however no specific data is kept for visits to Upper Klamath Lake because state park or similar facilities that would keep such data are not present (Hay, 2011). An estimation of the change in visits would therefore largely be speculative and is left out of this analysis other than to note the growth.

The point and functional estimates will be used to generate four net present values for the thirty-six year time horizon using the two discount rates of 4.375% and 8%. One difference in these calculations from the emergency transfer avoidance calculations is that benefits are accrued yearly rather than every six or nine years. The net present value is expressed in equation 3.18.

3.18 $$\text{NPV} = \sum \text{Benefits Transfer Estimate}^*(\mathit{discount\ rate}^r)$$

In equation 3.18 benefits transfer estimate refers to either the point or functional transfer estimate. Discount rate is either the solution for equation 3.1 or 3.2. The variable *r* refers to a set of years with values from zero to thirty six (0, 1, 2, 3..., 36). Table 3.5 below lists the net present value for each possible scenario.

Table 3.5

NPV of Benefits Transfer Estimates Over a 36 Year Horizon

Interest Rate	Benefits Transfer Type	NPV
4.375%	Point	$1,005,775,287
4.375%	Functional	$1,245,534,673
8%	Point	$674,453,586
8%	Functional	$835,231,624

As expected the smaller interest rate yields larger estimates. The estimates seem reasonable when considering contributing elements. The current condition of the lake makes it undesirable to use for most recreational activities. It does seem plausible that significantly increased demand would follow from strong water quality improvements as evidenced by the success of other large western lakes such as Lake Tahoe or Lake Shasta. The large size of Upper Klamath Lake provides many unique opportunities for recreationists that would not be available at smaller alternative sites.

Dredging Cost Estimates

The final step is to calculate a cost estimate for the dredging project. An estimate was accomplished by contacting an established dredging company and requesting a breakdown of costs for such a project. It is likely that such a large scale project would warrant a bidding war between several companies to bring cost estimates down. However, the specific estimates obtained are assumed to be reasonable approximations of the price range for such a project.

Input costs were obtained from Gregory M. Simmons, Senior Estimator at General Construction Company. These costs include: mobilization and demobilization (the process of transporting people and equipment to a job site), disposal preparation (the construction of a disposal site), replanting disposal site (recovering moved sediment with grass), and the dredging and disposal itself with considerations for profits and overhead. The estimates were considered for project sizes of 250,000 and 350,000 acre-feet. Cost breakdown was separated into fixed and variable costs.

In estimating the dredging costs, some assumptions are made that follow logical choices in the execution of such a project. These assumptions include the use of a hydraulic dredge as opposed to a mechanical dredge, and final grading and hydro-seeding of the lake shore and disposal area. A hydraulic dredge is considered far more cost and time effective for large scale projects. Hydraulic dredges are also more effective at removing loose sediment types consistent with the agricultural runoff that predominates the bottom of this lake (Hudson, 2009, p 3). Since the project accounts for the recreational value of improvements to the lake, it was considered necessary to allow for final grading of the disposal area and other "housekeeping" costs such as hydro-seeding grass along the lake banks after completion.

The project consists of fixed costs, incorporated regardless of the size of the project, and variable costs that will be calculated for both 250,000 acre-feet and 350,000 acre-feet as specified earlier. Most dredging estimates are calculated in cubic yards so the appropriate conversions from acre-feet must first be made. One acre is equal to 43,560ft^2. Therefore 43,560ft^2 * 1ft deep equals one acre-foot or 43,560ft^3. Divide this figure by 3ft * 3ft * 3ft or 27ft^3 to obtain a measurement in cubic yards of 1 acre-foot is equal to 1,613.33 cubic yards (Simmons, 2009). In terms of cubic yards our two dredging amounts are then 403,332,500 cubic yards and 564,665,500 cubic yards.

There is an initial transportation cost of $20,000 to haul the necessary equipment to and from the site. There is a $10,000 charge for use of a crane to assemble and disassemble the dredge, another $10,000 for the processes of assembly and disassembly. It costs and $5,000 to setup and take down the hose that will deposit the removed sediment to the designated site. $15,000 in costs are allocated to clear brush and ground cover and build dikes and a weir. Final grading and planting of the disposal area once finished is estimated to cost another $2,500. Summing these costs totals $62,500 per dredge location as shown below in table 3.6.

Table 3.6

Fixed Cost for Employing an Additional Dredge

Project Element	Cost
Transportation	$20,000
Crane Use	$10,000
Assembly/Disassembly of Dredge	$10,000
Hose Setup	$5,000
Dike Construction	$15,000
Grading of Disposal Area	$2,500
Total Fixed Costs per Dredging Site	$62,500

Source: Gregory Simmons, Senior Estimator General Construction Company

The variable costs include: dredge time, hydro-seeding, project overhead and profit margin. A twelve inch hydraulic dredge was selected as the most practical size for the majority of pumping. This selection was made due to the shallow nature of Upper Klamath Lake. Hydraulic dredges require certain minimum water depths to operate making larger dredges impractical in many areas (Ellicott Dredges, 2010).

A twelve inch hydraulic dredge will pump approximately 175 cubic yards/hour of solids (Searles, 2010). Dredge time is estimated to cost $100/hr for the operation of the dredge unit, $50/hr for the operation of a bulldozer at the disposal site, $150/hr for labor to operate each area (Simmons, 2009). This totals $300/hr which, divided by the rate of removal, gives us $1.71/cubic yard of sediment removed. Utilizing our calculation of cubic yards to acre-feet, 1,613.33*$1.71 = $2,758.80/acre-foot removed in variable costs. Now multiplying by our two desired dredge amounts we receive estimates of $689,700,000 for 250,000 acre-feet and $965,580,000 for 350,000 acre-feet for dredging and disposal costs.

Hydro-seeding is the next variable cost and a difficult one to estimate in this instance. Hydro-seeding is the process of spraying grass seed over a wide area in order to stimulate ground cover. Hydro-seeding will cost $500/acre and provide ground cover for disposal sediment sites that require resurfacing. The difficulty lies in knowing how much of the sediment disposal will be used in such a manner that it will require ground cover.

The sediment that is to be removed is largely the result of agricultural run-off and is therefore nutrient rich in nitrogen and phosphorus (Wood, 2002, p 5). This type of soil makes excellent fertilizer for farm land and with such an abundance created by the project, many agricultural growers may choose to purchase it for use in their production. In addition, the areas north and west of Upper Klamath Lake are sparsely populated; any destination site selected for the sediment may not require hydro-seeding if it is located in a remote area where a sediment disposal site would not create aesthetic issues. The acreage requiring hydro-seeding would also be dependent on the manner in which the disposal site was graded. If you deposit the sediment ten feet high, you would only need cover for the area exposed to the elements. One can think of many other uses of the soil where grass would not be needed, in construction purposes and so forth. These factors would all decrease the need for ground cover and in effect make it difficult to estimate an accurate cost level.

An assumption of 100,000 acres of hydro-seeding is made. This is a relatively large portion of the amount expected to be removed but this figure can easily be adjusted to desired levels. Multiplying by $500/acre the cost estimate is then $50,000,000 for hydro-seeding. One advantage is that the government owns the majority of land surrounding the north and west sides of Upper Klamath Lake. This land is primarily forest land included in the Fremont-Winema National Forest tract. The availability of nearby land for sediment placement will greatly reduce costs if this area is utilized. If this land is deemed unusable, large land parcels will need to be purchased. For the purposes of this study, the use of nearby federally owned lands will be assumed and no additional cost calculated for net impact on the land or opportunity cost of land use.

The next variable cost is a 15% charge for project overhead which accounts for: supervision, job office costs, vehicles, temporary living expenses, phone, fax and internet. Project overhead costs would be $110,964,375 for 250,000 acre-feet and $152,346,376 for 350,000 acre-feet. The final variable cost is a 10% charge of the direct costs added for the dredging firm's profit. Profit charges amount to $73,976,250 for the 250,000 acre-feet and $101,564,250 for 350,000 acre-feet (Simmons, 2009). All of these calculations are outlined in table 3.7 with the resulting totals for variable costs of $924,640,625 for the small project and $1,269,490,625 for the large.

Table 3.7

Variable Costs for Differing Project Sizes

Project Element	Cost	Calculation Method
Total Variable Costs Per Hour	$300	Dredge Operation + Bulldozer Operation + Additional Labor
Variable Cost of Removal	$1.71	Variable cost/Rate of Removal
Cost per Acre-Foot of Removal	$2,758.8	Acre-yard*Variable Cost of Removal
Hydro-Seeding	$50,000,000	Assumption based upon land availability and project size
Dredging and Disposal (Small)	$689,700,000	Cost Per Acre-foot of Removal*250,000 Acre-feet
Dredging and Disposal (Large)	$965,580,000	Cost Per Acre-foot of Removal*350,000 Acre-feet
Overhead (Small)	$110,964,375	15% of (Dredging and Disposal + Hydro-Seeding)
Overhead (Large)	$152,346,375	15% of (Dredging and Disposal + Hydro-Seeding)
Profit (Small)	$73,976,250	10% of (Dredging and Disposal + Hydro-Seeding)
Profit (Large)	$101,564,250	10% of (Dredging and Disposal + Hydro-Seeding)
Total Variable Costs (Small)	$924,640,625	Hydro-Seeding + Dredging and Disposal + Overhead + Profit
Total Variable Costs (Large)	$1,269,490,625	Hydro-Seeding + Dredging and Disposal + Overhead + Profit

Source: Gregory Simmons, Senior Estimator General Construction Company

Estimating Optimal Dredge Numbers

The large scale of this project forces us to examine time considerations. At 175 cubic yards per hour it would take one dredge team 263 years to accomplish this task. This timeframe is unacceptable so considerations for multiple dredge sites must be taken into account. Additional dredges would not alter the mathematics on the variable costs since 12 inch hydraulic dredges have a constant removal rate and no other dredge size is used in calculations. Therefore only the fixed costs for preparation and setup of additional sites would be increased.

The following equations were constructed to determine the optimal number of dredges to be used. The equations were constructed with considerations for additional site costs as well as foregone benefits from an increased timeframe. The benefits from the project will not be attained until it is completed and the additional water storage space is filled. What this implies is a reduction in NPV from increased project duration. It would follow that the optimal number of dredges should be determined by a combination of their fixed costs and their contribution to project expediency. Therefore equation 3.19 is constructed with J as a choice variable in order to determine the optimal number of dredges to employ, table 3.8 describes the variables.

3.19 $$\text{Cost} = \$62{,}500x + (\text{NPV today} - \text{NPV}^{J})$$

3.20 $$J = \frac{403{,}332{,}500 \text{ yds}^3}{1{,}533{,}000 \text{ yds}^3 x} \text{ or } \frac{564{,}665{,}500 \text{ yds}^3}{1{,}533{,}000 \text{ yds}^3 x}$$

Table 3.8

Explanation of Equation Variables

Values	Description
J	Number of years the project will take to
\$62,500	Marginal cost of an additional dredge
x	Number of dredges utilized
NPV today	NPV of recreational benefits over 36 years beginning from today
NPV^J	NPV of recreational benefits over 36 years beginning J years from today
403,332,500 yds^3	Number of cubic yards in the 250,000 acre-foot project
564,665,500 yds^3	Number of cubic yards in the 350,000 acre-foot project
1,533,000 yds^3	Rate of sediment removal per dredge per year
NPV today - NPV^J	Loss in NPV due to the anticipated project length

The above is an ad hoc optimization equation. In equation 3.19 cost is minimized by determining the optimal number of dredges. \$62,500x represents the marginal cost per dredge. It should be noted that this cost does not reflect increased costs from transportation distance of available dredges. These costs were not included in the estimator's calculations. It is assumed additional fuel and labor costs would not alter the linearity of the equation leaving these calculations valid. $(\text{NPV today} - \text{NPV}^J)$ represents the value lost from the time it takes to complete the project. This value is lost because benefits cannot be gained until the project is complete. Therefore each additional year the project takes, implies a reduction in NPV. By subtracting the NPV of a completed project today by the NPV of the J^{th} year, we obtain the difference in NPV from having the project extended an additional year. The equation was constructed so that a balance between the cost of transporting and mobilizing an additional dredge could be weighed against its contribution to the expediency of sediment removal.

What the equation suggests is that each dredge added reduces the overall cost of the project by increasing expediency. Put simply, the project should employ as many dredges as possible. This is due to the large increase in savings from project expediency compared to the relatively small marginal cost of transporting a dredge and preparing a disposal site. The large surface area of Klamath Lake would allow for many dredges to be accommodated but there may be difficulties in finding enough dredges within transportable distance. Since the optimization equation recommends employing as many dredges as possible, it is best to make an assumption on the number of dredges that might be attainable in such a project. A high end estimate of fifty dredges is used as a compromise between availability and expediency (Searles, 2010). Since the framework is available to recalculate fixed costs for a different number of dredges easily, this value is adaptable. Fifty dredges would result in a fixed cost estimate of $3,125,000. Using fifty dredges the project would take approximately five years to complete.

Something else to consider is whether dredging will interrupt any current recreational use of Upper Klamath Lake. Interruption is unlikely due to the large size of the lake itself. Since the lake is 232 km^2, recreators will move to other areas of the lake not being dredged upon at that time (Wood, 2002, p 1). A benefit to local industries would also be expected from the project since local workers and companies would be needed to execute the project and temporary housing in the form of apartments or hotels would be utilized for those workers not originally living in the Klamath Basin. The results of all benefits and costs calculations will now be discussed.

CHAPTER FOUR

RESULTS

The results of all calculations are combined into an easily referenced format in Table 4.1. Table 4.1 displays estimates for each of the twenty four possible scenarios. Each option is categorized by project size, the type of recreational benefits estimate used if any, curtailment frequency and interest rate used. Table 4.1 enumerates the total benefits, total costs and net benefits for each project scenario. Total benefits includes: the NPV of avoided emergency transfers and the NPV of any benefits transfer estimates. Total costs includes: dredging costs associated with project size and costs for setup of the assumed fifty dredged to be utilized. Net benefits are the total benefits minus the total costs.

Table 4.1

Summary of Project Scenarios

Size of Project	Transfer Type	Drought Intervals	Interest Rate	Total Benefits	Total Costs	Net Benefits
250,000	No Rec. Benefits	6	8%	$109,487,195	$927,765,625	-$818,278,430
250,000	No Rec. Benefits	9	8%	$81,710,037	$927,765,625	-$846,055,588
250,000	Functional	6	8%	$944,718,819	$927,765,625	$16,953,194
250,000	Functional	9	8%	$916,941,661	$927,765,625	-$10,823,964
250,000	Point	6	8%	$783,940,781	$927,765,625	-$143,824,844
250,000	Point	9	8%	$756,163,623	$927,765,625	-$171,602,002
250,000	No Rec. Benefits	6	4.375%	$155,255,424	$927,765,625	-$772,510,201

Summary of Project Scenarios

250,000	No Rec. Benefits	9	4.375%	$112,622,451	$927,765,625	-$815,143,174
250,000	Functional	6	4.375%	$1,400,790,097	$927,765,625	$473,024,472
250,000	Functional	9	4.375%	$1,358,157,124	$927,765,625	$430,391,499
250,000	Point	6	4.375%	$1,161,030,711	$927,765,625	$233,265,086
250,000	Point	9	4.375%	$1,118,397,738	$927,765,625	$190,632,113
350,000	No Rec. Benefits	6	8%	$109,487,195	$1,272,615,625	-$1,163,128,430
350,000	No Rec. Benefits	9	8%	$81,710,037	$1,272,615,625	-$1,190,905,588
350,000	Functional	6	8%	$909,104,127	$1,272,615,625	-$363,511,498
350,000	Functional	9	8%	$885,045,212	$1,272,615,625	-$387,570,413
350,000	Point	6	8%	$769,284,862	$1,272,615,625	-$503,330,763
350,000	Point	9	8%	$745,225,947	$1,272,615,625	-$527,389,678
350,000	No Rec. Benefits	6	4.375%	$155,255,424	$1,272,615,625	-$1,117,360,201
350,000	No Rec. Benefits	9	4.375%	$112,622,451	$1,272,615,625	-$1,159,993,174
350,000	Functional	6	4.375%	$1,400,790,097	$1,272,615,625	$128,174,472
350,000	Functional	9	4.375%	$1,358,157,124	$1,272,615,625	$85,541,499
350,000	Point	6	4.375%	$1,161,030,711	$1,272,615,625	-$111,584,914
350,000	Point	9	4.375%	$1,118,397,738	$1,272,615,625	-$154,217,887

Table 4.1 outlines the potential benefit-cost scenarios for the dredging project. There are a wide range of potential outcomes with the most optimistic projecting a positive value of $473 million and the most pessimistic projecting a value of -$1,191 million. Table 4.1 shows the positive effect a lower interest rate and functional benefits transfer have on overall benefit-cost.

Of those scenarios with a positive benefit-cost value, the majority utilize the lower of the two interest rates. The table is meant to be a useful guide to aid in the consideration of different potential project types.

A comparison of projects is made with the Long Lake reservoir. Long Lake was estimated to cost $690,000,000 and would provide an additional 350,000 acre-feet of water storage (Board of Supervisors, 2004). It is assumed that Long Lake would solve the need for emergency agricultural payments in a similar manner to dredging. This would generate an anticipated 36 year NPV of between $81 and $155 million, just as dredging would. Factoring in these benefits, Long Lake has a projected net benefit without recreational considerations of between -$609 million and -$535 million. This range compares favorably with net benefits of dredging that do not include increases to recreational values. However, it should be reiterated that the most important advantage of a dredging project is the immediate potential for recreational benefits without significant investment toward infrastructure. Long Lake would have no initial housing, roads or recreational access making potential recreational gains relevant.

Non-use values for improvement of habitat stability and increased value to lake-side homeowners were not calculated. Each of these values would require substantial research in their own right and were beyond the scope of this paper. It is entirely possible that the incorporation of these values could positively impact some smaller negative benefit-cost scenarios by enough to make them positive.

Table 4.1 can also provide a comparison with the option of no action taken. The value of benefits in scenarios listed "No Rec. Benefits" include only the estimated value of avoided emergency transfers. The total benefits in these scenarios quantify the NPV of emergency transfers over a 36 year horizon. These values therefore represent the benefit-cost of no action given differing interest rates and curtailment frequencies. The benefit-costs range from -$81 to -$155 million and are readily comparable with any other net benefits scenario.

CHAPTER FIVE

CONCLUSIONS

Whether or not this project is advantageous from a benefit-cost standpoint depends upon several factors as evidenced by table 4.1. Of those factors, the interest rate at which society values the future and the size of the project seem to create the most significant changes in value. It is immediately apparent that without recreational benefits, none of the potential scenarios are worth pursuing from a benefit-cost standpoint. The type of benefits transfer estimate used also has significant bearing on the overall value of the project with functional estimates generating larger value estimates. Although no clear determination can be made on the societal value of this project, the thesis provides a framework for decision making once certain assumptions are made.

Those with the potential to gain the most from dredging are recreational users as well as those with ties to recreational service industries including, hotels, boating rentals or sales, fishing stores, etc. Agricultural producers would gain from increased stability to production values and contract negotiations. The losers are dependent on where funding for the project would be secured from, the most likely source is a federal works project meaning American taxpayers would be the paying party. The state and local governments have already been in talks for several years now in an attempt to find a long term solution (Woodley, 2010). A project of this size would most certainly require federal funding. This would be in the government's self-interest since they supply emergency transfers when irrigation water must be discontinued.

Whether or not to act on a proposal such as this would be considered by a county and then state committee in conjunction with the federal agencies responsible for monitoring lake levels and other necessities for the endangered species. If a plan of action was devised amongst these groups it would be voted on at a state or local level if taxes were required to fund the project at those levels. Alternately a bill could be proposed in the house or senate to procure funds federally for such a project and would be voted on and changed in that avenue.

The costs of dredging are expressed as a single payment but must be considered in the context of a project that would constitute many years of work. The anticipated project length under assumed dredge numbers is approximately five years. In addition, water reserves must be stored over several years in uncertain amounts due to downstream flow requirements. This project should therefore be considered a long term solution to the problem of water availability.

Before any dredging might be done, it would be of greatest importance for governmental agencies to ensure that no net harm would be done to the endangered species living in the lake and river systems. Net harm should be the focus of such inquiries since it is likely that increased water storage would promote habitat stability downstream. Additionally the lake's potential to increase in depth with current water demands and supplies must be critically examined.

New contingent valuation research is needed to determine the potential recreational gains from improvement to the lake as well as any additional gains such as those to home values near the waterfront or non-use values from stabilizing downstream flows and in-lake levels for endangered species. Finally, it is very important to quantify the impact on algal growth from an increase in storage capacity. Without an increase in water quality, this study suggests that benefit-cost measures would not be satisfied to pursue dredging. Ethical policy should not affect this project once the safety of the endangered species is ensured. Politically speaking the goal is to stabilize a valuable agricultural commodity in a cost effective way that will resolve the issue over the long term and dredging has the potential to accomplish this.

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CLEAR LAKE UNIT

KLAMATH PROJECT
OREGON – CALIFORNIA

A Reconnaissance Appraisal of an Opportunity for Water Development in the Upper Lost River Watershed

THIS IS ONE OF APPROXIMATELY

TEN POSSIBLE OFF-STREAM

STORAGE SITES

BUREAU OF RECLAMATION
REGION 2, SACRAMENTO, CALIFORNIA

CONTENTS

LIST OF PLATES

INTRODUCTION

The Klamath Basin, in which the Clear Lake Unit lies, possesses the potential for further land and water resource development for various purposes. At present irrigation, power, fish, wildlife and recreation share the use of the resources that have been developed and seek to participate more extensively in the use of those which may be developed in the future. Various plans of development are possible depending upon physical factors, the emphasis which is placed on various possible purposes, and judgments of the relative contribution which these purposes will make to the growth and welfare of the local area, the State and the Nation.

This report sets forth a possible plan dealing with power, irrigation, fish and recreation, which provides reconnaissance estimates of the costs and effects if reservoir storage were added on Lost River for these purposes. Expansion of the Klamath Project to include these works would depend upon securing rights to use the additional water supplies that could be developed. Also, it would be dependent upon the land and water policies adopted in the basin. The Bureau of Sport Fisheries and Wildlife, for example, recommends that storage be provided for additional water for Tule Lake Sump and diversions be made from Klamath River for Tule Lake and the Lower Klamath National Wildlife Refuges in addition to the plans discussed in this report.

The report presents information on engineering and economic studies useful in guiding future actions which may be taken in

CHAPTER I

THE AREA

Existing Irrigation Development

The Klamath Project was originally authorized in 1905. Clear Lake Dam, on Lost River, one of the project's first features, was completed in 1910. The dam is an earth and rockfill structure about 40 feet high and 840 feet long. Clear Lake Reservoir has a total capacity of 527,000 acre-feet. The reservoir was originally developed for two purposes: to store water for irrigation use in Langell Valley, and to help prevent flood water from entering Tule Lake--the natural terminus of Lost River. Then in 1911, by Executive Order, Clear Lake National Wildlife Refuge was established and included within its boundaries, Clear Lake Reservoir. Gerber Dam, completed in 1925, is located on Miller Creek, a tributary of Lost River. It, too, was constructed to provide storage for irrigation in Langell Valley and to reduce flood runoff that would enter Tule Lake. Gerber Dam, a concrete arch structure about 90 feet high with a crest length of 485 feet, creates a reservoir with a total capacity of 94,300 acre-feet.

The Klamath Project has developed over the years until it now includes about 220,000 acres of irrigated farm land in the Upper Klamath River Basin. The existing features of the Klamath Project are shown and described in more detail on plate 2. A major part of the water supply of the project is obtained from the Klamath River. However, much of the project is served by diversions from Lost River, area and on Link River in the project area. Existing Klamath River plants include Copco One, Copco Two, John C. Boyle (formerly Big Bend), and Iron Gate. The two Link River plants, East Side and West Side, are located upstream from the confluence of the Klamath River and Lost River Diversion Channel and would not be directly affected by a future development on Lost River. The company has plans to add to its Klamath River hydroelectric system by construction of plants at Salt Caves, Keno, Bear Springs, and Warm Springs. The company expects this program to be completed in about 10 years, or about 1972. Total installed capacity of the existing Klamath River plants is about 160,000 kilowatts. Additional capacity of the new plants to be constructed is anticipated to be about 190,000 kilowatts.

Need for Additional Development

The need for additional storage on Lost River has long been recognized. With present irrigation development, a severe and prolonged period of drought, such as the one which occurred in the 1920's and early 1930's, would seriously affect irrigated farming in Langell Valley. In recent dry years since 1958, the need for additional water supply development has been emphasized, particularly in the Langell Valley service areas which are fully dependent upon direct release of storage from Gerber and Clear Lake Reservoirs. Clear Lake Reservoir, which covers a large area and is relatively numbers of people. Local residents and visitors from the heavy population centers, both north and south of the basin, use its hunting and fishing areas. Additional storage development would create new recreational and fishery opportunities to help relieve the pressure on existing facilities.

Lake Reservoir would be reduced. By operating the two reservoirs in conjunction with the modified Clear Lake Reservoir, the total firm annual yield of the upper Lost River storage system would be increased to a total of 84,000 acre feet. Of this total, 67,000 acre-feet would be required to meet the existing irrigation needs and to provide the new supplemental water supply. The remaining 17,000 acre-feet would be available for sale for power generation.

The 67,000 acre-feet would be sufficient to meet the optimum annual requirements of the Langell Valley Irrigation District and the Lost River Warren Act contractors, and to meet the other downstream contractual obligations such as those of the Horsefly Irrigation District. This quantity of water would eliminate the previously described irrigation shortages of the Langell Valley Irrigation District and Warren Act contractors in all years of record. The additional firm annual yield, 17,000 acre-feet, could be conveyed to the Klamath River via the Lost River Diversion Channel and sold to the Pacific Power & Light Company for power generation, probably during the period October through December. As the releases could be scheduled after the irrigation season, they would not interfere with irrigation operations of the Lost River system.

In addition to the firm yields described above, the Clear Lake Unit could also develop water that would be available only part of the time, following seasons of high runoff. This surplus water, averaging about 12,000 acre-feet per year, could also be scheduled would prevent water that enters the east side of the reservoir from flowing into the lower west side and being lost to evaporation and seepage. Thus, the east side would be used for temporary storage and as a means for diverting runoff through Clear Lake Dam for hold-over storage in the deeper Boundary Reservoir.

Some water would flow into the west side of Clear Lake Reservoir in most years from the minor watershed directly tributary thereto. During seasons of great runoff, water would accumulate in both cells to elevations that would submerge the low dike. On the other hand, during an extended or severe drought period, the water level in the west side would be lowered by evaporation and seepage and, over a period of several years, the area might be completely dry during some summer months. During such drought periods, even though water would not spill from the east to the west side, runoff from the area upstream from the dike would accumulate in the west side every spring. Under this development plan, much of the west side of the Clear Lake Reservoir could be used for grazing and wildlife purposes as is now done in many years when the reservoir level is low. Natural grasses and cover could be grown to the extent that they could be sustained without an artificial water supply. As a possible future improvement, it may be found desirable to develop a simple drainage system on the west side that includes a pumping plant to transfer accumulated water from the west to the east side. Although this might make possible an improved wild meadow development for

CHAPTER III

ECONOMIC AND FINANCIAL ANALYSES

This chapter presents information on the economic justification and financial feasibility of the potential project. The economic justification is tested by comparing the costs of the development with the benefits that would be attributable to the development. The financial feasibility is appraised by demonstrating a method by which costs of the development could be repaid.

Economic Justification

Benefits resulting from the development of the plan described herein would accrue from four sources: irrigation, commercial power, recreation, and warm-water fishery.

Irrigation benefits.--Irrigation benefits have been evaluated for 16,000 acres of irrigated land within the Langell Valley Irrigation District and 1,800 acres irrigated in the southern part of Langell Valley under Warren Act contracts. The irrigation benefits would accrue from elimination of water deficiencies presently encountered by irrigation water users. Benefits were measured by the farm budget method, based on reconnaissance standards. These benefits, both direct and indirect, are estimated at about $65,000 annually.

Power benefits.--Power benefits could accrue from the sale of water, which, without the development, would be lost from Clear Lake Reservoir by evaporation or seepage, or wasted to the Klamath River at a time when it would not be usable for power generation. The

Bureau of Reclamation. Such an estimate is considered to be satisfactory for the purposes of evaluating the general magnitude of the recreation function of a potential development. It would not, however, be satisfactory for more detailed feasibility studies.

The estimated annual visitor-day use for the two reservoirs of the potential storage system is 155,000; 85,000 for Gerber Reservoir, and 70,000 for Boundary Reservoir. On the basis of a value of $1.60 per day, as used by the National Park Service, gross recreational benefits would amount to $248,000 annually.

Total annual benefits.--The total annual new benefits that could result from the potential Clear Lake Unit development are summarized in the following tabulation:

Function	Annual benefits
Irrigation--direct and indirect	$ 65,000
Power--firm and surplus	167,000
Fishery	100,000
Recreation	248,000
Total annual benefits	$580,000

Other potential benefits.--In addition to the above described benefits, others may possibly accrue. They have not been evaluated since they would represent a refinement that would not materially affect findings indicated herein.

It is likely that the Horsefly Irrigation District and water users in Upper Poe Valley would be benefited by the development of a more firm water supply in Langell Valley. This benefit would

Economic and Financial Analyses

As previously mentioned, the division of Clear Lake Reservoir into two cells might provide an opportunity to develop the west side of the reservoir for grazing and wildlife purposes. Previous studies, however, have indicated that such development would have marginal economic justification and should be limited to a simple drainage system because the costs of a more elaborate development program would probably exceed the associated benefits.

Benefit-cost analysis.--Both benefits and costs are converted to annual equivalent values over a common time period to facilitate their direct comparison, termed the benefit-cost ratio. Since all of the evaluated benefits have been estimated as annual values over the whole period of analysis, the annual and annual equivalent values are considered to be the same. As previously indicated, total benefits amount to $580,000 annually.

Total annual equivalent costs include a capital cost and interest during construction amortization component, and the annual operation, maintenance, and replacement expenses. The total annual equivalent costs, computed over a 100-year period at an interest rate of 2-1/2 percent are estimated to be $359,000.

Comparing the annual equivalent benefits of $580,000 with annual equivalent costs of $359,000 yields a benefit-cost ratio of 1.6 to 1.0, demonstrating that the potential multiple-purpose development is economically justified.

repayment period. This would leave a balance of $1,405,000 of the irrigation allocation to be repaid from other sources. This assistance could be provided by surplus power revenues.

As indicated earlier, 17,000 acre-feet of firm water and 12,000 acre-feet of surplus water are estimated to be available annually for power production. For this analysis, unit revenues of $7 and $4 per acre-foot for firm and surplus water, respectively, have been used to indicate the repayment potential of the power function. The total estimated revenues from this source would be $167,000 per year. Over a 50-year repayment period, this would be sufficient to pay: (1) the allocated power investment including interest during construction; (2) annual operation, maintenance and replacement costs associated with the power function; and (3) interest on the unpaid balance of the power allocation at 2-1/2 percent per annum. In addition, the power revenues would be sufficient to provide the needed assistance to irrigation allocation and return about $613,000 in surplus revenues by the end of a 50-year repayment period.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This report shows that new, multiple-purpose development on Lost River is needed and could be economically justified. The plan outlined in this report is not necessarily the best plan or the only plan for development of Lost River. It was selected to demonstrate the possibilities for such a development. To formulate more specific plans and to fully evaluate the multiple-purpose aspects and alternatives of any proposed plan, further studies and resolution of questions of conflicting interests would be required. Water rights definition and resolution of refuge needs and their effects on the existing and potential project are among the significant matters of further study.

In its attached report, the Bureau of Sport Fisheries and Wildlife indicates substantial fishery benefits resulting from Boundary and enlarged Gerber Reservoirs. It expresses concern, however, about the effect the potential development would have on the availability of water for the Klamath Refuge system. Since the potential development is based on conserving water that now is lost by non-beneficial seepage and evaporation, or that wastes into the Klamath River, the water supply of the refuges will not be adversely affected. In fact, the supply might be somewhat enhanced by return flows to the refuges being sustained in dry years due to a firm irrigation yield in the upstream areas.

in a new development would require analyses of possible alternative sources of supply, particularly to the extent that water needed for the refuges is not used consumptively and could be salvaged for other project uses, or power. New supplies for the refuges would substantially affect the existing project and would likely require additional channel and outlet pumping capacities. Before refuge enhancement can be included in the new development, it would be necessary for the Bureau of Sport Fisheries and Wildlife to furnish Reclamation with tentative engineering data and criteria concerning the refuge areas to be developed, the types of development anticipated, points of water delivery, and water delivery schedules. Such information would have to be furnished for more than one level of development for plan formulation purposes. This and other aspects of new development could be affected by pending legislation.

Recommendations

1. It is recommended that no further investigations of the Clear Lake Unit be made at this time.
2. It is also recommended that any future studies be made as a combined effort of the Bureau of Sport Fisheries and Wildlife and the Bureau of Reclamation, and that the two agencies share the cost of the studies.
3. Finally, it is recommended that prior to any future studies, the following conditions be met:

BUREAU OF SPORT FISHERIES AND WILDLIFE

RECONNAISSANCE REPORT

AUGUST 1962

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE (1-RB)
1002 N. E. Holladay Street
P. O. Box 3737
Portland 8, Oregon

August 6, 1962

Mr. Hugh P. Dugan, Regional Director
Bureau of Reclamation
P. O. Box 2511
Sacramento, California

Dear Mr. Dugan:

This is a reconnaissance report of the Bureau of Sport Fisheries and Wildlife on effects the proposed Clear Lake unit, Langell Valley division, Klamath project, California and Oregon would have on fish and wildlife resources. It has been prepared in accordance with the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). It supersedes our report of June 13, 1962, relative to this project. Project data were obtained from your office in Klamath Falls, Oregon, prior to April 18, 1962. Biological data were obtained in cooperation with Oregon State Game Commission, and California Department of Fish and Game.

Oregon State Game Commission and California Department of Fish and Game have reviewed, and concur with this report as indicated in the attached copies of letters received from Director P. W. Schneider of Oregon State Game Commission, dated May 23, 1962, and from Director W. T. Shannon, of the California Department of Fish and Game, also dated May 23, 1962.

Clear Lake unit would involve four separate, but related, areas in Upper Klamath basin. These are: Clear Lake Reservoir, located in north-central California; Boundary Reservoir site, located in north-central California and south-central Oregon; Langell Valley; and Gerber Reservoir located in south-central Oregon.

The purpose of the project would be to provide supplemental water to about 18,000 acres of irrigated land in Langell Valley, provide firm water supply for power generation at downstream locations, and to enhance fish habitat and fishing in proposed Boundary Reservoir and Gerber Reservoir.

<u>Clear Lake Reservoir</u>. Clear Lake Reservoir is located approximately 16 air miles southeast of Tulelake, California. The reservoir is within the Executive Order Boundary of Clear Lake National Wildlife Refuge. Clear Lake Reservoir has a maximum surface area of about 25,000 acres, and

Operation of Boundary Reservoir would involve annual releases of 32,000 acre-feet of water during the summer for irrigation in Langell Valley, and a total of 17,000 acre-feet of water during October, November, and December for power generation at existing power developments on Klamath River. Water released for irrigation would be conveyed via Lost River and the existing network of canals in Langell Valley. Water released for power generation would flow to Klamath River via Lost River (40 miles) and Lost River Diversion Canal (8 miles).

Boundary Reservoir would be kept full through the summer as long as water was available for release from Clear Lake Reservoir. However, such releases would usually terminate about the end of September. In the winter, unless Boundary Reservoir was quite low, the outlet gates of Clear Lake Reservoir would remain closed, since Boundary Reservoir would usually fill with flows of tributaries below Clear Lake Dam.

Langell Valley. Langell Valley is located about 25 air miles southeast of Klamath Falls. The valley extends some 15 miles southeasterly from Bonanza, Oregon, to the Oregon-California state line. Principal land use involves production of small grains, alfalfa, improved pasture, and potatoes. Small untillable tracts are scattered throughout this area. Irrigation water for Langell Valley is now obtained from Clear Lake and Gerber Reservoirs.

No development is proposed in Langell Valley with the project, as increased volumes of irrigation water would be conveyed by means of existing canals. No changes in land use in this area are anticipated with the project.

Gerber Reservoir. Gerber Reservoir is located about 30 air miles east of Klamath Falls, Oregon, on Miller Creek. Development of Clear Lake unit would involve construction of a new dam immediately downstream from existing Gerber Dam to increase storage capacity in the reservoir. The dam would be an earthfill structure, 600 feet long and 110 feet high. Maximum reservoir depth would be 80 feet. Reservoir capacity would be increased from 94,000 acre-feet to 200,000 acre-feet with a maximum surface area of 6,300 acres. Average reservoir pool would be 80,000 acre-feet. Data indicate that without the project, Gerber Reservoir will be dry during or at the end of the irrigation season 10 years out of 100. With the project, the reservoir will not be dry because a minimum conservation pool of 1,000 acre-feet will be established.

Increased storage with the project would provide additional irrigation water for Langell Valley lands now served by North Canal. Approximately 35,000 acre-feet would be released annually for this purpose. Water would continue to be routed via Miller Creek to North Canal and distributed to project lands in existing canals.

400 antelope inhabit the refuge and adjacent area. Drainage of the west portion of the reservoir could create a shortage of water for big game. However, with development of livestock watering facilities as planned for this area, the project would not be detrimental to big game. It is possible that vegetation of value to big game would develop on exposed lands.

Upland game of the refuge consists primarily of mourning doves, sage grouse, chukars, and California quails. Approximately 1,000 doves, 300 sage grouse, 200 chukars, and a few quails use the refuge. The project is not expected to affect upland game resources significantly. Water which would be made available for livestock would also sustain existing populations of game birds in the refuge area.

Beavers and raccoons are found in the general area around Clear Lake Reservoir, but populations are low and trapping is not permitted on the refuge. Project development is not expected to have a significant effect on fur animals.

Clear Lake Reservoir provides aquatic and semiaquatic environment for a variety of nongame birds, outstanding of which is the white pelican. About 3,000 pelicans utilize an island in the western portion of the reservoir as a nesting site, and annually produce about 1,000 young. Drainage of the west side of the reservoir would render this nesting area unusable. It is possible that the pelicans would relocate elsewhere in the basin or on islands in the eastern portion of Clear Lake Reservoir. These islands should be reserved for such use.

Clear Lake Reservoir serves as a resting area for waterfowl during the fall and early winter. Principal waterfowl are mallards, pintails, American widgeons, and Canada, snow, and white-fronted geese. An average annual population of about 12,000 geese and 1,300 ducks have been observed on the reservoir during the years 1957 through 1961. The area is used for molting by about 1,000 Canada geese during the summer months. Approximately 400 geese and 200 ducks are produced annually in the area. With the project, production of geese and ducks would be reduced, and some reservoir area used by molting geese would be destroyed.

It is probable, however, that some of these geese would use nearby areas, including Boundary Reservoir for molting.

At present, the Bureau of Reclamations's plan of development for Clear Lake Reservoir has not been finalized. When such plans are completed, we expect to conduct detailed studies in cooperation with California Department of Fish and Game and to provide development plans for wildlife and cost estimates as required.

Gerber Reservoir. Gerber Reservoir is located within the migration route of mule deer comprising the California-Oregon interstate herd. Deer hunting is intensive in the region adjacent to the reservoir. Project features would not significantly affect deer populations.

Principal upland game of the reservoir area is the mourning dove. Populations are low, however, and little hunting occurs. A few sage grouse are found in the area. Proposed project development would inundate upland game habitat including a sage grouse strutting area.

Water fluctuations and shoreline features create unfavorable habitat for fur animals in Gerber Reservoir. Beavers, muskrats, and minks are found in the general vicinity, but they do not regularly enter the reservoir area. The project would not be detrimental to fur animals.

Waterfowl using Gerber Reservoir include mallards and Canada geese. The reservoir is an important resting area for Canada geese. Some hunting occurs within the reservoir site, but hunter effort is low. Development of Clear Lake unit would not be detrimental to waterfowl use or restrict hunting on Gerber Reservoir. Establishment of a minimum pool for conservation of fish and wildlife resources would prevent loss of waterfowl use and hunting value during years of drought when the reservoir would normally be dry.

Conclusion

The Bureau of Sport Fisheries and Wildlife has long recognized the value of maintaining wildlife habitat in Klamath Basin. In April 1956, the Fish and Wildlife Service submitted a report to the Secretary of the Interior entitled "Plan for Wildlife Use of Federal Lands in Upper Klamath Basin." This plan recommended that certain Federal lands of the basin be managed primarily in the interest of wildlife. Our Bureau strongly supports a comprehensive planning approach for development of upper Klamath Basin for wildlife. However, we do not believe that your proposed plans for Clear Lake unit would reduce opportunities for including fish and wildlife in a comprehensive plan for the upper Klamath basin.

Because of the preliminary nature of the studies described in this report, the ceilings in evaporation, transpiration, seepage, and other water losses resulting from the changes in impoundment are not definitely known. Since the project contemplates additional water uses for application, the amount available for use on the Tulelake and Klamath National Wildlife Refuges cannot be definitely determined. However, there is a paramount need for a firm water supply for these important waterfowl areas. We recommend, therefore, that Boundary Dam be designed to provide storage for 18,000 acre-feet of water for delivery to Tulelake Sump. As an auxiliary to Clear Lake unit, we recommend further that 32,000 acre-feet of water be made available for diversion from Klamath River for delivery to Tulelake

THE RESOURCES AGENCY OF CALIFORNIA
DEPARTMENT OF FISH AND GAME
722 Capitol Avenue
Sacramento 14

May 23, 1962

Mr. Paul F. Quick, Regional Director
Bureau of Sports Fisheries
U. S. Fish and Wildlife Service
P. O. Box 3737
Portland 8, Oregon

Dear Mr. Quick:

We have reviewed the Fish and Wildlife Service Reconnaissance Report on Clear Lake Unit, Langell Valley Division, Klamath project, California and Oregon, and generally concur with the findings contained therein.

We suggest, however, that more emphasis be placed on wildlife losses in the report. The Boundary Reservoir site is an important component of the winter range for deer and antelope. The Bureau of Reclamation should be made aware that mitigation of wildlife losses must be accommodated in the development of their proposed project.

Boundary Reservoir should furnish a good sport fishery for warmwater species, as does nearby Gerber Reservoir.

Thank you for the opportunity to review this report.

Sincerely,

/s/ W. T. Shannon

Director

STATE OF OREGON
OREGON STATE GAME COMMISSION
1634 S. W. Alder Street
P. O. Box 4136
Portland 8

May 23, 1962

Regional Director
U. S. Fish and Wildlife Service
Bureau of Sport Fisheries and Wildlife
P. O. Box 3737
Portland 8, Oregon

Dear Sir:

We have reviewed the draft of your letter report to the Bureau of Reclamation concerning the effects that the proposed Clear Lake Unit, Langell Valley Division, Klamath Project, California and Oregon, would have on fish and wildlife resources. We concur with your comments.

It must be understood that our concurrence does not constitute a delegation of responsibility for the manangement of the resources under the jurisdiction of the State of Oregon.

We appreciate this opportunity to review your reconnaissance report in draft form and make these comments upon it.

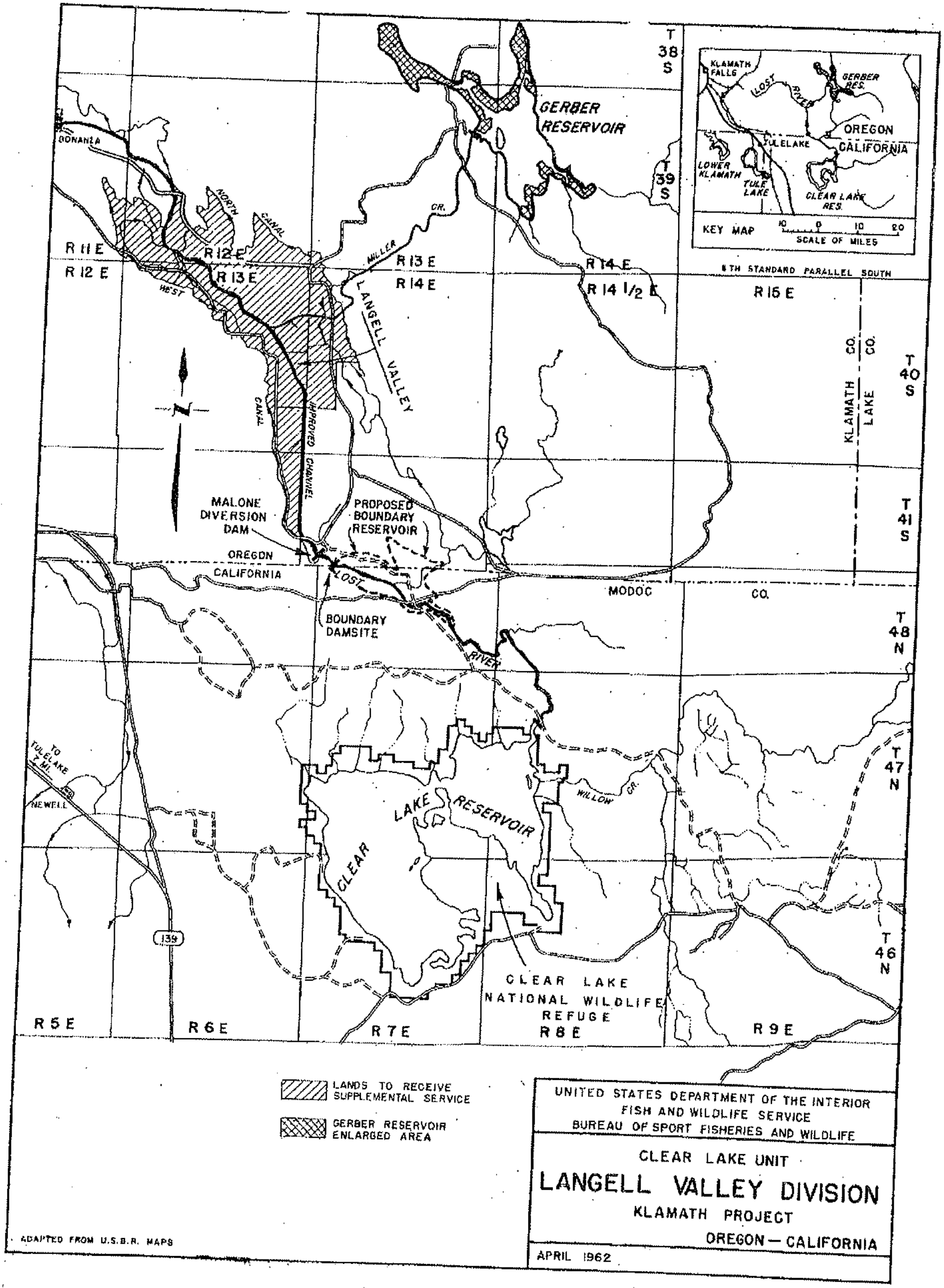
Sincerely yours,

P. W. SCHNEIDER
DIRECTOR

By

Clark Walsh
Assistant Director

cc:
California Dept. of Fish & Game



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KLAMATH FALLS
LOST RIVER
GERBER RES.
OREGON
CALIFORNIA
TULELAKE
LOWER KLAMATH
TULE LAKE
CLEAR LAKE RES.
KEY MAP
SCALE OF MILES
10 0 10 20
GERBER RESERVOIR
BONANZA
NORTH CANAL
WEST CANAL
MILLER CR.
R 11 E
R 12 E
R 12 E
R 13 E
R 13 E
R 14 E
R 14 E
R 14 1/2 E
R 15 E
6TH STANDARD PARALLEL SOUTH
LANGELL VALLEY
IMPROVED CHANNEL
KLAMATH CO.
LAKE CO.
MALONE DIVERSION DAM
PROPOSED BOUNDARY RESERVOIR
OREGON
CALIFORNIA
LOST RIVER
BOUNDARY DAMSITE
MODOC CO.
TO TULELAKE 7 MI.
NEWELL
139
WILLOW CR.
CLEAR LAKE RESERVOIR
CLEAR LAKE NATIONAL WILDLIFE REFUGE
R 5 E
R 6 E
R 7 E
R 8 E
R 9 E
LANDS TO RECEIVE SUPPLEMENTAL SERVICE
GERBER RESERVOIR ENLARGED AREA
UNITED STATES DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
CLEAR LAKE UNIT
LANGELL VALLEY DIVISION
KLAMATH PROJECT
OREGON — CALIFORNIA
APRIL 1962
ADAPTED FROM U.S.B.R. MAPS