A COST BENEFIT ANALYSIS OF THE NIMBUS FISH PASSAGE PROJECT

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A COST BENEFIT ANALYSIS OF THE NIMBUS FISH PASSAGE PROJECT

A Thesis

by

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Abstract

of

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Statement of Problem

The aging, decrepit diversion weir at the Nimbus Hatchery places the American River's Chinook salmon and Steelhead trout at great risk. Due to the weir's state of disrepair, a storm or high river flows could destroy it at any time, causing thousands of fish to miss the entrance to the hatchery and depriving the river of a new generation of fish. The United States Bureau of Reclamation (USBR) recently proposed either replacing the weir or removing it and redesigning the ladder that leads fish to the hatchery.

Methodology

This paper presents the results of a cost benefit to determine whether either proposed fish passage alternative would generate positive public benefit. My analysis uses benefits transfer to apply previously-determined values for fish. I analyzed the costs and benefits across several different scenarios, including a scenario in which recently-proposed salmon passage regulations would change the role of the hatchery.

Conclusions Reached

My analysis showed that the weir replacement or weir removal options could both lead to positive public value, depending upon the circumstances. Because the weir replacement carries higher up-front costs, that option is more tenable when one uses a low discount rate. Conversely, weir removal is the better option with a high discount rate. If the new regulations limit the usefulness of the hatchery, neither option is likely to result in a net benefit.

_______________________________________, Committee Chair

William D. Leach, Ph.D.

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Date

ACKNOWLEDGEMENTS

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Chapter 1

INTRODUCTION

Each October, tens of thousands of Sacramento residents and tourists flock to a small park on the south bank of the American River. They come to observe a definitive local cultural event. Dozens of similar celebrations occur in Northern California – Gilroy boasts of its garlic, Stockton pays tribute to asparagus, and El Dorado County showcases the fruits of Apple Hill. But none of these is quite like the American River Salmon Festival. Bands play, children enjoy puppet shows, and the public rejoices as untold numbers of salmon, exhausted after a grueling journey upstream, swim up a ladder and into a small pool to breed and die.

At least, that is how it usually happens. In recent years, however, worsening environmental conditions have sapped the salmon run; in 2008 only 6,000 salmon made that arduous trek, down from 30,000 to 80,000 in years past. According to USBR personnel, that is still enough adult fish for the hatchery to produce its annual quota of 4,000,000 salmon fry, but the fact that so few adults return to spawn does not bode well for the future of the species (D. Robinson, personal communication, November 2, 2009). The *Sacramento Bee* (Louey, 2008) reported that numbers were so weak that the Nimbus Fish Hatchery, located just downstream of the Nimbus Dam, had to keep its fish ladder closed during the Salmon Festival, thus depriving the gathered crowds of what should have been their main attraction. This year, the picture grew even bleaker. More weak salmon numbers, combined with the struggling economy, have forced the California Department of Fish and Game (DFG) to cancel the event (Locke, September 2, 2009).

The decline of fish in the American River is just like every other water-related policy issue in Northern California in that it pits a multitude of competing interests against each other in what appears to be a zero-sum game. Water, the most important natural resource on Earth, is vital for fish and other wildlife habitat, but people also drink it, grow crops with it and use it for washing and recreation. It remains to be seen whether Northern California's seemingly abundant water supply is sufficient to meet all of those competing needs. In the case of the Nimbus Dam, environmental and commercial interests who favor mitigating habitat loss to Chinook salmon and steelhead trout potentially stand opposed by people who enjoy the recreational opportunities for fishing and kayaking that the dam presents.

Commercial fishers have a significant interest in preserving a strong salmon and steelhead population. Unfortunately, they have also seen the most tangible losses as a result of the species' decline. Last year, they suffered a complete ban on salmon fishing off the coast of Oregon and California. A *National Geographic News* article (Blankinship, April 11, 2008) presented the point of view of many fishers: that the restriction was quite harsh, but also necessary due to the devastating circumstances. Unlike previous restrictions on fishing, the Pacific Marine Fishery Council saw little opposition from commercial fishing interests to its 2008 ban.

In June of 2009, the *Bee* (Weiser, June 5, 2009, p. A1) reported that National Marine Fisheries Service is investigating the feasibility of allowing fish to swim around the Nimbus and Folsom Dams and return to their historic spawning grounds. This move came in response to a lawsuit by environmental groups who argued that salmon and steelhead trout would soon go extinct absent drastic action. NMFS formed a task force to decide on a course of action by 2016 and then implement it by 2020. Here again, environmental interests oppose parties who divert water from the river for other purposes, since the success of the spawning fish would depend upon an increased flow of clean river water. Nobody has yet decided the fate of the hatchery if NMFS chooses to implement this regulation. Theoretically, the rule change could obviate the need for the hatchery, or it could alter its role (D. Robinson, personal communication, December 2, 2009).

THE EXISTING STRUCTURE

The life of a typical Chinook salmon or steelhead trout is, to quote Thomas Hobbes, “nasty, brutish and short.” Both salmon and steelhead are “anadromous” fish, meaning that although they live most of their lives in the salty waters of the ocean, they must swim hundreds of miles up freshwater rivers in order to breed (California Department of Fish and Game [DFG], n.d.). Every year, when water temperatures drop, salmon battle the currents of the Sacramento and American Rivers (as well as numerous smaller streams and tributaries) for hundreds of miles to reach their ancestral spawning grounds. They arrive exhausted, having not eaten during the entire journey. The fish might at least take some relief from the fact that they only have to undertake this torturous trek once, since they die as soon as they spawn.

As far back as a half century ago, Californians and the federal government were concerned over the decline of these previously abundant salmon and steelhead in the American River. When the Bureau of Reclamation built the Folsom Dam and the Nimbus Dam during the 1950s, it threatened to cut off the spawning habitat of the fish, since the dam restricted the fish's movement toward their historic spawning sites, which are up to 100 miles upstream. To alleviate this consequence, Reclamation also constructed the Nimbus Fish Hatchery in 1955 (United States Bureau of Reclamation [USBR], April 30, 2009). Since then, these two species of fish have depended upon the hatchery for their continued livelihood.

Each year, late autumn brings with it cold water and the start of the salmon spawning season. The salmon swim up the American River until they reach a small concrete barrier, known as a "weir," located a quarter mile downstream of the Nimbus Dam. By the time that the water temperature in the American River drops below 60 degrees Fahrenheit (usually in early November), DFG has installed a gate on top of the weir to prevent salmon from swimming past the fish ladder. Instead, they swim up the ladder into a holding pond. Fish can get into this pond, but the structure prevents them from ever leaving. From the holding pond, hatchery employees sort the fish that are ready to spawn from those that are not. Hatchery personnel kill the ones that are ready to spawn and remove the milt (sperm) and roe (eggs) to be mixed together for fertilization. They then raise the resulting offspring in the hatchery facilities for six months to a year (depending on species) before releasing them back into the Sacramento/ San Joaquin River system (DFG, 2009).

Some fish manage to miss the hatchery entirely, and instead swim through gaps in the weir. Those that survive make their way into the “stilling pool,” the area just downstream of the dam where the waters are relatively still. Since these fish will never reach the hatchery, and likely will never spawn, DFG allows recreational fishing in these waters. Every fall, hundreds of anglers cast their lines here in the hopes of catching a few doomed salmon.

THE PROBLEM

More than fifty years after its construction, the aging weir needs repair or replacement. The elements have battered it constantly; for example, heavy water flows during the winter of 1997-1998 caused significant damage to the weir (USBR, April 30, 2009). In its weakened state, thousands of salmon manage to swim past it each fall, where they become trapped between the weir and the dam, with no chance to reach the fish ladder or their spawning grounds. Though these fish are a potential boon for recreational anglers, they are lost to the hatchery’s spawning process. More ominously, the weir’s decrepit state leaves open the possibility that a major flood event could destroy it entirely and put an entire year’s salmon run at risk.

Government policy makers have been planning to give the hatchery a makeover for more than a decade and a half. The Bureau of Reclamation began to develop weir replacement strategies and alternative solutions in the mid 1990s (USBR, April 30, 2009.). Since then, Reclamation and DFG have convened a number of public meetings to solicit stakeholder input, and they have undertaken a preliminary environmental impact analysis. Reclamation and DFG anticipate that they will release the draft Environmental Impact Statement (EIS) and Environmental Impact Report (EIR) in December of 2009, and finalize these reports in 2010. Their schedule calls for implementation of the fish passage project by the summer of 2011, though as yet they have not decided which of the three alternatives they will pursue.

THREE ALTERNATIVES

USBR (2008, p.1) has narrowed the discussion down to three alternatives to confront the weir degradation. The first of the three proposed alternatives is to maintain the status quo and do nothing to the weir or fish ladder. If the Bureau rejects this option, it will either remove the weir and modify the fishway by extending the fish ladder to the base of Nimbus Dam, or it will replace the weir with a new, stronger weir. Appendix A shows arial photos of the hatchery area annotated to show the impact of the two action alternatives.

Status Quo Option

If the Bureau chooses to maintain the status quo, they will leave the diversion weir in place and make no renovations to the fishway. The hatchery will continue to install the weir gate every September and open the fish ladder every November (Bureau of Reclamation, 2008, p. 2).

The chief advantage of this option, of course, is that it would not require any construction costs up front. It could, however, end up costing Reclamation money if further damage to the weir necessitated greater maintenance and repair costs down the road. In years of heavy river flow, the weir will continue to sustain damage, which will further impair its effectiveness. A major flood could cripple the weir and necessitate its replacement, and could potentially cause the hatchery to close for an entire season, jeopardizing the salmon and steelhead populations (Bureau of Reclamation Alternatives, 2008, p. 2).

Modified Fishway Option

Reclamation may instead choose to modify the fishway and create a new passageway from the basin below the dam to the Nimbus Hatchery. This passageway would consist of a gently sloping concrete channel at the base of Nimbus Dam, from which the fish could swim to the hatchery. A year or two after the completion of the passageway, Reclamation would completely remove the diversion weir, along with the foundation and piers in place to support the weir. Reclamation would likely also redistribute the rock at the bottom of the river to improve spawning habitat (p. 3). A possibly controversial provision of this alternative is that it would also force DFG to choose one of three plans to restrict fishing in the area, ranging from a simple seasonal restriction on fishing within 250 yards of the fish ladder to an outright year-long ban on fishing within a quarter mile of the dam.

This project would require two to three years of construction work. In addition to the cost of materials and labor, construction would infringe on the ability of the public to enjoy the recreational benefits of the area. Construction equipment would block off more than a third of the hatchery's 170 parking spaces, and construction vehicles would need to drive across the roads and bike trails, thus temporarily closing off the area to bikers and joggers (p. 4). The ban on fishing would also presumably entail costs in lost recreational utility.

Weir Replacement Option

This option calls for Reclamation to construct a new and much larger weir (750 feet as opposed to the existing 326 foot structure) an improved fish ladder, and six bypass bays to divert river flows in the event of future weir maintenance (p. 6). The weir that Reclamation has proposed building would be much sturdier than the existing one – capable of surviving water flows of up to 160,000 cubic feet per second. Thus, under this alternative, the weir would not be as likely to need repairs in the event of a flood.

This alternative would require two consecutive years of construction during the summer months. As with the previous alternative, the construction would temporarily infringe upon the public's ability to enjoy the hatchery's recreational benefits, though the fishing restrictions proposed with this alternative are significantly less severe.

OVERVIEW OF THIS ANALYSIS

The purpose of this analysis is to answer the following questions:

- Would improving the hatchery result in positive public value?
- Which of the two proposed action alternatives would provide the most public value?

I will address these questions by conducting a cost-benefit analysis of these alternatives.

Over the course of the next four chapters, I use the technique of cost-benefit analysis to examine the feasibility of these alternatives. In Chapter Two, I discuss some existing academic literature that is relevant to this case, including some major works on the general theory of cost-benefit analysis, techniques used to define the value of nonmarket goods (in this case, the value of salmon and steelhead trout continuing to exist, aside from their value for fishing), and an examination of similar cost-benefit analyses. In Chapter Three, I present the methodology by which I conduct the analysis, and remark upon the assumptions and unusual techniques that I employ. Chapter Four contains the results of my analysis, including ranges of values for most favorable and least favorable circumstances. Finally, in Chapter Five, I present my conclusions, discuss the circumstances under which I drew those conclusions, issue policy recommendations, and recommend research strategies for other parties who might be interested in policy questions about fish preservation or hatchery construction in Northern California.

Chapter 2

LITERATURE REVIEW

Over the next several pages, I shall provide an overview of some of the existing academic and government literature that bears relevance to a cost-benefit analysis of the Nimbus Hatchery improvement project. Since cost-benefit analysis has become a very commonplace method of analysis, many examples exist in the literature that can offer insight into this project. Of particular interest are cases where researchers have conducted analyses of government-sponsored projects that impact recreation, natural resources and the local environment, and cases where researchers have attempted to attach a dollar value to natural resources with nonmarket uses, such as salmon and steelhead. Though previous researchers have come to widely divergent conclusions in their studies, an analysis of this literature reveals three key themes that pertain directly to the Nimbus project. First, previous water-improvement studies and government recommendations for economic analysis provide useful guidelines on a range of relevant issues including how to identify which costs and benefits to consider, which segments of the population deserve standing in an analysis, and what constitutes an appropriate discount rate. Second, while there is no clear agreement among previous studies as to the proper nonmarket value for a salmon or steelhead trout, it is at least possible to identify a reasonable range of valuation. And finally, using the technique of benefits transfer to value such resources, while controversial, is a common practice that saves time and resources while still yielding valid results if done correctly.

SIMILAR COST BENEFIT ANALYSES

It is logical to begin by reviewing the approaches used in similar cost-benefit analyses. While the academic literature is not rife with examples of cost-benefit analyses conducted on weir replacement at salmon hatcheries, there is a plethora of cost-benefit analysis pertaining to other types of river improvements and fish habitat restoration. Furthermore, the Bureau of Reclamation and the Environmental Protection Agency, among other agencies, have issued guidelines for researchers who wish to conduct cost-benefit analyses of river improvements and other environmental projects. In addition to these guidelines, the literature also offers perspective on appropriate discount rates and the scope of the population that deserves to have standing in an analysis, though by no means do the sources agree on the specifics.

Recommendations from Bureau of Reclamation

Reclamation recently issued a document (Platt, 2003) containing recommendations about and a blueprint for researchers who wish to conduct cost-benefit analyses of dam removals. Though the case of the Nimbus Hatchery is not a dam removal, it does bear some similarities, in that the removal of the weir would have some effects analogous to the removal of a much larger structure. Platt notes that potential costs of dam removal include direct costs such as construction, which does apply in this case, but also indirect costs incurred by damage to agricultural land, erratic effects on flood control and changes to water rights, which would not seem to apply. The possible benefits of dam removal are better aligned with the weir removal: increase in the quality of wildlife habitat, better site sustainability, lower maintenance costs and, most pointedly, increased productivity of local fisheries (p. 21). Obviously, the scope of these benefits as they pertain to the weir removal will be quite different from a dam removal, but they all represent important factors to consider.

Discount Rates

There is some disagreement in the existing literature as to what discount rate is appropriate in an environmental cost-benefit analysis. Platt notes that 5.875% was the established guideline from the Office of Management and Budget at the time of his writing in 2003, though he also states that analysts should also include a range of values (2003, p. 16). However, this guideline is far from standard. A blueprint for environmental cost-benefit analyses prepared by the United States Environmental Protection Agency (EPA, 2000) offers advice on discount rates but stops short of a clear recommendation. The discount rates discussed in this publication are significantly lower than Platt's OMB benchmark. One strategy mentioned by the EPA document is to peg the discount rate to returns offered by stable investments including Treasury securities, which yields a discount rate of around 1% to 3% (p. 60). In a cost-benefit analysis of salmon hatcheries and enhancement programs in Alaska, Boyce, et. al (1993) base their analysis on a 0%

discount rate, though they do also introduce a 4% and a 7% rate in a sensitivity analysis (p. 6). Dubgaard, et. al. (2002) use 3%, 5% and 7% in their cost-benefit analysis of a Danish river restoration project (p. 11). As is apparent, there is wide variation in the discount rates recommended and used by these studies. The only constant is that all either use or recommend a sensitivity analysis of discount rates, in which a range of values should be used.

Scope of Standing

The scope of the analysis varies as much as the discount rate from study to study, as there is no ostensible agreement as to which segment of the population deserves to have standing in a given cost-benefit analysis. Fuguitt and Wilcox (1999) contend that anyone who benefits from or incurs costs from a policy should have standing. However, they go on to note that in practice this isn't always done. At the very least, they recommend, the researcher should identify any possible spillovers that may result to people not granted standing (p. 54). Previous studies show that other researchers do not necessarily adopt Fuguitt and Wilcox's wide definition of standing. Platt's overview (2003) is geared toward researchers who intend to conduct analyses with a national scope (p. 11). Dubgaard's analysis of the Skjern River restoration expands the scope even further, granting standing to the entire European Union (2002, p. 10). In the case of Boyce's Alaska study, however, standing applies only to residents of Alaska , and effects on the population of the rest of the United States do not count in the final analysis (1993,

p. 6). Despite this variation, there does appear to be a pattern in that the scope of the population that merits standing is correlated to the government entity that funds the project or site under evaluation. For example, Platt's aims his recommendations toward projects pertaining to federally owned dams (2003, p. 11), so it is appropriate to consider the entire U.S. population in an analysis, while the Alaska salmon programs studied by Boyce all receive funding from the state of Alaska (1993, p. 2)

VALUATION OF SALMON AND STEELHEAD

Numerous studies exist in which researchers have estimated values for Chinook salmon and steelhead trout. As with discount rates, the only constant here is that there is a wide range of values in the existing literature, even though a salmon or a steelhead might seem at first glance to be a tangible good that should not yield much variation in value from location to location.

The existing literature contains a multitude of attempts by researchers to place a dollar value on the nonmarket uses of fish. The most common methods to do this are the Contingent Valuation Method (CVM), in which researchers conduct a survey and ask respondents to state how much money they would be willing to pay for a resource or how much they would accept in compensation for its loss, and the Travel Cost Method (TCM), in which researchers calculate the dollar value of the time and money that travelers are willing to spend in order to obtain access to a resource. Both methods share the same objective—estimating the "willingness to pay" (WTP) of individual members of society, and then summing this WTP across all members of society with standing.

Loomis and White (1996) conduct a meta-analysis of previous studies that values threatened and endangered species using these two methods. Interestingly, they note that in contingent valuation surveys, respondents are most often asked their willingness to pay for a resource rather than their willingness to accept compensation for its loss because the former scenario is more easily understood by taxpayers accustomed to paying sums of money for specific goods and services (p. 2). Loomis and White's average of previous studies finds that residents of the Pacific Northwest would be willing to pay an annual sum of between $31 and $88 in extra fees tied to their electric bills in order to see a 100% increase in the population of Chinook salmon and steelhead trout in that region, with an average of $63 annually (p. 3).

The majority of studies that attempt to discover the noncommercial values do so by tracking recreational fishers' willingness to pay for a fishing trip, rather than for an individual fish. For example, Cameron and James (1987) use a very large survey of 4,161 recreational fishers in British Columbia, Canada for their salmon valuation study (p. 18). By applying a closed-ended CVM, in which they asked respondents whether they would pay specific dollar amounts for salmon, Cameron and James conclude that catching an extra Chinook salmon adds $13.10 (in 1987 Canadian Dollars) to a recreational fisher's willingness to pay for a fishing trip.

A bit more recently, Layman, Boyce & Criddle (1996) estimate that an average consumer reaps between $16.99 and $60.80 in consumer surplus for each day spent fishing for Alaskan Chinook salmon. If the government were to double the legal harvest limit, then the surplus would rise to between $21.89 and $77.74 per day (p. 124). They base these results on a survey of 343 sport fishers conducted by the Alaska Department of Fish and Game. Using these results, they applied the Hypothetical Travel Cost Method, a blend of CVM and TCM in which respondents are asked to estimate how much they would be willing to pay for a hypothetical fishing trip, given different levels of fish abundance and harvest limits.

Studies that express value in terms of a dollar amount per fish, as opposed to the value of a fishing trip or the value of an arbitrary population increase, are somewhat less common. However, in a lengthy study conducted for the Bureau of Reclamation, Platt (2008) analyzed previously existing research to calculate values for both fishing trips and individual fish. He obtained a value for each individual fish by multiplying the average number of days it takes a fisher to catch a salmon by the fisher's willingness to pay for a day of fishing (p. 23). Under this method, Platt concluded that a Chinook salmon is worth $101.49 for an ocean sport fisher (p. 34) and $340.02 for freshwater fishers in the Columbia River Sport Fishing Section (p. 40). It is relevant for our purposes because the publication date is recent. Also, it is a Bureau of Reclamation study, and Bureau of Reclamation is the entity that will be conducting the weir replacement or repair. However, a limitation of this method of valuation is that it only takes into account the value of fish to people who fish. It does not encompass the option value or the existence value of salmon for people who do not fish. Additionally, the dollar figure Platt calculated seems to be an outlier, since it is much higher than the figures calculated by the other researchers.

Table 1 below shows the wide range of variation among salmon valuation studies. As is apparent below, there is a significant range of not only results, but also survey methodologies and sample sizes.

Table 1: Salmon Valuation Studies

Study (Year)	**Geographical Area and Focus**	**Methodology**	**Sample Size**	**Valuation**
Layman, Boyce & Criddle (1996)	Sport fishing value of Chinook salmon in Alaska	"Hypothetical Travel Cost Method"	343 anglers	One day of salmon fishing yields between $16.99 and $60.80 of consumer surplus
Cameron & James (1986)	Recreational fishing in British Columbia	Closed-ended contingent valuation	4161 recreational fishermen	Catching an additional Chinook salmon increases a fisher's WTP by $13.10.
Loomis & White (1996)	Value of endangered species in United States	Meta-Analysis of contingent valuation studies	N/A	Annual WTP for 100% increase in salmon and trout population averages $63.
Platt (2008)	Lower Columbia River Sport Fishing Section	Calculations based on existing contingent valuation data	N/A	Catching a Chinook salmon yields $340.02 in value to a recreational angler.
Layton, Brown & Plummer (1999)	Valuation of changes in Washington state fish populations	Stated Preference Method	1611 households	A 300,000 increase in salmon population would yield a $114.48

				annual WTP per household.

As with most economic goods, the nonmarket use of salmon experiences diminishing marginal returns as the quantity of salmon increases. Thus, respondents will be willing to pay more per fish for a relatively small population increase than they will for a large increase, even though the total willingness to pay for the large increase will be greater. To account for this in a study sponsored by the Army Corps of Engineers, Loomis (1999) constructed an equation that estimates the total nonuse value of fish that would accrue to the 12.6 million households in the Pacific Northwest and California.

Ln(nonuse value of fish) = 25.357-1.37315(Ln(number of salmon))

Under the data presented by Loomis, for example, a population of 10,000 salmon yields a marginal willingness to pay of $331,196, while a population of 500,000 salmon yields a marginal willingness to pay of $1,539. These figures represent the economic value of non-harvest uses of a single salmon, aggregated across all households with standing.

This study appears to be more useful than others for two reasons. First, it calculates the value per fish, which provides flexibility in calculating the value of fish populations of various sizes. Second, it accounts not just for a fish’s value to an angler, but its entire nonuse value.

BENEFITS TRANSFER

Though researchers vary widely in their choice of discount rates and the values they assign to nonmarket goods, as noted above, perhaps no area of cost-benefit analysis generates as much disagreement as the concept of benefits transfer. Benefits transfer refers to the practice of using values for nonmarket goods that have been calculated by previous researchers in cost-benefit analyses. This practice earns the ire of critics who believe that transferred values are unreliable and sometimes even illogical. However, the literature also reveals that this practice is very widespread because it offers significant advantages to researchers who lack the time and/or resources to conduct a widespread contingent valuation survey.

Shortcomings of Benefits Transfer

Numerous policy makers and researchers have pointed out flaws inherent in the practice of benefits transfer. Pearce (1998) argues that benefits transfer can be a very risky approach to valuation of environmental goods, and that no researcher should adopt it without serious consideration. As evidence, Pearce presents a case study of a British water company that used benefits transfer to provide nonmarket valuation of a river site that it had proposed to drain. When citizens complained to the government agency that oversees energy, the government ordered the company to alter its valuation by 98% (p. 95), suggesting the original valuation was untenable on technical grounds or political grounds or both.

In a meta-analysis of existing benefits transfer studies, Bergstrom and DeCivita (1999) point out many potential sources of error inherent in benefits transfer: inaccurate measurements, use of values pertaining to different population characteristics, misinterpretation of the level of welfare change at the study site, incorrect estimation procedures and judgment errors, among others (p. 80). Despite these myriad sources of error, Bergstrom and DeCivita conclude that government regulations promoting cost-benefit analysis, combined with the often prohibitive cost of conducting primary valuation studies, will cause benefits transfer to steadily increase in popularity (p. 85).

Arguments in Favor

As such, benefits transfer remains a very common practice in modern cost-benefit analysis. Champ, Boyle & Brown (2003) note that the practice dates back at least to 1973, when the United States Water Resources Council released a listing of standardized values for recreational activities. Other government agencies, including the Forest Service, began to follow suit, and by the early 1990s benefits transfer had become a standard practice (p. 446). The U.S. EPA (2000) also notes that benefits transfer has become more commonplace, and enumerates some of its key advantages, chiefly that it significantly reduces the time and cost required to conduct an economic study, but also that it is possible for the researcher to pick and choose from existing studies and select one which has been done well (p. 86). There is some empirical evidence that benefits transfer can work. For example, in an experiment comparing residents' stated value preferences regarding two water improvement projects in Spain, Colombo, Calatrava, and Hawley (2007) concluded that a value transfer using data from the first site would have yielded valid results for the second (p. 148).

Several sources agree that researchers can take steps to make benefits transfer more accurate, and improve the likelihood that the values obtained are correct. Champ, Boyle & Brown (2003, p. 449) argue that one can compensate for benefits transfer's shortcomings by conducting a sensitivity analysis and including a range of valuations. Brouwer and Spaninks (1999) argue that a researcher can improve the validity of a benefits transfer result by accounting for factors that could influence the preferences of people at the study site, such as socio-economic levels and people's attitudes, though a true measure of attitudes would likely require the type of primary research that benefits transfer seeks to obviate in the first place (p. 113).

SUMMARY

Previous literature illuminates the path to a useful cost-benefit analysis for the Nimbus Hatchery Fish Passage project. Though many of the studies cited pertain to projects that are different on the surface, the points they raise deserve consideration here. For example, it is important to consider a range of discount rates and a range of values for nonmarket commodities. Also, it is wise to be cautious in applying the benefits transfer approach, and to take safeguards against an inaccurate result.

Chapter 3

METHODOLOGY

This study seeks to determine whether either of the two proposed improvements to the Nimbus Fish Hatchery would increase public value, and if so, by how much. For clarification on the concept of public value, I turn to Mark Moore (1995). Moore spells out the concept of public value, the idea that public servants should pursue policies that improve life for the public, and holds that creating positive public value should be the goal of any public servant. In order to meet this criterion, a public decision maker must develop policies for which the results yield a total benefit to the public that is greater than the cost to implement the policy plus any restraints on liberty that result from that implementation (p. 27).

COST BENEFIT ANALYSIS

I chose cost benefit analysis because it is the most straightforward method of determining whether or not one of the proposed projects will create public value. Though the concept of public value is more abstract than the monetary values that cost-benefit assigns as measures, cost-benefit analysis seems to be tailor-made for measuring public value. As Fuguitt and Wilcox (1999) explain, cost benefit analysis consists of an enumeration of all policy's consequences and a comparison of the total social costs and the total social benefits that those consequences represent (p. 156). Analysts quantify these costs and benefits in order to make such a comparison possible. Under the rubric established by a cost-benefit analysis, a policy is worthwhile if the total social benefits are greater than the total social costs. Thus, a policy that yields a positive result in a cost-benefit analysis would appear to create positive public value for its constituents.

Though cost-benefit analysis is a useful measure of a project's potential to create public value, it is important to note that a cost-benefit result cannot in itself determine whether a project is worthwhile. Cost-benefit is, above all, a measure of economic efficiency. While efficiency is a noble goal and a good measure of effectiveness, it is by no means the only such goal or measure. Efficiency may oftentimes be at odds with other potential policy goals, such as equitable distribution of benefits to society, sustainability, or preservation of natural resources and the rights of nonhuman beings (Fuguitt and Wilcox, 1999, p. 38 – 41). A decision maker should carefully consider those other paradigms in addition to the results of a cost-benefit analysis.

FACTORS TO CONSIDER

As noted above, a thorough cost-benefit analysis should consider all costs and all benefits that an analyst reasonably expects to occur because of a project, including those that one cannot feasibly quantify in monetary terms. In addition, it is important to consider the scope of those costs and benefits, both in terms of the time period upon which they will occur, and the number of people whom they will affect. I intend the discussion in this section to be a generic overview of factors that any researcher could consider as he or she approached an analysis of any improvements to any fish hatchery. In the next chapter, I narrow the discussion to a specific analysis of the numbers as they pertain to Nimbus Hatchery's Fish Passage Project.

Costs and Benefits

Construction costs are the most direct, and likely most expensive, costs to society for a public hatchery improvement project. One must consider the scope of the costs as well as the period in which construction occurs. Society will also likely incur additional, less tangible costs because of construction. Large equipment will emit loud noises, stir up dust and dirt, and possibly block local vehicle or pedestrian traffic. The exact cost of this to society is probably difficult to ascertain, but one should at least acknowledge its existence. After construction is finished, the fish passage structure is likely to continue to cost money for maintenance and operations. These costs need to be itemized and included in the analysis on an annual basis.

Additional costs may come in the form of lost recreational opportunities. A change to the structure of the hatchery or the equipment in a river may preclude boating, swimming, or fishing. This will result in a cost to society, as it will force people to forego the activities they love. An analysis must consider these factors.

Since the purpose of a fish hatchery is to spawn fish, the most tangible benefits of a hatchery project are likely to come in the form of fish produced or saved. This is true in the case of a hatchery like Nimbus, which was designed to mitigate the effects on fish populations caused by blocking off their ancient habitat, as well as for other hatcheries that may be designed to augment or increase fish populations. Fish provide many benefits to the public. First and most obvious are the commercial boons fish bring to the economy. Commercial anglers catch fish and sell them in markets and grocery stores for human consumption. Additionally, fish provide recreational benefits to recreational anglers. These anglers may or may not be willing to pay $5 to $15 a pound for a salmon in a grocery store, but they derive value on a different level when they spend their leisure time casting fishing lines into their favorite rivers, lakes, and seas. Finally, there are passive use values: benefits that fish bring to members of the public who do not fish or even eat fish. For example, a citizen may not fish, but he or she may derive option value from the knowledge that he or she could fish if he or she chose to do so. In addition, that same citizen probably gleans some existence value from knowing that the local rivers and nearby seas teem with fish that constitute an important part of a healthy ecosystem.

Though fish are the most prominent benefit of a hatchery project, such an undertaking is likely to yield other benefits as well. If the project can lower the annual cost of maintenance to the structure, that is one benefit that must go into an analysis. Also, though hatchery construction may place a damper on recreational opportunities such as boating and fishing, as mentioned above, it is also possible that a hatchery facility could enhance these opportunities.

Timing and Present Values

Not all of the costs and benefits of a given policy will occur at the same time. Often, a project yields no social benefits until years after its completion, while the costs of construction may occur immediately. Conversely, the same project may continue to yield benefits for years into the future, long after the initial implementation costs have been paid. Money saved or paid out in the future is actually worth less than an equal face value of money saved in the present, both because of inflation and because of opportunity cost. Therefore, it is necessary to apply a discount rate to all benefits and costs that do not occur up front. More to the point, one should use a range of discount rates in order to preclude accusations that the results do not adequately consider the value of future gains and losses. As mentioned before, Platt (2003, p. 16) recommended 5.875% as a discount rate for government projects. As a real discount rate, however, this is a bit high. Thus, it is important to calculate a cost benefit anlaysis with several lower values as well. Additionally, one should include the results of a 0% discount rate to show what the results are when one considers future costs and gains to be equal to those incurred in the present day.

One must also keep in mind that while the benefits of a project are not likely to persist indefinitely, they may do so far into the future. The time horizon for the project being analyzed is important. As Fuguitt and Wilcox note, after a period of 60 to 75 years, normal discount rates effectively nullify all future costs and benefits (1999, p. 161). Therefore, it makes little sense to consider a time horizon that is much longer. In the case of a hatchery, it is prudent to use the expected life span of the equipment under construction as a guideline. For example, the weir currently in place at the Nimbus Hatchery is just over 50 years old, though it has experienced some degradation in recent years. Therefore, 50 years is a reasonable period of time upon which to consider the benefits of a weir replacement.

Scope of Society

Ideally, a cost-benefit analysis should consider the effects of a policy on all people in a society affected by that policy. “People” is a key word in that sentence – animals and natural environments do not merit standing as part of society, and their well-being does not affect the result, except for the extent to which their well-being affects human well-being. But all human beings who pay taxes that support a project, live within the jurisdiction affected by the project, or stand to lose some degree of well-being because of it, incur costs and deserve standing in an analysis. Likewise, all humans who make use of goods or services created by a policy deserve standing in an analysis.

METHODS OF VALUATION

Unfortunately, many variables that one must consider in a cost-benefit analysis are not measurable through market transactions alone. For example, a family may enjoy walking or biking at a public park. If there is no admission fee to the park, it is very difficult to quantify how much enjoyment that family receives from a trip to the park in any tangible way. However, the fact remains that they obtain value from the park, and any policies that change the park would result in the family incurring costs or benefits. Therefore, in order to assess the true costs and benefits of a project, one must rely upon alternative methods to value nonmarket goods. In the case of the Nimbus Hatchery project, such goods include the continued existence of threatened fish species and opportunities for recreational boating and fishing.

Contingent Valuation

Contingent valuation is a common method of assigning a value to a good that is not bought and sold in the marketplace. A researcher applies this technique by conducting a survey of people affected by a hypothetical policy change and asks them about their willingness to pay for a nonmarket good, or willingness to accept compensation for its loss. For example, a researcher might ask a hunter how much more money he or she would be willing to pay in taxes in order to guarantee that the forest in which he or she hunts would remain pristine and full of wildlife. The researcher then uses the responses to the survey to estimate a value for the previously unvalued good. It is important to note that contingent valuation is not without controversy. As Platt (2008, p. 19) notes, some economists shy away from using contingent valuation because the data is yields are completely hypothetical, and not based on any actual consumer behavior. In many cases, however, contingent valuation is the only way to accommodate for variables that are immeasurable merely through observed market behavior.

Benefits Transfer

The contingent valuation method solves one problem – valuation of nonmarket benefits and costs – but it creates another by requiring a considerable investment of time and resources. It is difficult and time consuming to conduct a valid survey to gauge affected residents' preferences with any degree of accuracy.

If one does not have the time or resources to conduct such a survey, benefits transfer might be the answer. Using this approach, a researcher takes values for a commodity obtained for another study and transfers them to the matter at hand. It is dangerous, however, to copy a dollar amount for a different study. There may be issues with the methodology under which used to derive the value, or the site from which it was drawn may be different. For instance, Seattle residents may be willing to pay a certain dollar amount for a 1,000 increase in fish populations in the Columbia River, but San Francisco residents would have entirely different opinions about the value of a proposed 50,000 increase in the Sacramento River. To skirt these pitfalls, I recommend using an equation derived from multiple observations, such as the one Loomis (1999) created. This equation is based upon several valuation studies of salmon populations in California and the Pacific Northwest, and it takes into account the magnitude of the fish population increase or decrease, thus avoiding some of the problems inherent in benefits transfer.

DATA SOURCES

I obtained my data from several different sources: USBR and DFG documents pertaining to the fish passage project, and personal communications with DFG and USBR personnel.

I spoke over the phone with David Robinson (personal communication, November 2, 2009), USBR's project manager for the fish passage project. Mr. Robinson provided me with technical background information about the logistics of the project, and pointed me in the right direction to find construction cost data. I also had an e-mail communication with Mike Brown (November 3, 2009), a research scientist for DFG. Mr. Brown graciously provided the angler survey data that I used to calculate the net cost of a fishing ban if the project goes through. The other crucial data in this analysis, the populations of fish that return to the hatchery every year, came from two documents issued by DFG: the Hatchery and Genetic Management Plan:
American River Fall-Run Chinook Salmon Program (2007), and the Hatchery and Genetic Management Plan: Nimbus Fish Hatchery Winter Run Steelhead Program (2007).

Chapter 4

RESULTS

As with any public works project, the Nimbus Fish Passage Project potentially engenders numerous costs beyond the obvious costs of construction and numerous benefits beyond the project's primary goals. Many of these costs are nebulous, and difficult to factor in an analysis of this scope. For example, it would be difficult to monetize exactly what effect the hatchery construction would have on recreational bicyclists, who might be slightly and temporarily inconvenienced by construction vehicles driving over the nearby American River Bike Trail. It is possible, however, to come up with reasonable figures for many of the other costs and benefits associated with this project. This chapter presents an enumeration of those costs and then demonstrates how those costs and benefits compare to each other under several different conditions.

POTENTIAL COSTS

The up-front cost of construction is the largest and most direct cost of the fish passage project, but it is certainly not the only one. Potential costs of the fish passage include:

- Construction Costs
- Loss of fishing opportunities

- Intangible inconveniences and pollution resulting from construction

Construction Costs

According to USBR's estimates, construction for the replacement weir option would cost $9.5 million. The construction would take place over two years, to be completed in 2012. Removing the weir and extending the fish ladder to the base of the dam would cost a much lower amount: $4.7 million. This option would take slightly longer to complete, with construction taking place over three years, to be completed in 2013 (United States Bureau of Reclamation [USBR], 2006, p. 16). Unfortunately, I was unable to obtain a year-by-year breakdown of when USBR would need to pay these costs. This would have a slight effect on the results of the analysis, since the net present value of costs paid in 2012 is a bit lower than that of those paid in 2013. For this analysis, I have considered the construction costs as if they were paid in 2011, the proposed year of construction for both options.

Another cost to consider is the dampening effect that the Fish Passage project would have on fishing. The weir replacement option would not affect fishing in the area between the weir and the dam. Essentially, nothing would change with regard to fishing because fish that managed to swim past the weir would still be considered lost to the process. However, under the weir removal option, all fish in the area would have the potential to swim up to the ladder, and DFG would impose a fishing ban to prevent local anglers from catching salmon before they could reach the ladder. The table below shows the number of salmon harvested by anglers between the weir and Nimbus Dam from 1991 through 2007 for each year the angler survey data were available.

Table 2: Angler Survey Data

Year	**Salmon Harvested**
1991	11,640
1992	5,211
1993	16,411
1994	4,850
1998	12,562
1999	14,787
2000	5,828
2001	304
2002	11,231
2007	974
Average	8,380

Source: (M. Brown, personal communication, November 2, 2009)

As is evident from these data, the total fish caught varies widely from year to year. The 2007 number was very small due to a miniscule salmon run, and the run shrank further in 2008, causing DFG to temporarily ban fishing in the area (M. Brown, DFG, personal communication, November, 3, 2009).

Taking the numbers at face value, though, the fishing ban would result in an average loss of 8,380 fish each year for recreational fishing. Of the values listed in Chapter 2, Cameron and James's number appears the most valid. Their data are based upon a large sample size of Chinook Salmon fishermen, the survey asked specific, closed-ended questions about willingness to pay per fish, and the result of the study is not out of line with other observed values. Their fish valuation figures, adjusted for inflation, come out to $18.58 per fish. Thus, the fishing ban that accompanies the weir removal option would decrease recreational anglers' welfare by $155,700.40.

Intangible Inconveniences and Pollution Resulting from Construction

The construction would likely inflict several inconveniences on visitors to the parkway in which the hatchery is located. A bicycle trail follows the length of the American river from downtown Sacramento to the suburban city of Folsom, and it passes the hatchery along the way. During the course of construction, it is likely that construction vehicles would need to drive across the trail, which would cause a mild inconvenience to bikers and hikers who use the trail. Construction vehicles and related activities would temporarily generate unknown amounts of air, water, and noise pollution.

POTENTIAL BENEFITS

Since the main goal of this project is to prevent a catastrophic weir failure, the two alternatives would yield benefits by preventing the loss of potential spawning fish. Thus, the chief benefits of the fish passage project are less tangible than the costs, but still potentially quite large. Potential benefits of the fish passage improvements include:

- Elimination of the risk of a catastrophic weir failure
- Increased opportunity for recreational boating (if weir is removed)
- Lowered cost of maintenance and operation for weir

USBR estimates that the current weir is weakened to the point that it would fail in the event that water flow exceeded 50,000 cubic feet per second (D. Robinson, personal communication, November 2, 2009). Historically, this happens about every 10 years, though it has been a dozen years since the last occurrence. Thus, in any given year there is about a 10% chance that the heavy water flow would destroy the weir to the point that the Nimbus Hatchery would lose an entire salmon run, and the resulting offspring. For the sake of thoroughness, I have also considered the problem with only a 5% chance of weir destruction, since Hatchery personnel might be able to perform emergency maintenance if a catastrophic event appeared imminent. According the USBR's species management plans for the Nimbus Hatchery, about .64% of Chinook salmon and 1.15% of steelhead from a given breeding class return to the hatchery as adults (2007, p. 22). Thus, if the hatchery raises 4,000,000 fall-run salmon and 400,000 steelhead annually, this should yield an average of 30,200 adult fish, including 25,600 Chinook salmon and

4,600 steelhead trout that return to the hatchery each year. The data for returning fish are listed in Appendix B.

I have chosen to use the valuation equation that Loomis (March, 1999) created for the Army Corps of Engineers, as discussed in Chapter II:

$$\text{Ln (nonuse value of fish)} = 25.357 - 1.37315(\text{Ln (number of salmon)})$$

Using this equation, the marginal value for the 30,200th fish comes out to $72,577.65. This number probably may appear at first glance to be high; it is in fact reasonable because it represents the value of a fish to all of society, defined as all 12.6 million households in the Pacific Northwest and California. Since this is a calculation of passive use value, the resource (fish) is not depleted by each member of society who gains utility from it. Thus, fish can have some value to every household in the region, and that value adds up quickly. Also, the marginal value of a fish drops as the population increases; thus, the 30,200th fish is much more valuable than the 100,000th fish. Since the population here is relatively small, each individual fish is quite valuable to society. Though Loomis's study looked chiefly at Chinook salmon, I have also applied this figure to steelhead trout. This is done partly for reasons of convenience; contingent valuation data for steelhead were far scarcer than for salmon. Also, the steelhead represent a far smaller proportion of the total anadromous fish population served by the hatchery than do the salmon. Using the numbers calculated by Loomis, the 30,200 adult fish that return to the river because of the weir yield a net public benefit of $10,600,000, or $13,750,000 when adjusted to 2009 dollars.

Operations and maintenance costs should be considered another major benefit of both fish passage project alternatives, as opposed to a cost since both are expected to reduce ongoing costs. Unfortunately, it was not possible as of the time of this writing to obtain an accurate accounting of the annual maintenance and operations costs for the weir currently in place. The data for operations and maintenance costs of the proposed alternatives are likewise unavailable, and will not be released for several months (D. Robinson, personal communication, November 2, 2009). Thus, instead of a straightforward cost-benefit analysis that includes these costs, I have calculated the switching value for these figures. That is, I calculated the annual operations cost that would cause the net present value of each alternative to switch from positive to negative net benefits.

MULTIPLE SCENARIOS

The time horizon of this analysis is not a cut and dry concept. While it would normally be prudent to consider the total costs and benefits over the entire life of the new weir or the hatchery, a possible regulatory change discussed by National Marine Fisheries Service alters the picture. NMFS's potential rule change would require the government to provide safe passage for anadromous fish to their historical spawning grounds dozens of miles upstream from the Nimbus and Folsom dams by 2020. As of the current date, nobody say for certain what effect this regulation would have on the hatchery. It is possible that the Hatchery could serve as a collection point for workers to transport fish around the dam or as a means to supplement the naturally-spawned fish populations. It is also possible that the hatchery could become obsolete. Due to this uncertainty, I conducted the analysis using two different periods: a 50 year period (roughly equivalent to a reasonable life-span for a weir), and a nine year period that ends at the year 2020. The nine year period assumes that the hatchery will generate no benefits after that year due to the new regulations. This is meant as a lower bound estimate, a sort of worst-case scenario for the hatchery.

In addition to the dual periods, I have presented multiple scenarios for two other variables: the likelihood of weir failure and the discount rate. Though my base scenario assumes a 10% chance that the weir would fail in any given year unless USBR replaces or removes it, I have also calculated the expected value of the costs and benefits for the project assuming the chance of failure is only five percent. Likewise, I have used several different discount rates, ranging from 0% to 5.875%.

Results

While I have allowed for variation in several key variables, the dual time frame is the most significant factor. Thus, I shall present the results of my analysis under two different headings: one with the longer period, and one with the shorter one.

Longer Time Frame

The longer period allows more benefits to accrue, and thus both alternatives generally yield positive net benefits. The base scenario assumes that there is a 10% chance of catastrophic weir destruction every year if no action is taken. I have listed the numerical results in Appendix C. Under this scenario, the weir removal option generates a net benefit of $11,502,000 with a high discount rate of 5.875%. That number rises to $53,359,000 with a discount rate of 0%. The weir replacement alternative yields a net benefit of only $10,633,000 at the 5.875% discount rate, but the benefits skyrocket to $57,875,000 with a 0% rate, which is a higher net benefit than the weir removal alternative. The weir replacement option, which carries a larger up-front cost and a greater net annual benefit (due to its lack of restrictions on fishing), is the preferred option at lower discount rates, while weir removal is better for higher rates. The two options are nearly equivalent at the 3% discount rate: weir removal generates $23,190,000 in net benefit, while weir replacement generates $23,829,000. Either option should reduce annual maintenance costs. I have not calculated the switching value for these costs under the base scenario, since they would only raise the total benefit by an unknown amount, and they would not change the fact that these options produce positive net social benefit.

The same patterns hold if we assume only a 5% chance of weir failure, though with lower net benefits. Again, weir replacement is the better option with a 0% discount rate ($24,188,000 of net benefit vs. $20,359,000). Again, weir removal is the better option at a higher discount rate. At the 5.875% level, weir replacement results in a social benefit of $830,000 and weir removal generates a benefit of $2,278,000. These benefit numbers are obviously much lower, but even if weir destruction is less of a concern, the hatchery projects will generate positive value over a 50 year time frame.

Shorter Time Frame

Over the short period, assuming a robust 10% chance of weir failure, the picture is less clear because benefits have much less time to accrue. Under these conditions, the weir removal alternative is a better option than weir replacement for every discount rate considered. At the 5.875% rate, weir removal nets $904,000 of benefit while replacement results in a net cost of $1,318,000. Weir removal hits the red ink at the 3% level as well (net cost of $125,000), but becomes positive at the lower rates. With a 0% rate, replacement yields a benefit of $1,500,000 versus a benefit of $3,368,000 for removal. In summary, building a new weir does not make economic sense if NMFS regulations would terminate its operational life after only nine years.

Reduced maintenance costs may be a mitigating factor here for weir replacement. For weir removal with a 5.875% discount rate, one needs to assume about $237,000 per year in reduced costs in order to consider this option a net benefit. At a 3% discount rate, the switching value is a much lower $19,000 in reduced costs annually. Since weir removal gives us a net benefit at every discount rate here, it is again not necessary to calculate the switching value for operations costs there.

When one assumes both a low (5%) chance of weir failure and a short (nine year) time frame, both alternatives appear much less tenable. Without factoring in reduced maintenance costs, weir removal results in a net cost of between $1,445,000 and $2,344,000, depending on the discount rate. Weir replacement has a net cost between $4,000,000 and $5,145,000. Both of these options would require major savings on maintenance and operations to break even. For example, at the 5.875% level weir replacement needs to save USBR $924,000 per year in order to be a net benefit. Weir removal requires a lower, but still substantial, cost savings to break even: $497,000 at the 5.875% rate.

Chapter 5

CONCLUSION

In this final chapter, I provide a normative description of what the results of this analysis mean for the viability of the two Nimbus Fish Passage alternatives. I then discuss some other criteria that USBR may use in making an ultimate decision about the project some of the issues inherent in this analysis. Finally, I present some suggestions to others who may be interested in contributing to the discussion of this and other similar policy matters in the hopes that they may further enrich the policy discussion.

CONCLUSIONS DRAWN FROM THIS ANALYSIS

The bottom line in this analysis is that either alternative could be viable from a cost-benefit standpoint, depending upon the results of external events and normative criteria to be determined by decision-makers. If NMFS's regulation makes the hatchery obsolete, or if one assumes a fairly high chance of weir destruction in the absence of action, then both options seem positive. Which option is best depends upon one's view of the future. If the hatchery becomes unnecessary, and if one assumes the weir has only a one in 20 chance of failing in any given year, then neither option is likely to result in positive net public benefit over the short term, since access to ancient spawning grounds would eliminate the need for the hatchery.

Both proposed alternatives would generate positive public value, even when one does not consider the probable reduction in operations and maintenance costs, as long as the NMFS does not enact regulations to return salmon to their traditional upstream spawning grounds and obviate the hatchery. In the absence of access to those spawning grounds, the hatchery would continue to serve as the primary method of mitigating losses to the salmon and steelhead populations, and the passage project would continue to generate annual benefits far into the future. Any additional savings from lowered maintenance costs would only add to the total public benefit.

Removing the weir and constructing the fish bypass would be the best option, as long as one assumes a high discount rate (meaning that benefits in the present are highly preferred to benefits in the future). With a lower discount rate, it makes more sense to replace the weir and continue to allow fishing. For a 3% discount rate, the two options generate net benefits that are very similar. If one option would actually save a significantly larger amount of money in maintenance and operations, then that might tip the scales in its favor. Essentially, though, this becomes a question of how much society values immediate gain versus how much it values future gain. Removing the weir and extending the fish ladder would be the preferred option for those who place a high value on immediate costs and benefits. Conversely, replacing the weir should be the preferred option of those who think that it is more important to consider the future, assuming that the weir will be around far into the future. In reality, budget constraints could also affect the decision. Since the weir removal option has a much lower initial cost, it would make sense for a cash-strapped government agency to choose this option.

The future, of course, is one of the great unknowns in this analysis. In the event that NMFS does order a restoration of traditional spawning territory starting in 2020, and the nature of these regulations stifles the hatchery's operational capacity, the fish passage project would generate benefits for less than a decade. Unless the projects save the government a considerable amount of money in annual maintenance costs, to the tune of hundreds of thousands of dollars per year, it may not be beneficial to undertake any of the proposed hatchery improvements with such a short span of benefits. That said, assuming that USBR still decides to proceed with hatchery improvements, the weir removal is the clear-cut best option here. At every discount rate, weir removal results in a much lower net cost than weir replacement, and at a low discount rate it may even provide some benefit, depending upon the actual chance of weir failure. Again, however, operations and maintenance costs could prove decisive. If weir replacement resulted in maintenance costs that were several hundred thousand dollars per year lower than weir removal, the opposite might be true.

COST-BENEFIT AS A BASIS FOR DECISION MAKING

I must note that cold calculation of costs and benefits was not the primary impetus that drove DFG and USBR to consider replacing the weir. USBR's departmental policies, especially in regards to threatened fish species, have essentially forced their hand in this matter (D. Robinson, personal communication, November 2, 2009). They decided to act because they feel the need to do everything in their power to preserve these beleaguered species. The fact that the total social benefits of such an undertaking might outweigh the costs is incidental.

I would not argue that USBR's decision-making techniques are invalid. Even though this analysis did find that the weir replacement or removal projects fail to provide a net benefit under several sets of circumstances, one needs to recognize that cost-benefit analysis should never be the only criterion used to make a policy decision. Cost-benefit analysis is at best a tool to be used in a policy discussion. It is a useful tool because it helps organize and compare priorities and show how resources can be allocated, but one of many tools nonetheless.

POSSIBLE LIMITATIONS OF THIS ANALYSIS

Another reason not to rely entirely upon cost-benefit analysis to make policy decisions is the fact that even the most meticulous cost-benefit analysis is an incomplete accounting of all the factors potentially at play. I know that this analysis is no exception. There were several difficult intangibles in this equation, including the precise value of the fish that hatchery improvements would spare and the maintenance savings of the projects.

Though I believe that the conclusions I drew are sound, this analysis did suffer somewhat from great uncertainty in the valuation of salmon and steelhead. Unfortunately, non-market valuation of a fish is a nebulous concept that has vastly different meanings to each individual. Thus, the existing studies provided values that were all over the map, as shown in Chapter II. Loomis's equation seems to be a good solution to this problem, in that it bridges the gap between multiple, divergent study results and accounts for variations in fish population. However, even this equation might show some bias due to the values gleaned from studies upon which it is based. It is impossible to determine how much a fish is worth with complete certainty. But the numbers generated by Loomis's equation are at least based upon empirical evidence from contingent valuation surveys, and thus provide an answer to a difficult question.

Fish valuation problems haunt the analysis of fishing as well. I used Cameron and James's value for salmon caught by anglers because their value seemed reasonable in light of the other available data. However, some values obtained by other studies are starkly different. For example, Platt's study yielded a value of $340 per fish. If one multiplies this value by the 8,380 fish caught every year, then the total value of those fish would be nearly $3 million. If I had used that value instead of Cameron and James's number, the fishing ban alone would have prevented the weir removal option from ever generating a positive net benefit. Thus, the uncertain value of a fish makes the picture even less clear.

Again, the lack of precise maintenance cost figures were a roadblock that this analysis was not truly able to overcome. In the absence of these numbers, I was not able to determine with complete certainty whether weir removal or replacement provide positive public value. However, the framework of the analysis should enable one to make a decision when those numbers are available, presumably after a few months time. The switching values that I have provided will at least allow one to decide on sight whether those cost savings bring the total net benefits for any given scenario above the level of the total costs.

OPPORTUNITIES FOR FURTHER RESEARCH

As mentioned before, the weir removal would open up increased possibilities for recreational kayakers and other boaters. Unfortunately, the current weir structure prohibits boating between the weir and the dam because the weir poses a significant safety hazard to small craft. Though interested parties proposed constructing a recreational kayaking course as part of the fish passage project, USBR does not appear to be moving forward with that option. However, it would be interesting to see if such a project would be worth the cost, since it could provide significant benefits for recreational boaters, and even open up the possibility of attracting national and international competitions to the American River. A future researcher might be interested in conducting a survey of local boating enthusiasts to determine whether removing the weir would draw more boaters to the river, or whether it would divert them from practicing their craft in other nearby locales. Another study, or another question in the same survey, could evaluate how much interest a world-class kayaking course would draw. By applying contingent valuation techniques and looking at the costs to build such a course, one might be able to declare whether a kayaking course would be beneficial.

Another researcher with more time and resources might improve his or her results by conducting a contingent valuation survey to obtain a more locally-specific estimate of a fish's nonmarket valuation. The data used in the Loomis study were collected from several different localities in the Pacific Northwest, but none of the studies used was for American river salmon and steelhead. A local survey could shore up this shortcoming. Ideally, this survey would go out to several hundred residents in the area near the Nimbus Hatchery, and it would contain questions designed to assess residents' willingness to pay to prevent the destruction of an entire year's worth of fall-run Chinook salmon and/or steelhead trout. It may also be useful to find the willingness to pay per fish. The survey should specifically state that it seeks the total value of the fish, including recreational and option value and not just its value for commercial or recreational fishing purposes. Not only would this be one way to hone the accuracy of this cost-benefit analysis; it would also help guide future decisions regarding fish species and water issues in Northern California – two topics that always carry their fair share of controversy.

It is entirely possible that the Nimbus Hatchery project could become moot in just over a decade, which is why both scenarios probably fail to generate positive benefits over the short time horizon. If the National Marine Fisheries Service determines that the current system is unsustainable, or if environmental groups' lawsuits prevail, USBR might be forced to provide anadromous fish with safe passage to their historical spawning grounds, dozens of miles upstream of the Nimbus and Folsom Dams, most likely by building another fish ladder around the dam or constructing a bypass or elevator for the fish. This would obviate or at least significantly reduce the role of the Nimbus Hatchery in preserving these fish. However, this strategy would certainly entail great costs of its own. Thus, an interested researcher would do well to consider conducting a cost-benefit analysis of the different strategies to bring anadromous fish back to their spawning territory. As with USBR's decision on the Nimbus projects, NMFS will likely consider many factors other than cost-benefit analysis before they make their decision on this matter. But such an analysis would help interested parties gain an understanding of the matter at hand.

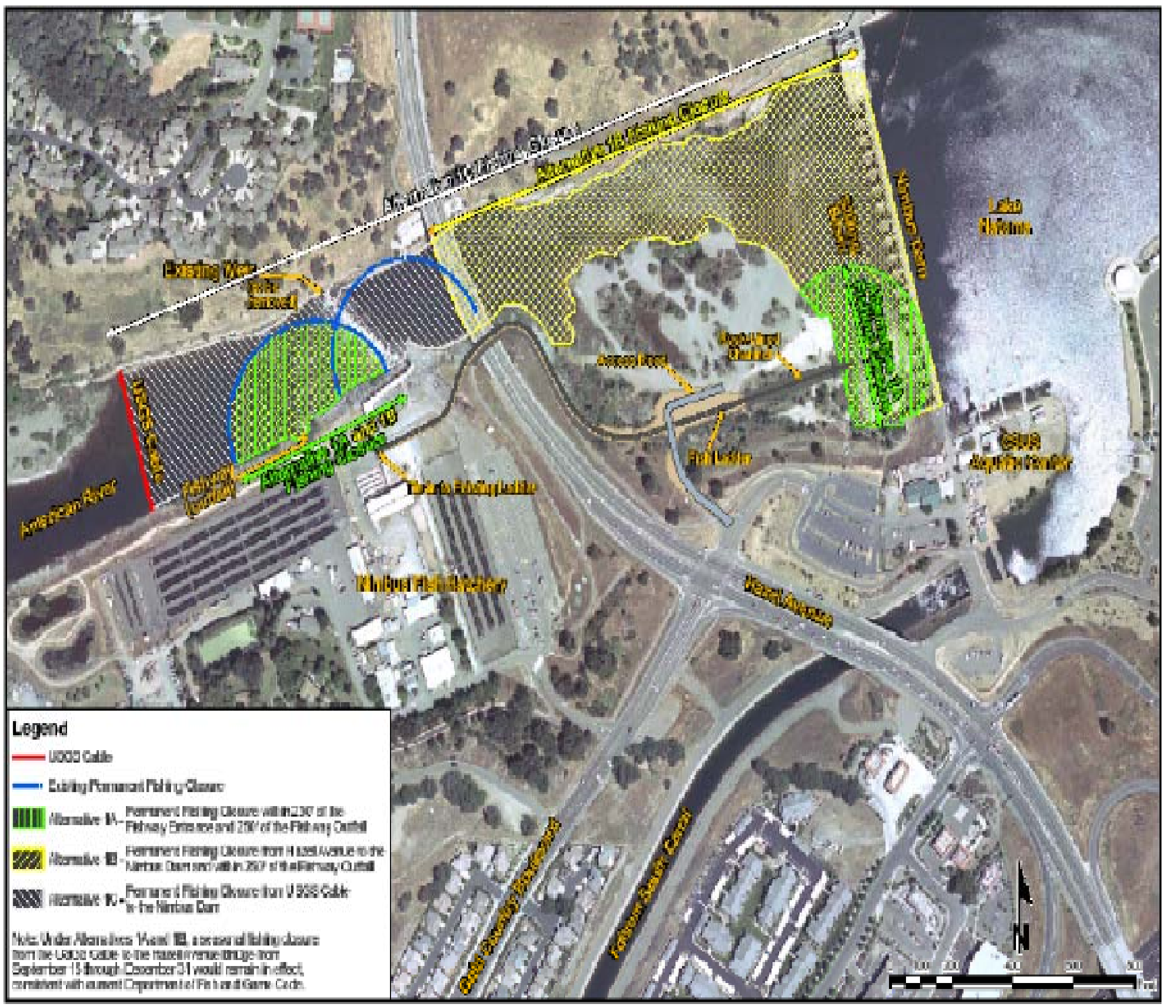
CLOSING WORDS

The proposed Nimbus Fish Passage Project must be considered in a larger context. USBR should do its best to anticipate NMFS's regulatory approach before it makes an ultimate decision on whether to implement one of its proposed alternatives. If USBR absolutely needs to choose one of the two alternatives, regardless of NMFS's decision, it should probably remove the weir and extend the fish ladder, since this option carries a much lower initial cost, and thus can recoup a larger percentage of its costs over a short time frame. Hopefully, the techniques outlined in this analysis, as well as the suggestions to other interested parties, can at least provide a partial road map for understanding issues involving endangered fish species in Northern California. These issues are likely to persist in the years ahead.

APPENDIX A

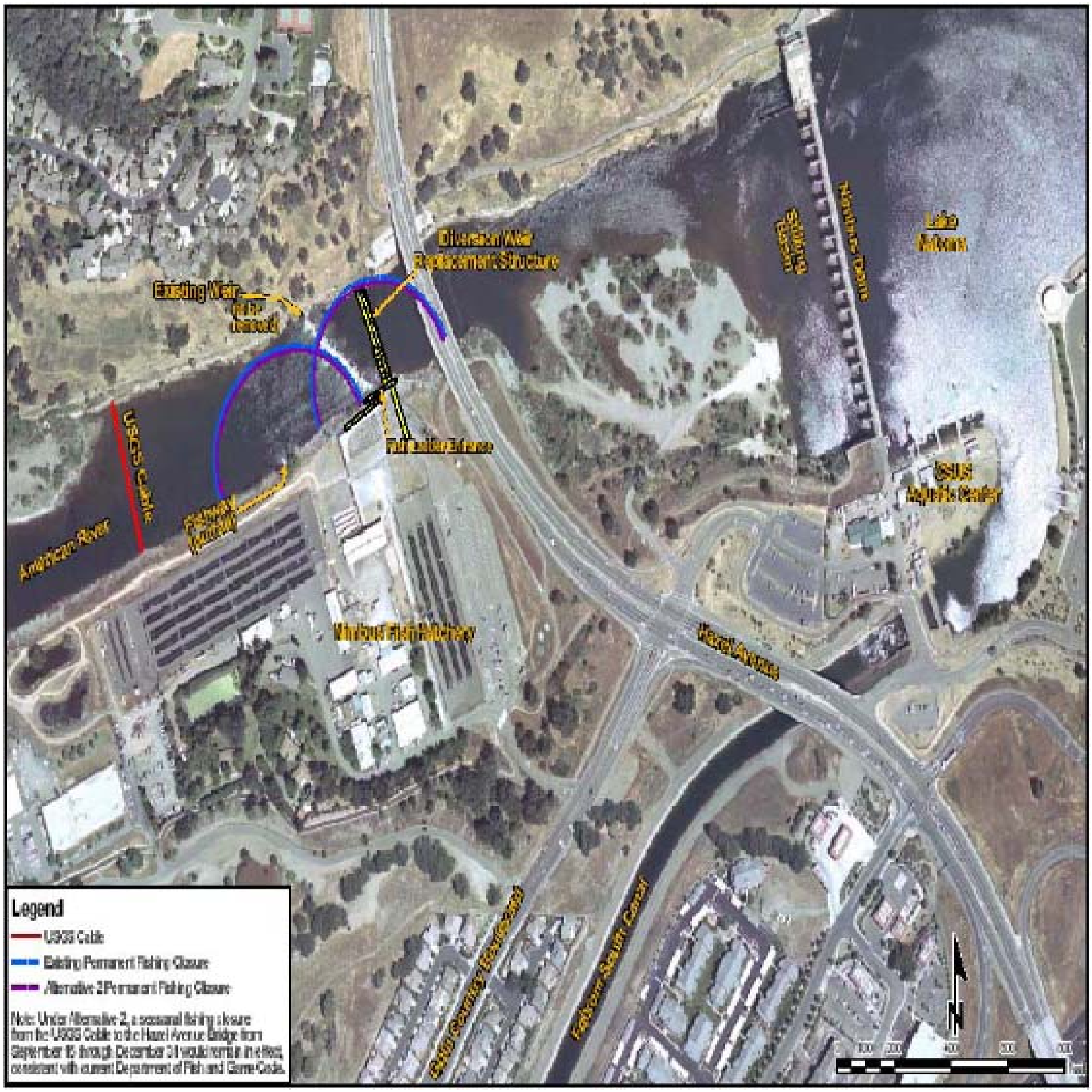
MAPS OF PROPOSED HATCHERY PROJECTS

Alternative 1: Weir Removal and Extended Fish Ladder



Source: USBR, April 30, 2009, p. 37

Alternative 2: Weir Replacement



Source: USBR, April 30, 2009, P. 38

APPENDIX B

NUMBER OF FISH RETURNING TO HATCHERY PER YEAR

i. Fall-Run Chinook Salmon

Table 1-1. Estimated survival rates of Nimbus Fish Hatchery fall-run Chinook salmon for 1994 – 2002 Brood years.

Brood Year	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003			
Release year	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004			
Grilse return year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006			
Adult return year (3 years post release)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Totals [2]		
Number of fingerlings released	8,430,523	4,083,701	4,663,756	1,253,570	0	0	4,131,750	3,475,650	0	3,944,400	17,469,126	(2,998,335)	
Number of smolts released	1,891,600	4,030,450	3,718,500	4,021,864	4,598,208	3,851,700	0	576,000	3,367,000	634,000	20,767,272	(2,668,932)	
Total juvenile Chinook salmon released	10,322,123	8,114,151	8,382,256	5,275,434	4,598,208	3,851,700	4,131,750	4,051,650	3,367,000	4,578,400	38,236,398	(5,667,267)	
Total estimated number of adults spawning in-river	17,900	25,031	14,347	17,078	6,708	25,200	9,000	4,472	11,200	n/a	130,936	(14,548)	3
Total number of adults returning to hatchery	10,369	12,890	9,226	9,230	4,024	19,942	7,439	5,107	12,703	n/a	90,930	(10,103)	3
Total number of grilse returning to hatchery	2,866	744	744	3,442	511	826	9,331	1,771	1,349	1,638	21,584	(2,398)	3
Total number of salmon returning	31,135	38,665	24,317	29,750	11,243	45,968	25,770	11,350	25,252	1,638	243,450	(27,050)	3
Estimated survival rate [1]	0.30%	0.48%	0.29%	0.56%	0.24%	1.19%	0.62%	0.28%	0.75%	incomplete	0.64%	(0.52%)	3

1 Estimated survival includes contribution of naturally-produced Chinook salmon.
2 Number in parenthesis is mean.
3 Total does not include 2007 grilse and adult return numbers.

Source: Lee, D. & Chilton, J, November 30, 2007, p. 22

ii. Steelhead Trout

Adult Spawning Year	2002-03	2003-04	2004-05	2005-06	2006-07	
Yearling steelhead brood year	**1999**	**2000**	**2001**	**2002**	**2003**	**Means**
Number of yearlings released	402,300	460,000	280,160	419,140	455,140	403,348
Estimated number of naturally produced steelhead in river spawning populations 1/	6	3	2	9	7	5
Estimated number of NFH steelhead in natural spawning population 1/	294	340	328	257	293	303
Total estimated in-river adult steelhead spawning population	300	343	330	266	300	308
Total number of hatchery produced steelhead trapped	3,499	3,637	3,645	3,354	2,615	3,350
Total number of naturally produced steelhead trapped	69	27	17	118	58	58
Total number of steelhead trapped	3,568	3,664	3,662	3,472	2,673	3,408
Estimated in-river steelhead run	3,868	4,007	3,992	3,738	2,973	3,716
Total estimated NFH steelhead harvest 2/	774	801	798	748	595	743
Total estimated NFH produced in-river steelhead	4,642	4,808	4,790	4,486	3,568	4,459
Percent return	1.15%	1.05%	1.71%	1.07%	0.78%	1.15%

1/ Assumes same ratio of hatchery and naturally produced steelhead trapped

2/ Assumes 20% arbitrary harvest rate

3/ Number of marked adult/number of yearling fish release 2 years prior

Source: Lee, D. & Chilton, J, December, 2007, p. 22

APPENDIX C

RESULTS OF COST-BENEFIT ANALYSIS

Fifty Year Time Frame and 10% Chance of Destruction of Existing Weir

Weir Removal	2011	2012	2013	2014	2015	2016	2017	2018	Per Year
Total Costs	4855.7[i]	155.7[ii]	155.7	155.7	155.7	155.7	155.7	155.7	155.7
Total Benefits	0	0	0	1,375[iii]	1,375	1,375	1,375	1,375	1,375
Difference	-4,856	-156	-156	1,219	1,219	1,219	1,219	1,219	1,219

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	11,502	23,190	39,829	53,359

Weir Replacement	2011	2012	2013	2014	2015	2016	2017	2018	Per Year
Total Costs	9500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Benefits	0	0	1,375	1,375	1,375	1,375	1,375	1,375	1,375
Difference	-9,500	0	1,375	1,375	1,375	1,375	1,375	1,375	1,375

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	10,633	23,829	42,607	57,875

All figures are in thousands of dollars.

Notes

[i] $4.7 million construction cost plus $0.1557 million cost to recreational fishing

[ii] $0.1557 million annual cost to recreational fishing

[iii] $1.375 million annual expected value of nonuse benefits from hatchery-reared salmon returning to the river as adults

Fifty Year Time Frame and 5% Chance of Destruction of Existing Weir

Weir Removal	2011	2012	2013	2014	2015	2016	2017	2018	Per Year
Total Costs	4855.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7
Total Benefits	0	0	0	688[i]	688	688	688	688	688
Difference	-4,856	-156	-156	532	532	532	532	532	532

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	2,278	7,293	14,489	20,359

Weir Replacement	2011	2012	2013	2014	2015	2016	2017	2018	Per Year
Total Costs	9500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Benefits	0	0	688	688	688	688	688	688	688
Difference	-9,500	0	688	688	688	688	688	688	688

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	830	7,303	16,601	24,188

All figures are in thousands of dollars.

Notes

[i] $0.688 million annual expected value of nonuse benefits from hatchery-reared salmon returning to the river as adults

Ten Year Time Frame and 10% Chance of Destruction of Existing Weir

Weir Removal	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Costs	4,855.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7
Total Benefits	0	0	0	1,375	1,375	1,375	1,375	1,375	1,375	1,375
Net Benefit	-4,856	-156	-156	1,219	1,219	1,219	1,219	1,219	1,219	1,219

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	904	1,948	2,851	3,368

Weir Replacement	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Costs	9,500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Benefits	0	0	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375
Net Benefit	-9,500	0	1,375	1,375	1,375	1,375	1,375	1,375	1,375	1,375

Discount Rates	5.875% -	3.000% -	1.000% -	0.000% -
NPV	-1,318	-125	908	1,500

All figures are in thousands of dollars.

Ten Year Time Frame and 5% Chance of Destruction of Existing Weir

Weir Removal	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Costs	4,855.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7	155.7
Total Benefits	0	0	0	688	688	688	688	688	688	688
Net Benefit	-4,856	-156	-156	532	532	532	532	532	532	532

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	-2,344	-1,971	-1,639	-1,445

Weir Replacement	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Costs	9,500.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Benefits	0	0	688	688	688	688	688	688	688	688
Net Benefit	-9,500	0	688	688	688	688	688	688	688	688

Discount Rates	5.875%	3.000%	1.000%	0.000%
NPV	-5,145	-4,674	-4,249	-4,000

All figures are in thousands of dollars.

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