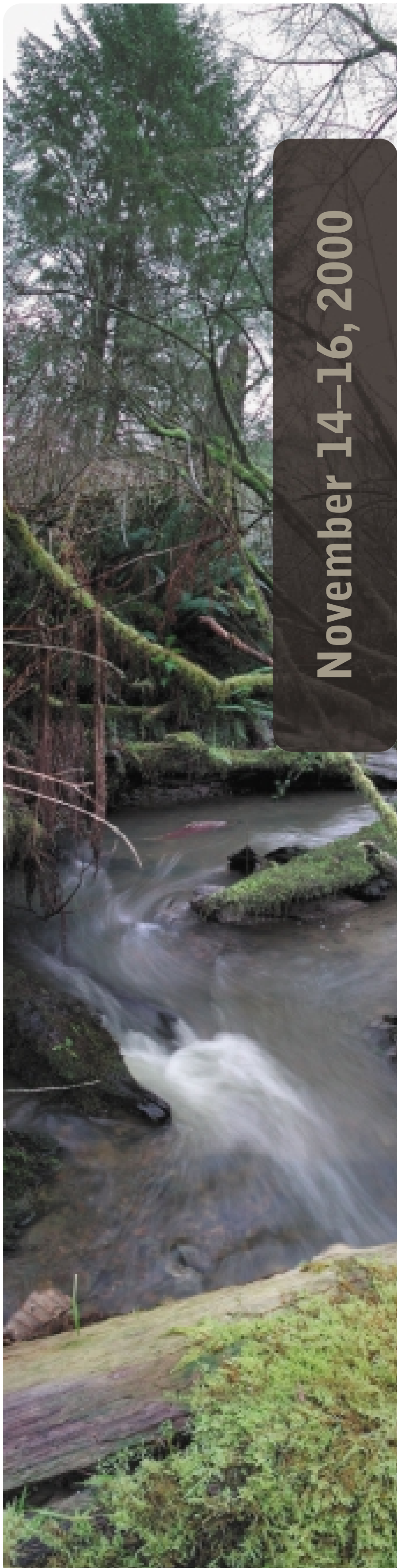
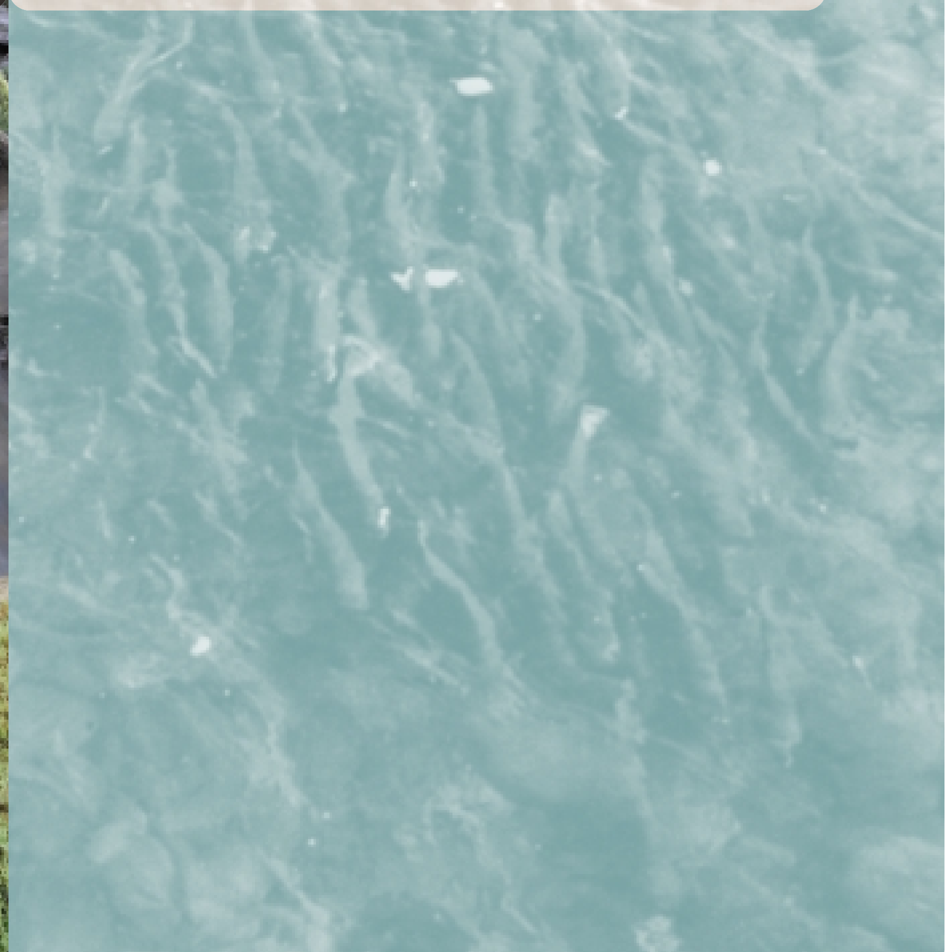


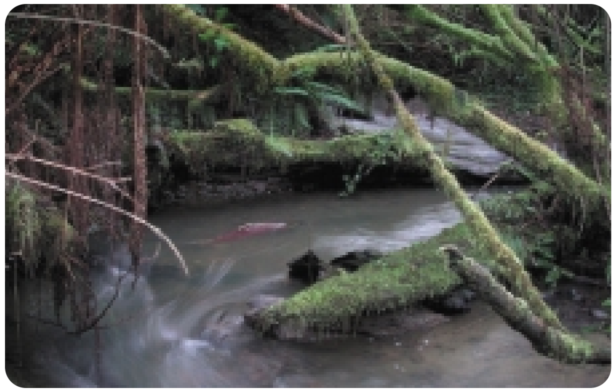
November 14–16, 2000

Proceedings of the

Salmon Habitat Restoration Cost Workshop

Oxford Suites Hotel
Gladstone, Oregon





Workshop Sponsors

NMFS, Protected Resources Division, Silver Springs, MD

NMFS, Southwest Fisheries Science Center, Santa Cruz, CA

NMFS, Northwest Region, Seattle, WA

Workshop Coordinators

Cindy Thomson, National Marine Fisheries Service

Stan Allen, Pacific States Marine Fisheries Commission

Wes Silverthorne, National Marine Fisheries Service

Workshop Staff

Robin Carlson, Pacific States Marine Fisheries Commission

Kathy Shimojima, Pacific States Marine Fisheries Commission

Jill Kelly and Michelle Boedeker, Transcription Assistance

Proceedings of the Salmon Habitat Restoration Cost Workshop

Stan T. Allen, Editor

Cindy Thomson, Co-Editor

Robin Carlson, Co-Editor

Published by

Pacific States Marine Fisheries Commission

205 SE Spokane Street, Suite 100

Portland, Oregon 97202-6413

Tel: (503) 595-3100 Fax: (503) 595-3232

March 2004

graphic design: Jeff Bright, www.jeffbrightdesign.com

spawning coho salmon photos: Thomas Dunklin, www.thomasbdunklin.com

In Memoriam

Patricia M. “Pat” Obradovich

20 May 1958 – 14 June 2002

Pat Obradovich joined the U.S. Army Corps of Engineers as an economist with the Portland District in May 1981. During her two decades of public service, she served as Chief of Economics, Acting Chief of Planning and Outreach Coordinator. She played a leadership role in formulating policy on projects ranging from salmon and ecosystem restoration to navigation projects along the Oregon coast and Columbia River. As a representative of the Corps, she established exceptional rapport with other agencies and environmental groups. She received 26 awards in the course of her career, including an Achievement Medal for Civilian Service. She is remembered by family, friends and colleagues as a person of great integrity, intelligence and humanity. We were honored to have her participate in the Workshop.

Table of **Contents**

Table of Contents

Order of Proceedings

I. Introduction

II. Sessions

OPENING: Potential uses and applications of habitat restoration cost information

SESSION ONE: Conceptual framework(s) for cost analysis

SESSION TWO: Road maintenance, road decommissioning, and stream crossing upgrades

Order of Proceedings

SESSION THREE: Streambank stabilization, streambank fencing, nuisance species control, and riparian zone management

- **Stream Restoration Cost Estimates**
  Brian Bair, US Forest Service, Cook, WA

- **Stream Habitat Restoration Cost Considerations**
  Mark Cocke, Natural Resource Conservation Service, Davis, CA

- **The Costs of Restoring Anadromous Fish Habitat: Results of a Survey from California**
  Steve Hampton, CDFG Oil Spill Prevention Response Program, Sacramento, CA

SESSION FOUR: Instream treatment (e.g., woody debris, rootwads, boulders, side channels, pools, spawning gravel, nutrient augmentation), conversion to non-structural flood control (e.g., meander zones)

- **Instream Structures, Applications, Costs, and Methods**
  Craig Bell, Salmonid Restoration Fed & Trout Unlimited N Coast Coho Project, Gualala, CA

- **Overview and History of Instream and Floodplain Restoration in Western Oregon on Private Lands**
  Mark Lacy, Oregon Department of Fish and Wildlife, Corvallis, OR

- **Costs of Restoration Work in an** Urban Environment
  Kathryn Neal, King County Dept of Natural Resources, Seattle, WA

SESSION FIVE: Upgrading and installation of fish passages and fish screens, offstream water storage

- **Fish Protection Facility Cost Drivers and Considerations: Why are Costs all Over the Board?**
  Darryl Hayes, CalFED Bay-Delta Program, Sacramento, CA

- **Upgrading and Installing Fish Screens: Developing Cost Estimates**
  R. Dennis Hudson, US Bureau of Reclamation, Boise, ID

- **Making a Good Run…A Watershed Approach to Restoration of Clear Creek**
  Harry Rectenwald, California Department of Fish and Game, Redding, CA

- **Oregon Department of Fish and Wildlife Fish Screening Program: Fish Screen Types and Costs**
  Bernie Kepshire, Oregon Department of Fish and Wildlife, Corvallis, OR

SESSION SIX: Wetland creation and restoration

- **Wetland Creation and Restoration**
  Steve Liske and Chris Bonsignore, Ducks Unlimited, Vancouver, WA

Proceedings of the

Salmon Habitat Restoration

Cost Workshop

November 14–16, 2000

Oxford Suites Hotel
Gladstone, Oregon

Introduction

Salmon Habitat Restoration Cost Workshop

CINDY THOMSON
National Marine Fisheries Service
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060
cindy.thomson@noaa.gov

Twenty-six Pacific salmon and steelhead stocks are currently listed as threatened or endangered under the Endangered Species Act (ESA). While the ESA specifies that the decision to list be based solely on biological criteria, it also requires that recovery plans for listed stocks reflect some consideration of economic effects. Specifically, the ESA states that “The Secretary [of Commerce, in the case of salmonid stocks], in developing and implementing recovery plans, shall, to the maximum extent practicable ... incorporate in each plan ... estimates of the time required and the cost to carry out those measures needed to achieve the plan’s goal and to achieve immediate steps toward that goal” (ESA Section 4.(f)(1)).

While habitat restoration is an important aspect of recovery planning, information on restoration costs is very limited. To help address this information gap, the National Marine Fisheries Service and the Pacific States Marine Fisheries Commission organized a Salmon Habitat Restoration Cost Workshop, which was convened on November 14-16, 2000 in Gladstone, Oregon. The goal of the workshop was to evaluate the feasibility of developing and applying standardized methodologies to estimate salmon habitat restoration costs.

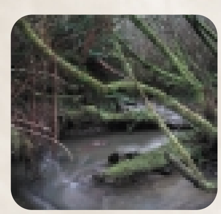
The workshop included an overview session as well as five additional sessions, each dealing with a specific type of restoration activity (see workshop agenda). Presentations were made by restoration practitioners representing a variety of disciplines (e.g., engineering, biology, forestry, geology, hydrology, economics) and entities (federal, state and local government agencies, non-governmental organizations, private industry, private consultants). In addition to identifying important cost factors, presenters were asked to address the following questions:

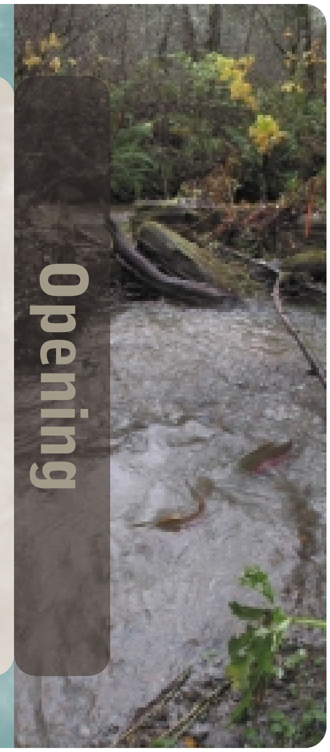
1. Are there formulas or rules of thumb that can be used to estimate restoration costs at the individual project level?

2. Is it possible to extrapolate restoration costs from individual projects to a large geographic scale, such as a watershed or evolutionarily significant unit?

3. If extrapolation is possible, how should it be done, what kinds of data would be needed and how would those data be obtained?

The workshop focused solely on restoration involving engineered modifications to the existing landscape and the direct costs associated with carrying out such projects. It is important to note that restoration takes other forms as well, such as restrictions on commercial and non-commercial uses of habitat (e.g., prohibition on timber harvest in a riparian area, closure of a decommissioned road to activities such as hiking). From an economist's perspective, a comprehensive analysis of restoration costs would include not only direct restoration project costs but also opportunity costs associated with land use restrictions that are intended to improve habitat. The focus of this workshop on direct project costs should therefore not be interpreted to imply that these other cost components are not relevant and important, but rather reflects the need to limit the scope of the workshop to what could be accomplished in a few days.





Potential uses and applications of habitat restoration cost information

The California Habitat Restoration Project Database: Cost Data

ROBIN CARLSON
Pacific States Marine Fisheries Commission
1807 13th Street, Suite 201
Sacramento, CA 95814
rcarlson@dfg.ca.gov

STAN ALLEN
Pacific States Marine Fisheries Commission
205 SE Spokane Street, Suite 100
Portland, OR 97202
stan_allen@psmfc.org

ABSTRACT

The California Habitat Restoration Project Database (CHRPD) is an ongoing effort to compile stream habitat restoration data and make this information widely available. The CHRPD will ultimately contain records for all restoration projects completed in California for which data can be obtained. An emphasis has been placed on the collection of cost data, making the database useful for detailed analyses of restoration project costs at local, regional and statewide levels.

INTRODUCTION

Planning the restoration and management of California's anadromous streams requires the ability to evaluate the successes and failures of past restoration efforts. Without a comprehensive, statewide stream habitat restoration project dataset, this kind of evaluation is difficult at best. There has until recently been no such dataset available; the CHRPD was initiated in 1999 to fill this need. The CHRPD is a cooperative effort involving the Pacific States Marine Fisheries Commission (PSMFC) and the California Department of Fish and Game (CDFG), with funding from the National Marine Fisheries Service (NMFS). In addition to serving as a repository for information about California habitat restoration projects, the CHRPD features a geographical component, with each project georeferenced. Widespread distribution of CHRPD data will assist restoration planners, policy makers, researchers and educators in analyzing and evaluating past trends, as well as making informed decisions regarding restoring streams and watersheds in the future.

The CHRPD aims to capture as many types of data about restoration projects in as consistent a manner as possible. Great variability exists in the availability of data for different projects, as well as in the quality and consistency of the data that is available. The standard project data collected, though, can be stated simply as who, what, when, where, why and how. Within these general categories are many detailed observations about the projects, maintained in a database structure that has the flexibility to accommodate varied levels of data quality and consistency.

A key component of restoration planning is the cost of the work to be done, so a special focus of the CHRPD is capturing cost data in as much detail as possible. Again, flexibility in the database structure is crucial, because the cost data availability and quality are especially variable. Also, it is important to be confident about the data that are present in the database, to ensure that calculations and analyses using cost data are as accurate and precise as possible.

DATABASE METHODS

Data Sources

All data currently in the CHRPD are from the CDFG's Fisheries Restoration Grants Program; these data include all stream habitat restoration projects completed since 1981 and funded through the CDFG. Expansion of the database to include restoration projects completed by other agencies and organizations in California is now underway.

Database Structure and Data Categories

The CHRPD is composed of a relational database, maintained in Access 2000, with each project georeferenced. The database structure is based on the StreamNet Data Exchange Format (www.streamnet.org), with new tables added to accommodate specific needs for data collection in California. The StreamNet database format includes the following data categories: project beginning and ending dates, purpose, project location, goals and treatment details, monitoring, project participants and both their work and financial input, land ownership, and species affected by the project. New data categories added for California data include: watershed planning recommendations (for watershed survey projects only), project funding proposals and appropriations, final report data (including whether the project goals were met), detailed budget information, and rates charged for specific budget items. The specific fields in each of these categories are described in Table 1 and a schematic of the database structure (not the actual table relationships) is shown in Figure 1.

Table 1. Data types in the CHRPD. Based on StreamNet database structure (www.streamnet.org) with California-specific changes

General Project Information	• Project name • Data compilation date • Source person for data • Source agency for data • Frequency data are to be updated • Primary subbasin (4th field hydrologic unit) • Status of project (planned, ongoing, completed) • Bibliographic information supporting data • Whether entire project is anonymous • First year of work on project • Last year of work on project • Purpose of project • Limiting factors addressed by the project

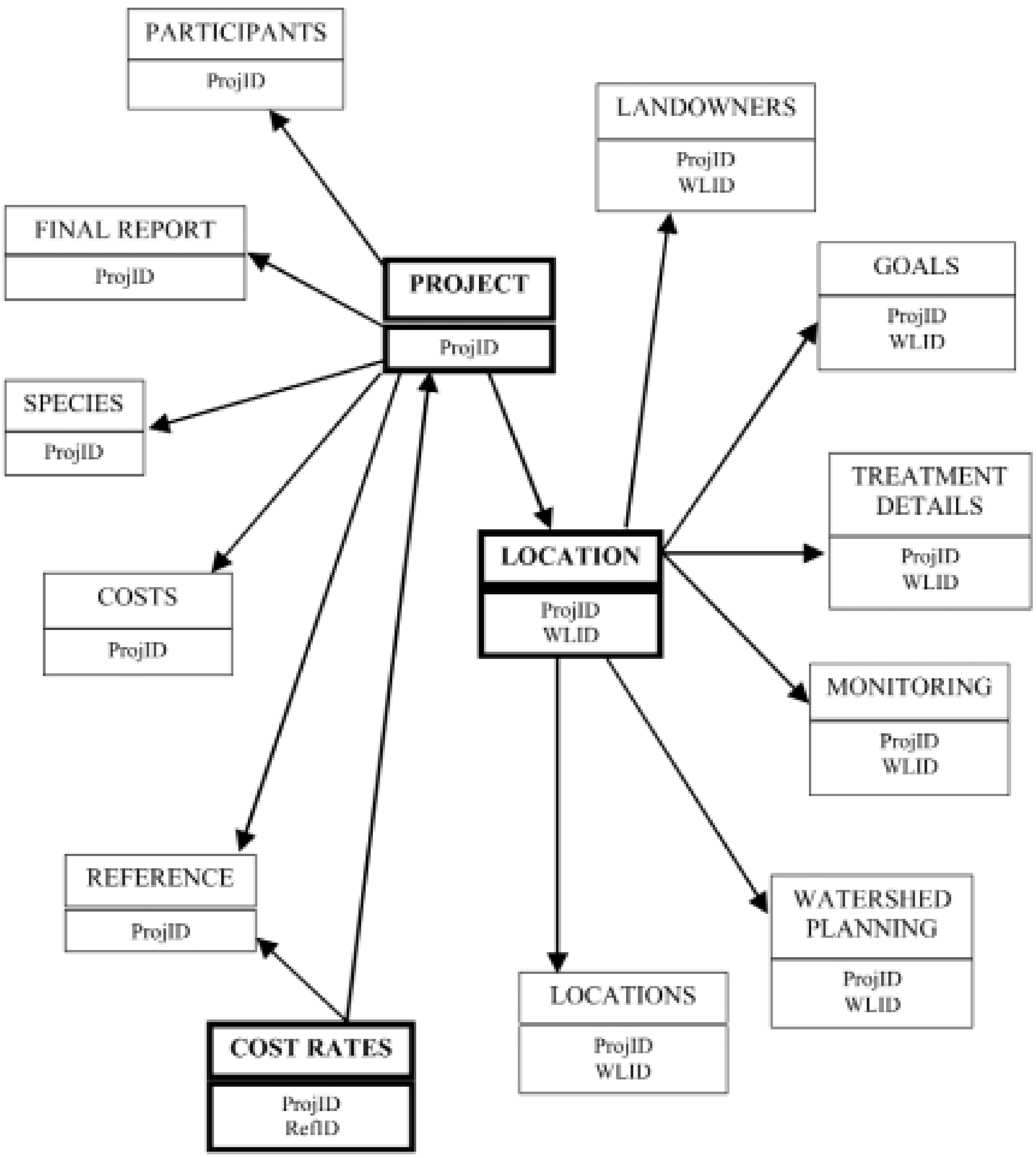
Table 1. Data types in the CHRPD. Based on StreamNet database structure (www.streamnet.org) with California-specific changes (cont'd.)

General Project Information (cont'd.)	• Time frame for which results are expected • Analysis of the project (things that facilitated, complicated or would help the project) • Whether a final report is on file • Whether the project goals were modified, and if so, how • Comments (general)
Target Species Information	• Species name • Whether species is a target species or a secondarily affected species (negative or positive) • Species run • Species subrun • Species rearing type (natural or hatchery)
Participant Information	• Participant name (may be many) • Whether participant wants to remain anonymous • Year(s) of participation for each participant • Project number used by the participant (for CDFG-funded projects, this is the contract number) • Name of program that participant operated under (for CDFG-funded projects, this is the name of the funding source) • Role of participant (funder, on-ground implementor, or both) • Whether participant is the primary coordinator for the project • Dollar amount of cash, in-kind support, labor, equipment, materials and total amount spent by each participant • Dollar amount of money requested by participant in project proposal and amount appropriated by funding agency (for funder participants only) • Contact person for each participant (name, title, address, phone, fax, email, comments • Comments
Location-Specific Information	• Site names • General work type category at each site (instream, riparian, upland, wetland, road work) • Site type • Spatial type (code for how project location is georeferenced: stream point or reach, nonstream point, nonstream arc, or polygon) • Land cover • Land use

Table 1. Data types in the CHRPD. Based on StreamNet database structure (www.streamnet.org) with California-specific changes (cont'd.)

Location-Specific Information (cont'd.)	• Goals for each work type, location • Details and quantity of work done at each location (also which work and how much was done by each participant) • Land ownership at each project location, including owner name, percent of project area owned, owner type (government, private, tribe, etc.), and contact for each owner • Recommendations for work to be done at specific sites based on watershed planning survey (for watershed survey projects only) • Comments
Monitoring Data	• Monitoring methods (if any) • Monitoring objectives • Whether control data were collected • Whether monitoring data are available • Types of data collected • Comments
Cost Information	• Costs of each item in the budget, including quantity and units • Items divided into personnel, materials, operating, and overhead categories • Both projected and actual budgets can be captured • Rates charged for various items can be recorded (in a table that also has the capacity to hold rate data from sources other than project documentation, such as restoration planning manuals or research papers) and then used to calculate average rates for these items

Figure 1. CHRPD general structure



This is a schematic of the database structure and does not represent the actual relationships between tables.
General data categories are in capital letters.
The names of the fields linking the categories are listed below the category name:
ProjID is a unique identifier for each project
WLID is a unique identifier for each work type and location within a project
RefID is a unique identifier for each reference from which project data have been collected.

Georeferencing

Projects are located geographically by marking the measures of their position along a stream; points have one measure and lines have two, one at the beginning and one at the end of their reach. Their locations can then be stored in a database table as coordinates along streams; the only data needed are the unique ID of the streams and the projects' distances from the mouths of their streams. These database tables can easily be converted to shapefiles for geographical analysis. In the case of projects that did not take place on streams (for example, road or upslope work) or projects whose streams do not yet exist in the streams coverage, their locations are mapped by heads-up digitizing directly into shapefiles. Polygons are also heads-up digitized and stored in shapefiles.

The process of georeferencing instream projects requires a GIS layer containing statewide routed hydrography. Routed hydrography makes it possible to treat an entire stream as a single entity, rather than a series of segments broken up by the stream's tributaries. As a result, it is possible to locate projects at specific locations along the stream, with reference to the entire stream length. Currently, the CHRPD is using 1:100,000 routed hydrography, but will take advantage of 1:24,000 hydrography once a complete layer is available for California.

Reference Files

In the case of the CDFG Fisheries Restoration Grants Program data, documents for each project have been stored in folders. In order to keep track of all of this supporting documentation, each folder is assigned a unique reference ID. The reference ID thus refers to a collection of documents. Because there are a large number of documents for each project, it would be impractical to assign unique numbers to each. As project files have been examined, they have been left in their original order in their boxes. The boxes are loosely organized by date of contract initiation, and in some cases there is no discernible order. Each file has been assigned a reference ID, though, so it is now possible to use the database to rapidly locate a particular paper file.

DATA QUALITY

General

The amount and quality of data that have been extracted from the database and paper files maintained by the CDFG Fisheries Restoration Grants Program vary widely. Both quantity and quality are dependent on contractor reporting, which is in turn dependent on CDFG requirements and enforcement of these requirements. The enforcement of minimum reporting requirements has improved dramatically over the years, so there are more data available for more recently completed projects. In addition, data quality is dependent on CDFG record keeping, the amount of paper documentation saved and the care with which data are entered into the database.

While all data categories suffer from occasional missing data, location data are profoundly affected by the manner in which the project was reported. For example, when a contract was granted to do work in several different locations, these locations are sometimes divided into several different projects (each with a separate ProjID). In other cases, though, these same locations are left as a single project (one ProjID and a WLID for each discrete work type and location). There has been little consistency in how projects are divided by CDFG and contractors for purposes of budgeting; one contract may have five budgets for five locations or only one budget for five locations. As a result, decisions about how to break up projects in the CHRPD have been made based on the need to capture as much cost data as possible. This means that if five budgets are reported within a single contract, the contract is entered into the database as five projects, but if five locations are given a single budget, the contract is entered as one project with five WLIDs. One important result of this system is that to obtain counts of projects completed, the total number of projects (ProjIDs) is less reliable than the total number of locations within each project (WLID and ProjID).

The project location data are also affected by the presence and quality of maps accompanying the contractors' reports. Some representation of the project location must be present in the file in order for the project to be digitized. How the project is digitized is entirely dependent on the way the contractor chose to represent it on a map. For example, a project involving the placement of five instream structures might be represented as five points along the stream by one contractor. It might be represented by a different contractor as a single line along the segment of stream containing the structures. Project locations are digitized with the greatest detail possible given the contractors' maps.

Cost Data

Reporting of cost data varies widely between projects, depending especially on the contractor, but also on when the project was done and whether all project documents have been saved in the files. In order to calculate average amounts spent on specific items for specific types of projects, it is very important to capture as many detailed cost data as possible. Unfortunately, many projects only have a projected budget on file, so the actual amounts spent are unknown. Of the projects that have any budget at all, 60% have projected budgets and only 45% have actual budgets. Furthermore, most budgets, projected or actual, are not itemized in great detail. Most often, when a budget has been itemized at all, it is divided only into personnel, materials, operating and overhead categories, without listing specific items within each category. Ideally, budgets list each separate item with the quantity and units purchased and the cost.

Many projects involve multiple funding sources, but the CDFG records often only include the money used from the CDFG grant. In most cases, it is impossible to determine whether the project used funding from other sources in addition to CDFG. In some cases, though, the final report states that additional funding was used but does not provide the amount. Only in rare cases are the additional funding amounts described. If in-kind contributions and funds from other sources are not reported, the total amount spent listed in the database will be a gross underestimate of the true total spent.

COST DATA PRODUCTS

The cost data being captured in the CHRPD lend themselves to analyses at many different levels, from local summaries of amounts spent on work done along a single stream, to statewide surveys of amounts spent within entire watersheds or basins. It is possible to report total amounts spent as well as amounts spent on individual budget items; average amounts are also easily obtained. Following are some examples of cost data summaries, including a map showing the total amounts of money spent on restoration projects in California basins (Figure 2), a summary of the total amounts spent on restoration projects in California each year since 1981 (Table 2), and the average rates charged for budget items in Siskiyou County, sorted by type of work done (Table 3).

Figure 2. Amounts spent on restoration projects by watershed

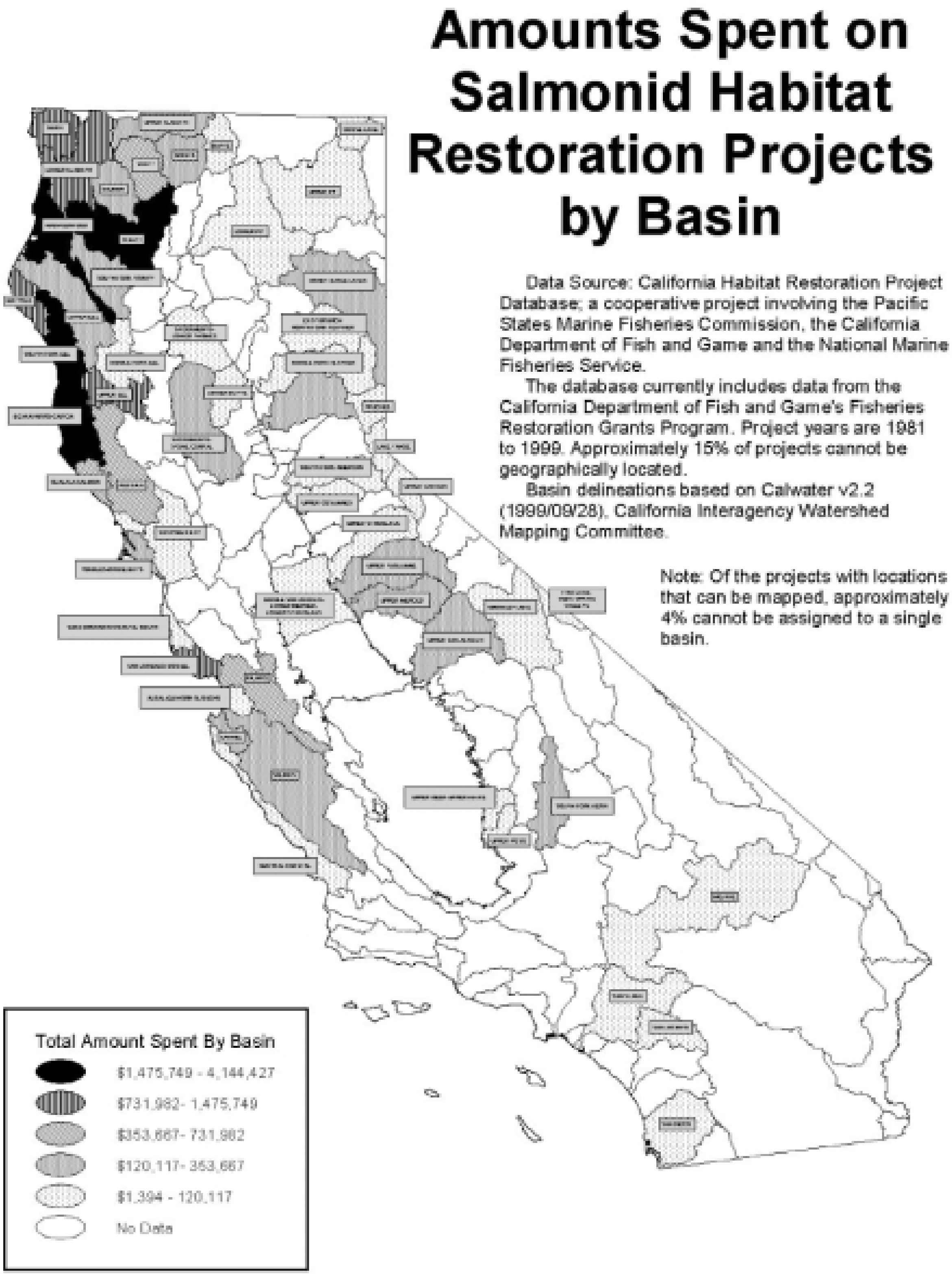


Table 2. Total amounts spent on restoration projects by year (corrected for inflation to 1999 dollars)

Year	Total # of projects	Total costs ($)	Average cost per project ($)
1982	5	263,129.85	52,625.97
1983	8	946,812.99	118,351.62
1984	21	1,003,358.61	47,778.98
1985	33	1,123,425.68	34,043.21
1986	40	1,171,509.73	29,287.74
1987	34	1,983,044.16	58,324.82
1988	32	2,011,743.69	62,866.99
1989	91	5,055,842.51	55,558.71
1990	122	8,198,886.22	67,203.98
1991	78	2,308,533.18	29,596.58
1992	61	1,506,625.51	24,698.78
1993	42	3,371,489.08	80,273.55
1994	40	1,207,227.43	30,180.68
1995	35	966,650.78	27,618.59
1996	25	449,949.92	17,997.99
1997	18	364,486.78	20,249.27
1998	12	333,898.58	27,824.88
1999	2	20,309.80	10,154.90

Table 3. Average rates charged for budget items in Siskiyou County (corrected for inflation to 1999 dollars)

Work Type	Budget Type	Item Name	Avg. Rate ($/unit)	Units	# Obsv.	Min. ($)	Max. ($)	St. Dev
Education, training, workshops	Personnel	Crew leader	10.71	hour	1	10.71	10.71	
Education, training, workshops	Personnel manager	Project	13.52	hour	1	13.52	13.52	
Instream work	Materials	Fencing	4,261.44	mile	1	4,261.44	4,261.44	
Instream work	Materials	Fisheries biologist	20.27	hour	4	20.27	20.27	
Instream work	Materials	Gravel	11.27	cubic yard	1	11.27	11.27	
Instream work	Materials	Gravel	3.83	ton	1	3.83	3.83	
Instream work	Materials	Lumber	0.58	foot	1	0.58	0.58	
Instream work	Materials	Metal gate	186.55	gate	1	186.55	186.55	
Instream work	Materials	Rip-rap	48.41	ton	2	18.53	78.29	42.26
Instream work	Materials	Rock	21.45	ton	1	21.45	21.45	
Instream work	Operating	Admin-istrator	23.37	hour	2	12.35	34.40	15.59
Instream work	Operating	Backhoe rental	40.53	hour	4	40.53	40.53	
Instream work	Operating	Dump truck rental	67.62	hour	4	67.62	67.62	
Instream work	Operating	Equipment lease/rental	30.10	hour	1	30.10	30.10	
Instream work	Operating	Excavator rental	130.00	hour	4	120.40	139.59	11.08
Instream work	Operating	Explosives technician	788.90	tree	1	788.90	788.90	
Instream work	Operating	Generator rental	115.80	week	1	115.80	115.80	
Instream work	Operating	Loader rental	110.76	hour	5	57.90	123.97	29.55

Table 3. Average rates charged for budget items in Siskiyou County (corrected for inflation to 1999 dollars) (cont'd.)

Work Type	Budget Type	Item Name	Avg. Rate ($/unit)	Units	# Obsv.	Min. ($)	Max. ($)	St. Dev
Instream work	Operating	Site preparation	31.05	foot	6	7.18	74.84	33.97
Instream work	Operating	Site preparation	31.05	hour	3	7.18	74.84	37.98
Instream work	Operating	Telephone	1.33	call	1	1.33	1.33	
Instream work	Operating	Travel	0.34	mile	1	0.34	0.34	
Instream work	Personnel	Biologist	16.16	hour	1	16.16	16.16	
Instream work	Personnel	Chainsaw rental	162.12	week	1	162.12	162.12	
Instream work	Personnel	Clerical	14.35	hour	1	14.35	14.35	
Instream work	Personnel	Construction supervisor	8.11	hour	1	8.11	8.11	
Instream work	Personnel	Crew leader	10.46	hour	2	8.79	12.12	2.35
Instream work	Personnel	Habitat biologist	46.37	hour	4	42.14	50.61	4.89
Instream work	Personnel	Hydrology technician	68.93	hour	4	60.20	77.66	10.08
Instream work	Personnel	Laborer	12.22	hour	20	6.95	18.34	3.53
Instream work	Personnel	Project manager	17.13	hour	6	10.42	20.27	4.87
Instream work	Personnel	Project supervisor	17.59	hour	1	17.59	17.59	
Riparian work	Materials	Fencing	15.99	foot	3	2.64	39.94	20.79
Riparian work	Materials	Fencing	15.99	post	3	2.64	39.94	20.79
Riparian work	Materials	Fencing	15.99	roll	3	2.64	39.94	20.79
Riparian work	Materials	Land dedicated	471.60	acre	2	419.20	524.00	74.10

Table 3. Average rates charged for budget items in Siskiyou County (corrected for inflation to 1999 dollars) (cont'd..)

Work Type	Budget Type	Item Name	Avg. Rate ($/unit)	Units	# Obsv.	Min. ($)	Max. ($)	St. Dev
Riparian work	Materials	Pipe	2.93	foot	1	2.93	2.93	
Riparian work	Materials	Pump and hose	1.52	foot	1	1.52	1.52	
Riparian work	Materials	Rock	8.97	cubic yard	4	6.37	11.58	3.01
Riparian work	Materials	Water	39.30	acre foot	1	39.30	39.30	
Riparian work	Operating	Admin-istrator	12.12	hour	2	12.12	12.12	
Riparian work	Operating	Backhoe rental	115.80	hour	1	115.80	115.80	
Riparian work	Operating	Power auger rental	40.40	hour	2	40.40	40.40	
Riparian work	Operating	Truck rental	25.25	day	1	25.25	25.25	
Riparian work	Personnel	Biologist II	18.22	hour	8	18.22	18.22	
Riparian work	Personnel	Civil engineer technician	26.06	hour	1	26.06	26.06	
Riparian work	Personnel	Fiscal officer	22.51	hour	7	22.51	22.51	
Riparian work	Personnel	Laborer	16.05	hour	4	7.10	39.67	15.80
Riparian work	Personnel	Project coordinator	15.00	hour	1	15.00	15.00	

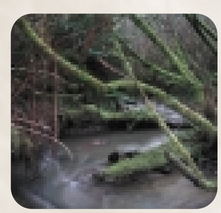
As this map and these tables demonstrate, the CHRPD is suited to a variety of different cost summaries and analyses. The geographical component of the database enables the production of maps that graphically represent the distribution of various aspects of the restoration projects (especially costs); summaries such as that shown in Figure 2 are particularly useful for providing a quick overview of past patterns of spending on restoration projects in California. The map demonstrates that most spending has been concentrated in the northwestern portion of the state, which corresponds to the areas of highest anadromous fish populations.

Another general overview of spending patterns is presented in Table 2, which summarizes spending on all California restoration projects by year. While the numbers of projects and total amounts spent on all projects varies widely from year to year (the extremely low numbers of projects in 1998 and 1999 reflects the fact that not all of the most recently completed projects have been entered into the database), the average cost per project has remained relatively constant.

More detailed summaries of the project data are also possible, as demonstrated in Table 3. Average amounts spent on various items listed in project budgets (projected and actual) are reported in this table for all of the projects completed in Siskiyou County between 1981 and 1999. The projects are sorted by work type, which allows comparisons of costs between different types of projects as well as between different geographical locations (projects could also be sorted by basin or watershed, for example). These data are particularly valuable for estimating the costs of new restoration projects; costs specific to work type and location are easily obtained and can serve as a basis for calculating expenditures on similar work in the future.

These are only a few examples of the many ways to represent CHRPD cost data. These data are very important for both evaluating past anadromous habitat restoration projects and planning future work. Cost data will continue to be a priority in the CHRPD. As mentioned in Table 1, new sources of cost data will be sought and these will supplement the data obtained from restoration project documentation. Other sources will include restoration planning manuals, surveys and studies, and estimates made by various restoration planners summarizing their work.

The CHRPD is currently seeking new sources of habitat restoration project data, expanding the focus of the database beyond projects funded by the CDFG. The goal of the CHRPD is to include all restoration projects completed in the state of California between 1981 and the present, and to update the data yearly so that the database remains current. A comprehensive database of California habitat restoration projects is a powerful tool for studying restoration efforts in the state and applying knowledge of past work to a better understanding of what needs to be accomplished in the future and how best to effect this change.

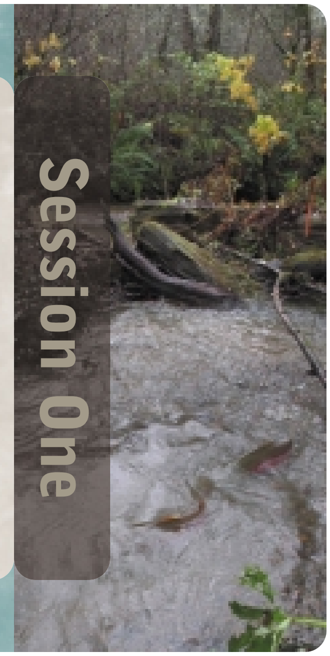


Conceptual framework(s) for cost analysis

The Role of Economics in Habitat Restoration

DANIEL HUPPERT
School of Marine Affairs
University of Washington
3707 Brooklyn NE
Seattle, WA 98105
huppert@uwashington.edu

Session One



ABSTRACT

Whenever habitat restoration planners choose to fund certain projects within a limited budget, economic information should help them understand and assess the trade-offs they are facing. In particular, by focusing on the costs and expected achievements of projects, economics promotes selection of projects that achieve as much restoration as possible for any given effect on the human economy. At the simplest level, an economic **cost analysis** demonstrates what is given up in order to accomplish a particular restoration objective. A more complex approach, the **cost-effectiveness analysis**, pairs the costs for alternative projects with a measure of project effectiveness or accomplishment. A more challenging approach – the **benefit-cost analysis** – estimates the value of project accomplishments in tandem with costs of projects. Finally, **economic impact analysis** assesses likely changes in regional incomes, employment or sales associated with a restoration project. Ultimately, economic tools focus on broad trade-offs inherent in funding salmon restoration – such as the balance between assuring sustained timber supply or electrical power and protecting and enhancing fish and wildlife. In salmon recovery planning in the Columbia river basin, all four economic analysis tools have been used in a variety of contexts. Under the Endangered Species Act economic considerations have a limited role in the key decision to list species. However, economic analysis should help decision-makers understand and evaluate the economic and other consequences of choosing a particular mix of restoration projects.

INTRODUCTION

Some standard economic evaluation tools can be used to assist in decision making about salmon habitat restoration projects. I will briefly describe four of these: cost analysis, cost-effectiveness analysis, benefit-cost analysis, and economic impact analysis. Any or all of these may be appropriate in specific circumstances. A problem in applying these to salmon habitat restoration is the difficulty of linking the costs of specific restoration activities to the broad objectives of salmon restoration, which typically include increased numbers and genetic diversity of naturally spawning fish. To describe the costs of achieving salmon recovery objectives requires that information about habitat restoration activities be supplemented by estimates of effects on salmon stocks. I provide a general framework for thinking about these connections between project activities/costs and the restoration objectives. Regarding the role of economic assessment/evaluation under the Endangered Species Act (ESA), I conclude that, while the role of economics is restricted, it can be a useful tool in screening and selecting recovery plan elements. Finally, I address a number of problems that arise in the practice of economic assessment in both salmon restoration and general natural resources planning.

FOUR ANALYTICAL TOOLS

Cost analysis attempts to understand and measure what is sacrificed to implement a specific project or to accomplish a particular objective. While sacrifices may be of various types, the goal of cost analysis is to sum up the sacrifices in terms of a common unit of measurement. Economists use the standard metric of currency units, mainly because those are the units in which people commonly express many small decisions to sacrifice one thing for another — for example, in making spending and taxing decisions. Economic costs include the obvious direct costs (e.g., personnel costs, materials, supplies, overhead, energy costs) and also opportunity costs — the value of other things given up in accomplishing the habitat restoration objective. When the project is fully paid for by the agency doing the rehabilitation, all the costs are direct costs and would show up as monetary costs in the agency budget. For example, the costs of replacing a culvert under a mountain road may be completely accounted for by the sum of materials, labor, and road machinery rental costs incurred by the agency.

On the other hand, if the agency strives to improve fish access through culverts by imposing and enforcing standards for culverts, then the costs would not show up as items in the agency's budget. Instead, they could appear as direct costs to road builders or landowners. Further, if roads are removed or decommissioned, there may be other opportunity costs — the value sacrificed in using those roads for recreation, access to timber, and fire control. In streamside habitat rehabilitation projects, for example, we may want to fence cattle away from a stream to protect vegetation within 100 feet or 300 feet of the water. By reducing the area available for grazing we may cause fewer cattle to be raised per acre of pasture. The reduced net profits in cattle production is an opportunity cost of habitat protection — we give up that value in order to use land resources for other purposes.

In Oregon and Washington, public water trusts are buying or leasing water rights from farmers in order to shift more water to instream flow. When farmers will give up their rights to divert water for irrigation, the opportunity cost to them is the reduced income from crops they could produce. If they are willing to lease a water right for, say, $100 per acre-foot per year, this suggests that they think the water would enable them to earn $100/year or less from the sale of additional crops. Hence, a negotiated price for water is a first-cut estimate of the opportunity costs of water in agriculture. Using prices in this manner draws the connection between the opportunity cost and actual cash outlays: the opportunity costs of the water being used in irrigation reflects the price the farmer would sell it for. In effect, the water trusts are paying for a series of water acquisitions at prices that reflect the opportunity costs of taking the water out of the agricultural sector and putting it in the river for fish. If, on the other hand, water is withheld from the farmers via legal action, then the farmer's would absorb the opportunity cost of reduced crop production and the agency demanding the action incurs no direct cost (aside from legal fees and costs of enforcement).

Cost effectiveness analysis incorporates the estimation of costs along with some measure of effectiveness for more than one project, allowing a comparison or ranking of projects. For example, there may be a number of ways to improve stream flow in a particular river reach — purchase of water rights, improved water conveyance facilities, increased upstream storage, or re-vegetation of riparian zone. If you have a limited budget, you may want to select one or a combination of these projects which give you the "biggest bang for the buck". The "buck" is the amount of funds available, and the "bang" is the amount of salmon habitat rehabilitation accomplished. A major challenge in using this technique to assess habitat rehabilitation, in my experience, is the quantification of project effectiveness.

You need a comparable measure of effectiveness across projects, and this generally requires a common unit of accomplishment for disparate kinds of projects. Flow improvements may be measured in terms of flow volume (acre-feet) or rate (cubic feet per second). Instream habitat quality may be measured in area of gravel beds or summer water temperature in deep pools, etc. These are not inherently comparable. One approach would be to establish for each of these the expected increase in juvenile fish survival or increase in numbers of returning adult spawners or the contribution to increased fish harvest associated with each habitat restoration project. Any one of these would provide a common measure of effectiveness.

With the ratio of cost to effectiveness identified for each project, one can then rank the projects in terms of cost-effectiveness. If the program budget is fixed, the projects should be chosen to get the most effectiveness possible within the available budget. To do this, simply choose projects from the top of the cost-effectiveness list, moving down the list until the budget is exhausted. If the program budget is undetermined but the overall program objective is quantified in terms of the effectiveness measure (e.g. an increase of 50% in juvenile salmon production for a stream), then projects could be selected to achieve the objective at least cost. The group of projects would be called the least-cost combination.

This simple approach to achieving cost-effectiveness must be modified, of course, if the projects are mutually exclusive or if the accomplishment of one project affects either the costs or the effectiveness of another project. In this more complex situation, one must evaluate the cost and effectiveness of all logical combinations of projects to determine the most cost-effective package of restoration actions.

Benefit-cost analysis is more comprehensive and demanding of information, because it requires quantitative measures of the value of achieving the program objectives (the benefits). Because the benefits and costs are expressed in similar units, one can compare these directly on an absolute scale. So, spending additional amounts on specific habitat restoration projects generates benefits in terms of commercial, recreational, and tribal fish harvests. If the quantified benefits exceed the quantified costs, the decision to spend more can be justified by the economic criteria that the public, collectively, is gaining more than it is losing.

When the objectives are expressed in terms of fish caught (rather than biodiversity preservation or aesthetics of natural habitats), the estimation of benefits can be relatively straightforward using techniques developed over the past three decades by environmental economists (Freeman 1993). Because the value of salmon harvest increases at a decreasing rate (that is, the marginal value declines), there is a point at which the value of increased harvests will fall below the cost of getting the increased harvest. We may not be at that point yet, but a benefit-cost framework would help to determine when we should stop spending on salmon habitat restoration and spend on something else. Even in salmon restoration, we may eventually want an estimate of the benefits of the program.

Finally, **economic impact analysis** generally measures the changes in the regional economy due to a program or policy. Hewings (1985) is a useful introductory text on the models. The economic changes are measured as increase or decrease in aggregate sales, or income, or employment. For example, if federal forest policy reduces the annual cut when shifting forest land from lumber production to wildlife habitat, there is going to be an effect on the local community. Because this effect is not captured entirely by a typical benefit-cost analysis, local communities and politicians may be interested in considering the effect of the policy on income and employment in the region. Disruption of the local economy involves social and other costs not explicitly measured in the usual economic cost assessment. In fact, in the framework process called Sub-Basin Planning in the Columbia Basin, being conducted by the Northwest Power Planning Council (NPPC), economic impact analysis is being done along with the other kinds of analyses.

All four of these analytical methods require that we analyze the project consequences relative to some baseline. When confronted with a claim that a particular program generates a great outcome, an economist is inclined to ask "Compared to what?" For project evaluation information to be relevant to a decision-making process, it all has to be cast in terms of a "with" and "without" action. You compare the outcome with the project to the outcome without the project, and this means you have to make some explicit assumption about the course of events in the absence of the project. This includes measuring the difference in the cost, the value, and the impact that is attributable to the project relative to some assumed conditions.

Example: Costs of the Fish and Wildlife Program in the Columbia Basin

A recent document shows that that costs associated with Bonneville Power Administration's Fish and Wildlife Program amounted to $3.48 billion over the 1978-1999 period (NPPC 2001). Of that total, $961.7 million were "direct expenditures" and the remainder were estimated opportunity costs. The direct expenditure categories were devoted to harvest management (3%), mainstream passage (23%), artificial propagation (32%), and habitat/watershed preservation (42%). During most of that period the expenditures have been guided by the NPPC. After the listings of Snake River chinook and sockeye salmon stocks, and subsequent National Marine Fisheries Service biological opinions, Bonneville Power Administration (BPA) negotiated a memorandum of agreement among Federal agencies that puts a cap on the costs of the program at $435 million per year.

The actual costs of the program will vary widely among wet and dry water years. This is illustrated by flow augmentation in the Snake River and the spill of water over dam spillways during the peak spring out-migration period for chinook smolts. Both of these actions tend to reduce the amount and value of hydropower produced in the basin, but the effect is more severe in dry years. The reasoning goes like this. Storage reservoirs in the system allow operators to shift water flow from the normal high run-off period in the spring to the relatively lower flow periods later in the year. This permits more hydropower generation during the period of relatively high electricity demand in the Pacific Northwest and California. This shifting of flow from spring to later in the year increases the value of the hydropower generation. When stream flow is augmented in the spring via releases from upstream storage reservoirs, more hydropower can be produced in the spring, but it is worth less then. In wet years, the sacrifice of hydroelectric power value is smaller because there is more than enough water to allow increased stream flow and shifting of water to later in the year. In dry years, spring season flow augmentation can be very costly in terms of hydropower opportunity costs. Unfortunately, the salmon are more in need of flow augmentation in dry years, when the opportunity costs of hydropower are higher. Similarly, the plan to divert some water over spillways in order to help migrating juvenile salmon to avoid the turbines will cause reduced hydropower production. That cost also will be lower per acre foot of water spilled in wet years and higher in dry years.

The negotiated cap on BPA's Fish and Wildlife Program cost is an average across many water years. The direct expenditure on the Fish and Wildlife Program is $127 million per year. That annual budget that is allocated to a series of project proposals submitted to the NPPC, which then decides which project to include in the annual program. The BPA administers the approved budget. Over the past decades, a lot of capital investment has gone into fish ladders at dams, juvenile by-pass systems, salmon hatcheries, and barging systems. The cost of those gets transferred to BPA's budget, and through average-cost pricing to the public and private utilities of the region, and then to retail customers of the region.

REQUIREMENTS FOR CONSISTENT COST ESTIMATES

A salmon habitat restoration program may include several things — replanting vegetation, replacing culverts, placing large woody debris in streams, fencing cattle away from the stream, or conservation easements of stream banks or timbered upland. These recovery activities occur over time and space, and they may be funded through difference agencies and planned by different groups. If we cannot get accountings of how much we spend on these various categories, along with monitoring the effects of these activities on fish populations, we'll never be able to look back and learn about the cost-effectiveness or cost-benefit of salmon restoration. It would be helpful to incorporate some routine practices in the cost collection and reporting of these projects in order to have consistent and accurate cost estimates. Some of these are discussed below.

Opportunity Costs

There is confusion in some quarters concerning the meaning and role of opportunity costs. "After all", the thinking might go, "we did not incur an expenditure, so how can we call it a cost?" But it is important to understand that economic cost is not necessarily an expenditure. Cost is the value of things given up in order to change the habitat condition. When market goods and services are purchased to implement a restoration (timber, gravel, machinery rental, laborers) we often assume that the market price, rental rate, or wage is a decent estimate of the opportunity costs or compensation required to obtain those inputs. The expenditures will be a reasonable estimate of economic cost only if the opportunity costs are adequately represented by the dollars changing hands in transactions. For non-market goods (changes in water flow, riparian vegetation, public land use) there is often no market price or dollar transaction that corresponds to the opportunity costs for those resources. These non-market costs often arise due to policies working in the inter-connected economic-ecological system. Hence, to include those costs in the calculation requires special attention to opportunity costs.

Opportunity cost is the value of the alternative resource uses that we won't have due to a restoration action. These costs can accumulate over time at a restoration site as more and more alternative uses for the resources are prohibited. Many opportunity costs are estimated for specific projects at specific places and times. But in a larger concept, most of these are parts of an overall plan where we cumulatively do a variety of things. It would be helpful to group the economic analyses of the opportunity costs into a total cost for a coherent collection of cumulative projects on particular rivers or region, e.g., the John Day or Deschutes rivers.

For example, in the Deschutes basin, a variety of riparian habitats projects have been completed on the Warm Springs Reservation. And the Oregon Water Trust has completed several purchases of water rights that are used to increase in-stream flows.[1] We could analyze each project and purchase to determine the cost (reduced value agricultural production, for example) to improve conditions slightly for some fish at some time of the year. But, what we really want to know is how these costs accumulate over the whole program and how the costs relate to the potential recovery of the fish. What do the cumulative costs and cumulative fish effects look like? If we look at a larger picture than individual water purchases or projects, we may learn a lot more about both the costs and the effectiveness, including how improved habitat for fish increases the numbers of fish and how we can connect that with the costs of doing so.

The following are some specific examples of opportunity costs:

• **Value of crops** sacrificed when we move water from irrigation to instream flow.

• **Value of recreational opportunities** lost. The Snake River is a case in point. If we take out a dam and create a free running river, we get some rafting and other kinds of recreational opportunities, but we give up recreational opportunities associated with the reservoirs. Both of these recreational opportunities have values that can only be estimated through structured study. The economic values won't be evident from data on recreational expenditures or project budgets.

• **Reduced hydropower** valued at its current or projected market value, when water is released to increase stream flow or when water is diverted over spillways instead of through turbines.

• **Reduced flood control** when dam are removed or levies breached. Damage to property and people due to increased flooding would be an opportunity cost of these kinds of restoration projects.

• **Reduced commodity production** from public lands. When we re-allocate resources and watersheds away from natural resource extraction towards restoration and preservation of natural habitat we produce less value in forest products and mining products.

• **Value of labor/capital/land in alternative uses**. The payments for labor on projects is usually represented by the wages paid. If significant volunteer (or coerced) labor is used on the project, then the opportunity costs of that labor would equal the wages that could have been earned in paying occupations. Similarly, the cost of rented capital equipment is adequately represented by rental payments. Equipment that is donated, borrowed or owned by a government agency also has an opportunity cost equal to the value that equipment could

1- For more information about Oregon Water Trust visit their website at http://www.owt.org/

bring in a rental market. Land, also, has opportunity costs. If riparian land is re-allocated to habitat restoration rather than residential, recreational, or agricultural use, its opportunity cost (value in the rental market) should be estimated.

Interim Use Losses

Another category of cost – interim use loss — is imposed on those who lose the use of some resources during the period of recovery. For example, if access to streamside habitats or fishing is curtailed during a 20-year project to rehabilitate streamside vegetation, the people who valued the use of that stream will suffer an economic loss. If the loss consists of non-market or recreational use value, estimation of that loss could be approached through a technique known as the travel cost model. Or more direct valuation methods, normally going by the title of "contingent valuation," could be employed to estimate the magnitude of the lost use value. When market-related losses occur, the lost use value could be approximated as the reduced profit or land rent or incomes associated with the lost use. When such recreational or commercial values are lost year-after-year for an extended period, then the total cost would be computed as the present value of the sequence of annual losses. (Again, see Freeman, 1993, for an extended discussion of the non-market valuation methods.)

Consistency Across Estimates

To compare the costs or benefits of alternative projects, we need to achieve some consistency across the estimates among projects. For example, a School of Marine Affairs student, Emily Anderson, examined a series of Federal Energy Regulatory Commission (FERC) hydropower dam re-licensing cases involving projects that affect fish runs for her thesis. She wanted to determine whether dam removal is the preferred decision when costs of satisfying fish passage requirements, among other things, exceed the value of the dam to the owner. Each FERC re-licensing case requires compilation of an Environmental Impact Statement (EIS). An EIS examines the social and economic effects of the alternative measures being considered. The economic costs and benefits of a re-license proposals are spread out over many years, typically 50 years. To compare the alternatives considered for each dam, and to make comparison across re-licensing cases, we want to express all future years' estimated economic costs and benefits in inflation-corrected dollars. If there is significant price inflation over the period of time being examined, the dollars in later years are worth less than dollars in earlier years. So, we use a price index (like the consumer price index, or the producer price index of the Gross National Product deflator) to adjust the benefits and costs for inflation.[2] We pick a base year, set the price index equal to 1.00 for that year, and express the value of a dollar as the inverse of the price index for other years. It actually doesn't matter which year you choose for a base year, so long as you are consistent.

After correcting for inflation, we want to consolidate the whole series of annual values into a single number called the net present value (NPV). This makes it possible to compare two or more uneven streams of costs and benefits over time. In a present value calculation, future values are "discounted" using an interest rate that reflects annual rates of return on capital. The discount factor for each future year is just the inverse of one plus the interest rate. Algebraically, the procedure looks like this:

$$NPV = \sum_{t=0}^{N} (B_t - C_t) \left(\frac{1}{1+i} \right)^t$$

where B_t is the benefit in year t, C_t is the cost in year t, i is the interest rate used in

2- This inflation-correction procedure is of course, unnecessary if the original cost and benefit projections were made assuming no inflation.

discounting expressed as a fraction (i.e. i = .07 for a 7% interest rate), and N is the number of years the project is expected to endure.

Incidentally, if decision makers are more comfortable thinking of costs or benefits on an annual basis, rather than in a lump sum figure like NPV, we can easily present the information in that way as well (or instead). The formula for equal annual payments that are equivalent to the NPV is:[3]

$$AnnualPayment = i \times NPV\left(\frac{1}{1-(1+i)^{-N}}\right)$$

The EIS documents for each FERC re-licensing case include net present value calculations, but different projects were evaluated using different base years for prices and different discount rates. While each project was evaluated correctly, the results were not comparable. Hence, to compare results across projects we had to dig into the details of each study, re-recreate the estimated time streams of costs and benefits, and calculate our own NPVs. That was a lot of work, for the student.

It would be easier if everyone used the same set of assumptions in economic assessments of projects, but there is no reason to expect that will ever happen. We can at least require that the documentation for such projects display the whole stream of cost and benefit estimates over the time span of the project, and that the inflation-correction and present value calculations be described explicitly.

Time Period

The time period over which the analysis is done matters as well. For example, if we're dealing with a project that produces some change in a river over a number of years, we will want an annualized cost for a fixed number of years (say, 50 years), preferably calculating each year's cost using a common interest rate and using dollars of common value. This would produce comparable numbers across projects. If one project is evaluated over 5 years and another is evaluated over a 25 year life, then neither the present values of the costs nor the equivalent annualized costs are strictly comparable.

What Interest Rate to Use

At the current interest rates in the US economy, I'd recommend a 2.6-3.7% rate for discounting benefits and costs of public projects. A look at the post-World War II history of the United States economy is helpful when considering inflation-corrected rates of return on various financial instruments. In Table 1, it is clear that short-term treasury bonds, longer-term bonds, and Moody's Baa rated bonds are all only slightly risky. Stocks (S&P) are very risky – the annual net return has varied from roughly –30% to +30% per year. As a general rule, higher rates of return are available on risky investments

Table 1. Average annual rates of return for various financial instruments (1947-1996)

	Nominal	Inflation Corrected
3-Month Treasury Bonds	4.93%	0.96%
10-Year Treasury Bonds	6.63%	2.60%
Moody's Baa Rated Bonds	7.69%	3.62%
S&P 500 Stocks	11.65%	7.43%

3- If you borrowed an amount equal to NPV and had to pay it back over 10 years with an interest rate of 8%, you could calculate the annual payment due at the end of each year by inserting N=10 and i = .08 in the formula.

than on less risky investments, i.e., shorter-term, less risky investments bring lower rates. Longer-term, higher-risk investments bring higher rates.

If we look at just the current year, we get a different impression. In fact, in the year 2000 the return on stocks generally was negative. Therefore, it is not helpful to look at only one year; we need to consider the average over a span of time. Deciding on the interest rate to use for present values or annualized values of a project should depend on the length of the project and the risk involved. A short term, risk-free project would be evaluated using the 3-month Treasury bill rate. For a longer-term, risky project we might discount using the rate of return on common stocks. Some restoration projects may well be packaged in a diversified way, keeping the whole portfolio risk low, in which case we might want to look at an interest rate in the low range. On the other hand, if we have a very risky project, we might want to use a higher discount rate to reflect that. Or, better yet, we could use an explicit model that incorporates the uncertainty in the decision criteria. For example, we might estimate probabilities of various outcomes for each project and choose a mix of projects that maximize the expected value of the restoration. In this latter case, we would not need to adjust the interest rates for uncertainty.

LIMITATIONS AND PROBLEMS IN ECONOMIC ANALYSES

Social values, pre-existing commitments, and property rights often preclude or limit the role of economic information in decisions. There are over-arching social and ethical concerns in some cases that overshadow economic consequences and make economic information less crucial to public decisions. A good example is the ESA, which has adopted a risk averse strategy declaring, in effect, that we're going to do whatever we need to do to prevent extinctions. The ESA does not say "depending on how much it costs." This strategy implies a limit to the appropriateness and usefulness of the economist's concern for balancing the costs of actions versus their outcomes (effectiveness or benefits). In effect, the "top level" decision to engage in a protective action for a threatened or endangered species is a higher social commitment. Nevertheless, cost-effectiveness can be a guide to choosing species preservation actions.

Another limitation is the inability to quantify social or economic equity. Most economic analysis tools used in project evaluation and policy analysis are focused on understanding the efficiency consequences of decisions. Efficiency is broadly construed in economic thought to deal with the entire range of concerns from technical efficiency to cost efficiency to maximizing net benefits from public programs. Little of the analytical apparatus is directly helpful in assessing the social values associated with equity – whether the actions taken distribute the costs and benefits in a way the we would generally accept as just. Still, the data that supports an assessment of economic efficiency can be turned to the task of describing the distribution of costs and benefits among classes of people. The classes can be defined as economic classes (poor, middle income, rich), or geographic populations (communities), or as economic functional classes (farmers, fishermen, government workers, stock holders), or as ethnic classes. In any case, the economic information can be used to display some of the important equity consequences along with the efficiency consequences. Economists have no more to say about the relative worthiness of various distributions of consequences than do other philosophers (which is to say a lot, but that is a story for another day).

Property rights associated with salmon habitats are evolving and changing under the influence of the ESA and due to the rise of innovative institutions like the Oregon and Washington Water Trusts (Whittlesey and Wandschneider 1992). Still, incompletely defined and non-transferable property rights can make calculation of economic values difficult. And even when heroic efforts to estimate values are successful, lack of property transferability can make the economic values fairly irrelevant to policy choices. Take agricultural water rights as an example. Agricultural economists have repeatedly shown that water diverted for agricultural use in arid areas has value as both input to crop production and as instream flow. But water rights were historically awarded only for "beneficial use" outside of the stream. And, worse, those water rights were allocated based on "first in time, first in right" and are largely non-transferable. So, a farmer with senior water rights has an economic incentive to hold onto and continue to use those rights even when the value of the water would be much greater in some other use (as instream flow or in use by a different water user downstream). So, one may find that a very sensible transfer of water from low-valued to high-valued use is essentially impossible to arrange. This is changing slowly and sporadically, as some states (Oregon, in particular) have passed legislation which gives instream flow rights some standing and permits holders of off-stream diversion rights to maintain ownership when they lease the rights for instream flow.

Another limitation is poor information about either the costs of taking action or the consequences of taking actions. We typically have inadequate data, and we face other issues that make reliable estimates of costs, effectiveness, or benefits impossible. Many times there is no good accounting system that allows us to track back from restoration measures in the field to expenditures at the agency. We know the overall budget by functional category (by agency unit and by labor versus materials costs), but it requires a real sophisticated cost accounting system to group costs logically for defined salmon restoration objectives. Further, when specific causes for species decline or recovery are difficult to determine and quantify, agencies tend to act in a crisis mode, without full consideration of consequences. Hence, decisions sensitive to cost-effectiveness and quantitative balancing of costs and benefits may be deemed too difficult or unnecessary.

Economics and the Endangered Species Act

The ESA process occurs in six stages (see Table 2): (1) the listing decision, (2) the designation of critical habitat, (3) jeopardy determinations (in which the Secretary of Interior or Commerce issues a "biological opinion" that a Federal agency program does or does not jeopardize an endangered species), (4) Section 7 interagency consultations (in which the action agency consults with the listing agency to avoid jeopardizing a species), (5) Section 7 exemption process, and (6) recovery planning and management. The extent to which economic factors can be considered in each stage is determined by the text of the Act, the legislative history of the Act, administrative discretion exercised by Federal agencies, and legal actions initiated by public interest groups or environmental activists. As noted in Table 2, economic information can be considered (a) in weighing the benefits of including an area in critical habitat against the benefits of excluding that area, (b) in evaluating alternative Federal agency actions to avoid adversely impacting a listed species or its habitat, (c) in appealing for a Section 7 exemption by the Endangered Species Committee, and (d) in estimating the cost of recovery measures considered in the Recovery Plan.[4] Economics has not been important in naming critical habitats,

4- See Gleaves and Wellman (1992) for a more extensive discussion of economics in the ESA process.

Table 2. Summary of ESA steps and economic contribution to decisions

Steps in ESA Decision Process	Scope for Economics	Apparent Importance of Economics in Decisions	Economic Concepts or Analytical Method
1. Listing Decision	None officially *but budgetary limits slow consideration of listings*	None	None
2. Critical Habitat Designation	Consideration of economic impact. Weigh benefits of including an area against benefits of excluding an area	Broad prohibitions on "taking" make this less important than ESA language suggests	Techniques for quantifying costs and benefits applied to additional restrictions on use of habitat
3. Section 7 - Findings of Jeopardy or No-Jeopardy	None — exclusively a biological/ecological assessment	None	None
4. Section 7 - Formulating Alternatives to Avoid Jeopardy	Agencies seek to comply with ESA while minimizing loss in services delivered to constituents	This is a very active area of activity under Federal ESA administration	Main methods are cost analysis and cost-effectiveness
5. Exemption from No-Jeopardy Mandate (Endangered Species Committee)	Explicit consideration of substantial economic loses due to Agency compliance	Economic assessment would seem to be an integral element of case for exemption	Economic cost and "impact" analysis are particularly relevant
6. Recovery Planning	Explicit call for "time and cost" assessment; weighing of economic consequences in planning	Economic evaluation of alternative approaches could be extremely useful, subject to biological uncertainties	Full suite of cost and benefit evaluation tools organized in a cost effectiveness analysis

because no specific action (and, hence, no specific economic consequences) are entailed in the critical habitat designation. On the other hand, the Section 7 exemption process is tantamount to the determination that social costs of species preservation are "unacceptably large." By a majority vote of at least five to seven, the Committee may grant an exemption, if they determine that:

(i) there are no reasonable and prudent alternatives to the…action; (ii) the benefits of such action clearly outweigh the benefits of alternative actions consistent with conserving the species or its critical habitat, and such action is in the public interest; (iii) the action is of regional and national significance; and (iv) neither the

> *federal agency concerned nor the exemption applicant made any irreversible or irretrievable commitment of resources prohibited by subsection (d) of this section.*[5]

While economic costs are clearly a major factor in appeals for exemption from the Endangered Species Committee, that process is rarely invoked.

Since the 1978 ESA amendments created the exemption process, the Committee has voted on only three applications: the Tellico Dam, the Graylocks Dam, and some Bureau of Land Management timber sales in the Pacific Northwest. Exemptions for the Tellico and Graylocks Dams were denied by the Committee. When the Bureau of Land Management (BLM) applied for exemption from ESA obligations for the sale of 44 tracts of timber, the Endangered Species Committee exempted 13 of the 44, denying exemption for 31 tracts. Several months later, however, the BLM withdrew its application for exemption, without having proceeded with the sale of the approved 13 tracts. So the exemption process has not become a significant route around the requirements of the Act. But it is always possible that claims of extreme cost or economic disruption can be taken directly to Congress, which can always provide a special exemption. This is exactly what happened with the Tellico dam.

Distribution of Costs and Equity Issues

The costs of a habitat restoration effort may be imposed upon one community, while some other community stands to gain the benefits of salmon restoration. For example, coastal communities typically receive benefit from ocean salmon fishing, while some costs of habitat protection impact inland communities. The regional economic implications among those communities may be a crucial factor for regional decision makers. Sometimes one community has five major sources of income, but another has only one or two. How resilient is the community where the salmon recovery costs are imposed? Such regional equity types of questions can be considered in a broader economic analysis of regional impacts.

I don't think that the economists who do these analyses are the ones who should be asked to determine an equitable distribution of costs and benefits among discrete communities. What we should be doing is providing information so that decision-makers can properly understand and weigh these kinds of issues. Decisions should be informed by information about geographic distribution of program costs on isolated communities without resilient economies, and about the locations of eventual benefits of recovery. If that information is not presented, decision makers are not going to be able to weigh the equity issue appropriately. To alleviate costs imposed on farmers and landowners, for example, the government (or non-governmental organizations) could provide financial assistance and initiate programs to soften the blow of reduced employment in rural communities.

Think about the John Day basin for example. There are people raising cattle, growing grass hay, and eking out a living along the river. If we have them give up some of their land by fencing streamside buffers, reduce their water diversions, and build manure ponds to control run-off of cattle feces, that will impose lower incomes on the farming operations. A full economic assessment of benefits and costs would include these lowered incomes as opportunity costs of the recovery effort. So here's a landowner faced with some real tangible costs that, maybe, will increase the potential fishing benefits to someone out in the ocean or in the Columbia River. The benefits largely are going to occur in the ocean and lower rivers, although there may be some

5- ESA section 7 (h)(A).

angling and fishing in the John Day River itself. But most of the benefits of an increased run is going to occur out of sight of the farmers. That's a tough trade-off for a landowner, especially one who is not making a fortune in farming. There is also a huge risk there, because improving stream habitats in the John Day will help salmon and steelhead only if a whole sequence of other things also happen. That is, the downstream people have to also cooperate by improving habitat and access, and the fisheries have to cooperate by not overfishing that stock.

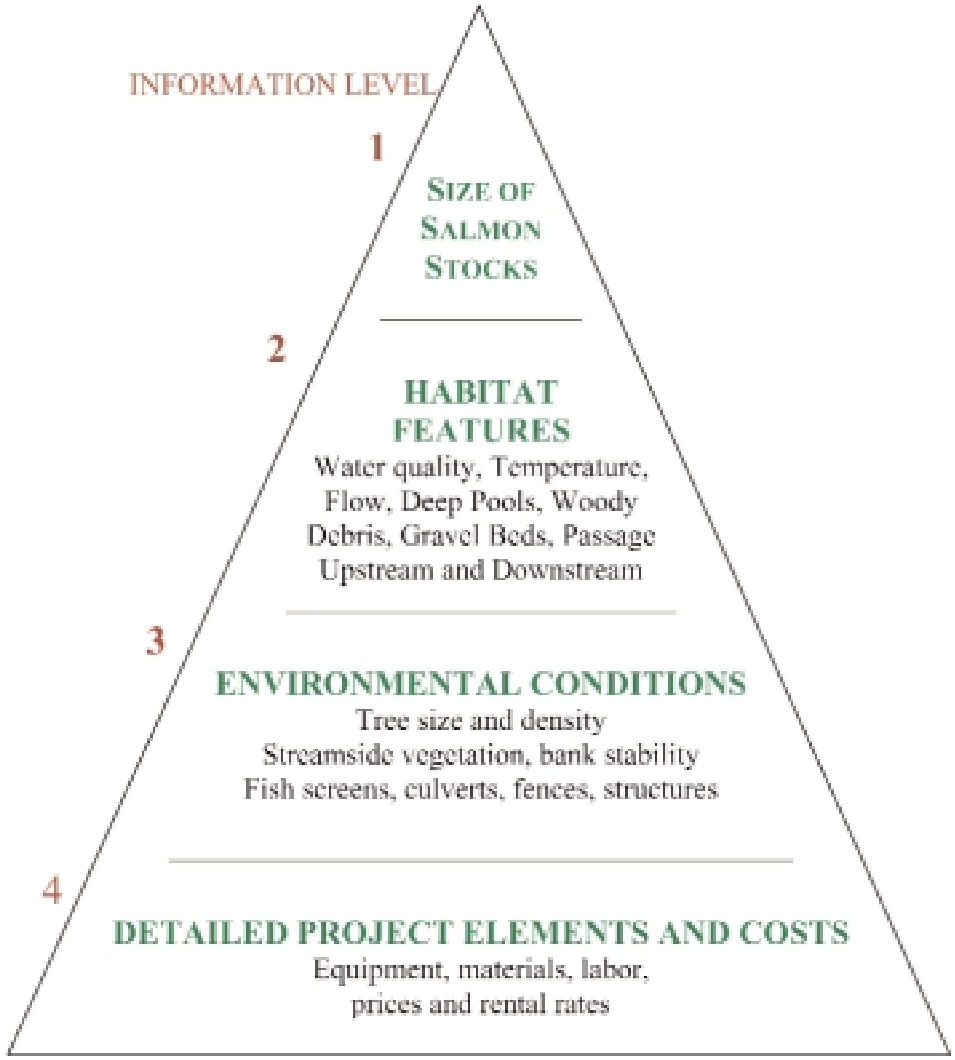
To get the landowners on board, you might compensate them for some of the potential losses. I think that's why the Conservation Reserve Program has allocated $500 million dollars to the Oregon-Washington-Idaho area. You can get landowners to accept a riparian conservation program that pays them a fair rent, or at least a respectable share of the cost. In essence, we're telling them, "We're going to rent this riparian area and we'd like you to manage it in the following way." They are not being asked to make un-rewarded personal sacrifices for some distant, risky benefits. The disparity between location of costs and benefits can provide a rationale for a compensation program. The economist needs to point out where the benefits and costs are occurring, so that decision processes can consider and deal with the economic equity issues that arise.

The problem of eco-ecosystem complexity

It is commonly understood that both the ecological and economic systems are multidimensional, dynamic, and interactive systems. One of the fundamental limitations of this discussion is that we are taking actions to modify certain physical aspects of the environment and then measuring what benefit that may have for a single species or a list of species. But there are, in fact, all sorts of other things that result from that physical modification. We might be controlling water flow for migration of juveniles, which may unintentionally change downstream water temperature. Or we might control erosion to improve spawning gravel, and that may affect flood control problems downstream. So, this is just a fundamental limitation of talking about a single species or even multiple species of salmon. The unintended effects are going to be a problem in applying some of these analytical techniques in developing recovery plans. While everyone seems focused on the recovery plans for the salmon species, they are not evaluating what it is doing for other species and unrelated effects beyond the purview of the recovery plan. Similarly, when costs are imposed on one element of the economic system, this often creates opportunities for gain by some other element of the system.

When the various ecological and economic factors are tightly linked it is actually going to be very difficult to do a thorough cost-benefit analysis. What you really need is the net cost and net benefits of all the consequences of an action. For example, in evaluating a proposed flow augmentation from the Snake River down through Hell's Canyon through the Lower Snake and into the Columbia, it turns out that not diverting water for irrigated agriculture in Idaho has both an opportunity cost to the farmers and a benefit to hydroelectric power producers downstream. When you increase the river flow for salmon migration, you also increase hydropower. So, when we assessed the cost of the Snake River flow augmentation, we took the reduced value of crops as a cost and then subtracted the increased value of hydropower to get a net cost (cost minus associated benefits) (Huppert 1999, p. 487). You can also imagine a case where some measure helps the salmon but also creates a recreational opportunity or improves the habitat for another species or harms another species.

Figure 1. Pyramid of information



Not everything that is good for salmon is good for everything else.) Once you start recognizing the multiple effects of these things, both economically and biologically, you are forced to look at a number of benefits that might accrue, either inadvertently or as a by-product of the restoration program, and to subtract the value of those benefits from the direct costs to come up with the net costs of the restoration. What that means is you can't get away from benefit estimation. Because some of the ancillary or unintended effects of restoration actions will create economic benefits which need to be assessed in order to determine the net costs of the restoration.

A BIGGER PICTURE

How do all these forms of analysis integrate with the economists' concerns about balancing benefits and costs, or at least being cost-effective, in salmon habitat restoration? Perhaps a good way to look at it is as a pyramid of information (Figure 1). At the very top of the pyramid (Level 1) would be some measure of salmon restoration, whether it be increased spawning run size, or increased spawning capacity of particular stream, or increasing sustainable catch, or even an index of spawning activity like the number of "redds." These constitute indicators of success in salmon population restoration.

Below that (Level 2) would be features important to functioning salmon habitat, like water quality, water temperature and flow, the presence or absence of deep pools and woody debris, the quality of the gravel beds for spawning, and so forth. These include the things that a field biologist can go into a stream and monitor. These are conditions that impact salmon, indicators of habitat quality or capacity.

Below that in the pyramid (Level 3) are broader environmental conditions that sustain and support salmon habitat quality, the underlying ecological structures. Late successional/old-growth timber in lower watersheds, streamside vegetation, sources of gravel bars would be important here. Also included would be human engineered features, like fences that keep the cattle away from streams, fish screens on water diversion structures, and properly engineered road culverts.

At the bottom of the pyramid (Level 4) are the specific inputs that have direct costs. Materials, personnel, supplies, and energy to assess habitat needs, plan projects, and carry out restoration efforts. These are the stuff of budget processes. What project inputs are used at what cost to change structural conditions to get improved habitat quality to successfully restore salmon populations? Normal accounting practice provides documentation of the human inputs to these projects; they are measured in terms of personnel hours, materials, supplies, and overhead.

Any given project planning/budgeting exercise must deal with at least the bottom two or three levels of this pyramid. Engineering/design teams typically develop a slate of inputs and related costs for a project to achieve some structural design criterion. For example, to fence five miles of stream over rough terrain and to re-plant streamside vegetation, the design team would determine needs for labor, materials, vehicles, and so forth. The cost estimate for the project is just the sum of these input costs. At Level 4 in the pyramid we have the information needed to discuss budgets: which categories of resources are directly used in changing the structure of that habitat, which cause changes in the conditions directly faced by the salmon.

The link between the top and bottom levels of the pyramid, however, is of fundamental importance to an economic assessment of the program. For either benefit-cost or cost-effectiveness analysis we need ultimately to link the expenditures on project inputs to the indicators of salmon restoration success. However, it is getting from the bottom of this pyramid to the top that can be a major problem for analysts. The quantitative link between the top level and the specific restoration projects is often fraught with uncertainty, theory, and controversy. Because salmon (especially coho, steelhead, and chinook) utilize such widespread features of the natural landscape over their life stages, each segment of the habitat can become a limiting factor. Is it spawning gravel, or deep pools for juveniles, or water flow during migration, or estuarine feeding areas, or ocean conditions, or upstream migration blockages that limit a particular salmon run? If the project being contemplated does not release the population from a binding constraint, then the project may achieve no significant success in augmenting the salmon population. And if the population does not increase, then there is no effectiveness and no economic benefit.

If we think about this in terms of basic microeconomics, we know that a "cost equation" reflects the accountant's budget; it is the sum of the price of inputs times the amount of those inputs; it is the wage rate times the hours and labor used, and the price of supplies times the number of supplies and the cost of renting times the square feet of office space, etc. All of these add up to costs estimated for project budgets. In order to do cost-effectiveness analysis, however, we use a more complex concept – the "cost function" which relates level of output to total costs, as in, "How much does it cost to produce 25 automobiles versus 50 automobiles?" The answer to that question requires thorough understanding of how the cost inputs will be used and of how the desired outcomes can be engineered and achieved by use of these inputs. That is a much more challenging analytical task than is the compilation of budgets for projects. To estimates costs of achieving particular outcomes (like salmon restoration indicators), we have to understand how units of inputs translate into a level of outputs. In microeconomics, the functional relationship between inputs and outputs is termed the *production function*. Above, I have used the pyramid metaphor to describe the same kind of linkage, involving cost accounting, engineering design, physical relationships, and (in the case of salmon) ecological/environmental relationships. These are the several steps needed to identify the budgets, people, and materials going into restoration and figuring out how to relate the costs to the outcomes that reflect project effectiveness or project benefits.

The above discussion suggests that the role of economists in the habitat restoration decisions is twofold. One is to help conceptualize the nature of the information requirements and choices being made. The other is — in collaboration with biologists, engineers and ecologist — to collect information and quantify the underlying technical and ecological relationships, so that the cost and benefits of specific projects can be displayed with enough confidence to justify attention by decision makers.

RECOMMENDATIONS

The outcome of our work responds to a need expressed by various planners and resources managers and emphasizes the need to develop generalized cost assessment techniques to improve decision-making. A systematic approach to reporting actual costs can resolve some of the issues related to uncertainty, as will sharing project experience. In addition, the more information that is shared across projects, the better restoration cost information will be more generally. Finally, as more projects are completed, maintenance and monitoring will become a much larger issue. The latter may suggest a need for more sampling and studies to look at these costs.

LITERATURE CITED

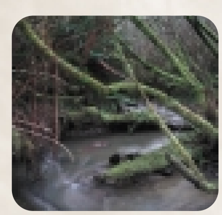
Freeman, A. Myrick III. 1993. *The Measurement of Environmental and Resource Values: Theory and Methods*. Washington, DC: Resources for the Future.

Gleaves, Karl and Katherine Wellman. 1992. Economics and the ESA. *The Public Land Law Review*. 13:149–165

Huppert, Daniel D. 1999. Snake River salmon recovery: quantifying the cost. *Contemporary Economic Policy*. 17(4):476–490.

Northwest Power Planning Council. 2001. *Inaugural Annual Report of the Columbia Basin Fish and Wildlife Program, 1978–1999.*

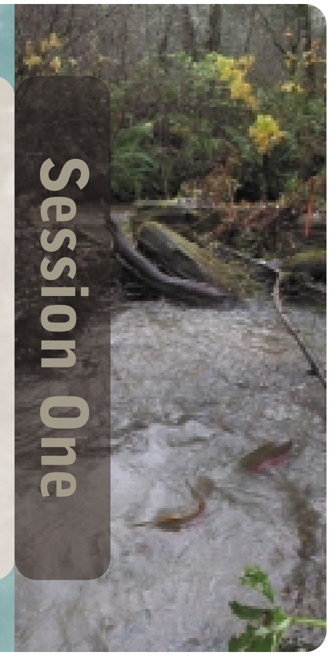
Whittlesey, Norman K. and Philip R. Wandschneider. 1992. Salmon recovery: as viewed by two economists. *Choices*. 2nd quarter:3–5.



Conceptual framework(s) for cost analysis

The Allocation Problem in Habitat Restoration

DAVID TOMBERLIN
National Marine Fisheries Service
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060
David.Tomberlin@noaa.gov



ABSTRACT

This paper explores the question of how best to allocate habitat restoration effort over space and time. Stylized examples are used to illustrate how threshold effects, competition among projects, risk, learning, and the choice of restoration objective affect desirable effort allocations. The paper concludes with some thoughts on the applicability of decision modeling to the habitat restoration planning problem.

INTRODUCTION

The allocation of limited resources over space and time is a key element of habitat restoration planning. Restoration planners must choose which activities to undertake, whether to spread effort among many projects or to focus on a few projects, and whether to launch projects as quickly as possible or to proceed experimentally. This paper identifies some salient features of this allocation problem, demonstrates their influence on desirable effort allocations, and assesses the suitability of decision modeling techniques for restoration planning.

The goal of habitat restoration may be expressed in general terms, such as "recover endangered species" or "improve habitat," but here the emphasis will be on goals that can be expressed as optimization problems, such as "maximize the number of returning spawners" or "minimize extinction risk for a population." The goal may be expressed in terms of restoration activity (e.g., miles of road decommissioned), human values (e.g., social welfare or economic impact), fish population characteristics (e.g., population size or extinction risk), or ecosystem characteristics (e.g., temperature change or reduced sediment load). Each of these can imply a different best allocation of restoration effort. This paper treats ecosystem characteristics as the yardstick by which success is measured and the level of restoration activity as the choice variable. Of course, it may in practice be very difficult to assess how ecosystem characteristics change in response to restoration effort.

Other aspects of the decision problem may be as important to the allocation decision as the chosen goal. Allocation decisions must be made at several spatial scales, and an allocation may be efficient in each of its parts yet inefficient as a whole. Cumulative (or threshold) effects within watersheds are likely, so that benefit is not a simple linear function of effort. Temporally, the possibility of learning from pilot projects must be weighed against the potential costs of waiting, and there are often lags between project implementation and efficacy. Metapopulation dynamics are both a spatial and a temporal complication. Importantly, decisions must be made under imperfect information about — or even ignorance of — both natural and social aspects of the project.

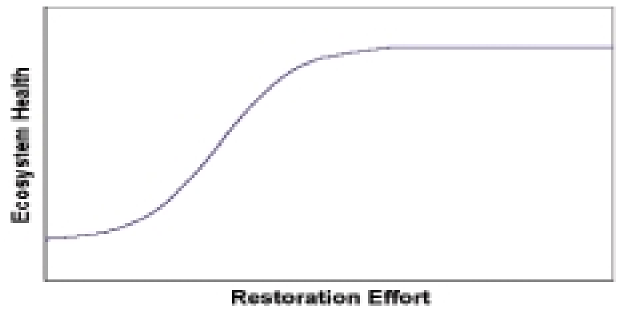
Below, stylized examples illustrate the importance of these considerations to the allocation problem. The next section addresses the spatial allocation problem in simple terms through a model with two competing projects. The paper then explores risk due to the inherent uncertainty of project outcomes, the possibility of learning from pilot projects, and the impact of an extremely risk-averse objective function on the desired effort allocation. The concluding section assesses the applicability of decision modeling to habitat restoration planning and suggests some elements of a decision science research to support this planning.

TWO RIVERS, ONE BUDGET[1]

Consider the problem of allocating restoration effort among two identical river basins so as to maximize some measure of ecosystem health. In each river, the more effort expended the greater is ecosystem health, but let us suppose that this relationship is sigmoidal rather than linear — that is, the marginal benefit of restoration effort is small at low effort levels, increases rapidly over the mid-range of effort, and decreases again as ecosystem health tapers off to some ceiling (Figure 1).

Suppose the goal is to maximize the sum of ecosystem health in the two basins, and that effort can be distributed between the rivers in any way, subject to a limit on total effort (i.e., a 'budget'). Letting H_i and E_i represent health and effort, respectively, in river *i*, the problem can be expressed as one of constrained optimization:

Figure 1. Cumulative effect



$$\text{maximize} \quad H_A + H_B \qquad (1)$$

subject to 1) $E_A + E_B \leq$ Budget (of time, personnel, funds, etc.)
2) H_i is the sigmoidal function of E_i shown in Fig. 1

Figures 2 and 3 depict this problem graphically by showing the health of the two rivers as mirror images — that is, E_A increases from the left and E_B from the right — which allows the sum $H_A + H_B$ to be depicted at all allocations of effort possible under a given budget constraint (here 12 and 6 units of effort, respectively). Figure 2 shows that when the budget is high relative to what's required to achieve maximum health, it is best to split the effort evenly among the rivers. By contrast, Figure 3 shows that when the budget is relatively small, it is best to concentrate the effort on one river. Given this problem, then, if the budget is very large, many distributions will be optimal or nearly so — but if the budget is small, spreading it among projects is a very poor allocation.

The problem as posed is not realistic, but the simple model provides a clear picture of how rules of thumb (e.g., "address the worst

1- This section follows Wu and Boggess (2000), who analyze the link between fish populations and habitat restoration efforts in the John Day River of Oregon.

Figure 2. Competing projects — large budget case

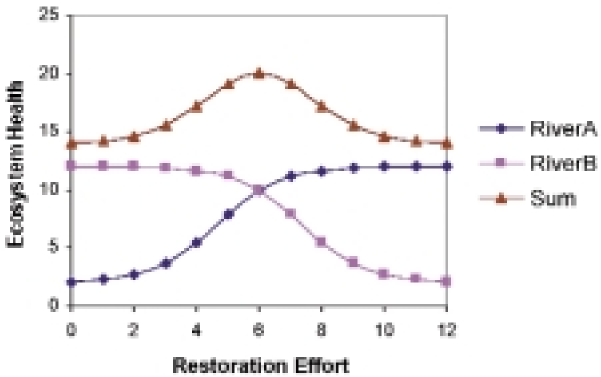
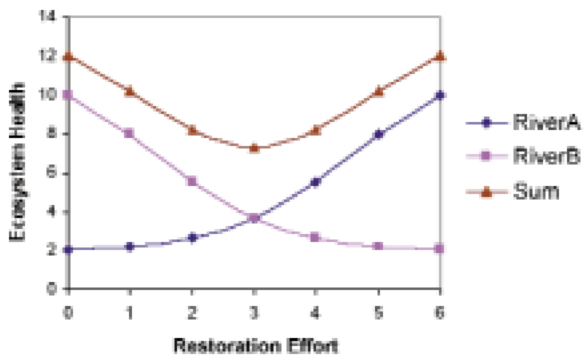


Figure 3. Competing projects — small budget case



problems first", or "spread the budget widely among projects") may lead to ineffective resource use. More complicated scenarios (heterogeneous rivers, differential responsiveness to restoration effort, etc.) can be formulated as linear or nonlinear programming problems to suggest allocations and to test the sensitivity of different plans to assumptions about model parameters.

INTRODUCING UNCERTAINTY

A serious weakness of the above analysis is that it ignores uncertainty about project outcomes. If outcomes are uncertain in the small-budget case described above, for example, diversification across projects might be desired to reduce the chance of an entirely disastrous outcome, even though we have seen that when outcomes are known with certainty all effort should be expended on a single river. The degree to which outcome risk influences the preferred course of action depends on both the degree of uncertainty about outcomes and on the decisionmaker's attitude toward risk.

A straightforward way to incorporate risk in the analysis is a mean-variance objective function, commonly used for portfolio analysis (see, for example, Bodie, Markus, and Kane 1996)[2]. In this approach, the decision problem is to maximize the expected value of the outcome less some penalty for variability, which is a function of the variance of the sum of ecosystem health in the rivers and a penalty parameter k:

$$\text{Maximize} \quad E(H_A + H_B) - kV(H_A + H_B) \qquad (2)$$

subject to the same constraints as before. Here, the parameter k represents the decisionmaker's degree of aversion to risk.

Figure 4 shows one river's ecosystem health as a function of restoration effort expended on an uncertain project for which two discrete outcomes are possible. While the expected value (the dashed line) is the same as the deterministic values in Figure 2, here two outcomes are possible, High or Low. Given this uncertainty in two rivers, the decisionmaker must choose how to allocate effort.

Figure 4. Discrete uncertain outcomes — small budget case

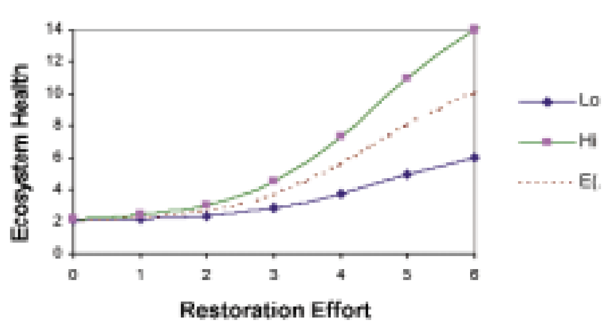
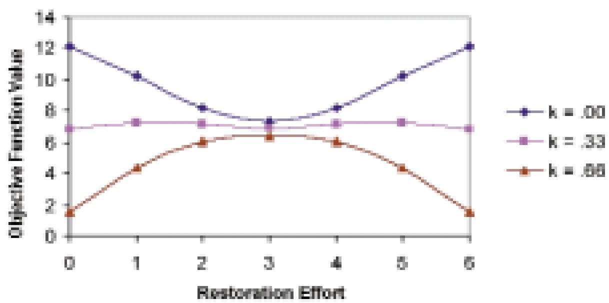


Figure 5 shows the value of the objective (2) under different values of the risk aversion

2- This approach is based on a particular implicit utility function (see e.g., Varian 1993 pp. 189-90).

Figure 5. E(A+B) - kV(A+B) — small budget case



parameter *k*. The objective value, which is now a function of ecosytem health, increases from the left for River A and from the right for River B, as before. When the decision-maker doesn't care about risk ($k = 0$), the best strategy is to focus all effort on one river, just as in the no-risk case from the previous section; when *k* is high, it is preferable to spread the funds among projects, that is, to hedge bets.

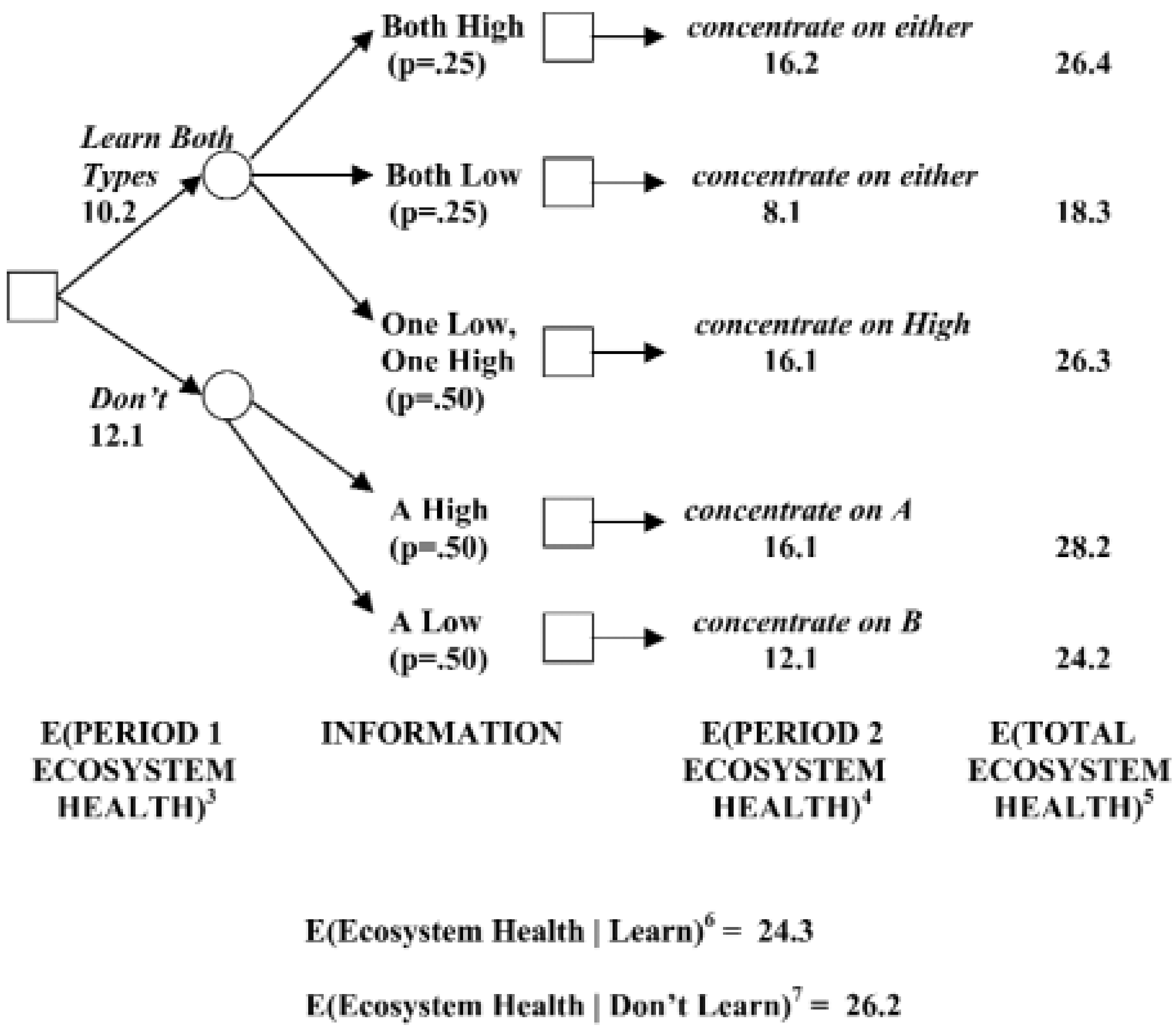
Quadratic programming, with the objective of minimizing the variance of total benefit subject to some minimum level of benefits, is a convenient way to solve more general problems of this sort. Extinction risk can also be addressed in the allocation problem via an appropriately articulated goal.

LEARNING FROM PILOT PROJECTS

Pilot projects, field trials or other information gathering may reduce uncertainty in many cases, allowing managers to make more informed decisions. The gains from learning must be weighed against the potential cost of waiting, and usually neither can be known with certainty.

The economics literature on learning is extensive (and, by the way, similar to the ecology literature on optimal foraging). Decision trees provide one simple tool for assessing the value of experimentation. Imagine the same uncertainty over outcomes as in the previous section, except that the planner now faces the same allocation decision in two consecutive years, and has the option to reduce uncertainty by learning: by investing at least one unit of effort in a river, the planner can learn the river's "type," which may be either High (i.e., very responsive to restoration work) or Low. Suppose knowing a river's type removes all uncertainty about how it will respond to restoration effort. While knowing the type of both rivers could aid the planner, the information comes at a cost if the planner is risk-neutral, because it can only be obtained by foregoing the option to concentrate effort entirely on one river (recall from Figure 5 that the best decision in the small-budget case, given risk neutrality, was to concentrate on one river). Figure 6 shows a simple example of a decision tree when outcomes are described by the sigmoidal function of previous sections, with uncertain results and a small budget, as in Figure 5. The left-most box represents the time at which the planner chooses whether to invest at least some effort in both rivers so as to learn both their types. The circles represent probability nodes, the planner's estimates of the probabilities of various outcomes depending on the decision made in the first period. In period one, the planner chooses whether to invest in learning, which implies a lower first-period expected benefit but reveals the types of both rivers. After this decision is made, the planner acquires the first-period benefit (10.2 or 12.1) and learns the type of one or both rivers. In period two, if the planner knows the type of both rivers, there will be no uncertainty about the best allocation, and the planner can simply choose the best strategy depending on the information now available. Depending on whether the types are both High, both Low, or mixed, the second-period benefits are 16.2, 8.1, or 16.1, respectively. By contrast, if the planner did not invest in information gathering in period 1, but chose to concentrate all effort on River A, the optimal choice will depend on the revelation

Figure 6. A decision tree. This figure shows, from left to right, actions and probabilities of uncertain outcomes before action is taken in period 1. If the planner invests in learning the types of both rivers, there is no uncertainty left in period two. If the planner does not make this investment and learns the type of only one river (here River A), there is still uncertainty about River B's type, but this node is not shown since it is not needed for the planner to make the optimal decision. The planner's problem is to choose the action plan that maximizes the expected benefit of restoration. As the results at the bottom show, in this case not learning turns out to be a better plan (in expectation).



3- Derived from the risk-neutral scenario (k=0.00) in Figure 5: 12.1 corresponds to the highest achievable level of ecosystem health when restoration is concentrated on one river; 10.2 corresponds to the highest achievable level of ecosystem health when at least one unit of the budget is spent on each river, which is necessary to learn the type of both rivers.

4- Derived from Figure 4 for the small budget scenario (total restoration effort = 6) as follows:

16.2 = 14.0 (ecosytem health associated with applying effort=6 to either river of High type)
+ 2.2 (ecosytem health associated with applying effort=0 to the other river of High type)

8.1 = 6.0 (ecosytem health associated with applying effort=6 to either river of Low type)
+ 2.1 (ecosytem health associated with applying effort=0 to the other river of Low type)

16.1 = 14.0 (ecosytem health associated with applying effort=6 to the river of High type)
+ 2.1 (ecosytem health associated with applying effort=0 to the river of Low type)

16.1 = 14.0 (ecosytem health associated with applying effort=6 to River A, type High)
+ 2.1 (expected ecosytem health of applying effort=0 to River B, type unknown)

12.1 = 2.1 (ecosytem health associated with applying effort=0 to River A, type Low)
+ 10.0 (expected ecosytem health of applying effort=6 to River B, type unknown).

5- Sum of Period 1 and Period 2 ecosystem health.

6- 24.3 = 0.25*26.4 + 0.25*18.3 + 0.5*26.3.

7- 26.2 = 0.5*28.2 + 0.5*24.2.

of A's type. If A is revealed to be 'High', the best thing to do is sink all of the next period's budget into A, since it is a sure thing. If A turns out to be 'Low', the best thing to do is bet that B will be 'High'. The decision tree shows the set of possible actions and their expected outcomes. In this (entirely artificial) case, the expected value of learning does not merit the cost, so the planner would be better off (in expectation) to plunge ahead without learning the type of both rivers.

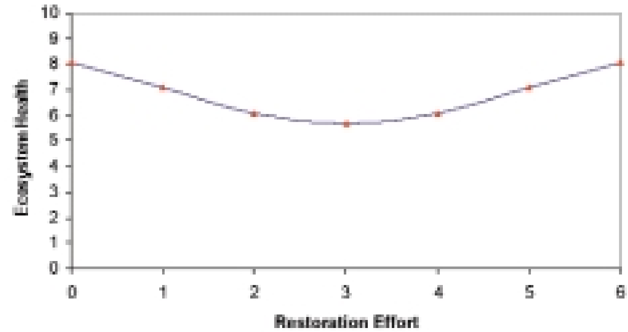
While this example assumes that investing in learning leads to definitive results, the learning process will usually only produce new, but still uncertain, estimates of outcome probabilities. It may even be the case that nothing is learned. Appropriate modification of the decision tree can address these complications. Risk-aversion can also be incorporated into a decision tree via introduction of an appropriate utility function (see Winston 1994 for an accessible introduction). Other analytical techniques to address intertemporal planning problems include dynamic programming (essentially a generalized decision tree representation) and simulation.

DIFFERENT GOALS, DIFFERENT ALLOCATIONS

The scenarios above have assumed that the desired effort allocation maximizes the expected value of ecosystem health, with perhaps a penalty for risk. Another type of goal, often motivated by strong risk aversion or by lack of information, is to maximize ecosystem health in the worst-case scenario (known as the "maximin" strategy). This strategy implies that the decision-maker does not consider the upside potential of risk, but is instead focused entirely on avoiding very bad outcomes.

Figure 7 depicts such a strategy[8]. The choice set is exactly the choice set under uncertainty when both rivers turn out to be type Low (that is, in the worst-case scenario). The goal is to choose an allocation that will make the best of this worst situation. Given the small budget and this objective, the best we can do is concentrate on one river or the other. Doing so allows us to avoid the worst possible outcome, which would result from splitting effort equally among two rivers that both turn out to be the Low type.

Figure 7. Maximin strategy — small budget



The maximin strategy does not require that outcome probabilities be known or estimated, as long as the set of possible outcomes can be defined. It may be useful as a way for planners to formalize notions of the safe minimum standard (from the economics literature) and the precautionary approach (from the conservation biology literature). In addition to maximin and maximizing expected value of the outcome, many other formulations of the goal can be considered (see Winston 1994 for some examples).

CAN DECISION MODELING CONTRIBUTE TO HABITAT RESTORATION PLANNING?

Restoration planning without reference to a well-posed decision problem may result in significant missed opportunities. For example, failure to account for a nonlinear relation between restoration effort and benefits, such as in the first example above, could lead to greatly reduced restoration efficacy. In the context of habitat restoration planning, a well-posed decision problem should explicitly address threshold effects, budget limitations, risk, and opportunities for exper-

8- Derived by graphing the Low outcome from Figure 4 for Rivers A and B (with HA increasing from the left and HB from the right), then taking their sum.

imentation, if at all possible. A clear statement of the objective is also essential, because different objectives, even when they share the same general aim of conserving endangered species, may result in quite different preferred effort allocations. The modeling approach described in this paper requires that a link between effort and outcomes be established, at least probabilistically. Without this link, there is little basis for taking decisions.

Assuming a coherent decision problem can be developed, what might habitat restoration planners gain by using decision models of the sort described above? In practical terms, models may produce situation-specific results or aid in the development of rules of thumb that can be used across projects, watersheds, and populations. Conceptually, modeling can address uncertainty, scale issues, extinction risk, and the incorporation of information through Bayesian learning, multiple objectives, multiple inputs, and multiple outputs. While models that produce precise prescriptions are almost surely unattainable in the field of habitat restoration planning, modeling can bring focus to planning discussion and help prioritize information gathering needs.

Mathematical programming models drawing on the many tools available in the operations research literature have been stressed above. Analytical models can also provide some useful insight into the nature of the problem, and with a range of plausible parameters can test whether there may be some reasonably robust rules of thumb for allocation. Simulation models may be helpful when the complexity of the system makes mathematical programming intractable.

The stylized examples presented above suggest a research agenda, focusing on information and risk, for the decision science aspect of habitat restoration planning. Key elements of this agenda might include:

- Representing the “technology” of habitat restoration, such as substitutability or complementarity of activities in habitat restoration, which could imply very different efficient effort allocations.

- Models to identify effective information acquisition strategies.

- Linking a restoration effort allocation model to a model of extinction risk, which could enable planners to address, for example, the feasibility of mitigating habitat loss by increasing restoration effort on other lands.

- Providing a framework for considering trade-offs among risks (short-term vs. long-term risks, risks in one population vs. in another).

- Explicitly introducing metapopulation structure and dynamics into the allocation problem.

LITERATURE CITED

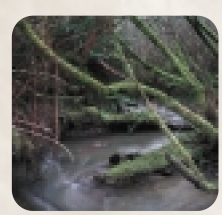
Bodie, Zvi, Alex Kane, and Alan J. Marcus. 1996. *Investments*. 3rd edition. Chicago: Irwin.

Varian, Hal. 1993. *Microeconomic Analysis*. 3rd edition. New York: W.W. Norton.

Wu, JunJie, Richard M. Adams, and William G. Boggess. 2000. Cumulative Effects and Optimal Targeting of Conservation Efforts: Steelhead Trout Habitat Enhancements in Oregon. *American Journal of Agricultural Economics* 82(May):400-413.

LITERATURE CITED (CONT'D.)

Winston, Wayne L. 1994. *Operations Research: Applications and Algorithms*. 3rd edition. Belmont, CA: Duxbury Press.

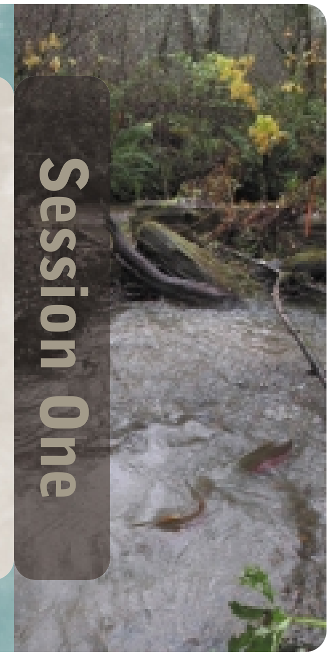


Conceptual framework(s) for cost analysis

Understanding the Estimation and Uncertainty in the Costs of Ecosystem Restoration

KATHARINE WELLMAN, Ph.D.
Battelle Seattle Research Center
P.O. Box 5395,
Seattle, WA 98105-5428
kfwellman@attbi.org

Session One



ABSTRACT

The estimation and accounting of direct financial costs of environmental restoration is challenging. In addition to the general lack of accurate cost accounting, recent experience has shown that the task of estimating costs for aquatic ecosystem restoration projects is subject to considerable uncertainty. This uncertainty often manifests itself in a significant difference between projected and actual costs of restoration projects. This presentation outline describes an analysis of available direct cost information for several aquatic habitat restoration projects and attempts to explain the uncertainty in the cost information that exists.

INTRODUCTION

This presentation outline briefly highlights results from an analysis of habitat restoration project costs and reviews findings of preliminary efforts to examine the factors that contribute to differences between projected costs and actual expenditures or the uncertainty factors in estimating costs. This work is based on research conducted by the Battelle Seattle Research Center as a part of two larger research and development programs of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers (USACE):

1. The Evaluation of Environmental Investments Program which was designed to compile and compare management measures, engineering features, monitoring techniques, and detailed costs for a representative sample of “non” USACE environmental projects, and

2. The Risk Analysis of Water Resources Investments which was designed to develop approaches to issues of risk and uncertainty that arise in water resource planning, engineering, and design.

DIRECT COST ANALYSIS OF NON-USACE RESTORATION PROJECTS

Approach

A number of attempts have been made in the past to analyze restoration costs. Some of the primary studies we examined as part of our literature search are listed in Table 1. Notice the significant variation in total per acre costs (reported in nominal terms) across the studies. Given the former, we worked to overcome some of the past limitations of restoration costs estimation efforts and derive unit costs estimates for each component of a project from a representative sample of wetland and habitat restoration projects across the U.S. In particular, we were interested in examining the unit-cost estimates for each component of each restoration project, in hopes of getting truly specific information on the financial costs of habitat restoration.

In this first study we reviewed over 90 non-USACE habitat restoration projects across the U.S. The data for our final analysis was derived from 39 of the most comprehensive of these projects. Table 2 lists ranges of costs of components that appeared more than once in our sample for which total and per unit costs were reported.[1]

Findings

We found that because the elements associated with the restoration projects analyzed vary across projects, and costs are allocated in different ways across the entire sample, it was impossible to make any statistically significant comparisons of the costs of specific components across projects.

We did find, however through a qualitative review that there are several factors that affect restoration project costs (Table 3). Factors like economies of scale have a significant impact on costs, as does the type of restoration. Design, initial site quality and adjacent site quality also affect costs, as does the baseline condition from which the project begins. If the project involves something that has already been restored, the costs will differ from a site that has not been touched yet. Appropriate technology, simultaneous construction or use at the site, and project management will also impact costs.

ANALYSIS OF UNCERTAINTY IN RESTORATION COST ACCOUNTING

Approach

In our second project, we attempted to analyze the uncertainty in restoration cost accounting or the basic systematic factors

Table 1. Non-USACE restoration cost studies

STUDY	PROJECT TYPES	COST RANGES
King and Bohlen (1994)	Wetland mitigation	$5 to $1.5 million per acre
Guinon (1989)	Wetland restoration	$1,626 to $240,000 per acre
NOAA (1992)	Wetland creation	$485 to $70,000 per hectare
DOI (1991)	Wetland restoration, creation, mitigation	$2,000 to $50,000 per acre

1- This cost data is reported in 1995 dollars.

Table 2. Comparable construction costs

ACTIVITY TYPE	COST RANGES
Gravel removal	\$3.27 to \$3,239 per ton
Rip rap installation	\$5.00 to \$19.00 per ton
Culvert installation	\$150 (for 48” diameter culvert) to \$1,103.85 per ft.
Channel cleaning	\$4.00 to \$8.00 per m^3.
Erosion control	\$1.40 to \$4.00 per ft^2.
Dike removal	\$1.92 to \$2.67 per linear ft.
Dike/dam/levees construction	\$5.00 to \$20.00 per linear ft.

Table 3. Primary factors affecting restoration costs

- Economies of scale
- Type of restoration
- Restoration design
- Restoration site quality
- Adjacent site quality
- Appropriate technology
- Simultaneous construction/multiple use
- Project management

that contribute to the difference between estimated and actual project costs. We wanted to determine whether cost differences was driven by errors in estimating the costs of labor and/or materials, or whether factors such as design difficulties and unanticipated site conditions were most directly responsible. Ultimately we hoped to identify procedural improvements for estimating and tracking project costs.

Data on estimated costs and actual expenditures were gathered for this study through several databases and paper files. In addition, a telephone survey targeted at project managers was developed and implemented. At their request, USACE projects — including Section 1135, their upper Mississippi program, and the Breaux Bill (Coastal Wetlands Planning, Protection, and Restoration Act) program — were the focus of our analysis. Data gathered from previous IWR studies were also used.

In the end, information on 47 projects was collected nationwide. A significant number were Midwest projects, as that is where many restoration efforts have been carried out. Some of the projects were from the West Coast and some were South Central Louisiana Corps projects. Data were categorized in terms of project types, separating the projects into *river/lake*, *wetlands*, and *other general habitat restoration* projects. Several of these included a salmon habitat restoration component. Data were also categorized in terms of management measures and whether the project involved a water control structure, re-vegetation, or what we called an "integrated ecosystem" restoration (e.g., removing a culvert and doing some replanting — anything that included more than one component).

The area of habitat restoration is a relatively new and evolving area of emphasis. Therefore, we focused on relatively recent projects that reflect the practical knowledge gained from past restoration efforts. Most projects included in the final sample were completed some time within the last ten years.

Our fundamental approach was to compare estimated costs to actual expenditures. We started by collecting our cost information at a very detailed level, looking again at materials, labor, monitoring, and maintenance. However we ultimately focused on three broad categories: planning and design, construction and construction management, and maintenance and monitoring costs. We had to aggregate back up again because of inconsistencies in the reporting and because we did not find the refined level of information we were seeking. Our final analysis focused on those projects with a "significant" difference between estimated and actual cost. "Significant" we arbitrarily defined as cost overruns or underruns of at least $100,000 or 20% of the original estimate.

Findings

Cost Discrepancies

The projects analyzed reflected a wide range of costs, as expected from past experience. We discovered that the wetland projects were less costly than most of the river and lake projects. We also discovered many of the least costly projects focused on re-vegetation or small drainage kinds of projects. The larger, integrated multi-dimensional projects were the most costly.

Approximately 30% of the sample involved some kind of cost overrun. A comparable percentage of projects were significantly under budget. Overruns varied from less than $100,000 to more than $2 million. The majority of cost overruns were related to construction rather than additional planning. On average, 95% of added cost went into construction. (Note, however, that this doesn't eliminate planning and design as important to cost uncertainty.) We discovered in talking to project managers and planners that the central problem lies in lack of thorough planning. Managers often reported they felt pushed to move in and implement before they were comfortable with their site preparation, site analysis, or planning activity. This approach has led to project change orders, delays, etc.

Further, it was learned that cost discrepancies decrease with cumulative experience, as only four of the projects completed since 1997 had major overruns. Learning therefore appears to be significantly related to uncertainty.

Cost overruns were more common in river and lake projects than in wetland creation and restoration projects (9 of 14). Some further analysis into the data and interview information indicated two reasons for this. First, the river/lake category included a number of larger projects where a general lack of experience could have played a part. Second, a number of the contractors were apparently less familiar with some of these types of larger river/lake projects. That unfamiliarity, combined with lack of cumulative experience, may have led to greater cost overruns.

Critical Factors in Restoration Cost Uncertainty

In the project-manager survey mentioned earlier, we asked a number of specific questions. Interestingly, across all the different types of projects, the same kinds of responses came up again and again. In talking to these individuals the uncertainty (discrepancies) that we had expected was not necessarily linked to cost reporting or cost accounting, but to a wider variety of factors as outlined below:

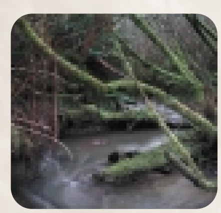
Incomplete site surveys: Unexpectedly difficult working conditions can always lead to cost overrun. Planners understand that a more detailed survey of a site may be important, but it clearly costs more money. There exists a significant tradeoff: How much time do you spend on sites before you design your project and move ahead toward implementation?

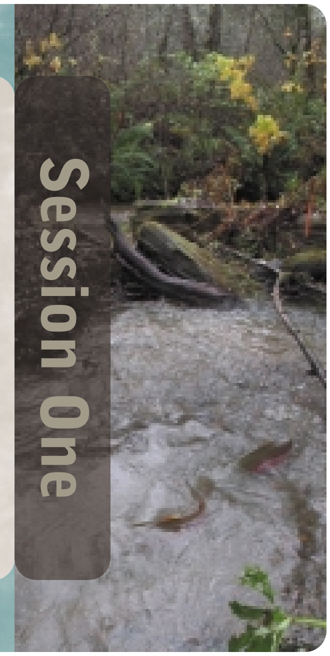
Insufficiently detailed planning: Local partners often feel pushed to "turn over the soil" before they feel prepared to move into implementation.

Project experience: Over time, experience can reduce some cost uncertainty.

Project scheduling or habitat protection: Often there is a need to suspend work to protect habitat areas during critical periods, whether it is spawning, mating, etc. Such suspensions can impact the cost of a project. This is a particularly interesting issue in salmon habitat restoration.

Difficulties with land acquisition: There can often be conflict with a property owner when needing to purchase and/or use a particular property. There can also be disputes over compensation. All of this takes time and adds to the costs of the program.





Conceptual framework(s) for cost analysis

Variables in Habitat Restoration Costs

MARK SHAW
Bonneville Power Administration
PO Box 3621
Portland, OR 97208-3621
mashaw@bpa.gov

ABSTRACT

This paper discusses some of the variability in habitat restoration costs and the many factors that capture that variability, including project design, project time, and choice of implementation tools. The paper presents examples and experience from different restoration activities, and the funding of these projects, conducted through the Bonneville Power Administration in the Columbia River Basin.

INTRODUCTION

Out of the $125 million that the Bonneville Power Administration (BPA) spends under its Fish and Wildlife Program annually, $40-50 million is spent on habitat restoration activities. This amount of funding and resulting assessment and analysis has provided BPA with a good idea of the variables and costs in some of its programs.

As with other agencies and organizations, BPA is seeing an increase in engineering and design costs because of increasing necessity. Over the past year and in conjunction with the Northwest Power Planning Council, projects are now coming to BPA in phased budgets. This new format was precipitated by large construction projects with incredible cost overruns. Projects planned for $2 million would go to $16-20 million. Clearly, we needed to find a solution, so we began structuring projects and their projected budgets in phases. First, planning costs, then construction and implementation costs, then monitoring and evaluation costs, and finally operation and maintenance costs. This is the first year that we have required this of our project sponsors, and the transition has not been easy because, understandably, most biologists are better at doing the job than estimating the cost. But they are getting a lot better at it, and so are we. Our focus on the long-term aspects of a project makes it crucial that we balance our operation and maintenance costs so that there is money left for implementation.

COST VARIABLES

Hidden Costs and Variations in Experience

In any restoration project, it is important to examine the often hidden engineering and design costs that result from collaboration with other agencies. Such costs are often not clearly reflected. For example, BPA has a Natural Resources Conservation Service Stream Team (NRCSST) in southeast Washington, which contributes on average $400-500,000 a year over a series of projects in that area. In addition, the NRCSST provides limited technical and policy support out of the regional office in Portland to projects throughout the basin. Engineers hired from other federal agencies such as the Bureau of Reclamation, have provided engineering support and staffing in the Grande Ronde Model Watershed and the Lemhi Model Watershed. Those costs are separate, then, from other project costs and not reflected in the totals.

Cost variability can also come when using retired state or federal engineers. Often these retirees view such involvement as a sort of hobby. Hence, they charge much less (e.g. $35 per hour) for a retiree compared with an engineer from a professional engineering firm, that can cost as much as $150 per hour.

Experience can vary as well from one firm to another, impacting costs. On a project in north central Washington, one engineering firm bid $20 per foot on irrigation diversion costs, and another bid $3.50 per foot. A good deal of that variation was based on their relative experience (e.g., whether a firm has ever really worked in a rural area, or has experience limited to laying sewer pipe in the city).

Timing of Contracts

When a request for bid goes out, timing of that request can impact the cost because it impacts the availability of firms and individuals. Statistics show that when a call for bids goes out in a rush, higher bids are received just as they are late in the season. Early calls for bids may well produce lower bids. When you get behind in your scheduling and timing, your request for bid is going out to firms that may already have a full schedule. Invariably, they come in to you with higher bids. Early in the season, firms are hungry for jobs and are willing to come in at lower bids.

Acts of God

Unpredictable events will invariably affect project costs. For example, during a bad fire season such as the one we recently experienced, you might not be able to hire a contractor with a front-end loader, since they would all be on the fire lines somewhere. And if you did locate one, they might bid their costs extremely high, as the demand for their services was high. Another example is the 1996-97 flood season when every contractor was occupied. Projects during that period experienced incredible variability in costs.

Mechanized Versus Hand Labor

There's a real revolution and a lot of learning occurring in the cost of revegetating and planting trees in riparian areas. As an example, a project on Asotin Creek (SE Washington), for two or three years used hand labor from the Salmon Corps and high school students, which was relatively low cost. But, over time, the effectiveness of doing that was very, very low. We have switched to mechanized labor (for example, using a Cat ripper and plunger on Asotin Creek and Tucannon River) where it's physically feasible to use those methods. That doesn't mean to say that very innovative specialized equipment might not cost more, but the success rate may be high enough to balance out the increase in cost.

Type of Equipment

Additional cost variables arrives with equipment choices. How big a channel is being dug? What size of front-end loader is needed to get in there? Does access into the channel require a very specialized piece of equipment, such as a front-end loader, track hoe, or a spider? Some of those costs can change a great deal from time of estimation.

Availability of Materials and Access to Them

In a BPA project on the Grande Ronde River (NE Oregon), our only access method to large woody debris, in this case from a blow-down, was a very large Chinook helicopter. This was very expensive, but to meet the objective of that project, it was the only way to get those trees off the ridge. That's where arbitrary cost effectiveness is difficult to come by if we're to meet the objectives of a project and restore natural function to a channel.

Availability of materials can increase costs dramatically. The cost of hauling rock to an area may increase the price of that rock 2-3 times. And changes in Federal forest practice also impact variations in cost. Very little tree cutting is occurring, especially on West Side forests that are in the range of the spotted owl. This is the case in the upper Salmon as well. Materials have become very scarce due, in part, to changes in both state and federal land practices, thus driving up costs (if you can find material at all).

Time (and Money) Spent Searching for Materials

The scarcity of materials means spending time and money to find them. Of course, advance planning can be helpful as staff can keep an eye out for materials. Sometimes timing is accidental, and materials become plentiful and easily accessible. In one instance, a windstorm blew through an area about two weeks before a project was to take place, and it literally blew down about a thousand trees. All of a sudden, materials availability went up and the cost went down for that particular project.

Size of the site also has an impact. At our Soda Creek project we are working in a channel that is 20-30 feet wide in a flood-prone stage versus in the Grande Ronde, where a site is easily 2-3 times that large. In the systems up in the Yakima and some of the larger rivers, costs can go up considerably due to the size of the equipment needed, the size of the rock, the root balls in the logs, etc. Or if a large channel is very sensitive to sediment and diverting those flows becomes necessary, a new channel has to be created; in a smaller channel, a smaller diversion would be needed. The unpredictability of the work and the materials needed influences the costs.

Complexity of design and requested material may also substantially change project cost. Specialized materials for a highly engineered concrete and steel structure versus using natural materials for the same results will result in substantially different costs. Fencing a riparian exclosure can take on several different designs. A simple, portable electric fence may meet a projects need, or it may require a multiple strand smooth wire high tensile fence, or a log buck and pole fence. Costs for such fences will vary widely depending on access and location to the construction site and availability of materials if using natural materials such as log poles.

Land Purchases

A number of issues impact the cost of land purchases. Most obviously, the cost is always based on an appraisal and a comparison with like property values in the area. Then the value of the water has an influence. In the desert, for example, it takes 40 acres to graze a cow for one season. The land doesn't grow very much, but the value of this area is increased many times with the value of an aquifer and the clean storage of water.

Costs can vary considerably if contamination clean up is required. For example, we purchased a contaminated property near Hermiston, Oregon, a necessary political move. The clean up of such an area that must be purchased can significantly drive up costs.

A further issue occurs if an area is rich in culture and resources. This impacts how much restoration activity can take place, whether monitored excavations are needed, and how much that costs.

And if the state where the project is located has in lieu taxes, over time, this can considerably change the cost of purchasing the land. The federal government (BPA is a federal agency) generally does not pay state or local property taxes, but in some cases where Bonneville does not maintain ownership of a fish and wildlife mitigation purchase, the controlling entity does pay property taxes through the property's Operations and Maintenance budget. We do a lot of irrigation diversion screening. The costs vary by the size of the diversion you're taking out and whether or not you have access. Purchasing easements to get in to the site also contributes to the costs. In the Yakima, we've learned that land costs can differ considerably and that politics can play a part. We have been taken to court a few times, as the owner tried to get the money he thought was appropriate. Another factor can be the views of the judge as to federal government involvement, which may influence the price of a particular property.

Instream Structures

Another contributing factor is the availability of trained and experienced experts. In some projects in the Grande Ronde, we have literally cut the costs in half by assembling, over time, a group of contractors with the experience to put a project in. Experience in design and options in construction techniques are really helpful. There is an old joke that asks how many engineers it takes to put in a j hook vane (a small rock structure put into a stream to protect the bank and enhance habitat diversity). The answer — depends on how many engineers are around. If there are lots available, it will take four or five of them to do the job, but with experience, it may take only one. We're finding a lot of variability in cost effectiveness when we hire outside contractors or whether we have teams of agency people, or contributed agency design time, who can cost effectively design and implement the projects. In addition, some design standards require more materials. A conservation district, for instance, is required by law to have their design comply with the Natural Resources Conservation Service (NRCS) design standards. The NRCS has certain design standards that rely on a strict interpretation of engineering design standards. I'm not trying to denigrate the NRCS, but they are moving slowly as to certain advances in instream engineering designs. For example, some rock structures on the Tucannon River done five or six years ago would literally fill up a large conference room. However, today we are using a tenth of the materials to do the same kind of project because we are making better decisions in design. Another NRCS factor is that their regulations require multiple levels of review, which can add to the costs.

A lot of innovation during construction is occurring. If your project has team members who really know their stuff, it can save considerable money when they're putting the projects in.

Easements

The use of easements is quite common now in our wildlife program, and we're getting into it as well with the fisheries program. We talked about cooperating with the Conservation Reserve Enhancement

Program (CREP) which has allocated $500 million dollars to Washington, Oregon and Idaho. We are actively supplementing some of the costs of implementing CREP to make them more attractive to the landowners. This extent of project supplementation varies by state and by whether we do a project ourselves or whether we use those same standards or standards established by other regulatory agencies.

Another cost variable is the time period of the easement, whether the rancher or farmer is willing to accept a 10- or 15-year easement or whether he wants a permanent easement. In a project under current consideration in John Day, potential purchases there may be impacted by something new: developer rights in the easements. In other words, keeping development off these properties is going to increase the cost in some areas.

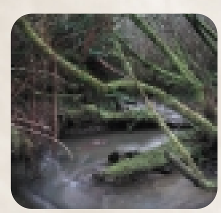
Variability in Costs on Habitat Restoration Projects

There can be a significant range of variability within the cost of stream restoration for projects that we fund right now. These projects include complete channel restoration, recreating natural form and function on a river. In a U.S. Army Corps of Engineers project here in Oregon, the cost has varied from $48 per linear foot in Southern Oregon to $100–140 per linear foot in Eastern Oregon. In an Oregon Department of Fish and Wildlife stream project in the Umatilla, the cost was upwards of $170 per linear foot; however, after some experience was gained in different areas, the cost was reduced to about $60 per foot. (Note: these figures may not reflect all costs.) For example, the cost of a project on the Red River, tributary to the Clearwater, ranged from $100 a foot upwards to $170 a foot. I would actually go up to $170 per foot for something that is actually going to last and actually produce some benefits for us.

David Rosgen in Colorado, the fluvial geomorphologist, has been one of the pioneers in the stream restoration techniques here in the Western United States. With his experience, he can get costs down to $17–$35 per foot, which shows the value of experience and innovation and ability to change. This kind of experience is highly valuable to have on a project. In two meander reconstruction projects on Asotin Creek, some of the crew had worked with Rosgen and we were able to get the costs down to about $37 per foot.

In another example project, we used an engineering firm and a retired engineer who was willing to keep the costs down. On Bear Creek in the Wallowa system, we put in a series of rock vortex weirs where there had been a channel widening due to channelization. The rock vortex weirs, facing downstream, decreased the channel width enough to create pool habitat at a cost of about $20 per foot.

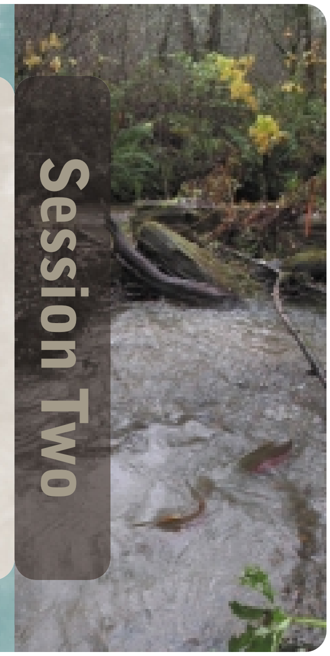
I think we are learning on both the local and global area. On the BPA web site there are examples of projects (www.bpa.gov) where good cost assessments have been done. I believe we're getting a lot smarter about controlling our costs, and I think if we pay a little more attention to these things and look at the reports that are available, we can get a lot closer than we are at estimating costs.



Road maintenance, road decommissioning, and stream crossing upgrades

Estimating Costs of Road Decommissions

BENGT COFFIN, Hydrologist
USDA Forest Service
Mt. Adams Ranger District
2455 Highway 141
Trout Lake, WA 98650
bcoffin@fs.fed.us



ABSTRACT

Road decommissioning has become one of the more common and beneficial restoration treatments applied to forested watersheds. Decommissions can look substantially different from watershed-to-watershed as a result of differences in landforms, conditions and local issues, as well as differences between practitioners and treatment approaches. Costs for decommissions can vary widely as well as a result of these differences. Cost estimates for decommissioning can be developed at any scale, but for high confidence in the estimates, on-the-ground surveys are essential.

INTRODUCTION

This paper summarizes the methods used for developing and refining cost estimates for road decommissions on the Mt. Adams Ranger District of the Gifford Pinchot National Forest. It describes some of the key information needs associated with developing cost estimates, identifies some of the reasons costs may vary between decommission projects, and identifies some of the issues that may be encountered when estimating decommission costs at larger scales. The basis for this paper is work that has been conducted on the Mt. Adams District over the past several years, during which time over 100 miles of road have been decommissioned. The paper is organized by major headings that were suggested by the National Marine Fisheries Service (NMFS) for this presentation. It begins with a brief synopsis of what is entailed in road decommissioning on the Mt. Adams District.

WORKING DEFINITION OF ROAD DECOMMISSIONING

There are many different interpretations of the term "road decommissioning." To some it means closing a road, walking away from it, and taking it off the road inventory. To others it implies full recontouring of the hillslope where the road was constructed. On the Mt. Adams Ranger District, our intent in decommissioning a road is to remove the drainage structures that reroute hillslope drainage and that present slope stability hazards. This requires removal of culverts, eliminating the need for roadside ditches, and removal of fill material from stream channels and from unstable locations. In addition, the road surface is scarified to improve infiltration, promote the establishment of vegetation, and to reduce overland water flows. A typical road decommission on our District would include the following work items:

- Remove all culverts and associated fill
- Reshape and stabilize stream crossings
- Scarify the road bed and compacted areas
- Waterbar the road bed
- Excavate and stabilize unstable fills
- Revegetate the road surface, crossings, and disturbed areas
- Install and implement a road closure — both physical and legal

In essence, all culverts and associated fill material are removed from stream crossings, swales, and at ditch relief culverts. After removing the fill and culverts, excavated slopes are shaped back to a stable angle, generally attempting to mimic the slope of adjacent undisturbed slopes. In some cases, structural elements are added to the excavated stream bottom (rocks, woody debris, etc.) to improve stability and add diversity to the channel. The entire road surface is then scarified or decompacted (using an excavator) to encourage water infiltration and re-establish vegetation on the road surface.

Waterbars are constructed on the scarified roadbed to drain any surface water that does accumulate on the road surface. Where fill slopes appear unstable, are cracking, or where there have been failures in the past, fill material is excavated and placed against the cut slope of the road or hauled to a more stable location. The road is then revegetated with local native grasses, tree seedlings are planted at stream crossings, and a physical closure is constructed at the entrance to the road. The closure usually includes a large berm backed up by a ditch to prevent vehicles from driving over it. Finally, we put a legal closure on a road, because many people will still try to drive on it. The legal closure is important because it allows our law enforcement officer to enforce the closure.

INITIAL COST APPROXIMATION

Information Requirements

The following list includes informational items we have found to be necessary in developing initial cost estimates:

- Land ownership
- Location of project relative to equipment and labor
- Length of road to be decommissioned
- Number of segments and proximity to one another
- Number of stream crossings
- Depth of fill at all culverts
- Type of road construction
- Geology/landform stability/past failures from road system
- Cost of past decommissions in the area

Identifying major land ownership lines is simple, and can be helpful in estimating costs. For example, if the project is on National Forest lands—and particularly in areas managed under the Northwest Forest Plan—the level of pre-project surveys and environmental documentation is quite high relative to other areas. The Northwest Forest Plan requires that prior to any ground disturbing activity, surveys must be undertaken for amphibians, mollusks, fungi, lichens, and other organisms. This takes time, can only be done during certain seasonal time windows, and can be quite expensive. In addition to Forest Plan requirements, consultation with regulatory agencies including the U.S. Fish and Wildlife Service, NMFS, and State agencies also takes time and therefore has associated costs.

Secondly, the location of the project relative to equipment and labor must be considered. Bringing heavy equipment and operators hundreds of miles to a project site adds to the cost. Similarly, if there are several segments of road to decommission, are they in close proximity or will the equipment need to be transported a considerable distance from segment to segment? Each time the equipment is loaded onto a trailer for transporting, costs go up.

Culverts are typically the primary expense in road decommissioning because it takes quite a bit of time to excavate the culvert and fill material, and to shape the slopes of the excavation. Identifying the number of culverts involved in the project and how deep they are beneath the road surface is key to developing cost estimates. Costs for culvert removal can go up almost exponentially with deeper culverts, because so much more fill removal is required, and because access to deep culverts is difficult. In addition, when large amounts of fill need to be removed, there is often no room to place the material nearby, so it must be end-hauled to another location. Hauling of fill material can significantly affect project costs.

Knowledge of the topography and geology of the area, and of road construction techniques is essential. In particular, having some information on landform stability and, if possible, a record of past failures on the particular road system can be important indicators of how much of the road will need to be recontoured for stability. In areas with unstable slopes, or steep slopes where cut and fill road construction methods have been used, costs can be increased dramatically to stabilize and/or remove road fills. In addition, with road systems that have a long history of failures, there may be additional costs in acquiring access to the entire road (i.e. in some cases, partial repairs of a road are required just to allow access to other unstable sites and culverts further out on the road system). On-the-ground knowledge is particularly important here.

Availability of accurate information about the unit cost of past decommissions in the area can be most valuable when developing cost estimates. This information, especially when correlated with accurate topographic data, road locations and landform characteristics can go along way toward developing reasonably good first approximations of cost. For example, Table 1 provides an array of costs we've encountered on past road decommission projects

By itself, this table can be helpful to a planner for providing some context on the range of past decommission costs in the area. When combined with a topographic map that depicts the locations of these past decommissions, the data becomes even more useful. In

Table 1. Example project costs and unit costs for six road decommissions

Project Name	Muddy Cost ($)	Clrwtr Cost ($)	Wind Cost ($)	Dry Cost ($)	Trout Cost ($)	Curly Cost ($)
Treated Road Lengths (km)	7.05	3.75	18.57	10.35	14.24	21.3
Total Project Cost ($)	105,681	33,565	49,926	73,682	26,052	75,712
Per Unit Cost ($/km)	14,990	8,951	2,688	7,119	1,829	3,555

this case, the map would show that the higher cost decommissions all occurred on steeper, more incised hillslopes. The lower cost decommissions were located on gentle slopes, valley bottoms, or ridgetops. There are many other variables that go into the ultimate cost of the decommission, but in this case much of the variability in cost can be indexed by the slope angle and degree of dissection in the landscape where the decommissions occurred.

Methods for Estimating Cost

Publications are available that can help estimate decommissioning costs. The Forest Service *Engineering Cost Guide* provides costs to government for labor and equipment. The edition we use covers all of the National Forests in western Washington, and provides costs for a range of laborer and equipment types. Each forest or region has a similar required guide, and these rates are enforced; e.g., contractors working for the Federal government must pay employees at the stated wage rates in the guide. This holds true with cost-share projects on private land that are funded with Federal dollars as well.

An *Equipment Performance Handbook* provides specifications for the kind of production and performance to expect out of a particular piece of equipment. For example, this handbook describes how long it would take a particular piece of equipment to accomplish a given amount of work. Combining the estimates in this book with the cost information provided in the Engineering Cost Guide can give a reasonable estimate of the cost for various decommission work items. Reviewing the cost of past projects provides another means of checking that cost estimates are reasonable.

In estimating material costs, it is important to know what the local issues are. For example, on our District, we strive to use locally-derived native species for revegetation. The cost of acquiring the necessary amounts of seed for this type of treatment are quite high, and in some cases can rival the cost of contracted heavy equipment work. Other areas may not require native or local grass seed, or may have better sources of that material, so costs can be significantly lower. It is important to discover what the local issues are, and what requirements will be placed on the project by regulatory agencies before choosing materials and before developing a cost estimate.

REFINING INITIAL COST ESTIMATES

Estimation Methods

The following list identifies some of the information that is helpful in refining initial cost estimates:

- Field reconnaissance of roads:
  - Accurate road length
  - Count of pipes, including depth, size
  - Types of crossings (e.g., stream class)
  - Identify unforeseen conditions (road failures, impassible bridges, etc.)
  - Locate and recon unmapped roads
  - Identify/quantify road stability issues
  - Identify soil types, road surfacing
  - Identify road grades
  - Identify fill placement sites if necessary
- Distance to culvert disposal/recycling
- Knowledge of local issues (fish/botany/wildlife/recreation/access)

We walk or drive the entire length of every road proposed for decommissioning to get an accurate road length and to identify conditions on the road that will affect the cost and implementation of the decommission. Roads shown on U.S. Geological Survey (USGS) maps and U.S. Forest Service (USFS) maps are often inaccurate in terms of the length, the location, and sometimes even the existence of the road. Through field surveys, we've identified numerous roads that weren't mapped; we've also field checked mapped roads and found them to have been previously decommissioned, or that they are entirely covered with vegetation and not even recognizable as a road anymore. Unmapped spur roads off of roads planned for decommissioning must be evaluated and treated during the project, because once the decommission has occurred, they will be inaccessible for road maintenance, drainage repair, or for subsequent decommissioning.

In some cases, a road identified for decommissioning will be inaccessible or partially blocked by a fill failure or culvert washout on the road. Field visits of all candidate roads will allow the project designer to identify this type of access difficulty and to build the cost of dealing with it into the cost estimate and the design. These situations are not unusual since many of the roads to be decommissioned are unneeded roads that have not been well-maintained in the past.

During field surveys, all culverts and crossings are documented and evaluated. Culvert sizes, depths of fill, type and condition of bridge materials, as well as the types of stream encountered can all affect the decommission design, the equipment necessary to implement the treatment, and ultimately the cost of the project.

Field surveys are also essential for identification of road and slope stability concerns. Where road fills are cracked, show evidence of past movement, or have failed, special design considerations must be built into the cost estimate. These areas, and the treatments designed for them can significantly affect the types of equipment needed, the time involved in the decommission, and the unit costs. In situations where substantial amounts of fill need to be removed, identification of fill placement sites may be necessary. On narrow forest roads it is often difficult to find disposal sites nearby. Long distance end-hauling of fill material can dramatically affect decommission costs.

Our contractors are required to remove all culverts from National Forest lands after they've been excavated. Although we don't pay for the hauling of culverts as a direct bid item, the contractor must cover these costs somewhere in the bid, and the costs for hauling and for disposing or recycling the culverts must be accounted for in the cost estimate.

Local issues can affect where and how you decommission, and ultimately the cost of the decommission. Some of the factors to consider include: location of the project relative to habitat for threatened and endangered species or municipal watersheds, land ownership, mitigations required by State and Federal agencies, degree of road access that must be maintained during and after the project.

Changes in Unit Cost with Increasing Scale

Larger projects may yield some economies of scale, though on our District we have not had experience with this. Some of the areas where economies may be realized include: reduced mobilization costs, better prices on erosion control materials including grass seed and straw mulch, less overhead associated with contract development and advertising, and more efficient environmental documentation (i.e. doing one Environmental Assessment instead of several). Also, once an operator has been working in an area under a particular set of guidelines, he can often find more efficient ways of accomplishing the work, and can improve his cost estimates for subsequent work. Probably the most important gain in having one large contract as opposed to several smaller contracts is the increased consistency in the work, and the potential for less oversight being required once the operator has a clear picture of what is desired.

ESTIMATING COSTS AT LARGE GEOGRAPHIC SCALE

Information Requirements

Generally, the same type of information is needed regardless of scale. As previously mentioned, having information on the cost of past decommissions can be invaluable for estimating costs. But the estimator should be sure to look at both the *average* of past costs, and the full *range* of costs experienced. Localized or site-scale issues associated with a particular road can cause the cost to vary widely from average costs of past decommissions. In addition, the state of the local economy and job markets can significantly affect the demand for this kind of work, and thus the amount a contractor will bid.

Availability of Data Sources

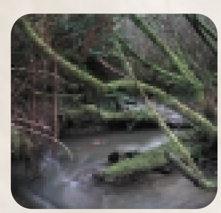
Topographic maps from the USGS and USFS are readily available and can be used as a rough indicator of stream crossing frequency and slope gradients—both helpful for estimating costs of decommissions. Quality of these maps is good for topographic data, but probably is only low-to-moderate for roads. Local Geographic Information Systems (GIS) are typically a better source for getting initial road locations and lengths, but even the GIS layers can have a wide range of accuracy. Information on slope stability can be found in USFS GIS mapping, or from State level maps that can be acquired through State Department of Natural Resources. Maps of any type however, will not replace on-the-ground surveys for developing accurate cost estimates consistently.

Confidence in Cost Estimates for Large Scale Projects

Confidence in estimating costs is dependent upon the level and quality of data available. At large scales, the readily available data (if no field work is done) is probably not of high enough resolution or quality to provide high confidence in the cost estimates. However, if information is available on the cost of past decommissions in an area, reasonable estimates of the range of expected costs can be developed even without good on-the-ground surveys. With information on the cost and location of past decommissions and on-the-ground data from field surveys of target road systems, cost estimates for large scale projects could be developed with high confidence.

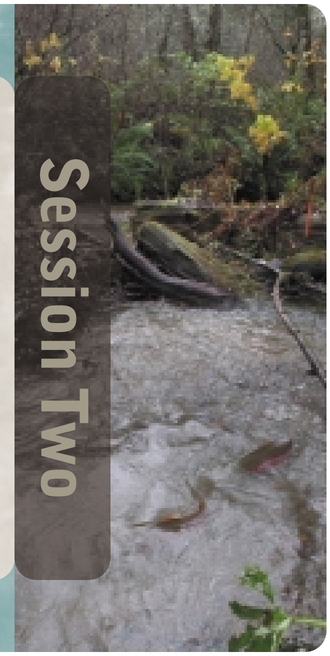
CONCLUSION

Cost estimates for road decommissions can be developed at any scale. Data most critical to developing accurate cost estimates include the length of road, number of stream crossings, depth of fill at crossings, and relative stability of landforms and roads in the area. In the absence of field surveys to assess this information, readily available data (USGS maps, USFS databases, etc.) are probably not detailed enough to provide for high confidence in cost estimates at any scale. However, cost information from past road decommissions in a particular area can be used in conjunction with available road and landform data to develop reasonably good first approximations of cost both at smaller and larger scales. Higher confidence levels can be achieved only through field surveys of road systems proposed for decommissioning. Economies of scale may occur with larger projects, but savings are not expected to be particularly significant. A more likely benefit of larger-scale projects would be the potential for improving the quality and consistency of the projects by working with the same operator(s) on a large number of decommissions.



Road maintenance, road decommissioning, and stream crossing upgrades

Cost of Upgrading Stream Crossings



JOE DUPONT
Idaho Department of Lands
3780 Industrial Ave S
Coeur d'Alene, ID 83815
jdupont@cda.idl.state.id.us

ABSTRACT

This paper discusses various alternatives that exist to upgrade culverts so that they will provide acceptable fish passage as well as the costs associated with implementing these alternatives. Most of the streams involved are perennial fish-bearing streams, although some intermittent streams do have fish spawning in the spring when flows are adequate.

INTRODUCTION

Over the past several years the Idaho Department of Lands has been conducting surveys and research to evaluate what impacts are influencing fisheries in Idaho. One of the major impacts we are finding are man made fish barriers that prevent fish from accessing excellent habitat or restrict fish populations upstream of these crossings from having a migratory life cycle. In an effort to reduce the impacts from these barriers, the Idaho Department of Lands as well as other organizations is putting a lot of effort into identifying barriers and determining how to upgrade them. I have been involved extensively in training individuals on how to identify what a barrier actually is and what it takes to provide acceptable fish passage.

I understand these experiences do not exactly make me an expert in dealing with cost issues; however, it's important to realize the Idaho Department of Lands must manage its land first to provide for a secure maximum long term financial return for its beneficiaries. Consequently, cost is always a consideration when designing stream crossings and is something I must always be aware of.

Figure 1 shows a culvert that is a fish barrier. Probably close to 99% of stream crossings that I deal with that impede fish passage are problematic culverts. Consequently, when dealing with upgrading stream crossings, we are really addressing the issue of upgrading culverts so they provide fish passage.

Figure 1. Fish can't get through here?

Before I discuss how to evaluate the cost of upgrading culverts we must first know why a culvert is a barrier in the first place. Different fish passage problems can be solved with different fixes, some of which are much more expensive than others.

There are three main reasons why culverts cause fish passage problems. First, the drop from the outlet is too high. Second, the water velocity through the culvert exceeds a fish's swimming ability, especially in the springtime when rainbow or cutthroat trout are migrating through. Finally, the water depth inside the culvert is too shallow. This is a big issue, especially now that we must size our culverts so that they can pass 50 to 100-year peak flows. When we make that allowance, almost inevitably the water becomes too shallow during low-flow periods. State rules govern what is acceptable for each of these issues. There are numerous alternatives to fixing these passage problems and not too surprisingly depending on which alternative we choose, the cost will vary considerably.

When determining which alternative to use to upgrade a crossing so it provides fish passage the first three things I consider are:

1. What alternatives will provide acceptable fish passage?
2. Which alternatives will meet the traffic needs for the site? For example we wouldn't want to put a ford at a site where we need year round access.
3. What alternatives will have a low chance of failure over the long run? For example if we place materials into the culvert we want to insure the crossing will still allow peak flow events to pass through it.

Once you have a list of alternatives that will provide acceptable fish passage, provide the necessary traffic requirements and have a low risk of failure, it's time to consider the cost of upgrading the culvert. When evaluating the cost of upgrading a culvert I consider the following:

- Cost of materials, including delivery to site
- Cost of installation
- Longevity of structure
- Maintenance of structure

CULVERT UPGRADES

Using those four cost criteria (materials, installation, longevity and maintenance), I will now walk through several alternatives that we regularly consider in Idaho. A cost comparison will tell us which might have the best cost benefit. Note: In these examples, I'm not going to consider the cost of totally removing a crossing and putting in a new one because it is much cheaper to upgrade a culvert in place, wherever practical.

Examples

Angle Iron Fish Ladder

Installing an angle iron fish ladder is one alternative for increasing water depth and slowing water velocity in a culvert. Figure 2 shows such a ladder. When properly installed, the fish ladder will create a step pool sequence throughout the length of the culvert allowing fish places to rest as they migrate through. This particular culvert occurs at about a 5% grade and is about 50 feet long. With that fish ladder in place, even juvenile fish will have no problem getting through.

When we're determining the cost of one of these ladders, we first ascertain materials cost, including delivery to the site. The ladders aren't expensive: $15 a foot for one about four feet wide; for a 50-ft. culvert, that's $750. We usually build these in 15- to 25-ft. lengths, so they can be transported on a flatbed, which runs up to $35 an hour for delivery. Of course, in Idaho this may be cheaper than in other states.

Figure 2. Angle iron fish ladder

In our area, rock typically runs $3 per cubic yard for rock that's a foot in diameter. For each fish ladder, it usually takes a cubic yard of rock per cross member. For a 50-ft. culvert with 10 cross members the total cost for rock will be $30. Loading the rock into the transport truck runs $0.50 a yard, which seems cheap; if we're hauling a lot of rock, the costs can quickly add up. Getting the rock to the site is often the most expensive part. In the example in Table 1, delivery of the rock costs $0.60 per cubic yard per mile (a round trip of 30 miles thus costs about $180). If we're in an area where it's hard to find good rock, that travel distance can double or even triple.

Once everything is at the site, the cost shifts to installation of the fish ladder. Fortunately, installing an iron fish ladder can be done with manual labor in about two hours with experienced supervision. Our going rate for manual labor is $25 per hour. Once the ladder is placed inside the culvert, rock must be placed behind each cross member. This is definitely the hardest part of the installation, and for a culvert with a 4-ft diameter, this takes about 4 hours. Once the rock is in place the top end of the ladder must be chained to a dead man of some sort — either a big piece of rip rap, angle iron or railroad iron. The whole project totals $1,185, which is relatively cheap. Table 1 reflects costs of the actual project for the culvert shown in Figure 2.

Table 1. Angle iron fish ladder average costs

Item	Cost ($)
Materials including delivery to site:	
Fish Ladder 50 ft. long ($15/ft)	750
Delivery on Flat Bed truck ($35/hr)	70
Rock for fish ladder ($3/yd^3) (1/ yd^3 per cross member)	30
Loading rock ($0.50/ yd^3)	5
Delivery of rock – 30 miles ($0.60/ yd^3/mile)	180
Labor for installing the fish ladder:	
Installing fish ladder – 2/hrs ($25/hr)	50
Placing rock – 4/hrs ($25/hr)	100
Total	**1,185**

Chimney Block Fish Ladder

Another alternative is a second type of fish ladder called a chimney block ladder, which operates under the same principle as the angle iron ladder. Here, the cost of material, the chimney block, is the most expensive part. We try to keep the ladders spread 5 feet apart, depending upon the grade of the culvert. In the example in Table 2, the 50-ft.-long culvert received 2 blocks every 5 feet for a total of $100. The main cable that runs the length of this culvert (60 ft.) costs $0.50 a foot for a total of $30. Tether cables that attach the main cables and hold the chimney blocks in place cost $50 for 100 feet plus cable clamps, washers, and a hook to hold everything in place at another $20. One pickup truck can deliver all the materials to the site in a round trip of two hours for a total of $50.

Table 2. Chimney block fish ladder average costs

Item	Cost ($)
Materials including delivery to site:	
Chimney blocks – 2 every 5 ft. ($5/block)	100
Main cable – 60 ft. long ($0.50/ft)	30
Tether cables – 100 ft. ($0.50/ft)	50
Cable clamps, washers, and hook	20
Delivery – 2 hr. trip ($25 p/hr in pickup truck)	50
Labor for installing the fish ladder:	
Labor – 5 hrs. ($25 p/hr)	125
Total	**375**

Again, this is fairly inexpensive for materials and only manual labor is needed for its installation. From experience, it takes about five hours to put in place, adding $125 for labor for a grand total of $375, or one-third the cost of the angle iron fish ladder. In the right situation, a chimney block ladder can be very cost-effective.

Figure 3. Correctly installed chimney block fish ladder

Welding Baffles into Culverts

Baffles are another solution for increasing depth and slowing water velocity in a culvert (Figure 4). This alternative is more expensive than the last two as shown in Table 3. Baffles can be welded into a culvert on site for about $225 a baffle – this includes cost of materials. A 50-ft. culvert with baffles 5 ft. apart would require 10 baffles or $2,250. But it's more complicated than that. To facilitate the welding, the culvert must be dry so a pump and hose are required (rented), the stream is dammed

Table 3. Welding baffles into culvert — average costs

Item	Cost ($)
Weld in baffles – 10 baffles ($225/baffle)	2,250
Pump and hose rental – 8 hrs. ($10/hr)	80
Labor – 8 hrs. ($25/hr)	200
Total	**2,530**

upstream of the culvert and the water pumped around. Typically, 8 hours or a full day are needed to weld all these in place. At $10 an hour, the pump will cost $80 plus 8 hours of labor (to man the pump and make sure the dam functions appropriately) at $25 an hour, or another $200. Now the grand total is $2,530, twice as much as the angle iron fish ladder and six times the cost of a chimney block ladder.

Figure 4. Baffles welded into a culvert

Backing Water into the Culvert (Drop Structure)

An additional technique is backing water into the culvert. Basically, we install a grade-control structure or drop structure downstream from the culvert, which backs water up into the pipe. Figure 5 shows how this technique can greatly slow water velocity and increase depth inside the culvert. This technique can also be used to reduce the drop from the culvert.

This relatively simple alternative has only one required material: rock. A typical project needs about 20 cubic yards of rock; at $3 per cubic yard, that equals $60. The expense comes in loading and hauling that material to the site. The example in Table 4 shows a round trip of 30 miles at $0.60 per mile per cubic yard totaling $360. This becomes expensive if the hauling distance is 100 miles or so. This alternative also requires an excavator, which must be transported to the site. On a low-boy in a 2-hour round trip at $100 an hour, it would add $200 to the cost. In our example, the excavator took 4 hours to complete the task, although that will vary with the size of the excavator and local rates. Last, additional labor costs added $100, for a grand total of $1,180, about the same price as the angle iron ladder.

Figure 5. Backing water into the culvert by use of drop structures

Table 4. Backing water into culvert — average costs

Item	Cost ($)
Materials including delivery to site:	
Rock – 20 yards ($3/yd³)	60
Loading ($0.50/yd³)	60
Hauling – 30 miles ($0.60/yd³)	360
Labor for installing drop structure:	
Mobilization – 2 hrs. ($100/hr)	200
Excavator – 4 hrs. ($100/hr)	400
Manual labor – 4 hrs. ($25/hr)	100
Total	**1,180**

A word of caution: Each of these alternatives will reduce the capacity of the pipe. Most states require that stream crossings pass a certain peak flow event. Hence, if one of these alternatives will reduce the ability of the culvert to pass these peak flow events below what is required by law, they're probably not acceptable alternatives or the crossing will need some additional modifications.

Such modifications that will increase the ability of a crossing to pass peak flows include: putting in overflow pipes if there is a wide enough flood plane, mitering the entrance of the culvert, and raising the road fill over the culvert to increase the amount of head — the higher the head, the more water that can shoot through the culvert. When increasing the head, we must be sure to seriously armor the crossing or there can be serious problems. I've seen a lot of culverts that held year after year in that way, but I've also seen some that have blown out.

It should be noted that, in our area, the Forest Service will also armor the entire crossing. They don't raise the fill, but they have it functioning like a vented ford. In a flood, the water flows over the top of the crossing, but the culvert is armored in such a way that it will stay in place. This is very expensive and those costs are not broken down here.

Cost of Maintenance

For all these crossing upgrades, maintenance is an important issue. At the Department of Lands, we maintain our culverts annually. If there is debris stuck in front or inside the culvert, we remove it; if branches or vegetation are starting to grow in front, they are also removed. When we place materials inside the culverts, that often increases the maintenance costs because debris is more likely to become hung up inside the culvert.

For the most part, maintenance isn't expensive (Table 5). Most often, the annual check-up reveals little or no maintenance needed, so on average, it takes another 15 to 20 minutes of labor per crossing to maintain the angle iron or chimney block fish ladders. At $25 an hour, that's only $10 a year per culvert.

With the baffled culverts, maintenance generally averages less time because we have solid structures. However, when we do have problems, e.g., a piece of wood knocks a baffle out, it costs a lot more to replace it.

Finally, with the drop structure, maintenance runs about $40 per year. The rock structures will shift over time; when that happens, excavators must go in to do the work. In the life of a culvert, it isn't unusual to readjust the drop structures two or three times.

Table 5. Average cost of annual maintenance

Item	Cost
Iron Fish Ladder	$10/yr
Block Fish Ladder	$10/yr
Baffled Culvert	$20/yr
Drop Structure	$40/yr

Maintaining these structures is low compared to the overall cost. But the maintenance needs to be done or more serious and more expensive problems will arise. For those who can't or are not willing to maintain these types of crossings on an annual basis, these aren't good alternatives to consider. Some agencies have so many structures to maintain that they can't check them all. In my opinion, we shouldn't install more stream crossings than we can maintain on an annual basis as that increases the risk of failure.

Longevity

The final thing to consider when looking at overall price is longevity of the structures (Table 6). Over time culverts become dented

Table 6. Longevity of structures

Item	Longevity
Iron Fish Ladder	30 years
Block Fish Ladder	10 years
Baffled Culvert	30 years
Drop Structure	30 years

and they rust through; from bed-load movement, they'll get abrasion or holes punched in them. We're finding these culverts last from 15–60 years, depending on bed-load movement, how corrosive the water is, and the type of traffic. On average a culvert typically lasts about 30 years. When we put in an iron fish ladder, typically it will last the duration of the culvert, about 30 years; with the block fish ladder, however, the chimney blocks will chip or crack so its longevity is closer to 10 years. The baffles should last the entire duration of the culvert as will the drop structure if installed properly.

Putting It All Together: Culvert Upgrades

Table 7 pulls all the cost considerations together for a comparison of the different alternatives (minus the baffle). I did not include baffles because the cost is much more expensive than the others. When developing the overall cost, it is important to consider the interest lost from the money we put into this crossing, in this case, 30 years (30 years because that is the longevity of the most durable structures). Here I used simple interest, because when the Department of Lands does business, they put money into a permanent endowment fund. The money earns interest and that interest is given out to the schools, so it's not rolled back in and compounded. With private individuals, compounded interest is more appropriate. Obviously, the more money spent up front, the more interest is lost over time.

In the final analysis, over 30 years the price of all three alternatives is comparable, with $700 separating the high from the low. In a situation such as this where the overall costs are similar, I recommend selecting the alternative that is going to last the longest and requires the least maintenance. For example, in this case I would suggest putting in the angle iron ladder. If we anticipated that the culvert would have to be replaced in

Table 7. Putting it all together (initial cost + maintenance + longevity)

Cost Item	Iron Ladder	Block Ladder	Drop Structure
Initial cost	$1,185	$375	$1,130
Interest lost (for 30 years)	$2,133	$675	$2,034
Maintenance	$300	$300	$1,200
1st removal/replacement	$0	$574	$0
Interest lost (for 20 years)	$0	$688	$0
2nd removal/replacement	$0	$722	$0
Interest lost (for 10 years)	$0	$434	$0
Total	**$3,618**	**$3,768**	**$4,364**

ten years than the chimney block culvert would be the way to go.

CULVERT REPLACEMENTS

There are many culverts where there is no reasonable way to upgrade them so that they will provide acceptable fish passage, or any upgrades will put the crossing at a high risk of failure. In situations like this, the only practical way to restore fish passage is to remove the culvert and replace it with a fish friendly stream crossing. When replacing a culvert I consider a bridge, a bottomless type culvert, a ford or a properly installed culvert. The cost of each of these crossings can vary tremendously depending on conditions of the site and the design plan. I will go over some of the things to consider when determining the cost of these types of stream crossings.

Bridges

Bridges tend to be the most expensive stream crossing; however, they also tend to be the most fish and environmentally friendly crossings. Typical bridge design constitutes a deck, abutments, footers and wingwalls. The cost of each of these structures fluctuates greatly depending on the type of material used. Table 8 indicates what current installed prices for a bridge are, depending on the type of materials to be used. The deck can be made with steel, concrete, or wood. A wood deck runs $150–300 per foot whereas steel or concrete runs $800 per foot. Decommissioned railroad cars are also available as material; they cost about the same as wood, $150–300 per foot.

Another expensive structure on these bridge designs is the abutment. They hold the whole bridge in place and give it stability. The cost of abutments can vary widely. Wood abutments typically cost about $5000 each installed, +/-$1000. Steel or concrete run about $10,000. Abutments are not needed if we construct a pass through bridge. These bridges span the entire stream channel and rest on footers. Footers cost less than half the price of abutments, but with footers the cost of the deck will be more as the deck must be another 10–15 ft in length so that it can span the entire stream channel. Another consideration in bridge design is wingwalls, usually used with abutments. Wingwalls insure that the abutments aren't undercut by sediment being piped away from them. Again, cost depends upon the type of material used.

Table 9 shows the cost of some of the different bridge designs used in Idaho. The photo examples are of bridges on streams less than 20 feet wide where we typically see culvert problems. Note: These prices include installation, but they don't include a design cost. For my agency, the Department's hydrologist, engineering geologist, and fish biologist do most of the design work; consequently the cost of our work is not factored

Table 8. Average costs of bridge design

Material Used	Deck	Abutments	Footers	Wingwall
Wood	$150–300/ft	$5,000	$2,000	$2,500
Steel/concrete	$500–800/ft	$10,000	$3,000	$5,000
Rock				$2,000
Railroad car	$150–300/ft			

Table 9. Total costs and longevity of four different bridge types

Bridge Type	Total Cost	Longevity
Wood stringer	$10,000–$20,000	25–50 years
Pre-fabricated concrete	$15,000–$25,000	40–60 years
Railroad	$15,000–$30,000	40–60 years
Steel or concrete	$30,000–$50,000	50–75 years

in. If the design is hired out, that cost should be added in.

Wood Stringer Bridge

Figure 6 shows a wood stringer bridge, which ranges in cost from $10–20,000. This bridge is actually on the upper end of that cost range. It's a fairly sturdy structure designed to pass loaded log trucks, and it cost about $18,000 when completed. The issue with wood bridges is their low longevity (approximately 30–50 years); over time the wood tends to rot.

Figure 6. Example of a wood stringer bridge

Prefabricated Concrete Bridge

Figure 7 shows a prefabricated concrete bridge. Basically everything is made in the shop; then it is brought to the site and dropped in place. Prefabricated concrete bridges range from $15–25,000. This one was on the low side at about $17–18,000. The issue here is limited span: the biggest I've seen was about 20 ft long. Larger ones are harder to handle and can break during installation. Their longevity is 40–60 years. Cost of annual maintenance is pretty negligible; in fact, it may not be necessary to go in every year and remove material. However, a wood running surface will only last 15–20 years and costs $1,500 to replace.

Figure 7. Example of a pre-fabricated concrete bridge

Railroad Bridge

Figure 8 shows a railroad bridge, where the rail car was cut in half and laid side by side with gabion abutments under it. Railroad bridges range from $15–30,000 in price, about the same as a wood bridge. Because railroad bridges have a bit longer life span, we rarely put wood bridges in any more. The pictured railroad bridge cost about $24,000 installed. Different vendors sell the railroad cars and price lists are available. Price and quality can vary widely; i.e., if you buy an old beat-up flat car, it will only last about five years.

Figure 8. Example of a railroad bridge

It should be noted that in some states rail cars cannot be used on public roads or forest roads because they don't have design specifications. There is a supplier that upgrades them for such use, but these are a lot more expensive. They have struts underneath and have rails on either side. They don't look like actual rail cars any longer. It is also possible to have rail cars re-engineered for use in crossing projects.

Figure 9 shows a steel or concrete bridge. We have chosen this material a lot lately. Whether steel or concrete, prices range between $30–50,000. This isn't a particularly large bridge; it spans 40 feet or less and cost $45,000 to put in place. The advantage of this alternative is that you can put wood or gravel over it or pave it. Gravel makes grading the road easier; the grader can go right over the bridge and not be slowed down, although he must be careful not to push the dirt off the side. Longevity is 50–75 years, although shifting stream channels might shorten that.

Figure 9. Example of a steel bridge

Other Culvert/Passage Types and Costs

Some additional options for stream crossings include bottomless arches, buried culverts, and fords. Table 10 provides average costs and expected longevity for these additional options.

Bottomless Arch

Bottomless arches are built by digging down outside the stream channel and putting in footers of corrugated metal or concrete (Figure 10). Note that concrete is

Table 10. Cost and longevity comparison for three additional options

Culvert/Passage Type	Cost/ft	Total Cost	Longevity
Bottomless arch	$400–600/ft	$15,000–$25,000	30–60 years
Buried culvert	$150–300/ft	$8,000–$20,000	20–50 years
Ford		$500–$5,000	Varies

much more expensive than corrugated metal. Then, in either case, corrugated metal sheets are added on top. In Idaho, the installed price is $400–600 per foot. The bottomless arch shown in Figure 10 cost about $23,000. Bottomless arches are often cheaper than bridges. However, contractors tend to hate them because they have to be constructed on site and they can be quite difficult to put in. Fine sediment can be a problem because it can erode and undercut the footers and cause the structure to fail. The finer the sediment, the deeper the holes need to be for the footers.

Bottomless arches have a huge range in longevity, with a life span ranging from 30-60 years. Those with a shorter longevity seem to occur in streams with shifting channels, considerable bed-load movement and/or corrosive waters.

Figure 10. Example of a bottomless arch

Buried Culvert

Burying a culvert can be an excellent technique to insure it will provide proper fish passage. Figure 11 shows what the inside of a buried culvert looks like. Notice all the large substrate that occurs in the bottom of the culvert. This substrate mimics a natural stream bottom and will allow even small fish such as sculpin to pass through. This technique works on streams with gradients up to about 5%. Over that grade, it is recommended to install angle iron fish ladders to hold all the rock in place. The installed price for a buried culvert ranges from $150–300 per foot. The culvert shown in Figure 11 was 40 ft. long and was installed for $12,000.

Figure 11. Example of a buried culvert

Longevity for these culverts can vary widely (20–50 years), depending on bed load and the corrosive nature of the water. I recently heard of several culverts that were installed 15 years ago that now have holes in them because of the bed-load moving through. With a buried culvert, abrasion does not occur along the bottom of the culvert as it is protected by rock. The only place abrasion appears is on the sides above the rock line, which tends to increase the lifespan of this type of culvert over what we see with typical culverts.

Ford

The last solution presented here involves fords. While many people denigrate them, I believe they are under-utilized and can be a great alternative, especially on streams with large flood plains or where extensive channel shifting occurs. With a ford, we don't restrict the stream channel, and the only material needed is rock for the approaches. Where we don't need year-round traffic, a ford can be a great alternative. Constructing a ford costs from $500–5,000,

Figure 12. Example of a stream ford

although they can cost much more if the stream grade exceeds 3–4%. In this situation I would not recommend a ford. Typically all that is needed for a ford is to rock the approaches, usually about 150 feet on each side of the stream so that vehicles can clean their tires off before they get to the creek.

Culvert Replacements — Comparison of Options

In a recent real-life example, Idaho Department of Lands compared the cost of installing a steel bridge, a bottomless arch, and a buried culvert. The stream had a V-channel and a lot of bed-load movement. In this situation, the steel bridge had an expected longevity of 75 years, but the bottomless arch had a life span half that because of amount of bed-load. The buried culvert we estimated at 25 years, a third of the steel bridge.

Initial costs were estimated at $45,000 for the bridge, $20,000 for the arch, and $12,000 for the buried culvert. The interest lost period was the full 75 years, the longevity of the most durable structure (the steel bridge). Again, the more money spent up front, the more money we lose in interest over that time. This particular steel bridge had a gravel surface, so the maintenance was very low as described above. The bottomless arch, if built correctly, also has low maintenance since material rarely jams around it. Buried culverts, on the other hand, have a higher maintenance cost,

Table 11. Comparison of options (initial cost + maintenance + longevity)

Cost Item	Steel Bridge	Bottomless Arch	Buried Culvert
Initial cost	$45,000	$20,000	$12,000
Interest lost (for 75 years)	$202,500	$90,000	$54,000
Maintenance	$375	$600	$1,875
1st removal/replacement	$0	$55,200	$28,125
Interest lost	$0	$115,920	$84,375
2nd removal/replacement	$0	$0	$41,250
Interest lost	$0	$0	$61,875
Total	$247,875	$281,720	$269,125

because they do tend to jam with debris more often.

Table 11 shows the rundown of the costs that would be associated with these different alternatives. Over 75 years, the bridge is the cheapest alternative. It also requires the least maintenance, is the most environmental friendly, and has the best longevity.

Note: In many cases, longevity will be considerably higher for buried culverts and bottomless arches, reducing the total by as much as $60–80,000. In that case, the decision is more difficult and we must balance environmental friendliness with cost. A lot of it depends on your policies and preferences. However, if the costs are close in total, I will always lean towards environmental friendliness.

LANDSCAPE APPROACH

I will close with a discussion on evaluating the costs of upgrading culverts in a larger area, such as a watershed or Evolutionarily Significant Unit (ESU).

The first step in determining the cost of upgrading culverts in a large area is discovering how many stream crossings there are. A typical topographic map shows where the roads cross the creeks, but these maps are seldom accurate. The maps seldom show all the roads that exist, so an on-site survey of the watershed is preferred. We did a survey recently in a watershed where maps showed 13 road crossings. We located four additional crossings in this case that were not depicted on the maps.

The next step is to determine which culverts have problems and what are those problems. When in the field, we determine what type of crossings there are, what the stream gradients are (for culverts), the length and size of the culvert, the type of corrugation, the drop into the inlet and out of the outlet, and the depth of the holding pool (Table 12). With this information, we usually can tell which crossings are fish barriers and why. In the watershed survey mentioned above, we found that 12 of the 17 crossings were actual fish-passage problems; i.e., they violated the fish passage rules of our Stream Channel Protection Act.

Once the crossings that are barriers are identified, it's important to consider the size of the watershed upstream, how wide the flood plain is, the grade of the stream, and the other issues identified in Table 12 before we can determine what alternative will work best and be most cost effective. With this information, we can relatively quickly (probably within a day) and easily determine the cost of upgrading the culverts throughout the designated area.

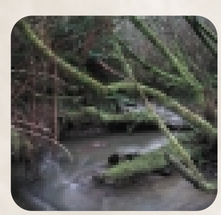
Table 12. What to consider and know when evaluating a stream crossing for fish passage problems

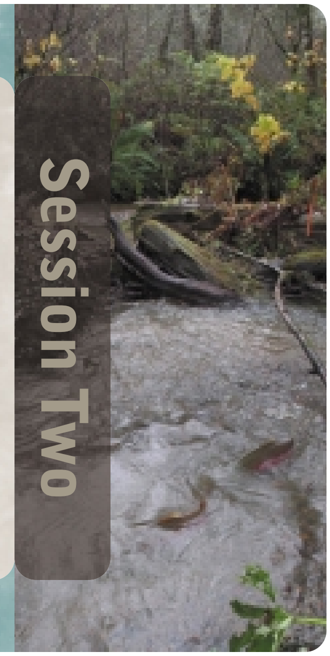
- Type of crossing
- Gradient
- Length and size of culvert
- Corrugation
- Drop into inlet
- Drop from outlet
- Depth of holding pool

However, if we look at a larger area, like a designated ESU, the process becomes more difficult and complex. This is way outside my area of expertise, but after thinking about it for a while here is my thought. First, I would break the ESU into land ownership (U.S. Forest Service, Bureau of Land Management, State, private, and Tribal), and from each of these owners, I would pick 5 to 10 10–20,000 acre watersheds, and go through the process described above, including the on-site reconnaissance. Once 5–10 watersheds had been evaluated, we could expand by ownership for the entire state. It may be necessary to also categorize by state, since different states do business differently.

If you do enough sub-samples you could actually develop confidence intervals around your cost estimates.

A lot of money and effort is currently being put into upgrading stream crossings and I'd just like to reinforce that improving a stream crossing is one of the best ways to increase the range and available habitat for fish. There are significant problems with stream crossings and these upgrades are a good way to use our money efficiently and effectively. Our hope too is that over time, these fixes will help salmon populations rebound.





Road maintenance, road decommissioning, and stream crossing upgrades

Forestland Crossings: Assessment and Costs

MIKE JANI
Mendocino Redwood Company
PO Box 390
Calpella, CA 95418
mjani@mendoco.com

ABSTRACT

This paper presents the viewpoint of the practitioner on private land who is assessing and repairing stream crossings on forestland.

INTRODUCTION

The 235,000 acres of the Mendocino Redwood Company lands are located mainly in Mendocino County, California, with some acres in Sonoma County. A former holding of Louisiana Pacific Corporation, it was recently purchased by a private family and is now a small family-run operation. This ownership provides a great deal of latitude for what occurs on the land.

The Mendocino Redwood Company program starts with assessment and a systematic road inventory. As part of that inventory, we use Global Positioning Systems (GPS) to accurately locate all of the road locations and culverts, and in assessing the road segments for failure. Data collected in the field are integrated into the company's Geographic Information System (GIS) and are used to prioritize road remediation and restoration efforts. In that process, we map throughout the ownership and through each sub-watershed, where we have problems and, if there are culverts, where there are fish passage problems. Road features can be displayed based on database attributes, such as treatment immediacy. The crossings GIS data layer can be queried to identify all sites that meet certain criteria. For instance, the crossings data layer can be queried for all sites that have more than 100 cubic yards of controllable volume.

In the coastal streams of California, and probably throughout the entire range of coastal California, the primary limiting factor for salmon is sediment. In our road inventory, we look carefully at the culverts in order to measure and quantify what exists in the way of controllable sediment. Part of this action is in response to federal mandates, not only through the Endangered Species Act (ESA), but also requirements with Total Maximum Daily Load (TMDLs). All of the streams that are within our ownership have anadromous candidate species that are already listed. Our assessment is preliminary to Federal expectations of private landowner reductions of sediment loading.

MANAGING CROSSINGS

As an example of a project we are working on, Figure 1 shows a diverted watercourse with a subsequent crossing failure on Ackerman Creek in Mendocino County, California. One of our big issues was quantifying the material to be removed. For this particular project, we did not get final approval until late September, and we were concerned about starting a fill removal late in the season. The culverts (Figure 2) will be replaced with a railroad flatcar bridge in 2001. Upstream, we plan to do graded material, probably 10–12 ft. deep, and install weirs. There are also cattle grazing in this area, so fencing and revegetation will also be necessary. By the time the whole project is complete, we estimate a cost of $143,000 to remove the pipes and put in the bridge. And all the material has to be end-hauled, loaded into a dump truck, and taken out. In addition, the graded material upstream will be removed using dump trucks; fortunately, it contains enough rock so that we can use it for road rocking on other parts of the property.

Figure 1. A diverted watercourse (Ackerman Creek, CA)

Figure 2. Three culverts which are scheduled to be replaced with a railroad flatcar bridge in 2001 (Ackerman Creek, CA)

Figure 3. A culvert and downspout installed on top of an old Humboldt crossing (Little North Fork Navarro River, CA)

In 25 years of doing restoration projects, I've learned that all the best forestry ideas already exist, and basically what we are doing is reversing history. Figure 3 shows an old Humboldt log crossing that collapsed on the Little North Fork of the Navarro River in Mendocino County. The previous forester found water flowing over it, so he installed a culvert. Our decision has been to remove both the culvert and the Humboldt crossing, and reunite the stream with another feeder stream by means of a railroad flatcar bridge. In the coastal regions of California, using culverts is almost a guarantee for failure. We do use them occasionally and even sometimes re-install them, but this is rare because streams in California really flash, moving huge amounts of bed load, and we have found it impossible to size for the kind of catastrophic events and landslides that occur in our coastal mountains. So heavy maintenance of culverts is inevitable, and we want to prevent that.

As we are doing assessments, we also consider non-fishery issues. In one case, we had an obligation to maintain an historical structure (Figure 4), which was all redwood and not apt to rot or collapse. Our risk assessment considered the historic value of keeping this old bulkhead in place, so we chose not to remove the old redwood logs, and it gave plenty of fish passage.

Figure 4. Degree of crossing removal may involve assessment of more than just fisheries issues

Armoring

The simplest method is removing crossings and then using logging, or other available material, to "armor" what has been moved out of the crossing to prevent erosion.

Figure 5. Tractor crushed logging debris at road or skid trail crossings

Tractor-crushed debris works perfectly (Figure 5), eliminating the need for straw bales or other imported material. One excavated crossing was an old log crossing. We incorporated the wood back into the design of the removal, leaving large woody debris (LWD) in the area of influence, although not within the stream zone itself (Figure 6).

Figure 6. Incorporating large woody debris

There are also more expensive methods of working with crossings. Not every crossing do we want to remove; with some, we want only to eliminate the ability of sediment to get into the stream system. A very simple approach is to lay down good clean gravel (Figure 7). The same range of price for material and equipment occurs for us as elsewhere. Clean rock gravel can run $8–10 per ton. It's easy to find in Mendocino County, but in Santa Cruz County for instance, it might have to be hauled 60 to 70 miles. The point source for material is important. It may be more beneficial in an area where rock is scarce to put the road to bed under vegetation and not allow traffic on it.

Figure 7. Rocked surface at crossing

Rolling Dips

Rolling dips can be substituted for cross drains on roads that are not used year-round (Figure 8). To construct a rolling dip, an inexperienced operator can spend 3–5 hours using a bulldozer to rough one out, but an experienced operator can install one in half an hour.

Rolling dips are used in a variety of ways. One is to sheet water off the road; a second is to minimize the use of side drain culverts. At other times, where an existing culvert is a good solid pipe and not decomposing, we install a dip as a backup because of the flashing nature of our streams.

Therefore, we assess all of our culverts, and where there is no backup option, we install a rolling dip just below where the culvert might fail. The water then would go into the rolling dip and across the road where we direct it off on an armored down spout, or an energy dissipater at the indigenous soil/nick point of the fill. With that armored, if a failure occurs, we're less likely to lose the entire fill.

Figure 8. A rolling dip draining surface runoff onto a fillslope covered with strawmulch (Soda Springs Road, Albion River Watershed, CA)

Building a rolling dip may take 3–4 hours to excavate and put down the armoring, depending on the depth of the fill. In some cases, I've had to use excavators and large rip rap that runs $10–12 a ton with the project taking 1–2 hours to do the hard facing. However, it is a very simple safeguard for forest roads.

In other circumstances, we're increasingly using complete no-culvert-type roads with rolling rock line dips that can be driven over by a pickup truck or a fire truck for emergencies (Figure 9). This has eliminated our need for continual maintenance and inspection. One consideration with rock armor crossings is to make them wide enough to drive through; if not, the only access will be by ATV. When we're going to use this road again for logging, we'll fill the dips with straw, bury them with dirt, and drive over them while logging, and then dip them out when we're done. Sometimes we

Figure 9. Example of a rock-armored crossing

put these in on our logging roads where the log trucks can drive right out of them.

The best kind of rock to use for dips is regular pit-run rock because the variety of sizes tends to lock together and not move if it is compacted well with a roller compactor or a tractor. Then depending on the “flashiness” of the stream, we may install a cross log or some larger riprap to hold back that rock.

A rolling rock dip can be installed in two hours of tractor time; cost also depends on how far the rock must be hauled. The cost of hauling may include 1–2 dump trucks of rock and another hour of tractor time to roll it and compact it.

Other parts of these restoration projects and culvert removals start escalating in cost if the area has steep ground or requires a large amount of fill. Also, an inexperienced operator will be tempted to make it look nice with each pass of the bucket, using costly time, when what is needed is to haul dirt as fast as possible with some minimal beautification at the end. The equipment runs anywhere from $100 to $150 per hour with an operator, so we want to get the most out of it. In crossing removals, an excavator that has relatively long reach is helpful. Another handy item is having a thumb on a minimum 3-ft bucket, so the operator can grab woody debris and move it around.

Bridges

A note on arched culverts: we have completely abandoned their use. The ones on the property cause us nothing but grief. Any time river systems move large amounts of material as they do in California, the foundation of an arched pipe must be down to bedrock or they are constantly undermining and failing. We’ve shifted almost entirely to bridge installations on our major streams. Where we had culverts, we are putting in railroad flatcar bridges (not boxcar). A boxcar

Figure 10. Frame bridge

Figure 11. Steel-decked bridge

cannot carry nearly the load of a railroad flatcar with its big deep I-beam, although boxcars are good for really short spans.

Bridge Installation

Figure 10 shows a frame bridge and Figure 11 shows a steel-decked bridge. The latter costs a bit more but provides a ready-made running surface. Installation involves a fairly simple method, normally requiring two pieces of equipment: a bulldozer with a winch and, on the other end, an excavator or a loader that holds the bridge back so it can be suspended. The bulldozer pulls across the cavern to be spanned instead of pulling down to the creek and up the other side and tearing everything up. We suspend these with the bulldozer and then set them in place on either side. However, this process is complicated if the site is on a bend.

Figure 12. Example of a railroad flatcar bridge installed with riprap along the channel

There are several different ways of doing this type of construction. We can pull them in to bare dirt, which is simplest and cheapest, but won't meet most specifications. However, we do this in the woods sometimes when we're putting one in temporarily. If we're making a permanent installation, sometimes we'll square off a redwood log, one that's not going to rot, and set it on a log curve, which works very well. If the span is so great that the bridge can't cover the span, say 90 feet, we'll build bents of steel, which cost \$2,500–\$5,000, and back them with pressure-treated material. (Note: The maximum footage out of flatcars is 90 ft, usually 50–90 ft.)

But pulling the bridge across sometimes requires a bit of ingenuity. Renting a crane is an option; they can handle these bridges. However, in forest settings the roads are so narrow and winding that we often cannot get a crane in to lift the bridge. Sometimes the bridge has to be offloaded at the highway and then hauled miles to the location. Forest roads tend to be very windy. Log trucks are made to negotiate those roads, but 90-ft. railroad flatcar bridges won't go around those curves so they have to be pushed and pulled.

There are ways of installing bridges when it's only possible to have equipment on one side of the stream. The easiest is to bring in a crane, but as mentioned above, that is not always possible. In one case we could not get a crane in, so we used an old logging idea. It took two men one day to build it, using a gin pull, a redwood log, and an 800-lb. block that the bull line of the cat is run through. It was then attached to the bridge to get sufficient width to bring it across so we could set it on the bend. That's rather a lost art these days. That kind of engineering in the forest is going by the wayside, but there are still people around who do it. To get the dozer across, we built a road from the other end of the ranch to that point and we walked it around. We used that same technique when we could not get a dozer on the other side to pull. We built an A-frame in the middle of the stream and we did it all from one side with lines running across and back. It costs a little more for set-up this way, but never more than two man-labor days.

Bulkheads

Another aspect of bridge construction is often necessary use of bulkheads. The steel frame in Figure 13 cost around $5,000 to build; it was backed with pressure-treated 3x12 or 4x12 Douglas fir. The complete bent ran about $6,500. Then the approach and the back filling of compacted material were added in. By the time this bridge was in place with a deck on it and bents in place, the total was $30,000. Fortunately, we didn't have to build another bulkhead on the other side.

Figure 13. Example of bridge installation bulkheading

In some places on our property, there is no way to tell where the old channel was because so much disruption has happened in the watershed. Often, we will armor the lower base of a crossing removal before we put the flatcar in, as insurance that we won't get a lot of back cutting and then undermining. The riprap here was ungrouted and backed with fabric. In the rolling rockline dip method discussed above, we lay down fabric before we put the riprap down.

Note: We've returned to several of these bulkheads and planted willow. In the coastal regions of California, things re-vegetate so fast that it will be re-vegetated in two or three years.

CROSSING CONSIDERATIONS

In my experience, I have found the following to be important considerations when working on a crossing project and developing costs:

- Time starts and stops at the loading area. If the work location requires trucks to drive a long way in and out, it may be necessary to pay travel time. Some truckers charge extra for hauling riprap.
- Traffic and road conditions matter. When estimating truck times on maintained main line or secondary roads, 3 minutes per mile is average.
- Loading time varies (7–15 minutes). The distance from the truck staging area to the loading area should be kept as short as possible.
- Semi end dumps need a flat level spot to dump.
- The 28´ to 32´ semi trailers are most suitable for use on logging-type roads.
- Riprap weighs about 2,700 lbs/cu yd.
- Pit run rock weighs about 2,600 lbs/cu yd.
- When estimating hauling costs for pit run rock or excavated earth, be sure to consider the swell of the material. We use a 25% swell factor.

- When ordering trucks, be sure to communicate the type of material to be hauled and the type of road to be used. Many highway dump trucks are not suitable for larger rock or logging type roads. If the wrong type of truck shows up on the job and the driver refuses to haul, you will lose a day of production.

- Riprap is classified by weight groups. For example, the weight group of Head Stone is approximately 1 cubic foot or 100 pounds. The weight group of 1/4 ton is approximately 5 cubic feet in size. This weight grouping continues on up to Rocks, which will weigh many tons per rock. When hauling the larger sizes, care must be used to place the rocks in the dump box in a manner that will let them dump out without jamming in the box. This need will often result in loads that weigh less than the truck's capacity.

CROSSING PROJECT AVERAGE COSTS

The following provides an average range for costs incurred in crossing projects. It should be noted that costs will often vary by location and availability of equipment, materials, and labor.

Hauling Costs

- Bobtail dumps: Most dump boxes on this size truck are designed to haul 3–15 cubic yards. Legal loads vary from 2–6 tons. Rate per hour: $50–55.

- 10 wheel dumps: Most dump boxes on this size truck can haul 10–12 cubic yards or 12-ton loads legally. If the truck does not need to enter the highway and the haul road has been graded, 15-ton loads are possible. Rate per hour: $68.

- Semi end-dumps: Semi dump trailers vary in length from 28´ to 40´. Most are designed to haul 20 cubic-yard loads. A 28´ trailer can haul approximately 17 tons legally; a 40´ trailer, approximately 24 tons. If the truck does not need to enter the highway and the haul road has been graded, 28-ton loads are possible. Rate per hour: $75.

Rock Costs

- 3/4 minus = $8.50 per ton on board truck.
- 1 1/2 rock = $8.50 per ton on board truck.
- 6″–12″ cobble rock = $11.75 per ton on board truck.
- Rip rap = $15.00 per ton on board truck.
- Rock pit development costs vary; however, $1.00–$1.50 per ton is the average for pre-drilling earthwork.
- Rock drilling and blasting cost average = $2.25 per yard with 5,000 cubic yard minimum.

Railroad Flatcar Costs

- 53´ steel frame = $10,000–$12,000 FOB dealer's yard.
- 62´ steel frame = $12,000–$15,000 FOB dealer's yard.
- Cost to deck 53´–62´-ft. cars with 12´ wide wooden deck: labor = $2,500, materials = $2,500.
- 85´–89´ steel-decked cars = $15,000–$20,000. The width on the deck is about 8´6″.

Excavator Costs

- 30,000 lb size class:
  Rental per hour = $85–$125
  Bucket capacity = 0.38–0.98 cubic yards
  Digging depth of 18 ft.
- 40,000 lb size class:
  Rental per hour = $85–$145
  Bucket capacity = 0.88–1.42 cubic yards
  Digging depth of 19 ft.
- 50,000 lb size class:
  Rental per hour = $100–$175

Bucket capacity = 0.38–1.88 cubic yards
Digging depth of 21 ft.

Dozer Costs

- D4 size = hourly $72 and up
- D6 size = hourly $65 and up
- D7 size = hourly $75 and up
- D8 size = hourly $90 and up

Crane Costs

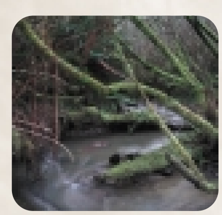
- Rental per hour = $150 and up
- The crane may require support crew and equipment that add to the cost.
- Larger railcars may require 2 cranes to swing into place.

Sheet Piling

- Sheet piling can be used for bridge abutment construction when the maximum stream channel width possible is needed.
- Sheet piling can be purchased in various lengths, up to 30´.
- It can be installed using the bucket of an excavator to push it into the ground.
- Approximate cost is $5.50 (plus tax and freight) per square foot, for a medium gage steel pile.

Road Paper

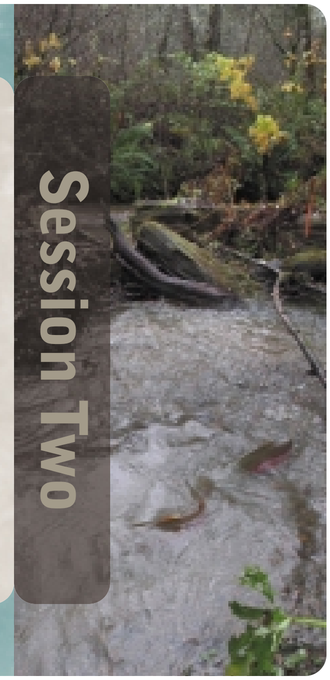
- 8 oz. non-woven filter fabric in 12.5´ x 360´ rolls is $380 per roll (plus tax and freight). If you buy the larger size rolls, the cost per square foot is somewhat lower; however, the cost of handling them in the woods is greater as they are awkward and heavy.



Road maintenance, road decommissioning, and stream crossing upgrades

Road Upgrading, Decommissioning and Maintenance — Estimating Costs on Small and Large Scales

WILLIAM WEAVER
DANNY HAGANS
Pacific Watershed Associates
1652 Holly Drive
McKinleyville, CA 95519
pwa@northcoast.com



ABSTRACT

One of the most important threats to the health of stream systems is sediment delivery due to anthropogenic erosion. Road networks are often one of the most important sediment sources, so it is vital to the health of the watershed that they be maintained in good condition or decommissioned when no longer useful. This paper presents a detailed look at the process of planning and carrying out road upgrading, decommissioning and maintenance projects. The emphasis is on cost estimation; especially the ways that standardized data collection can facilitate the development of accurate estimates. Also included is a discussion of the ways in which cost estimation changes depending on the scale of the project, the type of use of the road (seasonal or year round, public or private), and whether a single road or an entire road network in a watershed is slated for treatment.

INTRODUCTION

Before considering the details of road repair work, it is important to understand the proposed project from a geologic perspective. More specifically, knowledge of the erosion and sedimentation history of an area, and the relative magnitude of various sediment sources, is necessary to properly evaluate the need and potential benefit of road work. Not everything that goes on in the watershed, even on the road systems, affects aquatic resources. It is critically important when deciding how much effort it will take to upgrade or decommission a road that care is taken to spend the money wisely and only on work that will have a beneficial impact on the aquatic system.

Road repair work is a broad category that encompasses many different types of improvements to forest road systems. These changes may, for example, improve access along the road, as when cut bank slides that have covered the roadbed are removed. However, road repair work does not always have an impact on aquatic resources. Hill slope failures, cut bank failures, gullies and surface erosion are not always connected with the stream channels, and so are not delivering sediment into the streams. Although road repair is something that landowners want to see completed, the work can be very expensive. When improving habitat for fish or aquatic resources is the top priority, it is important that only a limited amount of money be spent on repairs that do little to improve or protect the aquatic system. This requires a clear separation of typical road maintenance and upgrading work (designed to improve the transportation system) from those upgrading and decommissioning activities that are focused on reducing the magnitude or threat of sediment delivery to streams (Weaver and Hagans, 1999; Harr and Nichols, 1993; Weaver and Hagans, 1996).

In order to ensure that the work benefits fish, it is important to evaluate all potential projects by measuring or evaluating the effect the road is having on erosion and sedimentation into the streams in the area. This entails looking specifically at three elements of road systems, including stream crossings, potential road-related landslides and road surface drainage. Sediment can be generated and delivered from these locations in response to episodic storm events as well as from chronic erosion during normal runoff events. It is important to evaluate the susceptibility of stream crossings and potential landslides to failure and sediment delivery. Likewise, it is important to measure the connectivity of road surface drainage with streams, so that treatments can be designed to disconnect them, and thereby greatly reduce or effectively eliminate the movement of fine sediment and water off the road system and into streams.

It is important when conducting erosion inventory assessments on road systems that recommendations for treatments be very specific and be focused only on those features that would otherwise deliver sediment to a stream or other protected resource. There is typically only a limited amount of money available for treating road systems. For example, it does not make sense to upgrade an entire road system if only 20% of the money could be spent to stop most of the ongoing or future sedimentation caused by that road system. A virtually limitless amount of money could be poured into upgrading and decommissioning roads, but with limited funds, it is crucial to focus only on work that will directly protect or improve aquatic resources.

DIAGNOSING AND TREATING PROBLEMS ON ROADS

Road System Erosion

The four main erosion processes on road systems are surface erosion, gully erosion, mass erosion and channel erosion. Each process produces sediment, and a certain amount of this sediment may end up in streams. Usually, a lot more sediment is produced by the road system than is actually delivered to the streams. The key, then, in performing road system assessments is to define the scope or magnitude of road work to reduce sediment delivery to stream channels and to distinguish between sediment production (erosion) and sediment delivery (yield) to stream channels. Improving or protecting stream habitat requires preventing sediment delivery, but not necessarily controlling or preventing all erosion in the system.

Road-related problems fall into two categories. The first is chronic erosion and the second is episodic erosion, which is storm-related. Chronic erosion produces fine sediment every year, every time there is surface runoff, whether there are severe storms or not. Chronic surface erosion delivers fine sediment to streams wherever road drainage is discharged to a channel. Episodic erosion can be divided into mass soil movement and fluvial erosion. Fluvial erosion is mostly due to stream crossing washouts and gullies created by either stream diversions or hill slope gullies below ditch relief culverts along roads. Road-related mass soil movement that

Table 1. Sources and magnitude of road-related sediment delivery in selected Northern California watersheds[1]

		Sediment delivery for road-related erosion sites			
Site location	Process	Delivery range for sites (%)	(yds³)	Average delivery (yds³)	Percent of road-related sediment delivery (range)[2]
1. Chronic surface erosion from bare soil areas (road surfaces, ditches and cutbanks)[3]	Surface erosion	75–100%	NA	NA	15%–85%
2. Road-related landslide erosion	Mass wasting				15%–80%
Fill slope failures		5–100%	5–2,500	220	
Landing failures		5–100%	5–2,000	385	
Cut bank failures		50–100%	10–150	80	
Hillslope landslides[4]		25–100%	10–10,000	3,500	
3. Stream crossing erosion	Fluvial erosion				35%–80%
Stream crossing washouts		100%	5–3,000	225	
Stream diversions (gullies)		80–100%	5–2,800	400	

1- Data based on inventories of Salmon Creek and Rowdy Creek road systems; sediment delivery from stream diversions based on data from Jordan Creek (lower Eel River).

2- Typically, watersheds with geologies like Salmon Creek and Rowdy Creek are dominated by fluvial processes, where road-related fluvial erosion (washouts and gullying at stream crossings) is expected to account for up to 85% of future sediment delivery. Road-related mass wasting is comparatively less in the watersheds. In steep, potential unstable watersheds on the north coast, such as those of the lower Eel River and the Mattole River, mass wasting may account for up to 65% of future road-related sediment delivery. In these watersheds, fluvial processes are relatively less important.

3- Sediment delivery from road-related surface erosion occurs where the road is hydrologically connected to the stream system. Delivery volumes are based on contributing length of road reach, use levels, surface erosion rates and duration of analysis. Delivery is based only on connected road reaches. Does not include surface erosion from non-road sources. Road erosion inventories reveal that many watersheds in central and north-central California, and in the Sierra Nevada mountains of eastern California, are dominated by surface erosion and fine sediment delivery.

4- Small to large hillslope slides triggered by road cuts, road fills or by altered hydrology (diversion or discharge).

results in sediment delivery to streams usually comes from fill-slope failures, failures from crossings of steep headwall swales, and occasionally from large cut-bank failures that go over the road and into a stream channel. Table 1 provides statistics on the relative volumetric importance of the different types of erosion on sediment delivery to streams in a variety of inventoried watersheds. As is clear from the table, the relative and absolute contribution of road-related sediment to stream channels can vary dramatically from one watershed to the next, and across the landscape from region to region.

Chronic Erosion

Chronic erosion from road surfaces is highly related to traffic use on the road, as well as the characteristics of the road surface. It is important to emphasize that the volume of chronic erosion that is occurring is less important than how much of the eroded sediment is actually being delivered to streams. For example, for one large landowner on the North Coast of California, erosion inventories were conducted for a variety of sediment sources, including, chronic surface erosion, road-related landslides, and fluvial and stream crossing erosion. The results of the erosion inventories were then compared to the measured volume of sediment that was actually delivered to stream systems. The findings indicated a wide variability in the percentages of sediment that finally made it into streams compared to the sediment that was eroded (See column 6, Table 1).

With respect to chronic surface erosion, fine sediment delivery in a watershed is partially controlled by the amount of the road system that is actually connected to the stream network. In many North Coast watersheds, less than 5% to 15% percent of the road is hydrologically connected to the stream system through inboard ditches or through hill slope gullies below ditch relief culverts. As a result, only that small percentage of the road is actually delivering sediment into the stream system (Table 1). In some other inventoried watersheds, up to 85% of the road network has been documented as being hydrologically connected to streams. In these watersheds, depending on erosion rates, fine sediment delivery from road surface erosion can overwhelm other road-related sediment sources.

This means that it is not necessary to treat the whole road in order to prevent stream sedimentation. Only the segments of road that are delivering sediment and that are hydrologically connected to the stream system need to be treated. This limits the numbers of and types of road treatments that need to be considered. Important treatments include installing or upgrading culverts, waterbars and rolling dips, and outsloping roads currently in use.

Episodic Erosion: Road-Related Landslide Erosion

Sediment deliveries for road-related landslides (usually fill slope failures) range from 5% to 100% of an individual landslide (Table 1), though in many cases the landslides do not deliver any sediment at all (0% delivery). Most of the landslides that occurred on roads in the assessment areas did not go into the stream channels, though they may have moved down the hillside and deposited sediment on a road, a terrace or a slope. It is important to distinguish between those that are delivering sediment and those that are not. The priority is to identify and treat the road-related landslides that deliver (or could deliver) sediment to a stream channel, and to not spend limited resources on landslides that do not impact or threaten aquatic resources.

Episodic Erosion: Stream Crossing Erosion

Virtually 100% of the sediment produced by every stream crossing that washes out ends up in a stream channel (Table 1). Because a stream crossing is by definition "crossing a valley with a channel that has a definable bed and bank, and shows evidence of periodic sediment transport," any erosion at this type of site will enter the stream.

When culverts plug and water flows down the road and across the hillside, in a process known as stream diversion, those gullies are usually well connected to the stream system. Based on recent watershed inventories, any time there is culvert failure at stream diversions, 80–100% of the sediment that is eroded from those gullies will be delivered to a stream (Table 1). Stream diversions can create large gullies and large volumes of eroded sediment that are efficiently delivered to streams (Weaver *et al.* 1995). Stream diversions onto steep hillslopes can also cause landslides and debris flows that produce potentially huge volumes of sediment delivery.

The critical thing to remember is that not all stream crossings are the same and not all hillslope gullies are the same. Each has different degrees of delivery to the stream channel. The bottom line is that erosion inventories and road assessments must be done on the ground, and not

Table 2. Summary road erosion inventory and sediment yield data for selected, inventoried watersheds in Oregon and Northern California

Watershed	River basin	Watershed area (mi^2)	Road length (mi)	Road density (mi/mi^2)	Future yield (yds^3)	Unit yield (yds^3/mi)
Shaw Creek	Eel River, CA	4	18	4.5	9,200	511
Jordan Creek	Eel River, CA	5	34	7.1	94,140	2,769
Bear Creek	Eel River, CA	8	39	4.9	131,605	3,375
McGarvey Ck.	Klamath River, CA	9	68	7.8	164,800	2,441
Pine Creek	Klamath River, CA	21	104	5.0	45,400	437
Elk River	Humboldt Bay, CA	22	133	5.9	88,090	662
Tish Tang Ck.	Trinity River, CA	31	74	2.4	17,100	231
Dumont Ck.	S. Umpqua R., OR	31	114	3.6	12,020	106
Mill Creek	Trinity River, CA	50	177	3.5	137,200	775
New River	Trinity River, CA	277	175	2.0	32,400	185
Totals		**460**	**936**	**2.0**	**731,958**	**782**

remotely, in order to accurately identify the risk and potential volume of future stream crossing erosion and sediment delivery. The most valuable assessment is on-the-ground, where the individual characteristics of each existing and potential sediment source can be identified.

Table 2 shows the results of field inventories of over 900 miles of forest and ranch road in ten different watersheds. Column 6 lists the predicted future yield from road-related sediment sources including potential fill-slope failures (fills with visible cracks and scarps), stream crossings that are prone to partial or complete wash out, or diversion, and from other sediment sources including gullies developed from road surface runoff. The future unit sediment delivery ranged from 100 to over 3,000 cubic yards per mile.

It is important not only to identify how much sediment is being delivered to the streams, but also to focus attention on the watersheds where there is critical habitat to protect. Biological considerations must also be taken into account when prioritizing road work that is aimed at protecting or restoring channel conditions and habitat. Some streams may not be worth improving, especially if there is very little likelihood fish will return once the habitat has been restored. Large amounts of money could be spent without achieving much success for the targeted fish species. In contrast, streams that are experiencing only low sedimentation rates and still have healthy populations may be well worth the effort, because small amounts of money may stop future anthropogenic sedimentation entirely.

Erosion/Sediment-Source Inventories

There are several different types of sediment-source inventories. The bottom line in determining the cost of either upgrading or decommissioning road systems is the ability to have an adequate on-the-ground inventory. In the past, erosion inventories have typically been "backward-looking," where people have walked the roads looking for voids or "holes" where erosion has occurred. This is the classic kind of study conducted by geologists for erosion inventories of major road systems and for sediment budget studies. About 95% of the literature documents erosion events that have already happened on roads, but this does little to provide significant insight into the locations and magnitudes of future erosion and sedimentation. Similarly, such studies do little to identify where monies might be best spent to control or prevent future erosion and sediment delivery.

A "forward-looking" or "predictive" inventory generates the information needed to develop costs for either upgrading or decommissioning roads, and for "turning off" or preventing existing or future sediment sources, respectively. The development of a predictive inventory requires more subtlety in the inventory process. In this case, the goal is to predict the location and evaluate the potential magnitude of erosion events that have not yet happened. This means trying to determine the likelihood that a slope is going to fail or a stream crossing is going to wash out, and what the volume and magnitude of the potential failure will be. This type of inventory requires more professional judgment. It is, however, not all that difficult when standardized techniques and protocols have been developed and are adhered to in the field.

Over the last 10 years, we have trained approximately 20 commercial salmon fishermen out of work in Northern California, and a number of scientists and physical science technicians, to do predictive road inventories and erosion assessments. Many are working full time now under grants administered by the California Department of Fish and Game and other funding agencies to inventory private lands. The inventories are being done on industrial and non-industrial forest lands, ranch lands, rural subdivisions, agricultural lands, and on public road systems throughout Northern California. The most significant prerequisites include the ability to "read" the landscape and the geomorphic/hydrologic processes that occur along roads, understanding of how the design and construction methods of a road can influence natural processes, training in standardized erosion inventory protocols and treatment prescriptions, and the necessary tools and equipment to complete the job.

Predictive inventories can occur at three different levels: a screening-level assessment, a reconnaissance-level assessment, and a fully quantitative assessment. These levels are summarized in Table 3. To complete a prescriptive on-the-ground site-by-site analysis of the road system and develop a viable plan of action for erosion prevention and erosion control, a quantitative assessment of the road system is necessary. It is important that all roads in a watershed (i.e. currently active, as well as abandoned roads) be included in an assessment. This allows for a more complete understanding of the current and potential risk of anthropogenic sediment production in the watershed.

The screening-level assessment makes it possible to categorize watersheds or large basins, to determine how much of the landscape is in sensitive terrain, what the road densities are in each of those terrain types, and what likely costs are associated with treating the roads in each of those different land categories. For a screening-level assessment, we use remote analysis via maps, existing data and Geographic Information System (GIS) techniques. We thereby obtain a screening-level tool that enables the development of generic cost estimates with low to moderate confidence that the work can be completed for that amount of money. At this level, there is

Table 3. Road sediment source inventory and assessment methods (PWA, 2000)

Assessment Type	Method	What you get	What you don't get
Screening level	Remote analysis employing maps, existing data and GIS analysis techniques employing management and landscape factors	Screening level tool to relatively rank roads in a watershed for their potential for sediment delivery. Generic, low to moderate confidence costs could be developed based on extrapolation of costs for roads in similar terrain, geology and geomorphic settings.	No site-specific location or quantification of potential sediment sources or development of treatment prescriptions or costs.
Reconnaissance level	Field reconnaissance survey of high priority roads	Ground verified inventory of obvious sites and suspect locations on high priority roads. Classification of estimated future yield in volume classes. Documents the frequency and general magnitude of the "threat." Costs can be estimated generically, with moderate confidence, by employing averages based on data from similar roads with similar site frequencies in comparable similar settings.	Not all roads are included in the survey. No treatment prescriptions, quantitative sediment delivery measurements or cost-effectiveness analyses are performed.
Quantitative	Field inventory of future sediment sources from all roads, or selected roads, in the watershed	Identification and quantification of potential sources of sediment delivery along all roads. Volumes, probabilities and a variety of road site data for crossings, fills and road drainage. High confidences cost estimates are developed based on physical measurements and evaluation of treatment sites.	Development of specific risk reduction plan, with prescriptions, costs, and cost-effectiveness analysis is not required but is generally undertaken.

no site-specific quantification of potential sediment sources or actual prescription of site-by-site costs or treatments.

Once the screening-level assessment is complete, the reconnaissance-level assessment requires going to the highest priority areas — those areas most likely to be generating sediment and delivering it to streams from the road systems — and doing walk-through surveys of the roads quickly. In these surveys, we identify stream crossings and categorize them by volume. The volume categories might be, for example, 0 to 50 cubic yards, 50 to 200 cubic yards, 200 to 500 cubic yards and larger than 500 cubic yards. This tally gives some idea of the frequency and sizes of all the sediment sources along the road. Generic cost estimates can then be made based on the tally. A reconnaissance-level assessment does not provide actual treatment prescriptions or quantitative sediment delivery measurements. As a result, it is impossible to produce a cost-effectiveness analysis at this level (Weaver and Sonnevil, 1984). Specific measurements of the potential sediment volumes delivered to a stream channel are supplied by the quantitative assessment.

The quantitative assessments that we are currently doing are part of an ongoing watershed restoration program in Northern California that are funded primarily by the California Department of Fish and Game (CDFG), but also being matched or partially funded by landowners and other state and federal granting agencies with interest in water quality. In excess of $20 million dollars a year are being applied to quantitative assessments and implementation projects for upgrading and decommissioning roads, including a full inventory of future sediment sources along road systems in the affected watersheds. The CDFG Fishery Restoration Grant Program is focused on watershed-wide work. For a 30 square mile watershed, for example, there might be an assessment budget of $125,000 to $175,000, depending on the road density in the basin. This is to be spent on the complete identification and quantification of potential sediment sources, as well as development of prescriptive measures and associated costs elements to correct or treat each existing or potential sediment source. It takes 10 to 30 minutes in the field at each individual site of future sediment delivery to collect pertinent inventory information and to develop the recommended treatment for that site. This assessment includes everything from quantifying the future sediment delivery (assuming no erosion prevention treatment was to be applied) to determining which types of heavy equipment will be required at that work site. After completing all three levels of assessment, the final product consists of a specific risk reduction plan (including treatment prescriptions, needed materials, equipment and labor), a budget and a cost-effectiveness analysis. Chapter 10, in the CDFG Salmonid Restoration Manual (1998), discusses in detail all the elements of a fully quantitative analysis.

Road Treatment

There are really only two choices for treating roads that have been determined to be existing or potential sediment sources. Both treatment types are generally referred to as "storm-proofing" (Pacific Watershed Associates, 1994; Weaver and Hagans, 1999). Either the road can be upgraded and maintained, or it can be decommissioned, either temporarily or permanently. In the past there would have been a third option: walking away from the problem and letting the road "return to nature". Most forest roads on the North Coast were historically in the walk-away category at some time during their lives. Built 30–40 years ago, they were used to access an area for timber harvest, and were simply left alone when they were no longer needed. Management practices have changed since then, and walking away from roads that are current or potential sediment sources is no longer considered a viable choice.

The Storm-Proofing Process

The storm-proofing process involves five different steps, described in Figure 1. First is *problem identification* through inventory field assessment, the details of which were discussed above. The next is *problem quantification*, which means determining how much sediment volume will be delivered to the stream if nothing is done. This information impacts cost-effectiveness. Thus, it does not make sense to do storm-proofing work where a lot of money will bring very little return benefit. It is important to be able to compare the future sediment production and delivery at each site in order to eventually prioritize them for treatment.

Figure 1. Five-step process for storm-proofing forest roads

1. Problem identification (through inventory and assessment)
2. Problem quantification (determination of future yield in the absence of treatment)
3. Prescription development (both heavy equipment and labor-intensive methods)
4. Cost-effectiveness evaluation and prioritization of sites proposed for treatment
5. Implementation of upgrading or decommissioning treatments

The third step is the *development of a prescription* for road treatment, which includes both heavy equipment and labor-intensive measures for erosion prevention or erosion control. The fourth step is performing a *cost-effectiveness evaluation and prioritizing the sites* to be treated. The cost-effectiveness evaluation will help make it possible to spend money where it will yield the greatest return for the investment. Cost-effectiveness is determined for a site or a group of sites by calculating the total cost of performing the work and dividing that figure by the volume of sediment that is expected to be prevented from delivery to a stream. Note: this is not the volume of earth which must be excavated and/or moved to accomplish the recommended treatments. Once the sites have been prioritized, the fifth and final step in the storm-proofing process can be taken: actually carrying out or *implementing the road treatment*. Storm-proofing includes either decommissioning the road, or upgrading and maintaining it.

Road Maintenance

If personnel and resources cannot be committed to providing regular inspection and maintenance for the life of the road, then roads should be built—or rebuilt—as temporary and then properly decommissioned. This is the rule that should be followed if long term fisheries protection is to be achieved. In other words, if the landowner cannot afford to maintain a road, then it should not be put there in the first place. Road maintenance activities include inspections and preventive maintenance, such as winterizing. This includes storm inspections, emergency maintenance, and identifying and treating problem culverts. For large landowners, the maintenance process can be greatly improved by developing a culvert coding or rating system, so it is easy to determine which culverts are most likely to cause erosion problems and which will most likely require storm-period inspection and maintenance.

DEVELOPING COST ESTIMATES

Data Needed for First-Approximation Cost Estimates

Road Upgrading and Decommissioning

For road decommissioning and upgrading, the data that are generally available are photographs and maps based on digital topographic data. Air photographs are also sometimes available, and are very useful for developing estimates of road density and stream-crossing density. After reviewing the photographic and geographic data for an area, you can look for cost data from recently completed upgrading and decommissioning projects that were undertaken in similar geologic and geomorphic terrain. Those cost data are invaluable for making first-approximation estimates on a watershed-wide basis. For example, decommissioning roads across steep inner gorge slopes with high stream-crossing frequencies may cost around $50,000 per mile. In contrast, working on ridge roads or roads in upper hillslope areas of a watershed may only cost $5,000–$10,000 per mile. Knowing where the proposed project is located in the landscape of the watershed, and the associated road and stream crossing densities, will allow you to develop first-order approximations of storm-proofing costs.

Road Maintenance

Developing cost estimates for road maintenance requires data from the same sources as mentioned above. In addition, it is important to know the characteristics of the road surface and the age of the road. From these data, we are able to generate cost estimates, based on the costs of earlier or nearby projects, in much the same manner as for road upgrading and decommissioning storm-proofing projects.

Data Needed for Estimating Cost Categories

Heavy Equipment

In order to develop reasonable cost estimates for heavy equipment work in both road upgrading and road decommissioning projects, it is important to know excavation volumes. Excavation is perhaps the single most expensive work task in many storm-proofing projects. For the first approximation, cost estimates may be based on the number of stream crossings and the average volume per crossing. After doing field reconnaissance inventories, we put each stream crossing in one of several volumetric ranges (e.g., <100 cubic yards, 100–500 cubic yards, or >500 cubic yards). A detailed quantitative survey on an inventoried road system will provide the actual volume of sediment that will be excavated.

It is also critical to know the production rate for the heavy equipment that will be performing the earth moving. The Caterpillar production performance handbook contains exact rates. Another way to obtain production rates is to simply watch heavy equipment excavating stream crossings, excavating unstable fills, and installing or constructing other erosion control and erosion prevention measures (e.g., rolling dips or road outsloping). Production rates are then developed by averaging the observed volumes of sediment excavated or the rates of "installation" for each category of work that is completed. We have developed a standard list of production rates that field inventory personnel employ in conducting inventories and developing cost-estimates for proposed treatments. As a result, all field personnel apply a standard work rate for each task when developing plans for work at new sites.

End-hauling volumes and distances also need to be included in heavy equipment cost estimates, as they can dramatically affect project costs. Even during the driest part of the summer, 40% (or more) of the material excavated from a site (such as an upgraded stream crossing) may not be suitable for re-use at the site and must be end-hauled.

Finally, there are a number of other activities that need to be estimated and added to the project costs. For example, equipment mobilization, road opening costs (for abandoned roads), the installation of general road surface drainage improvements, technical oversight or supervision of the equipment, and overhead costs necessary to manage each equipment subcontract. These costs are all important to take into consideration when developing estimates of project costs.

Labor

To determine or predict labor costs for a proposed project, the amount of time needed to complete each task is calculated. For example, installing a downspout on a culvert will be allocated a given number of hours for a 20-foot downspout of a certain diameter and a greater number of hours for attaching a 30-foot downspout of the same diameter. These time estimates are based on typical efforts – amounts of time taken to complete similar tasks on previous projects. For road upgrading projects, labor is typically employed for a variety of stream crossing installation tasks (bolting culverts, adding downspouts, installing trash barriers or flared inlets, etc.), as well as for mulching, seeding and planting of bare soil areas. Some projects involving bio-technical treatments or gully control measures may be largely installed by hand labor. For road decommissioning projects, most labor is for mulching, seeding and planting activities. From the estimates of time needed for each task, cost estimates for each site and for the project as a whole are calculated using the current labor hourly pay rates for the area of the project. Hourly rates can vary significantly from region to region.

Materials

Material costs are also based on costs for completed projects of similar types, and from established cost lists from suppliers and manufacturers. We use the typical amounts of materials needed for each task, for example, 50 foot long 18 inch diameter pipe for ditch relief culverts, or 40 to 100 feet of 36 inch diameter stream crossing culverts. Materials estimates must take into account design criteria, such as the size of the culvert needed to fit the drainage area and peak discharge for a 100-year flow. Other materials might include bands for connecting culverts, flared inlets, road and rip rap sized rock, seed, plants and straw mulch.

Controls on Costs

Figure 2 contains a list of factors that can impact the costs of road upgrading, decommissioning, and maintenance. These factors must always be taken into consideration when developing cost estimates.

Figure 2. Controls on costs

- Maintenance status of road (open or abandoned/overgrown or washed out)
- Type of road (commercial, ranch, residential, public, etc)
- Inventory, prescription and layout costs
- Assessment and prescription “accuracy” (experience of personnel)
- Heavy equipment and laborer experience in comparable work
- Storm-proofing design specifications
- Stream crossing design standards
- Secondary erosion control treatments “required” (e.g. channel or fill slope armoring)
- Equipment availability and equipment used
- Equipment rental rates (including operator and fuel)
- Surfacing requirements and availability (costs for rock or paving)
- Site frequency
- Stream crossing frequency
- Connectivity of road surface with stream channels
- Supervision requirements
- Site volume (volume excavated)
- Endhaul volume
- Endhaul distance
- Layout requirements (staking or descriptive specifications)
- Contracting method (hourly or bid)
- Overhead

Road Upgrading and Decommissioning

An important factor controlling the difficulty and cost of a project is the status of the road: whether it is currently open or abandoned, and if it is abandoned, whether it is overgrown or washed out at one or more locations. The road status directly affects the access costs for the project. If, for example, the road to be decommissioned is washed out, it will be necessary to rebuild stream crossings and landslides simply to get the equipment to the project work site. During the course of a decommissioning project, equipment will eventually need to remove (excavate) the stream crossings that were just rebuilt. In that case, a washed-out or overgrown road that has been abandoned for some time may cost considerably more to decommission than an open, maintained road that can be driven to the end of the project site. We have developed good cost estimates that predict how much work effort (equipment time) it will take to reopen a road, and how much it will cost per mile to treat roads that fall into each of these different categories (washed out, overgrown, open).

Inventory, prescription, and project layout complexities also are important determinants of project costs. The State of California has a set a standard cost limit for road erosion inventories and erosion prevention planning. The CDFG's Fishery Restoration Grant Program has set an upper limit of about $1,200 per mile for full inventory and assessment, and the development of prescriptions for erosion control and erosion prevention plans for road systems.

The experience and skill of the personnel carrying out the inventory, assessment and project planning are critical factors in determining the final project cost. Good (accurate) inventories are absolutely necessary for the development of cost-effective projects. Equipment operator expertise in implementing the prescriptions is similarly important, and inexperience can greatly increase costs or decrease project cost-effectiveness.

Another control on project cost is whether or not secondary erosion control treatments are required. Secondary erosion control treatments are those designed to control or prevention erosion on bare soils that were exposed as a result of the main storm-proofing treatment. If for example, after a stream crossing has been excavated on a decommissioned road, the channel bed and bank needs to be armored to prevent down cutting or bank erosion, the project costs will be considerably higher than if no such treatment is required. In many cases, the secondary erosion control treatments are very expensive to apply, and these costs do not necessarily translate into proportionately more sediment prevented from entering the stream. Secondary erosion control is often not as cost-effective as the primary road treatment measures (Weaver and Sonnevil, 1984).

Equipment availability, types of equipment used, and rates charged for equipment rental and operation are factors that directly affect project costs. Equipment rates can vary considerably from region to region, often mirroring general cost-of-living expenses in the local communities or nearby cities. For example, rental rates for the same hydraulic excavator can vary as much as 60% between rural northern California and the San Francisco Bay area. Similarly, the proximity of materials and supplies for the road work is a key cost determinant. If, for example, you are replacing stream crossings on a rock surfaced or paved road, the road will need to be re-surfaced as a part of the treatment. If rock must be brought in from 10 miles away, it will be much more expensive than if the rock can be obtained locally.

Working on paved public roads has proven to be highly costly. Public road departments typically provide increased engineering as compared to private roads, and this added design step increases costs. In addition, public roads require a suite of different prescriptions than do private roads. For example, public roads require a variety of safety designs that exclude the use of such road surface drainage features as rolling dips. Alternate designs are often required. Work on public roads also requires the use of additional safety measures, such as traffic control, that can add substantially to project costs. Finally, costs associated with extra endhauling of spoils, re-paving, striping, installing guard rails and other measures can make the same storm-proofing project cost up to three times more than comparable projects on private land road systems.

The physical characteristics of the road network under consideration will also have a significant impact on project cost. The density of roads in the area, the frequency with which stream crossings occur, and the connectivity of the road surfaces with stream channels all must be taken into consideration. More roads will likely mean more work to be done, as will a higher frequency of stream crossings. How connected the road surface is to the stream channel network will dictate the number of ditch relief culverts, rolling dips, or miles of road reshaping work that must be completed. Costs will generally increase with higher levels of road/stream connectivity.

Supervision requirements, volume of fill to be excavated at the site, and end-haul volumes are all important considerations. Layout requirements at the site are also factors: whether you will have to stake the site or simply provide prescriptive specifications. Contracting methods make a difference, depending on whether you employ an hourly contract or you utilize a minimum or least-cost bid. Overhead costs vary between agencies and contractors and can thus have some impact on the final project cost.

A final issue is that of staging: having materials and equipment on site at the right time in order to maximize project and cost efficiency. For example, in working with a large industrial landowner in Northern California, road upgrading work was given a lower priority than logging operations. This meant that whenever equipment was needed for logging, it could not be used for the road work for 3 or 4 days, leaving the equipment operator with little to do until the missing equipment was returned (in this case, dump trucks). In the end, a storm-proofing project that was originally predicted to cost about $45,000 per mile ended up costing over twice as much.

Road Maintenance

Road maintenance costs depend primarily on road length and road density; these often determine the scope of the job and the maintenance status of the road. Maintenance costs are also affected by the age of the road, which might be new, developed, or seasoned. Maintenance costs for a road that has been upgraded and storm-proofed can be expected to be much lower than for one that is underdesigned, poorly constructed or in significant disrepair.

The stream crossing frequency along a road often has a large impact on the level of maintenance required. Ridge-top roads, which have many fewer stream crossings than riparian roads, generally require less maintenance than riparian roads. Similarly, poorly drained roads, regardless of their location, often require regular maintenance to keep them in a passable condition. Another important factor determining maintenance costs is the value of the resources near the stream, because maintenance will of necessity be much more complex and of greater importance along roads that impact streams with very sensitive resources.

Finally, there exist many different interpretations of what constitutes appropriate and complete maintenance. The standards that can be applied to road maintenance are many. The standards that are eventually adopted in a given project area can greatly affect the cost to do the work, with more rigorous standards demanding higher costs for implementation. For example, if a culvert plugs every year, is it proper to simply clean it out each year, or does the culvert need to be upgraded as a part of the routine maintenance operation? These two treatment options clearly involve very different implementation costs.

Refining Cost Estimates

For a first approximation of storm-proofing and road maintenance costs, it is fine to rely on existing cost data for similar work in similar terrain. Refining the first approximation requires a site-by-site analysis of project costs at the reconnaissance level and a detailed quantitative inventory (see above).

At the reconnaissance level, more detailed cost estimates are based on the frequency of stream crossings in the road system, the sediment volume ranges at each of the crossings, the potential for fillslope failure, the estimated lengths of ditches to be disconnected from the system, the various drainage structures to be installed, and the estimated end-hauling requirements for the road system.

In order to obtain a final detailed cost estimate, it is necessary to visit the sites and tailor the costs to each individual site. This is information that is provided in a quantitative inventory and assessment of the road or road network.

The final complications in determining project costs are often the result of the different definitions of road treatments that are applied by different people. It makes it difficult to aggregate and compare costs between projects if people do not employ the same definitions of effective road treatments. For example, while road decommissioning means excavating stream crossing fills down to the original streambed to some people (so that post-treatment downcutting will not occur), to others it may mean simply removing the culvert pipe and leaving most of the fill in the streambed. Clearly, these two different implementation standards will have very different costs and outcomes associated with them. Standardized definitions and treatment prescriptions, and detailed project objectives, are marks of effective erosion prevention and erosion control projects.

ESTIMATING COSTS FOR LARGE-SCALE PROJECTS

Cost Variation

Unit costs often decrease with the scale of the project (economy of scale). However, costs are very dependent on the types of work included in a project. For example, if an entire watershed transportation system is included in a project, the average cost per mile of road treated will drop dramatically as compared to a project that proposes to treat only the highest priority sites, or a small sample of all the possible sites. This is because you are including high priority sites, moderate priority sites, and low priority ridge top roads. The ridge top roads have very low stream crossing frequencies and as a consequence may not have as much work that needs to be done. The average amount spent per mile may be around \$15,000–\$20,000. In contrast, if the project only includes the high priority sites, the average unit cost may be \$50,000–\$60,000/mile. It is thus very important to know what “types” of roads have been included in a project when comparing costs between your proposed project and other projects that may have been completed in the same general area. The nature and location of project work in a watershed can have a significant effect on cost.

In some cases, it is possible to take advantage of discounts on material orders for larger scale restoration efforts. When purchasing culverts, for example, a single 20 foot, 24 inch standard culvert is relatively more expensive than a mile of culvert from the same vendor. The price may decrease by 20% to 25% when the order is increased to comparatively large amounts of materials or supplies.

Larger projects may also have reduced mobilization costs compared to smaller projects. The heavy equipment will only have to be brought to the area once, and can be moved around within the watershed as the project progresses without need of the expensive mobilization equipment.

Finally, there will be a cost reduction associated with increased operator experience and the development of a large pool of experienced operators. Two of the most important determinants of the cost of both road upgrading and road decommissioning projects are the skill and experience of the operators. With a large-scale restoration effort, an opportunity exists to develop a large group of skilled operators, which can lead to greatly reduced project costs. In addition, each individual contractor will give much better hourly rates for large jobs, because of the increased job security. A contractor may charge $125 an hour to decommission a mile of road, but if the contract will last the entire summer, the rate may drop to $100 an hour.

Changes in Information Requirements

Researching and properly preparing all of the information needed for restoration project planning changes very little as the size of the project increases. It is still necessary to have the same ground-based information, on a site-by-site basis, that will allow you to effectively prescribe the individual road treatments and predict costs.

It is important, though, to employ standardized inventory and prescription tools and protocols, developing “intelligent uniformity” in the way that the project prescriptions are developed and laid out. Just as the skill of the operators can make a big difference in the work on the ground, the people who are planning and prescribing the work have an even more fundamental role in determining what work is done and how much it costs. The skill and experience of the people doing the inventory and laying out the work plan are critically important in keeping costs down and maintaining cost-effectiveness.

In order to ensure that skill standards are employed and followed on a project, it is very useful to require that the inventory personnel and the equipment operators have all been thoroughly trained and have been through a standardized training assessment. This will lead to the development of consistent and repeatable results on the ground. In any long-term restoration program, uniformity, consistency, and repeatability are critical to the success and cost-effectiveness of a storm-proofing project.

Developing the Feedback Loop

Our work is all adaptive restoration, which means that we monitor and document the work that is being performed. It is important to require operators to record and report how much time and effort is spent on each work site. As a result, your ability to estimate the cost and time required to complete a work task or a complete project element will improve over time. You will also be able to clearly recognize when inefficient or ineffective inventory personnel, equipment operators or laborers are adversely affecting restoration effectiveness or cost-effectiveness.

Large-Scale Data Sources and Availability

If a project is to be planned on a large scale, it is crucial to have access to data sources that encompass the entire area under consideration. The quality and complexity of these sources can vary widely. Road network maps available for the project might include GIS maps from a large timber company, the county, or the state. You might also rely on USGS topographic maps, orthophotos or Digital Elevation Models of the project area that can then be converted into project maps.

Experience has demonstrated that anywhere from 15% to 50%, or more, of the roads in a forested landscape are not shown on existing maps, depending on the land ownership in the area. We have dealt with some timber companies that have put literally 90% of their roads on their maps, and others that have mapped only 50% of the roads built in the watershed. Some companies have not mapped their roads at all. Even in the U.S. Forest Service, the general custom is to show on maps the roads that are currently open and maintained and to omit the roads that are not maintained, those abandoned 20 to 30 years ago and since overgrown with vegetation. Both used and unused roads represent potential sediment sources, and ought to be identified on maps and inventoried in the field.

Road maps are typically unavailable for small landowners, unless they have been actively involved in resource extraction (such as timber harvesting). Landowners that have less than 5000 acres are not likely to have GIS systems; at most, they will have a paper map of their roads. Road maps for small landowners are usually difficult to obtain, unless there has been a level 1 air-photograph analysis of the watershed through time. If that is available, you can track and identify all the roads that have ever been constructed in the watershed.

Digital topography is available and can be useful for determining approximate stream-crossing frequencies, which is one of the key elements in estimating the cost of a project. Road construction history is generally not available, but it can be useful for determining road status: which roads are abandoned and which roads are maintained. It is possible to look at the most recent aerial photographs and see the roads that are being used. However, there will always be roads that are hidden beneath the vegetation, especially in coastal areas. Some of the road network may be open and driveable, but still invisible in the most recent aerial photography.

In addition to geographic data, it is also important to make use of large-scale data sets regarding local contractors and equipment rates. These are necessary for cost estimating, and are generally readily available from the private sector. Phone calls and solicitations for non-specific equipment bids will quickly generate hourly cost rates for a variety of equipment types and project areas. The same "bids" can be used to identify those contractors with appropriate equipment for road storm-proofing, as well as those contractors with relevant past experience on similar projects.

Developing Cost Estimates from Level 3 Field Inventory Data

Level 3 field inventories are for fifth-field watersheds. Developing costs at the watershed level involves the completion of nine

Figure 3. Developing cost estimates from Level 3 field inventory[1] data

1. Problem identification (depends on the volumetric definition of a "site")
2. Problem quantification (volume measurements and calculations)
3. Determine equipment needs (desired capabilities and types)
4. Estimate production rates and equipment times
5. Estimate equipment costs, with logistic multiplier (30%) for prescribed treatments, by site
6. Estimate road opening costs (dependent on maintenance status and re-vegetation)
7. Estimate mobilization costs (dependent on equipment needs and availability)
8. Calculate material costs (culverts – for upgrading, seed, mulch, etc.)
9. Calculate labor costs (mostly for culvert installation, planting and mulching)

1- Costs for field inventory and preparation of implementation plan: $800–$1,200/mile, or less

different steps, which are listed in Figure 3. First the sites to be treated must be identified. Sites are defined as features that are likely to deliver sediment to a stream channel in excess of a given number of cubic yards. This threshold level of sediment delivery is typically set anywhere from 10 to 50

Table 4. Sample techniques and costs for decommissioning and upgrading rural roads

Treatment	Typical use or application	General costs1
DECOMMISSIONING TREATMENTS		
Ripping or decompaction	Improve infiltration; decrease runoff; assist re-vegetation	\$500–\$1600/mile
Construction of cross-road drains	Drain springs; drain insloped roads; drain landings	\$1/ft (\$25–\$50 ea)
Partial outsloping (local spoil site; fill against the cutbank)	Remove minor unstable fills; diverse cutbank seeps and runoff	\$1/yd³; \$2500–\$9500/mile
Complete outsloping (local spoil site; fill against the cutbank)	Used for removing unstable fill material where nearby cutbank is dry and stable	Averages \$10,000+/mile (\$1/yd³)
Exported outsloping (fill pushed away and stored down-road)	Used for removing unstable road fills where cutbanks have springs and cannot be buried	\$1–\$4/yd³, depending on push distance
Landing excavations (with local spoil storage)	Used to remove unstable material around landing perimeter	\$1–\$2/yd³, high organics can increase costs
Stream crossing excavations (with local spoil storage)	Complete removal of stream crossing fills (not just culvert removal)	Averages \$1.50–\$3.50/yd³, but can vary considerably
Truck endhauling (dump truck)	Hauling excavated spoil to stable, permanent storage location where it will not discharge to a stream	\$3–\$5/yd³ on top of basic excavation work
UPGRADING TREATMENTS		
Outslope road and fill ditch	Converting and insloped, ditched road to an outsloped road to disperse road runoff	\$170/1000 feet
Rolling dip	Constructed to drain the road surface and, if deep enough, the ditch	\$85 each
Rock road surface	Surface road using 1.5″ to 2.0″ crushed rock	\$4,250/1000 feet
Install ditch relief culvert	Culvert installation to improve dispersion of road and ditch drainage	\$550–\$650 each

Table 4. Sample techniques and costs for decommissioning and upgrading rural roads (cont'd.)

Stream crossing upgrade	Culvert installation or replacement (in this case 36″ x 40′ in a 200 cu yd fill)	$2,445 each
Straw mulch	Mulch bare soil areas with 3000 lb/acre straw	$13/1000 sq ft
Costs are variable depending on material costs, equipment types and rates and operator experience.		

1- These are direct treatment costs for equipment working at a site. They do not include transportation, moving from site-to-site, overhead, supervision, layout, or any other costs. Costs will vary for site to site and from watershed to watershed. Heavy equipment treatments performed using D-6 and D-7 size tractors and hydraulic excavators with average 2 yd^3 bucket size. Data from PWA and NPS, Redwood National Park (1992).

cubic yards per site. Less than the threshold, and the site is not inventoried or is inventoried at a reduced level.

Next, the problems to be treated at the selected sites are inventoried and quantified. This involves measuring the volume (cubic yards) of sediment that will be delivered to the stream system if the roads are left untreated. Next, determine which types of equipment will be needed to do the work that has been prescribed. This typically includes excavators, bulldozers, and dump trucks for road decommissioning. In addition to these, water trucks, graders, rollers and other equipment are often employed on road upgrading projects. Production rates are estimated based on the site characteristics and the complexity of individual work sites. For example, we calculate how many cubic yards can be excavated in an hour based on the limiting piece of equipment, which is usually the excavator. In excavating a large, deep stream crossing containing abundant organic debris (logs), you might apply an excavation rate of 35 to 45 cubic yards per hour for an excavator with a 2 cubic yard bucket. On the other hand, if the stream crossing is small and less complex, the work may be completed at a rate of 85 to 100 cubic yards an hour.

Other factors determining the project cost include the time needed to move the equipment between sites, the costs for opening abandoned roads so that equipment can be brought in to the most remote work sites, and the time and costs required to seed and mulch the site after the upgrading or decommissioning work is complete.

We have developed a set of standardized unit costs for different types of treatments. These are described in Table 4. The list includes many of the common practices used in upgrading, decommissioning and maintaining roads. We apply these standard costs in the field when developing initial cost estimates. Based on years of experience, the standards are a reliable method for approaching a first cost approximation.

In the field, costs are developed using a spreadsheet similar to the one shown in Table 5. The spreadsheet contains all of the major cost categories associated with a project, which include moving the equipment in and out of the site, road opening costs, heavy equipment requirements for treating all the sites, heavy equipment requirements for disconnecting the road surface drainage from the stream channel, labor costs, culvert costs, re-vegetation costs and project technical supervision. Each one of these categories is supported by a separate spreadsheet used to calculate individual costs in detail. After determining the project costs, the total future sediment delivery prevented by the project can be calculated, as can the cost effectiveness of the project ($/yd^3 of sediment prevented from being delivered to the stream system).

Table 5 is an example of a completed cost spreadsheet for high or high to moderate priority sites in a watershed. In this particular road system, the total cost for completing all storm-proofing work in the watershed was calculated to be $730,000. We calculated that for this project, we were preventing a future sediment yield of approximately 62,000 cubic yards. The cost effectiveness was about $12 per cubic yard for the average road.

Table 5. Cost worksheet for high and high/moderate sites

Cost category	Equipment	Cost rate ($/hr)	Treatment (hrs)	Logistics (hrs)	Total (hrs)	Total estimated costs ($)
Move in/out (Lowboy)	Excavator	95	4	NA	4	380
	Dozer	70	4	NA	4	280
Road opening costs	Excavator	115	213	NA	213	24,495
	Dozer	85	213	NA	213	18,105
Heavy equipment requirements for site specific treatments	Excavator	115	1479	444	1923	221,111
	Dozer	85	1534	460	1994	169,507
	Dump truck	60	425	128	553	33,150
	Backhoe	65	0	0	0	0
	Grader	85	0	0	0	0
Heavy equipment requirements for road drainage treatment	Excavator	115	18	5	23	2,691
	Dozer	85	336	101	437	37,128
	Backhoe	65	0	0	0	0
	Grader	85	24	7	31	2,652
Laborers		20	740	22	962	19,240
Rock costs						43,601
Culvert costs						115,346
Mulch, seed costs						6,952
Layout, coordination		50	NA	NA	728	36,387
Total estimated costs						730,484
Future yield (yds^3) (includes chronic road surface erosion and sediment delivery)						61,192
Cost-effectiveness ($\$/yds^3$)						11.94

Using standardized spreadsheets and lists of previous costs for different types of work can greatly help to streamline the cost estimation procedure. These devices also help to ensure that cost estimates for erosion prevention and erosion control work associated with road storm-proofing remain consistent over both time and geographic area. This helps maintain highly consistent and accurate work standards and cost-effectiveness.

To quantitatively determine whether it is possible to make predictions about project costs based on site characteristics, we did an analysis where we compared a number of different parameters for five watersheds. The total length of road in those watersheds or watershed assessment areas was 328 miles. Furthermore, the calculations were only based on high and moderate priority sites, not the low priority sites.

The costs for implementing these road decommissioning projects ranged from $10,500 to $30,500 per mile. We were able to achieve a reasonable prediction of cost based on the number of sites per mile, which ranged from 2.8 to 9.3. The best predictor of cost, though, was the measure of future volume (cubic yards) of sediment prevented from entering the stream within the project boundary. Our study demonstrated that it is possible to get a rough idea of how much a project is ultimately going to cost based on the amount of sediment saved by that project, and the density of treatment sites.

Table 6 has decommissioning unit costs per mile for five different watersheds, which contain 27 miles of decommissioned road. Our unit costs for this work ranged from $25,800 to $77,400 per mile. The difference in costs is primarily a function of the number of sites (site density), which ran from a low of about 8 sites per mile to a high of about 25 sites per mile. In addition, the unit volumes of material that needed to be excavated from the stream crossings in order to decommission the roads, ranged from about 3,500 to 10,000 cubic yards per mile. Both the site density and the amount of fill to be exca-

Table 6. Analysis of data from five road decommissioning proposals, Northern California watersheds (1998 and 2000)

Project	Total cost ($)	Road length (mi)	Sites (#)	Excavated volume (yd³)	Unit cost/mile ($/mi)	Unit cost/vol ($/yd³)	Site density (#/mi)	Unit vol/mile (yd³/mi)	Unit vol/site (yd³/site)
Rowdy Creek 1999	134,245	5.2	41	18,500	25,820	7.25	7.9	3,560	451
Salmon Creek 1998	304,790	7.3	61	44,000	41,750	6.92	8.4	6,030	733
Rowdy Creek 2000	374,876	6.3	53	42,000	59,500	8.93	8.4	6,670	792
Redwood Creek 2000	290,461	4.5	57	36,000	64,550	8.06	12.7	8,000	632
Little River 2000	301,936	3.9	100	42,000	77,420	7.19	25.6	10,770	420
Totals	**1,406,308**	**27.2**	**312**	**182,503**	**51,700**	**7.71**	**11.5**	**6,710**	**585**

Table 7. Typical road upgrading and road decommissioning costs

Road upgrading[1] (difficult roads; 100-year design)	$42,500/mile
Road upgrading[2] (moderate to difficult roads with high site density)	$45,500/mile
Road upgrading[3] (watershed-wide, low & high priority roads; 100-year design)	$25,000–$35,000/mile
Road upgrading[4] (watershed-wide average; 100-year design)	$10,000–$35,000/mile
Road decommissioning[5] (moderately difficult roads)	$51,000/mile
Road decommissioning (range of roads – ridge spurs to moderate complexity)	$2,000–$35,000/mile

1- Based on 20 miles of actual costs for treatment of high priority road reaches; with mix of about 20% decommissioning and 80% upgrading.
2- Based on detailed field inventory and cost estimate for 19 miles of road.
3- Estimates based on approximately 160 miles of "storm-proofed" road.
4- Based on mix of road types from 328 miles of inventoried forest roads, including a range of high priority (streamside) to low priority (ridge) road systems in 5 watersheds. Includes both upgrading and decommission road reaches.
5- Based on detailed inventories and cost estimates for 27 miles of road decommissioning.

vated can be good indicators of project cost. Unfortunately, predictions of this kind require some fieldwork in order to quantify site densities and amounts of fill to be excavated on a watershed level scale. Some of this landscape level information is predictable, based primarily on data other people have collected in similar watersheds or similar terrain, but in most cases there is no substitute for surveying the area directly.

Typical Costs

Road Upgrading and Decommissioning

Table 7 provides a list of typical project costs, based on six general categories of road upgrading and road decommissioning on non-public, unpaved road systems. These costs have been obtained from storm-proofing work completed or in-progress. The costs have been extracted from inventories, estimates, and completed project cost totals. The averages here are representative of a range of different projects, and so provide a general perspective on the costs that can be expected for various types of projects. Considerable variability can be expected and paved public roads will be significantly more expensive.

Upgrading difficult roads with a 100-year design standard has averaged $42,500 per mile. This average is based on 20 miles of upgrading work completed in 1999 and includes all stream crossing upgrades, road surfacing, and excavation and removal of unstable fill slopes with a potential for future sediment delivery.

The second item, road upgrading at moderate to difficult sites with a high site density, is an estimate based on 19 miles of road. The average amount spent on these projects was $45,500. Our definition of difficult roads includes roads built in the riparian zone and steep stream-side slopes. These roads were built on steep slopes probably in the 1940s or 1950s. In some cases the roads are old railroad grades that have been since converted to truck roads. Riparian roads are very close to the stream, and the potential for sediment delivery to the stream from any failures is high. The combination of difficult riparian roads with the very high site density of these projects results in costs that are at the high end of what one would expect in the average North Coast watershed.

If the cost estimate is expanded to include an entire watershed, which in this case is about 40 square miles, the unit costs for upgrading or decommissioning virtually all the roads in the watershed would probably be about $20,000 to $25,000/mile. When working on all of the roads in a watershed, the work will not necessarily be spread out evenly: the watershed will be prioritized and in so doing, the places most likely to fail and most likely to deliver sediment to the streams are selected first. As a result, the sites that are selected and completed in the first two years are going to be the most expensive sites. They will also be the most time consuming sites. However, even though this means that only a few miles will be treated, there will be a big reduction in the volume of, and potential for, future sediment delivery.

The third item is an average cost for upgrading roads in an entire watershed, including both high and low priority roads and employing a 100-year design standard. The cost is $25,000–35,000 per mile, based on 160 miles of storm-proofing completed on land owned by an industrial timber company. The estimate includes a wide range of types of road, from ridge roads (which has few crossings and is relatively easy to treat) to riparian roads (which have many crossings and are difficult to access and work on).

The fourth estimate is for road upgrading on a watershed scale, with 100-year design standards. It is based on a mix of road types across 328 miles of road inventoried on another industrial timberland owner. The estimate is similar to that in item 3, since both are on the watershed level and include a variety of road types and locations.

An average cost for road decommissioning is listed as the fifth item. The decommissioning in this case is on roads with moderately difficult sites, and is based on detailed inventories for 27 miles of completed project work. If the work is done in an efficient manner, the cost may be around $51,000 per mile. In the sixth and final cost figure, the average cost for road decommissioning individual forest and ranch roads is listed as $2,000 to 35,000 per mile. This is for a range of roads and sites on the entire watershed level and thus includes all levels of difficulty. Depending on site densities and locations of the road (ridge, riparian, mid-elevation), the cost can vary considerably.

Road Maintenance

Typical maintenance inspection costs for forest road systems are approximately $25 per mile per year. This includes a full annual inspection of all roads, stream crossings and fill slopes that are showing signs of potential instability. It also includes intermittent winter storm maintenance inspections and inspection during and following major storm events. Road maintenance is separate from any timber harvest-related activity and separate from a storm-proofing program where the roads are actually upgraded. Maintenance just means keeping the roads at minimal level of stability, so they do not decompose and the culverts do not plug and wash out. Routine culvert replacement, culvert cleaning, and fill slope excavations (where needed) can cost about $275/mile per year. This higher cost is based on roads that are actually failing and need to have immediate maintenance measures taken to prevent more catastrophic failure. These costs are from an industrial forest landowner with over 3,000 miles of forest roads.

Maintenance costs can be difficult to calculate, though, because the standard costs calculated for the work can vary between different groups and different projects. For example, publicly maintained county roads will have a significantly different set of cost figures from those of a large industrial landowner. Rural subdivisions will have another set of inspection and maintenance costs. It is best to base cost estimates on as many different sources of comparable situations as possible.

EVALUATING COST ESTIMATES

Confidence in Watershed/ESU Cost Estimates

Cost estimate reliability is dependent upon the level of the estimate, and whether it is a preliminary first-approximation or the result of a detailed estimating procedure. Confidence in an estimate also depends on data availability and the quality of the data. Typically there is not much data available for a given project location, and the quality of the estimate is fair to poor. We have completed extensive inventories in Northern California covering over 1,000 square miles of land, a large area from which to compile cost data and multiple cost-estimates.

Confidence in cost-estimating is greatly increased by employing real data from road upgrading and road decommissioning projects. Generally, as the project area increases, the confidence level for estimates of the costs to do work in that area decreases. The greatest confidence in cost estimates for road storm-proofing is achieved for projects that have detailed quantitative inventories and assessments of problems sites (together with specific prescriptions for erosion prevention and erosion control work, including heavy equipment and labor needs, and material costs), and project cost data for similar work actually completed in the local area.

CONCLUSION

When estimating the costs of road upgrading, decommissioning and maintenance, it is important to understand that generalizations and extrapolations of similar cost data can only go so far. In the end there is no simple way around the need for detailed surveys of the area under consideration for upgrading, decommissioning or maintenance. Road surveys and quantitative inventories are crucial first steps in planning and developing cost estimates for new road treatment projects. Standardized methods for conducting sediment source inventories and for developing project costs can help maintain consistency between projects and creating a body of data that can be used as a reliable base from which to develop new projects. We have found that there are some site characteristics that can be used as reliable predictors of project cost, in particular the future sediment yield prevented by the project. Correlations such as this can only be made based on years of experience in the field, but they can be very valuable tools for developing new projects.

REFERENCES

Flosi, Gary, *et al*. 1998. Chapter 10: Upslope Assessment and Restoration Practices. *California Salmonid Stream Habitat Restoration Manual*, 3rd Edition. California Department of Fish and Game, Inland Fisheries Division.

Harr, R.D. and R.A. Nichols. 1993. Stabilizing forest roads to help restore fish habitats: A Northwest Washington example. *Fisheries*. 18(4):18–22.

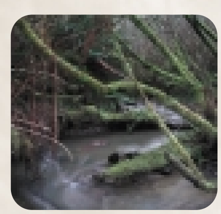
Pacific Watershed Associates. 1994. *Handbook for forest and ranch roads*. Prepared for the Mendocino County Resource Conservation District in cooperation with the California Dept. of Forestry and the U.S. Soil Conservation Service. Mendocino Resource Conservation District, Ukiah, California. 163 pages.

Weaver, William E., Danny K. Hagans, and James H. Popenoe. 1995. *Magnitude and causes of gully erosion in the lower Redwood Creek basin, Northwestern California*. U.S. Geological Survey Professional Paper 1454I, pp. I1–I21.

Weaver, W.E. and D.K. Hagans. 1999. Storm-proofing forest roads. In: *Proceedings of the Skyline Forest Sedimentation Conference*, Corvallis, Oregon. April, 1999, pp. 230–245.

Weaver, W.E. and D.K. Hagans. 1996. Sediment treatments and road restoration: protecting and restoring watersheds from sediment-related impacts. Chapter 4, In: *Healing the Watershed, A Guide to Native Fish Restoration*, Pacific Rivers Council, Eugene, Oregon, pp. 109–143.

Weaver, W.E. and R.A. Sonnevil. 1984. Relative cost-effectiveness of erosion control for forest land rehabilitation, Redwood National Park. In: *Erosion Control…Man and Nature, Proceedings of Conference XV*, Int'l Erosion Control Assoc., Feb. 23–24, 1984, Denver, Colorado, pp. 83–115.

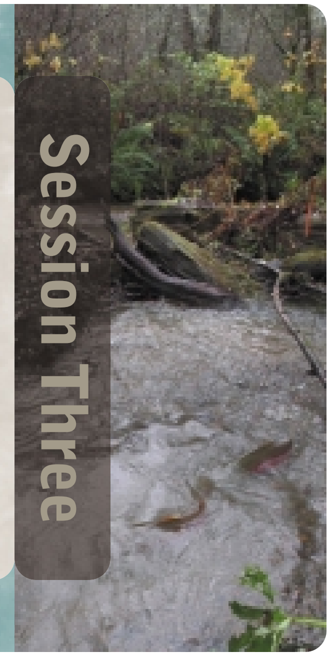


Streambank stabilization, streambank fencing, nuisance species control, riparian zone management

Stream Restoration Cost Estimates

BRIAN BAIR
USDA Forest Service
Gifford-Pinchot National Forest
1262 Hemlock Road
Carson, WA 98610-9725
bbair@fs.fed.us

Session Three



ABSTRACT

The Wind River watershed in Washington State poses restoration challenges characteristic of Pacific Northwest watersheds, and is used here to exemplify the difficulties in estimating restoration costs on both small and large scales. This paper emphasizes the major influences on the cost of restoring the Wind River drainage, and the factors that can wreak havoc on cost estimation. Also discussed are the roles played by watershed analysis and stream surveys.

INTRODUCTION

The Wind River Watershed is located on the west slope of the Cascade Mountains in the Gifford Pinchot National Forest, Southwestern Washington State. The watershed contains 150,000 acres and drains into the Columbia River at river mile 155, approximately 10 miles upstream of Bonneville Dam (Figure 1). The Wind River ecosystem is a typical west-slope Cascade environment, with average annual precipitation ranges from less than 60″ per year in the southeast portion of the watershed to over 120″ per year in the west and northwest. Approximately 75% of the annual precipitation falls between November and March. Because the watershed lies in the western Cascades at elevations ranging from less than 100 feet to nearly 4,000 feet, both rain and snow are common during the winter months (Coffin 2001).

The predominant land management activity within the Wind River watershed has been timber harvest. Timber harvest within the basin began in the late 1800's. "Splash dams" were constructed on the main stem Wind River and tributaries to stockpile and transport logs down stream to the mills along the Columbia River. Riparian areas were targeted for harvest due to the large quantities of old growth timber and access to the stream (Figure 2).

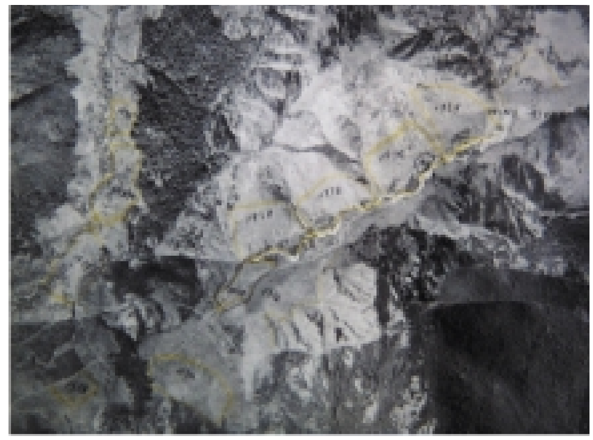
The U.S. Forest Service (USFS) manages 89% of the land within the Wind River watershed. The Northwest Forest Plan Record of Decision categorizes the Wind River Basin as a Tier 1 Key Watershed that provides critical habitat for anadromous salmonids. Federal management will largely determine the quality of habitat in the Wind River watershed.

Figure 1. Wind River watershed, Skamania County, Washington

Most populations of salmonids that historically occupied the Wind River watershed are considered depressed (WDF *et al*. 1993). Shipherd Falls, which is 4.3 miles upstream from the historic mouth of the Wind River, was a natural barrier to all anadromous fish except steelhead (Bryant 1949); summer steelhead were dominant and numerous above this barrier. The U.S. Fish and Wildlife Service (USFWS *et al*. 1951) estimated the summer steelhead run size was 3,250 with an escapement of 2,500 spawning adults. The current number of wild summer steelhead spawning in the Wind River has been reduced to approximately 200 adults in recent years (Rawding 1997). In addition, a fall race of chinook that dominated the lower reach of the Wind River is depressed and composed of a substantial number of stray hatchery fish (WDF *et al.* 1993).

Anadromous fish losses have been attributed to adverse ocean conditions, the construction of Bonneville Dam, timber harvest, and rural development of the upper watershed (WDW *et al*. 1990). These activities in the upper watershed have severely impacted riparian areas and stream channels in several key steelhead sub watersheds. Poor upland, riparian, channel conditions cumulatively produce maximum water temperatures exceeding 24°C (75°F), risk of increased peak flows and increased sedimentation (USFS 1996).

Figure 2. 1944 U.S. Department of War aerial photograph of the Upper Wind River (river mile 20–25), Skamania County, Washington



Estimating Costs

Deciding where to spend allocated money to restore a watershed is critical. Stream surveys, sub-basin assessments and watershed analysis were used to evaluate limiting factors in the Wind River. Fish habitat and water quality have been negatively impacted by past riparian timber harvest, stream clean-outs, road building and regeneration harvest within the rain-on-snow zone. Alluvial reaches within the main-stem Wind River and tributaries, which contain the majority of steelhead spawning habitat, have been significantly impacted. Many of these reaches were disturbed over 80 years ago, yet habitat and water quality have not recovered and in some cases are getting worse.

In the Wind River, the USFS has taken a watershed approach to restoration. In 1992, the Wind River watershed was assessed and the USFS, USFWS and Underwood Conservation District (UCD) initiated cooperative habitat restoration projects in 1994. The Wind River Restoration Team (WRRT) was formed in 1994 in response to the decline of steelhead within the Wind River basin. The team includes technical specialists from the UCD, USFWS, Washington

Department of Fish and Wildlife (WDFW), U.S. Geological Survey (USGS), Washington Trout and the Yakama Nation. Acknowledging that watershed-scale restoration can only be successful if all stakeholders are involved, the UCD, in cooperation with Skamania County and the WRRT, facilitated the development of the Wind River Watershed Council in 1997. The group is comprised of representatives of landowners, businesses, logging companies, government agencies, conservation groups, schools, and others.

The restoration projects completed to date are products of stream surveys (1987–1998), a sub-basin assessment (1992) and watershed analysis (1996 and 2001) conducted by the USFS. Projects on private lands are products of stream surveys conducted by UCD and USFWS. The goals of these projects are to accelerate the recovery of water quality and fish habitat in which wild Wind River steelhead evolved. These goals will be achieved by utilizing a holistic, community-based watershed restoration approaches on both public and private lands. Past restoration efforts within the watershed have addressed degraded streams, riparian areas, and hill-slopes. An adaptive management strategy has permitted partners to build upon past successes in restoring degraded water quality and habitat within the Wind River sub-basin. On-going collection and analysis of biological, physical habitat, and water quality data will fill information gaps on private and public lands. This information is necessary to assess watershed processes and success of past restoration efforts and to identify future restoration needs. Coordination and education of land owners, the community, and other stakeholders is an important part of achieving restoration goals and preserving wild steelhead within the watershed.

The goals of restoration efforts in the Wind River have been to accelerate the recovery of riparian, in-stream habitat and water quality in which the steelhead evolved. The objectives to accomplish these goals are: reduce road densities, reforest, and rehabilitate riparian areas, flood plains, and stream channels. The USFS, USFWS, Bonneville Power Administration and UCD have made significant progress in restoring hydraulic processes and rehabilitation of critical habitat. Since 1992, approximately 100 miles of road have been stabilized or “storm-proofed”, 35 miles have been decommissioned, 120 acres of flood plain have been reclaimed, 300 riparian acres have been planted and 3,000 pieces of large woody debris (LWD) have been placed back in 8 river miles of stream. In addition, the USFWS and UCD have initiated restoration on private lands with the implementation of two “demonstration” projects. One is a reforestation project along Martha Creek near Stabler, and the other is a riparian and channel rehabilitation project on the Wind River. Funding was recently secured to conduct additional projects in the privately owned portion of the watershed. These activities will assist landowners with riparian and channel restoration, slope stabilization and erosion control.

Stream Restoration Cost

For the purposes of this presentation, three types of restoration projects will be discussed: stream bank stabilization, channel rehabilitation and riparian reforestation. The majority of stream bank stabilization projects within the Wind River consist of constructing large woody debris revetments; log cribs, bank barbs and groins. Several projects have included rock groins or bank barbs and are included in cost estimates. Stream channel rehabilitation consists of a myriad of activities ranging from total channel reconstruction to reconstructing log jams that serve as channel slope grade controls to maintain or restore flood plain connectivity. Riparian reforestation activities include planting conifers, hard woods and shrubs with conventional hand crews to transplanting whole trees and shrubs with heavy equipment.

Costs for bank stabilization on public lands within the Wind River range from approximately $46,000 to $222,000 per river mile. For channel rehabilitation, the USFS cost range from $41,000 to $137,000 per river mile with a mean of $86,000 per river mile. Riparian reforestation cost range from approximately $4,000 to almost $8,000 per mile, and with and average of $5,000 a river mile, or $110 per acre.

Major Factors Affecting Cost Estimation

• *Scope, treatment intensity and stream size:* Large projects tend to have lower cost per river mile. Planning, design, National Environmental Policy Act (NEPA) requirements, equipment mobilization cost on small bank stabilization projects (< 3,000´) can exceed implementation cost, which quickly drive up the cost per river mile. Large scale projects (1–9 river miles) absorb or significantly reduce the implementation to fixed cost ratio and are more efficient. Treatment intensity varies from site to site. Again using bank stabilization as an example, 200´ of bank may be treated with a single log jam/bank barb, while another site with 200´ of unstable bank may take a series of barbs and floodplain contouring to stabilize the site. The size of the stream can make a significant difference in the cost. Typically, planning, design, regulatory coordination and treatment intensity radically increase with stream size and are inversely proportional to stream order.

• *Access:* Access to the project site usually dictates the equipment type and labor intensity. In some areas where material such as large woody debris could not be hauled directly to a site, helicopters are typically used. Cost for heavy helicopters can cost upward of $8,000 an hour.

• *Material availability:* Although the USFS manages almost 90% of the watershed and the timber contained within it, obtaining the quantity and quality of large wood can be a challenge. Trees that are cut to put in the river are no different than those being cut to send to the mill; the same regulations apply to both.

• *Type of contract:* The type of contract can greatly influence the project cost. Hourly equipment rental (with operator) contracts are the cheapest; however the liability associated with the work greatly increases as well as the time and personnel it takes to direct the on the ground work. Construction contracts can cost up to 50% more than equipment rental contracts; however, the contractor assumes the responsibility.

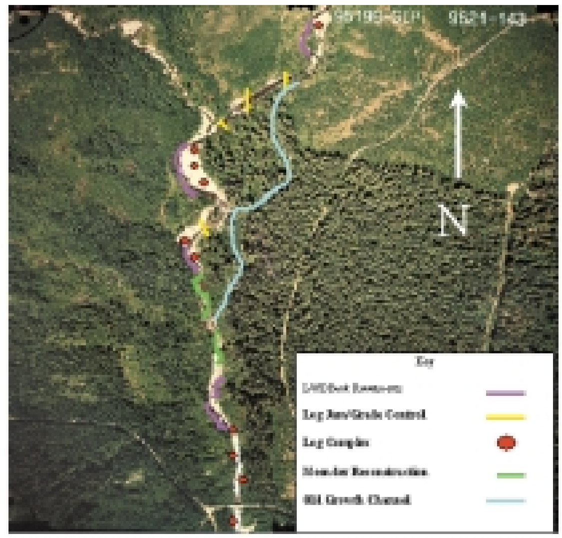
• *Time:* The amount of time to complete the project is affected by all of the factors mentioned above. In addition, the permitting process (hydraulic permits, NEPA, endangered species consultation) can be very time consuming. For example, conducting the appropriate level of NEPA may take a year or more, especially if endangered species or significant cultural resources are involved.

Figure 3 provides an example of common access and material availability issues. This is Wind River at river mile 24, where work on three river miles of stream has been completed this year. Riparian areas were thinned and then hauled or yarded directly into the river. Approximately 2,000 trees were then used to install grade controls, construct logjams, and reconstruct meanders at a cost of $65,000 a river mile.

Figure 4 shows a project that took place in an area that was experiencing channel

Figure 3. The Mining Reach riparian and stream channel restoration project, Skamania County, Washington

Figure 4. Trout Creek restoration, Wind River watershed, Skamania County, Washington



down-cutting. The damage was the result of three historical actions. First, all of the timber alongside the creek was cut, and then the upper watershed was logged. The cumulative effects of these actions decreased bank stability and are thought to have increased peak flows. Finally, the proverbial straw that broke the camel's back — logjams that were thought to be migration barriers to steelhead were removed, which resulted in down-cutting or incision and subsequent lateral migration of the stream channel. The project area contained very young stands of trees; therefore there was little onsite material available for construction. Trees were salvaged from a wind blown stand of trees 20 miles away, stockpiled nearby and then a helicopter was used to fly the trees to the project site. The difficulties involved in importing the trees to the site almost tripled the cost per river mile compared to the previous example. Restoration cost for rehabilitation of this project ranged between $140,000 and $150,000 per river mile.

Refining Cost Estimates

Table 1 shows a range of cost for restoration. For planning, design, and NEPA, costs range from $21,000 to $110,000 per river mile. The mean is about $70,000 for the planning phase.

Material acquisition and material transportation to project sites can become one of the most expensive components of stream restoration. Trees and LWD have been primarily used for restoration in the Wind River. Boulders and rock have also been used in certain circumstances. Obviously projects with ample on-site material cost significantly less than projects that involve extensive haul distances or helicopter transport. For material transport equipment, the use of a helicopter greatly increases the cost, to at least $64,000 per river mile and often as much as $150,000 per river mile. If material can be ground transported to the site, the cost can drop down to as low as $17,000 a river mile. These costs do not reflect the cost of trees. If purchasing trees is necessary, the material costs may exceed $145,000/ river mile.

Labor costs are typically access-driven. Depending on the site, labor cost can range from $17,000 per mile if access is limited or drop to $112 per river mile if access to sites is not restricted. Riparian planting and thinning is typically the most labor intensive

Table 1. Typical restoration costs

Item	High end (cost/river mile)	Low end (cost/river mile)	Reasonable mean (cost/river mile)
Plan, design & NEPA	$110,040	$21,833	$68,880
Materials (trees)	$64,900	$14,747	$20,566
Mobilization	$8,200	$1,333	$2,777
Equipment	$122,000	$17,333	$20,800
Labor	$17,167	$112	$5,000
Riparian planting/ maintenance	$7,646	$3,893	$5,512
Instream structure maintenance	$24,640	$4,760	$5,600
Total	**$354,593**	**$64,011**	**$129,135**

aspect of stream restoration. Riparian planting, which is arguably always needed in conjunction with streambank stabilization, runs $4,000 to $7,000 per river mile.

Maintenance of riparian and in-stream improvements are important. Monitoring of plant survival and growth plots in riparian areas along the Wind River and tributaries have shown that mortality of newly planted trees can approach 60%. Vegetation management is needed to control the competing vegetation and browse from ungulates. Streams are dynamic and some level of maintenance of in-stream structures must also be maintained. Unfortunately, it is rare for most projects to receive sufficient funding for adequate monitoring or maintenance.

Another issue that can greatly affect the cost of the project is whether the equipment is rented hourly or included in a construction contract. A typical hourly equipment rental contract may include the hiring of a timber faller, a tracked excavator, and bulldozer with operators. The work is directed by the designer. In contrast to hourly equipment rentals, construction contracts require extensive, detailed plans (“blueprints”) for the contractor to follow. Cost for construction contracted in-stream work can significantly increase cost due to the extent of design specifications, site and contract preparation. In addition, site variances are typically the norm and not the exception which can wreak havoc with the best designs. Site variances can never be fully anticipated and typically lead to costly modifications. Experience has demonstrated that construction type contracts can cost over seven times that of equipment rental contracts and the results can be less than acceptable.

Table 2 provides examples of three projects: Trout Creek, which is approximately one river mile; Panther Creek, which is about 2/10ths of a river mile; and the Mine Reach, which totaled approximately 3 river miles. Looking at cost per river mile, there are some significant differences between the three projects. Trout Creek was the most expensive, because material access was limited to the project sites. Heavy helicopters were needed

Table 2. Project budgets: Trout Creek, Panther Creek and Mine Reach

Trout Creek 30208	Unit	Unit cost	Days/acres/logs	Cost	
Plan, design & NEPA	per acre	393	100	$39,300	
Excavator	per day	1300	16	$20,800	7.8125
Dozer	per day	820		$0	
Riparian thinning	per acre	900		$0	
Labor crew	per day	600	15	$9,000	
Planting	per acre	110	3	$330	
Helicopter	per log	333	125	$41,625	heavy helicopter $7,500/day
Log haul	per log	115	125	$14,375	$4.5/log/mile rootwads attached
Move in/out	in & out	8000	1	$8,000	
Materials	bulk	4000	1	$4,000	
Rig	per month	220	1	$220	
Total cost				$137,650	
Cost/rm	river mile	1.1		$137,650	
Panther Creek 30508	**Unit**	**Unit cost**	**Days/acres/logs**	**Cost**	
Plan, design & NEPA	per acre	393	10	$3,930	21833
Excavator	per day	1300	2.4	$3,120	12 sticks per day
Dozer	per day	820		$0	
Riparian thinning	per acre	900		$0	
Labor crew	per day	600	1	$600	
Planting	per acre	110	0.2	$22	
Helicopter	per log	333	0	$0	
Log haul	per log	115	28	$3,220	

Table 2. Project budgets: Trout Creek, Panther Creek and Mine Reach (cont'd.)

Panther Creek 30508	Unit	Unit cost	Days/acres/logs	Cost	
Move in/out	in & out	500	1	$500	
Materials	bulk	500	0.01	$5	
Rig	per month	220	0.05	$11	
Total cost				$7,478	
Cost/rm				$41,544	
Mine Reach 30408	**Unit**	**Unit cost**	**Days/acres/logs**	**Cost**	
Plan, design & NEPA	per acre	393	280	$36,680	
Excavator	per day	1300	50	$65,000	35 sticks per day
Dozer	per day	820	32	$26,240	skid 55 sticks/day
Riparian thinning	per acre	900	20	$18,000	88 trees/day
Labor crew	per day	600	10	$6,000	
Planting	per acre	110	250	$27,500	
Helicopter	per log	333	0	$0	
Log haul	per log	115	0	$0	
Move in/out	in & out	500	2	$1,000	
Materials	bulk	4000	1	$4,000	
Rig	per month	220	2	$440	
Total cost				$184,860	
Cost/rm	river miles	3		$61,620	

to stockpile logs near the project sites which were placed with an excavator. The helicopter could have been used to do the placement, but it would have raised the cost from $333 per log to over $1,100 per log. In contrast the Mine Reach restoration project utilized on-site materials acquired from second growth riparian stands of timber, which dramatically reduced project cost.

The NEPA analysis for many of the projects used as examples in this presentation were grouped to reduce costs and may not reflect typical cost for projects on a similar scale. Individually, any one of these projects could have NEPA cost up to $60,000 or $110,000 per river mile.

LARGER SCALE COST ESTIMATES

Can we estimate river work on a watershed scale? On a watershed scale, it is definitely possible to estimate costs for river work. However, good stream survey data and watershed analysis or assessments are essential for prioritizing projects and estimating costs on a watershed scale. Without knowledge of existing watershed conditions and a sense of project priorities, cost estimates would be baseless and serve little utility.

Planning projects on the watershed level can lead to incremental cost savings relative to NEPA, consultation and design, as in the project examples discussed above. However, before projects are lumped into a single NEPA document for the sake of cost savings, considerable public outreach and forethought should go into the decision. For instance, restoration for three different streams that added up to about seven river miles was combined into one NEPA document which substantially reduced cost and increased efficiency. However, if one of the stream segments or a portion of the project was controversial and then appealed, it would have resulted in a delay of the other two projects. Therefore the cost savings of grouping projects should be weighed with the potential risk.

Can we estimate costs on Evolutionarily Significant Unit (ESU), state, or regional scales? This is less likely. Gross generalizations could be made to approximate restoration cost per region. However, the differences in limiting factors and treatment methods would differ radically from region to region and ESU to ESU. For instance, addressing limiting factors on the west side of the Cascade Mountains may predominantly involve culvert removals for fish passage, riparian and channel rehabilitation. Whereas on the east side of the Cascades, limiting factors associated with cattle grazing, irrigation diversions and sediment runoff from cultivation are addressed. Cost could be extrapolated from watersheds within each ESU. However, the cost range would be so large that cost estimation on an ESU or regional scale may be of little use or may over or underestimate the cost which would undoubtedly under serve the resource and potentially squander taxpayer money.

CONCLUSION

The best way to maintain confidence in cost estimates on large scales is to only make approximations at the fifth field watershed level or lower. This limits the area of interest to around 250,000 acres, where it is still possible to take into account the specific conditions in the watershed. In addition, it is important to have funding for the projects that will span several years, allowing time for project planning and environmental permitting. It is possible, however, that standardized costs estimated for large areas (watersheds and greater) may never be appropriate, and that working from the individual conditions at each restoration site may be the only way to develop reasonable estimates of project costs.

REFERENCES

Bryant, F.G. 1949. *A survey of the Columbia River and its tributaries with special reference to its fishery resources. 2: Washington streams from the mouth of the Columbia River to and including the Klickitat River (Area 1).* U.S. Fish and Wildlife Service. Spec. Sci. Rep. No. 62.

REFERENCES (cont'd.)

Coffin, B. 2001. *Water Withdrawals in the Wind River — An Analysis in Support of the Wind River Watershed Analysis and Wind River Water Quality Restoration Plan*. USFS Mt. Adams Ranger District, Washington.

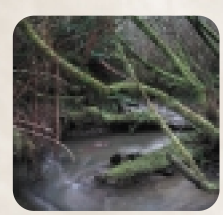
Rawding, D.J. 1997. *Stock status update for steelhead in the lower Columbia River, Washington*. Washington Department of Fish and Wildlife, Olympia, WA.

U.S. Fish and Wildlife Service and Washington Department of Fisheries. 1951. *Lower Columbia River fisheries development program, Wind River area, Washington*.

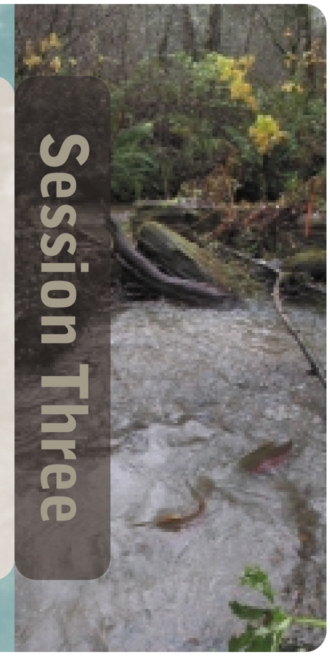
U.S. Forest Service. 1996. *Wind River basin watershed analysis*. Wind River Ranger District, Carson, Washington.

Washington Department of Fisheries, Washington Department of Wildlife, and Western Washington Treaty of Indian Tribes. 1993. *1992 Washington State salmon and steelhead stock inventory*. Olympia, WA.

Washington Department of Wildlife, Confederated Tribes and Bands of Yakima Indian Nation, and Washington Department of Fisheries. 1990. *Wind River subbasin salmon and steelhead production plan*. Olympia, WA.



Session Three



Streambank stabilization, streambank fencing, nuisance species control, riparian zone management

Stream Habitat Restoration Cost Considerations

MARK COCKE, Civil Engineer
Natural Resources Conservation Service
430 G Street #4164
Davis, CA 95616-4164
mark.cocke@ca.usda.gov

ABSTRACT

There are many important factors to consider when planning work and estimating the costs for stream habitat restoration projects. These factors range from the people and organizations involved in planning, coordinating and carrying out the project to the specific physical characteristics of the watershed in which the work is done. This paper addresses the difficulties involved in developing restoration projects, especially in estimating project costs. It also discusses the issues that must be raised whenever restoration projects are aggregated for planning on a larger scale (counties or regions).

INTRODUCTION

In order to design, plan and execute stream habitat restoration projects, care must be taken to understand the watershed in detail. If project planners do not have in-depth knowledge of the entire watershed, it is possible that restoration projects will fail due to a design that addresses a local problem on a stream without treating any of the root causes of stream degradation throughout the system. On a larger scale, it is important to understand that conditions vary between watersheds. This variability can arise from a variety of sources, including both human and natural conditions.

People, Agencies and Communication

Project costs vary considerably depending on who is doing the work. The variation is based primarily on the fact that contractors and staff from different agencies and companies bill different rates for their work. Using contractors for restoration work can be very expensive. The Natural Resources Conservation Service (NRCS) contracts out the work undertaken to ensure that our restoration projects comply with National Environmental Policy Act (NEPA) regulations. Contractors must charge between two and three times what the normal Federal salary is to break even. For example, if a private contractor has a salary of $30 to $40 an hour, he or she will charge at least $120 an hour in order to have the same level of insurance, retirement and vacation as a federal employee. Consulting companies have overhead too, which adds to the cost.

When a project involves contract construction and equipment operation, it is necessary for the coordinating agency to invest time in developing a very detailed work plan so that the contractor will complete the work in an appropriate and satisfactory manner. In addition, our inspector must be on site to be sure that the project plan is being followed. If we do the work ourselves, in-house, it is not as important to spell everything out in the plan, because our engineers and fish biologists will be directing the workers and will know what needs to be done in any given situation to make the project successful. However, there can be benefits to contracting work out. The contractor absorbs the risks and the downtime involved in the project, which means that he or she needs to incorporate the uncertainty of working in a natural system into all bid estimates.

The work market and location also have an impact on the final project cost. A loader operator who is an owner/operator in a depressed timber area will charge much less when a potential job comes along. At the same time, an operator in Southern California who is working steadily and making a lot of money is going to be reluctant to come to Northern California without the promise of considerable money. Differences between rates charged by contractors can be as much as a half million dollars per mile.

Another important consideration when dealing with people in relation to a restoration project is the possibility of disputes with other landowners in the area. It is important to spend time negotiating with local stakeholders so that the project is not stopped later when considerable time and money have already been invested. It is much easier to work with landowners who are our friends than landowners who are really angry. An angry landowner can get his or her friends just as angry, creating public resistance. Ensuring that we are able to do important restoration work in an area sometimes means making compromises.

One of the most important steps toward developing a successful restoration project is acquiring a comprehensive understanding of what all of the problems are in the stream system under consideration. Knowing what is wrong at just one spot may not be very helpful, and can mean that treatments devised without having a larger perspective are unsuccessful. Without having a good understanding of the system, it is also more difficult to obtain the permits necessary to do the job. As a result, we have discovered the extreme importance of good communication with all of the people who have knowledge of the area. An important component of what we do is to talk to geologists, engineers, fish biologists, vegetation specialists, soil specialists and hydrologists, in order to build a larger picture of the landscape. It is also crucial for us to be able to explain to other people the work that we are doing. Good communication can make many aspects of the project planning and implementation processes run more smoothly.

Physical Characteristics of the Landscape

Understanding the history and current state of the stream system is crucial. Knowledge of the floodplain has proven to be a serious issue. Without understanding the history of California's redwood country, it is difficult to make sense of the current landscape. When this area in California was logged, the standard process was to put up a 25 to 30 foot wooden dam, fill the dam with logs, and wait. When winter came and the dam was filled with the river running over the top, the loggers would blast the dam and the stream would run straight down its gradient to places like Point Arena and Gualala and other small coastal communities. The flow would literally move every bit of wood and sediment in the system down the gradient. The result is that bedrock and very poor habitat now dominate these streams. Without knowing this history, we might not understand how this system with lots of large wood has streams that only contain bedrock.

In California much effort in the last 80 years has been spent fighting fires, in particular in some of the Sierra systems where there are truly beautiful meadows. Looking at the soil layers under the meadow, most of the layers are of organic soil and white granitic sand. Once you reach the layers deposited in the last 80 years, though, all of a sudden there is a solid 15 to 18 inches of organic material and no gravel or sand. Fighting fires has eliminated a source of sediment for the streams. Now people are finally starting to realize that fires provide some of the materials necessary for the creation and maintenance of good habitat.

Terraces on the upper elevations of the watershed are consistent features of the landscape that we work in. Terraces are abandoned floodplains; as the stream cuts deeper into its substrate, new floodplains are developed at the lower elevation, leaving terraces above. Lack of riparian vegetation on floodplains and terraces is a big problem, and leaves the streambank unprotected during flood events. It is very difficult to revegetate many of the areas in which we work because much of the land ownership is private and grazing is very prevalent. In areas where cattle are not grazed, deer and other wildlife prevent the establishment of new plants.

Spanish Creek, one of the streams in our area, is an example of a fairly healthy system because the stream has relatively good contact with the flood plain and has sufficient vegetation. Because the stream has an appropriate amount of meander and interacts well with the flood plain, it will be possible for us to induce reasonably rapid recovery.

Our region is probably the most active part of the world with respect to landslides. There are a number of features of the landscape that contribute to this activity. The streambeds are composed largely of bedrock. There is a lot of large woody debris on the hillsides, which are very steep. A landslide is composed of fine-grain sediment and a large number of rocks and trees. Once a landslide has begun, it crashes against the other side of the valley wall and stops, creating a cascade with large wood holding it together. Then, after a large event such as this, the slide incrementally meters out bedload into the stream system. If the area is logged, with all of the large wood removed, there is nothing left to hold all of the material together, and another landslide is inevitable.

Logging has eliminated in 10 to 15 years all the root systems that were holding the mountains together. Instead of a big landslide every 120 years, we now see 40 landslides every 10 years or so. As a result, fine-grain sediment is entering the coastal range systems that are starved for large wood. There is less coarse-grain sediment because the deep-seated landslides are no longer the dominate landslide mechanism in these systems.

Due to differences in location, local conditions and land management, stream systems vary widely, which makes extrapolation to a general level difficult. Some of the available tools for characterizing streams are the various classification theories, including those of Rosgen, Horton, Chum, Montgomery, and Buffeton. When Rosgen's idea was first proposed, it was fairly simple, designed to group streams into a small set of possible categories. Many of the classification systems were simple at the beginning. Horton classified streams using a combination of eight parameters, which allows for 164,000 different combinations. Classification is important because it enables everyone to communicate with each other about streams, but it is important to remember that each stream system is different and should also be considered individually.

Here is another way of looking at stream systems: across landscapes. Depending on location, there will be high mountains, bedrock, glacial material, transport material, and depositional areas. A valley in the depositional phase is depositing and storing sediment. Once logging and other changes to the upper elevation landscape start to occur, the streams in that valley may start transferring the sediment. In the Pacific Northwest, in coastal California, in the Sacramento flood plains, when we transform a depositional reach into a transport reach, it is very bad for the health of the watersheds, leading to massive sediment build-up and the loss of complex stream habitats.

STREAM HABITAT TREATMENTS

Channel Evolution: Space vs. Time

Stream channels evolve over time. The channel evolution model consists of four steps. First, there is the pre-incision stage, where the channel has not started to cut into the substrate. Next is incision, which begins at a primary nick point. The channel then widens, allowing the accumulation of deposits on the channel floor. Finally, the stream reaches a state of dynamic stability. The changes that channels undergo over time can be dramatic. We have talked to an owner who said that as a kid, he could swing a rope across his creek. Standing on the edge of a 25-foot wide channel, we imagine that he must have been one brave kid! In reality, when he was young, the channel was not very deep and was only about six feet across; in 70 years the channel has changed considerably.

Restoration projects should always be considered in the context of time. This is not always easy; in many cases, no one is around who knows what the landscape used to be like. In other cases, the land use has changed so much or is now changing so quickly that it is difficult to determine the channel's current stage of evolution. This makes it more difficult to correctly define the problem to address with restoration work. For example, the NRCS attempted to treat an eroding meander reach that was immediately downstream of a small highway bridge on Salmon Creek near Vancouver. We upgraded the bridge, which concentrated stream flow so that increased velocity through the bridge eroded the bank. To counteract the erosion, we put in willow and toe rock for stabilization. One reason for the bridge improvement was to accommodate subdivisions going in nearby. We learned there was a head cut about a half mile downstream of the bridge. It became clear that we could put all the good bank material we wanted on the stream and we could clear any log jams, but if we did not define the problem correctly and fix it, all money spent on peripheral problems would be wasted.

Over time, we have improved our ability to define the problem on the stream reach we are working on. We can put Band-Aids – and in a lot of cases stream bank protection measures are just that – on many of our systems and never really accomplish anything because we have not taken the time to define the problem. This is why watershed-wide analysis is important, because all of the problems within a given watershed must be addressed if the health of the stream is to improve. We may not be able to understand the entire system immediately, and sometimes we do have to make rapid decisions to treat urgent problems. We do, however, owe the people we are doing the work for at least an attempt at understanding the whole problem. We work primarily on private lands, and clients call because, for example, their bank is eroding, their bridge is blowing out, or their vineyard is in danger. Unless we know why the system is behaving that way, we cannot select a restoration technique that will be sustainable.

Adaptive Management

Adaptive management is the basis of our planning process. All of our plans are developed with the understanding that modifications will be made over time as we become more familiar with the system and with the consequences that our treatments will have on the landscape. It can be difficult for management, lawmakers and fiscal staff to acknowledge that we may come back and ask for more money or make mistakes and have to learn from them. As long as we are working in natural systems, however, we need to constantly reexamine our plans with reference to the conditions in the real world. As discussed above, natural systems are always evolving. Changes in natural systems are the result of a myriad of causes, including human, ecological, geological and meteorological events. Whatever the cause of the change, though, it is crucial that restoration planning take this evolution into account.

COST ESTIMATION AND PROJECT PLANNING

Developing a cost estimate is probably the most difficult and time-consuming part of developing a watershed assessment. It is important to understand how restoration costs are distributed across ESA, region-wide or area-wide planning units. The biggest risk of watershed analysis is assuming one stream system is like another and basing cost analysis on that assumption. If the assumption is incorrect, a region-wide or watershed-wide analysis will break down. When crossing watershed divides and trying to make region-wide assessments, we must be able to group problem areas in similar reaches, so that we are sure that the costs are comparable.

Landscape variables are the single biggest factor affecting project costs. Other issues can also impact costs, though. One important cost consideration is the skill level of the operators working on a project. There are operator schools where a lot of time is spent teaching the participants how to operate and maintain their machines. Individual operators can also learn as they work on a project and, based on experience, can become highly skilled. We have had operators who could take a bucket as big as a table and control it within about half an inch, depending on the weight of the load.

Materials are another important cost factor. Fencing can be a very cheap installation. In order to estimate the cost of a fencing project, we can go to Costco and price the fence and then price a labor source. On the other hand, when we looked at root wads or bioengineering as a stabilization solution for Indian Creek in Quincy, we realized we would have to go for a major timber sale, because it was all private land. In the private sector, trees are not free. We would have had to move more logs to treat the 7 miles of stream than had been harvested in the last five years. The supply of trees in that area had been exhausted. Unfortunately, big trees are needed for bioengineering treatments, and taking the last old-growth Sugar Pine and Ponderosa Pine in an area to fix a stream is probably not the best idea. Obtaining woody materials can be a very expensive aspect of the project.

There are a number of different cost guidelines that we use when we develop project cost estimates. The Dodge Manual provides private sector costs for heavy equipment operation. In more remote areas, where all the loggers have moved out and the heavy equipment is gone, we have to contract out our heavy equipment work. This is expensive and both the cost and the quality of the work can be extremely variable. In areas with a good construction industry infrastructure, heavy equipment prices can be on the order of $100-$125 an hour. Big cranes can cost as much as $1,000 an hour, but we do not use those as often.

The planning process itself involves a considerable amount of expense. Obtaining permits for the project can be a major hurdle. In some cases, more money may be spent on permitting that on the actual project. An Environmental Impact Statement (EIS) is time consuming and expensive, but that expense can be lessened somewhat by obtaining an EIS for the entire program, rather than on a project-by-project basis. However, even if we do a programmatic EIS, 10 years later the odds are very high that we will have to revisit the statement and, in some cases, redo the entire NEPA and California Environmental Quality Act (CEQA) process. Even though we have a record of decision because we did an original EIS, there will be new California Department of Fish and Game people, new regulatory people, new landowners, and new concerned individuals who did not agree to the original EIS. The test of a good CEQA or Federal document is that we do not get sued.

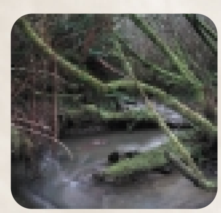
We hope to get people to see that that the most important aspect of restoration work is time. Our efforts are laying the groundwork for severely degraded systems to re-grow the vegetation that will aid in their repair. Planting trees stabilizes stream banks and upland areas, but it also provides future material in the form of large woody debris. This material will be of use in naturally maintaining future bank stability as well as providing better in-stream habitat for the fisheries. For large meadow systems that have been degraded down to a cobble surface, we recommend planting upland trees and nursing them through the deer-predation period. This treatment is fairly inexpensive, about $5,000 an acre. Then we wait for the next fire in the fire and flood sequence to supply the stream with the sediment it needs, particularly fine-grain sediment.

Calculating time into the restoration plan can be particularly effective in areas where our budget is limited. When we do not have the option to spend a million dollars a mile on the stream treatment, we use time as part of the equation. We set the stage for recovery by spending $5,000 to $10,000 per stream mile on various planting and stabilization treatments, but the system does not completely recover until a triggering mechanism, whether fire or some other kind of catastrophe, supplies the stream with the materials it needs.

Maintaining cost effectiveness must always be taken into consideration when planning projects. An economics group in California is looking at the economic values of floodplains and wetlands on a $300,000 Environmental Protection Agency grant. They have produced a study of a restoration project that indicates that taking out levies and restoring the wetlands has more positive economic benefits than failing to restore the wetlands and leaving the levy system to degrade. There are benefits to water clarity in the lake and streams, to recreation, and to the county because they will no longer need to maintain the levies. We need more cost effectiveness studies like this, because they provide a concrete measure of the need for restoration work.

It is impossible to overestimate the value of learning from past mistakes. One very important area in which this idea needs to be applied is in development planning. For example, the best kind of flood protection is preventive, which means that we should not build in floodplains. There is an Executive Order (EO11338) that states that the Federal government will not subsidize construction in floodplains and will not provide subsidized flood insurance for houses built in documented floodplains. This sounds great, except the fact that most floodplains have not yet been mapped. So a contractor or developer can walk the Wind River Watershed and find a piece of private ground that has not been mapped because no one is living there, and then put in a subdivision. We should have learned by now that building in floodplains does not make sense, ecologically or economically.

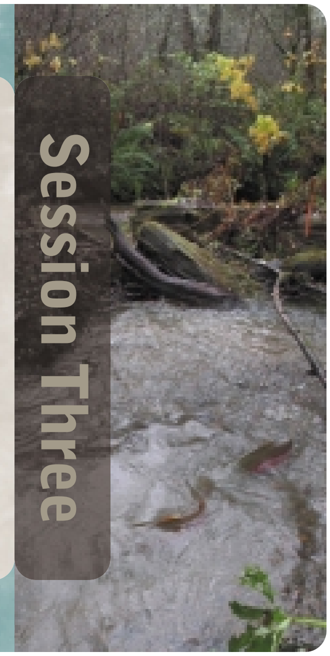
There are excellent economic justifications to be made for not making mistakes in the first place. However, when mistakes are made, we need to have a good understanding of the system that we are working in before we start looking for solutions. A lot of the systems that we are asked to work in have changed considerably in a fairly short amount of time since degradation of the system began. We need to discover what is going on before we start talking about the solutions we are going to implement. It is entirely possible to aggregate watersheds into larger regions in order to assign costs on a regional basis. However, this does require that we examine each watershed and group them based on the specific details that we have learned about each one. This will lead to an error between 25 and 50% in the estimate. If we work from the top down without knowing each watershed individually, the error is likely to be as much as 200 to 500%.



Streambank stabilization, streambank fencing, nuisance species control, riparian zone management

The Costs of Restoring Anadromous Fish Habitat: Results of a Survey from California

STEVE HAMPTON
Office of Spill Prevention and Response
California Dept. of Fish and Game
P.O Box 944209
Sacramento, CA 94244-2090
shampton@ospr.dfg.ca.gov



ABSTRACT

This study reviews 60 restoration projects designed to improve anadromous fish habitat in coastal California streams. These projects are broken down into three categories: those designed to create aquatic habitat through instream structures, those designed to improve the canopy through riparian plantings, and those designed to decrease erosion through bank stabilization. The cost data are analyzed for all the projects. The instream structure projects are analyzed in greater detail. The results suggest that the cost per stream mile for such projects may not be correlated with stream gradient, but are, as expected, correlated with the number of instream structures per mile.

INTRODUCTION

A wide variety of river corridor restoration projects are employed to improve habitat for fish and the organisms they depend on for survival. These projects include the creation of instream structures, the enhancement of riparian vegetation to increase the canopy over a stream, the implementation of bank stabilization strategies to decrease erosion, the removal of fish barriers, the creation of jump pools, and the creation of more large-scale watershed management plans to improve overall stream health.

This study is aimed at examining restoration projects that specifically benefit instream biota. Thus, watershed management plans and riparian restorations that involve large tracts of habitat away from streams (as opposed to streamside vegetation for stream shading) are not included here, as they benefit a wealth of other biota outside the stream. This study focuses only on the first three types of restoration projects: instream structures, streamside vegetation to increase canopy, and erosion stabilization.

All projects possess certain site-specific aspects that make them, and their costs, unique and difficult to compare. Thus, a large sample size is required to minimize this factor. With regard to the creation of jump pools and the removal of fish barriers, site-specific characteristics are especially important. This fact, combined with a rather small sample size, caused these types of projects to be removed from this study.

Beginning in 1981, the California Department of Fish and Game (CDFG) issued grants and solicited restoration projects under the Fishery Restoration Grants Program that were designed to protect, improve, and restore habitat for anadromous fish in the North Coast area of the state. In recent years, this program has been administered by the Native Anadromous Fish and Watershed Branch and has benefited from greatly increased funding. This study examines 60 completed projects for which there were sufficient data to analyze the cost per stream mile for each project. These projects are located along the north coast of California, primarily in Humboldt and Mendocino Counties. These streams provide habitat for steelhead, coho and chinook salmon, and coastal cutthroat trout.

While there is much literature to guide and analyze the implementation of restoration projects from a biological and hydrological perspective, there is little available information regarding the costs of restoration. However, cost data are increasingly important to obtain in light of natural resource damage assessment (NRDA) guidelines recently promulgated by the National Oceanic and Atmospheric Administration. These guidelines recommend that the costs of restoration be used as the basis for calculating natural resource damages to habitats injured by pollution events. In large damage claim cases, specific restoration projects may be identified and their costs estimated. However, in smaller cases, the desire to reduce assessment costs and the time until settlement of damage claims may require the use of default or generic restoration costs. In such cases, the results of this study may provide a basis for such cost estimates.

It should be noted here that the cost data used in this analysis do not include budgets for oversight by the Trustee agency (CDFG), monitoring of the success of the project, or long-term maintenance. Also, some of the planning costs and time dealing with permitting was borne by CDFG.

INSTREAM STRUCTURES

Instream structures are widely used to improve habitat for anadromous fish in cold water streams. Such structures may include the construction of boulder clusters, weirs or sills, log shelters and other types of cover structures, and other actions designed to improve stream habitat. We examined a sample of 37 projects that created cover structures.

Table 1 provides a summary of the data from these 37 projects. The gradient data

Table 1. Summary data regarding cover structure projects (n = 37)

	cost	stream length (ft)	# of structures	cost per stream mile	structures per mile	gradient (ft/mile)
Average	$20,693	5,996	15.5	$25,277	19.7	191
Median	$18,150	4,900	12.0	$20,835	12.1	155
St. dev.	$12,926	4,613	11.5	$16,256	19.5	166
Max.	$57,658	24,380	60.0	$70,754	96.0	728
Min.	$4,925	1,100	1.0	$5,638	1.3	25

were difficult to obtain and may include some erroneous estimates because many of the project reports lacked a detailed map of the project site and location. In these cases, the exact site and thus the gradient had to be estimated from topographical maps and the available information in the project report.

It was hypothesized that restoration costs per stream mile would be higher on streams with a steeper gradient because a greater number of instream structures would be needed to enhance habitat. An alternative hypothesis is that streams with steeper gradients are more likely to already have sufficient natural instream structures and, due to more difficult human access, may be less disturbed. Plotting the costs per stream mile against the stream gradient for the projects demonstrates little correlation. The correlation coefficient is -0.19. The negative correlation may be explained by the fact that the number of instream structures was negatively correlated with stream gradient (corr = -0.23).

Plotting the costs per stream mile against the number of structures per stream mile, however, yields a strong positive correlation of 0.64. The average cost per structure was $1,762, with a standard deviation of $1,270. The median was $1,444. This relationship is expected, of course, as it is the structures that generate much of the restoration costs.

Another hypothesis is that there are returns to scale in implementing restoration projects. Given a certain amount of fixed costs, the average cost per stream mile may decrease as project length increases. Indeed, this seems to be the case, as cost per stream mile was negatively correlated with the stream length of the project area (corr = -0.43).

However, this simple correlation does not convincingly make the case of increasing returns to scale, as the number of structures per stream mile was also negatively correlated with stream miles (corr = -0.41). The question thus becomes, does the cost per stream mile fall as the project length increases simply because of increasing returns to scale, or because the number of structures per mile falls as project length increases?

A multiple regression analysis was conducted to answer this question, regressing the costs per stream mile (the dependent variable) against stream gradient, the number of structures per mile, and the stream length of the project (the independent variables) (Table 2). Note that the resulting independent variable coefficients from a multiple regression (ordinary least squares) are essentially correlation coefficients but with the other independent variables held constant. Thus, we can examine the relationship between restoration costs and size with the number of structures per stream mile and stream gradient held constant.

The R-squared statistic is a measure of the overall fit of the model. It implies what percentage of the change in cost per stream

Table 2. Multiple regression results

Independent Variable: cost per stream mile   Number of Observations: 37
Degrees of Freedom: 33   R Squared: 0.46

Dependent variables	Constant	Stream gradient	Structures per mile	Stream length (ft.)
Coefficient	24,482	-0.88	427	-65,568
T-Statistic	1.93*	-1.67	3.42**	-0.91

* significantly different from zero with a 95% level of confidence   ** significantly different from zero with a 99.5% level of confidence

mile can be explained by the dependent variables. The R-squared statistic of 0.46 is relatively good, considering a cross-section analysis with only 33 degrees of freedom.

The coefficients may be interpreted in the following way. The constant suggests a starting point, that stream costs are $24,482 per mile, with adjustments to be made according to the coefficients of the other variables.

The coefficient for stream gradient is negative, implying that costs rise as gradient falls, all other variables held constant. This result seems counter intuitive and may be erroneous, a result of the small sample size and poor quality of the gradient data. Note that, with a low t-statistic of -1.67, it is not statistically different from zero with a high level of confidence.

The coefficient for structures per stream mile is highly significant and implies that each structure per mile is associated with an additional $427 in project costs per mile. Using the median of 12.1 structures per mile, this results in a total of $5,167 additional cost per mile.

The t-statistic associated with stream length implies that the coefficient is not significantly different from zero. The fact that this coefficient is not significant leads us to reject the hypothesis that there are increasing returns to scale associated with larger projects, regardless of the number of structures per stream mile. There do not appear to be increasing returns to scale. Note, however, that the range of projects examined in the data vary from 1,100 feet long to 5,996 feet long. It may be that this sample size did not include a wide enough range in the size of projects to detect increasing returns to scale.

Using only the most significant variables, the constant and the number of structures per stream mile, the resulting equation may be expressed:

$$\text{Cost per stream mile} = \$24{,}482 + \$427^{*}\ (\#\text{ of structures/mile})$$

In a NRDA utilizing Habitat Equivalency Analysis (HEA), the size of the restoration project is known, as it is scaled during the exercise. If a specific restoration area is identified and the number of structures per stream mile can be estimated, the equation above may be used as a reasonable cost estimate of the proposed project. However, if the specifics of the project are not known, one may instead rely on the sample average ($25,277) as the estimated cost per stream mile. Note again that the complete costs for planning, trustee oversight, monitoring, and permitting are not included in these data.

STREAMSIDE VEGETATION

Eleven of the projects examined focused primarily on improving stream shading via riparian restoration immediately adjacent to streams. Extensive riparian restoration projects aimed at developing or enhancing riparian vegetation well removed from streams (such that the plantings would be too far from the stream to provide a shade canopy over the stream) were not included in this sample. The projects in the sample included such activities as alder planting, willow sprigging, and exclusionary fencing.

Table 3 provides a summary of the data from these 11 projects. Compared to the instream structure projects, these projects tended to be less expensive, with an average cost of $13,693 per stream mile. Note the wide range in costs per stream mile, reflective of the difference between projects requiring irrigation or the planting of more mature trees versus simple willow sprigging. The average cost may be applicable in HEAs regarding injuries to relatively flat lowland streams, where instream structures may be less relevant, but stream shading is important.

The other primary difference between these projects and the instream structure projects is the length of stream targeted by

Table 3. Summary data regarding streamside vegetation projects (n = 11)

	cost	stream length (ft)	cost per stream mile
Average	$14,068	12,899	$13,693
Median	$9,800	8,505	$13,030
St. dev.	$11,183	11,910	$13,541
Max.	$41,959	36,960	$47,530
Min.	$4,700	1,200	$1,047

the projects. Streamside vegetation projects averaged over twice the length of the instream structure projects.

EROSION CONTROL

Twelve of the projects examined focused on erosion control through various bank stabilization techniques. These activities often included riparian planting (in terracing) or elements similar to instream structures, but generally required more labor and materials, as reflected in the costs.

Table 4 provides a summary of the data from these 12 projects. These projects were far more expensive than the others, with an average cost of $43,620 per stream mile. Note again the wide range of costs per stream mile, again reflecting the wide range of applicable erosion control techniques. These projects also focused on very long stretches of stream, averaging over four miles in length.

CONCLUSION

It is often said that restoration projects are highly variable, with each project subject to a unique set of problems and obstacles at the project site. This variability is reflected in the data summaries, where wide ranges of costs are evident. Understanding actual restoration costs requires understanding this variability and minimizing it. It is thus best handled by either dividing up the projects into more types, based on project characteristics, or by obtaining large sample sizes where the variation can be overwhelmed by the average. Because few databases of restoration costs exist, and details regarding project characteristics or unique attributes are not readily accessible, accomplishing either task

Table 4. Summary data regarding erosion control projects (n = 12)

	cost	stream length (ft)	cost per stream mile
Average	$27,473	21,866	$43,620
Median	$21,391	4,490	$24,811
St. dev.	$14,255	39,985	$41,527
Max.	$49,942	132,000	$122,941
Min.	$7,265	1,585	$882

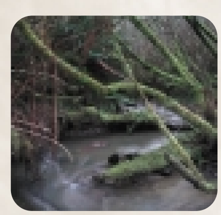
to reduce sample variability is difficult. Nevertheless, this presentation of cost data should assist restoration planners as well as those engaged in restoration-based natural resource damage assessments.

COMMENTS

It should be noted that, during the presentation of this information at the Habitat Restoration Cost Workshop, it was pointed out that the costs of these projects may be significantly underestimated for two reasons:

1. The labor costs in these projects are substantially lower than for similar projects in other states. In one example labor wage rates were ten times higher than in one of these projects.

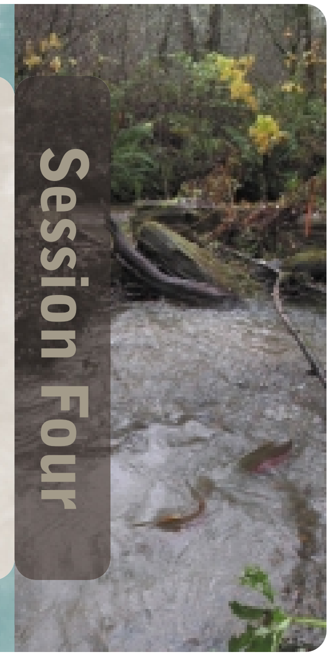
2. These costs do not include planning, design, and permitting. In Idaho (on larger streams), this element has accounted for over 50% of total costs.



Instream treatment (e.g., woody debris, rootwads, boulders, side channels, pools, spawning gravel, nutrient augmentation), conversion to non-structural flood control (e.g., meander zones)

Instream Structures: Applications, Costs and Methods

CRAIG BELL
Trout Unlimited North Coast Coho Project
P.O. Box 1256
Gualala, CA 95445
acenlil@mcn.org



ABSTRACT

The Trout Unlimited North Coast Coho Project is working to reestablish coho salmon refuges throughout Mendocino County. This work is an excellent example of the value of a cooperative program involving conservation timber interests and people dedicated to recovering commercial and recreational coho salmon fisheries. We have spent years placing habitat structures in streams, and this paper draws on that experience to discuss the planning, budgeting and implementation of instream structures. The development of cost estimates on a broader geographic scale is also considered.

INTRODUCTION

Stream restoration in California has been ongoing for about 25 years, and is referred to as an evolving art and science by its practitioners. While the current emphasis is correctly shifting to upslope erosion control, there is still a need to increase instream habitat complexity as part of a comprehensive watershed approach. Regulatory changes governing timber operations under Endangered Species Act listings, the Clean Water Act Total Maximum Daily Load Program, and the development of Habitat Conservation Plans seek to restore properly functioning riparian and instream habitat. Although restoring riparian habitats is crucial, it must be noted that once riparian zones in coniferous forests have been severely disturbed, natural recruitment of large wood in streams will not occur for over 60 years (Seddell *et al*. 1988). Seddell further states that in logged watersheds throughout the Pacific Northwest, large wood in streams has been reduced on average by 80–90%. The addition of instream habitat enhancement structures is vital to remedying this situation and ensuring that streams are able to support fish populations. Properly placed and constructed instream structures provide summer and winter juvenile rearing pool habitat, insect food production, storage and sorting of spawning gravels, bank protection, refuge from predators, and possible water cooling effects from forced sub-surface flows.

There is a wealth of information about designing and installing instream structures in the *California Salmonid Stream Habitat Restoration Manual* published by the California Department of Fish and Game (CDFG). The manual (Flosi *et al.* 1998) contains guidelines for structure placement, suitable materials, and fastening techniques. It also provides standardized budget formats for different types of restoration project. Additional information concerning standardized costs for construction can be found in the latest CDFG *Request For Proposals* (RFP) (CDFG 2000). These two documents are of invaluable help when developing a restoration projects and laying out all of its associated costs. Please refer to the References section of this paper for information about how to obtain both of these resources.

CALCULATING COSTS FOR INSTREAM STRUCTURES

When developing project budgets, it is important to have a rough estimate of how much an instream structure will cost. Structures can be divided into two categories: simple and complex. Simple structures such as a single secured "digger log" or single straight or diagonal "log weir" is valued at around $750. A complex structure such as a "spider log" consisting of at least three logs that are 12 inches in diameter and 10 feet in length has a standard cost of $2,250. The minimum recommended size for logs used in structures is 12 inches in diameter and 10 feet in length. Boulder structures such as "weirs" have a standard cost of $2,000. Boulder wing deflectors are valued at $2,250 with an emphasis that the apex boulders be a minimum of 3 feet in diameter. The standard cost of boulder clusters is $250 per boulder (CDFG 2000, p. C19). It is important to emphasize that these costs are to be used only as a guideline. For example, complex structures involving multiple large logs and boulders are more costly. Also contributing to the cost are the ease of access for crews and heavy equipment, local labor, equipment and material rates, and the distance over which logs, rootwads and boulders must be transported. Project proponents should itemize these increased costs in their proposals to assure proper funding consideration. A sample project proposal is provided in Appendix 1 of this paper to illustrate how project costs are generally reported.

There can be many different factors to consider when developing labor, materials and equipment costs for a project. One way to make up for increased costs for one aspect of the project is to find a way to decrease the costs in another category.

Labor: Labor rates cited in proposals in California are typically $12 to $14 per hour for laborers and $15 to $20 per hour for crew supervisors. Who is chosen to perform the labor on a project will have a large impact on the cost. Organizations such as the California Conservation Corps (CCC) and Americorps are made up of young people who have a strong "esprit de corps" and a demonstrated ability to operate effectively in remote hike-in locations. This can make up for some of the increased accessibility and transport costs associated with remote locations. Additionally, groups that involve high percentages of volunteer labor or other in-kind matches improve the cost-effectiveness of operating in very remote or inaccessible locations.

Materials: Of note is the newly developing technique of falling or placing large unanchored trees into streams. There have been some successes and indications of greater cost-effectiveness than with hand-crew intensive structure building. No standard value has been established yet for placing whole trees. Instream structures typically require 30 feet of minimum 5/8 inch galvanized steel cable at $1.25 per foot, or threaded rod at $1.30 per foot. There will be additional costs for clamps (for the cable) and nuts and washer plates (for the threaded rod). Epoxy tubes for rock fastening are $25 per tube. Structures built under current guidelines are expected to last a minimum of 10 years. When structures are built using redwood and 5/8 or 3/4 inch cable, their lifetime is substantially longer.

Equipment: Some standard heavy equipment rental rates are as follows: backhoe $70 per hour, excavator $80 to $120 per hour, dump truck $50 per hour, Cat with winch $80 to $90 per hour. Construction of instream structures also requires some specialized tools that allow hand crews to move and fasten large logs and boulders in remote locations. Heavy-duty hand-operated winches called grip-hoists cost over $1,000, chainsaw-operated winches cost $600, gas-operated rock tools cost $900, and gas-operated wood drills and chainsaws each cost $600. Typically project proponents charge a rental fee that allows them to rent tools or maintain the ones that they own. High-quality tools in good operating condition are essential for the productivity of the work crew.

In California, equipment that costs more than $500 cannot be bought using a state contract. This can be quite a hardship for groups doing restoration work, though, because the specialized tools needed to accomplish the work are expensive to buy and to maintain. The National Marine Fisheries Service (NMFS) should consider a funding mechanism with which to "seed" motivated watershed groups, volunteers, and perhaps startup restoration contractors with the means to purchase these expensive specialized tools. This would allow many very dedicated individuals and groups to pursue more effectively the work they are already doing without compensation.

FUNDING FOR INSTREAM STRUCTURES

The CDFG Fishery Restoration Grants Program funds millions of dollars of restoration projects each year. The program has been in existence for about 20 years, which have been a period of constant refinement of the definition of a "good" restoration project proposal. Submitting a good proposal requires a thorough knowledge of both the CDFG RFP (CDFG 2000) and the California Salmonid Stream Habitat Restoration Manual (Flosi *et al*. 1998). The CDFG holds workshops at various locations around the state to help advise potential project proponents on the development of a successful project proposal.

When under consideration for funding, proposals are scored according to a protocol that has been developed in order to make the decision process as objective as possible. One important aspect of a successful proposal is the amount of matching funding that has been obtained for the project. The February 11, 2000 CDFG *RFP* defines "hard match" as materials, equipment, and cash. "Soft match" includes the salaries of permanent funded government employees and office space. While project planning costs are not considered hard match, they do, in the case of watershed plans, demonstrate local stakeholder buy-in and a level of science-based prioritization. Planning efforts can make a restoration project more highly desirable as a candidate for funding.

Once projects are complete, CDFG staff evaluates them to ensure that their objectives have been met. A standard evaluation form is used, which asks the evaluator to rank the project's success according to specific criteria. For example, if the new structure was supposed to make a pool, the evaluation asks whether there is now a pool at that location and how deep the pool is.

CALCULATING LARGER-SCALE COSTS

For recovery planning and funding considerations, it is very important to consider the aggregation of restoration costs over unit areas such as tributaries, subbasins, watersheds, and evolutionarily significant units (ESUs). No accurate large-scale cost projections have yet been developed. However, CDFG Associate Fishery Biologist Barry Collins is charged with monitoring and data management and is reported to be developing an analysis along these lines. It is also possible to get some idea of average costs in various geographic areas by reviewing the project proposals that are considered for funding every year by CDFG. For instream structures, I found application rates ranging from 15 to 40 structures per mile, with a cost of $2,200 to $2,500 for a complex structure.

The streams in which we are working are generally first, second and third order, in the upper regions of the watersheds. These are the refuges – the only places where salmon and steelhead have adequate water temperature and stream structure complexity to spawn. Because these streams have relatively low flow, the structures that we install are fairly small. A complex structure might cost around $2,250. If 30 structures are installed per mile, the total cost will be $67,500 per mile. For simple structures the cost might be as low as $3,360 to $7,000 per mile. Projects typically contain a mix of simple and complex structures, so the cost will vary accordingly. There is no demonstrated cost-per-unit reduction when building increased numbers of structures.

In order to develop estimates of costs for larger geographic areas, there are a number of large-scale data sources that can be used. The CDFG, in cooperation with the CCC, Americorps, and members of individual watershed groups, has completed stream habitat surveys covering thousands of miles. The surveys involve assessing the habitat type along each reach of the stream, which includes measuring the flood-prone area, the large woody debris shade cover rating, and the Rosgen channel type. From these parameters, it is possible to determine which instream structures are appropriate for each reach. In addition, timber companies have performed both instream and road surveys. These surveys indicate stream-reach miles that are in need of habitat improvement and, in some cases, the instream structures that would be appropriate.

Experience can also be a valuable tool in prescribing stream treatments. A fisheries biologist or restoration contractor who has a good knowledge of the stream and of previous restoration efforts can look at the stream and recommend the necessary structures. This kind of judgment based on life experience can be invaluable and can allow restoration work to proceed even in the absence of detailed stream surveys, which can be very expensive.

Of great importance is that current instream and upslope watershed conditions be addressed when instream treatments are prescribed. It makes little sense to build instream structures in 80º F water, in streams heavily overburdened with untreated sediment delivery sources, or above migration barriers. I have seen streams so heavily overburdened with gravel that structures are completely ineffective in scouring pools with depths of more than one foot. Sediment loads can be so heavy that they break apart 5/8-inch galvanized cable, which will destroy structures. Structures installed under these conditions are clearly a waste of money. Furthermore, the future land use in the watershed must be taken into account. It is futile to try to improve habitat by placing instream structures in an area that will be clear-cut in a year or two.

It would be very helpful if NMFS in consultation with State fish and game departments would develop a prioritization system for projects. This system could be used to direct immediate funding towards maintaining seriously threatened remnant wild salmon and steelhead populations. The habitat protected using this money would be along the lines of “refugia” or “habitat anchors." Ideally, soundly constructed instream structures should be designed as part of a comprehensive sub-basin restoration plan that treats controllable sediment sources along with restoring riparian vegetation, and includes a monitoring plan to demonstrate habitat response and project effectiveness.

COST-EFFECTIVENESS OF INSTREAM STRUCTURES

There are a number of ways to further improve the value and cost-effectiveness of instream structures. Some suggestions follow.

• *Ensure that prescriptions are the result of a survey or the recommendation of a trained and experienced habitat specialist or contractor.*

• *Streamline the permitting process.* We have seen some situations where an opportunity to do instream work has been lost due to an inability to obtain the necessary environmental permits. During the time it takes to go through the permitting process, projects can become less feasible and considerably more expensive. If coordination between state and federal agencies were improved, the length of the permitting process could be dramatically reduced.

• *Try to be sensitive to contractors and the work season.* Short work seasons make it more difficult for contractors to make a living: they are unable to support themselves for the rest of the year and are forced to give up restoration work in favor of a full-time job.

• *Use proven standardized fastening techniques employing sound, properly sized logs, rootwads, and boulders.*

• *Incorporate instream projects with upslope sediment treatments, timber harvest plans, or bank stabilization projects.* This makes it possible to take advantage of the heavy equipment that will already be at the site for the other work being accomplished in that location. Using heavy equipment for instream structures can be vastly more cost-effective than building the same structures "by hand."

• *Provide funding for structure maintenance.* This will extend the life of instream structures and improve their function. Upgrading structures using new materials can be particularly effective. For example, 1/2-inch cable can be replaced with 5/8-inch cable, and new and improved epoxy glues can be used.

• *Assist watershed groups and volunteer efforts.* It would be very beneficial to aid contractors in purchasing needed expensive specialized restoration equipment with some sort of start-up grant.

• *Fund regional technical training and conferences.* This can be accomplished through such organizations as the Salmonid Restoration Federation, For the Sake of the Salmon, Resource Conservation Districts, and local watershed groups. Training and conferences create opportunities for the sharing of valuable experience, so that new workers do not repeat the mistakes made in the past.

DISCUSSION

Those promoting stream restoration do not say that restoration alone will recover salmonids. Recovery will come from a comprehensive package that addresses limiting factors through regulatory reform and protection, including acquisition of key habitat and provision for adequate stream flows. Fishermen and fishing organizations such as Trout Unlimited have great potential as allies, workers, and proponents of projects to recover the once-magnificent West Coast salmon and steelhead runs. It is important to recognize that those people working to restore salmonid populations are highly motivated and in tune with current science. Their dedication is demonstrated by the fact that they consistently volunteer large amounts of time towards the goal of salmon and steelhead recovery.

REFERENCES

California Department of Fish and Game, Watershed Restoration Branch. Fishery Restoration Grants Program. February 2000. *Request for Proposals (RFP) — RFP2000.* [Can be obtained online at http://www.dfg.ca.gov/nafwb.fishgrant.html.]

Flosi, Gary *et al.* 1998. *California Salmonid Stream Habitat Restoration Manual, Third Edition.* California Department of Fish and Game, Inland Fisheries Division. [Can be obtained online at http://www.dfg.ca.gov/nafwb.manual.html.]

Seddell, James R. *et al.* 1998. Chapter 3: What we know about large trees that fall into streams and rivers. In: Maser, Chris *et al. From the Forest to the Sea: A Story of Fallen Trees.* Gen. Tech. Rep. PNW-GTR-229. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Appendix 1. Example Project

Instream Component
South Fork Garcia River Watershed Restoration Project

Background

While the highest priority focus of Trout Unlimited's South Fork Garcia Project is upslope erosion control, there is a good opportunity to improve instream habitat. Mendocino Redwood Company (MRC), as part of a Timber Harvest Plan (THP) requirement, has agreed to put to bed a section of haul road that runs along the South Fork. Once this road is decommissioned, future access for heavy equipment will not be possible. MRC has agreed to provide equipment, manpower, and materials match in the form of a D7 with a winch, delivery of redwood root wads, and an additional donation of 5000 board feet of high-quality > 10″ redwood logs to be used for structures.

The South Fork Garcia is a good candidate for instream structure placement. It is one of only four Garcia River tributaries where coho salmon have been documented in the last 10 years (2 adult coho were found during a 1996 spawner survey). According to a Louisiana Pacific (LP) 1996 survey, pools made up only 22.4% of the stream reach and no pools measured deeper than 3 feet. LP's 1995 temperature data collected from mid-July to early October indicated a mean summer temperature of 59º F (15º C), embeddedness of 14.5%, and canopy of 90%. The gradient in the proposed project reach is 1–3%.

Proposed Land Use

MRC owns approximately 90% of the sub-basin and is managing for commercial timber production. With the commitment of MRC to address and repair sediment sources, both THP-linked with their funds and PWA-identified sites with public-private match, the outlook for success is good. MRC's commitment to educate its licensed timber operators by Pacific Watershed Associates in the classroom and the field represents a breakthrough for local watershed efforts. Future timber harvesting will likely be moderated by constraints of the ESA coho listing, the Clean Water Act (TMDL), and Sustained Yield Plan/Habitat Conservation Plan provisions as developed.

Objective

To improve summer rearing and winter spawning and rearing habitat for Coho salmon and steelhead by installing instream habitat structures.

Location

The South Fork Garcia is found on the Gualala U.S. Geological Survey 7.5-minute topographic map. The Planning Unit is 113.70012. It is further identified by Township 12 North and Range 15 West, Sections 29–34, and Township 11 N, R 15 Sections 3–4. The proposed work sites are located on South Fork Garcia River Map A. Fifteen suitable sites were identified and tagged in a Trout Unlimited (TU) October 1998 survey. Ten sites will be chosen depending upon the size and shape of logs and rootwads delivered by MRC. Site locations have been measured to the foot by belt chain and tagged by ribbon. All work will be photo-documented for the final report.

Project Description

Ten structures (six complex and four simple) are proposed. They will include spider logs (with and without rootwads), downstream-V log weirs with and without rootwads, diagonal and straight log weirs with rootwads, Hewitt ramp, and digger logs. Standard pinning and cabling techniques will be employed as described in the *California Salmonid Stream Habitat Restoration Manual* [see title question above] (1998) using 5/8″ galvanized cable and threaded rebar. The high quality of the redwood materials being donated by MRC should ensure long project life. TU staff and volunteers will perform maintenance and monitoring.

Permits

DFG 1601/1603 Streambed Alteration Agreement. A signed landowner access agreement is attached to the overall proposal.

Scheduling

Work will take place during summer low-flow period 1999.

Table A1. Estimated budget: South Fork Garcia River instream structure component

	Number of Hours	Hourly Rate	Amount Requested	Amount Cost Share	Project Total
PERSONNEL COSTS					
Project Leader	60	$15	$0	$900	$900
Volunteer Laborers	60	$10.00	$0	$600	$600
TOTAL PERSONNEL COSTS			**$0**	**$1,500**	**$1,500**
MATERIALS AND SUPPLIES					
5500* board ft. fresh redwood logs @ $570/1000 bd.ft			$0	$3,135	$3,135
10 redwood rootwads @$50			$0	$500	$500
500 feet 5/8″ galvanized cable @ 1.10/ft			$550	$0	$550
100 5/8″ cable clips @ 1.60			$160	$0	$160
100 feet threaded rebar @ 1.50/ft			$150	$0	$150
Plates and anchor nuts for rebar			$100	$0	$100
Tool rental: 2 grip hoists, high lift jack, gas-powered wood drill, webbing, bars, cable cutter, wrenches, gas hammer drill, axe, safety gear			$0	$400	$400
Chainsaw at $30/day			$240	$0	$240
Wood and rock drill bits			$100	$0	$100
3 epoxy tubes @ $25			$0	$75	$75
TOTAL MATERIALS AND SUPPLIES			**$1,300**	**$4,110**	**$5,410**
OPERATING EXPENSES					
16 hours D7 with winch @ $70			$0	$1,120	$1,120

Table A1. Estimated budget: South Fork Garcia River instream structure component (cont'd.)

	Amount Requested	Amount Cost Share	Project Total
8 hours dump truck @$50	$0	$400	$400
Subcontractor - cable rigger 50 hrs. @30/hr	$1,500	$0	$1,500
Liability insurance	$1,150	$0	$1,150
Transportation 450 miles @.24	$108	$0	$108
Photographic supplies	$30	$0	$30
Printing, duplicating, and postage	$30	$0	$30
Telephone	$20	$0	$20
TOTAL OPERATING EXPENSES	**$2,838**	**$1,520**	**$4,358**
Administrative overhead @ 10%	$280	$0	$280
TOTAL ESTIMATED BUDGET	**$4,138**	**$7,130**	**$11,548**
PERCENT COST SHARE: 61.7%			

Figure A1. South Fork Garcia River proposed instream work survey # TU 981 (surveyed October 1998)

Numbers refer to feet measured from confluence of Fleming Creek and the South Fork.

0 - Confluence of Fleming Creek

285 - Channel Maintenance Site No. 1 — Modify jam by removing rootwads with Cat winch and utilize them in constructing an instream structure 100 feet downstream. (Note: these rootwads appear to have dislodged from a bank armoring site upstream. Additionally there are signs of previous barrier removal work at this jam site.)

380 - Instream Structure site No. 1 — Cable rootwads removed from jam to plunge pool redwood log.

520 - Structure site No. 2 — Using Cat winch — pull rootwads to armor road bank. Add rootwads and rock to armor bank and create pool habitat. Cut downed alders to allow stream flow away from eroding roadbank.

800 - Structure site No. 3 — Cable additional redwood log/rootwads to existing cross-channel plunge pool log.

963 - Structure site No. 4 — Cable two additional logs to improve plunge pool effect.
1110 - Structure Site No. 5 — Drop rootwads from roadside bank. Cable to redwood logs and cable/epoxy to rock.

1430 - Confluence of Little South Fork. Culvert to be replaced by MRC with railcar bridge. Save large logs for instream use.

1630 - Channel Maintenance Site No. 2 — Clear brush on roadside bank. Reverse pull redwood root to open channel.

2200 - Structure Site No. 6 — Pivot log and cable to existing cross-channel log to enhance plunge pool.

2280 - Structure Site No. 7 — Using Cat winch, chainsaw, and cable, configure blowdown redwoods into downstream V weir.

2600 - Log Jam — Small jam-fish passage OK; check again in 1999.

3150 - Structure Site No. 8 — Construct demonstration “Hewitt ramp” using redwood logs, planks, and large nails.

3212 - Structure Site No. 9 — Deliver rootwads from road to scour pool habitat.

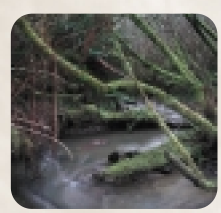
Note: Confer with MRC forester about available redwood logs for structures in this reach.

3360 - Structure site No. 10 — Build spider log structure.

5070 - Structure Site No. 11 — Pull rootwad and cable to redwood log. Add additional rootwads from road.

5200 – 5800 - Four additional sites here — check with MRC on rootwad availability.

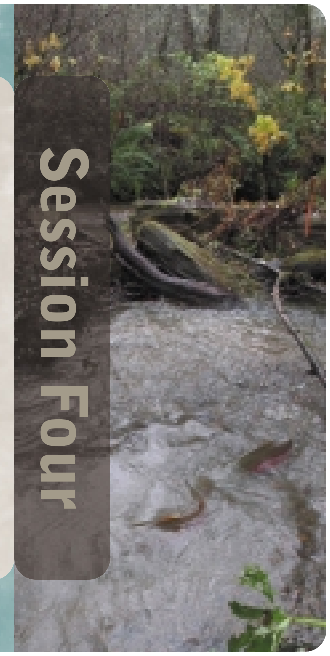
Note: Channel Maintenance sites are not proposed for funding under SB 271.



Instream treatment (e.g., woody debris, rootwads, boulders, side channels, pools, spawning gravel, nutrient augmentation), conversion to non-structural flood control (e.g., meander zones)

Overview and History of Instream and Floodplain Restoration in Western Oregon on Private Lands

MARK LACY
Oregon Dept of Fish and Wildlife
7118 NE Vandenberg Avenue
Corvallis, OR 97330
mark.lacy@state.or.us



ABSTRACT

In 1996 the State of Oregon began what is known as the "Oregon Plan." The Oregon Plan is a cooperative voluntary program to recover salmonids and overall watershed health for present and future generations of Oregonians. As a result of the Oregon Plan, the Western Oregon Habitat Restoration Project was created. It is a cooperative project between Oregon Wildlife Heritage Foundation, Oregon Forest Industries Council (OFIC), Watershed Councils, small urban or rural landowners, and Oregon Department of Fish and Wildlife (ODFW). The purpose of the program is to restore watershed health by addressing passage, roads, instream, and riparian floodplain habitats for salmonids and other indigenous native species.

INTRODUCTION

Between 1994 and 1999 ODFW wrote "Habitat Restoration Guides" for all coastal basins and the Willamette basin. It was a GIS query generated database using the Oregon Aquatic Inventory ODFW database to identify potential streams for large wood placement projects based on channel width, gradient, and reach type — constrained or unconstrained. The reports were reviewed by local ODFW District Biologists and additional sites were added based on information not available from the Aquatic Inventory database. The reports were then circulated to interested cooperators as a beginning point for restoration activities.

ODFW has been the technical partner and industry and councils have contributed access, materials, and equipment to complete the projects. After the coho and subsequent listing of other species (i.e. steelhead, chinook) under the Endangered Species Act (ESA) the cooperative funding sources have become more difficult to obtain. ODFW now continues to work with OFIC but we often write grants through Oregon Wildlife Heritage, ODFW Restoration and Enhancement, Oregon Watershed Enhancement, National Fish and Wildlife Foundation, USFWS Partners for Wildlife, Jobs in the Woods, NMFS Community Based Grants, Umpqua Derby, and other sources — to obtain the funding to implement the projects.

COSTS

In the following sections, cost factors for the following activities are addressed: restoration guide development and production, ground based restoration, aerial based restoration, high-lead cable system restoration, culverts, and legacy road improvements.

Planning Guide and Development

One basin restoration guide (1 biologist for 6 months @ $3,500/mo)	$21,000
Printing ($40.00/guide times 50 copies)	$2,000
Total	**$23,000**

Annual Cost of Fully Funded Habitat Biologists

Currently the biologists work for ODFW with experimental biological aides (EBAs) to assist with monitoring. Personnel salaries (PS), services and supplies (SS) and capital outlay are funded through the Oregon Wildlife Heritage Foundation. Funding sources include ODFW Restoration and Enhancement Board, Oregon Watershed Enhancement Board and National Fish and Wildlife Foundation. The Willamette project received some funding from Portland General Electric and a grant from the Mt. Hood National Forest. The project coordinator position is not included in the table below.

7 Biologists in 00/01			Monitoring EBAs in 00/01		
PS	SS	Total	PS	SS	Total
$333,289	$66,658	$399,947	$152,093	$30,419	$182,512
/12 mo	/12 mo	/12 mo	/7 mo	/7 mo	/7 mo
$27,774	$5,555	$33,329	$21,728	$4,346	$26,073

Habitat Project Coordinator in 00/01		
PS	SS	Total
$55,000	$11,000	$66,000
/12 mo	/12 mo	/12 mo
$4,584	$916	$5,500

Total Project Costs

Biologists, Coordinator	$465,947
Monitoring	$182,512
Capital (computers, GIS, etc.)	$6,000
Total/year	**$654,459**

Implementation Cost Estimates for Ground Based Stream/Floodplain Enhancement Projects — Cooperative Project (Non-contract)

(Estimates are based on one (1) mile restoration stream segment on private industrial forest land in the Willamette basin.)

Design, layout, implementation for biologist — 160 hours for 1 person @ 40/hr	$6,400
Implementation/staging/logistics, Company Rep — 16 hrs @ 50/hr	$800
Equipment — log-loader/shovel @ 140.00/hr for 32 hrs	$4,480
Equipment — skidder @ 50.00 hr for 32 hrs	$1,600
Equipment Mobilization	$1,000
Self loading log truck to move material @ 60/hr for 16 hrs	$960
Material — logs or whole trees 120/mile @ 500.00/stick	$60,000
Seeding and/or planting with labor @ 300/mile	$300
Monitoring — stream survey/ biological	$2,000
Photos, etc.	$50
Total	**$77,590**

Implementation Cost Estimates for Ground Based Stream/Floodplain Enhancement Projects — Cooperative Project (Contracted)

(Estimates are based on one (1) mile restoration stream segment on ODF lands in the Tillamook State Forest.)

Design and Layout, Biologist — 160 hours for 1 person @ 40/hr	$ 6,400
Equipment — log-loader/shovel for mobilization, material prep, staging, and placement @ 140/hr for 80 hrs	$11,200
Material — logs or whole trees 120/mile @ 500.00/stick	$60,000
Seeding and/or planting with labor @ 300/mile	$300
Contract preparation — 60 hrs at 40/hr	$2,400
Monitoring — stream survey/ biological	$2,000
Photos, etc.	$50
Total	**$82,350**

Reference — Lacy and field biologists

Aerial (Helicopter) Large Wood Placement

(This example was on Oregon Dept of Forestry State lands in the Tillamook State Forest.)

Design, layout, imp for Biologist — 320 hours for 1 person @ 40/hr	$12,800
Implementation/staging/logistics, Company Rep — 16 hrs @ 50/hr	$800
Equipment — "vertel ship" and ground crew, payload 11,000 lbs for 12 hrs @3,571/hr	$42,852
Equipment — spotter helicopter in dense canopy 13 hrs @525/hr	$6,825
Equipment — trac-hoe to push trees over for 40 hrs @ 100/hr	$4,000
Supplies — cable, ribbon	$3,828
Material — logs or whole trees (on site) 120/mile @ 500.00/stick	$60,000
Monitoring — stream survey/ biological	$2,000
Photos, etc.	$50
Total	**$133,155**

Reference — Lacy, Plawman

Aerial (Helicopter) Large Wood Placement

(This example was on USFS Federal lands in the Umpqua National Forest for 8 stream miles and using 584 trees.)

Design and Layout, Biologist — 320 hours for 1 person @ 40/hr	$ 12,800
Equipment — "chinook ship", and ground crew, payload 25,000 lbs for 36 hrs @7,200/hr[1]	$259,200
Material — logs or whole trees and staging 584/tree @ 120/stick	$ 70,080
Implementation team — 6 bios for 32 hrs @ 40/hr	$ 7,680
Overhead team — road guards, fire 5 members for 32 hrs @ 30/hr	$ 4,800
Contract prep, printing, misc	$ 9,500
Monitoring — stream survey/ biological	$ 16,000
Photos, etc.	$ 550
Total	**$380,610**
(per mile)	($ 47,576.25)

1- The chinook generally flies for $9,000–$12,000. This contract is a multiple year contract.

Reference — Lacy, Harkelroad

High Lead Cable Large Wood Placement Projects (as Part of a Timber Operation without Separate Turns)

(A turn is defined as an active lane that the cable is suspended above during the timber harvest operation without changing the angle, deflection, or haul back. The wood is placed in the existing system.)

Estimates are based on one (1) mile restoration stream segments	
Design and Layout, Biologist — 40 hours for 1 person @ 40/hr	$1,000
Implementation/staging/logistics, Company Rep — 16 hrs @ 50/hr	$800
Equipment and labor — tower, loggers	$600
Equipment Mobilization	$0
Material — logs or whole trees (on site) 120/mile @ 400.00/stick	$48,000
.Monitoring — stream survey/ biological	$2,000
Photos, etc.	$50
Total	**$52,450**

High Lead Cable Large Wood Placement Projects (as Part of a Timber Operation with Separate Turns)

(A turn is defined as an active lane that the cable is suspended above during the timber harvest operation, but making specific settings to place the wood outside of the harvest corridors.)

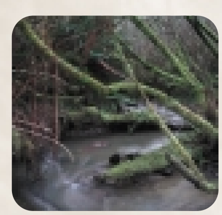
Estimates are based on one(1) mile restoration stream segments	
Design and Layout, Biologist — 40 hours for 1 person @ 40/hr	$1,000
Implementation/staging/logistics, Company Rep — 16 hrs @ 50/hr	$800
Equipment and labor — tower, loggers	$4,000
Equipment Mobilization	$0
Material — logs or whole trees (on site) 120/mile @ 400.00/stick	$48,000
Monitoring — stream survey/ biological	$2,000
Photos, etc.	$50
Total	**$55,850**

Reference — Lacy, Workman

Culverts and Bridges on Private Industrial Lands

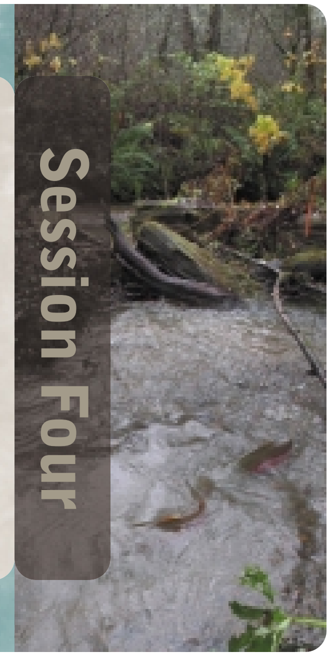
(Provided by Jerry Workman, Forest Engineer, Willamette Industries, Lebanon, Oregon.)

Cross drain culverts (includes time and materials) — 18″ 6.50/foot average of 30 feet	$195
Culverts (includes time and material) — 36″ 14.00/foot average of 40 feet	$560
Culverts (includes time and material) — 60″ 30.00/foot average of 40 feet	$1,200
Culverts (includes time and material) — 40 % buried, 60″ 150.00/foot average of 40 feet	$6,000
Baffled Culverts (includes time and material), 10 foot 300.00/foot average of 40 feet	$12,000
Baffled Open Bottom Culverts without concrete footings (includes time and material), 12 foot 750.00/foot average of 40 feet	$30,000
Open Bottomed Culvert with concrete footings (includes time and material), 18 foot 900.00/foot average of 40 feet	$36,000
Bridge — 12 feet wide, concrete, (includes time and materials) 2,000.00/foot average of 50 feet	$100,000



Instream treatment (e.g., woody debris, rootwads, boulders, side channels, pools, spawning gravel, nutrient augmentation), conversion to non-structural flood control (e.g., meander zones)

Session Four



Costs of Restoration Work in an Urban Environment

KATHRYN NEAL
King County Department of Natural Resources
201 S. Jackson Street
Seattle, WA 98104
kathryn.neal@metrokc.gov

ABSTRACT

This paper describes cost factors that are particular to local governments completing salmon habitat improvement projects in watersheds that surround a major city. King County, Washington surrounds the Seattle metropolitan area, and is the most populated and one of the fastest-growing counties in the state. Organizational and policy factors as well as costs resulting from physical characteristics of the project sites are significant determinants of project cost. Also discussed are some of the techniques and strategies that have led to successful projects in the past. Specific examples are drawn from the author's ten years direct involvement in the design and construction of in-stream habitat restoration projects for King County.

INTRODUCTION

King County Water and Land Resources Division's (WLRD) habitat work focuses on streams, rivers and wetlands in urbanizing basins of the Puget Sound lowlands. The Division is involved with a variety of surface water initiatives, of which instream habitat projects are only one part. Types of instream habitat improvement projects include rebuilding streambeds with boulders, gravel, and woody debris, removing or replacing culverts to improve fish passage, installing large woody debris (LWD) for habitat diversity and erosion control, bioengineered bank stabilization, reconnecting a watercourse to its floodplain, and excavating groundwater-fed side channels. LWD may be anchored to the site by partially burying each piece in the streambank or bed, or may be placed unanchored with a crane or helicopter. Most instream projects include an important riparian revegetation component, and many include improvements to wetlands. The Division also designs and constructs regional retention/detention ponds, neighborhood drainage assistance projects, stormwater drainage systems, and flood hazard reduction work. WLRD is also active in proposing policies and regulatory remedies, and in public involvement and education. This broad perspective enhances the range of opportunities and resources for habitat work.

Figure 1. Streambed rehabilitation project under construction. Project design team ecologist checking invert of instream boulder wedge. (Case study project 4)

The combination of physical and organization factors sets a particular environment within which King County staff design and construct habitat improvement projects. This paper highlights the most salient features of that environment, and points out how these features affect project cost and quality.

Physical Setting

King County is located on the east side of the Puget Lowland in Washington State. The Puget Lowland is a north-south trending trough, with Puget Sound along its axis, and the Cascade and Olympic Mountains bordering it to the east and west, respectively.

King County has a marine climate dominated by airflow from the northern Pacific Ocean. Annual precipitation increases from west to east as a result of the orographic rainfall effect of the Cascade Mountains. Annual precipitation ranges from 900 mm (36 inches) near the shores of Puget Sound to 4000 mm (156 inches) at the Cascade Crest. Typically, approximately 70% of precipitation falls between the first of November and the end of February. These climatic conditions support conifer-dominated forests that historically extended from the marine shoreline to alpine tree line.

The streams that drain this forested landscape support many aquatic organisms including five species of salmon (pink [*Oncorhynchus gorbuscha*], coho [*O. kisutch*], chinook [*O. tshawytscha*], sockeye [*O. nerka*], and chum [*O. keta*]), two species of trout (rainbow [*O. mykiss*] and cutthroat [*O. clarki*]), and two species of char (Dolly Varden [*Salvelinus malma* Walbaum] and bull trout [*S. confluentus*]), as well as numerous other vertebrate and invertebrate species.

Since pioneers of European and Asian descent began settling the area in the mid-

1800's, the landscape was altered by agriculture, logging, fishing and coal mining, which were the primary supports of the new economy. More recently, urban and suburban development with its associated infrastructure has had a pervasive impact on rivers, streams and wetlands.

The intensity of residential, commercial, and industrial land development has increased, and so has the degradation of aquatic resources that is an unintended consequence of that development. Many suburbs of Seattle have grown at rates of 30 to 40% over the past decade. Development is most evident in the western portion of the County nearest Puget Sound, and is ongoing in the foothills to the east, where farming is still active. The mountainous eastern part of the County continues to be used for timber harvest and recreation.

Types of stream degradation that have been observed are:

- Natural channels have been dredged, diked, straightened, and/or cleared of LWD
- Wetlands and marine estuaries have been filled and/or drained
- Riparian zones have been cleared or overwhelmed by aggressive introduced plant species
- A variety of fish-impassable structures, including culverts, weirs, and dams, have blocked anadromous fish access to hundreds of kilometers of stream channel
- Water quality has been degraded by a variety of pollutants
- Large areas of impervious surface have altered stream hydrology — increasing flow peaks and probably decreasing base flows

Organizational Setting

The problems listed above have become increasingly obvious to most residents of the area. King County has taken an increasingly active role in protecting and restoring the resource values of rivers, streams and wetlands. King County has done leading-edge work as one of the first jurisdictions to invest considerable energy in watershed planning and in habitat restoration projects.

The projects discussed in this paper were all undertaken with habitat improvement as the primary goal of the work, not as mitigation or as a secondary benefit of infrastructure work. These projects were managed through the Surface Water Engineering and Environmental Services Section of WLRD, now Capital Projects and Open Space Acquisition (CPOSA). CPOSA staff focus on building projects, and work within the context of the larger Division. The overall WLRD mission is "to sustain healthy watersheds, protect wastewater systems, minimize flood hazards, protect public health and water quality, preserve open space, working farms and forests, ensure adequate water for people and fish, manage public drainage systems, and protect and restore habitats." The entire Division is made up of about 200 people, and the CPOSA work group is composed of about 50 people. It is helpful that design, permitting, and construction expertise is focussed in one working group, which also has access to resources in the entire Division. Many of the restoration projects are based on the watershed planning work that was initiated by WLRD (formerly known as Surface Water Management in the 1980's).

HABITAT ENHANCEMENT PROJECTS

Project Identification and Funding

The basin plans often set the context and sequence of projects the CPOSA group undertakes. A comprehensive, persistent watershed planning effort helps ensure that projects are identified and funded from a whole watershed perspective, and that the needs and opinions of citizens, tribes, organizations, and cities are taken into account. In addition to the formal basin plans, projects are identified through citizen input, King County staff observations, referrals from other public agencies, joint studies, and County Council requests.

Project funding must be established before the project design team is brought together. The entire process may take a number of months or even years. Planners from other sections within WLRD generally take the lead in initial project identification and scoping, and in setting an initial budget. Senior ecological and engineering staff from CPOSA are often involved in the process. Project proposals are developed and County Council approves funding. In some cases, projects are funded jointly by the County and one or more cities. Grants from a variety of sources may also be involved in funding a project. If a project requires additional funds for some reason, WLRD must return to Council for approval. The Division has limited ability to move money between projects.

In spite of what is sometimes a time-consuming process, in some cases the County has been able to move quickly to solve an emerging problem. For instance, at Rutherford Creek (see page 161 for case study), the problem was clearly defined, data showed conditions were becoming worse, and a project team and budget had already been assigned to address habitat degradation in the particular watershed. Also, provisions are in place for addressing emergencies immediately.

An organization spends time and money on a project before the project is formally initiated. The planning process is essential to make sure that problems and potential solutions are accurately identified. Extensive consultation is in the public interest, and may be expensive, but is not usually charged to the project budget. A significant time lag between initial project conception and actual mobilization of the project team may mean that the project needs to be re-scoped or that the funding level is not right.

The process attempts to identify and resolve conflicts, for instance disagreements within the community about desired land use and resource values. If unresolved issues must be taken up by the design team, project costs will be increased. As an extreme example, costs of defending a lawsuit can be extremely high and will be charged to the project budget.

Project Implementation and Experience

Habitat enhancement projects vary in size, with budgets ranging from $15,000 to $750,000. A linked series of projects may have an aggregate budget that exceeds $1,000,000. Most projects are less than $400,000 for design, construction, and the initial maintenance and monitoring.

For a typical habitat enhancement project, one to three years are required from the time the project team begins work until design, permitting, and construction of earthwork and planting phases are complete. Monitoring and plant maintenance usually continue for another three to five years.

Project Design Teams

Within CPOSA, a multi-disciplinary design team is assembled after the project is identified and funded. Typically, professionals on the design team include engineers and ecologists, often with support from a geologist and a landscape architect. The size of the core team varies depending on the complexity of the project. Graphics and computer aided design and drafting support are integral to the project team, as are survey staff. The project team often draws on the expertise of professionals working in other sections of WLRD, including for instance wetlands scientists, lake stewardship coordinators, noxious weed control specialists, public involvement facilitators, real estate and open space acquisition specialists and especially watershed planners. The core team works under the direction of a functional manager, and is essentially self-directed, using consultation to arrive at decisions. The core team is responsible for validating the scope and budget, and for project design, permitting, construction, and follow-through.

Staff Continuity

Most design work is done in-house, though design consultants sometimes augment County staff. As often as possible, the same team will work together on a suite of projects in one watershed. This enables the team members to develop a detailed working knowledge of the physical characteristics of the basin, and also the involved landowners and citizen groups. Consistent teams for each watershed greatly enhance the efficiency of the work.

The watershed-level approach has the further benefit of allowing the restoration team to develop long-term working relationships with the regulatory agencies and staff involved in each watershed. For instance, the design team often consults with the fisheries habitat biologist (Washington Department of Fish and Wildlife [WDFW]) and the grading inspector (King County Department of Development and Environmental Services [DDES]) early in the design process. This can make the permitting process more efficient, because regulatory and ecological constraints are identified from the beginning and can be integrated into the project design. Not only is the design team as a whole involved in regulatory and design issues, but an ecologist and an engineer are typically assigned to be on site during construction. CPOSA has a good reputation for compliance with the letter and spirit of regulations, and the design team works closely with the builders to achieve the desired result. Natural materials such as streambed gravels or LWD are highly variable, and it is valuable to have the designer on site when working with them. This practice also means that the plan drawings can be relatively straightforward, describing the intent and general characteristics of the habitat structures, and leaving details of each structure to be field-specified.

Whether a project is going to be bid or is going to be built by County forces, CPOSA projects require formal project plans, not a brief work order. Plans are designed to communicate — to the construction contractor, the field crew, and also to regulatory agencies reviewing sensitive area and fisheries issues. Project teams strive to keep complexity of plans consistent with the complexity of the project. Specialized graphics designed to communicate with the public may be useful, and take time to prepare. The project teams often find basemaps compiled from Geographic Information System (GIS) databases very useful, and these are available much less expensively than in the past.

Our restoration teams are highly interdisciplinary, which means that each design team has the benefit of a variety of perspectives. The commitment to interdisciplinary teams means that a broader range of issues tends to be raised during the design process. This tends to increase the quality of designs, in that construction feasibility, regulatory requirements and ecological benefits are integrated with the original design process. Realistically, this consultative process may significantly increase design costs, since the project budget must pay for each hour working through any protracted disagreements. It is difficult to be certain whether the extra time spent in team discussion saves the project money in the long run. Investing the effort and money in the beginning means that projects are better-prepared for review by regulatory agencies. And, working out truly difficult issues in the broader regulatory or public forum would be more expensive than within the design team.

Regulatory Requirements

King County enjoys a robust permitting environment. Practically by definition, habitat restoration projects are built in ecologically sensitive areas. Projects typically require a Clearing and Grading permit from King County DDES, and a Hydraulic Project Approval from WDFW. A Shorelines Exemption and Water Quality Certification from Washington State Department of Ecology, and a US Army Corps of Engineers (Corps) Nationwide Permit Exemption are often obtained. Since March 1999, when Puget Sound chinook salmon were listed as threatened under the Endangered Species Act (ESA), a formal Biological Assessment and consultation with National Marine Fisheries Service and U.S. Fish and Wildlife Service are often required. The Corps in particular has submittal format requirements that add to project costs, even if special studies are not required. As a matter of policy, and because of the desire to maintain a trust relationship with the agencies, CPOSA teams consult with regulators whenever possible before formal permit applications are submitted. Indian tribes have a great interest in projects that affect fisheries resources, and are organized and effective in commenting on proposed projects through the State Environmental Policy Act (SEPA) process. WLRD is a SEPA lead agency for surface water projects, which means that Determinations of Non-Significance are made and reviewed within the Division, rather than at DDES. This represents a cost saving to the project, because it simplifies the process. The Division is rigorous about adhering to all notification and comment period requirements. Regulatory costs are included in the project's design budget. In general, group decisions and group actions are more time-consuming and therefore expensive than individual decisions.

Whether a project budget bears the full impact of expanded consultation depends on how many of the participants are being paid out of that budget. For instance, Federal and State regulatory staff provide their services to the project for free. Additional expenses come in the form of additional submittal requirements, meetings and studies. King County DDES staff bills the project for time spent in review, field inspection, and monitoring at a substantial rate (currently $132 per hour, the same rate a development project would be charged).

Public Involvement

Some habitat projects are built on private property, and some are built on public property that is often well-loved and much-used. A very few of the habitat projects in King County are in truly remote locations. Landowner relationships are a very significant factor in whether a project will prove to be feasible, and in the ultimate cost of a project. When a project has a broad range of stakeholders or is controversial, a public meeting may be the best choice in working with the community. In any case, explaining the project goals, benefits, and specific actions takes time and may be a significant part of the project budget.

It is generally recognized that we are working with resources that are both valuable and vulnerable. Individual citizens' opinions of WLRD's work vary widely, and are expressed in actions ranging from very negative to very positive. For instance, a recent project involving the helicopter placement of LWD in a ravine near Lake Washington was challenged by a SEPA lawsuit questioning the concept of LWD placement, and was also enhanced by a donation of trees from a neighboring landowner. The donated trees were gratefully accepted. The lawsuit was dismissed about 3 months later, but project staff spent about 60 hours responding. Normally, a project's budget would bear those costs. In this particular case, it was felt that the lawsuit proceeded from a broader dispute, and not from concerns with this particular project. The project team's direct costs of the lawsuit, and the County's legal costs, were paid from separate budgets, but there were ancillary costs that impacted the project. Construction was delayed for one year.

Apart from capital projects, public education and involvement in protecting aquatic resources is an important part of WLRD's mission, and the Division has an on-going investment in public involvement efforts. As part of on-going division-wide programs, hundreds of volunteers donate their time every year to plant native vegetation and to monitor the water quality of small lakes. When appropriate, volunteers will assist with planting newly constructed restoration project sites. Volunteer planting events are especially useful for large sites, where there are thousands of plants to be installed. Team leaders, refreshments, tools, and instructions in how to plant a tree are provided by the county. Adequate parking or shuttle busses must also be provided. The project team shares the costs of coordinating these events with the Public Involvement work group, and the results have been very satisfactory. Benefits include not only getting the plants in the ground quickly at a reasonable cost, but also community involvement and stewardship of sites. Volunteers have also assisted with maintenance of plants in the first years after they are installed through the Habitat Partners program.

Design-Build Projects

Construction labor may be drawn from County roads and parks maintenance crews, general contractors, specialty subcontractors, Washington Conservation Corps (WCC) crews, and volunteers. Members of the design team will also be on site during construction. Their role is not limited to construction oversight, but is likely to include survey, water quality monitoring, and determining the specific placement of habitat structures.

County crews frequently construct habitat projects. In particular, some Roads Maintenance crews have been specialized for habitat and river-related work. Supervisors and the field staff are experienced at working in sensitive areas, and familiar with regulatory constraints and with materials and construction techniques that are specific to habitat projects. Consistently working with the same group improves communication, and helps reduce risks and some uncertainties. Because the design team can work closely with the construction supervisor during the conceptual design phase, construction feasibility issues are addressed early. Considerable administrative costs (often on the order of $5000) are avoided by eliminating the bid process. There is a $70,000 limit set by state law to the size of capital projects that can be undertaken by County forces. The limit is for construction labor, materials, and equipment. The statutory limit does not apply to maintenance projects (for example, work on river levees).

When projects go out to bid and are built by a general contractor, actual construction costs have been found to be comparable to County forces. Public works contracting rules apply, and prevailing wages are paid on all jobs. In addition to the costs of working through King County Finance Procurement Section to bid the job, additional design costs are incurred because the plans and specifications are necessarily more refined in order to serve as Contract Documents. The additional costs vary depending on project complexity, but can easily amount to 100 hours of staff time, which will result in $7000 to $9000 in charges to the project. For many habitat structures, i.e. LWD deflector logs, the plans will say "Field placement under direction of engineer or biologist." Such language increases uncertainty and risk for a contractor, and will increase the bid price. Construction Engineering and Inspection tasks may take approximately the same amount of time as a design-build project, but the work itself will involve more contract administration, and less field design. If the low bidder has not employed a particular technique before, for instance coir wraps with willow cuttings on a streambank, County staff will spend extra time with the construction crew.

The Washington Conservation Corps (WCC) is a particularly important element of the construction labor resources. The WCC is an Americorps program involving youths, aged 18–25, who work full-time on restoration and enhancement projects for King County. Corps members are technically state employees, on contract to the County. CPOSA keeps at least one WCC crew busy all year on planting, watering, and other hand work. Between 1999 and 2003, the cost for a supervised 4-person crew for one week varied from $3000 to $5000. An ancillary benefit is that the crew is based in CPOSA, and is coordinated by a CPOSA ecologist. The training they receive provides a good knowledge of habitat projects, native plants, design and construction methods, and ecological issues.

Monitoring

Costs of monitoring for project success in terms of durability, structural stability, and plant survival are covered by the project budget. Costs of more rigorous scientific studies are planned and budgeted separately, and are not addressed in this paper. Such studies may be funded and accomplished by other work groups within the Division, or in cooperation with the University of Washington. Critically assessing the results of completed habitat enhancement projects, and ensuring that significant findings inform future projects is a goal of the work group.

Summary of Cost Factors

The physical and organizational setting in which habitat improvement projects are accomplished has a weighty impact on the costs of those projects. The factors affecting project costs can be separated into three groups – advantages, challenges, and value-neutral factors that must be carefully clarified. Based on CPOSA's experience, there are several strategies that improve the likelihood that enhancement efforts will produce useful results. These working methods usually tend to maximize cost effectiveness, but in some cases the mandate to consult with a wide range of stakeholders, including multiple professional disciplines, private landowners, regulatory agencies, and political representatives will increase costs compared to construction projects with a single owner.

These advantageous strategies include:

- Unified interdisciplinary design teams
- Construction crews experienced in habitat work
- Design-Build capability
- Basin plans underpinning habitat restoration work
- Watershed knowledge brought to bear before and after project initiation
- Working relationship with regulatory agencies – trust
- Working relationship with construction crews – trust
- Washington Conservation Corps

There were organizational factors at work in the last few years (since 1995) that have made it more difficult to complete projects quickly at the lowest possible cost. The Department of Natural Resources underwent a major reorganization, in which the county organization (7,000 employees) merged with Metro (6,000 employees). Resulting staff changes and re-shuffling of work loads impacted project schedules and employee morale.

Annexations and incorporations are reducing the County's service area in urbanizing areas, and also reducing the tax base. The changes are a result of cities forming and annexing in the highest density areas, which means that the county is losing funding at a rate disproportionately greater than the land area that is being lost. This results in uncertainty within the organization about future funding levels for habitat restoration work.

The Endangered Species Act (ESA) listing of chinook salmon in 1999 also impacted the Division. The listing made the process of obtaining permits for habitat enhancement projects much more difficult, because the federal agencies involved were faced with a suddenly increased workload, and because permit submittal requirements and processes were changing. The level of effort required to obtain Corps of Engineers permits increased suddenly for the design teams, which was not foreseen when the project budgets had been established. After the first few years, the cost impact of this change decreased, but has not disappeared. Procedures and expectations within the County have adjusted to the new requirements.

Other cost factors are in themselves neither harmful nor beneficial, but care must be taken to define them explicitly before comparing or analyzing project costs. To give a complete picture, cost tracking must be inclusive of all design, construction, construction oversight, and follow-up costs, including labor, materials, and equipment. Work performed for both the earthwork and planting phases of a project must be included, as well as any construction contract amounts or specialty contractors. The starting and ending points in time of the "project costs" must be defined. Some organizations include planning and monitoring in a project's costs, some do not. These practices may vary depending on the nature of a project. Road or building construction projects may be treated differently than habitat enhancement work. Whether or not overhead costs are routinely captured in an organization's project cost reports is embedded in its accounting practices. Cost tracking may become more difficult in times of organizational upheaval.

DEVELOPING AND TRACKING PROJECT COSTS

For the case studies analyzed for this presentation, "project costs" begin at the time that the design team is formed and has its first meeting. The team begins to charge their costs to a project number that has been established in the County's accounting system. Project costs continue to accrue through design, construction and follow-up periods. Construction usually includes earthwork and planting, and may include multiple phases of each. Follow-up may include plant establishment, invasive species control, and monitoring. Project costs end at the time when the project number is closed out, usually when permit-driven monitoring is complete and any repair work is done. Routine monitoring costs may be estimated and project funds set aside to accomplish the work.

All CPOSA staff time spent working on the project is billed to the project charge number, at a fully burdened rate that varies from about $40 to $90 per hour. In the CPOSA section, the overhead multiplier is recalculated each year, in an attempt to accurately reflect the actual cost of providing staff services. It has varied from about 2.3 to almost 2.7. Management and administrative staff do not bill the project – their contribution is paid out of the multiplier applied to staff costs to arrive at the fully burdened labor rate.

The design team may consult other County staff within WLRD, and those professionals generally do not bill the project directly. In particular, Basin Stewards are WLRD employees who are involved in communicating with the public, and with tracking project progress, watershed issues, and citizen concerns. They often work closely with the project team. If legal advice must be sought, the Prosecuting Attorney's staff is available, and does not directly bill the project. These additional resources add considerable value to the project design. The County's accounting system does not automatically track the total level of effort expended to accomplish the project. On the other hand, intranet access to the detailed project charges has been developed since 2001. Both costs and hours expended by the design team and County construction crews are recorded and can be analyzed.

Construction crews work for the Roads Department, and their labor costs are billed to the project at a fully burdened rate, but the multiplier is lower, about 2.0. County construction labor costs range from about $40 to $60 per hour.

Consultants and contractors do not present the same subtleties in project cost tracking, since their overhead costs are always included in the invoices paid. In this sense, it is useful that the County determines and tracks overall costs, and not just wages, for Capital Improvement Project (CIP) staff.

For comparison purposes, and when using project data to estimate future project costs, it is preferable to report hours spent to accomplish project tasks, rather that to compare total dollar figures. It would also be important to define what tasks were accomplished, and whether some work was funded by other sources. "Hours spent" represents the level of effort expended in that particular design/permit/construction environment to accomplish a particular scope of work. Labor rates specific to the organization could then be applied to arrive at budgets or design cost estimates.

Organizations tend to retain and distribute total project cost dollar amounts, as opposed to detailed project cost breakdowns by task. Also these cost figures are retained at certain milestones in a project's lifespan. It is instructive to compare initial planning-level scopes and budgets with budget amounts approved for funding by Council, then with construction estimates and design costs as the project design evolves, then with final costs. All too often, cost information does not specify which costs are included, or whether the cost figures are budgets or actual expenditures. Obviously, it's important when researching project costs to ascertain what has been reported.

Some of the habitat restoration projects are partially funded by grants. Granting agencies typically favor paying construction costs, and may place limitations on what kind of expenditures may be used as matching funds. Grant reporting requirements are usually specific, and specify cost categories that often do not mesh perfectly with the cost categories set up internally within a public agency. The translation effort becomes a project management cost.

Cost Categories

The county accounting system breaks project costs into the following categories:

- 001- Consultant costs. Does not include consultant contract management costs
- 002- Acquisition costs to purchase right-of-way, easements, fee title and limited use or access permits
- 003- Construction costs, by County forces or contracted
- 006- 1% for art
- 007- In-house labor
- 008- Property services support, includes appraisals, negotiation, etc.

009- Construction management, engineering, inspection, closeout

013- Hazardous waste assessment and removal

Expenditures and formal estimates are tracked by the above categories throughout the life of the project. However, for estimating and explaining the costs of projects, the following categories are more useful, because they track the tasks to be done in something closer to chronological order:

Design (all phases)
Construction (all phases)
Follow Through (all phases)

For a project with multiple phases, it is helpful to sequence them chronologically when doing project planning and estimating. Table 1 describes typical costs associated with each phase.

Most habitat enhancement projects include both earthwork (grading, culvert replacement, streambed rehabilitation, LWD placement) and installation of native plants. During the design phase, the earthwork and

Table 1. Typical tasks associated with project design, construction and follow-through

DESIGN		
	Design and Permitting	

		Project assessment
		Conceptual design
		    Earthwork
		    Plantings
		Permit application submittals
		Plans, specifications, and estimates
		    Earthwork
		    Plantings
		Consultant contract management

	Permit Fees	
	Landowner Relations/Land	
	SEPA	
	Public Involvement	
CONSTRUCTION (consider earthwork and planting separately as two phases)		
	Survey/Staking	
	Construction Access	
	Mobilization	
	Stream Diversion	
	Fish Removal from Work Area	

Table 1. Typical tasks associated with project design, construction and follow-through (cont'd.)

	Erosion and Sedimentation Control	
	Earthwork	
	Materials Procurement	
	LWD Acquisition	
	LWD Placement	
	Structures	
	Construction Management	
		Engineer and biologist on site
FOLLOW THROUGH		
	Maintenance	
		Structures Plant establishment
	Monitoring	
		Permit driven (often limited to plant survival and coverage) Structural stability Evaluating project success
	Closeout	
	Communicating (both within and outside the organization)	

the plantings are interdependent, though the two kinds of work are shown on separate plan sheets. For construction, the two kinds of work are very separate. The planting work is done after the earthwork, by a different work crew, and requires a separate mobilization. The native plants, being alive, have very different needs than other construction materials.

"Landowner relations" includes negotiating right-of-way on the land as well as negotiating the geographical scope of the project. Many habitat projects are on private land, which means that the landowner is brought in as partner. That can take quite a lot of time, and we are not always successful.

SEPA costs are also included in the design phase, and generally amount to $3,000 to $8,000. Costs include preparing the environmental checklist and publishing all notifications, and responding to any comments. Public involvement costs are separate from SEPA because they involve public meetings, such as explaining the project to a Homeowners Association. Often we are dealing with a riparian corridor that was set aside as part of a subdivision, and must get permission from the majority of owners in that subdivision to do the work.

Functionally, it makes sense to lump design and permitting costs together, because the processes are so integrated.

Figure 2. Excavation of defined floodplain for O'Grady creek (Case study project 5)

Engineers on the design team may take the lead in producing project plans, and ecologists take the lead in submitting for permits and consulting with regulatory staff. All team members work together on the design, and ecological issues are central to the content of the design.

The next broad cost category is construction costs. This includes the traditional three sub-categories: materials, equipment, and labor. Depending on the nature of the project, one sub-category may be the dominant cost of the project as a whole. For example, at O'Grady Creek (case study 5), the project involved excavating a flood terrace in a pasture and moving 13,000 cubic yards of earth on site. The quantity of earth to be moved drove the costs of the entire project. Equipment was carefully chosen to do this work most efficiently. Twelve hundred lineal feet of stream was also constructed as part of the project. The streambed meandered, was constructed to exacting grade, and incorporated over 300 pieces of woody debris. Even so, the streambed construction was completed in a fraction of the time needed for the mass earthwork, and was a smaller component of overall project costs.

Figure 3. Crane overcomes tight construction access for delivery truck (Case study project 4)

Access to the project site is an important cost-determining factor. Bringing people and equipment to sensitive, remote sites can be challenging. In some cases it is necessary to build an access road and then decommission it at the end of the project. Figure 3 shows a situation in which an existing access road down a steep ravine was adequate to deliver a concrete box culvert to a stream crossing, but there was no space for the truck and trailer to turn around. The crane placed the culvert and picked the trailer up to turn it in midair.

Another issue is that of stream diversion; usually it's necessary to bypass the flowing water around the work zone. If the

Figure 4. Silt fence along the Sammamish River

Figure 5. Silt curtain in the Sammamish River

stream is diverted, fish and other aquatic life are be removed and relocated prior to the diversion. Regulations regarding monitoring projects during construction have grown stricter recently, which can add labor costs. Equipment can usually be borrowed from the Division's Science and Monitoring workgroup.

Sediment and erosion control measures vary depending on the nature of the project, and deserve special attention near slopes, flowing water, and salmon habitat. Figures 4–5 show work at the confluence of Gold Creek and the Sammamish River. A culvert on the tributary was replaced for fish passage, and the confluence area was completely reshaped. The river has been extensively modified by the Corps of Engineers in the early 1960s. In order to control flooding during the growing season, the low gradient, sinuous, sand-bedded river was straightened and uniformly channelized with a trapezoidal cross-section. The County, nearby cities, and the Corps are working together to restore some habitat diversity, especially at stream confluences. The Sammamish River is a major migration route for five species of salmon, including chinook. Figure 4 shows a silt fence along the river margin to prevent sediment from the bankwork from mobilizing into the river. Figure 5 shows the downstream end of the temporary flow diversion pipe, and a silt curtain in the Sammamish, which was installed to prevent sediment carried by Gold Creek from being mobilized into the mainstem.

Special techniques include placing logs in flowing water along streambanks, soil lifts wrapped in coir fabric, live willow cuttings, and field placement of habitat features such as woody debris complexes or streambed boulders stepped up to serve as "fish ladders." If it is known that an experienced habitat work construction crew will do the work, some uncertainty is removed from the cost estimate.

Special equipment that is frequently employed includes large trackhoes with a thumb, wide tracked vehicles for wetland work, cranes, and helicopters for placing LWD. From experience, project staff have become familiar with the capabilities and costs of some of this specialized equipment. A helicopter costing $5000 per hour may be the least expensive method to install relatively large quantities of LWD, depending on the particulars of the project site. For instance, a helicopter will have minimal impact to a vegetated riparian corridor, but cannot be allowed to fly over housing. Special arrangements must be made to fly over power transmission lines.

Special materials frequently used in instream work include boulders, streambed gravel, and LWD. LWD deserves special consideration, as it can be a major component of project costs. Procuring wood of the appropriate size, shape, and species should be considered separately from the cost of installing it. CPOSA has staff assigned to search for and stockpile wood for the habitat restoration projects, to reduce duplication of effort, and to help assure wood is available to all projects. The most important issues are transportation and timing. Wood can often be obtained for the cost of hauling or harvesting – but those costs will be significant. On one occasion, suitable pieces were available at a construction site as mitigation for development, and could be trucked directly to the project's staging area less than ten miles away without intermediate stockpiling. This is unusual — during the design process it is prudent to estimate the cost of wood based on more difficult circumstances.

Cost Estimating Process

The design team begins work with an initial scope and budget, and as it moves through the design process and the project becomes more defined, the cost estimates become more definite and reliable. It is important to develop a realistic cost framework during project conception that will enable work to begin, and to be completed without seeking additional funds. For similar work in a particular basin, or for a program embracing a group of similar projects, it is possible to have shared funding so that individual project budgets can be flexible.

It is essential for the organization to identify for the project team what the expectations, parameters, and priority of the projects are. Typically, King County desires to maximize habitat benefit for the money expended, and in that case, the design team should have flexibility to assess the scope critically and adjust the budget and schedule accordingly, within certain limits.

First Approximation of Cost

An experienced project manager will often have a sense of the scale of the project and therefore of the cost. For instance, with a basic understanding of the scope, it is possible to estimate whether a project will be about \$15,000, about \$100,000, or about \$400,000. Very soon, it is necessary to develop an estimate based on specific items and quantities. It is helpful to estimate construction costs first, followed by design costs, and then to add follow-up costs. This is because the construction work is more tangible, and elements are more easily visualized and listed. Design costs are primarily labor costs, and depend solely on the level of effort needed to define the work, and then to secure consensus permission to proceed. In addition to labor, materials, and equipment, factors that must be considered include:

- Scale and type of project
- Construction method and access
- Bid process (design-build or general contractor)
- Permits required
- Land ownership
- Land use and watershed issues
- Regulatory constraints and timeframes
- Ecosystem protection

An important phase of any project that is easy to overlook are follow-through costs, including monitoring if the organization has made a policy commitment to that. In addition to permit-driven monitoring requirements, follow-through work items might include consultations with landowners, plant establishment, observations of changes in the ecosystem, and supplemental plantings.

Refining the Estimate

To refine design and construction cost estimates, project managers use a standard CPOSA cost estimating template that is easily modified for each project. Detailed historical cost information is not retained in a central database, but is generally available from project managers who have done similar projects. A reliable source of cost information are the "bid book," which results from an annual request from the County for proposals from vendors and subcontractors. The construction group then has access to these companies on a work order basis. For instance, habitat restoration projects might make use of equipment rental services, erosion control fabrics, and hazardous tree removal services. Another asset is our ability to consult with experienced construction supervisors during the design phase of a project.

Familiarity with the watershed is very helpful in estimating cost and risk. Knowledge of physical characteristics, such as soils and river flow regimes, is useful. Equally important is an understanding of prevailing land uses and concerns of the residents.

PROJECT COST EXAMPLES

Bear-Evans Habitat Improvement Projects

The first three case study projects were part of a comprehensive habitat improvement project in the Bear Creek/Evans Creek system. The watershed is in the vicinity of Redmond, Washington (Microsoft headquarters and rapidly urbanizing) and drains to the Sammamish River. The Bear Creek Basin Plan was adopted and funded by King County Council in 1990. Reconnaissance and planning had begun in the 1980's. This watershed was one of the first comprehensive Basin Plans undertaken by King County because it encompassed significant natural resources, including a viable run of wild salmon, and was under threat from rapid development.

The Bear/Evans Habitat Enhancement Project identified 14 miles of stream in the watershed along Bear, Evans, Cottage Lake, and Mackey Creeks. The scope included identifying the specific problems along the stream reaches, and then working with interested landowners to resolve those issues.

In the first year (1993), a team of habitat biologists walked the entire 14 miles of stream reach, and kept detailed data on in-stream habitat features and riparian vegetation. Before the stream walk, each of the 350 property owners involved were contacted for permission to enter their property. Access permission (and denial) was tracked on maps. Habitat features were mapped onto assessor's maps by hand, for purposes of project identification. Many of the logistical issues encountered during the study phase could be overcome much more quickly with GIS capabilities that the County now enjoys.

Potential project sites, often involving more than one landowner, were identified based on the observed problems. The sites were prioritized in order of the severity and importance of the problems using a weighted equation that the project team developed. Landowners were contacted to discern their interest. Two pilot projects and about 15 habitat improvement projects ranging in cost from $5,000 to $400,000 were eventually completed. Additional potential projects await funding or new owners more interested in working with the County.

Landowner perspective and needs proved to be the most significant determinant of whether a project was feasible. Sites with significant problems generally have those problems as a result of past land management. Some of our most successful project were on sites with new owners.

County staff worked with a design consultant during the study phase of the project, and on some of the individual project sites. The costs of the study phase are not included in the individual case study project costs.

Figure 6. Bank stabilization work on Bear Creek to improve salmon habitat. The star on the watershed map indicates the approximate project location.

Case Study 1. Bear Creek at Conrad Olson Farm, In-stream and Floodplain Enhancements

Conrad Olson Farm is a historic homestead on Bear Creek, and was purchased in 1995 by the City of Redmond as part of their park system and a proposed regional trail. Project design, construction, and plantings were completed in January through November 1995. The permit-driven monitoring period lasts five years.

The 8-acre site (Figure 6) includes about 1400 lineal feet of Bear Creek, about half of which was treated with instream and bank stabilization features. Features included deflector logs with rootwads, keyed into the banks and anchored with boulders; live willow cutting mats; willow stakes; coir wraps and logs installed parallel to the bank and anchored with rebar; instream habitat logs; and toe rock (rounded boulders) in some locations. Design plans were produced by an experienced consultant, with involvement of a CPOSA engineer and ecologist.

Table 2. Conrad Olson Farm project costs

ITEM	COST
Design	$118,000
Land	$2,600
Permits	$19,600
SEPA	$10,800
DESIGN TOTAL	**$151,000**
County Force Construction	$11,000
Construction Contract	$135,000
Volunteer & WCC Planting	$31,000
Construction Management	$40,500
CONSTRUCTION TOTAL	**$217,500**
1996 Replanting	$14,000
Irrigation System	$11,500
Plant Maintenance and Monitoring (budgeted over 5 years)	$50,000
FOLLOW THROUGH TOTAL	**$75,500**
GRAND TOTAL	**$444,000**

The project was undertaken under terms of a Memorandum of Understanding with the City of Redmond. Project costs are itemized in Table 2. Land costs ($2,600) reflect time spent negotiating the agreement language and attending Council meetings. The construction management costs ($40,500) cover one engineer and one biologist who were on site 100% of the time during the project, and the project manager's time.

Of the seven treatment reaches, six were built under a bid process by a general contractor. One reach involved erosion near a County bridge at the upstream end of the site, and was build by County maintenance crews. In addition to reinforcing the bridge abutment with rip-rap, about 150 feet of eroding bank immediately downstream was treated with LWD deflector logs, bank logs, and coir wraps layered with live willow cuttings from an on-site grove. Many of the techniques in the seven treatment reaches were somewhat experimental. Most have performed well, with the exception of a series of logs that were cabled to boulders in mid-stream. A meander cut-off has occurred near the middle of the stream reach, and changed conditions at what was expected to be a deposition zone immediately upstream. This caused some toe rock to be undercut, and left a willow mat too far above the water level to grow. Willow stakes were installed the next year and are doing well. Even with unexpected changes, the work is satisfactory, and no further repairs are planned.

About three acres of the floodplain was planted with native trees and shrubs, and almost two acres were cleared of dense stands of Himalayan blackberry. A well-attended volunteer planting day resulted in the installation of thousands of plants very quickly. The WCC crew did the required site prep and layout, and follow-up plantings and clean-up after the event. Public involvement staff who planned and publicized the event did not charge their time to the project. As a result, the majority of costs shown are for plants and mulch. Planting design costs are lumped with the overall design costs.

Plantings were done in autumn 1995. The following March, a 25-year recurrence interval flood pulled about 30% of the new plantings in the floodplain out of the ground. Many were simply tamped back in, but about 1000 additional shrubs were purchased and installed.

A temporary irrigation system was designed and installed and was in use for the first two summers. Fortunately, city water was available on the farm. On most habitat sites, water must be withdrawn from the river or trucked to the site. In addition, the new plantings were cared for through a volunteer program called Habitat Partners. Pairs of volunteers adopted specific parts of the site, and returned regularly to weed the plants. Plant survival at the end of the monitoring period was over 90%, which is outstanding. In comparison, on sites that are not cared for, our monitoring reports show 30% to 50% survival. We have learned through experience that it is very important to take care to establish the native plants we bring to a site.

Case Study 2. Bear Creek at Conover, Bank Stabilization and LWD

This project on Bear Creek presented a bank erosion site about 100 feet long that had been identified as a habitat problem during the study phase of the project. The land use was a single-family residence, with horse acreage. Horses were grazing up to the bank edge, so riparian vegetation on one side of the creek was almost non-existent. A modified version of one of the same bank treatments at Conrad Olson Farm was used, with deflector logs including rootwads. Boulders, coir wraps, and willow cuttings were incorporated into the bank.

This was, in a sense, an opportunity project because on first interview, this property's owners were not interested in working with the county. In fact, they had already refused a request from the King County Roads Department to accept cash for use of their land as a mitigation site. They had very clearly stated that they did not want the county involved in their land. However, the 1996 flood changed their mind. They lost a tree and about 15 feet of land to bank erosion right in front of their house. They called the Basin Steward and asked to be included in the habitat enhancement program. As at the Conrad Olson farm, design and construction were completed within one year. This was only possible because the pre-project planning and funding were already in place.

It was of primary importance to the landowners that the project would stabilize their bank, but they had no objection to a softer design that did not rely on rip-rap armoring. They agreed to keep the horses out of the small streamside pasture, and the riparian area was planted with native trees and shrubs.

Table 3. Bear Creek at Conover bank stabilization and LWD project costs

ITEM	COST
Design	$28,000
Easements	$1,400
Permits	$8,200
SEPA	$2,800
DESIGN TOTAL	**$40,400**
County Force Construction	$24,600
Construction Contract	NA
WCC	$3,600
Construction Management	$11,400
CONSTRUCTION TOTAL	**$52,600**
GRAND TOTAL	**$93,000**

Easement costs shown in Table 3 are for a Temporary Construction Easement from the landowners, which is required by the County in order to work on private land. Permit costs include fees paid, and also an estimate of the time spent specifically preparing permit submittals.

The same King County crew that had done the work downstream of the bridge on the Conrad Olson Farm the summer before did the construction work. Construction Management costs include an engineer and a biologist on-site for the entire construction time, about a week. The Washington Conservation Corps (WCC) crew spent an additional week doing clean-up work and planting, which was very cost-effective.

Case Study 3. Rutherford Creek Streambed Rehabilitation

Rutherford Creek is a tributary to Evans Creek in the Bear/Evans basin. Historically, it had been an important spawning channel for coho salmon, with a median value of 335 spawners observed per mile in surveys conducted between 1976 and 1978. In the project reach, the streambed had incised up to five feet deep, compared to a previous cross-section depth of almost two feet. The growing streambed incision was measured by a monitoring team working in connection with a proposed large residential development a few miles upstream in the watershed. The incising reach was relatively short but was growing longer, with a 3.5-foot high headcut at its upper end. Both the headcut and increasing velocities due to the changing stream morphology were preventing fish passage.

The county had noticed the problem about three years earlier, when the incision was less severe. A project involving check dams built of small rock (about 1 foot in diameter), placed by hand, had been built in an effort to solve the problem. The check dams blew out and the incision continued, so that the cross-section of the stream was a deepening trench about 5 feet wide at the top and 2 feet wide at the bottom.

The 1998 design involved restoring the stream's original cross-section, based on observations of upstream and downstream reaches, with a matrix of streambed material that would be competent to withstand erosive forces. This project involved about 600 feet of streambed reconstruction, incorporating LWD and boulder weirs. Streambed material that had been sluiced out of the rapidly incising reach and

Figure 7. The two photos to the left show the streambed work in progress. The photo on the right was taken about one week after construction.

deposited on a downstream farmer's field was incorporated into the new streambed. The project (Figure 7) was designed and completed within the year, because the funding, the design team, and the watershed planning were already in place.

As indicated in Table 4, easement costs and landowner negotiations costs were low ($800), because the incising reach was located in a subdivision within a native-growth protection easement which was dedicated to King County for uses consistent with the project.

The reach presented an interesting construction access challenge, on account of the mature native vegetation in the riparian corridor, including big-leaf maple, western red cedar, and douglas fir trees, vine maple along the stream banks, and sword fern and salal in the understory. About halfway down the project reach, an outlet pipe from the subdivision's R/D pond (maintained by King County) ran to the stream. Once the design team learned that Rutherford Creek typically went subsurface through the project reach in the summer, it was decided to use the streambed itself as construction access. The empty R/D pond was used as a stockpile and gravel mixing area.

Table 4. Rutherford Creek stream rehabilitation project costs

ITEM	COST
Design	$44,500
Easements	$800
Permits	$3,600
SEPA	$2,700
DESIGN TOTAL	**$51,600**
County Force Construction	$33,100
Construction Contract	NA
WCC	$10,600
Construction Management	$18,200
CONSTRUCTION TOTAL	**$61,900**
GRAND TOTAL	**$113,500**

About 40 pieces of woody debris were integrated into the new streambed. The completely rebuilt stream channel was intended to have a step-pool morphology. Boulder wedges, constructed of a well-graded mix that included rock up to 3 feet in diameter, were incorporated into the fill at approximately 40-foot intervals. The wedges are not obvious in the finished project, and are intended to act as catch-points in controlling the stream gradient.

The WCC crew spent a few days before the project tying streamside vegetation out of the way of the heavy equipment. After the heavy earthmoving was done, the WCC moved some streambed material by hand, and planted disturbed areas with native plants.

The project reach has been monitored since construction, and includes several measured cross-sections. There has been no evidence of channel expansion or formation of nickpoints.

O'Grady Creek Projects

In contrast to the preceding case studies, the following two projects on O'Grady Creek were built under accelerated schedules and very uncertain permitting environments. As a result of these and other factors, costs are noticeably higher.

O'Grady Creek flows to a slow-moving sidechannel of the Green River, which joins the mainstem about a quarter-mile away. The project site is on O'Grady Creek less than a mile upstream of the confluence. Coho, chum, and steelhead inhabit the creek. The river is also used by chinook and sockeye. The project site is within an 880-acre open-space riparian park.

Both projects were funded in March 1999, shortly after chinook salmon were listed as threatened under the ESA. A basin plan has not been completed for the Green River, and the two projects were activated in response to the County Council's wish to demonstrate their concern for threatened resources. The desire was to finish the design work quickly and build both projects before the year was over.

Ironically, the very action (the ESA listing) that gave these projects their urgency and funding also added additional steps and uncertainty to their design and permitting. The County instituted an internal Biological Review Panel in order to ensure compliance with the Federal requirements. A Biological Assessment was prepared for both projects, and submitted to the Corps of Engineers the first week of July, along with project plans. In spite of a vastly increased workload, Corps staff was able to visit the site in August. They expressed concerns about possible impacts to the wetlands adjacent to O'Grady Creek that could result from the proposed work to improve instream habitat stability at the alluvial fan. As a result, the second project was not built until 2000.

For both projects, landowner negotiations increased design costs. The property is managed by King County Parks, and a representative from Parks was included in the design meetings. She contributed to design decisions, and made sure that Parks' long term interests as stewards of the land were protected. One issue was that the habitat improvements must not result in increased maintenance responsibilities for Parks. Accordingly, the design team set aside money for plant maintenance and adaptive management, to make sure that a riparian forest would be fully established before the CIP project was closed out. A second issue proved more troublesome, and resulted in many hours of negotiation before it was resolved. It was a labor dispute between the two maintenance shops over the right to do the work. Meetings probably added only about $3,000 to the direct project costs, but added greatly to pre-construction stress levels and uncertainty. (The upper level managers who eventually settled the matter do not bill to the project budget.) These costs are lumped with overall design costs in Tables 5–6.

Design and construction projects often generate unexpected problems, and habitat restoration projects are no exception. It's axiomatic that contingency funds and some float in the schedule are highly desirable.

Figure 8. Culvert replacement for fish passage at O'Grady Creek (Photos taken immediately before and after construction)

Figure 9. Looking downstream from the new culvert at the rebuilt reach of O'Grady Creek after construction. The streambed here is about three feet higher than the eroded streambed. Buried boulder wedges create a stepped reach of pools for fish passage. LWD was added for habitat diversity.

Case Study 4. O'Grady Creek Culvert Replacement for Fish Passage

The O'Grady Creek culvert replacement project was substantially completed in September 1999. A 30-inch diameter corrugated metal culvert that blocked fish passage was replaced with a 10-foot wide concrete box culvert. Over 200 lineal feet of streambed was reconstructed in order to eliminate the 3.6-foot incision immediately downstream of the old culvert. The design concept for the reconstructed stream reach was to build a series of pools and boulder wedges, providing fish passage in both the short term and in the future, when sediment transport is expected to fill the pools with gravel (Figure 9). This strategy minimized imported fill and buffered the downstream system from the movement of the upstream sediment wedge that the old culvert had forced. About 50 large logs with rootwads were incorporated into the pools so as to create local scour pockets and improve habitat diversity in the project reach.

In addition to the work at the main culvert, 3 smaller culverts were removed from tributaries emerging from the toe of an adjacent escarpment, and a half-mile long existing access road was decommissioned. In order to demonstrate competency in habitat work, Parks maintenance donated about $17,000 worth of labor and equipment to do

Table 5. O'Grady Creek culvert replacement project costs

ITEM	COST
DESIGN TOTAL	**$99,000**
County Force Construction	$68,000
Salvaged Culvert ($8,000 value)	$0
WCC Planting	$3,000
Construction Management	$42,000
CONSTRUCTION TOTAL	**$113,000**
GRAND TOTAL	**$212,000**

the work on the small culverts. The fact that the two work sites were physically separate helped to avoid a labor union dispute. The extra work and costs are not included in Table 5.

Native trees and shrubs were planted in all disturbed areas in November 1999. The same month, coho and chum salmon were observed using the rebuilt stream reach, and spawning was observed upstream of the new culvert. The project was successful, but more expensive than anticipated.

Because the design effort was integrated with the wetland and stream enhancement project, design costs are not broken down into sub-categories for either of the two projects. Permit submittal costs and consultation costs both within and outside of King county are included in the $99,000 total shown in Table 5. The cost of preparing the Biological Assessment is not shown here, because the same document was required for the more extensive Stream Habitat Enhancement project. Site survey costs are not included either, for similar reasons. The new concrete box culvert was salvaged from a Roads project for which it was no longer needed. Costs of delivering and placing the culvert are included in the $68,000 County Force construction cost. Construction management costs are relatively high, because there were at least two design team members on site at all times. Often, an additional ecologist was on-site collecting water quality data and assisting with the removal of the three small culverts.

Case Study 5. O'Grady Creek Wetland and Stream Habitat Enhancements

About 400 feet downstream of the culvert replacement project on O'Grady Creek, the stream gradient begins to decrease noticeably as the creek begins its transition onto the flat gradient of the valley bottom (Figure 10). Looking downstream over the alluvial fan, it is possible to see sediment deposition and evidence of channel movement, both very natural processes. The area has been identified as a fish passage problem because of frequent stranding of adult and juvenile salmon on the pasture turf of the abandoned homestead. For instance, in February of 1996, sediment deposited by storm flows forced O'Grady Creek to leave its channel. It flowed in a broad sheet over the pasture and was not able to establish a new channel to connect to the Green River. The water infiltrated into the pasture, stranding fish and cutting off fish passage to the upper system.

The project involved constructing about 1200 feet of new stream channel within an excavated floodplain bench. The excavated soil was placed on site in gentle mounds along the margin of the bench. The stream channel was constructed in the lowest part of the excavated bench, and incorporated over 300 pieces of woody debris partially embedded in the earth. The design called for planting live willow stakes along the stream banks, and waiting for two growing seasons (until summer 2002) before connecting the new stream channel to flowing water.

The total graded area on site was about 8 acres, which were planted in native trees and shrubs. The goal of the plantings is to establish a healthy riparian forest with a patch-

Figure 10. Problems associated with the alluvial fan reach on O'Grady Creek

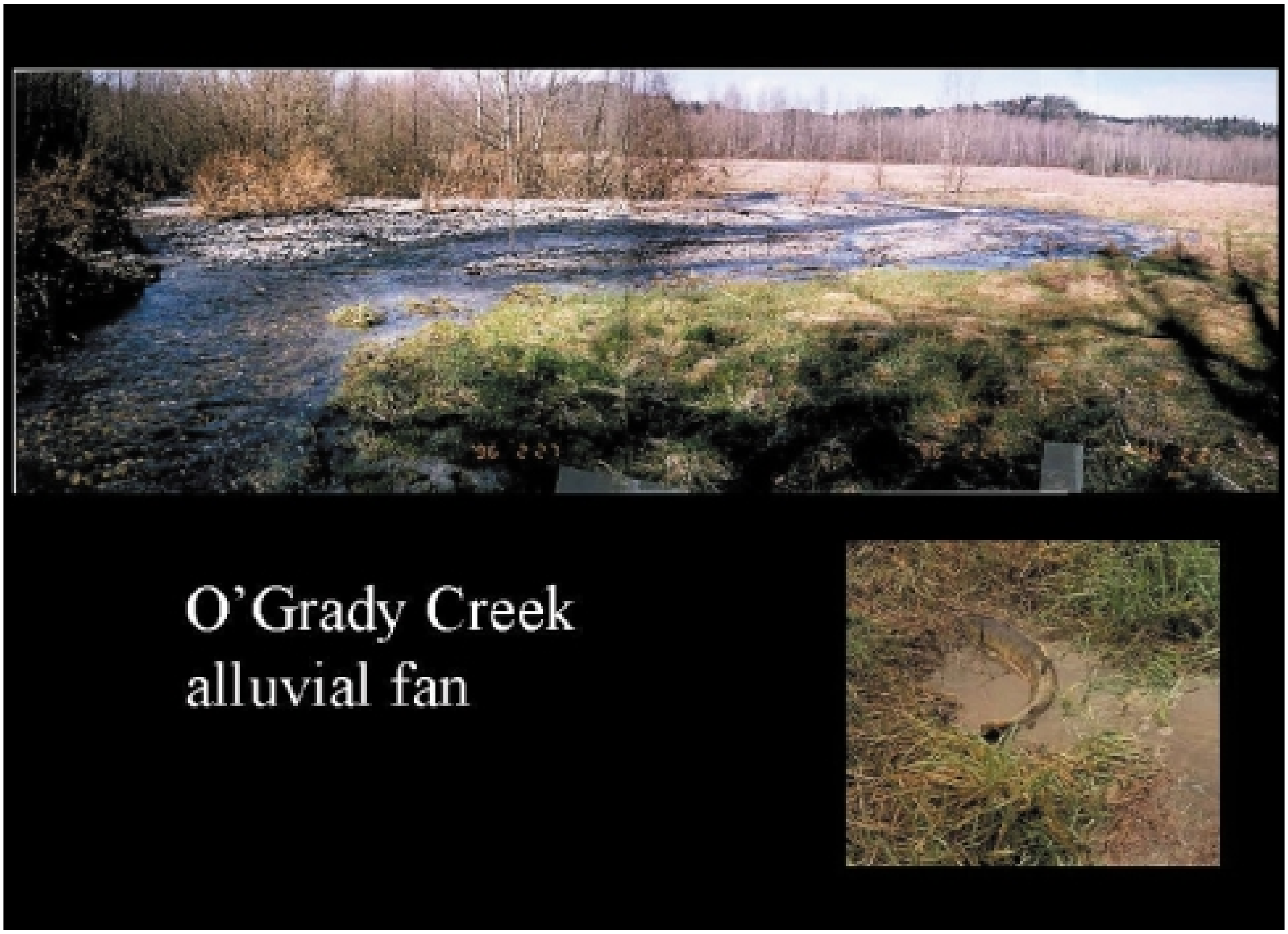


Figure 11. Earthwork to create new stream alignment with floodplain bench, May 2000. Wetland area is to the left side of the photo, and the side channel of the Green River is behind the trees in the background.

Figure 12. Volunteer planting event for O'Grady Creek stream enhancement project, November 2000. The new stream channel is visible as it meanders toward the sidechannel of the Green River. It was not connected to flowing water until May 2002.

work of different plant communities. Experimental plots designed to overcome reed canarygrass infestations were installed in the wetland buffer. Existing wetland emergent and scrub-shrub plant communities were enhanced with additional plantings.

The first phase of the earthwork was completed in May 2000 (Figure 11). Surrounding cottonwood trees were just going to seed and covered the site thoroughly. The planting plan was adjusted to take advantage of this windfall. In November 2000, 180 people attended a volunteer planting event on the site (Figure 12). With the assistance of the WCC crew, about 2500 trees and 1000 shrubs were planted.

Design costs for this project were truly stupendous (Table 6). The additional expenses can be attributed mainly to organizational factors. Efficiencies were expected and realized from starting two projects on the same site with the same design team. Costs such as preparing the Biological Assessment and a detailed site survey were charged to the larger project rather than the culvert replacement project. Later in the design process, especially after the projects were split apart in August after input from

Table 6. O'Grady Creek wetland and stream habitat enhancements project costs

ITEM	COST
Design	$342,000
Planting Design	$9,000
Survey (also used for culvert project)	$28,000
DESIGN TOTAL	$379,000
County Force Construction, 2000 (Roads)	$67,000
County Force Construction, 2002 (Parks)	$35,000
Construction Contract	NA
CONSTRUCTION TOTAL	**$169,000**
Volunteer and WCC Planting, 2000	$34,000
2003 Plantings (set aside)	$25,000
Construction Management	$33,000
Plant maintenance and Monitoring	$25,000
FOLLOW THROUGH TOTAL	**$72,000**
GRAND TOTAL	**$620,000**

the Corps of Engineers, costs were more clearly separated.

Internal uncertainty within King County created extra consultations in an attempt to control potential liability resulting from the ESA listing. Staff has since gained experience in working with the Federal Services and in preparing documentation such as the Biological Assessments.

After the projects were split apart, the design team focused their effort on the culvert replacement project. Once it was completed near the end of September, the team assessed the concerns the Corps had expressed about wetland impacts. Flow and ground saturation measurements were made before and after the seasonal rains began in November. The wetland and its associated hydrology were mapped as closely as possible. Wetlands specialists within WLRD were consulted. The team concluded that it would not be able to quantify potential impacts to the wetland because of the complex and dynamic nature of the site. In particular, the ever-changing pattern of distributary flows and the multiple sources of water feeding the wetland would make it difficult to do a conclusive analysis over a period of years. We could not gather enough data in one year to satisfy all the possibilities.

The project was redesigned to minimize wetland impacts. Significant enhancements to the wetland plant community were added to the project scope, and additional funds were set aside for monitoring and adaptive management. The details of the stream channel design at the upstream and downstream end were also refined.

A proposal to build the project in February in order to meet a funding deadline was studied in detail and ultimately rejected by the internal Biological Review Panel, because of the risk of rain causing sediment and erosion control problems. During the period that the project was delayed, extra time was required for design because of staff turnover.

The project is on track to be a success. Juvenile fish began using the stream channel immediately after it was opened to flowing water in May 2002. Adult salmon continue to access the upstream reaches of O'Grady Creek and spawning has been observed every year. In 2003, the cottonwood seedlings are generally about 3 feet high. The biggest issues are plant survival in the drier upland areas and deer predation. Also, a vigorous crop of thistle and tansy from the adjacent infested pasture has taken over large areas of the site. It is expected that the trees will eventually overcome the weeds. A follow-up volunteer planting is planned in Autumn 2003, and site maintenance (with project funds) will continue for an additional two years.

CONCLUSION

Habitat restoration work in urbanized areas requires a different approach than does work in less densely inhabited areas. The WLRD in King County has developed a strategy for building habitat enhancement projects within urbanizing watersheds. Design, permitting, and construction expertise resides in a workgroup that can draw on County-wide resources, including planning work carried out by the Division. Ideally, stream enhancement work is carried out in the context of a watershed-wide assessment of the causes of habitat degradation.

It is very important to focus on the organization of the design teams, so that people acquire familiarity with the physical and social characteristics of the watersheds where they work. Ecological and regulatory issues, and construction feasibility issues are best addressed from the beginning of the design team's work. The team members should be directly involved in working with construction crews. A design/build project management approach is desirable. Care must be taken to maintain native plants in the first years after they are installed.

It is important to design projects on a firm foundation of past experience, incorporating the lessons learned and data gathered from previous projects. The design approach must acknowledge the dynamic character of natural stream systems and work within the context of landscape processes. Projects should be modeled on natural templates, utilize native materials, and use the least invasive construction method feasible. Many habitat restoration projects are innovative in one respect or another. Project teams need some flexibility in scope, schedule, or budget in order to deal effectively with the uncertainties associated with new solutions.

Projects are designed within ecological constraints, and also within institutional parameters. In an urbanized setting, dealing with large numbers of project participants is an important issue, and it is crucial to budget sufficient staff time to meet and negotiate with landowners and other stakeholders, such as tribes, cities, and regulatory agencies. This staff time can increase project costs, as can another characteristic of urban basins: the lack of plentiful materials such as woody debris near the project site.

Local government agencies are often the proponents of habitat enhancement projects. For good reasons, they tend to be risk averse and they need to respond to the valid concerns raised by all stakeholders. Consensus-building can be expensive. Solving these problems while maintaining low project costs has required creativity and good planning.

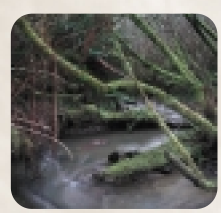
REFERENCES

Bethel, J.P., and K.J. Neal. 2003. In D.R. Montgomery, S. Bolton, D.B. Booth and L. Wall (eds.) *Restoration of Puget Sound Rivers*. University of Washington Press, Seattle, Washington. pp. 394–421.

Kruekeberg, A.R. 1991. *Natural History of Puget Sound*. University of Washington Press, Seattle.

King County Surface Water Management Division. 1990. *Bear Creek Basin Plan*. Seattle, Washington.

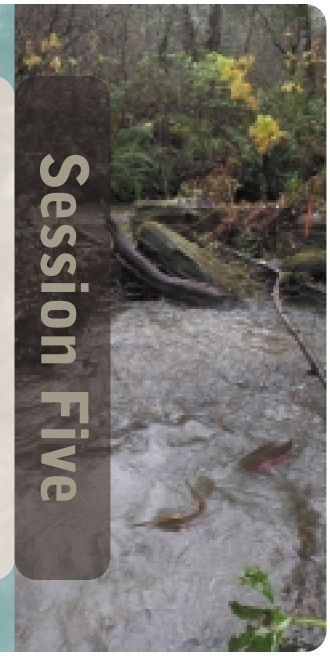
Moses, T., S. Morris, and D. Gorman. 1997. Institutional constraints to urban stream restoration, Parts 1 and 2. *Public Works* June pp. 36–39 and July pp. 40–43.



Upgrading and installation of fish passages and fish screens, offstream water storage

Fish Protection Facility Cost Drivers and Considerations: Why Are Costs All Over the Board?

DARRYL HAYES, Consultant
CALFED Bay Delta Program
2485 Natomas Park Drive, Suite 600
Sacramento, CA 95833
dhayes@ch2m.com



ABSTRACT

Fish screens are physical barriers designed to prevent fish entrainment and/or impingement at diversions, while allowing water to pass. This paper discusses fish screening projects and the variables that dictate project costs.

INTRODUCTION

The State of California is currently expending millions to fund fish screening projects through the CALFED Bay Delta Program, through the Central Valley Project Improvement Act (CVPIA), through the California Department of Fish and Game (CDFG), and through several bond acts. Much of the money has been used for priority projects, including those on the largest streams and in the most critical habitat. Many smaller facilities have also been constructed.

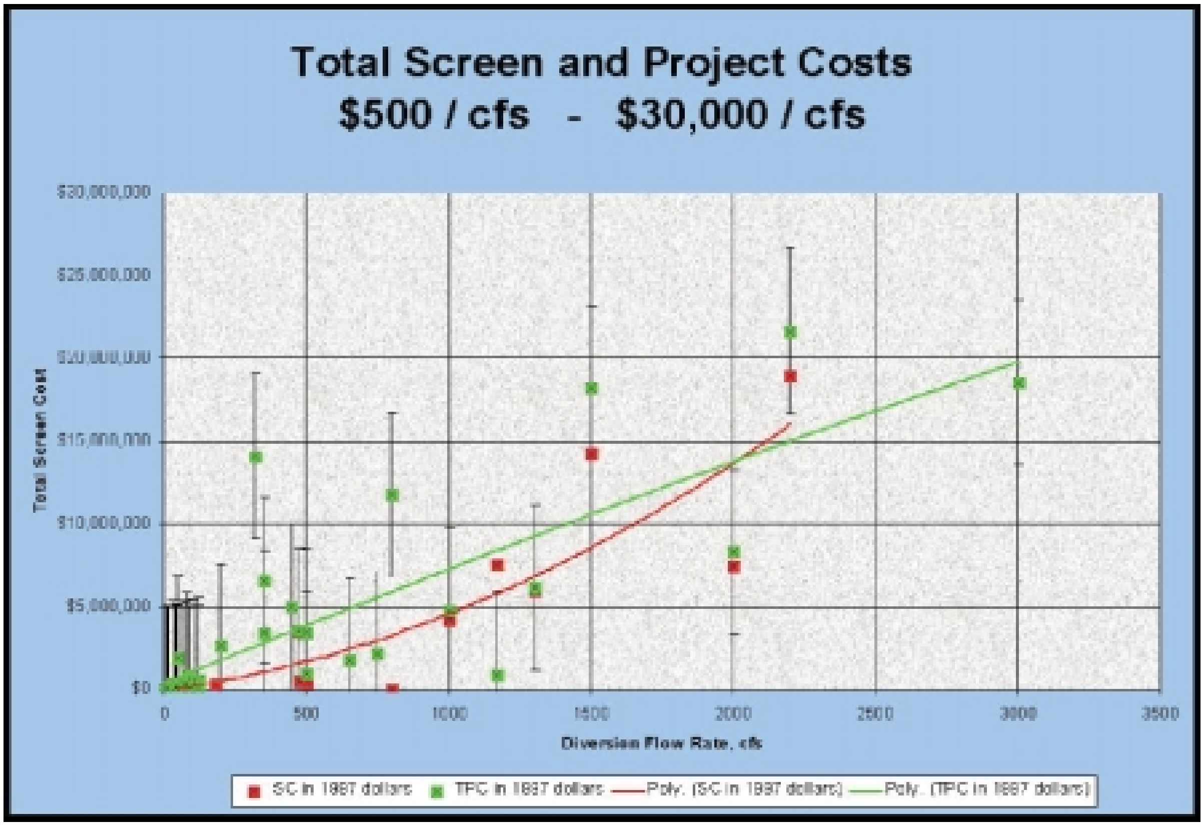
Screen project costs vary widely, and there are many different elements that make up a project. The fish screen itself is often a relatively small portion of the total project, which will also include pumps, cleaning systems, site work, and other aspects of the facility. It can be quite difficult to separate the cost of the screening portion of the project from the total project costs. For example, screen costs may only account for $5,000 of a $100,000 job. It is not easy to make general estimates that will hold true for a variety of projects.

COST COMPARISONS

Evaluating screen project costs on a large scale will necessitate comparing many different projects. If we are trying to estimate the costs of past projects, it is important to know how the costs were reported in the past, so that cost comparisons are consistent. Figures 1 and 2 show some of these comparisons. Figure 1 is a chart of screen cost as a function of the diversion flow rate for screen and total project costs in California, and Figure 2 shows cost as a function of diversion flow rate for recent large facility screen costs.

When making comparisons like the ones above, it is important to keep in mind the following questions. Would the same facility be designed today? Does the

Figure 1. Total screen and project costs (primarily California projects)



project include the support facilities necessary to operate and maintain the facility? Does the project include relocation or major site work? Does it include upgrades to old facilities? Does it include exposure to flood events? Is it an on- or off-river facility? Does the design account for water level fluctuations and operations?

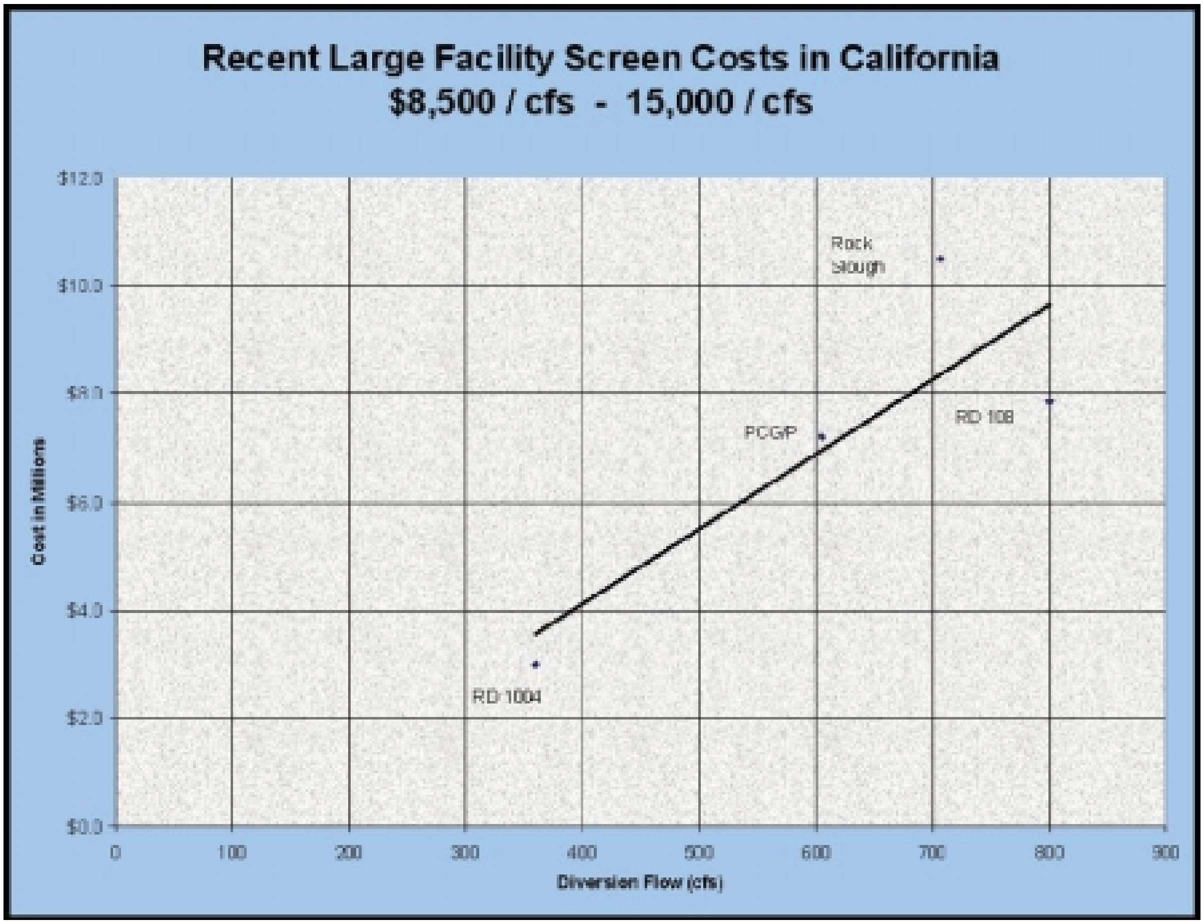
Project Planning: Issues and Considerations

Many different issues must be considered when planning a fish screen project, and each has an impact on the final project cost. The major planning categories include: 1) site development, 2) local community issues and concerns, 3) hydrology and channel morphology at the site, 4) project design and construction, 5) future operation and maintenance of the facility, and 6) environmental documentation and permitting.

Environmental permitting can limit the facility options. For example, habitat can restrict activities and prevent work in that area. Another conflict can arise if other restoration actions in the area have goals that do not integrate well with a fish screen facility. For example, a watershed group might want to establish a meander in a river system. This effort will likely be contrary to putting in a screen facility, which could require the establishment of a hard point at the diversion.

The environmental permitting process is currently difficult and cumbersome and needs to be streamlined for many fish screen and restoration projects. Successfully getting through the process is very expensive and often generates a lot of confusion. In California, through the CVPIA Anadromous Fish Screen Program, an effort has been made to centralize the permitting process by

Figure 2. Recent large facility screen costs in California



assigning one program representative to work through the process with the applicant. This has been fairly successful, especially on the smaller-scale projects. There have been recent changes to some of the Army Corps of Engineers permitting processes (including smaller pumped diversions into the nation-wide permit) that have been helpful.

FISH SCREEN CRITERIA

Some of the most important causes of escalating screen costs are increasingly restrictive juvenile fish screen criteria. These criteria include the following:

• *Screen openings*: The trend is toward smaller and smaller openings. For salmon and steelhead fry protection, the currently required slot size is (profile bar) 1.75mm. The smaller the opening is, the more difficult it is to keep the screen clean, and the more expensive to maintain the facility.

• *Approach velocity*: This criterion depends on the location of the screen. In the upper northwest part of California, there is a 0.33 feet per second approach velocity (on cross screen area), while in the Sacramento River Delta the requirement is 0.2 feet per second. The reason for the difference is primarily due to the fact that the Delta criterion includes fish other than salmonids.

• *Sweeping velocity*: The criteria can require screens to be located away from existing diversion locations.

• *Bypasses*: Whether or not a screen bypass is necessary must be determined, and can have a significant impact on the final project cost.

• *Screen hydraulics*: Uniform approach velocities require additional hydraulic control.

It is crucial not to let the screen criteria get in the way of fish protection. We must ask ourselves if we are really more interested in protecting the criteria instead of the fish. For instance, a screen may be designed for the most restrictive criteria and fish life stage, even though the probability of that species occurrence in an area is minimal. Following criteria to the letter can drive the cost of the screen facilities up, which in some cases may make it impossible to actually implement the design. In those cases, the fish lose.

There are times when we should consider alternative screen designs, if a site-specific case can be made. However, there is often resistance to alternative designs, due to either precedence issues or less than optimal protection to fish, albeit small. Alternative designs such as Coanda screens (overflow screens) or high velocity screens may be good solutions to particular design problems.

Design flow rate can be an important consideration in screen sizing. In the negotiation between the diversion owner and the agencies involved, the cost may be driven much higher than the diverter can afford in an attempt to design the screen for maximum flow. It may be much more realistic to design for 95% flow instead of 98% or 99%, because this flexibility may mean the difference between building and not building the screen.

The cost of a facility can also be driven by the research opportunities. When research is conducted, it is important to determine who

Figure 3. Hydraulic and biological relationships near screens (lab research)

should share the cost and who will benefit from the knowledge gained. Research costs often end up being the responsibility of the irrigation district, but districts are typically reluctant to pay for research because they will not directly benefit from much of what is learned. The CALFED Bay Delta Program however is very interested in the scientific benefits of monitoring and has shared in some of those costs.

Laboratory research can provide valuable insight and potentially reduce future screen costs through an understanding of the biological and hydraulic interactions at screens. Figure 3 shows a research project simulating a long and continuous screen that looks at a

Figure 4. CCWD Los Vaqueros pumping plant intake sampling net (field research)

lot of different fish species to investigate the different relationships between approach velocity and sweeping velocity. Research like this can go a long way in helping us understand whether a criterion can be applied to many different species as well as many different sizes of fish.

Field research is also important. Some of the larger facilities provide valuable opportunities for monitoring screen efficiency and success. Figure 4 shows the Contra Costa Water District's Los Vaqueros pumping plant in the Delta. Slots were designed into the facility so monitoring activities could be done. However, the additional concrete and steel needed to construct the slots increased the cost of the project. For this facility, much of the work is being carried out by CDFG, which will be reimbursed by the diverter.

RETROFITTING EXISTING FACILITIES

It can be cost-effective to retrofit existing pumping plant or diversion facilities with screens, but it depends on several conditions, each of which can drive project costs significantly:

- *Pump Adequacy*: The pumps must be able to overcome the headloss caused by the screens.

• *Electrical Requirements*: Almost all screens today require an automatic cleaning system and an electrical power supply to keep things going. We have a project in the Delta marsh area, on an island with no power. It would cost $80,000 to string underwater cable and bring power to the site. On this particular project, they actually used solar panels and batteries, but those still add considerably to the price of the project.

• *Structural Adequacy*: Old pumps typically sit on old piles or structures. The new screens must be supported with them, or most often need to be replaced.

• *Relocation Issues*: Poor hydraulics, morphology pump depth, or operations disruptions may necessitate moving the site. In California, the CVPIA may pay for relocation if it will be beneficial to the fish or screen function. Relocation costs can be significant since it can involve new research, engineering, and all new facilities.

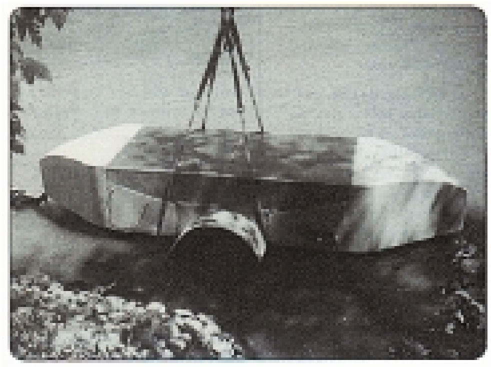
• *Operational Disruptions*: If the project involves a large screen facility and the work takes two construction seasons (typically our construction seasons are during irrigation seasons), it can be very difficult to plan for optimal project timing. Significant costs can be incurred attempting to stage work so as not to disrupt our facilities.

COST CONSIDERATIONS BY PROJECT PHASE

Design Cost Drivers

Often the biggest determinants of project cost are the river conditions, including debris, water level and sedimentation. Facilities in flood prone areas can be problematic and handling this debris and sediment is a major cost for almost all facilities in California. Planning for good hydraulic performance is crucial to ensure that the facility is able to operate under a wide variety of river conditions. This planning drives costs up, but in the end makes for much more cost-effective and successful facilities.

Figure 5. Universal stream bottom retrievable fish screen



There was a time when standardizing screen designs seemed to be a great idea. If a “universal” screen worked, unit cost of the facilities might go down. For instance, one such design looked feasible at a total installation cost of around $2,000 per cubic feet per second (CFS). This screen, the universal stream bottom retrievable fish screen, is shown in Figure 5. The idea was to put them in rivers and lakes or wherever anyone needed a diversion. The screen could float and be retrieved. However, because the early installations did not take into account river morphology or sediment issues, this standardized screen has not had a “universal” application.

As discussed above, building in operational flexibility is key to successful projects, even though they may be more costly. Fish facilities often cost more today because we design them to be able to handle a much broader range of conditions. For example, in many cases unsuccessful fish ladders do not work because they are built to operate in only a narrow range of flows and water levels and are unable to effectively manage debris. Figure 6 shows a facility that has been built to work in a variety of conditions,

Figure 6. Operational flexibility (adjustable overflow gates allow proper ladder hydraulics with 3-foot pool fluctuation)

with automatic adjustable gates that can deal successfully with water-level fluctuation. Figure 7 shows a screen facility that includes a brush cleaner on an inclined plate and a sediment trap, which are both features that increase the screen's ability to function under varied conditions. Not surprisingly, facilities such as these are more expensive than simpler facilities.

Construction Cost Drivers

Often, construction methods can be limited, driving project costs. There are certain times, for example during migration season, that piles cannot be driven. At some sites construction may be restricted to certain hours during the day due to noise restraints. These limitations can dramatically increase the project cost if it is necessary to lengthen the construction period in order to accommodate the restrictions. It is very important to plan for these construction contingencies early in the project, in order to minimize the effects on cost.

Construction in large rivers can also drive costs. Figure 8 shows construction of the Princeton Cordora Glenn-Providence

Figure 7. RD 1004's operational flexibility helps insure project reliability in extreme conditions

Irrigation district. It was necessary to keep the entire project area dry during construction despite extreme flow events in the Sacramento River. There were tremendous pumping and de-watering costs incurred for the project. Figure 8 shows just how deep the structure is — the water level outside the project area is about 30 feet.

Operations and Maintenance: Costs

The costs associated with project operations and maintenance are usually significant and are often overlooked. It is rare for project planners to spend enough time considering who will operate and maintain the facilities. Most fish screen projects require control and cleaning systems that operate almost continually, especially during the irrigation season.

In addition, there is a huge need to maintain the equipment protection systems, including corrosion protection and replacing

Figure 8. PCG-P's facility behind significant cofferdam

worn parts. Maintaining these systems requires material and staffing.

Following is a more detailed discussion of some of the life cycle costs that are necessary to maintaining screen facilities. These factors and costs must be anticipated when a project is planned.

Underwater Access

Many projects in the river require divers to inspect the facilities periodically. The labor cost for this service generally runs about $1,500 a day. There has been a movement in California to report the results of required inspections, which is a cost that one of the participating stakeholders will have to bear. In California, the National Marine Fisheries Service (NMFS) keeps some records on screen facilities in order to develop histories that will aid in determining the track record of the facility.

Screen Cleaning

Figure 9 shows an airburst-cleaning screen. The advantage of this type of cleaning system is that there are no moving parts underwater. However, the screens still require a significant amount of work in the off season. Someone has to scrub them periodically, which requires time and money. Figure 10 shows some screens with bristles that were not maintained, allowing growth behind the screen to get packed in. If screens are not regularly monitored and maintained, weak spots will develop that will eventually affect the structural integrity of the screen.

Figure 9. Airburst screen cleaning system

Figure 10. Improperly cleaned and maintained screen

Figure 11 shows a screen that is completely packed with debris. Nothing will be able to pass through this screen. Figure 12 shows a water backwash system that has a spray nozzle to internally spray the backside of the screen just enough so that the water outside will push the material away. This type of cleaning system typically works

Figure 11. Debris-clogged screen

Figure 12. Water backwash cleaning system with clogged spray nozzle

well unless debris is allowed to accumulate in the nozzles (i.e. lack of filter), which will eventually lead to the failure of the facility.

Figure 13 shows a screen that had to be taken out of the stream shortly after it was put in. In an attempt to install screens inexpensively, several installations were installed with lightweight screens and minimal engineering at a cost of $1,000–2,000. In brief, lightweight irrigation screens were applied to the Sacramento River. However, the river has tremendous debris loads and other conditions that the screens were not designed for. These facilities had no failsafe system, no emergency blowout panels, relief systems, or pump shutoffs, just a screen strapped onto the end of a pipe. In Figure 13, a backwater

Figure 13. Andreotti fish screen 9/96 (collapsed screen)

Figure 14. Butte Creek Farms screen 4/12/99 (screen failure)

system was ineffective and failed in just a matter of minutes due to the suction load on the screen. Figure 14 shows another screen with a similar clogging failure due to poor cleaning.

Corrosion

Figure 15 shows a facility built in slightly brackish water. This system worked well in another setting, but here there were issues with electrolysis and dissimilar metals at this site. In fact, a stainless steel structure was eating away at the screen because of the

Figure 15. Corroded screen — dissimilar metals and poor water quality (outside view)

Figure 16. Corroded screen (inside view)

poor water quality in the stream. Interestingly, nobody recognized that this was going on until the diving inspector announced that there was a big hole in the screen. This experience underlines the importance of regular inspections, reporting requirements, and accountability for proper screen functioning. Figure 16 shows the same screen as in Figure 15, but from the inside. There is clearly very little fish protection provided by a screen in this condition.

In Figure 15, it is possible to see stripes on the screen of an internally backwashed system which uses spraybars to do the backwash. This system is effective where the nozzle sprays, but not elsewhere. This leads to the striping pattern, which is caused by poor cleaning. Over time, even self-cleaning systems require cleaning maintenance.

Figure 17. Grit damage to the screen cleaning system

Sedimentation

In Figure 17, it is possible to see the damage caused by suspended sand on the shaft of an internally backwashed screen. This type of system has sealed bearings inside the screen; however, sand is able to enter these supposedly sealed bearings, which eventually caused the system to stop functioning.

Operations and Maintenance: Lessons and Considerations

It is of primary importance that operations and maintenance be cost-effective for either the landowner or the agency. Someone

Figure 18. Retrievable cylindrical screen (two views)

must pay for them and if it is left up to landowners, as it is in California, operations and maintenance may be neglected. For example, if there is a hole in their screen but the landowner still gets their water, they are probably not going to complain. Unfortunately, the fish ultimately pay for a lack of attention to the screens.

Retrievability

It is very important to inspect screens periodically, which means that the screens should be retrievable. It is best to put screens in the water that can be removed during the non-irrigation seasons. These features will increase the cost of the project, but the increased life expectancy of the screen will usually more than compensate for higher initial costs. The screens will last at least two to three times as long and will be more effective for the landowners and the fish. Figure 18 shows two views of a retrievable cylindrical screen that is easily removed from the water for monitoring and maintenance.

Providing Access

Many facilities in small creeks are difficult to access. For example, it may be difficult to reach them during a rain event. Access for maintenance or inspection must be factored into the cost of these facilities; without access, the maintenance cannot happen.

Fail-safe Back-up Systems

These can be as simple as alarms or pump shut-offs. In one project in the Suisun Marsh area in California, they have put into place a very effective facility monitoring system. Telemeters indicate how the facility is working: when it is operating, whether or not the brushes are working, and other relevant data. This information is sent to a central office so they can obtain a status report and know whether to send someone out to the facilities. Back-up systems are very cost effective and preventative to add to a project.

Brush Cleaning

Generally, brush cleaning is a better method than air or water systems. The screens have to be scrubbed, often manually, but the result is a cleaner and more effective screen. Once again, the expenditure of a higher initial cost is repaid later in terms of the duration and proper functioning of the screen.

Figure 19 shows a small screen that is an example of the best screen technology that

Figure 19. Small screen state-of-the-art

has been developed. Screens like this are being used to replace older failed screens. This screen has a capacity of about 15–20 CFS. This installation replaced a year-old facility that originally cost a little over $25,000. This new screen cost $100,000, and it still looks brand new after a year. This screen is retrievable, making inspection, cleaning, and maintenance much easier. This screen incorporates all the lessons that we have learned over the years. It has brush cleaning and internal baffling for hydrologic control, which creates an even distribution of flow through the stream. The even distribution of flow also makes for a cleaner screen, because debris is more likely to accumulate where the flows are uneven. The screen is made of wedge-wire, which has proven to be the most durable and easy to clean material. It is more expensive, but is reliable and durable, providing better fish protection.

SCREEN PROGRAMS AND COST INFORMATION RESOURCES IN CALIFORNIA

- CVPIA Anadromous Fish Screen Program (Bill O'Leary, USFWS)
- CALFED Ecosystem Restoration Program (Terry Mills, CALFED)
- IEP Central Valley Fish Facilities Coordination Team (Rich Wantuck, NMFS)
- NRCS Family Water Alliance Screen Program (Sue Sutton, FWA)

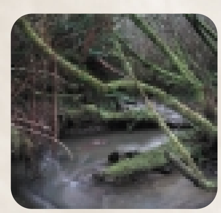
Listed above are a number of resources for more information on costs. The CVPIA Anadromous Fish Screen Program is a clearinghouse for quite a few fish screening projects now in California. For example, an irrigator who wants to apply for these funds does not need to approach several different funding sources and coordinate several different programs. Instead, they can apply only once and have access to many different funding sources.

There are several other programs that are not included in the CVPIA program, although most coordinate with each other. One of these is the CALFED Ecosystem Restoration Program, which funds a lot of screening facilities and has access to some funds that CVPIA does not. Through 1999 CALFED has funded over $40–50 million on screening projects, primarily on the larger facilities.

In California, small screens have been funded through the Family Water Alliance (FWA) at the Natural Resource Conservation Service (NRCS). They focus on the smaller screen facilities, while CALFED and CVPIA concentrate on the larger facilities. A fish facilities coordination team in California serves as a very effective forum in which to coordinate efforts, collaborate on facilities planning, and share the many lessons learned.

One other source of information on screening projects is the Watershed Report put out by the CVPIA. This document shows facility costs on a tributary basis. It is available on CD-ROM.

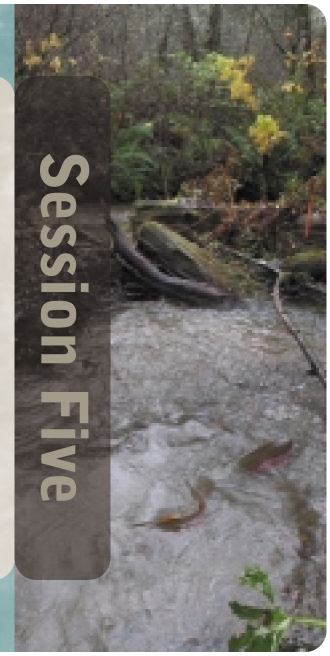
Central Valley Project Improvement Act Tributary Production Enhancement Report. A draft report to Congress on the feasibility, cost, and desirability of implementing measures pursuant to subsections 3406(e)(3) and (e)(6) of the CVPIA. USFWS. Sacramento, CA. May 1998.



Upgrading and installation of fish passages and fish screens, offstream water storage

Upgrading and Installing Fish Screens: Developing Cost Estimates

R. DENNIS HUDSON
U.S. Bureau of Reclamation, Pacific Northwest Region
1150 N Curtis Road, Suite 100
Boise, ID 83706-1234
rhudson@pn.usbr.gov



ABSTRACT

This paper uses upgrading and installing fish screens to discuss the development of cost estimates for projects on both single site and watershed levels. Included in the discussion is the process of determining costs for an individual project in the planning stages, from a reasonable first approximation to a final refined cost estimate. Also considered are the feasibility of estimating costs on a larger scale and some of the processes by which these estimates might be developed.

INTRODUCTION

About 16 years ago, the Bureau of Reclamation (USBR) began the process of upgrading fish screens in the Yakima River Basin, Washington. The 20 major mainstem diversions chosen for work had flows that ranged from a few hundred cubic feet per second (CFS) to a few thousand. In 1984, the initial estimate for upgrading those 20 diversions with fish ladders and fish screens was \$16–17 million, based on a rate of \$1,500 per CFS. After appraising the sites and calculating a first approximation of reasonable project costs, USBR doubled the estimated cost to \$35 million. By 1990, we had finished the first phase of the work and the cost had reached \$60 million.

Cost estimation is a difficult process that requires flexibility and the ability to incorporate into the budget unexpected changes in the project plan. Estimating costs for fish screening projects generally begins with the development of design criteria for the screens. A first approximation of cost can then be developed based on these criteria and on the specific environmental and regulatory conditions at the project site. This first approximation will then be altered as the project design is refined and as the regulatory requirements are met.

Developing cost estimates on a watershed or higher level is more difficult, and requires a method for developing a generalized cost framework. One such method is the creation of cost curves based on previous fish screen projects in a given state. These curves can provide very rough estimates of project costs based on the size of the screen to be constructed.

ESTIMATING COSTS AT THE PROJECT LEVEL

Upgrading and Installing Fish Screens

In many cases, upgrading fish screens is not feasible. Existing fish screens are typically 20–30 years old. The design criteria have changed so much over the intervening years that it is usually not practical to fit a new structure into the existing screen structure. Often the new structure will have three times the screen area of the existing structure. On a couple of sites, it has been possible to retrofit an existing structure and fit a different kind of screen in, which saves a little money. Usually, however, we end up tearing out the old structure—or even leaving it in place—and building a brand new structure.

Most USBR screens have been built by contract. The Bureau does the design work, then hires a contractor to build the screens. The State agencies also build screens by contract, but they also have their own crews and build some of their own screens, which saves some money.

The type of contract used in the project can have a significant impact on the project cost. Whether the contract is Federal with Federal funding, State without Federal funding, or private can make a big difference in cost as a result of the contracting procedures and requirements.

There are some alternatives to upgrading or rebuilding screens. On one site, we eliminated a small diversion altogether. Then we wrote a grant for a couple of landowners to excavate some wells in the gravel next to the river and put in sprinkler systems. This action was beneficial for both the landowners and the fish. There have been other situations where we have combined diversions, eliminating one diversion point and placing a slightly bigger screen on another.

Design Criteria

In developing cost estimates on a watershed or larger scale, the design criteria are a major factor. Also important are the size of the diversion and the specific site conditions. Costs can vary widely within these categories.

With regard to design criteria, the Endangered Species Act (ESA) has produced a great deal of fear, not only in water users but also in State and Federal agencies. Because the water users have observed some ESA enforcement actions, they are concerned and are looking for help in order to make their diversions compliant and thereby avoid having their operations shut down. The National Marine Fisheries Service (NMFS) has very specific design criteria that dictate how a fish screen should be laid out and how it should function. NMFS is generally unwilling to make exceptions to these criteria because they do not want to open themselves up to litigation from an environmental group or others. Although USBR has good working relationships with NMFS and other agencies, it seems as though the trust that has been developed over the years has eroded to some extent.

In the past, at a few sites, USBR designed the fish screens to fully meet design criteria for about 95% of all expected diversions. On rare occasions (5% of the time), the criteria would be compromised somewhat, but the screens would still provide effective fish protection. These designs were approved by NMFS on a case-by-case basis after review of canal operational scenarios and consideration of the likelihood of fish presence during the times that criteria might be slightly compromised. Due to the ESA listings, NMFS no longer will even consider such designs. As a result, the need to meet very rigid ESA design criteria has led to increased project costs at some sites. For example, at one site, a pumping plant built on a bend of a river had tremendous sediment problems. A decade ago we looked at a number of alternatives to reduce sedimentation. The best solution was to block off part of the channel, reroute the river, and bring water into the lower end of the channel; this solved the sediment problem. Now USBR is upgrading the screens, and NMFS and others are insisting that we reopen that channel. This will require us to put in new headgate structures and a desilting basin in addition to building screens. Where we initially estimated that we could replace the screens for $1 million, our estimate now is about $6 million. Unfortunately, this stream is in an area where the fishery resource is fairly marginal. The question then arises: is this where we want to spend our money, or would we be better off spending half of that money somewhere else where there might be a more significant improvement and where there might be more fish to protect?

Currently, the USBR screening budget is limited. All funding for our budgets comes from Congress. Projects often have to be postponed until sufficient funding becomes available; in some cases, enough money is never found. As a result, many tough decisions must be made about where and how to work.

Developing Site-Specific Costs

Once we know the design criteria, have an idea of the flow through the diversion, and know some minimal site information, we can come up with a first estimate of cost. These data are often obtained by comparing the site with a similar site or using an historical cost. Then we make adjustments to the cost based on specific variations at the site and our own judgments about what will be appropriate at a given site. For operations and maintenance costs, at this stage we normally include a percentage: 2.5% of the construction cost.

Because most USBR screens are built by contract, we can estimate a cost per contract for an initial first approximation. Typically, we will also include a percentage (usually 25 to 40%) of the contract cost to cover data collection and design work, contract administration, construction supervision, and environmental requirements. In some cases, though, the costs for these items have been twice that much.

It is sometimes the case that we end up designing a project three times before we are finished. Because we want to obtain a refined cost on a site-specific basis, we gather detailed design data, topography, water surface elevations, cross sections, and whatever else is needed to define the site and the problem, including the flow records for the diversion. With all of this information, we put together a conceptual plan and a layout showing the outline of the structure with some preliminary hydraulic studies so that we know that the structure will work.

At this point, the project is not designed down to the nuts and bolts, but there is a structure laid out. This structure provides an idea of the size and the thickness of the walls and the heights and sizes of the screens. From this plan, we will develop estimates of quantities needed of earthwork, riprap, concrete, pipe, and screens. To these quantities we can apply unit prices developed from recent jobs. Taken together, these figures provide a reasonable estimate of the project cost, which includes contingencies that allow for unexpected conditions.

Table 1 is a cost summary for the Fogarty Fish Screen in the Yakima Basin. This summary is used to demonstrate typical costs for a screening project. On this particular project, USBR started the preliminary work in 1995. Through the Fish Passage Program in the Yakima Basin we set up a technical work group with representatives from NMFS and the U.S. Fish and Wildlife Service plus Washington State and the Tribes and irrigation districts. All plans were submitted to these groups, and we arrived at a consensus on a project that we could move ahead with.

On this site, the consensus was to put the screens in front of the head gates on the

Table 1. Fogarty Fish Screen 8-1-96 (revised 8-8-97 & 3-18-98)

Item	Schedule	Est. Quantity	Unit	Unit Price	Amount
1	Mobilization and preparation	Lump sum	7%	ls	$21,000.00
2	Clearing and grubbing	Lump sum	ls	ls	$5,000.00
3	Diversion and care of stream	Lump sum	ls	ls	$10,000.00
4	Excavation, common canal	305	cy	$10.50	$3,202.50
5	Excavation, common structure	304	cy	$10.50	$3,192.00
6	Excavation, common pipe trench	180	cy	$9.00	$1,620.00
7	Backfill about structures	61	cy	$6.00	$366.00
8	Select bedding, pipe trench	32	cy	$4.00	$128.00
9	Backfill, pipe trench	134	cy	$12.00	$1,608.00
10	Compacted backfill, structure	61	cy	$6.50	$396.50
11	Compacted backfill, trench	32	cy	$9.00	$288.00
12	Compacted embankment – canal	719	cy	$12.00	$8,628.00
13	Riprap	10	cy	$45.00	$450.00
14	Furnish and lay 15″ pvc pipe	310	lf	$30.00	$9,300.00
15	Reinforced concrete in structures	79	cy	$800.00	$63,200.00
16	Cement		cwt	$6.00	
17	Reinforcing steel		lb	$0.65	
18	Miscellaneous metal work	Lump sum	ls	ls	$7,500.00
19	Trashrack	144	sf	$35.00	$5,040.00
20	Steel screen drum assembly	5580	lb	$3.50	$19,530.00
21	Stainless steel woven wire fabric	1010	lb	$3.50	$3,535.00
22	Overhead screen support structure	4375	lb	$3.00	$13,125.00
23	Motor & drive mechanism	880	lb	$4.00	$3,520.00
24	3-ton hoist	200	lb	$15.00	$3,000.00
25	Steel walkway grating	2930	lb	$2.50	$7,325.00
26	1″ pipe handrails	1805	lb	$2.00	$3,610.00

Table 1. Fogarty Fish Screen 8-1-96 (Revised 8-8-97 & 3-18-98) (cont'd.)

Item	Schedule	Est. Quantity	Unit	Unit Price	Amount
27	Timber stoplogs		fbm	$0.80	
28	4″ gravel surfacing	144	sy	$13.00	$1,872.00
29	7′ high chain fencing	431	lf	$25.00	$10,775.00
30	F&I 24″ x 48″ slide gates	3	ea	$2,000.00	$6,000.00
31	Accessory electrical equipment	Lump Sum	ls	ls	$10,000.00
32	Remove existing screen structure	Lump Sum	ls	ls	$12,000.00
33	Power Line modifications	0.25	mi	$40,000	$10,000.00
34	F&I 48″ CMP @ headworks	Lump Sum	ls	ls	$12,000.00
35	F&I ramp flume	Lump Sum	ls	ls	$3,500.00
36	Replace screen at on-farm pump	Lump Sum	ls	ls	$1,500.00
37	Canal reshaping & trimming	1300	cy	$25.00	$32,500.00
38	Allowance for unlisted items	Lump Sum	10%	ls	$27,000.00
TOTAL FOR SCHEDULE					**$321,711.00**
Contingencies @ 25%					$80,289.00
FIELD COST					**$402,000.00**
Indirects @40%					$161,000.00
TOTAL CONSTRUCTION COST					**$563,000.00**

river. We also agreed that we would not need to take fish into the canal. After we had started the final design work, though, the biologists changed their minds, deciding that it would be better to put the screens on the canal. This would mean that fish would go down a little bypass to a side channel that feeds back into the river. This design change prevented the project from starting until the next year, and time had to be spent redoing the design before the next construction season. As a result, the project cost increased dramatically.

Another complication in the Fogarty Fish Screen project concerns access to the work site. Bonneville Power Administration (BPA) had obtained right-of-way for the screen structures but had been unable to get the necessary access road easements. BPA does not want to use eminent domain to obtain the property. As a result, we have been trying to get right-of-way on an easement for an access road for three years. The project is on the schedule now for the fall of 2001. If we cannot obtain the right-of-way, however, the screen will probably not be built. The

Fish Passage Program in the Yakima Basin is nearing completion and we may run out of funding for the Fogarty project. This project provides a good example of the kinds of unexpected problems that can arise and potentially derail even well planned work that really needs to be done.

ESTIMATING COSTS ON A LARGER SCALE

In attempting to develop cost approximations on a larger scale, it is important to consider a number of different types of information about the project. These factors include unit costs for project materials, information requirements for project planning, the availability of large-scale data sources for comparisons between projects, and the level of confidence in the data used for comparison.

Unit Costs

There is not generally much difference in unit costs for fish screens between specific sites and watersheds. However, there are some opportunities to reduce costs when a larger scale is considered. If several diversions are grouped into one contract, there can be notable savings in the cost per screen.

Site Information

On a larger scale, the information needed to make a reasonable approximation of cost is similar to that needed on a single site basis. With a watershed, for example, it is important to know the number of diversions in the watershed and the sizes of those diversions. This information might be gathered as a range of sizes or as typical sizes of the diversions. Even without such detailed information, it is usually possible to make an educated guess.

For example, the states did screen inventories about ten years ago, and Oregon estimated about 3,000 diversions in the State should be screened. Washington and Idaho also did screen inventories, so information about diversions needing screening in these three states should be readily available. However, these inventories are now ten years old and need updating. In addition, it is very likely that the inventories were not comprehensive. A group of water users in the Klickitat Valley in Washington has developed a list of several hundred diversions that need screening in that valley alone. Most of these diversions probably did not show up in the Washington State inventory. As more people decide to take action on this issue, it is very likely that many more undocumented diversions will be found.

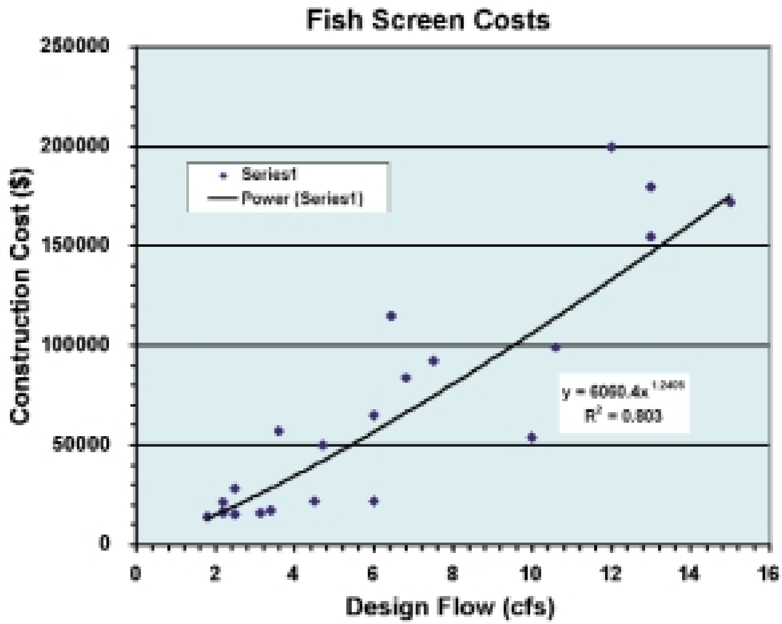
While it is possible to make larger scale approximations of cost within a given watershed, it is much more difficult to compare and aggregate costs between watersheds. There are too many differences between the specific conditions in watersheds to generalize beyond a single watershed level.

Cost Information

Next, cost information is needed to apply to the site information in order to develop a cost estimate. Historical costs for projects in the area are useful when they are available. We have some records of historical costs on USBR projects, but they are not always in a usable form. It is sometimes necessary to do some digging to get the right information out of the records, because it is not always obvious what features are included in a specific line item in a budget. In some cases, the cost for fish screens cannot be determined separately from other work that was included in the same budget.

When historical costs are not available, another option is to develop generic cost estimates. Plotting the costs of typical screens against their sizes on a graph and fitting a curve to the points can do this. Developing these curves requires a source of screen cost information for a variety of screen sizes. One place to start is with the states which have

Figure 1. Washington State fish screen costs, 1 to 15 CFS



compiled cost information on screens that they have built. On the Idaho Department of Fish and Game web site are listed fish screen costs for the last five or six years. Planning, engineering, materials, and subcontracting categories break out these costs. The State of Washington web site also has a table of some screens with size and cost per CFS.

Data Confidence

It is important to remember that if data is to be synthesized from a variety of sources into a single database for developing cost curves, the costs must be adjusted so that they are comparable. The contents of project budgets can vary widely, so that while one budget may only include labor, materials and operating costs, another may include those items as well as project design, construction supervision, contract administration and overhead. Differences such as these make the two budgets incompatible, and they should not be used in the same curve unless they can be adjusted to match. The real difficulty arises when it is not clear just what items are included in a set of cost figures. In this case it is important to be cautious when making comparisons.

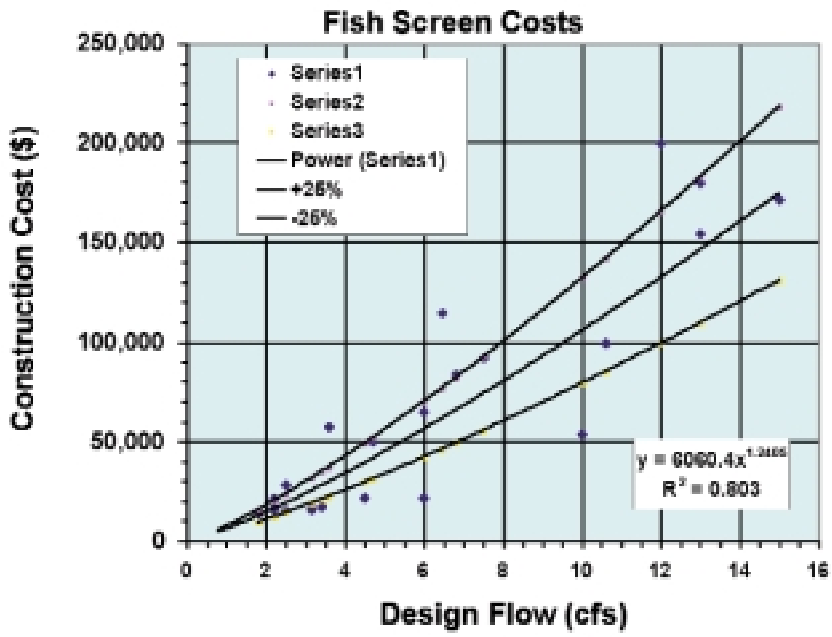
Developing Cost Curves

Following are some examples of cost curves created using cost data that can be found on the state web sites for Washington and Idaho.

Figure 1 shows a curve based on screen costs listed on the Washington State web site. There appears to be a lot of variation in costs based on the size of the screen. For example, there are a couple of points for screens between 10 and 12 CFS that have widely divergent costs – one cost $100,000 and the other $200,000. The same thing is true for a couple of points at about 6 CFS, where one screen cost $20,000 and the other $120,000. Clearly costs vary from site to site.

Some of the variation is also explained, though, by a lack of standardization of which items were included in the costs. The Washington web site had adjusted all of the screen costs to 1999 price levels, but some of

Figure 2. Washington State fish screen costs, 1 to 15 CFS (± 25%)



the costs, especially for the larger screens, weren't adjusted for other criteria. These points include a lot of USBR reclamation sites as well as Washington sites. When USBR built the first 20 diversions from 1984 to 1990, we used a 0.5 foot per second (ft/s) approach velocity. In our phase II program, which covered another 60 sites, we used 0.4 ft/s. That change in approach velocities makes a large difference in cost per CFS. Thus, when looking at the data, it is important to know what criteria were used so that appropriate adjustments can be made. This will ensure that the final curve is based on comparable costs.

Figure 2 includes curves drawn 25% above and 25% below the curve shown in

Figure 3. Washington State fish screen costs, 1 to 58 CFS (± 25%)

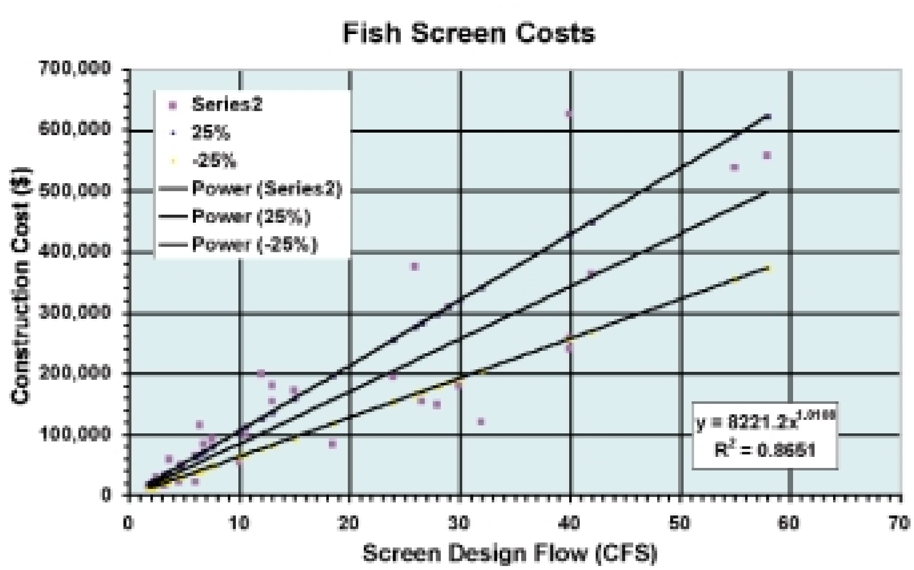


Figure 4. Washington State fish screen costs, 1 to 210 CFS (± 25%)

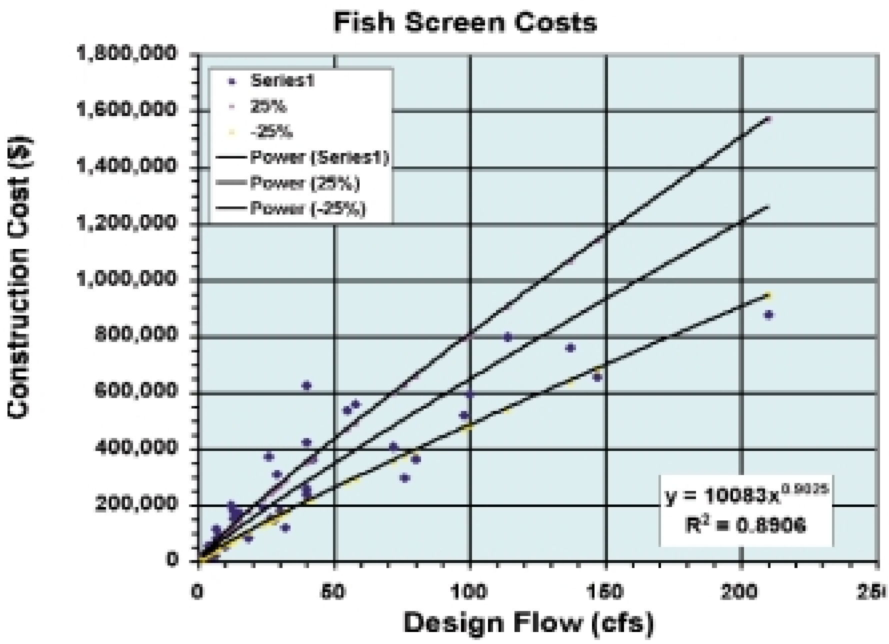


Figure 1. When estimating the cost to restore a new project site, it can be useful to locate the project on the curve based on the screen's design parameters. Then, using other information about the project (for example, how difficult the conditions at the site may be, or how many regulatory issues will need to be addressed), the cost may be adjusted within the plus and minus 25% curves. Quite a bit of individual judgment must be used when estimating the cost for a specific site, but these curves can be useful for first approximations.

Figure 3 includes more project sites than were used to develop the curves in Figures 1 and 2. These new sites have screens that are larger than those in the first two figures, up to almost 60 CFS. The curve is much the same as for the first two figures, although slightly less steep. It appears that the average size of the diversions in a given watershed will influence the overall cost curve.

Projects with screens of an even greater size (up to 210 CFS) are included in Figure 4. Once again, the shape of the curve has changed relative to curves developed using only the smaller screens. This time, though, the curve has become steeper, giving further evidence that the cost curves are dependent on which projects are included. As a result, it is important to understand that the use of cost curves for initial project cost estimation is limited to rough initial cost approximations. Refined project costs must be obtained using data specific to each project site.

The curve in Figure 5 was developed using cost estimates for projects before their final design was completed. This is in contrast to the previous curves, which were developed using actual costs from completed projects.

CONCLUSION

Figure 6 is a representation of the decrease in variance in cost estimates as knowledge of a project site increases in detail. With decreasing variance in cost estimates comes increased confidence that the estimate will be close to the final project cost at any given site. As the project planning process progresses, the known details about a project location accumulate and the accuracy of cost approximations grows.

Figure 5. Washington State fish screen costs, initial estimates

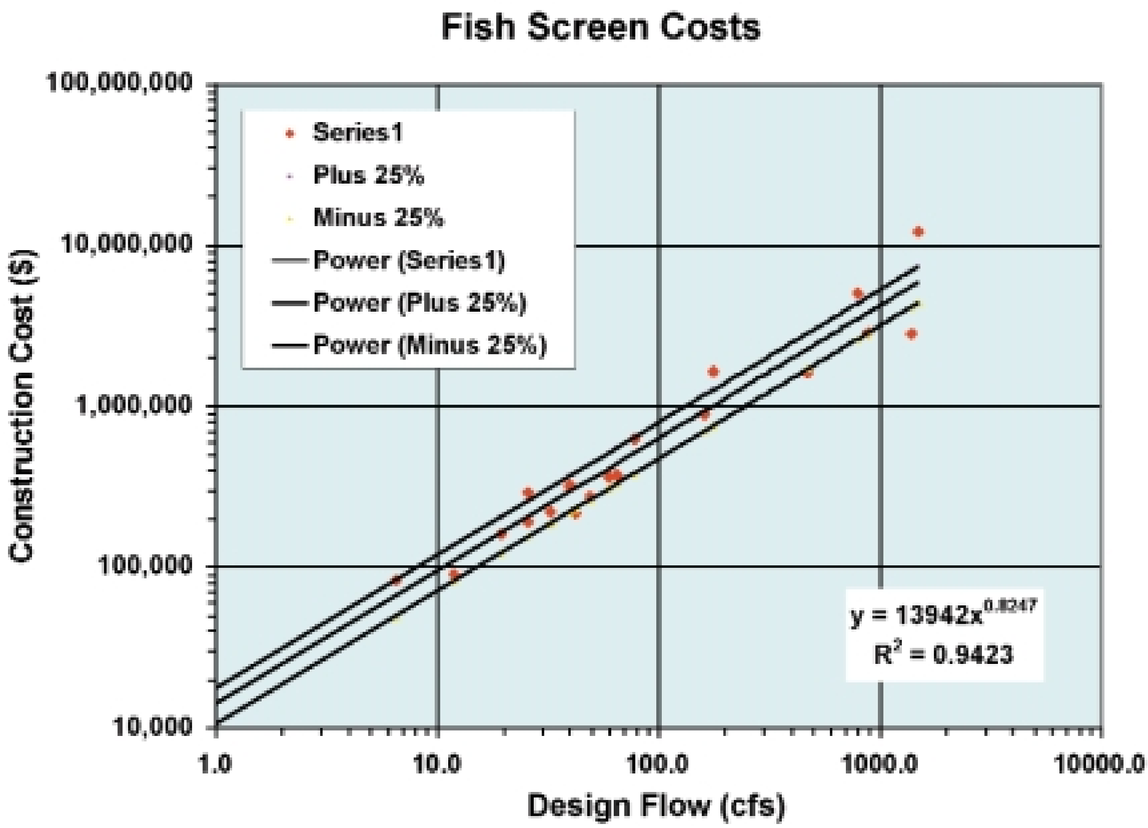
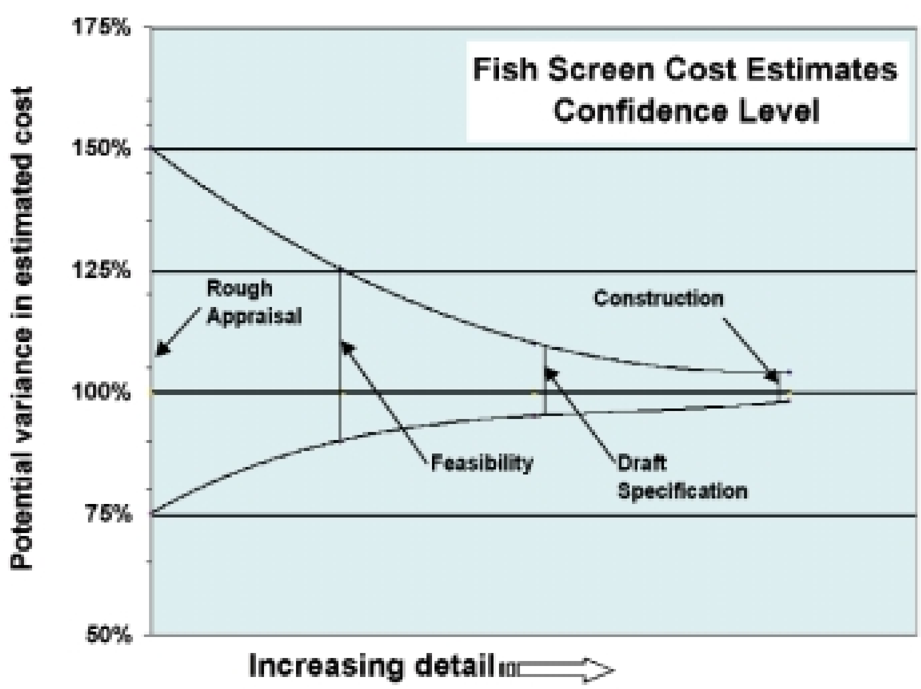
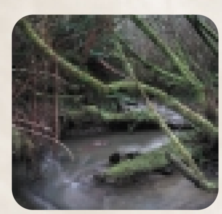


Figure 6. Fish screen cost estimates confidence level



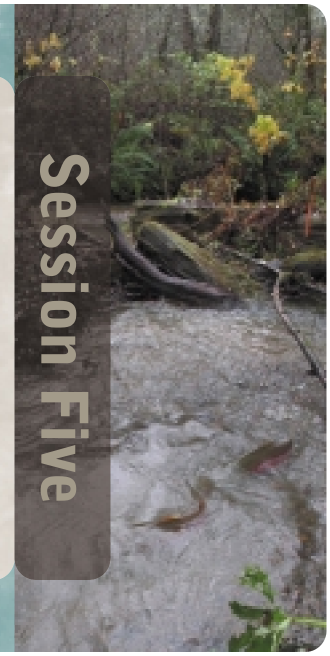
Estimating project costs requires both a general understanding of the amounts spent on a variety of similar projects as well as very specific knowledge of the site to be treated in the project. Using fish screens as an example, it is possible to see that while generalized methods of estimating project costs have some utility in generating rough cost estimates, it is crucial to have a detailed understanding of a given site in order to refine the estimate. This makes it difficult to develop cost estimates on a watershed or larger scale, and as a result, only rough estimates can be made at higher levels.



Upgrading and installation of fish passages and fish screens, offstream water storage

Making a Good Run... A Watershed Approach to Restoration of Clear Creek

HARRY RECTENWALD
California Department of Fish and Game
601 Locust Street
Redding, CA 96001
hrectenw@dfg.ca.gov



ABSTRACT

Successful salmon and steelhead restoration efforts depend on developing a community based watershed approach to planning habitat restoration projects that focuses on implementing the most biologically effective projects. Once fishery problems are identified and understood by all the interested and involved parties in the community, the success of the program depends on removing limiting factors to the populations of anadromous fish. One problem that is well understood is restoring access to cold water habitat on anadromous streams. On lower Clear Creek, a tributary to the upper Sacramento River, there has been decades of restoration planning effort for the watershed. Remedy of fish passage at Saeltzer Dam, located 6 miles from the mouth of the stream, has been a priority project over several years. Several modifications to the fish ladder at the dam were unsuccessful. This paper presents the ultimate remedy for this problem which resulted in the removal of the dam facilitated by exchanging the owner's water rights to another service area. Of special concern are the planning processes and methods of reaching public and agency consensus on the different restoration options that achieve the objectives. Identifying the long-term costs associated with the restoration planning efforts is difficult at best. Identifying construction and project management costs to implement the project are simpler; however, many of the necessary development costs such as legal agreements and activities to achieve community acceptance are difficult to quantify.

INTRODUCTION

Restoration of salmon is often facilitated through a community based planning process that takes a watershed approach and prioritizes actions that have biological effectiveness. Identification and acceptance of problems and solutions is a long-term process that involves experts, community members and owners of the water and land resources involved in proposed actions. Consensus between all of the involved parties can determine if a project can move forward.

Through several different restoration planning efforts taking place in lower Clear Creek over a number of years, fishery agencies identified six habitat factors that limit production of salmon and steelhead. The two key limiting factors to habitat were flow reductions below dams and fish passage problems at Saeltzer Dam. Streamflow in lower Clear Creek is reduced first by Whiskeytown Dam which diverts approximately 87 percent of the natural flow out of the lower Clear Creek basin, then by Saeltzer Dam which has a right to divert a large portion of the releases from Whiskeytown Dam. Experimental actions to increase the streamflow below the two dams were first accomplished in 1992 and 1993. As a result it appeared that the juvenile fish produced due to these increased flows returned three years later as adults in numbers significantly larger than in the past (two to three times past averages), indicating high biological effectiveness for this action.

The lack of adequate fish passage at Saeltzer Dam blocked fish from 10 miles of cold water habitat located downstream of Whiskeytown Dam. The Saeltzer Dam Fish Passage and Flow Preservation Project implemented in 2000 is presented to illustrate a process of planning, developing, funding, permitting and constructing a project, complete with early public involvement and environmental analysis.

Keeping Track of Costs

Over a twenty year period, various salmon and steelhead restoration efforts were started by different institutions with each producing a different document. All the documents identified a need for fish passage improvement at Saeltzer Dam. Because long-term planning occurs on a watershed basis and supports sets of actions throughout the watershed, there is no cost accounting effort for individual actions. Costs for earlier efforts were essentially absorbed by the fishery and water management agencies.

In the last decade there was a focus on community based restoration planning that involved conferencing with interested and involved parties to achieve common understandings on biological problems and potential solutions. A broad multi-agency restoration planning process for salmon, steelhead, and riparian habitat in the upper Sacramento River watershed was completed by the State of California fourteen years ago. The major elements of this consensus based plan for the river basin included Clear Creek. In 1992 Federal legislation was passed that focused on funding the major actions described in the State's Upper Sacramento River Basin Restoration Plan. This legislation focused on restoring fish and wildlife in the portions of the Sacramento River affected by the Central Valley Project operated by the U.S. Bureau of Reclamation (USBR), including lower Clear Creek where flows are controlled by Whiskeytown Dam as a part of the Central Valley Project. The specific actions included improving streamflow from Whiskeytown Dam, providing fish with passage at Saeltzer Dam (located 10 miles downstream) and channel restoration. The Federal legislation provided a funding source. Costs to administer the program were spread out over the entire Central Valley.

PROJECT PLANNING

Planning for the Saeltzer Dam project included participation of interested and involved parties in the following ways:

- An *open planning process* was used over a period of several years to develop a list of potential solutions. The Coordinated Resource Management Process (CRMP) was the main process used by the group facilitating the effort, the Western Shasta Resource Conservation District (WSRCD).

• *Motivation of the owner of the dam and water* to solve environmental problems occurred with increased awareness coupled with conservation interests, access to outside funding sources and confidence in the engineering feasibility.

• *Local community acceptance* came with increased awareness of the acute nature of the biological problems and the ability of the project to accomplish restoration with willingness of the private owners. The CRMP process and the environmental decision-making process facilitated most of the public discussion.

• *Consensus among government agencies* occurred as coordination and resolution of different policies took place among all the Federal, State and local agencies. The CRMP process and interagency conferencing facilitated most of this discussion.

• *Environmental advocate group acceptance* came with awareness that the agreements made with the dam owner would protect the public trust resources. The agreements were included in the environmental documents circulated for public review.

The detailed planning process began with the formation of a technical team consisting of representatives from the primary agencies and organizations interested in restoration of Clear Creek (Table 1). The team evolved into the Coordinated Resource Management Group facilitated by the WSRCD. Different members of the team solicited the involvement of interested parties in the community, the upper Sacramento River basin, potential funding agencies as well as the owners of the water resources and the dam. To advance the project at Saeltzer Dam, the California Department of Fish and Game (CDFG) and Department of Water Resources worked together to complete engineering and geology studies appraising ten potential solutions for feasibility and cost. From the list of optional solutions, three were selected by the involved parties and the owner

Table 1. Agencies involved in the technical team initially developed for lower Clear Creek restoration

- U.S. Bureau of Reclamation
- Cal Fed Ecosystem Restoration Program
- U.S. Fish and Wildlife Service
- National Marine Fisheries Service
- Natural Resource Conservation Service
- National Park Service
- California Department of Water Resources
- California Department of Fish and Game
- California Regional Water Quality Control Board
- Western Shasta County Resource Conservation District
- Shasta County Environmental School
- Clear Creek Coordinated Resource Management Group

Table 2. Three optional solutions for solving fish passage problems at Saeltzer Dam on lower Clear Creek selected for detailed studies

- Rehabilitate existing dam and install fish screen and ladder.
- Remove existing dam and construct new low dam with fish ladder and screen at biologically superior upstream location.
- Remove dam and transfer water rights to diversion points outside of watershed while preserving stream flow in the creek as controlled by Whiskeytown Dam.

Table 3. Comparison of three optional solutions to the fish passage problem at Saeltzer Dam located on lower Clear Creek

Parameter	Rehabilitate and modernize dam	Remove and reconstruct dam	Remove dam, move water right and preserve flow
Estimated cost	$ 3.7 million	$ 4.6 million	$ 5.0 million plus 900 acre feet of environmental water
Long-term biological effectiveness	**Poor** Previous fish ladder and screen efforts failed due to site. Structurally the dam is in poor condition.	**Moderate** Risk of operational problems and flood damage. Possibility of stranded investment due to future water right exchange.	**High** Channel returned to original condition. Flow augmented and preserved.

for more detailed engineering analysis (Table 2).

The detailed analysis is summarized in Table 3 in terms of estimated cost and expected biological effectiveness.

The first option of re-laddering the dam with the lowest cost estimate ($3.7 million), had the least biological effectiveness. Poor performance was expected because three extensive modifications of the ladder could not totally overcome the fish passage delay and blockage. The passage problem was compounded by a steep natural gorge located immediately below the dam that depleted energy reserves of the fish before reaching the dam. Separate attempts to bypass the gorge via an underground tunnel ladder and blasting did not significantly improve passage at the dam. Additionally the dam's advanced age and poor structural condition led to a possibility of dam failure in the future. If a failure was somehow associated with fish ladder construction, it could lead to a damage claim from the dam owner for reconstruction costs.

The second option was to remove and reconstruct the dam and a fish ladder at a better location with a medium cost ($4.6 million), and relatively moderate biological effectiveness. Moderate performance was expected due to a high risk of flood damage to the new facilities. An additional concern was the possibility of a stranded investment in the screen, ladder and dam if in the future the owner pursued a water exchange to service another watershed where they had large land holdings. This possibility promoted discussions on the third option where the water exchange could be conducted before investments were made in the dam.

The third option had the highest cost, but also the highest long-term biological effectiveness and no risk of a stranded investment. The dam would be removed and the water resources exchanged to other areas not serviced by Saeltzer Dam. Water right considerations were a major part of the project. The flow would be preserved by modifying the agreement between the USBR and CDFG for water releases at Whiskeytown Dam. The flow preservation agreement was necessary because if Saeltzer Dam was removed and the water rights were exchanged to other service areas outside of the basin, there was no guarantee of flows to be released from Whiskeytown Dam. Without the agreement supplying water to Saeltzer Dam from Whiskeytown Dam, the creek flow would be governed by a 1960's agreement with the CDFG that specified summertime releases as low as zero cubic feet per second.

PROJECT DEVELOPMENT

Collaboration

Working with Institutions

Attaining consensus among a large number of institutions having different mandates and policies required coordination. Tracking cost for this activity is difficult at best and varies with each project, depending on complexity. The goal is for each agency to understand the perceptions of the other agencies and how they view the options. For example, the language in the Federal legislation addressing Clear Creek specified construction of a "new ladder" on Saeltzer Dam. To some agencies the legislation meant the options to move or remove the dam could not be considered under that program. Precedence is another common agency concern that needs to be addressed to develop new methods and actions. It was also valuable for the agencies to recognize that no action is a decision resulting in lost time and restoration opportunities for species that do not have much time to recover so they can continue to exist. Sorting out all of the varied and conflicting policies is necessary to enable everyone to work together in earnest.

Working with the Affected Community

It was considered by all to be infeasible to implement a project without full disclosure to the community and acceptance among the involved parties. The stakeholders must be identified, and then encouraged to communicate their needs and interests to the project proponents. For this to occur effectively it requires some members to overcome trepidations about government sponsored actions in their watershed. Communications were encouraged by sponsoring the development of watershed groups and meeting at convenient times and locations to encourage public participation. Meetings for watershed groups were often in the early evenings at familiar places, such as local schools, or along the creek, to be more convenient to community members. Hopefully, project goals and objectives were developed that were acceptable to the majority of those in the general community. Another helpful aspect of communicating with the community is obtaining some of the history on the occurrence of fish and wildlife in the watershed, which is sometimes more complete than what is in the agency files.

Working with Watershed Groups

In the Central Valley of California there are numerous watershed groups that are community based. Developing these groups require funding to cover the costs of meeting places, newsletters and the time it takes for citizens to organize and operate the group. The cost to develop the group includes an enormous amount of citizen volunteer time in addition to monetary grants to the groups. The time necessary to develop a working group varies considerably and spans years because the issues are as varied as the personalities in the watershed.

Many restoration actions in the watershed are not directly related to the stream, but are related to the ecosystem and contribute to community acceptance. In a watershed approach, funded actions sometimes help the community as well as the ecosystem. One example is wildfire prevention which protects property in the community and protects the creek from excessive sedimentation. Taking a comprehensive approach to the health of the ecosystem can also help to promote community stewardship of resources in the future. This ensures the long-term effectiveness of restoration projects.

Working with Environmental Groups

There were diverse interests among the environmental groups, including whitewater recreation, stream restoration, dam removal and fishing. As the project progressed, the focus was on the content of agreements between agencies and the dam owner for streamflow preservation, fisheries protection and expenditure of public environmental funds. One of the concerns was that past agreements made by the fishery resource agencies did not provide adequate protection of the public's resources over the long-term. Funding assistance for the project was also successfully solicited from a private source with environmental interests. The content of the agreements was made public in the environmental documentation phase of the project. During development of the agreements, there were many inquiries about the process and content, but there is no way to assign precise costs for the required effort.

Working with the Owners of the Water and the Dam

Three agreements were negotiated with the owner and responsible agencies to select the proposed project for public review. Terms covered exchange of the owner's water rights to another service area, preservation of streamflow in Clear Creek and issues relating to dam removal, canal abandonment and easements. The details included the amount of money from various environmental funding sources, the amount of water in the exchange, the price, the use of environmental water accounts and defining the responsibilities for each party. The final streamflow agreement was complicated because it had to reconcile three previous flow agreements that applied to a ten-mile stretch of creek. A large part of the cost during the negotiation and agreement process was the time that had to be devoted by legal and technical staff from each of the parties to the agreements. This cost was not documented but it was substantial.

Working with the Funding Sources

The funding sources were interested in the construction portion of the project and not the planning. The project manager was responsible for updating the fund providers on cost and schedule. This portion of the project management cost was included in the overall budget for the project. The overall cost of the project was relatively close to the estimated cost.

Environmental Documentation and Decision Making

Environmental documentation discloses and analyzes the impacts, mitigates impacts, responds to comments and certifies the documents in order to get the necessary permits. The specific process selected under the National Environmental Policy Act was an Environmental Assessment with a Finding of No Significant Impact; the State process under the California Environmental Quality Act used an Initial Study and Mitigated Negative Declaration. This is a moderate level of environmental documentation and process with an abbreviated public review schedule. However, the level of detail and analysis was similar to a fuller level of environmental documentation. The years of scoping prior to the project supported this approach. In addition, the documents made specific commitments to mitigate for each impact in the project description to ensure the public of their full funding and completion. If the process is not done correctly the project can be halted by a disenfranchised party.

Mitigation for the wetland associated with the irrigation canal was a special case. This area was not considered a permanent wetland since the owner had the right to dewater the canal at anytime. Wetlands along the stream, however, are permanent so mitigation was provided by redirecting the water from the canal to the stream where the higher summer flows would permanently sustain wetlands. One complication of the project was that adjacent property owners no longer received the incidental benefits from leakage after the canal was abandoned. However, because the leakage was not owned or paid for by these adjacent land owners there was no way to use public funds to mitigate for the loss. In addition, the water right holder had a right to include a reasonable portion of the canal leakage in the water exchange that moved the water to a new service area.

Environmental Findings

Removing the dam provided free passage of salmon and steelhead to 10 miles of cold water habitat between Saeltzer and Whiskeytown dams. This habitat was especially important to spring-run chinook salmon and steelhead in Clear Creek. Both species are scarce in Clear Creek and are listed under the Federal Endangered Species Act as threatened in the Central Valley. By increasing the number of self-sustaining populations of these species in the Central Valley, it increases the probability the species will recover in the Central Valley. The cold water habitat above Saeltzer Dam was estimated to be sufficient to support a population of 3,000 chinook and 5,000 steelhead.

Now that Saeltzer Dam is no longer a barrier, the fish can access the coldest water in lower Clear Creek. When the dam was a barrier it took very large flows to extend the cold water release from Whiskeytown Dam to below Saeltzer Dam. An additional benefit of the project was that such large water releases for temperature control were no longer necessary, allowing this water to be conserved or used for other beneficial purposes.

Design and Permitting

The construction agency was the USBR. Removal of Saeltzer Dam first required removal of the sediments that were impounded up to the crest of the dam. Due to a history of gold mining in the watershed, the sediments had to be sampled for mercury. Contaminated sediments had to be disposed of in accordance with Clean Water Act permit requirements. Sediment removal and erosion control was needed to prevent sedimentation of salmon spawning habitat below the dam. Permit requirements to monitor, excavate and dispose of the sediments were included in the project design and contracting as well as the cost estimate.

Loss of riparian vegetation in the project area was either avoided or mitigated through replanting. Riparian vegetation along the canal was not disturbed but, as noted previously, it was dewatered and compensated for by increasing flows in the creek. The canal wetlands were not filled and dewatering was within the rights of the owner. The canal was surveyed for species of special concern that had special designations and a contingency fund was established to take appropriate actions if any were found. Ultimately no species of special concern were found along the canal.

Saeltzer Dam was constructed in 1914, making it necessary to conduct a survey for historical values. It was determined that the dam did not have historical value because it was partially reconstructed after a previous dam failure 40 years ago.

The dam was located in a floodway administered by the California Reclamation Board. A simple determination was made that removal of the dam would not increase flooding, due to the negligible size of the reservoir and the fact that it was filled with sediment. Removal of sediments avoided any loss of channel capacity in the creek below the dam.

Access to the construction and disposal areas did not require an easement since the entire reservoir and surrounding uplands were owned by the CDFG. The owner of the dam had an easement with the CDFG that was transferred back to the Department and added some legal costs.

Design and Construction

The USBR completed the project on schedule and in substantive compliance with permits. The design and contracting process incorporated all mitigation commitments. Some of the more stringent permit terms required larger costs and innovative design solutions. The cost of handling the mercury included core sampling of the reservoir, dewatering sediments to prevent the release of contaminated water, disposing of sediments and dewatering effluent in appropriate areas. The initial cost estimate was for 25,000 cubic yards of sediment removal but only 13,000 cubic yards needed removal due to the configuration of underlying bedrock.

The design work investigated a concern that there might be a bedrock sill located under sediment in the reservoir that would turn out to be a natural barrier to fish migration. Sediment coring revealed there was no such sill. In addition, historical records indicated salmon migrated a great distance above the site prior to the construction of Saeltzer Dam.

Table 4. The schedule for implementing the Saeltzer Dam Fish Passage and Flow Preservation Project on Clear Creek during the year 2000

• Agreements	February to June 2000
• Environmental Document	March to July 2000
• Design Process	March to June 2000
• Construction	July to November 2000
• Site Restoration	December 2000

Implementation

The project schedule (Table 4) required that all agreements and environmental documents be certified before the construction season ended at the start of the rainy season.

Initially there was much uncertainty in the agreement process which led to difficulties in determining which project option was going to be implemented. For instance, if removing the dam meant not preserving the flow in the creek, it would be better to modernize the dam to maintain the release water from Whiskeytown Dam to Saeltzer Dam that was conjunctively used by fish. The design process costs were high because it remained flexible since it was simultaneous with agreement processes. In addition, design efforts had a relatively short schedule.

The schedule for the environmental documentation process was supported by biological surveys done over the previous three years in anticipation of the project. Surveys for some biological resources must be done years in advance of construction to be certain of the occurrence and abundance of species of special concern.

Construction was compressed to the last four months of the dry season, making it a challenge to manage such a large contracting and acquisition procedure. The selected contractor had to have a hazardous waste license to handle the contaminants and the contract had to have flexibility to handle unexpected situations.

Historical Dam Removal Actions in the Region

In Northern California during the early 1900's, numerous small dams were constructed to supply water to mining operations. Many of these dams made sections of stream inaccessible to spawning migrations of salmon and steelhead. By the 1950's a large number of the mines had been abandoned along with the dams; however barriers remained to block fish movement. The CDFG made a concerted effort to contact the owners and advise them the dams would have to be made passable to fish or be removed pursuant to state law. By the mid-1950's twenty-four dams were surveyed and removed to make a total of 210 miles of good spawning stream accessible to migrations of anadromous fish. The total cost of the operation was estimated at three thousand dollars. Removal actions were typically the explosive shattering of structures to the point they were not a migration barrier. This method could not be successfully employed in modern times.

SUMMARY

As the overall lower Clear Creek watershed restoration effort evolved over the period of fifteen years, a variable amount of effort was directed at solving the flow and passage problems associated with Saeltzer Dam. Table 5 summarizes the phases in the long-term development of the project. Over the history of the project, many of the elements in implementing the project were undertaken simultaneously. Beginning efforts focused on modifying the fish ladder over the dam, restoring creek sections immediately downstream and monitoring the effectiveness of these modifications. These initial efforts can be characterized as being low intensity and long-term. Once the persistence of the problem was documented and the need to resolve it was legislatively mandated in the CVPIA, efforts intensified within the watershed group and involved parties to implement a permanent remedy. Thus the development cost over time had a long period (10 years) of relatively low effort followed by a shorter period (5 years) of elevated activity, intensifying during the year the project was implemented. Cost tracking is more certain for actual on the ground activities compared to planning and consensus efforts.

For the lower Clear Creek restoration effort the process of setting up a watershed group to develop a community based planning and acceptance process took time and

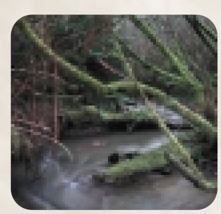
Table 5. Basic elements of the Saeltzer Dam Fish Passage and Flow Preservation Project on lower Clear Creek

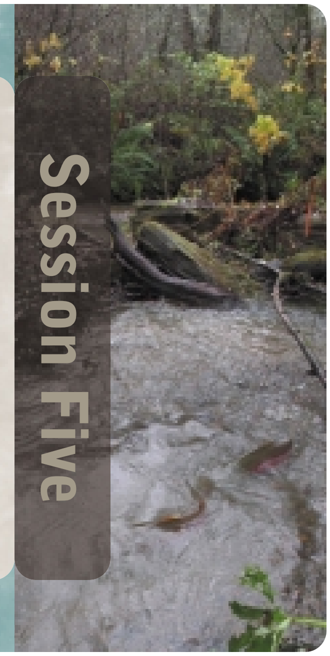
1. Problem identification and documentation using a watershed approach
2. Developing and testing alternate solutions for fish passage and flow problems
3. Development of a community-based planning forum
4. Project planning and alternative analysis
5. Negotiating with the owner of the water resources and the dam
6. Seeking community acceptance on selected alternatives
7. Seeking advocate group acceptance on selected alternatives
8. Completing the environmental decision-making process
    - Completing environmental surveys
    - Developing appropriate mitigation
9. Finalizing agreements for land and water resources.
10. Developing designs and cost estimates for selected alternatives
11. Seeking funding sources
12. Completion of permitting, contracting and construction

funding. Fortunately, the WSRCD was able to provide a ready made structure for developing a community based watershed group, including a skilled non-profit entity to handle contracts. A key part of the effort was to have citizens step forward and participate to lead the process. The process owes much to the citizen participants who care a great deal about the community, as well as the environment, and spend much of their personal time discussing and resolving a myriad of watershed issues. The watershed approach can build community acceptance by developing mutually beneficial projects and supporting stewardship.

Implementation depended directly on the cooperation of owners of land and water resources involved in the project. Legal support was needed to make the commitments between the owners and agencies last in the form of binding agreements. Legal support costs varied with the scope of the issues, and each party had technical and legal counsel to review major actions. Four parties and their legal counsel developed three agreements. One agreement included an additional cost for environmental insurance for mercury contamination. The cost depended on the uncertainty and the risk; thus the detailed survey contributed to the insurance analysis.

After construction there were a variety of hidden costs, mostly associated with monitoring and making adjustments to the project. Monitoring activities included erosion control effectiveness, fish passage effectiveness, stream channel adjustments and water quality. The channel changes were not as expected. Some parts of the site were more stable than expected and others less stable. Some adjustments were required because the high flows that were expected to make adjustments did not occur due to dry conditions. Other hidden costs that can be substantial from a biological perspective are delayed restoration actions due to lack of decision-making ability, controversy and/or litigation. Some of the species in the watersheds have such low population levels that they do not have much time left to begin recovery so they can exist in the future.





Upgrading and installation of fish passages and fish screens, offstream water storage

Oregon Department of Fish and Wildlife Fish Screening Program: Fish Screen Types and Costs

BERNIE KEPSHIRE
Oregon Department of Fish and Wildlife
7118 NE Vandenberg Avenue
Corvallis, OR 97330-9446
Bernard.m.kepshire@state.or.us

ABSTRACT

The Oregon Department of Fish and Wildlife (ODFW) has been directly involved in the development, modification, and placement of fish screens for many years. This paper presents an overview of the major types of fish screens currently in use and a discussion of the average costs for fish screens in the State of Oregon.

INTRODUCTION

As the photograph in Figure 1 demonstrates, vast numbers of fish are killed each year in ditches where they have been stranded after passing through unscreened diversions. To address this problem, the State of Oregon has implemented a cost-share program that gives farmers incentives to screen their diversions. ODFW provides expertise and years of experience, ensuring that the projects are functional and cost-efficient.

Figure 1. Fish kill in unscreened part of diversion (fish in ditch between diversion point and screen, eastern Washington)

Table 1. ODFW Fish Screening Program, average fish screen costs

Fish screen type	N	Flow rate (cfs)	Cost ($)	Cost/cfs ($)
Rotary drum	12	0.4 – 25.0	4,500 – 45,000	1,309 – 11,250
Rotary drum, prefab (all 18″d drums)	4	0.8 – 2.0	7,392 – 7,834	3,859 – 9,358
Belt	3	10.0	23,135 – 31,608	2,313 – 3,161
Panel	2	12.0 – 30.0	36,926 – 85,000	2,833 – 3,077
Pump, low velocity	10	0.5 – 1.8	801 – 1,662	801 – 1,915
Pump, Clemons	10	0.6 – 4.2	1,000 – 3,441	520 – 2,220
Pump, Sure Flo	10	0.5 – 6.0	1,029 – 2,856	476 – 2,450
All fish screens are self-cleaning except for the low velocity pump screen				

Table 1 presents a comparison of the different screen types in use today, the flow rates (cubic feet per second, CFS) that they are designed for, their total cost ranges and their costs per CFS. This table will be used as a reference in the discussion that follows.

FISH SCREEN TYPES

Box Screens

The science and engineering behind fish screening has progressed considerably over the years. One of the earliest fish screens deployed in Oregon was called the Iron Maiden. At that time, keeping project costs low was the highest priority, so the Iron Maiden is simply an iron box weighing about 600 pounds with a 1/8-inch perforated plate screen. While it did not cost much, it was far too heavy for safe and effective installation.

After the Iron Maiden, we developed an aluminum version of the box screen. These were light, but screens had to be manually cleaned.

Figure 2 shows a box screen, which will handle 5 CFS and costs $1,000 per CFS. The screen has a brush system with a paddle. We can easily lift this screen, place it in a truck and put it in a ditch.

Figure 2. Paddle box screen (screen at ditch diversion point in Jack Creek, eastern Oregon; stream powers paddle; brush on one paddle cleans screen; 1 cfs)

Rotary Drum Screens (Custom and Pre-fabricated)

Table 1 shows that for about a dozen sample rotary drum screens, the flow rates ranged from 0.4 to 25 CFS, with the 25 CFS model costing $45,000. It is important to note that for a larger scale project, the cost per CFS will tend to be smaller than for smaller screens. The rotary drum screen in Figure 3 was built in the ODFW shop in John Day, Oregon. Very little engineering is required to construct these screens, which helps to keep the screen costs low. At our screen shop, we have forms for the screens that can be used for most of the diversions in the John Day Basin because the diversions are all very similar — fairly flat with some fall to them.

Figure 3. Rotary drum screen (self-cleaning single drum screen; paddle powered; one-bay; John Day River Basin, eastern Oregon)

Generally we install small screens as in Figure 3, which cost $4,000–$5,000 per CFS. The screens are powered by paddle wheels because there is often no available electricity. Water enters the structure, turns the paddle wheel, gets reversed through a couple of gearboxes, and then goes to the drum. The drums all turn in the same direction and are very well sealed. The fish enter a bypass that carries them safely back to the stream.

Sealing the drum screens is very important. The drums we use now are wrapped with perforated stainless steel plates with 3/32-inch diameter holes. The drums have both side and bottom seals. The seal integrity is very important. Work at Battelle Seattle Research Center has shown that salmonid fry can fit easily through a 3/32-inch opening.

Drum screens can be distinguished by the number of bays. Figure 3 shows a one-bay screen; we also have examples of two-, three- and four-bay screens. Figure 4 shows a four-bay drum screen. The reason for the different numbers of bays is related to the flow rate; streams with highly variable flows are more efficiently served by screens with multiple bays. Ditches are usually watered up in the first few days of spring. Often the screen flow can exceed the maximum that one screen can handle, necessitating multiple screens. When the stream flow drops in August and September, though, bays can be shut off, leaving only one or two drum screens working.

Figure 4. Rotary drum screen (self-cleaning drum screen; paddle powered; four-bay; Rogue River Basin, southwestern Oregon; 29 cfs)

The four-bay screen in Figure 4 is for flows up to 25 CFS and costs $45,000 to construct. This was a joint project, with an ODFW crew doing most of the concrete and metal work. Trout Unlimited paid for some of the costs, and some labor and equipment (dump trucks) were donated.

Figure 5 is an example of an electric-powered rotary drum screen. We use these screens only rarely and so do not maintain a list of prices. The screens have small electric

Figure 5. Rotary drum screen (self-cleaning drum screen; electric powered; eastern Washington)

motors turning the drums. Water flows along the screen faces into the bypass. Electric-powered drum screens can be very large, as shown in Figure 6.

Figure 6. Rotary drum screen (large drum screen, 19´ in diameter; Red Bluff, California)

Table 1 shows some figures for rotary drum pre-fabricated screens (18-inch diameter), which are a bit costly. The cost for flow rates of between 0.8 to 2.0 CFS runs $4,000–$9,000/CFS installed. However, the high costs are more than compensated for by the savings if a farmer wants to move his entire water right to another ditch. A pre-fabricated screen can be easily removed from one ditch and placed in another with only minor modifications needed.

Belt Screens

We have a few belt screens installed in Oregon. Figure 7 shows an example in Washington, and Figure 8 an Oregon example. Belt screens are self-cleaning, with the belt moving in an endless loop powered by electricity. As the water goes through the stream, the debris is carried down the ditch. Belt screens tend to be expensive. The screen in Figure 7 handles about 10 CFS. It is lifted in the winter, but is normally down behind

Figure 7. Traveling belt screen (eastern Washington)

Figure 8. Traveling belt screen (plastic; 10 cfs solar powered screen; eastern Oregon)

the trash rack in the stream. The screen in Figure 8 is a plastic panel system that costs about $3,000 per CFS. It has a solar battery.

Panel Screens

Panel screens with self-cleaning brush systems are used in California (Figure 9) and Washington. These screens accommodate water depth changes more effectively than rotary drum screens.

Figure 9. Self-cleaning panel screen (160 cfs wiper brush self-cleaning screen; electric powered; Parrot-Phelan Diversion in northern California)

Pump Screens — Low Velocity

There are three major types of pump screens. Figure 10 shows the first type, a passive screen (low-velocity). The pump is up on the bank, and the suction end in the stream. The screen mesh is 3/32 inch to meet National Marine Fisheries Service (NMFS) screening criteria. A shear flow is required in addition to sweeping velocity in order for the screen to work. Usually the sweeping velocity in the vicinity of the screen is a lot higher than the approach velocity of 0.4 feet per second. There is so much surface area that leaves and other debris tumble when they go downstream instead of hanging up on the

Figure 10. Low velocity pump screen (Pump-Rite manually-cleaned pump screen; water velocity balance tube inside)

screen. The screens tend to maintain themselves fairly well if there is a good sweeping flow. I know farmers who do not clean this type of screen for an entire irrigation season without losing any of the functionality of the screen. The frequency with which the screens must be cleaned depends on location and debris load in the stream, including algae.

A man in Junction City, Oregon invented the screen shown in Figure 10. It is inexpensive and it has no moving parts, so the cost per CFS is low. The screen can handle about 1 CFS.

Pump Screens — Clemons

The Clemons self-cleaning pump screen has cleaning arms that spin inside the stationary screen and blow debris off the mesh. The screen in Figure 11 has 10 meshes to the inch, which exceeds NMFS screening standards. The unit is very heavy, so it stays in place. Clemons screens cost $520–$2200 per CFS and can handle up to about 4 CFS.

At installation, we tell the farmers to place a construction block underneath the screen to keep it above any stream debris or fine silt that might disrupt the screen. Generally, when these are installed in the streams in March or April, most of the heavy flows are over, so the screen will not get silted in. Generally, irrigation season in

Figure 11. Clemons pump screen (self-cleaning pump screen)

Oregon begins in March or early April, depending on spring rainfall, and runs until the middle or end of October. Once irrigation is finished, we remove all of the screens and replace them again in the spring.

Pump Screens — Sure Flo

Figure 12 shows a mainstay of self-cleaning screens: the Sure-Flo self-cleaning pump screen. Refer to Table 1 for the cost range for this type of screen. This screen has jets inside that spin the screen and clean the

Figure 12. Sure-Flo pump screen (self-cleaning pump screen; water velocity balance tube inside)

debris. The Sure-Flo screen also has a balance tube inside to ensure the approach velocity is uniform. There are probably 200 of these screens currently installed in Oregon, and they have proven successful. The larger unit shown in Figure 12 operates at about 2.7 CFS, but Sure-Flos can be bought off the shelf that will handle about 5.5 CFS.

FISH SCREEN BYPASSES

In any discussion of fish screens, bypasses will be mentioned frequently. A bypass takes the fish that have been prevented from entering the diversion by the screen and delivers them safely back into the stream (Figure 13). Bypasses must be carefully monitored because every year the stream may shift during a winter storm. This means that suddenly the bypass no longer empties into the stream but instead dumps the fish out onto rocks.

Figure 13. Fish screen bypass (bypass safely returns screened fish to stream; bypass can be very long, even hundreds of feet; eastern Oregon)

Bypasses are a very important tool for us to measure the success of the screens. On some of the bypasses on drum screens in the Rogue River Basin and the John Day Basin, just before the bypass goes into the

Figure 14. Screen bypass trap box (fish saved by screen are sorted by species and counted; steelhead smolts in box in photo; John Day River Basin, eastern Oregon)

river, we construct a concrete box (Figure 14). Then we periodically put another screen into the box and, as the bypass water from the stream comes into the box, we trap whatever fish are in there. We can then ascertain fish species and obtain an estimate of the numbers of fish that are being saved by the screen.

SCREEN INVENTORY

An attempt at an inventory of Oregon diversions was made about 10 years ago. At that point, if our biologists knew of a diversion, they told us about it. However, many diversions were unknown. So we went to the Water Resources Department and obtained the Oregon Water Rights Information System database, which lists all the permits and certificates for water rights held in the State of Oregon. Unfortunately, the names were those of the *original* landowners, as far back as the middle 1800s!

We hope to access federal money that President Clinton signed into law from the Irrigation Mitigation Act of 2000 (PL106-502), which will make available to the States of Oregon, Washington, Idaho, and Montana $25 million per year over a five-year period for screening and passage at diversions. The State of Oregon hopes to get some of this money for a complete inventory to find the still un-catalogued diversions.

Our current estimate is that there are more than 55,000 unscreened diversions in Oregon, and at least the top 3,000–3,500 need to be screened to save listed species.

The best data that we have for Oregon is for the Columbia River. We know every diversion on the Oregon side of the Columbia River. We have also done a comprehensive survey on the Willamette River. Water Resources personnel, Oregon State Police and staff from ODFW went in boats up and down the river from Eugene to the mouth of the Willamette looking for diversions. They found about 510. Water Resources staff are now identifying who owns them. This process will also identify problems with the water rights. For example, it didn't take long to realize that some of those diversions on the Willamette were illegal.

FISH SCREEN COSTS

The easiest screens to accurately predict costs for are pump screens. Their installation is privately contracted and uses off-the-shelf technology, which means that costs will fall within a well-defined range. The costs for pump screens generally tend to be lower than for ditch screens. In addition, pump screens are an easy sell to the farmers, because they also keep snails and debris out of rainbird sprinklers. When farmers see a little 3/32-inch mesh screen that will keep the snails out and the State offers them a 60% cost-share program, they love it.

Building Our Own Screens

One cost-reducing measure that has developed in Oregon is that unless rotary drum screens are over 25 CFS, we no longer need to incur engineering expenses. We have enough cumulative experience to have an existing design. And because our shop staff builds the screens, the costs stay much lower than if we contracted out the engineering and construction. Our screen shop has sets of forms for any drum screen size that is currently used in the State of Oregon up to 25 CFS. All that is needed to design a screen for a new diversion is a quick and inexpensive survey of the ditch. The surveyor can measure the ditch and develop a plan immediately based on our standard designs.

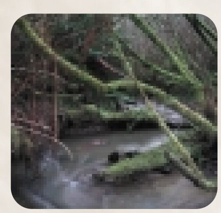
Most of our screen costs are for materials, construction and installation labor. The ratio of labor costs to material costs on drum screens is 70:30. We have a useful manual from the John Day screen shop that contains all the costs for building screens, including component costs and supplies for every kind of screen (pre-fabricated and otherwise). The costs are broken out by channel, perf-plate, flat-bars, rubber seals, form costs, reinforcing steel and concrete. Another table in the manual gives the necessary screen dimensions for different levels of stream flow. For example, if the diversion is 3 CFS, the table lists the screen diameter that will be needed to handle that flow.

The one thing we cannot know until we complete a project is how much bypass pipe is required. We also cannot know how much travel and hotel time will be required for installation crews (pouring the concrete and putting in the steel). However, the John Day shop cost manual includes cost for per diem and mileage, so we can make an initial estimate when we are planning a new project.

FISH SCREENING ORGANIZATION

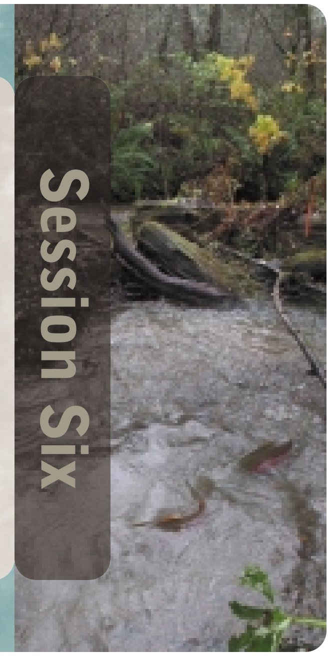
The ODFW coordinates fish screening installations throughout the state, with a statewide coordinator and three field coordinators who handle southwest Oregon, the Willamette Valley/Deschutes, and eastern Oregon. We work with 95 watershed councils throughout the State. The watershed councils then work directly with farmers to interest them in screening their diversions. Our cost-share program is voluntary and done when a farmer expresses interest. We do not force farmers to screen any diversions under 30 CFS.

The state has a very good working relationship with the water-user community, including large irrigation districts that generally have screen flows over 30 CFS, and smaller farmers. Many of the ditches we screen are only 1 to 5 CFS. Oregon has very small water diversions compared to the diversions in California. The largest unscreened diversions in Oregon—there are two of them—are each about 1,000 CFS.



Wetland Creation and Restoration

CHRIS BONSIGNORE
STEVE LISKE
Ducks Unlimited, Inc.
1101 SE Tech Center Drive, Suite 115
Vancouver, WA 98683
cbonsignore@ducks.org
sliske@ducks.org



ABSTRACT

This paper discusses the work of Ducks Unlimited and the factors the organization considers in designing projects and estimating their costs.

INTRODUCTION

Ducks Unlimited (DU) started in 1937. We completed our first restoration project in 1938 in the Canadian prairies primarily focusing on ducks. Since that time, DU has expanded its efforts all over the Continental U.S., across Canada, and into Mexico. A substantial amount of work is done in the Pacific Northwest, where DU now has five engineers on staff. Of course, the focus is much more than ducks these days. In fact, over 900 species have been recorded at restoration projects developed by DU and others. Fish are also considered in many of our restoration activities.

It should be noted that about 40% of all threatened and endangered species use wetland systems at one or more points in their life cycle. DU focuses on habitat-based conservation. Some of our objectives as we look for restoration opportunities are to mimic the natural hydrology of the site when that's possible, promote diverse communities of native wetland plant species, and provide a mosaic of habitat types for multiple species of fish and wildlife.

Emergent wetlands are one of the types of systems that we typically work in. They are an important part of the ecosystem and, of course, waterfowl are drawn to them in large numbers, so we've worked with emergent wetland restoration for a number of years. It has been and will continue to be a primary focus for our projects.

DU has also started to do considerable riparian restoration, as it relates to water quality improvements and fish enhancement projects. Many of our typical marsh projects involve a substantial riparian component (up to 25%). We are also working on the coast (bays and estuaries) with a number of projects (at Willapa Bay, for example). These types of projects are quite different from some of our "normal" wetland restoration projects, and it is something that we are beginning to do a lot more of.

SITE ASSESSMENT

In the initial stages of the project implementation process, site assessment should occur. Factors that can affect project success and costs include suitability of soils, topography, hydrology, potential impacts to neighbors, presence of threatened and endangered species, and presence of invasive species (which are becoming much more of a problem in any restoration project).

Soils

Soils must be assessed carefully, because it is important not to spend a lot of money trying to restore an area that may not hold water. This sounds simple enough. However in some cases we're really not restoring wetlands; we're creating them if the soils have not had a history of wetland development and are not hydric. A good analysis of the soil is the first step in any wetland restoration project.

Hydrology is an obvious consideration. For instance, suppose you have an area that looks like a wetland. This area may be functioning properly in terms of its hydrology, but in reality it is partially drained at the far end and the drainage ditches have not been kept up. So in reality, the hydrology has not been restored; if you wanted to restore the hydrology, the project would probably be more of an enhancement.

One of the things you can look at to see the effects of hydrology on a project are a hydrograph. Hydrographs give you a feel for what sort of a system you have. They provide elevation information and, if your site happens to be in a flood plain (e.g., a floodplain wetland), you can calculate where the elevation is in the flood plain and get a picture of how the hydrology varies across the site.

One would never imagine that many areas restored by DU had once been wetlands. This is the sort of thing we run into often, when working on either private land or, in some cases, a public refuge. Often the land has been completely drained by tile systems for agricultural purposes. In many cases what's needed is to break those tile lines and let the hydrology return itself to the area.

Potential Impact on Neighbors

Another key consideration is the impact your project has on your neighbors. A good example is a site just outside of Salem, Oregon. An historic channel of the Willamette River formed a large shrub swamp and emergent wetland, but it has been drained for over 100 years now. The site produces incredible agricultural ground, but we want to restore a part of it to wetland. One of the neighbors, a farmer, doesn't want to do any restoration. The challenge is to figure out what needs to be done to ensure restoration in the area and yet not impact the farmer who wants to continue farming.

This, of course, impacts cost. We might have to build levies to protect the farmer from flood waters and, on the other side of the levy, we might have to build a ditch to collect any water that might seep through the levy — so that we don't impact the neighbor on the other side.

Species Considerations

Consideration is needed for a lot of other species. DU still primarily focuses on waterfowl, but all of our projects have an impact on other species. Consideration of threatened and endangered species is a key part of this. As we develop sites, we have to be very careful about the impact our work may have on other species. An extensive species survey and botanical survey often becomes a vital component of the initial assessment of the site (and costs).

Invasive species are also a very big factor. Comparing restoration at a site where you have invasive species to one where you have a primarily native wetland plant community shows significantly different effects on costs and planning. An example of an invasive species is Reed Canary grass, a big problem all over the western side of the Cascades. To really restore an area with this type of invasion, you have to scalp a lot of the Reed Canary grass out, and allow some of the native plants to germinate and try to compete with the remaining Reed Canary grass. You will never eliminate it, but you must reduce it.

Locating and referring to reference sites is important. You can go back and reference these areas and have a clear goal of where you are heading with your restoration activity. It also helps in assessing a site because it lets you visualize what that site may become one day. Of course you may do that at different geographic scales to determine how that affects costs.

COST APPROXIMATIONS

Information is needed in three areas to provide a reasonable first approximation of project costs. These areas include topographic surveys, project design, and the actual construction costs. When we do these initial estimates of cost, we often do not have any funding in hand, so topographic surveys and designs are not yet done. That does make it a little more difficult to estimate costs but, if funding is available and designs are completed, construction costs can be refined significantly.

Topographic Surveys

Topographic survey costs will vary considerably. Some sites may be very wet and choked with weeds, making access very difficult. Other sites may be dry and driveable with a truck or an all-terrain vehicle and we can get surveys done quickly. In this case we can survey several hundred acres in a day with a geographic positioning system (GPS) unit. Other sites are very thick and a GPS survey will not work, so traditional survey methods have to be used.

Project Design

An issue to consider is what we call the "partner" factor. The more partners involved in a project, the more difficult it is to reach consensus on what is to be done, thus raising the planning costs. Each partner may want to see something a little different, and this tends to add to planning costs as well as restoration costs. This may not be something we typically think of, but it is a factor to be considered.

Of course, permits are a consideration, depending on the type of project. Some projects need more permits than others and that impacts costs.

The scope of the work is a factor — whether we're building levees to impound water or excavating ponds. Typically excavating dirt is cheaper on a per-yard basis, but it's much more expensive on a per-acre basis to create that impoundment than levees are. Building levees are much more cost-efficient.

Another consideration is the source of water. Does a new gravity flow system need to be constructed, or can an existing water source and gravity flow system be implemented? Or will you need to construct a pump station to get water to the site? This also brings up the question of diesel versus electric as your power source for a project. If you are in a remote location you might choose diesel. Electricity brought to a site often is very costly.

What is the level of design? Are you building levees and installing typical, off-the-shelf water control structures, or are you going to do something more complicated? You may have a water diversion structure that requires a fish ladder or screen incorporated into it, for instance.

Construction Cost Considerations

- *Location of site:* We need to consider where the site is and if we are going to have high mobilization costs to get equipment on-site. Are any road improvements or clearing needed? Are there reliable local contractors, or will we need to bring them in from a long distance? These issues will tend to drive the costs of a project up.

• *Imported materials:* The soils surrounding the site may not be suitable for the type of structure you want to build, so you may have to import material. Import of materials can be very expensive depending on the availability of material needed, distance to haul it, and the availability of equipment and people necessary to haul and deliver it.

• *Type of equipment:* The equipment necessary to do the job can vary significantly in expense. Scrapers for instance, are very cost effective. However there are some sites where scrapers simply cannot be used.

• *Inspection:* Depending on the complexity of the design and the trust in those doing the work, inspection levels and cost can vary significantly.

• *Size of the project:* Obviously if you are moving 100 yards of dirt, it is much more costly per yard than moving 10,000 yards of dirt, on an economy of scale.

• *Length of the project:* If the project is going to last longer than a year, maybe two or three, you need to take inflation into account. Also, each time the contractor comes back they will charge for mobilization, which will increase costs. The Davis-Bacon Act concerning prevailing wages may impact costs as well.

• *Contingency:* There is always something we run into during construction, or even during the design stage, that was not accounted for. You should typically add a contingency to your cost estimates.

• *Maintenance:* These costs vary depending on the type of restoration. Perhaps the project is a permanent pond that is fed with gravity water, with very low maintenance. Management of vegetation might require disking or mowing. If a pumping plant is involved, there are higher maintenance costs. Also, depending on the size of the restoration, we might purchase the equipment for the maintenance versus renting. It also depends on the landowner. If the landowner is a farmer with none of the equipment needed to do the job, we might have to hire a contractor. On the other hand, if the landowner is a federal agency, they may have plenty of equipment to do the job themselves.

DU maintains a bid summary on all projects, so that when we estimate big projects we can go back and see what the unit prices were on previous projects. We have unit prices for various types of work: mobilization, stripping, earthwork, riprap, structures, etc. So we have a good idea of what the going rate is. We typically don't break up costs by equipment, labor, etc. Those costs are included in the unit prices for specific items of work.

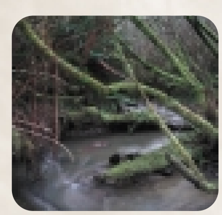
WAYS TO REFINE CONSTRUCTION COST ESTIMATES

As mentioned above, by doing a topographic survey and conceptual design, you can more accurately estimate what the quantities are. This will help refine the scope of work, and allow you to more accurately estimate the construction costs.

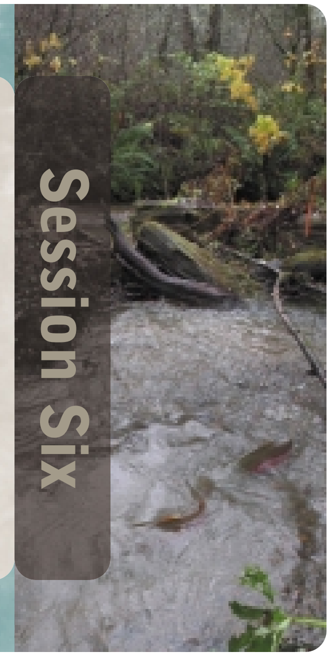
If you can get contractors on site, they are a good source of information. Contractors are often more than happy to come out and look at projects if they know that they will get a chance to bid on it. Then, of course, you can get bids on a project. This will let you know where you stand with respect to the funds available.

Data Sources

The RS Means Catalog lists all types of construction activities with costs broken out by equipment, labor, and material. It is a good source of information. Blue Book rates for rental equipment are easily available. There is also a lot of information available on the Internet. Again, contractors are a good source of information.



Wetland Creation and Restoration Cost Factors: U.S. Army Corps of Engineers



A presentation by **PATRICIA M. OBRADOVICH**[1]
U.S. Army Corps of Engineers
Portland District, P.O. Box 2946
Portland, OR 97208-2946

ABSTRACT

This paper addresses topic-related issues that are specific to the programs of the Army Corps of Engineers in terms of the laws, policies, and regulations that impact us. Then it describes some of the programs used by the Corps for ecosystem restoration.

INTRODUCTION

I work with the Portland district of Corps of Engineers in planning programs and project management grants. In the past I've been the chief of the Economics Section and the chief of the Planning Branch. I don't actually get out on the ground, but I work with a lot of the biologists, hydrologists, and cost estimators. And I work with the public right now, finding out what people's needs are and then seeing if programs or authorities that we have available might help. If we don't have something, I try to find if somebody else out there does. If these individuals or groups need legislation, I determine how we can go about getting that or working with the congressional staffs. We don't lobby, but we tell people what their options are for getting assistance.

LAWS AND POLICIES THAT INFLUENCE OUR COSTS

On this topic, a lot of issues are specific to our programs in terms of the laws, policies, and regulations that impact us. The Corps of Engineers does flood-damage reduction navigations, and ecosystem restoration is on equal footing with those other project focuses for funding. So we do ecosystem restoration, and we do it with local sponsors because we are required to have cost-sharing sponsors in anything that's a new work activity. We are not a granting agency like the Federal agencies are. We can do some creative things: we do in-kind help occasionally, but we can't give money. In fact, we ask local sponsors to give us money to do the projects. These sponsors are required to provide lands, easements, right-of-way, relocations, and disposal areas, and they're also required as sponsors to do the operation, maintenance, repair and

1- Ms. Obradovich passed away before she was able to complete her Workshop paper. The transcript of her oral presentation is provided here. Please contact Martin Hudson (503-808-4703) for further information on Corps activities.

rehabilitation. Eventually, the project gets turned over to the local sponsor.

• *Land:* This tends to be biggest item in our cost estimates and anything else that we're doing. In fact, one of our policy issues is that land should not be more than 25% of the total project costs. The Corps is not a land acquisition agency; we manage our project lands, but we're not in the business of acquiring land. Of course, policies can be waived and changed, but in general if a project involves an intensive land cost, we may not be able to play.

• *Monitoring:* Again, this is a policy issue. No more than 1% of restoration cost should go for monitoring. When this policy came out this year, people nationwide questioned the number. Monitoring also cannot continue more than five years after construction. Our guidance tells us that we should be looking at adaptive management, especially for very large projects, and that should be no more than 3% of total project costs. Again, I don't know what those percentages are based on or if they are solely an attempt to keep costs down, as we're using Federal dollars on these projects.

• *Real estate costs:* For Corps projects historically, we want to see property titles. For restoration projects now, people are more willing to go to easement or something less than fee title if it's economically warranted and it makes sense, although sometimes easements can be as costly as a fee title.

• *Other tools and resources:* A list of studies and reports from the Evaluation of Environmental Investments Research Program is available on the Internet or through the Institute of Water Resources (IWR). Again, they may be of special interest to economists. These are not applicable in every case, but there are some things to consider and there are some good illustrations of National Review Corps Environmental Projects, etc. The IWR is located in Virginia and the Waterways Experiment Station is in Vicksburg, Mississippi, so there is a lot of expertise that we can draw on nationwide. One tool we have is the IWR Plan for environmental restoration. This tool does cost-effectiveness analysis and incremental cost analysis to help us answer questions about whether the project is worth it or which is the best investment of a number of alternatives. The tool can also be downloaded off the Web. There are also people available to help answer questions; they'll even come out and do demonstrations for groups that want to apply it to a project.

CORPS OF ENGINEERS PROGRAMS AND AUTHORITIES USED FOR RESTORATION

Two study programs are available that can lead to projects.

General Investigations Program

The General Investigations Program (Table 1) is for comprehensive basin-wide watershed efforts. It involves a long time frame, but the good feature is that on occasion it can bring about 65% Federal funds to the project and there is no limit on the Federal cost side. This is something to consider for a very large-scale area, such as the Puget Sound area, where I know they're doing some work. This method is slow in that it requires both congressional authorization and appropriation even to start the study process; i.e., one can get an authority from one bill but not have any money to start, so it might take a while to make that happen.

This is a two-phase study process. The first is all at Federal expense. The second phase is cost-shared 50-50 with a local sponsor. This latter may impact the ability to do good planning as there will be pressure to

Table 1. USACE programs for restoration: General Investigations Program

- Best for comprehensive basin-wide watershed efforts of multiple problems
- Requires Congressional authorization and appropriation to initiate
- Reconnaissance Study
- $100,000 all Federal expense
- Sponsor cost shares feasibility phase of the study (50/50)
- Requires project authorization and appropriation

keep costs down in the planning stages too, since the dollars belong to the sponsor as well. There's a certain amount of negotiation, but there is a trade-off between getting good surveys and good information versus trying to get into the next phase of the effort. Once the feasibility stage is completed, which includes all your NEPA compliance, etc., the applicants have to go back to Congress again for authorization and project appropriation. So to get from the start of the study to implementation sometimes can take 5–10 years. That's the reality.

We actually have authorization and appropriation now to start a study on the lower Columbia River for ecosystem restoration. Initially the States of Oregon and Washington had signed on and some interested local sponsors, but I think it's going to take a lot of sponsors and a lot of effort to make that come together and really do something good in the lower estuary.

Continuing Authorities Program for Restoration

Table 2 describes the Continuing Authorities Program, so-called because Congress has delegated the authority to the Corps of Engineers to manage these programs. Congress provides an appropriation every year for a number of authorities that are specific to ecosystem restoration. Section 1135 addresses modifying either a Corps of Engineers project or Corps of Engineers land to benefit the environment. The second, Section 206, is purely aquatic ecosystem restoration. If you want to do good stuff out there that's wet, you could probably use this authority. Section 204 deals with dredge material disposal for environmental restoration.

Table 2. Corp programs for restoration: Continuing Authorities Program

Section 1135 — Project Modifications for Environmental Improvement

Section 206 — Aquatic Ecosystem Restoration

Section 204 — Beneficial Use of Dredged Material

- Authority and funding delegated to the Corps
- Smaller scope projects
- Statutory limit on Federal costs
- Cost sharing — generally 65/35
- Sponsors can be NGOs for ecosystem restoration
- Single planning and design process
- 1–3 years from start to construction

These authorities are delegated. They are generally smaller in scope, and they have a Federal cost limit, generally around $5,000,000 per project. Cost sharing is normally 65/35, with the 65% Federal. So a project of $6 or $7 million is possible although most are a lot smaller, generally

$100,000 to $500,000. Also, groups like Ducks Unlimited and other NGOs can be sponsors for ecosystem restoration projects. These are more expedited projects that usually take 1–3 years to complete construction.

COST ESTIMATION ISSUES

Cost estimation is only a piece of the puzzle. If one is seeking the biggest "bang for the buck," a team is needed to look at the formulation and evaluation of projects. Even with a small-scale project, there are many variables and then it's difficult to move to larger scale and make the kinds of gross assumptions about what will work. One suggestion for ESU watershed-wide assessments is to do a two-phase process with some demo projects to demonstrate success and get some cost information and see what works, then apply what's been learned to the larger scale.

If we don't know what the goals and objectives are to begin with, the project is already in trouble. What is it that the group really wants to accomplish? What are the conditions of the existing habitat? What are the limiting factors and what you can do to influence those factors? What are the actions to take to improve habitat? Another issue is real estate. What is the project area? Is the land available? What are the current adjacent uses of that land? We must consider neighbor impacts, or if they are doing something on their adjacent lands that will be detrimental to the project. Zoning and fee title versus easement are also considerations. Is the land even suitable for restoration?

Discussions with multiple contractors are really important. It's important to find people who know heavy equipment and know the area. Never underestimate the ingenuity of contractors. Bring in experienced people from the beginning who can give their advice and ideas. Get your most experienced staff early on in the process and it will make things a lot better for you.

Permitting costs are a big issue now for the State of Oregon Water Quality Certification for bridge and fill removal, since we have to pay for those certificates based on volume. If the permitting costs haven't been planned for, it can get pretty expensive pretty quickly. And there must be some estimate for signage. When you allow public access, there is access for only operation and maintenance. You have to think about the kinds of things that have been covered in this Workshop — bond, profit, labor rates, contingencies. Our contingencies are generally 15–25% on the first estimate.

How will you dispose of barrow material? One quote on one acre, 1600 cubic yards is 161 10-yard dump trucks. That's a lot of material to move and if we don't know where it's going, it can be very expensive to get rid of.

Real estate issues are prevalent. Our real estate people do a lot for us, not just in estimating costs and value but, since there is a local sponsor, responsibility to acquire land. We do a lot of work on the real estate side to do appraisals of their estimates and things like that for crediting their cost-share.

Potential relocations can also be really expensive. If we clear an area and someone has utility lines or there are natural gas lines that have to be moved, those things can add up fast and slow the process.

Is there to be passive or active management of the area? What is realistic to expect of the sponsor? Some maintenance, like control of Reed Canary grass, takes a lot of labor every year. And if we don't think the sponsor can handle it or it will be too costly, we've got to really think about what we want to do there.

Is there a relationship between the initial cost and operational and maintenance cost? If we increase initial costs by doing certain things, is there a way to decrease the O&M over the long run so that the average annual cost is lower and you're not relying as heavily on people doing maintenance over time?

Increasing scale can provide some benefits but, if the project goes into two seasons, the plans involved can get too far away. Costs always go up. And with larger-scale projects, we need to ensure that the pieces of the restoration all fit together to serve the overall goals and that they are not at cross-purposes. This is another area where use of demo projects might be worth considering.

Expanding cost estimators to watershed, ESU or state level seems to be an iffy proposition at best. So iffy must be some sort of cost engineering problem. But that's the same stuff that you've heard.

Resources

We have access to a lot of detailed information in terms of developing cost estimates.

Portland District Corps of Engineers Points of Contact:

- Geoff Dorsey, Wildlife Biologist (503-808-4769)
- Kim Larson, Fisheries Biologist (503-808-4776)
- Pat McCrae, Regional Economist (503-808-4758)
- Brian Shenk, Chief-Economics Section (503-808-4750)
- Pat Jones, Chief-Cost Est. Branch (503-808-4790)
- Ron Musser, Real Estate Appraiser (503-808-4680)
- Matt Rea, PM-Amazon Creek Restoration (503-808-4732)
- Doug Putnam, Continuing Authorities Program Manager (503-808-4733)

ACE Examples

• *Trestle Bay located on the lower Columbia River on the Oregon side:* A railroad trestle was constructed here to repair the jetty in the early 1900s. In 1995 working with the State of Oregon, the Parks Department looked at breaching that trestle and opening up about 600 acres of inner-tidal and sub-tidal habitat to allow movement of fish and other animals as well as export material into the system. The overall cost of the finished project was about $200,000 including planning and construction. One of the things I wanted to mention is that in our cost estimate, I think they assume that we're taking a contractor in and work between 10–14 days because of weather conditions and things like that. He had it done in 3 days. So they said never underestimate the ingenuity of a contractor.

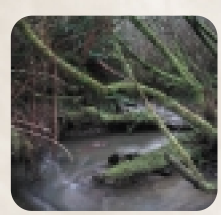
• *Amazon Creek in Eugene*: We've been working on this project with the City of Eugene, Lane County and Bureau of Land Management (BLM). It's been a long ongoing process and in construction for the last year or two. There is an old flood-control channel that goes through there and some side channels. The project is to take some of the levies, set them back, and expose areas to more of a natural flood-plane condition plus restore between 200–400 acres of wet prairie habitat. About 80 miles of geotextile jute fabric was laid in October of 1999. It's probably one of the biggest projects like that seen.

A couple of key features to note: BLM already had some of the lands as did the City of Eugene. The value of the lands was about $1.2 million. If they had to acquire the lands, that would have been the end of the project. Also in the planning and design phase, we did not have good survey data. We used aerial surveys and when we went to do excavation, the lands were lower than we thought. This is a complicating factor because we had another wetlands project going on at Fern Ridge near Eugene and we were taking barrow material over to Fern Ridge to do ponds over there and suddenly we had less material than we estimated.

Therefore a miscalculation on one project has an impact on another—a real argument for good survey data.

We also need good people on the site during construction. During the first year I don't think we had an ecologist. Also, one of the key things here was planting and seeds. Native seeds can be a very expensive proposition: one has to think about the timing of where the material is coming from and who's going to grow it. It's very expensive to have nursery folks doing that, and you've got to make sure you've got it when you need it.

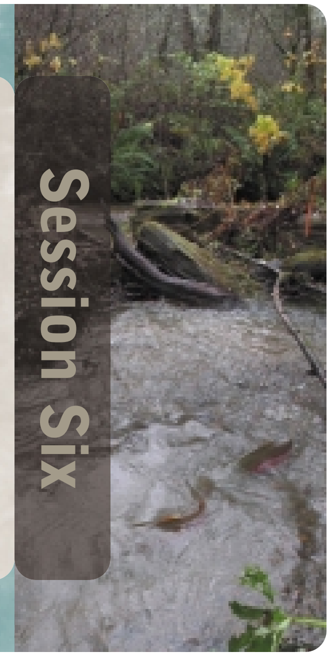
One last issue on this project: monitoring. In our cost estimate, we had $150,000 for three years for the hydrology aspects of monitoring and then we also had $200,000 for five years for monitoring the wetlands. That's being managed by the City of Eugene and BLM.



Wetland creation and restoration

Estimating Wetland Restoration Costs at an Urban and Regional Scale: The San Francisco Bay Estuary Example

JOHN STEERE
San Francisco Bay Joint Venture
1330 Broadway Ave., Suite 1100
Oakland, CA 94612
jsteere@igc.org



ABSTRACT

The considerations in and difficulties of estimating wetland restoration and costs are discussed, with examples drawn from the Implementation Strategy of the San Francisco Bay Joint Venture (SFBJV).

INTRODUCTION

Cost estimations for wetland restoration, particularly in urban areas, are complex and controversial, given the many human and natural constraints. In conducting cost estimations, the construction elements of a restoration project and knowledge of the site conditions necessary are used to meet ecological targets and to address site constraints. The most expensive cost factors tend to be the design accommodations that must be made for co-existing or adjacent land uses and infrastructure, as these overlapping human uses present constraints that must addressed. As a result, making cost estimates for wetland restoration projects, particularly in more urban settings, can be problematic. While estimates can be made, they have great variability, and some practitioners believe that attempting to make them on the basis of "per acre restored" or "per cubic yard of earth moved" are at best inadequate and at worst misleading (Jasper Lament, Ducks Unlimited).

Just how problematic such general cost estimation can be is shown by site-specific factors that affect construction logistics. These are at once critical and highly variable. Among the most variable of the factors are soil contaminants and access issues. For example, contamination raises the prospect that soils will have to be removed from the site, a process that can cost 10–50 times that of on-site relocation; in addition, consultation fees and chemical testing can almost equal the cost of soil removal. Regarding access, whether it's by road or barge makes a great difference, since transportation costs will be far greater if it's the latter. Levee layout can either promote or discourage site access. Other variables that make standard cost estimation problematic include climatic conditions (wet versus dry weather—with wet markedly increasing costs), local market conditions, contractor competition, and oil prices. All of these have a significant and indeterminate impact. As a result, levee construction can vary from $1/cubic yard to well over $100/cubic yard, depending on the project.

In light of this difficulty in making realistic estimations, I could conclude this paper here. Nevertheless, it is worthwhile to focus on the design factors and outline the site variables and constraints that drive cost estimates for wetlands restoration and construction in urban settings like the San Francisco Bay Area.

COST ESTIMATION

The level of specificity in a cost estimate is largely a function of how far along the restoration effort is in the design process. First estimations are referred to as "engineer's estimates" and tend to have high uncertainty due to the lack of knowledge about site conditions and the lack of specificity of a conceptual design. In some cases, there may be several design alternatives. "Contractor's estimates" should be solicited when the design is largely complete, since they tend to be more detailed and site-responsive.

Wetland restoration costs can vary widely and are largely determined by the land uses adjoining the wetlands, with a secondary factor being the target wetland type to be restored — seasonal/freshwater, tidal, mudflat, vernal pool complex, and moist grassland being the major types in the Bay Area. The simplest restoration projects can cost as little as $1,000 per acre, while more complex tidal wetland restorations can cost $100,000 or more per acre. According to the Goals Project, most projects will be in the "range of $10,000 to $20,000 per acre" (Goals Project 1999, p. 173). The *Estuary* newsletter pegs it higher: "In the restoration trade, word is that average costs are $20,000 to $30,000 per acre" (Anon. 1995, p. 1). No matter what unit estimate is employed, a rule of thumb is that 80% of costs tend to be for construction-related activities while the remaining 20% are attributable to permitting, planning, and engineering costs.

The following is an enumeration of the physical factors involved in "typical" tidal marsh construction and the average cost estimates associated with them:[1]

Construction

- Quantities of excavation or earthwork (average around $2/cubic yard)
- Access road construction ($100–200/linear foot)
- Clearing and grubbing ($1,500/acre)
- Grading ($1–50/cubic yard)
- Soil Disposal on-site (up to $1/cubic yard) vs. off-site ($10–50/cubic yard)
- Dike breaching (usually one to three)
- Number and types of permanent or temporary weirs, pumps or other controls
- Levee repair ($5–6/linear foot)
- New dike/levee construction ($30/linear foot)
- [optional] Security fences and patrols ($5–50/linear foot for materials)

Planting and Planning

- Hydro-seeding levees (about $1,000/acre)
- Planting of low marsh (LLT to MHT); tidal marsh is not generally needed
- Planting of high marsh (above MHT: $0.30 to $4/plug, depending on plant size)
- Irrigation (seasonal for first 3–5 years)
- Planning Permitting & Engineering (PP&E) can comprise up to 25% of construction cost (e.g., an $800,000 construction bill could result in $200,000 in PP&E costs).

Site Constraints

Cost estimates will vary greatly, especially according to site constraints, which can

1- Many of the cost factors and constraints noted in this section were provided by Stuart Siegel, a practicing wetland ecologist with significant experience in tidal wetland restoration in the Bay Area. Jeff Haltiner, Roger Leventhal, and John Zentner provided additional background information.

impact costs as well as dictate equipment and construction methods. Here is an accounting of the customary site constraints and considerations:

- Access (existing level of and quality)
- Utilities, levees, and roads that need to be worked around or modified
- Substrate conditions in work areas; moisture content of soil (need for drying)
- Existing hydrologic regime; flood control issues
- Potential for contaminants to be present in work areas
- Size of site measured in area, perimeter, and possibly volume
- Source materials for re-vegetation (on- or off-site)
- Need for on-site staging area for mixing soils or other handling needs
- Public access/security issues (proximity to existing development and parklands)

Construction Steps

Cost estimates for restoration will often break out according to characteristic steps in the construction of a tidal or seasonal wetland project.

Typical steps in wetland restoration project construction:

- Mobilization (contractors bring in materials and equipment)
- Demolition of structures (if needed) and moving utilities (transmission and TV cable lines, etc.)
- Clearing and grubbing (trees and brush)
- Earthwork excavation and grading (removal of up to 6″ of soil)
- Soil preparation
- Planting and irrigation installation
- Demobilization (contractor removes equipment)

Seasonal wetland construction tends to have fewer steps and design/cost factors. These factors include the following:

- Moderate excavation
- Grading ($1–10/cubic yard)
- Clearing and Grubbing
- Number and types of permanent or temporary weirs, pumps, or other controls
- Planting: Native marsh plugs at 2″ centers (10,000 plugs per acre at $0.30/plug — e.g., Baltic rush)

SOME COST ESTIMATION ISSUES

In the following section, five sets of questions that were posed by those who convened the Habitat Restoration Cost Workshop are addressed.

What are the annual maintenance factors and monitoring issues related to restoration projects?

- A management plan should specify the ongoing operations, maintenance, and monitoring needs of the project.
- Annual operations might include adjusting weirs, vegetation and water control structures, mosquito control, predator control, among other activities.
- Maintenance might include lubricating pumps, replacing weir boards, mowing or discing vegetation, repairing small structures, etc.
- Monitoring can range from basic monitoring of site conditions needed to make ongoing operational adjustments to complete performance monitoring and reporting (adaptive management). For large-scale projects, if possible, build a "Monitoring/Management Endowment" of at least 3–5% of the construction budget to finance long-term monitoring.
- Levee maintenance may be minor or considerable, depending on levee construction quality and the underlying soil characteristics

(the greater the level of clay content, the less costly the maintenance involved, generally).

What are the means of addressing different cost categories (e.g., labor, equipment, materials)?

- Labor and equipment, and sometimes materials, can be mixed. For example, for the "earthworks" category, one considers the volume, the operational rate of the equipment to be used, the cost of equipment rental including mobilization, the transit cost of soils to/from the site, site preparation work, and any handling needs. The construction of levees is commonly estimated on a per-linear foot basis.
- Labor costs also include construction oversight and management. These costs are generally calculated on a time unit basis and applied to the total estimated construction time.
- Labor costs can also be considered discretely for things such as re-vegetation, where typically it occurs on a crew basis with few equipment needs.
- Materials costs include whether materials come from on- or off-site, quantities needed, amount of handling necessary to utilize the materials, etc.

How could cost estimates be refined beyond a reasonable first approximation?

1. The uncertainties in cost estimating arise from several factors, including:

   - Limitations in understanding of the site conditions (soils, contaminants, etc.)
   - Degree to which project elements are known and designed
   - Ease or difficulty of site access
   - Regulatory uncertainty with regards to construction limitations
   - Vagaries of contractor bidding in light of overall work availability (busy contractors = higher costs).

2. The more knowledge available about the site, the project details, and the regulatory requirements, the more one can define a project and therefore reduce uncertainty in the estimates.

3. Often a very large part of a project's expense is earthworks, especially soil disposal. There are a number of options for the disposition of soils. The least expensive is leaving them somewhere on-site, such as using them for levee re-construction or in the creation of a bird island. Still relatively inexpensive is using them for a nearby unrelated construction project. The most expensive option is to haul soils off to a landfill for disposal, as this includes increased labor as well as hauling and tipping fees.

How would costs per unit change with increasing scale?

Economies of scale exist with the majority of projects.

- Often a single structure can affect vast areas so only one structure is needed regardless of size.
- Perimeter features, such as flood control levees, have a smaller edge-to-area ratio with increasing size.
- Mobilization and demobilization, equipment and labor costs on a per-unit basis diminish with increasing scale.
- For on-site labor, there is usually a lower learning curve and increasing efficiency the longer the job.
- In some instances, increasing project size fundamentally modifies those design elements that are necessary, which may well eliminate a constraint present in the smaller project size.
- Occasionally, larger projects mean more costs because of increased complexity, greater equipment needs, and a greater

range of construction and monitoring methods.

How would information requirements change at larger project scales?

• Understanding the site becomes that much more critical in order to understand issues such as "constructability" and monitoring ability.

• The larger the site and the greater the complexity of natural and social variables that enter into project design, the greater the need for integration of disciplines and the more comprehensive the background information must be.

REGIONAL COST ESTIMATION AS IT RELATES TO IMPLEMENTING HABITAT GOALS OF SAN FRANCISCO BAY JOINT VENTURE

Let us now apply the described cost factors to a regional wetland restoration initiative that is being coordinated by the San Francisco Bay Joint Venture (SFBJV). The SFBJV is a partnership of public agencies, environmental organizations, the business community, local government, and landowners working cooperatively to protect, restore, increase, and enhance wetlands and riparian habitat in the San Francisco Bay Watershed. The Joint Venture has adopted an incentive-based and ecosystem perspective and is working through its partners to complete on-the-ground habitat projects benefiting waterfowl, fish, and wildlife populations by leveraging resources, developing new funding sources, fostering greater cooperation and communication, and creating partnerships. The SFBJV recently completed its Implementation Strategy, which presents a 20-year concept plan for renewing wetlands and wildlife in the region (SFBJV 2001). Members of SFBJV's management board have approved the plan. The Management Board consists of 27 agencies and private organizations whose members agree to support and promote the goal and objectives of the Joint Venture and who represent the diversity of wetlands interests found in the San Francisco Bay Region (see Figure 1 for complete listing of management board members).

Figure 1. Joint Venture Management Board

Non-Profit and Private Organizations

- Adopt a Watershed
- Bay Area Audubon Council
- Bay Area Open Space Council
- Bay Planning Coalition
- Citizens Committee to Complete the Refuge
- Ducks Unlimited
- National Audubon Society
- PG&E Corporation
- Point Reyes Bird Observatory
- Save San Francisco Bay Association
- Sierra Club
- The Bay Institute
- The Conservation Fund
- Urban Creeks Council

Public Agencies

- Bay Conservation and Development Commission
- California Department of Fish and Game
- Coastal Conservancy
- Coastal Region, Mosquito and Vector
- Control Districts
- National Fish and Wildlife Foundation
- National Marine Fisheries Service
- Natural Resources Conservation Service
- SF Bay Regional Water Quality Control Board
- San Francisco Estuary Project
- US Army Corps of Engineers
- US Fish and Wildlife Service
- Wildlife Conservation Board

Habitat Goals

As the defining feature of the Implementation Strategy, the Joint Venture has developed specific science-based habitat

Table 1: Habitat goals for the San Francisco Bay Joint Venture

Habitats		SFBJV tracked habitat goals (acres)			SFBJV habitat goal categories (acres)[1]		
SFBJV habitat goal categories	SFBJV tracked habitats	Acquire[2]	Restore[2]	Enhance	Acquire[3]	Restore	Enhance
Bay habitats	Tidal marshes	43,000	32,000	20,000	63,000	37,000	35,000
	Tidal Flats	12,000	4,000	6,000			
	Lagoons	1,500	50	1,500			
	Beaches	113	60	35			
	Salt ponds	6,000	1,000	7,500			
Seasonal wetlands	Diked wetlands	16,000	6,000	12,000	37,000	7,000	23,000
	Grasslands and assoc. wetlands	21,000	1,000	11,500			
Creeks and lakes	Lakes	3,000	1,000	6,000	7,000	5,000	22,000
	Creeks and riparian zones	4,000	4,000	16,000			

goals for wetlands that its partners will seek to accomplish over a 20-year period. A total of 260,000 acres of wetlands and creeks will be acquired and/or restored or enhanced within this planning horizon. These habitat goals are divided among three categories: bay habitats, seasonal wetlands, and creeks and lakes. Each category represents a group of habitats, (e.g. "bay habitats" consist of tidal flats and tidal wetlands, salt ponds, beaches and lagoons), as shown in Table 1.

The basis for the habitat goals are as follows:

• *Tidal marsh:* Based upon Regional Habitat Goals Project historical and modern tidal marsh coverage, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Tidal flat:* Based upon Regional Habitat Goals Project historical and modern tidal flat coverages, estimate of currently protected lands, assessment of required shorebird support, and estimate of potential 20-year accomplishments.

• *Lagoon:* Based upon Regional Habitat Goals Project historical and modern lagoon coverages, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments. Goal for restoration refers to natural lagoon-beach complexes.

• *Beach:* Based upon Regional Habitat Goals Project historical and modern beach coverages, estimate of currently protected lands, narrative recommendations of Goals Project, and estimate of potential 20-year accomplishments.

• *Salt pond:* Based upon Regional Habitat Goals Project historical and modern salt pond coverages, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Diked wetlands:* Based upon Regional Habitat Goals Project historical and modern diked wetland and storage/treatment pond coverages, Goals Project regional ecological goals, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Grasslands and associated wetlands:* Based upon Regional Habitat Goals Project historical and modern moist grassland and grassland/vernal pool complex coverages, Goals Project regional ecological goals for Agricultural Baylands, goal of no net loss of existing moist grassland and grassland/vernal pool complexes, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Lakes:* Based upon Regional Habitat Goals Project historical perennial pond coverages, modern mapping by National Wetlands Inventory, estimate of currently protected lands, and estimate of potential 20-year accomplishments.

• *Creek and riparian zones:* Based on estimates of historical amount of natural creek channel using the Regional Habitat Goals Project historical rivers and creeks coverage. Estimated from existing channels.

Cost Estimation

A cumulative cost summary for this set of collective habitat goals has been identified and is illustrated in Table 2. *This summary should not be seen as a rigid economic analysis but rather a set of basic preliminary cost estimates provided to assist the Joint Venture partners in grasping the financial commitment needed to reach the goals. No attempt was made to adjust costs for inflation over the 20-year project period. However, just as some costs will increase due to inflation and other unforeseen factors, other costs can also be reduced through economies of scale for large restoration projects that will inevitably be initiated.*

Cost considerations include the following:

• *Tidal wetland restoration:* The San Francisco Bay Joint Venture chose to use a conservative average of $5,000/acre for region-wide tidal wetlands restoration cost estimation, which assumes relatively large-scale restoration projects (John Zentner, Zenter and Zentner). This rate incorporates a conservative level of permitting, planning, and engineering costs. However, this estimate does not account for variations caused by sediment removal and re-grading. If these factors are included, as with larger, more complicated tidal restoration projects, the costs can increase to $100,000/acre (Jeff Haltiner, Philip Williams Associates)

• *Seasonal wetlands:* A typical estimated cost for seasonal wetland restoration is $900,000 per 100 acres. It is important to note that this figure represents a large-scale restoration. A simple reduction to cost per acre would not account for the effects of economies of scale. This figure includes such services as excavation, re-vegetation, permitting, planning, and engineering. PP&E, as with tidal wetlands, is about 20% of total cost, which also includes for five years of management monitoring.

• *Creeks and lake habitat:* The estimated cost of creek and lake habitat restoration is fairly complex and ranges from $20,000/acre to $52,500/acre. The primary consideration is the habitat's location within the Joint Venture's geographic scope. A project's location describes an approximate level of development, which in turn specifies the possible

Table 2. San Francisco Bay Joint Venture wetland habitat costs (in millions) by subregion

Subregions	Bay habitats		Seasonal wetlands		Creeks and lakes		Total by subregion	
	20 yrs	Annual	20 yrs	Annual	20 yrs	Annual	20 yrs	Annual
Suisun Subregion								
Acquire	15.000	0.750	55.000	2.750	-	-	70.000	3.500
Restore	10.000	0.500	9.000	0.450	40.000	2.000	59.000	2.950
Enhance	2.000	0.100	6.000	0.300	80.000	4.000	88.000	4.400
North Bay Subregion								
Acquire	115.000	5.750	90.000	4.500	-	-	205.000	10.250
Restore	75.000	3.750	36.000	1.800	20.000	1.000	131.000	6.550
Enhance	13.000	0.650	12.000	0.600	40.000	2.000	65.000	3.250
Central Bay Subregion								
Acquire	45.000	2.250	5.000	0.250	-	-	50.000	2.500
Restore	20.000	1.000	0.000	0.000	52.500	2.635	72.500	3.625
Enhance	4.000	0.200	1.000	0.050	157.500	7.875	162.500	8.125
South Bay Subregion								
Acquire	1401.000	7.000	35.000	1.750	-	-	175.000	8.750
Restore	80.000	4.000	9.000	0.450	92.000	4.600	181.000	9.050
Enhance	421.000	2.100	4.000	0.200	253.000	12.650	299.00	14.950
San Francisco/San Mateo Coast[2]								
Acquire	TBD	-	TBD	-	-	-	TBD	-
Restore	TBD	-	TBD	-	60.000	3.000	60.000	3.000
Enhance	TBD	-	TBD	-	50.000	2.500	50.000	2.500
Total costs by type	561.000	28.050	262.000	13.100	845.000	42.250	1668.000	83.400
Monitoring = extra 3%	577.800	28.890	269.900	13.490	870.350	43.520	1718.000	85.900

If the 3% "monitoring endowment rule" were applied to the estimates in the table, the total cost for the Implementation Strategy rises by $50 million to approximately $1,718,000,000.

project width. Two riparian corridor widths were used: 1) 40 meters for all riparian zones in rural and suburban areas, and 2) 50 feet for urban riparian corridors. The wider corridor was assumed for all of the North Bay and Suisun subregions and for one half of the South Bay and San Francisco/San Mateo subregions. The 50-ft. corridor was also used for half of the South Bay and San Francisco/San Mateo subregions and all of the highly urbanized Central Bay subregion.

• *Wetland enhancement:* The estimated cost for enhancement of bay habitat and seasonal wetlands is estimated to be \$1,000/acre. This rate remains constant regardless of location within the Bay and includes such individual costs as re-vegetation, exotic species removal, limited irrigation, and modest management. The process of calculating enhancement costs for creek habitat is comparable to restoration estimates in their complexity. The same considerations of location, corresponding levels of development, and riparian corridor are accounted for in the estimated averages for enhancement. Creek enhancement is assumed to include such services as native re-vegetation and exotics removal, maintenance of existing channel meanders, bank stabilization, and erosion control. Factors that can add to the general cost of a project such as earth moving, extensive irrigation, and long-term management are not included.

• *Monitoring:* While long-term monitoring is an essential component of any restoration and enhancement project, it was not factored into the projections shown in the Table 2. Monitoring varies individually from project to project. One method of approximating the cost of long-term monitoring uses a cost per acre per number of years (e.g., \$550/acre for five years). Another common method is to create a long-term "monitoring endowment" from an equivalent of 3% of the construction costs.

Cost Summary

The total cost of accomplishing the habitat goals contained in the SFBJV Implementation Strategy is roughly *\$1,668,000,000 or \$83,400,000/year* for 20 years without monitoring. Table 2 shows the summary goals for the Bay Area divided into specific cost objectives for each of the five subregions of the SFBJV.

The average rates for unit costs of acquisition, restoration, and enhancement projects for each of the three habitat categories within each subregion are displayed in Table 3 (next page). These computations reflect a conservative estimate for construction costs and were reviewed by resource managers and scientists with extensive experience in restoration and enhancement.

CONCLUSION

The Joint Venture's habitat goals presented in its Implementation Strategy offer a dramatic vision of more than doubling the existing tidal wetlands and more than tripling the riparian habitats that ring the Bay through restoration and enhancement. Identifying rough costs for acquiring, improving, and rehabilitating the Bay Area's natural legacy is an exercise in helping the SFBJV's partners understand the magnitude of their undertaking. The estimated \$1.7 billion price tag for this vision is very conservative; if one uses a less conservative figure of \$20,000/acre for tidal wetland restoration, the total rises to about *\$3.8 billion* for accomplishing the Joint Venture's long-term habitat goals for the region.

Whether one looks at the factors and constraints that underlie the intent to set individual estimates for tidal and seasonal wetland restoration, as we evaluated at the outset of this presentation, or steps back and identifies very general estimates at a regional level for restoration of the Estuary, what links both is the principle that such

Table 3. Average cost rates for the SF Bay Joint Venture Implementation Strategy

	Bay habitats	Seasonal wetlands	Creeks and lakes
Suisun Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$40,000 per acre
Enhance	$1,000 per acre	$1,000 per acre	$20,000 per acre
North Bay Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$20,000 per acre
Enhance	$1,000 per acre	$1,000 per acre	$10,000 per acre
Central Bay Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$52,500 per acre
Enhance	$1,000 per acre	$1,000 per acre	$26,000 per acre
South Bay Subregion			
Acquire	$5,000 per acre	$5,000 per acre	ND[2]
Restore	$5,000 per acre	$900,000 per 100 acres	$46,000 per acre
Enhance	$1,000 per acre	$1,000 per acre	$23,000 per acre
San Francisco/San Mateo Coast[1]			
Acquire	TBD	TBD	ND[2]
Restore	TBD	TBD	$20,000 per acre
Enhance	TBD	TBD	$10,000 per acre

Source: SFBJV (1999)

1- The San Francisco/San Mateo wetlands acreage appears as TBD("To Be Determined") since they have not been estimated. This subregion was not part of the *Habitat Goals*.

2- ND = Not Determined. Costs for riparian acquisition are too variable; it was also assumed for the sake of practicality that protection strategies focus on conservation easements for riparian buffers, which can be procured without cost in some instances.

efforts require a dedication that is interdisciplinary, collaborative and unflagging. The high costs are not meant to be daunting but rather indicative of the collective commitment necessary to realize this biologically renewing vision of the SF Bay Region.

While experts offer diverse, if not divergent, advice on the costs of wetland restoration, it's important to realize that more money may not necessarily translate into better wetland projects, contrary to popular belief. As noted wetland expert Carl Wilcox of the California Department of Fish and Game remarked, "Most of the best restorations aren't engineered. You can engineer them to death, but you're still better served by just creating a simple template and letting natural processes takes over." Whatever the enticement of revising nature to meet our interests, looking for the solutions that are elegant and work with nature are usually the best.

LITERATURE CITED

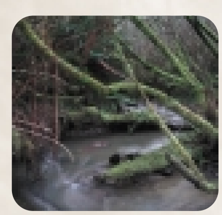
Anonymous. Apr. 1995. What price restoration? *Estuary*, p.1.

Goals Project. 1999. *Baylands Ecosystem Habitat Goals*. A report of habitat recommendations prepared by the San Francisco Bay Area Wetlands Ecosystem Goals Project, U.S. Environmental Protection Agency, San Francisco, Calif./S.F. Bay Regional Water Quality Control Board, Oakland, Calif.

San Francisco Bay Joint Venture. 2001. *Restoring the Estuary: An Implementation Strategy for the SF Bay Joint Venture*.

ACKNOWLEDGEMENTS

Additional information contributed by:
Stuart Siegel, Restoration Ecologist
Roger Leventhal, Consulting Engineer
Jeff Haltiner, Principal Hydrologist
Philip Williams Associates



Workshop Conclusions and Recommendations

CINDY THOMSON
National Marine Fisheries Service
Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060
cindy.thomson@noaa.gov

INTRODUCTION

Participants at the Salmon Habitat Restoration Cost Workshop provided thoughtful insights into many aspects of habitat restoration. This paper is an attempt to synthesize some common themes from the presentations as they relate to the three overall topics of the workshop: estimating restoration costs at the individual project level, feasibility of extrapolating project-level costs to larger geographic scales, and types of data needed to do such extrapolation. The paper concludes with a summary of workshop recommendations.

RESTORATION COSTS IN THE LARGER CONTEXT OF HABITAT RESTORATION ECONOMICS

Huppert describes various types of economic analyses that can be used to evaluate trade-offs associated with habitat restoration. *Cost analysis* is used to estimate the value of resources foregone to accomplish a particular activity (e.g., a restoration project or program). *Cost-effectiveness analysis* is used to evaluate restoration activities in terms of cost per unit of effectiveness, that is, to determine which activities provide the "biggest bang for the buck"; this type of analysis requires that all projects be characterized according to a common unit of effectiveness. *Benefit-cost analysis* is used to evaluate activities in terms of the relative size of benefits and costs; benefits and costs must be expressed in common units (i.e., dollars) in order to conduct this type of analysis. *Economic impact analysis* is used to estimate effects of restoration activities on income and employment in local economies. Huppert also clarifies the concept of "opportunity cost" as used in economic analysis to include the value of goods and services foregone in order to achieve restoration.[1] Based on this concept, restoration costs include not only direct expenditures but also (for instance) the value of crops foregone to increase instream flow. Huppert's paper thus provides a larger economic context for the workshop, which focused on the complexities associated with one component of economic costs, namely, direct restoration expenditures.[2]

1- Opportunity costs are similarly incurred if restoration is foregone. As noted by Rectenwald, "...hidden costs that can be substantial from a biological perspective are delayed restoration actions due to lack of decision making ability, controversy and/or litigation. Some of the species in the watersheds have such low population levels that they do not have much time to begin recovery so they can exist in the future" (p. 205).

PROVIDING A COMPARABLE COST BASIS FOR EVALUATING RESTORATION PROJECTS

It is important that restoration project costs be evaluated in a comprehensive and comparable manner (see Huppert, Wellman, Weaver/Hagans, Neal, Hayes, Hudson). For instance, cost analysis should ideally include all costs incurred over the life cycle of a project. Multi-year costs should be corrected for inflation to the same year and an appropriate discount rate applied to annual cost estimates. In comparing costs across projects, it is important to consider whether data on comparable cost elements are available for each project and whether the projects were designed to meet similar standards of what constitutes restoration.

Meaningful comparisons of project costs are often difficult to achieve, for a number of practical reasons.

Difficulty of obtaining data on actual costs: Wellman's systematic evaluation of 47 restoration projects (which revealed some significant differences between estimated and actual costs) suggests that cost comparisons across projects are best done on the basis of actual costs. However, as indicated by Carlson/Allen's experiences with the California Habitat Restoration Project Database, cost estimates included in project proposals are often more readily available than data on actual costs incurred. Records of actual costs (e.g., from invoices or final reports) are not always maintained in a complete or consistent manner and can be difficult to reconstruct, especially if records are kept in paper rather than electronic files.

Accounting practices: Not all costs associated with procurement of funding, planning, design, permitting, public outreach, contract administration, construction supervision, maintenance and monitoring are necessarily billed to the project. Even in cases where such services are billed to the project, applicable overhead rates and the types of costs covered by those overhead rates may vary, due to differences in financial accounting practices among administrative entities.

Spending caps: Some of the differences in project costs may be attributable to different constraints imposed by project sponsors. For instance, it is not uncommon for sponsors to cap the amount of money that can be spent on particular aspects of a project. Given the strong incentive to get projects on the ground, it is more typical for planning, design, maintenance and/or monitoring costs to be capped than construction costs.[3]

Multiple funding sources: Some projects have multiple funding sources. While individual sponsors typically monitor the costs associated with their own share of a project, they do not necessarily have information on the costs covered by other co-sponsors. In such situations, it may be difficult to determine the total cost of the project, due to the difficulty of piecing together cost information from the various co-sponsors (see Carlson/Allen).

Allocating costs among projects: Some contracts cover a mix of fairly discrete restoration activities (e.g., restoration at multiple sites). Putting diverse projects under the umbrella of a single contract is often cost-effective and administratively efficient. However, it also complicates attempts to allocate contract costs among projects, particularly if the costs reported on contract invoices are lumped in such a way as to

2- Huppert is aware of the limitations as well as strengths of economics. As he notes, "Social values, pre-existing commitments, and property rights often preclude or limit the role of economic information in decisions. There are over-arching social and ethical considerations in some cases that overshadow economic consequences and make economic information less crucial to public decisions" (p. 24).

3- For instance, the California Department of Fish and Game's Fishery Restoration Grants Program caps road inventory and assessment costs at $1,200 per mile (see Weaver/Hagans) and equipment purchase at $5,000 (see Bell). Neal notes that capital construction projects undertaken in King County are capped at $70,000. According to Obradovich, the Army Corps of Engineers caps land acquisition at 25%, monitoring at 1% and adaptive management at 3% of total project costs.

effectively preclude any practical attempt at cost allocation (see Carlson/Allen).

Treatment of in-kind contributions: Restoration projects often involve in-kind contributions by watershed councils and other groups that mobilize public participation. While it is important that such contributions be recognized as part of project costs, determining the extent of in-kind work and imputing a value to it is not always easily done.

Making within-category cost comparisons: Even in cases where projects are similar in terms of restoration requirements and total costs, differences in contract incentives or restoration strategies can affect how expenditures are distributed across cost categories. For instance, contractors who are allowed to recover some of their mobilization costs up front may bid mobilization higher and construction lower than contractors who are not given this option. Another example pertains to the division of expenditures between labor and equipment on revegetation projects, which may depend on whether the work is done mechanically or by hand crews.

FACTORS AFFECTING RESTORATION STRATEGIES AND COSTS

While disparities in accounting practices can create apparent cost differences among projects, costs are also affected in substantive ways by site-specific factors and institutional constraints. The following is a brief description of major cost factors identified by workshop participants. While the specific effects of each factor vary from project to project, all of the factors are universal in terms of their potential applicability to the various types of restoration activities discussed at the workshop.

Project Objective

Restoration strategies and associated costs vary among projects, depending on the objective. For instance, Jani identifies several potential reasons for repairing stream crossings (i.e., recover salmonids, protect other aquatic species, meet Environmental Protection Agency standards for Total Maximum Daily Loads). Weaver/Hagans note the importance of distinguishing between road restoration that facilitates salmonid recovery by reducing sediment delivery versus road improvements that enhance transportation. Coffin notes that road decommissioning can mean different things to different people (e.g., road closure, elimination of slope stability problems, complete topographic obliteration of the road).

Workshop participants emphasize the importance of diagnosing site-specific problems in the context of the watershed in which they occur. This requires careful consideration of the interconnectedness of the site with the watershed (see Weaver/Hagans, Cocke, Bell, Neal, Rectenwald). Site-specific considerations pertain not only to current conditions but also expected future conditions at the site. For instance, Weaver/Hagans point out the importance of "forward looking" sediment inventories that anticipate future road problems rather than merely document historic problems. Jani suggests rolling dips as a suitable low-cost alternative to cross drains for directing runoff from roads that are not expected to be used year-round. Cocke describes erosion control measures at a bridge implemented in anticipation of increased traffic associated with nearby subdivision development. Bell points out the limited utility of instream restoration in areas that are expected to be clear cut in the near future. Hayes notes the importance of designing Central Valley fish screens to handle significant debris loads under a wide variety of flow conditions.

Project Design Standards

In many cases, Federal and State agencies provide design standards for restoration activities that fall under their jurisdiction. Additionally, a number of government and non-government entities have produced habitat restoration manuals and cost guidelines that facilitate the work of restoration practitioners. Workshop participants provide numerous examples of design standards. For instance, Shaw notes that restoration done by conservation districts must comply with Natural Resources Conservation Service design standards. Dupont notes that stream crossings must typically be designed to withstand 50- to 100-year peak flow events. The stringency of design standards and the strictness with which they are enforced can have a significant effect on the restoration strategy chosen and associated costs. For instance, Hayes and Hudson point out that National Marine Fisheries Service design standards for fish screens have had a significant effect on the cost and feasibility of screening projects.

Project Size and Complexity

Project size can be defined in a variety of ways. For road projects, costs generally increase with the number of road miles and stream crossings treated, and also with the volume of sediment and the number and size of culverts that must be removed (see Coffin, Weaver/Hagans). Restoration costs in riparian areas increase with the number of acres requiring revegetation or number of miles requiring fencing. Channel size can affect stream restoration costs in terms of planning, design and heavy equipment requirements, and the number, size and complexity of materials (e.g., logs, boulders, bank barbs) required to do the job (see Shaw, Bair, Bell, Neal). Fish screening costs are affected by the size of the diversion being screened (see Hayes, Hudson). Wetland restoration costs increase with the size of the project (size often being related to design requirements) and the volume of soil being moved (see Bonsignore/Liske, Obradovich, Steere).

While larger restoration projects generally cost more than smaller ones, costs may increase less than proportionately with the size of the project (see Wellman, Coffin, Weaver/Hagans, Bair, Hudson, Kepshire, Steere). Materials may be discounted and contractors may be willing to work at lower rates because of the increased job security associated with larger contracts. Mobilization costs, as well as overhead and administrative costs, may also be subject to economies of scale. Large-scale projects may become more cost-effective as construction crews become more familiar and proficient with work requirements. Design requirements may not be proportional to the size of the project. For instance, Kepshire notes that, while fish screen costs tend to increase with the flow rate (measured in cubic feet per second, CFS) that the screen is intended to accommodate, the cost per CFS tends to decrease with project size. Steere points out that doubling wetland acreage does not necessarily require doubling the number of wetland structures (e.g., pumps), as such structures often provide good wetland functioning for a range of wetland sizes.

On the other hand, large or complex restoration projects also pose significant challenges (see Rectenwald, Bonsignore/Liske, Obradovich, Steere). Information, planning and consultation requirements tend to increase with size and complexity. Complex projects that extend over a prolonged period may require exceptional persistence to ensure that the project does not lose momentum or get sidetracked from its ultimate objective. Obtaining a complete cost accounting of such projects is likely to be challenging, particularly if extensive consultation among multiple parties is required in the planning phase.

Availability of Materials, Equipment and Labor

Availability of materials, equipment and labor varies with local conditions (see Shaw, Coffin, Jani, Bair, Cocke, Neal, Bonsignore/Liske, Obradovich, Steere). A requirement to revegetate riparian or wetland areas with native plant stock may be difficult to meet, depending on the availability of such materials in their natural settings and the cost of obtaining adequate stocks from nurseries. Appropriate soils to build wetland structures may need to be imported if they are unavailable at the restoration site. Heavy equipment may not be readily available in some forest areas due, for instance, to the decline of the construction infrastructure that once supported the logging industry. Changes in forest practices have reduced the amount of woody debris available for restoration, and considerable time and effort may be required to stockpile an adequate supply of wood for a project (e.g., by salvaging trees downed by storms). Restoration practitioners often seek "recycling" opportunities — e.g., salvaging culverts, soil or rock from one project for use on another project; transforming soil excavated at wetland sites into levies or bird islands — as a way to cut costs.

Availability is also a matter of timing (see Shaw, Cocke, Steere). When the local economy is strong or in the aftermath of events such as fire or flood, competition for construction contractors tends to bid up equipment rental and labor rates and result in higher bids on restoration projects. Costs may also exhibit a seasonal pattern, with restoration projects costing less at the beginning of the construction season, when contractors are more eager to obtain work, than at the end, when the availability of contractors tends to dwindle.

Skill and Experience

Skill and experience of personnel are critically important in all phases of a project (see Wellman, Shaw, Jani, Weaver/Hagans, Cocke, Bell, Neal, Obradovich). Cost-effectiveness is greatly enhanced by sound advice in the assessment and design phase, competent and attentive construction supervision, and crews who are skilled equipment operators, know the local area and have prior experience with similar projects.[4] Competent work in one phase of a project enhances performance in other phases. Thus, for instance, competent planning reduces the likelihood of problems in the construction phase; capable construction crews require less supervision than inexperienced ones. Depending on the nature of the work, Conservation Corps, Americorps, and volunteer programs (including local watershed groups) may be cost-effective sources of labor.

Site Accessibility

Legal or physical impediments may need to be addressed in order to obtain access to the restoration site.

Legal Access

The legal right to conduct restoration may need to be secured by measures such as zoning, purchase of land or easements (see Wellman, Shaw, Neal, Hudson, Rectenwald, Obradovich). The cost of land is affected not only by the initial purchase price but also by any long term commitments (e.g., property taxes) that may accompany the purchase.[5] Easement costs are affected by the duration of the easement and by whether the intent is merely to secure access or to impose additional restrictions (e.g., preclude future development in the easement). Access in developed areas may require consultation with multiple parties. Neal, for example, notes that, in King County, permission must be obtained from the majority of homeowners in a subdivision in order to construct a riparian corridor set aside as part of the subdivision. Access can pertain to water as well as terrestrial rights. For instance, Rectenwald describes a dam removal project

4- Jani provides a particularly vivid picture of the role of skill and ingenuity in developing cost-effective solutions to difficult restoration problems. See, for instance, his description of how to install a bridge when equipment can be positioned on only one side of the stream and the area is inaccessible to a crane.

5- According to Shaw, this is not an issue for Federal entities, which are exempt from State and local property taxes.

in California's Central Valley that involved an exchange of water rights. Depending on the nature and complexity of the issues involved, staff time (including lawyers) needed to conduct negotiations and complete transactions regarding access issues may be considerable.

Physical Access

Addressing impediments to physical access can have a significant effect on costs (see Shaw, Coffin, Jani, Weaver/Hagans, Bair, Bell, Neal, Rectenwald, Bonsignore/Liske, Obradovich, Steere). For instance, roads that are abandoned, overgrown or washed out are harder to access than open roads. Wetland sites that are waterlogged or covered with weeds are harder to survey and work than dry open sites. Costs of getting equipment, materials (e.g., rocks, logs, soil, plants, culverts) and work crews to and from the restoration site vary widely, depending on the nature of what is being transported, distances traveled, difficulties associated with the transportation mode or route, and access conditions at the site itself. For instance, the cost and inconvenience of transporting woody debris may be minimal if such material is available near the restoration site, but increases significantly if a helicopter is needed to transport the material to a remote site.[6] Costs increase if construction, improvement or clearing of roads is required to gain access to a site, particularly if those roads then have to be decommissioned once the restoration is done. Costs associated with wetland restoration can be significantly higher if materials must be transported by barge instead of by land. In many cases, materials (e.g., excavated dirt, old culverts) must also be transported from the restoration site to a disposal site. Disposal costs can be particularly high if the materials removed are contaminated and must be treated or taken to specialized disposal sites.[7]

Other Site Characteristics

In addition to access, a variety of other site-specific factors also affect restoration strategies and costs. The following are examples of some of the more common factors cited by workshop participants. Many of these examples also serve to illustrate the contrasting strategies used in different landscapes and the role of professional judgment in dealing with local requirements and work conditions.

Road restoration — Landscape features can have a significant effect on road restoration costs (see Coffin, Dupont, Jani, Weaver/Hagans). For instance, road surface characteristics, stream crossing frequency, slope stability and number/size/depth of culverts are important cost factors. Work on public roads is generally subject to more stringent engineering and safety requirements than work on private roads. Restoration strategies vary, depending on the larger context in which they occur. For instance, culverts are commonly used at stream crossings in Idaho. However, flashing streams and heavy sedimentation in the northern California coastal mountains result in a high rate of culvert failure and therefore greater reliance on options such as rock armor crossings and railroad flatcar bridges.

Instream restoration — Instream treatment costs (see Shaw, Cocke, Bell, Lacy, Neal) depend on factors such as channel characteristics (e.g, depth, velocity, substrate, gradient), specialized

6- In some cases, helicopter use may also involve dealing with restrictions on flyovers around houses and power transmission lines.

7- Rectenwald provides a particularly compelling example of disposal of mercury-contaminated sediments at a dam removal site, which was conducted in accordance with Clean Water Act permit requirements. The work included core sampling of the reservoir, dewatering the sediments to prevent the release of contaminated water, and disposal of sediments and dewatering effluent. The contractor hired to carry out the work was required to be licensed to handle hazardous wastes. One of the legal agreements made between the agencies and the dam owner to implement terms of the restoration included a requirement for environmental insurance for mercury contamination.

equipment and material requirements, and whether the stream must be temporarily diverted around the work area. One treatment strategy is to introduce unanchored trees and boulders into the stream and allow nature to take its course. Another more engineered approach utilizes artificially anchored woody material and boulders. The latter approach involves more intensive use of hand crews and higher maintenance but is more commonly used, particularly in areas such as urban streams.

Revegetation — Revegetation costs can be significantly affected by irrigation and other requirements (see Shaw, Bair, Cocke, Neal, Steere). Irrigation costs depend on the availability of a nearby water source and the size of the irrigation system, as well as the period of time over which irrigation is needed. Costs are also affected by the extent to which plantings require protection from predators (e.g., cattle, deer) and the extent of ongoing maintenance needed to control nuisance vegetation (e.g., reed canary grass). Use of mechanized labor for planting is usually more costly than hand labor, but the success rate tends to be higher as well.

Wetland restoration — Wetland restoration strategy (see Bonsignore/Liske, Obradovich, Steere) depends on the type of wetland being created or restored.[8] Adjacent land uses are a significant cost consideration. An assessment (including consideration of soils, topography and hydrology) must be made to determine the suitability of the site for restoration. Availability of water is an important cost consideration; for instance, use of an existing water source and a gravity flow system is much less costly than pumping water to the site. For some projects, it may be necessary to demolish existing structures and/or relocate utility lines from the prospective wetland area. Costs also depend on the scope of the work (e.g., building levees, excavating ponds) and the extent to which maintenance of wetland structures (e.g., weirs, levees, pumps) and ongoing control of invasive plants and/or mosquitoes is needed once the initial work is completed. Costs associated with disposal of excavated soils vary widely, depending on whether the soils can be reused onsite or must be transported elsewhere and whether the soils are contaminated.

Fish screens — Fish screen requirements and costs (see Hayes, Hudson, Kepshire) are affected by issues related to flow rate, debris and sedimentation. Relevant cost factors include screen and screen structure requirements, extent of site preparation, and features such as the power source, cleaning system and backup system. Prefabricated screens that minimize the need for detailed engineering and rely on non-electric power sources (e.g., paddle wheels) are cost-effective options for some small diversions in places like Oregon. Such standardization is less suited to large complex diversions such as those found in California's Central Valley. Routine inspections and reporting requirements are important for identifying problems with screen functionality. Screens that can be retrieved from the water during the non-irrigation season are initially more costly but also have a longer life expectancy and are easier to inspect and maintain. Ease of maintenance affects not only cost but also the incentive to perform maintenance. Fish bypasses should also be monitored to ensure that year-to-year changes in the stream have not rendered them ineffective; bypasses

8- Steere, for instance, categorizes wetlands in San Francisco Bay to include bay habitats (tidal marshes, mudflats, lagoons, beaches, salt ponds), seasonal wetlands (diked wetlands, grasslands and associated wetlands) and creeks and lakes.

are also a useful tool for monitoring the effectiveness of the screen in protecting fish.

Coordination Requirements

Depending on the nature of the project, staff time devoted to planning and design may be significant and costly (see Wellman, Cocke, Neal, Obradovich, Steere). Project planning may require considerable consultation among engineers, geologists, hydrologists, biologists and other experts who can provide an understanding of the local landscape, determine the source of the problem and develop solutions. Wellman, for one, points out that sound planning goes a long way toward preventing cost overruns and delays in completing the construction phase of a project. Coordination may be desirable beyond the needs of a single project. For instance, Hayes cites the benefits of coordination among fish screening programs in California's Central Valley.

Coordination can be particularly time-consuming and costly for projects that are large and complex, require extensive interagency consultation or involve a large number or diversity of interest groups (see Neal, Hudson, Rectenwald, Obradovich, Steere). Interagency coordination may be challenging, as different agencies operate under different mandates and funding constraints, and may have different perceptions regarding what constitutes adequate restoration. While coordination may be costly, it is important to note that some restoration may not be feasible without the support of multiple partners who bring funding, technical expertise or other resources to the project. Coordination provides an opportunity to pool assets and better anticipate and resolve problems that can impede success of the project.

The feasibility and cost of conducting restoration on private lands depend critically on landowner cooperation (see Shaw, Cocke, Neal, Bonsignore/Liske, Obradovich, Steere). Landowners vary widely in the extent of their willingness to participate in restoration activities; cooperation becomes even more uncertain if multiple landowners are involved. A significant amount of staff time may be spent negotiating with landowners and (particularly in urban areas) holding public meetings with homeowner associations and other groups. A restoration project may have unintended effects on adjacent properties, in which case it may be necessary to negotiate with neighboring landowners regarding mitigation of such effects.[9]

Environmental Review, Permitting and Public Input Requirements

Depending on the nature and scope of the restoration, a project may be subject to environmental review and permitting requirements (see Coffin, Bair, Cocke, Neal, Hayes, Rectenwald, Bonsignore/Liske, Obradovich, Steere). For instance, Federal projects are subject to the documentation and public comment requirements of the National Environmental Policy Act (NEPA). States also have statutory requirements for environmental review — e.g., the California Environmental Quality Act (see Cocke), Washington's State Environmental Policy Act (see Neal). In cases where a project may result in "take" of a species listed under the Federal Endangered Species Act (ESA), applicable requirements (e.g., consultation, incidental take permit, habitat conservation plan) must be met. In addition, the Army Corps of Engineers, State resource agencies and some county agencies have permitting requirements for activities that fall within their jurisdiction. One reason for the differences in restoration costs among Federal, State and private lands pertains to differences in review and permitting requirements. The issue becomes further complicated if the restoration occurs on land in mixed ownership, i.e., with different

9- Bonsignore/Liske provide a mitigation example involving construction of levies around a restored wetland area to prevent water from seeping onto neighboring properties. Steere cites the need to accommodate adjacent or co-existing human uses as a major cost consideration in urban wetland restoration projects.

parcels subject to different permitting requirements.

Project review, permitting and consultation activities are important for anticipating and addressing environmental concerns and ensuring adequate opportunity for public input. These requirements may also add significantly to the cost and time required to complete a project, particularly in cases where the project is large in scale, controversial or affects a large number or variety of stakeholders (see Rectenwald). Controversy can arise from any number of sources. For instance, road decommissioning may raise concerns among hikers or other user groups regarding loss of access to a recreational area. Adding woody debris to streams may raise concerns by kayakers. Projects that have the potential to affect a multiplicity of interest groups (e.g., dam removal, urban restoration) may be particularly demanding in terms of environmental documentation and public input. However, while satisfying such requirements may be costly (sometimes even costlier than the restoration itself), inadequate attention to these requirements may increase the likelihood of public opposition or litigation once the project is underway, which is also costly.[10]

Scheduling Issues

Restoration costs are affected by the need to accommodate activities that are going on simultaneously with the restoration (see Wellman, Weaver/Hagans, Bell, Neal, Hayes, Hudson, Obradovich). For instance, construction may be limited to certain hours of the day to alleviate noise concerns. Fish screening projects may be timed to minimize interference with migrating salmon or the irrigation season. Extraordinary weather events may occur that delay completion of the work. Restoration on private land may be interrupted if the landowner decides to temporarily divert equipment to other, higher priority uses. Significant delays between project planning and mobilization may require that the original plans (including environmental documentation) be revisited and perhaps modified before proceeding with implementation. Construction delays associated with delays in obtaining funding, permits or easements may result in scheduling conflicts with other projects and perhaps (in a worst case scenario) postponement of the project until the following season. Regardless of the reason for delays, the resulting downtime can add to the cost of the project. Conversely, scheduling may also be advantageous to a project. For instance, cost savings may occur if restoration can be scheduled to take advantage of heavy equipment that may already be at a site for another purpose, or if restoration at multiple nearby sites can be simultaneously scheduled to ensure efficient use of equipment that will need to be mobilized to do the work.

Contract Versus In-House

An important consideration in restoration planning is whether to conduct the work in-house or under contract (see Hudson, Kepshire). Agency practices in this regard vary widely. For instance, some agencies design their own fish screens and contract out the construction. Others have an in-house "shop" that constructs screens (sometimes according to standardized design criteria), with installation handled either by agency crews or contractors. Screen shops tend to be cost-effective in situations where standardized screen designs have wide applicability.

The choice between conducting restoration in-house or under contract involves consideration of factors such as project cost, project control, project liability and the extent of in-house expertise and resources (see Bair, Cocke, Neal). When construction is contracted out, the project sponsor may incur significant planning and administrative costs associated with project design, review of proposals and contract monitoring. In such cases, the

10- For Federal projects subject to NEPA requirements, one potentially cost-effective strategy is to cover multiple projects in a single NEPA document. Potentially controversial projects, however, should not be bundled in this manner, as controversy regarding any single project can hold up implementation of all the projects covered by the NEPA analysis (see Bair, Cocke).

contractor assumes most of the liability associated with completion of the project.[11] Liability concerns tend to bid the contract price up. When construction is done in-house, plans must be sufficiently detailed to satisfy up-front permitting requirements, but the need for detailed specifications may be somewhat mitigated by the availability of in-house engineering and biological expertise to assist with the project as it progresses. In such cases, the project sponsor assumes the liability associated with project problems and delays. "Intermediate" arrangements are also common, whereby agency staff directs the work of operators and equipment hired on hourly contracts. Hourly contractors are likely to rent equipment on an as-needed basis rather than incur the overhead cost associated with purchase and maintenance of equipment.

FEASIBILITY OF EXTRAPOLATING COSTS FROM INDIVIDUAL PROJECTS TO LARGER GEOGRAPHIC AREA

In order to estimate habitat restoration costs to recover ESA-listed salmonids, it is first necessary to comprehensively evaluate restoration needs (see Huppert, Dupont, Weaver/Hagans, Bair, Cocke). Concerted efforts are being made by government, private sector and local watershed groups to conduct on-the-ground assessments that focus on limiting factors and ways to reduce their influence. These assessments are typically done at the watershed level, as restoration problems are best understood in the context of the watershed in which they occur. However, detailed watershed assessments are being conducted on only a portion of salmon/steelhead habitat. Resources to perform such assessments are limited, and ability to perform such assessments on private lands is often contingent on landowner cooperation. For areas where on-the-ground assessments are not available, it may be necessary to resort to more approximate assessments of restoration needs based on less detailed sources of information. For instance, topographic maps are useful for identifying relevant landscape features, such as the distribution of existing roads and their intersection with stream crossings. It is also important to consider the limitations of topographic maps and other data sources.[12] Developing a comprehensive picture of aggregate salmon/steelhead habitat restoration needs thus requires critical evaluation and synthesis of information of varying quality gathered from many different sources.

Estimating costs associated with addressing aggregate restoration needs is also problematic. Workshop participants (see Coffin, Weaver/Hagans, Bair, Bonsignore/Liske, Steere) emphasize the importance of on-site surveys to ensure that project cost estimates accurately reflect site-specific requirements. However, recovery plans for ESA-listed salmonids will require estimation of aggregate restoration costs associated with multiple projects over an extended geographic area. The infeasibility of developing detailed on-site cost estimates for every such project makes it necessary to consider the possibility of extrapolating the costs of individual restoration projects to a larger geographic scale.

Most of the workshop participants who discussed the feasibility of extrapolation were willing to consider it, though under limited circumstances and with the understanding that such cost estimates would have a large margin of error.[13] Given the

11- For Federally funded projects, an additional cost consideration is the Davis-Bacon Act, which requires construction contractors to pay hired laborers the local prevailing wage rate for work of similar type. Other funding entities may also have similar prevailing wage requirements of their own.

12- For instance, Coffin and Weaver/Hagans note that on-the-ground road surveys frequently reveal the presence of roads that do not appear on existing maps. Hudson and Kepshire note that existing inventories of water diversions may provide good coverage of larger unscreened diversions, but a significant number of smaller diversions are likely to be missing from such inventories; determining ownership and legal status of diversions is also a challenge.

13- Several workshop participants, however, were hesitant to consider extrapolation under any circumstances. With regard to streambank restoration, Bair states, "It is possible, however, that standardized costs estimated for larger areas (watersheds and greater) may never be appropriate, and that working from the individual conditions at each restoration site may be the only way to develop reasonable estimates of project costs" (p. 112). Obradovich notes that "Expanding [wetland] cost estimates to watershed, ESU or state level seems to be an iffy proposition at best" (p. 223). Steere similarly points out that "While estimates [of urban wetland restoration costs] can be made, they have great variability, and some practitioners believe that attempting to make them on the basis of 'per acre restored' or 'per cubic yard of earth moved' are at best inadequate and at worst misleading ..." (p. 225).

sensitivity of restoration costs to site-specific characteristics, they generally recommended that data on project costs be extrapolated only to other projects involving similar work done in the same watershed to address similar problems (see Coffin, Dupont, Weaver/Hagans, Cocke, Hampton, Hudson). Two specific approaches to cost extrapolation consistent with this advice were suggested at the workshop.

Method A: Base cost estimates for a given type of project on recent historical costs for the same type of project in the same watershed.

Method B: Base cost estimates on predictions derived from models that explicitly relate costs to characteristics of the project and the landscape in which it occurs. Two models were presented at the workshop that illustrate this approach:

> Using data on 37 instream restoration projects in north coastal California, Hampton estimates a multiple regression model relating cost per stream mile to stream gradient, number of structures per stream mile and stream length. The overall fit of the model was $r^2=0.46$, with the coefficient on one of the explanatory variables (structures per stream mile) being statistically significant at the 95% level. Hampton cautions that the data used in his analysis did not include complete costs for planning, permitting, monitoring and maintenance.
>
> Hudson uses a sample of fish screen projects in the State of Washington to estimate a model relating project cost to design flow. Three versions of the model were estimated using data on screens designed for flows of 1–15 CFS, 1–58 CFS and 1–210 CFS. Goodness-of-fit was high for all three versions ($r^2 = 0.803$, 0.865 and 0.891 respectively) and was even higher ($r^2 = 0.942$) for a fourth version that was based on proposed rather than actual costs. Hudson also provides interval estimates (±25% of the costs indicated on the cost curves) to reflect uncertainties regarding the comparability of costs across projects.

Specific suggestions made by workshop participants regarding methods A and B — as well as their more general observations regarding the availability and quality of restoration project data and the factors that drive restoration costs — would appear to suggest the following:

> Both methods A and B require cost and location data on individual restoration projects. Available data are not likely to include full life cycle cost information at the individual project level. Thus efforts will need to be made to ensure that the data include at least comparable cost elements across projects, with the expectation that subsequent adjustments to these cost estimates may be required to account for whatever cost elements are missing from the analysis.
>
> Method A involves estimation of watershed-specific statistics such as mean cost per project, and therefore requires that a sufficiently large and representative sample of projects be available for each type of restoration activity in each watershed.[14] In applying method A, it will be desirable to limit the

14- The U.S. Geological Survey (USGS) developed a system of eight-digit hydrologic unit codes (HUCs) to categorize major watersheds in the U.S. according to four classification levels. The first two digits of a HUC classify the U.S. into 21 regions, the second two digits define 222 subregions within the regions, the third two digits define 352 accounting units that nest within or are equivalent to the subregions, and the fourth two digits define 2,149 cataloguing units within the accounting units. Regions, subregions, accounting units and cataloguing units are referred to respectively as 1st, 2nd, 3rd and 4th field HUCs. California is divided into 153 4th field HUCs, Oregon into 92, Washington into 73 and Idaho into 92. There are 368 4th field HUCs in the four states combined (less than the sum of the number in each state, as some HUCs overlap state boundaries), and 294 of these 368 HUCs overlap with one or more salmon/steelhead ESUs.

The Natural Resources Conservation Service (NRCS), in coordination with the USGS, is updating national watershed maps to the 5th and 6th field levels. State-level mapping efforts have been ongoing as well. For instance, California's Interagency Watershed Mapping Committee (IWMC) coordinates changes and enhancements to California's official watershed map (known as Calwater), which delineates the landscape to a sub-watershed level of detail (3,000–10,000 acre areas). The IWMC, which includes State and Federal agencies, is working to ensure that Calwater meets State and Federal mapping standards (see data to recently completed projects to better ensure that the data reflect current design standards and the current state of restoration technology. Depending on data availability, attempts should also be made to further stratify watershed-specific cost estimates on the basis of other relevant cost factors.[15]

Method B involves estimating the relationship of project costs to project and landscape characteristics that are hypothesized to affect costs. Method B thus requires detailed information on the characteristics of restoration projects and the landscape in which they occur. To the extent that available project data include information on project design standards, the model should be specified to capture the effect of changing design standards on costs. However, to the extent that design standard data are not available, it will probably be advisable to include only recently completed projects in the model (as in method A).

In order to link model predictions from method B to specific watersheds, descriptive landscape information will be needed for each watershed corresponding to the types of landscape variables included in the model. Method B is more data intensive but also potentially more informative than Method A, as it quantifies the relationship of project costs to project and landscape characteristics. The success of method B will be contingent not only on data availability but also the performance of the statistical model.

As indicated by workshop participants, extrapolation methods are likely to produce restoration cost estimates with a high margin of error. The particularly strong reservations expressed by two of the wetland experts regarding the feasibility of extrapolation would seem to suggest that wetland restoration requirements are particularly individualistic. Ongoing consultation with restoration practitioners will be advisable in the course of developing aggregate restoration cost estimates for salmon/steelhead recovery plans.

With regard to data requirements, many of the types of project-level data needed to apply methods A and B to restoration activities are being collected in the California Habitat Restoration Project Database (CHRPD) (see Carlson/Allen). The CHRPD is a work in progress and concerted efforts are being made to augment the database with projects originating from a variety of funding sources. Experience to date with the CHRPD suggests a number of ways in which databases maintained by project sponsors can be made more useful for cost analysis. For instance, while information on project location is essential for linking individual projects to their associated landscape characteristics, location information contained in project descriptions are often imprecise. While cost analysis is best done on the basis of actual rather than proposed costs, records of actual costs are not always maintained or reported in a sufficiently detailed manner by project sponsors to be useful for cost analysis. Some standardization of reporting requirements among project sponsors would facilitate cost analysis. Workshop participants developed a list of data elements that address this particular need (Table 1). Some project sponsors already have reporting requirements that closely resemble Table 1; it is important that such requirements be enforced (see Carlson/Allen).

---

http://www.ca.nrcs.usda.gov/wps/calwater/).

In terms of estimating habitat restoration costs at a watershed level, it should be noted that definition of the term "watershed" is somewhat ambiguous and subject to change over time. For instance, 4th field HUCs are sometimes referred to in common usage as "watersheds", although in areas where 5th field subwatershed mapping has been done (e.g., by the Forest Service in some of the national forests), the 5th field designation is likely to be referred to as a "watershed". In an upcoming update to Federal mapping guidelines, 3rd and 4th field HUCs (currently referred to as accounting and cataloguing units) will be renamed basins and subbasins, and newly delineated 5th and 6th HUCs will be named watersheds and subwatersheds.

15- Dupont, for instance, suggests that project costs be stratified by land ownership as well as watershed.

OTHER ISSUES AND RECOMMENDATIONS

While the focus of the workshop was on habitat restoration cost estimation, participants also suggested ways to enhance the effectiveness of restoration both at the individual project level and at the large scale planning level. Their recommendations are as follows.

Obtaining Comprehensive Picture of Restoration Activity

Restoration funding originates from many sources and is distributed through many channels, making it difficult to comprehend the full extent of restoration in terms of projects or expenditures. In order to understand the "big picture", it is important that this picture include information on projects sponsored by the various funding sources. It is also important that monies not be double counted, as monies may be transferred through one or more channels before being allocated to specific projects. Even determining which projects to classify as salmon habitat restoration may be problematic, as some projects are intended to specifically benefit salmon, while others are motivated by a broader environmental interest (e.g., clean water, general wildlife benefits) that may include but not be specifically focused on salmon.

While ambiguities exist regarding exactly which monies and projects to attribute to salmon restoration, it is nevertheless clear that some accounting of this type must be made. Significant sums of money have been allocated to restoration and it is important to determine what has been accomplished as well as what remains to be done. Databases such as the CHRPD (see Carlson/Allen) are important for documenting the scope and distribution of restoration activities across the landscape. The CHRPD will be a useful tool for recovery planning for ESA-listed salmon and steelhead in California.

Ensuring Maximum Benefits from Restoration Funds

It is important that restoration monies be allocated among projects in a way that yields maximal benefits to salmonids. However, as noted by Huppert, "A problem in applying these [cost-effectiveness analysis, benefit-cost analysis] to salmon habitat restoration is the difficulty of linking the costs of specific restoration activities to the broad objectives of salmon restoration, which typically include increased numbers and genetic diversity of naturally spawning fish" (pp. 24–25). Given this difficulty, benefits to fish are often measured in terms of how well the restoration activity addresses limiting factors (e.g., sedimentation, water temperature) that impede salmon recovery. Measures of restoration effectiveness (whether expressed in terms of fish population parameters or limiting factors) are essential for providing the feedback necessary to evaluate and improve restoration techniques and for prioritizing projects for funding. Isolating the benefits of any single restoration project relative to the totality of restoration activities within a watershed is often problematic. Even determining the effects of entire watershed restoration programs can be difficult, as the effect of such programs on fish populations takes time to become apparent and must be distinguished from the effects of other confounding human and environmental factors.

Several workshop participants discuss ways to relate funding decisions to restoration benefits:

> Tomberlin provides an optimization model for allocating restoration funds both temporally and across space (e.g., among projects, rivers, watersheds). He identifies a number of factors that should be explicitly considered in funding allocation decisions — namely, the objective that allocation is intended

to achieve, the size of the available budget, the nature of the relationship between restoration effort and benefits, the degree of uncertainty in the effort-benefit relationship, and the decision maker's attitude toward risk. Tomberlin also provides stylized examples that demonstrate some of the insights that can be gained from his model. For instance, he shows that — when the objective is to maximize the sum of restoration benefits across two rivers, both rivers share an identical sigmoidal effort-benefit relationship that is known with certainty, and the restoration budget is too small to be of much benefit to either river if divided between rivers — funding should be concentrated in one of the rivers. However, if the effort-benefit relationship is uncertain, funding should be distributed between the two rivers to reduce the chance of getting no benefits at all. More complicated variations of these scenarios can also be developed (e.g., allowing each river to exhibit a different effort-benefit relationship).

Weaver/Hagans focus on a particular type of restoration activity (road repair) as it relates to a particular restoration benefit (preventing sediment delivery into streams). They emphasize the importance of predictive (i.e., "forward looking") sediment source inventories and describe how to develop such inventories at screening, reconnaissance and full assessment levels. They also describe a systematic process for determining whether to upgrade, maintain or decommission a road based on five steps: problem identification, problem quantification, prescription development, cost-effectiveness evaluation and prioritization, and implementation. Specific outputs of their process include a risk reduction plan, a budget, a cost-effectiveness analysis and prioritization of sites to be treated.

Recognizing and Addressing Life Cycle Requirements of Restoration Projects

Restoration sponsors are often encouraged to use funding in ways that are visible and engender public support. This translates into an inordinate attention to the more visible aspects of restoration, namely construction. In some cases, this emphasis on "moving dirt" is further reinforced by legal, policy or contractual constraints that effectively limit the amount of money spent on planning, maintenance and monitoring — less visible aspects of restoration that are nevertheless critical to project success. Inadequate attention to planning can lead to delays, cost overruns and poor execution of project requirements in the construction phase. Given the importance of maintenance to the success of a project, it is important to realistically appraise whether funding and other incentives are adequate to ensure that maintenance requirements will be met; projects should not proceed without a reasonable expectation of adequate maintenance. Monitoring is essential for evaluating the success of restoration projects in meeting their goals and objectives, and also provides the type of feedback needed to evaluate and improve restoration techniques.[16]

Restoration practitioners are well versed in the life cycle requirements and costs of restoration projects.[17] It is also important that policy makers and the public have a realistic appreciation of the need to address total project requirements, the inexact nature of restoration science and the length of time it takes to see results.[18] In order to encourage greater attention to maintenance and monitoring requirements, it is important to consider why these activities are not

16- While monitoring is typically viewed as a post-construction activity, Weaver/Hagans also use a form of monitoring in the construction phase of their projects by requiring their operators to record the time and effort spent on various tasks. This information is used to refine cost estimation procedures and improve project efficiency.

17- Dupont, for instance, provides excellent examples of life cycle costs for stream crossings in Idaho.

adequately addressed in the first place. For instance, monitoring can add significantly to the cost of a project,[19] and landowners may be particularly reluctant to pay for research-related monitoring. In such instances, collaborative or cost-sharing arrangements with research-oriented entities may be desirable.[20]

Streamlining the Regulatory Process

Regulatory and permitting requirements serve a valuable function by providing protection for vulnerable species and ensuring adherence to clean water and other environmental standards. However, the permitting process often requires clearances from multiple agencies and can be lengthy, costly and uncertain in terms of timing and outcome. Some progress on streamlining has been accomplished, particularly for smaller restoration projects.[21] Continuing efforts are needed to ensure that permitting requirements are clearly and explicitly defined and that the permitting process moves forward in a timely manner with minimal "red tape" (see Bell, Hayes).

Enhancing Public Participation

A variety of restoration and monitoring programs exist that encourage and facilitate public involvement in habitat restoration. Public participation is valuable for fostering an attitude of stewardship toward habitat and for augmenting restoration efforts over and above what agencies can provide with their limited resources. It is important that public involvement be supported with adequate funding to organize, train and otherwise support volunteer participation in restoration efforts.[22]

A variety of programs exist that encourage the participation of private landowners in salmon habitat restoration projects by providing design and other technical assistance or facilitating permit acquisition and access to funding sources.[23] While many take advantage of these services, others are not interested or are concerned that such participation may draw attention to themselves in terms of agency oversight of their land use activities. Positive incentives and "win-win" situations, of course, work best for obtaining landowner cooperation.[24]

Managing Projects Effectively

Restoration is particularly challenging for large or complex projects that involve multiple agencies with overlapping jurisdictions and diverse stakeholders. Workshop participants emphasize the importance of managerial skills as well as technical expertise in ensuring the success of restoration projects. For example:

> Neal describes project management procedures in King County that may be useful in other populated urban settings. She points out the importance of restoration design teams that include a range of professional disciplines. The teams are organized by watershed, which allows

18- Cocke provides a particularly vivid description of the dynamic nature of stream systems and the long-term effects of human behavior and natural processes on the system. He emphasizes the need to incorporate adaptive management into the restoration planning process. He notes that restoration often involves laying the groundwork for continuing as well as current beneficial effects (e.g., trees planted to stabilize stream banks also serves as a future source of large woody debris) and makes the point that "...the most important aspect of restoration work is time" (p. 119).

19- Hayes cites a case in which slots were built (at considerable expense) into a Central Valley pumping facility to facilitate monitoring.

20- According to Neal, King County maintains separate budgets for restoration projects and research-oriented assessments, with research sometimes undertaken collaboratively with the University of Washington. Hayes notes that the CalFED Bay Delta Program sometimes engages in cost-sharing arrangements with irrigation districts for research-related monitoring at fish screen facilities.

21- Hayes cites as an example the Anadromous Fish Screen Program — established under the Central Valley Project Improvement Act — which has streamlined its permitting process by ensuring that a single staff person works with an applicant on all permitting requirements.

22- Neal describes King County's sponsorship of volunteer planting events, including provision of parking/shuttle buses, team leaders, refreshments, tools and planting instructions. Rectenwald notes the importance role played by watershed groups in community-based restoration planning and the significant amount of effort and citizen involvement (as well as monetary grants) needed to make such groups successful.

23- Hayes cites the work of the Family Water Alliance, a program sponsored by the Natural Resources Conservation Service that works with farmers on small screen projects. Hayes also points out that the CVPIA Anadromous Fish Screen Program streamlines its funding process by providing irrigators with access to multiple fish screen funding sources via a single application.

members to develop detailed knowledge of that watershed and long-term relationships with relevant stakeholders and the staff at regulatory agencies who have jurisdiction in the watershed. Regulatory agencies are consulted early on to ensure that environmental requirements are reflected in the early stages of project design. Collaborative and pro-active arrangements such as this help build long-term relationships with regulatory agencies and the public that are based on trust and ensure successful restoration.

In his discussion of a dam removal project in California's Central Valley, Rectenwald provides many specific suggestions for dealing with the complex coordination requirements of the project. For instance, he points out the importance of understanding the mandates and policies of different agencies and dealing with agency aversion to setting a precedent by changing standard ways of conducting business. He emphasizes the need to appreciate the motivations and concerns of the dam and water rights owner. He encourages the use of community knowledge to augment agency knowledge regarding the history of salmon runs in the watershed. He notes the contribution that local watershed groups make to community-based planning. To enhance public participation, he suggests scheduling meetings at times and places convenient to the public and ensuring that the same person is consistently available to represent the project in interactions with the public. Rectenwald advises full and early disclosure of information relevant to the project (including any potential adverse effects on stakeholders), outreach activities that allow stakeholders to participate in the development of options that mitigate adverse effects, and environmental documentation that includes the specific mitigation measures developed in the course of negotiations. His case study vividly illustrates the importance of skillful management and collaboration in ensuring the success of protracted, complex and controversial restoration projects.

FINALLY…

Restoration involves the application of technology to complex natural systems within an often complicated legal, institutional and social context. Restoration is ultimately a human activity — conducted by people who respond to restoration opportunities, constraints and incentives in adaptable and ingenious ways. Workshop presenters provided insights into all these dimensions of restoration. We thank them for sharing their knowledge and expertise with us.

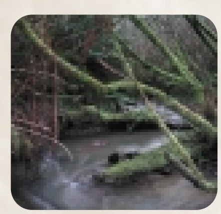
Table 1. Restoration project data requirements for cost analysis, as suggested by workshop participants

- Goals and measurable objectives
- Project description
- Project location[1]
- Project manager (contact person)
- Funding source(s)
- Project costs[2]
    - Planning
    - Design
    - Permitting/environmental review
    - Construction[3]
    - Monitoring
    - Maintenance
    - Overhead

1- Location should be identified in as specific a manner as possible. Some standardization of location descriptors would be helpful.

2- Both proposed and actual costs should be provided for each cost category. Cost estimates should be complete, including matching funds.

3- Construction costs should be broken down by labor, materials and equipment. Labor expended in each cost category should be reported in person hours and dollars.



24- Hudson cites an instance where, in lieu of screening an existing water diversion, the Bureau of Reclamation assisted the landowners in obtaining funding to excavate wells and install a sprinkler system, thereby allowing elimination of the diversion and benefitting both the landowners and the fish. Rectenwald notes that wildfire prevention can serve dual purposes in terms of reducing sedimentation in a creek and protecting property in the community. Kepshire notes that pump screens, which keep snails as well as fish out of irrigation ditches, are popular among Oregon farmers.

Salmon Habitat Restoration Cost Workshop

Final Agenda

November 14–16, 2000

Sponsored by:	National Marine Fisheries Service
Hosted by:	Pacific States Marine Fisheries Commission
Location:	Oxford Suites Hotel (next door to PSMFC) - Gladstone, Oregon
Objective:	To evaluate the feasibility of developing and applying standardized methodologies to estimate salmon habitat restoration costs.

Day 1 (November 14)

8:00 a.m. – 12 noon

Introduction and Welcome — 15 minutes
Cindy Thomson — NMFS, Southwest Fisheries Science Center, Santa Cruz, CA
Steve Freese — NMFS, Northwest Region, Seattle, WA

Potential uses and applications of habitat restoration cost information
(including habitat restoration project database and StreamNet) — 45 min
Cindy Thomson — NMFS, Southwest Fisheries Science Center, Santa Cruz, CA
Stan Allen and Robin Carlson — Pacific States Marine Fisheries Commission

Conceptual framework(s) for cost analysis — 3 hours
(30 minutes per presenter, followed by open discussion and synthesis of all information presented under this topic)
Dan Huppert — School of Marine Affairs, Univ of Washington, Seattle, WA
Mark Shaw — Bonneville Power Administration, Portland, OR
David Tomberlin — NMFS, Southwest Fisheries Science Center, Santa Cruz, CA
Trina Wellman — Battelle Seattle Research Center, Seattle, WA

1:00 p.m. – 5:00 p.m.

Road maintenance, road decommissioning, stream crossing upgrades — 4 hours
(30 minutes per presenter*, followed by open discussion and synthesis of all information presented under this topic)
Bengt Coffin — US Forest Service, Trout Lake, WA
Joe DuPont — Idaho Dept of Lands, Coeur d'Alene, ID
Mike Jani — Mendocino Redwood Company, Calpella, CA
Bill Weaver — Pacific Watershed Consultants, McKinleyville, CA

Day 2 (November 15)

8:00 a.m. – 12 noon **Streambank stabilization, streambank fencing, nuisance species control, riparian zone management** — 4 hours
(30 minutes per presenter*, followed by open discussion and synthesis of all information presented under this topic)
Brian Bair — US Forest Service, Cook, WA
Mark Cocke — Natural Resource Conservation Service, Davis, CA
Steve Hampton — CDFG Oil Spill Prevention Response Prog, Sacramento, CA

1:00 p.m. – 5:00 p.m. **Instream treatment (e.g., woody debris, rootwads, boulders, side channels, pools, spawning gravel, nutrient augmentation), conversion to non-structural flood control (e.g., meander zones)** — 4 hours
(30 minutes per presenter*, followed by open discussion and synthesis of all information presented under this topic)
Craig Bell — Salmonid Restoration Federation & Trout Unlimited North Coast Coho Project, Gualala, CA
Mark Lacy — Oregon Dept of Fish and Wildlife, Corvallis, OR
Kathryn Neal — King County Dept of Natural Resources, Seattle, WA

Day 3 (November 16)

8:00 a.m. – 12 noon **Upgrading and installation of fish passages and fish screens, offstream water storage** — 4 hours
(30 minutes per presenter*, followed by open discussion and synthesis of all information presented under this topic)
Darryl Hayes — CalFED Bay-Delta Program, Sacramento, CA
R. Dennis Hudson — US Bureau of Reclamation, Boise, ID
Bernie Kepshire — Oregon Dept of Fish and Wildlife, Corvallis, OR
Harry Rectenwald — California Dept of Fish and Game, Redding, CA

1:00 p.m. – 4:00 p.m. **Wetland creation and restoration** — 3 hours
(30 minutes per presenter*, followed by open discussion and synthesis of all information presented under this topic)
Steve Liske and Chris Bonsignore — Ducks Unlimited, Vancouver, WA
Pat Obradovich — US Army Corps of Engineers, Portland, OR
John Steere — San Francisco Bay Joint Venture, Oakland, CA

4:00 p.m. – 5:00 p.m. **Where do we go from here?**

Attendee Listing

Pete Adams
Chief — Salmon Analysis Branch
National Marine Fisheries Service
3150 Paradise Drive
Tiburon, CA 94920-1205
415-435-3149 ext. 232
415-435-3675 fax
Pete.Adams@noaa.gov

Stan Allen
Program Manager
Pacific States Marine Fisheries Commission
205 SE Spokane Street, Suite 100
Portland, OR 97202-6413
503-650-5400
503-650-5426 fax
stan_allen@psmfc.org

Brian Bair
Project Fisheries Biologist
USDA Forest Service
Pacific Northwest Region
Gifford Pinchot National Forest
Wind River Administration Site
1262 Hemlock Road
Carson, WA
509-427-3250
509-427-3215 fax
bbair@fs.fed.us

Craig Bell
Director, Salmonid Restoration Federation
& Local Project Coordinator, Trout Unlimited
North Coast Coho Project
P.O. Box 1256
Gualala, CA 95445
707-884-3012
707-884-3016 fax
acenlil@mcn.org

Chris Bonsignore
Biologist
Ducks Unlimited, Inc.
1101 SE Tech Center Drive, Suite 115
Vancouver, WA 98683
360-885-2011
360-885-2088 fax
cbonsignore@ducks.org

Greg Bryant
Natural Resource Mgmt. Specialist
National Marine Fisheries Service
1655 Heindon Road
Arcata, CA 95521
707-825-5162
707-825-4840 fax
Greg.Bryant@noaa.gov

Mark Capelli
Recovery Coordinator
National Marine Fisheries Service
735 State Street, #616
Santa Barbara, CA 93101
805-963-6478
805-963-2438 fax
Mark.Capelli@noaa.gov

Robin Carlson
HRPD Data Analyst/Programmer
Pacific States Marine Fisheries Commission / CDFG
1807 13th Street, #201
Sacramento, CA 95814
916-324-8298
916-323-1431 fax
RCARLSON@dfg.ca.gov

Mark Cocke
Civil Engineer
Natural Resource Conservation Service
430 G Street, #4164
Davis, CA 95616-4164
530-792-5663
530-792-5794 fax
mark.cocke@ca.usda.gov

Bengt Coffin
Hydrologist
USDA Forest Service
Mt. Adams Ranger District
2455 Highway 141
Trout Lake, WA 98650
509-395-3384
509-395-3424 fax
bcoffin@fs.fed.us

Miles Croom
National Marine Fisheries Service
777 Sonoma Avenue, Room 325
Santa Rosa, CA 95404-6515
707-575-6068
707-578-3435 fax
Miles.Croom@noaa.gov

Joe DuPont
Idaho Department of Lands
3780 Industrial Ave S.
Coeur d'Alene, ID 83815
208-769-1525
208-769-1524 fax
jdupont@cda.idl.state.id.us

Steve Freese
Regional Economist
National Marine Fisheries Service-NWR
7600 Sand Point Way NE
Building 1, Bin C5700, NW02
Seattle, WA 98115
206-526-6113
206-526-6544 fax
Steve.Freese@noaa.gov

Steve Hampton, Ph.D.
Resource Economist
Office of Spill Prevention and Response
California Department of Fish and Game
P.O Box 944209
Sacramento, CA 94244-2090
916-323-4724
916-324-8829 fax
shampton@ospr.dfg.ca.gov

Darryl Hayes
Water Resources Engineer
CalFED Bay-Delta Program
2485 Natomas Park Drive, Suite 600
Sacramento, CA 95833
916-920-0212, ext 402
916-920-8463 fax
dhayes@ch2m.com

R. Dennis Hudson
Program Manager
Bureau of Reclamation — PNW Region
1150 N Curtis Road, Suite 100
Boise, ID 83706-1234
208-378-5250
208-378-5171 fax
rhudson@pn.usbr.gov

Dan Huppert
Associate Professor
University of Washington
School of Marine Affairs
3707 Brooklyn NE
Seattle, WA 98105
206-543-0111
206-543-1417 fax
huppert@uwashington.edu

Mike Jani
Chief Forester
Mendocino Redwood Company
P.O. Box 390
Calpella, CA 95418
707-485-6751
707-485-7918 fax
mjani@mendoco.com

Bernie Kepshire
Fish Screening Program Coordinator
Oregon Dept Fish and Wildlife
7118 NE Vandenberg Avenue
Corvallis, OR 97330-9446
541-757-4186 x255
541-757-4252 fax
Bernard.m.kepshire@state.or.us

Mark Lacy
Fish Biologist
Oregon Department of Fish and Wildlife
7118 NE Vandenberg Ave.
Corvallis, OR 97330
541-757-4186, ext 227
541-541-757-4252 fax
mark.lacy@state.or.us

Steve Liske, P.E.
Regional Engineer
Ducks Unlimited, Inc.
1101 SE Tech Center Drive, Suite 115
Vancouver, WA 98683
360-885-2011
360-885-2088 fax
sliske@ducks.org

Kathryn Neal, P.E.
Senior Engineer
Surface Water Eng. and Env. Svcs.
King County Dept of Natural Resources
201 S. Jackson St.
Seattle, WA 98104
206-296-1961
206-296-8033 fax
kathryn.neal@metrokc.gov

Pat Obradovich
Civil Works Prog Develop Coord.
Army Corps of Engineers
Portland District
P.O. Box 2946
Portland, OR 97208-2946
503-808-4730
503-808-4736 fax
Patricia.M.Obradovich@usace.army.mil

Mark Plummer
Senior Fellow
Discovery Institute
10816 NW Oxbow Ridge Ct.
Vancouver, WA 98685
360-571-5703
206-292-0401
206-682-5320 fax
mplummer14@home.com

Harry Rectenwald
Senior Environmental Specialist
California Department of Fish and Game
601 Locust St
Redding, CA 96001
530-225-2368
530-225-2381 fax
hrectenw@dfg.ca.gov

Mark Shaw
Director — KEWN-4
Division of Fish and Wildlife
Bonneville Power Administration
P.O. Box 3621
Portland, OR 97208-3621
503-230-5239
503-230-4564 fax
mashaw@bpa.gov

Wes Silverthorne
Economist
National Marine Fisheries Service
777 Sonoma Ave., Room 325
Santa Rosa, CA 95404-6515
707-575-6087
707-578-3435
Wes.Silverthorne@noaa.gov

John Steere
Director
San Francisco Bay Joint Venture
1330 Broadway Ave., Suite 1100
Oakland, CA 94612
510-286-6767
510-286-0470 fax
jsteere@igc.org

Steve Thompson
National Marine Fisheries Service
777 Sonoma Avenue, Room 325
Santa Rosa, CA 95404-6515
707-575-6067
707-578-3435
Steven.A.Thompson@noaa.gov

Cindy Thomson
Economist
National Marine Fisheries Service — SWFSC
110 Shaffer Road
Santa Cruz, CA 95060
831-420-3911
831-420-3977 fax
Cindy.Thomson@noaa.gov

David Tomberlin
Economist
National Marine Fisheries Service — SWFSC
110 Shaffer Road
Santa Cruz, CA 95060
831-420-3910
831-420-3977 fax
davidt@tib.nmfs.gov

Colin Wagner
Ridolfi Engineers Inc
1411 Fourth Ave., Suite 770
Seattle, WA 98101
206-682-7294
206-682-5008 fax
colin@ridolfi.com

Bill Weaver
Geologist/Owner
Pacific Watershed Associates
1652 Holly Dr.
McKinleyville, CA 95519
707-839-5130
707-839-8168 fax
pwa@northcoast.com

Katherine Wellman
Senior Research Scientist/
Natural Resource Scientist
Battelle Seattle Research Center
P.O. Box 5395
Seattle, WA 98105-5428
206-528-3323
206-528-3552 fax
wellman@battelle.org

Index of Figures and Tables

Index of Figures and Tables

Notes

Notes

Pacific States Marine Fisheries Commission
205 SE Spokane Street, Suite 100
Portland, Oregon 97202-6413
www.psmfc.org