University of California, Santa Barbara
Donald Bren School of Environmental Science and Management

Assessment of Stressors on Fall-Run Chinook Salmon in Secret Ravine (Placer County, CA)

A Group Project Submitted in Partial
Satisfaction of the Requirements for the

Degree of Master's of Environmental Science and Management

June 2003

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The mission of the Donald Bren School of Environmental Science and Management is to produce professionals with unrivaled training in environmental science and management who will devote their unique skills to the diagnosis, assessment, mitigation, prevention and remedy of the environmental problems of today and the future. A guiding principle of the School is that the analysis of environmental problems requires quantitative training in more than one discipline and an awareness of the physical, biological, social, political and economic consequences that arise from scientific or technological decisions. The Group Project is required of all students of the Master's of Environmental Science and Management (MESM) Program. It is a three-quarter activity in which small groups of students conduct focused, interdisciplinary research on the scientific, management and policy dimensions of a specific environmental issue. This Final Group Project Report is authored by MESM students and has been reviewed and approved by:

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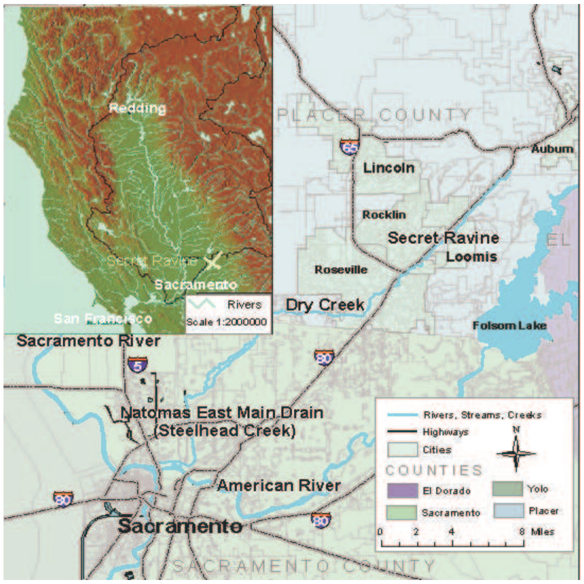
In this study we investigate the impact of anthropogenic stressors on the fall-run chinook salmon (*Oncorhynchus tshawytscha*) in Secret Ravine, Placer County, CA through an Ecological Risk Assessment (ERA). The Central Valley fall-run species has experienced exponential decline in the last half-century, and community stakeholders are interested in understanding the causes of this decline. As a guide, we use the Relative Risk Model as a guide, a specialized form of ecological risk assessment, which was developed by Dr. Wayne Landis of Western Washington University. Our study combines quantitative source analysis of land use through geographic information systems (GIS), with dose-response estimates of biological, chemical and physical stressors to the salmon. Because the Relative Risk Model was designed to rank and prioritize ecosystem effects on a regional scale, we have also created a model which may be better equipped to evaluate stressors at the watershed scale (the "Stressor-Driven Risk Model"). Both models enable use of qualitative input in the absence of complete data, allowing managers to take action based on prioritization of known risk.

We analyzed and quantified the risk associated with twelve sources and ten stressors. We used the top three stressors associated with the most highly contributing sources from the results in the Modified Relative Risk Model to compare effects directly associated with the top stressors in the Stressor-Driven Risk Model. Sediment was identified as a top stressor in both models. We synthesized the results of both models to be able to more comprehensively characterize the stream system and its impacts on the fish in order to make management recommendations to stakeholders. The risks facing the fall-run chinook salmon reflect many of the risks that threaten the overall stream health of the larger Secret Ravine watershed and the Sacramento River drainage system. Therefore, the results of the ERA should serve as an important first step to management of fall-run chinook, as well as management of similar creeks under threat of encroachment by suburbanization.

Executive Summary

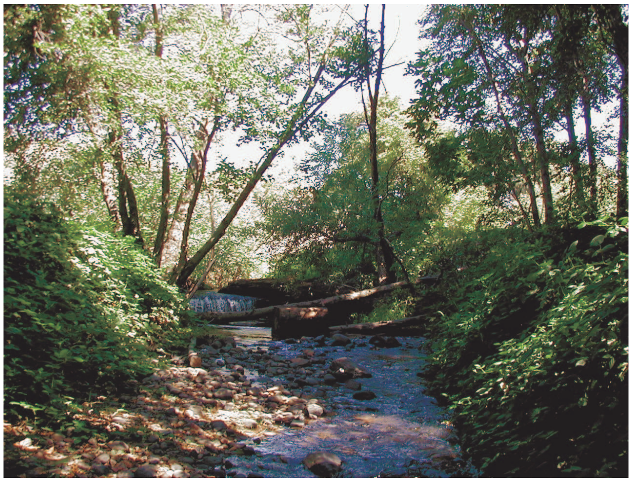


Location of Secret Ravine Within the Sacramento River Watershed

Introduction

Secret Ravine is a 10.5 mile-long creek located east of Interstate-80 in Placer County. The stream is part of the upper Central Valley watershed, and is a tributary of Dry Creek, which drains into the Sacramento River.

Secret Ravine supports a population of fall-run chinook salmon, but has experienced an estimated ten-fold decline in the last forty years, a rate even higher than the similar declining trend of chinook salmon in the Central Valley over this same time period (Gerstung 1965). "The chinook salmon is the preeminent anadromous[1] fish in California, whether measured by economic value, popular recognition or ecological importance" (Yoshiyama et al. 1998). The Central Valley fall-run species has maintained populations high enough to prevent them from being listed as Endangered under the Federal Threatened and Endangered Species List in California. However, their designation as a Candidate Species for "Threatened" status, without actual federal protection, makes assessment and mitigation of their decline even more urgent. Proliferation of salmon in smaller tributaries such as Secret Ravine is also thought to contribute highly to preservation of genetic diversity in larger rivers such as the American and Sacramento (DCC 2001).



A Stretch of Secret Ravine

Causes for this decline can generally be attributed to urban encroachment, pollution and other forms of land use alteration. Secret Ravine stakeholders were interested in targeting the causes of decline within the Secret Ravine watershed because it is considered to have the best spawning habitat in the immediate area (G. Bates, pers.

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[1] **anad·ro·mous:** ascending rivers from the sea for breeding. http://www.webster.com/cgi-bin/dictionary.

comm. via J. Love 2002).

Under the guidance of CalEPA, group members were charged with developing an ecological risk assessment (ERA) to compare the various threats of anthropogenic stressors on fall-run chinook salmon. Based on the results, we prioritized sources and stressors for local organizations so restorative and preventative measures could be taken to protect the salmon population.

Significance and Scope

The scope of our study concentrates on stressors located in Secret Ravine proper. Our analysis eschews stressors related to adverse affects in the ocean, in the delta and in the larger tributaries, even though fall-run chinook spend a significant portion of their life cycle in these areas. However, as parts of each life stage occur in Secret Ravine, we had cause to focus our efforts in the creek.

Roseville, the city into which Secret Ravine drains, is also the fastest growing in Northern California. The cities surrounding the watershed have undergone complex transformation: from placer and hydraulic mining, to orchard use, to suburban and residential development.

The Secret Ravine watershed contains a canal system still in place from the Mining Era, which contributes to an altered flow regime. The creek is characterized by patchy substrate of high quality gravel overlain by excess fine sediment, or sand, and fairly adequate temperatures for all life stages of fall-run chinook. The creek also contains high-quality macroinvertebrate food supply for juveniles, fair - but highly invaded - riparian cover, and a relatively high density of beaver dams. Dry Creek (downstream of Secret Ravine) had been assessed 100% toxicity levels in previous habitat surveys, so there was also cause for concern for high toxicity levels in Secret Ravine (G. Bates, pers. comm. via Fish Group 2002).

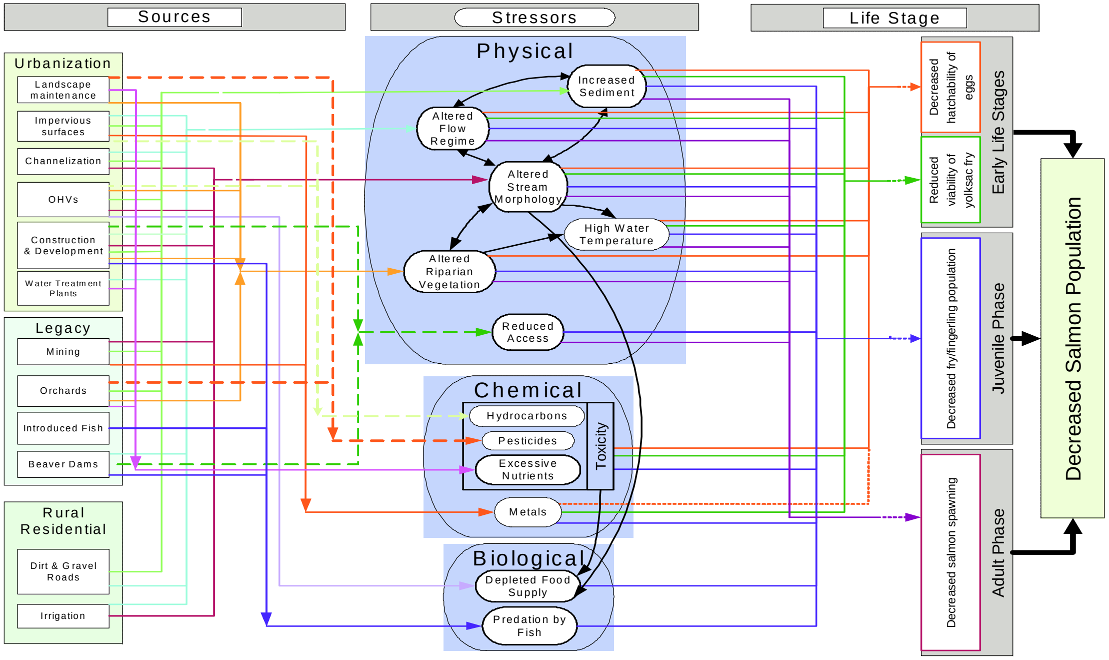
An ecological risk assessment "is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" (U.S. EPA 1998). Within the ERA framework, we used available data and information to help understand and predict the links between sources, stressors and their resulting ecological effects.

There are three phases of an ERA: 1) problem formulation; 2) risk analysis; and 3) risk characterization (U.S. EPA 1998).

Problem Formulation

Problem formulation, the first phase of an ERA, includes a clear definition of the problem, and a plan for analyzing and characterizing risks. In consultation with our stakeholders we chose reproductive success of the fall-run chinook to be our assessment endpoint. Our endpoint, based on the viability of each life stage, depends upon completion of the life-cycle (e.g. the ability of an adult to reach spawning grounds and reproduce; the ability of the eggs to hatch; or the ability of the alevin to emerge from the redds).

The conceptual model we designed delineates the pathways that connect all possible sources (twelve on our system) to all possible stressors (ten on our system) to the three major life stages of the salmon that occur in Secret Ravine.



Conceptual Model - Stressors on Chinook Salmon - Secret Ravine

Risk Analysis

Risk analysis evaluates the ecological impact that will occur from exposure to a stressor and determines the method for evaluating risk posed to the endpoint of the ERA.

Two models were used to characterize risk in Secret Ravine: the Modified Relative Risk Model (MRRM) and the Stressor-Driven Risk Model (SDRM). The Relative Risk Model (RRM) is a specialized form of ecological risk assessment developed by Dr. Wayne Landis of Western Washington University. Initially, this model gave us a systematic way to quantify ecological risk posed by sources and stressors in Secret Ravine. Using the Relative Risk Model (Landis 1997) as a template, we developed a Modified Relative Risk Model specific to Secret Ravine.

The Modified Relative Risk Model (MRRM) combines quantitative source analysis of land use through Geographic Information Systems (GIS) and reference values to estimate biological, chemical and physical stressors to the salmon. Based on these estimates, data for the region are converted into a ranking system. A risk score, or the quantification of risk, is calculated for sub-watersheds (or "risk regions"), sources, stressors, and habitats.

In order to address the limitations of the traditional RRM and the MRRM, we developed the Stressor-Driven Risk Model. The crux of the Stressor-Driven Risk Model lies with the use of percent effect (percent habitat reduction or percent reduction in population) specific to the three life stages of salmon. These percentages are calculated using dose-response curves, reference values or habitat loss estimations. Risk for sources and stressors is expressed as 'percent effect,' rather than as ranks. This eliminates problems associated with multiplying ranks throughout the model, and gives the SDRM greater precision in the biological components.

The MRRM uses analysis of sources, stressors, habitats[2] and exposure filters[3] to qualify risk. The SDRM uses predominantly stressor effects to determine risk. Both use a combination of data from the creek and literature to estimate these relationships.

At its best, the data included one to three years of sampling sites collected on Secret Ravine throughout the extent of the watershed (sediment, morphology, toxicity, metals and food supply) and strong support of these data in the literature and from local experts. At worst (as in the case of flow), there was very little actual associated data, the stressor analysis only had enough extrapolated data to focus on one criterion associated with that stressor (e.g. scour), and there was high natural variability associated with the stressor itself. All data suffered from limited sampling sites over limited years.

Risk Characterization

Risk characterization describes the actual assignment of values to each of the risk factors and includes a summary of assumptions, scientific uncertainties, strengths and limitations of the analysis (U.S. EPA 1998). The Modified Relative Risk Model uses ranks to characterize effects in each risk region, while the Stressor-Driven Risk Model integrates the "percent effects" of each of the stressors across the entire watershed.

The following equation incorporates ranks with habitat, exposure and effect was used to calculate a risk score for the MRRM.

Risk Score = (Source Rank) x (Habitat Rank) x (Effects Rank) x (Exposure 1 filter) x (Exposure 2 filter)

The SDRM quantifies stress in terms of effect on fish populations. To better discern the impact of stressors, the effect was translated into percent mortality or percent reduction in habitat for each life stage. Once the percent effect of an individual stressor is determined, the percent effect for each life stage was multiplied together. In essence, the product simulates the percent survival of fall-run chinook salmon through the three life stages in Secret Ravine. The percent effect result is subtracted from one and multiplied through the three life stages. This value is subtracted again from one, rendering a total percent effect.

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[2] "Habitat" is used as another parameter to capture the affected life stages of salmon (as opposed to conventional ecosystem-type habitats used in a regional risk assessment). Habitat in our study refers to the water column, the benthos, or both.

[3] The first exposure filter (Exposure 1) assesses whether or not the source emits the stressor. The second exposure filter (Exposure 2) assesses whether or not the habitat will be exposed to the stressor.

$$\textbf{Total Percent Effect}_{\text{(per stressor)}} = 1 - [(1 - PE_{egg}) \times (1 - PE_{juvenile}) \times (1 - PE_{adult})]$$

In the uncertainty phase of risk characterization for the MRRM, we measured the sensitivity of the assignment of the ranks to the total risk scores. With the SDRM, we estimated the uncertainty of our results based on the natural variability of the system.

Results and Recommendations

Sediment, flow and morphology ranked as the top three stressors in the MRRM, while sediment, reduced access and toxicity ranked as the top three stressors in the SDRM.

Top Three Stressors

Modified Relative Risk Model	Stressor-Driven Risk Model
Sediment	Sediment
Flow	Reduced Access
Morphology	Toxicity

Despite large differences in the risk characterization phases of these models, sediment ranked highly in both models. This in part demonstrates the impact of the conceptual model in elucidating ecosystem pathways on Secret Ravine. Because sediment ranked highly in both models, we have confidence that this stressor may be particularly problematic for Secret Ravine. Although flow and morphology did not register as the highest stressors in the SDRM, these stressors are associated with the "sediment-flow-morphology" cycle on the conceptual model and should be addressed in any management plan. Reduced access and toxicity stand out as two glaring omissions from the MRRM. Reduced access, the lowest-ranking stressor in the MRRM, had few sources, while toxicity, with the third lowest risk score, had only one habitat (the benthos) associated with it. However, reduced access is the only stressor that deals directly with the potential consequences of delay in adult spawning and in juvenile emigration. Thus, it is reasonable to conclude that reduced access would pose a high risk to salmon and may be a high-ranking stressor. Toxicity can cause high mortality during the early life stages of fall-run chinook, especially in regards to heavy metals that may be associated with mine tailings. Thus it was reasonable to expect that this stressor would pose some of the worst risk to the fish.

Consequently, sources associated with stressors registering the highest percent effects - that also had the highest magnitudes - were discussed. Sediment had eleven total contributing sources. Impervious surfaces and off-highway vehicles were the leading sources causing increased sediment in Secret Ravine. Both non-structural and structural management practices should be implemented to prevent sediment loading. Of the five sources contributing to toxicity, impervious surfaces, landscape maintenance and waste treatment plants are the highest potential contributors. In areas where impervious surfaces are extensive, we recommend that localized bio-filtration devices be installed to minimize the effects of peak flow runoff. While the benefits of beaver dams seem to be outweighed by the physiological costs to the fish of reduced access itself, the monitoring and breaching of particularly problematic beaver dams needs to be considered in more detail.

This study gave us the opportunity to test the suitability of performing an ecological risk assessment for chinook salmon. While the MRRM may be best used for determining the most important stressors (risk) to a system in a preliminary fashion (and as a data-needs assessment tool) the Stressor-Driven Risk Model demonstrates that ecological risk assessments can also convey biologically meaningful results in absence of a complete data set. Indeed, the SDRM had the ability to estimate that stress internal to Secret Ravine was responsible for half of the mortality associated with the entire life cycle of the fish migrating through this watershed. Thus, we strongly feel that ecological risk assessments that are biologically-sensitive to the needs of the species are an important first step in resolving problems associated with declining salmon populations. Although both models suffer from an inability to accurately account for the contributions particular sources make to stressors on the system, we are confident in the magnitudes we assigned to sources in the SDRM. We could thus use these magnitudes to estimate the impact that mitigating them would have on improving salmon health. The models highlight sources of concern. Any future analysis of source contributions necessitates a separate study in itself.

Acknowledgements

The UCSB Fish Group would first like to thank Barbara Washburn from CalEPA for developing this project and providing us the opportunity to work on such an important issue. We are thankful for her guidance and expertise over the summer and throughout the entire project. We would also like to thank Jim Donald from CalEPA for his helpful recommendations and insights.

Special thanks and appreciation goes to our advisors Bruce Kendall and Carol McAusland for their constant encouragement, contributions and invaluable expertise.

We would also like to thank Gregg Bates and Dave Baker from the Dry Creek Conservancy for sharing their knowledge of Secret Ravine. Thanks to Hal Freeman and Sarah Egan from ECORP Consulting, Inc. for performing the Secret Ravine Habitat Study, and for doing it around our schedule. We would also like to thank Rob Titus from California Department of Fish and Game for sharing his knowledge of salmon, his time, and his equipment. And to Tim Horner and Steve Rounds from California State University, Sacramento for the use of their petrology lab and their time.

There were also many other people we would like to thank who made this project possible because of their contributions: the Dry Creek Watershed Council, Jamie Ballard from Placer County Water Agency, Jim Carlise from CalEPA, Christopher Costello from the University of California, Santa Barbara, Loren Clark from Placer County, Linda Deanovic from University of California at Davis, Emily Hart Hayes from University of Western Washington, Audra Heinzel from CalEPA, Gary Hobgood from California Department of Fish and Game, Melissa Hugenberger from Placer County, Bruce Joab from CalEPA, Brian Keating form Placer County, Kate Kirsch from Foothill Associates, Chris Lee from Department of Water Resources, David Leland from California Regional Water Quality Control Board, Stacy Li from National Marine Fisheries Service, Glenda Marsh from Department of Water Resources, Christopher Marwood from the University of California, Santa Barbara Rob Nelson from City of Roseville, Mike Posehn from Dry Creek Conservancy, David Siegel from CalEPA, Brent Smith from Placer County Water Agency, Matt St. John from California Regional Water Quality Control Board, Kris Vyverberg from California Department of Fish and Game, Brad Valentine from California Department of Fish and Game, Lori Webber from California Regional Water Quality Control Board, and especially Shirley Williams from CalEPA, and the guys at the burrito cart.

Finally, we were extremely grateful to have had each other as team members, in terms of both the dedication we felt for this subject, and the sense of humor we shared along the way.

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List of Acronyms and Abbreviations

BOR - Bureau of Reclamation
BPJ - Best professional judgment
CEP - Coastal Ecotoxicology Program
CEQA – California Environmental Quality Act
DCWC – Dry Creek Watershed Council
DDT - Dichlorodiphenyltrichloroethane
DFG – Department of Fish and Game
DHS – Department of Health Services
DPR – Department of Parks and Recreation
DWR – Department of Water Resources
DQO – Data Quality Objectives
DTSC – Department of Toxic Substance Control
DWR – Department of Water Resources
ECORP Consulting – not an acronym, a consulting firm
EHIB – Environmental Health Investigations Branch
EIR – Environmental Impact Report
ERA – Ecological Risk Assessment
ESA – Endangered Species Act
GIS – Geographic Information Systems
HCP – Habitat Conservation Plan
MRRM - Modified Relative Risk Model
NOAA – National Oceanic and Atmospheric Administration
NOAEL – No Observed Adverse Effect Level
NMFS – National Marine Fisheries Services
NRCS – Natural Resources Conservation Service
NTU - Nephalometric Turbidity Units
OEHHA – Office of Environmental Health Hazard Assessment
OHVs - Off-highway vehicles
PE - Percent effect
PBL - Percent pools by length
PCCDD - Placer County Community Development Department
PCFC – Placer County Flood Control
PCWA - Placer County Water Association
PG&E - Pacific Gas and Electric
RCHAS - Reproductive and Cancer Hazard Assessment Section
RWQCB – Regional Water Quality Control Board
SACOG - Sacramento Area Council of Governments
SDRM - Stressor-Driven Risk Model
SRAMP - Secret Ravine Adaptive Management Plan
SWRCB – State Water Resource Control Board
TIEs – Toxicity Identification Evaluations
TPE - Total Percent Effect
UCSB - University of California, Santa Barbara

USDA – United States Department of Agriculture
U.S. EPA - United States Environmental Protection Agency
USFWS - United States Fish and Wildlife Service
WQCB - Water Quality Control Board

1 Introduction

1.1 Significance of the Project

"The chinook salmon is the preeminent anadromous[4] fish in California, whether measured by economic value, popular recognition or ecological importance" (Skinner 1962, McEvoy 1986, Yoshiyama et al. 1998 as quoted by Yoshiyama et al. 1998). The Central Valley river system, encompassing the Sacramento River drainage in the northern half of California and the San Joaquin River drainage in the south, comprise the only system in the world which supports four separate races (runs) of chinook which use the system for spawning year round (Yoshiyama et al. 1998). The Central Valley fall-run species have maintained populations high enough to prevent them from being listed as Endangered under the Federal Threatened and Endangered Species List in California. However, their designation as a Candidate Species for "Threatened" status, without actual federal protection, makes assessment and mitigation of their decline even more urgent. Their numbers have dropped from the hundreds of thousands at the turn of the 19th century, to several thousand in the 1960s, to several hundred within the Dry Creek watershed. Secret Ravine drains into the Dry Creek watershed, which is itself a tributary of the Sacramento River. Proliferation of salmon in these smaller tributaries is thought to contribute to preservation of genetic diversity in the larger rivers such as the American and Sacramento (DCC 2001). Moreover, as a top predator in Secret Ravine, the risks facing the fall-run chinook salmon indicate many of the risks that threaten the stream health in the larger watershed system of Secret Ravine. The group will synthesize the results of the two ecological risk assessment models to provide a focal point for options that will assist community leaders, the public, state and federal agencies in making better-informed decisions about the management of the Secret Ravine watershed.

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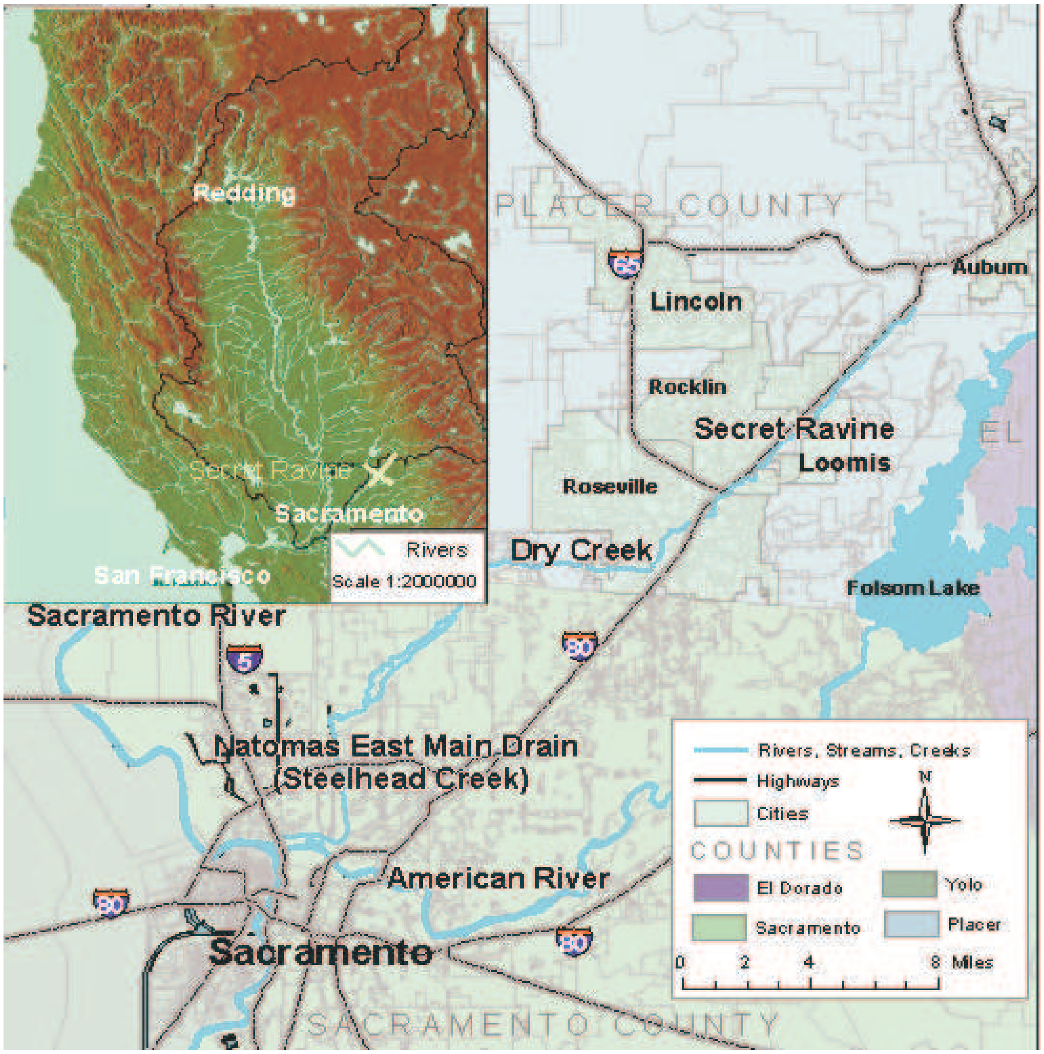
[4] **anad·ro·mous:** ascending rivers from the sea for breeding. Etymology: Greek *anadromos* running upward, from *anadramein* to run upward, from *ana-* + *dramein* to run -- (Webster Dictionary definition).http://www.webster.com/cgi-bin/dictionary.



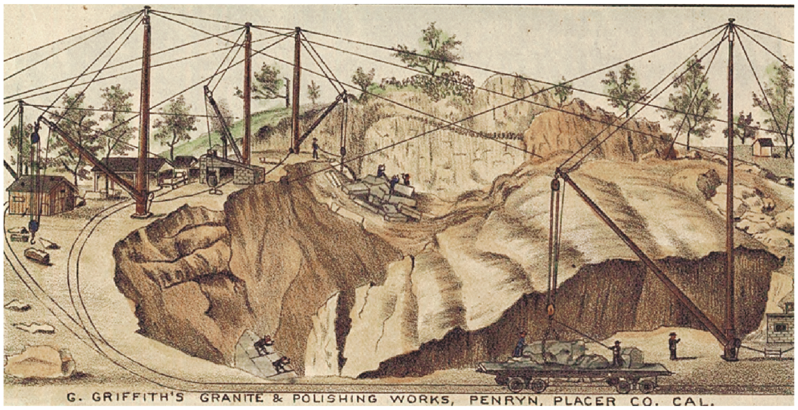
LOCATION OF SECRET RAVINE WITHIN THE SACRAMENTO RIVER WATERSHED

2 Background

2.1 Historic Uses of the Watershed

Secret Ravine drains into Dry Creek, which is a small tributary of the Sacramento River via the Natomas Main Drain (also known as Steelhead Creek, see above), and lies in western Placer County between the city of Roseville and the Newcastle area (Department of Water Resources 2002). Secret Ravine is a relatively small water body (37-square miles in area) that is linked through a series of drainage systems to the San Francisco Bay and Pacific Ocean. Humans have inhabited the watershed as far back as 1500 A.D. when the Nisenan people of the hunter-gatherer Maidu tribe depended on the natural resources within the watershed for sustenance (DCC 2001). By the early 1800s Europeans had reached the Nisenan territory - which extended to the crest of the Sierra Nevada mountains in summer months - and half a century later much of the land surrounding Sacramento was privatized into large land grants (PCCDD 1989).

Large-scale mining provoked the first major debate over the use of water for Californians in counties such as Placer, formed three years after the discovery of gold just east of Dry Creek, and named after the Spanish word for 'sand or gravel deposits containing gold' (Haley 1923).



HISTORIC RENDERING OF A DREDGE MINE IN PENRYN, PLACER COUNTY (1886)

(**Appendix A: Mining in the Secret Ravine Watershed** contains a more detailed account of mining history within the Secret Ravine watershed). Water used primarily for hydraulic mining to permit access to gold-bearing gravels, went unregulated until the passage of the 1887 Wright Act[5] (Rogers and Nichols 1967). In addition, the Caminetti Act was passed in 1893 to limit the impacts of hydraulic mining, (estimated to have been 46,025,391 cubic yards per year on the Yuba in the late 1800s) "to permit hydraulic

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[5] The Wright Act granted rights to non-riparian owners for the first time, (landowners whose holdings did not border natural stream channels) by permitting the creation of public irrigation districts (Rogers and Nichols 1967).

mining to be carried on, provided the same can be accomplished without injury to the navigability of said rivers or injury to the lands adjacent thereto" (Haley 1923). These two acts, in combination with the increasing value of land for agriculture, led to the great proliferation of large-scale irrigation systems in the state, and to the onset of commercial farming in the region.

Secret Ravine has a unique canal history coincident with these events. An intricate series of canals were constructed during the peak of the placer gold mining (circa 1870), which were used to deliver water from the Pacific Gas and Electric hydroelectric dam operation on the Yuba/Bear rivers (B. Smith and J. Ballard, pers. comm. 2002). The bulk of the water was meant for municipal use in southwestern Placer County. Placer County Water Association employees estimated that nearly 100% of the water in Secret Ravine was derived from the canal system during dry summers, with some of the canals running into natural waterways. In addition, 30% of the water was lost from the system through evaporation, leaks, straws and unlined canals. These events - which carry through to the present (water is still sold in miner's inches) - reinforced the idea that landowners and irrigation cooperatives can aggressively use "prescriptive rights" to convey water to their property via the canal.[6] They have also currently made the flow rates necessary to derive adequate stage depth for the salmon and other creek life nearly impossible to determine, not to mention flow rates for municipal use. The pre-World War II era in the Secret Ravine region was characterized by commercial agriculture, dredge mining and cattle herding.

JAMIE BALLARD (PCWA) AT BOARDMAN CANAL GATE

Orchards became the most successful crops and furnished a market for populations throughout the Sierra foothills via the Central Pacific Railroad, which helped inflate the population of Roseville from 250 in 1906 to 6000 in 1924. Dredge mining peaked in areas of present-day Rocklin and Penryn during the war years, producing the second largest output since the Mining Era.

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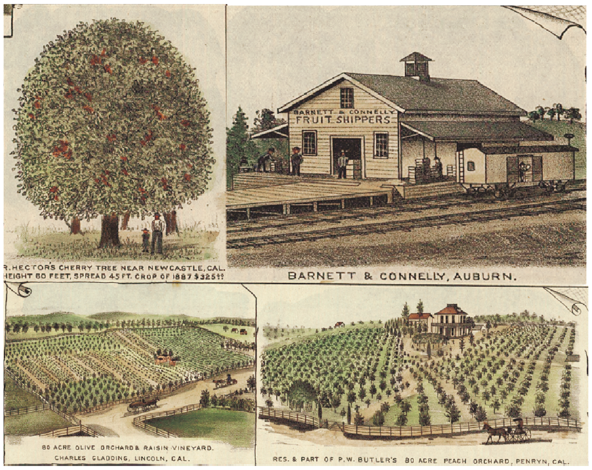
[6] Defined in multiple ways, Rogers & Nichols variably describe the legal definition of prescriptive rights as "loss of private easement to water or water facilities by nonuser or adverse possession, 25 ALR2d 1265, 1308, 1333," "the easement by prescription in artificial drains, pipes or sewers, 55 ALR2d 1144," or simply, "the parasites of water rights" (Rogers & Nichols, p. 325). Prescriptive rights succeed riparian and appropriative rights in the evolution of water rights in California. They were very controversial at the time (and still are), as appropriative rights are based on a grant from the stage or federal government and prescriptive rights based on 'adverse use.' Prescriptive water rights are obtained when 'open possession of non-public water is taken for a reasonable beneficial use [where] the taking must be adverse and hostile to the owner's claim and made under a claim of exclusive title and right' (Rogers & Nichols, p. 339). Nevertheless, a major portion of the irrigation rights on lands in California originated in prescription.



HISTORIC RENDERING OF ORCHARDS IN NEWCASTLE, AUBURN, LINCOLN AND PENRYN (1886)

Increasingly intensive farming methods, together with the urbanization of the floodplain following the war, led to large flooding events in the 1960s throughout the watershed.

2.2 Geology

The Secret Ravine drainage basin "is underlain by granitic rocks of Mesozoic age and is capped unconformably by volcanic and volcaniclastic rocks of the Miocene Mehrten Formation (primarily occurring in the lower watershed) and by Pleistocene alluvial fans and fluvial deposits of the Tulock Lake and Riverbank Formations" (Jones and Stokes 1994). Extensive Placer mining in the 19th century has resulted in an abundance of highly permeable decomposed granite. These sediments (including the Mehrten Formation) tend to be coarser and better suited for salmon and steelhead habitat, "although there is still excess fine material" (T. Horner, pers. comm. 2003).

The entire watershed is undergoing accelerated bank erosion and channel enlargement due most likely to increased flows from urbanization and various adjacent land uses (Jones and Stokes 1994). Landsliding does not seem to be an issue within the watershed due to the lack of steep slopes.

2.3 Biology

The chinook salmon (*Onchorhynchus tshawytscha*) is part of the family Salmonidae, which includes salmon, trout, and whitefish. It is the largest Pacific salmon, usually weighing over 30 pounds and growing to 58 inches. Chinook are the most abundant species of salmon in California, but the least numerous of Pacific Coast salmon (McGinnis 1984).

Salmon are anadromous: they migrate from the sea to fresh water to spawn. Chinook salmon are widely distributed in the north Pacific Ocean during the ocean phase of their life. Ocean temperatures set their southern limits. During their freshwater phase, chinook salmon are found in North American streams as far north as Kotzebue Sound, Alaska and as far south as the San Joaquin and Kings River in Central California (McGinnis 1984).

Chinook salmon show a diversity of life histories with two basic types: stream-type and ocean-type. The chinook that spawn in Secret Ravine are ocean-type salmon; they spawn soon after entering freshwater and juveniles spend a relatively short time rearing in freshwater (Moyle 2002).

The spawning period of a chinook salmon determines which run they belong to: fall-run, late-fall-run, winter-run, or spring-run (Moyle 2002). The salmon we focus on in this study are fall-run chinook. Their spawning period is from late September to December, with a peak in October and November (Moyle 2002 and DCC 2001).

Female chinook build spawning areas, known as redds. Typically, redds are built at the tail-out of pools, but given the small size of Secret Ravine, most redds are built at the tail-outs of runs (G. Bates, pers. comm. 2002 and R. Titus, pers. comm. 2002). Chinook require clean and loose gravel that will allow for proper oxygen exchange and remain stable throughout incubation (DCC 2001). The female uses her tail to clear away fine sediment and gravel, creating an oval area where several pockets of eggs are deposited. After fertilization the eggs are buried 20 to 60 cm below the gravel surface. The size of a redd is directly proportional to the size of the fish. (Fish and Wildlife Service and Coastal Ecology Group Waterways Experiment Station 1988). After spawning, adult salmon die due to an irreversible enzymatic change (Page and Brooks 1991).

FEMALE CLEANING THE REDDS

Eggs of the fall-run chinook salmon hatch after 40 to 60 days of incubation. The alevins (yolk-sac fry) remain in the stream bottom for four to six weeks, living off the nutrient rich yolk attached to their body (DCC 2001). Once the yolk-sac is absorbed the fry emerge from the gravel and begin migrating toward the estuaries, where they begin the transition necessary to live in the ocean.

SALMON EGGS NESTED IN SPAWNING GRAVELS

During the transition from a freshwater to a saltwater existence, the juveniles are known as smolts. Smolts migrate to the ocean from the estuary when freshwater increases river flow and turbidity, and decreases temperature (Moyle 2002). Smolts grow to adults in the ocean, where they remain until they are mature enough to spawn. Thus the cycle repeats itself.

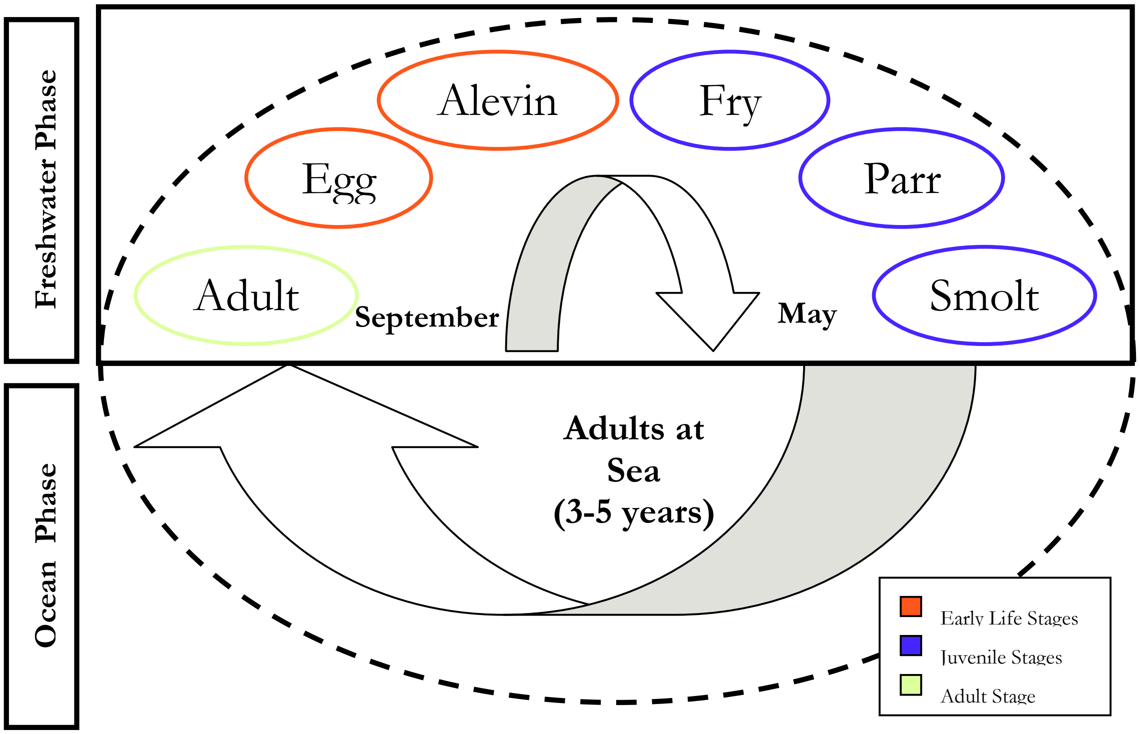


FIGURE 2.1 LIFE CYCLE ON SECRET RAVINE

Life Stage	Presence in Secret Ravine
Eggs and Alevins	November, December, January, February
Juveniles	Late January, February, March, April, May
Adults	September, October, November, December

TABLE 2.1 LIFE STAGES IN SECRET RAVINE

Chinook at various life stages utilize Secret Ravine at different times (**Table 2.1**). Eggs and alevins reside in the benthos from November through February. When they emerge from the gravel as fry, the juveniles use Secret Ravine as feeding grounds from late January through May. Chinook return to spawn as early as September, to as late as December. For each stressor, these months were considered when analyzing risk, unless otherwise noted.

2.4 Population, Distribution and Migration

Although historical abundances of Central Valley chinook before the onset of large-scale fishing operations are uncertain, early commercial catch records set the maximal production at around one to two million spawners per year (Yoshiyama et al. 1998). Differences in life history timing, spatial distribution and habitat requirements have not only enabled the four runs to most efficiently maximize the resources of the drainage system, they help account for markedly different population histories (Yoshiyama et al. 1998). All four races were heavily overfished as soon as seine-river fishing (1850s), and later commercial ocean fishing (early 1900s) replaced Native American catches, so that 5-10 million pounds of fish per year were being caught during this period. It was recognized as early as the 1870s that the salmon runs had begun to decline, due to such causes as hydraulic mining, dredge mining and loss of habitat due to construction of dams (CFC 1871:44 as quoted by Yoshiyama et al. 1998). Nevertheless, in addition to having to navigate lower relative topographical reaches (fall-run can migrate as far upstream as 1000 feet in elevation) and having their runs timed with fairly reliable storm events, the fall-run most likely sustained much less harvest pressure in the early years relative to the other runs due to their entry into rivers under a more highly deteriorated state. The elevation threshold also prevented the fall-run from being as highly affected by major water projects (Yoshiyama et al. 1998). As soon as the spring and winter runs were depleted, however, the fall-run became disproportionately exploited in the early 1900s, so that by the 1960s, the Sacramento drainage contained an average of only 176,000 spawners.

Although CDFG and USFWS initiated spawning escapement surveys in the late 1930s, little attempt has been made in the literature to standardize the data in order to produce rigorous statistical analyses of the population dynamics of the Central Valley runs. Correction factors would need to be applied to adjust for differences in sampling effort and accuracy, counting methods, and inconsistent time series among streams (Yoshiyama et al. 2000). The uncertainty associated with population estimates is exacerbated by the dearth of research that has been done on the impacts to salmon in the ocean, which include harvest, predation and climatic variability. Eric Gerstung reported in the 1964 Fish & Game survey, however, that for every one fish that was produced in Secret Ravine, another three could have been expected to be taken by commercial fishing (CDFG 1965).

Nevertheless, abundance estimates, when viewed as approximations with wide confidence intervals, can be useful to show major trends in terms of magnitude over recent decades (Yoshiyama 2000). They can also be used to describe "the spatial and temporal periodicity of chinook spawning" in Secret Ravine (R. Titus, pers. comm. 2002), which would allow us to roughly estimate, correlations with preferred spawning habitat, which has particularly important implications for management recommendations. We also used CDFG data to estimate the population size of the

Secret Ravine fish through their full life cycle by looking at several points outside of the system: fry estimates at the outlet of the San Francisco Bay Delta, and adult estimates at the base of the Sacramento main stem. We used this data to estimate whether the numbers were declining disproportionately outside of Secret Ravine, or whether, once reaching Secret Ravine, chinook encounter such poor habitat that they produce disproportionately few offspring within the creek proper.

From 1997 to 2002, the adult spawning counts have averaged 160 annually for Secret Ravine, and the outmigrating juvenile accounts have averaged 15,000 per year for roughly the same time period (1998-2002). We chose to focus on Secret Ravine because Secret Ravine is considered to have the best spawning habitat in the local area (G. Bates, pers. comm. via J. Love 2002). Indeed, Department of Fish and Game counts from 1964 indicate that 900 live fish and carcasses were estimated in Secret Ravine, comprising 90% of the estimate in the Dry Creek drainage system. This is a considerable number, given the small areal extent of Secret Ravine relative to habitat that such large fish would normally seek out (R. Titus, pers. comm. 2003). And although Secret Ravine may be an atypical fall-run stream in many ways, apart from the chronic problem of excess sand (Li, Swanson, Nelson, Meyers, Titus, Dvorsky via DCC 2001) and decomposed granite (E. Gerstung via R. Titus, pers. comm. 2003) the creek is noted for its consistently good quality gravel, abundance of deep pools and adequate riparian cover. Temperature and flow typically coincide in optimal amounts when the fall-run migrate upstream (R. Titus, pers. comm. 2003). Nevertheless, the small size of the watershed, together with its overall low gradient make salmon in this system even more dependent on proximate conditions such as appropriate habitat and ambient weather conditions.

Chinook salmon are thought to use magnetic fields and other general clues to draw them from the deep ocean to the coast, and olfactory sensing, to bring them back to their natal streams (R. Warner, pers. comm. 2003). The evolutionary need for these fish to migrate has been explained as a response to prehistoric glacial movement, and today is understood as driven by the change in resource availability between freshwater and ocean environments (Alcock 2001). Freshwater is more appropriate for the salmon in terms of breeding grounds because of ostensibly fewer predators and increased likelihood of finding mates of a common population (R. Warner, UCSB Lecture 2003). Nevertheless, once salmon have migrated as far as their natural physiological limits and olfactory senses will take them (indeed, they are thought to be able to recognize their own kin, if not the precise redd from which they emerged), they would seem to be limited primarily by habitat and metabolism. Thus, homing cues can guide them back to their natal streams, but choice of spawning location would seem to be habitat limited, and thus, on such a small system as Secret Ravine, highly dependent upon the timing of individuals within the fall-run. Straying is increasingly common, however (R. Warner, pers. comm. 2003), and with 30% of hatchery-produced fish annually being conveyed to the Sacramento main stem (Yoshiyama et al. 1998), the ability of the four extant runs of salmon to try to retain their genetic integrity on the basis of their homing skills alone is yet a further over-arching stress to fall-run populations.

2.5 Current Uses of the Watershed

EAST ROSEVILLE PARKWAY, NEAR THE CONFLUENCE

In 2002, the last of the fruit-packing businesses in Roseville closed (G. Bates, pers. comm. 2002). Currently no large-scale cattle operations remain in the Secret Ravine drainage (Placer County 1994) and the agriculture that once dominated the watershed has been replaced with new suburban development. Today the western portion of Placer County, containing Secret Ravine, has a population of 237,145 people, that over the next 25 years is projected to increase by 75% to 415,335 (SACOG 2002).

In 1963, the California Department of Transportation, CalTrans, began construction on a northern interstate from the San Francisco Bay area through Sacramento to Reno (California Highways 2002). The completion of Interstate 80 (I-80) in 1972 brought a record number of vehicles through the Secret Ravine watershed and influenced its future land use. CalTrans estimates 146,000 vehicles a day travel past Secret Ravine on I-80 (CalTrans 2001). These trips include through-traffic heading east over Donner Pass, local traffic traveling to Roseville and the Rocklin area, and commuters traveling to the Sacramento metropolitan area. Travelers on I-80, given the opportunity provided by daily congestion of highway traffic, can see the Secret Ravine riparian area bordering the highway to the southwest from Newcastle to the Taylor Road exit.

The zoning of much of western Placer County consists predominately of rural residential and single-family designations (**Appendix B-1: Secret Ravine Landuse**). The influence of this zoning, together with Interstate 80, have contributed to the whole-scale change in land use, creating an area ideal for developing bedroom communities for the businesses in downtown Sacramento. This trend of suburban development has become the main use of the Secret Ravine area and has been projected to continue over the next 25 years (SACOG 2002).

To support this transformation of the cities of Roseville, Rocklin, Loomis and Newcastle from agricultural to suburban land uses, new infrastructure improvements were required. A hospital, a community college, and recreational facilities such as a multiplex movie theater and a park can all now be found in the Secret Ravine drainage (**Appendix B-4**). Additionally, the Secret Ravine watershed contains sewage treatment ponds for Newcastle and the Castle City trailer park (G. Lockwood, pers. comm. 2002) as well as the Boardman Canal, which transports drinking water via the water treatment plant for most of western Placer County (B. Smith, pers. comm. and J. Ballard, pers. comm. 2002). The recreational use of the watershed includes activities associated with suburban open space such as hiking, biking, baseball, paint ball and off-roading on off-highway vehicle trails. See **Appendix B: GIS Maps** for current photographs of Secret Ravine.

3 Problem Formulation

3.1 Approach

An ecological risk assessment (ERA) "is a process that evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors" (U.S. EPA 1998). Within the ERA framework, available data and information are used to help understand and predict the links between sources, stressors and their resulting ecological effects. Findings can then be used to prioritize environmental decisions (U.S. EPA 1998).

We are using this ERA process, defined by the U.S. EPA, to assess the physical, chemical, and biological stressors on the fall-run chinook salmon in Secret Ravine. Our goal is to prioritize sources and stressors for local organizations so restorative and preventative measures can be taken to protect the salmon population.

There are three phases of an ERA: 1) problem formulation; 2) risk analysis; and 3) risk characterization (U.S. EPA 1998). The first phase, problem formulation, includes a clear definition of the problem, and a plan for analyzing and characterizing risks (**Appendix D: The Framework for Ecological Risk Assessment**). To access the existing information associated with Secret Ravine, we spoke to various local stakeholders and compiled extensive data. In consultation with our stakeholders we chose reproductive success of the fall-run chinook to be our assessment endpoint. Our endpoint is based on the viability of each life stage, and essentially depends upon completion of the life-cycle (e.g. the ability of an adult to reach spawning grounds and reproduce; the ability of the eggs to hatch; or the ability of the alevin to emerge from the redds, etc.). The problem formulation phase also involved the development of the conceptual model (**Appendix E: The Conceptual Model**), which synthesizes our understanding of the relationships of the stressors, sources and effects in the system. The second phase, risk analysis, is driven by the data collected in the problem formulation phase. The data is used to assess how the exposure to stressors is likely to occur and the ecological impact that will occur from the exposure. The risk analysis phase also determines the method for assigning ranks to sources, stressors, habitats and exposure filters. The third phase, risk characterization, estimates risk. It includes a summary of assumptions, scientific uncertainties, strengths and limitations of the analysis that culminates in a description of risk.

In the following ERA, two models were used to characterize risk in Secret Ravine: the Modified Relative Risk Model (MRRM) and the Stressor-Driven Risk Model (SDRM). By using these two models, we hope to gain slightly different perspectives on risk analysis in order to yield the most comprehensive understanding of the potential risk to the salmon in Secret Ravine.

The Modified Relative Risk Model was designed using the Relative Risk Model (Landis 1997) as a template. The Relative Risk Model (RRM) is a specialized form of ecological risk assessment developed by Dr. Wayne Landis of Western Washington University. Specifically, we looked at a regional ERA performed by Emily Hart Hayes, a graduate student in Landis' lab (Hart Hayes 2002). Initially, this model gave us a systematic way to quantify ecological risk posed by sources and stressors in Secret Ravine.

With our CalEPA clients, Barbara Washburn and Jim Donald, we modified this approach, retaining its basic structure, but changing sections of it in order to accommodate certain unique features of Secret Ravine. Consequently, the Modified Relative Risk Model (MRRM) combines quantitative source analysis of land use through Geographic Information Systems (GIS), with dose-response and effect estimates of biological, chemical and physical stressors to the salmon. Based on the dose-response and effect estimates, data for the region is converted into a ranking system. An equation that incorporates these ranks with habitat, exposure and effect is then used to calculate a risk score. A risk score, or the quantification of risk, can be calculated for sub-watersheds (or "Risk Regions"), sources, stressors, and habitats.

The way in which a rank is established for stressors in the RRM was not suitable for our purposes, hence we modified this in the MRRM. The traditional RRM used a process of natural breaks to assign a spectrum of possible ranks, essentially requiring that every number in the range is assigned, despite whether the absolute level of risk warrants the most extreme ranking. Instead, we used scientific literature to establish baselines associated with risk. This enabled us to incorporate biological meaning into the ranks. We also assigned ranks relative to the data points so that every number in the range does not need to be assigned. Therefore, while we assigned the highest rank to stressor effects directly associated with mortality, there is no way of equalizing the value of a rank for one stressor with that of another (e.g. a '2' for temperature will not necessarily connote the same level of risk as a '2' for morphology).

In order to address the limitations of the traditional RRM and the MRRM we developed the Stressor-Driven Risk Model (SDRM). The crux of the Stressor-Driven Risk Model lies within the use of percent effect (percent habitat reduction or percent reduction in population) specific to the three life stages of salmon. These percentages are calculated using dose-response curves, reference values or habitat loss estimations. Each stressor and source affects life stages differently, so this model will allow us to express these differences, yet not give more importance to any one life stage. Accordingly, the risk scores for sources and stressors will be expressed as 'percent effect' rates, rather than as ranks. This will eliminate problems associated with multiplying ranks throughout the model, and give the SDRM greater precision. The SDRM will prioritize stressors and sources over the entire creek, instead of assigning ranks per risk region. By comparing the results of the MRRM to those of the SDRM, we hope to achieve the most complete understanding of the processes at work on Secret Ravine.

3.2 Conceptual Model

The conceptual model (**Appendix E: The Conceptual Model**) is a "written description and visual representation of predicted responses by ecological entities to stressors to which they are exposed and includes ecosystem processes that influence these responses" (EPA 1998). The conceptual model for this risk assessment contains a listing of sources, primary stressors, secondary stressors and life stages of the fall-run chinook salmon. The model was developed iteratively via numerous discussions that included stakeholders, EPA staff and resource professionals. All interactions were chosen based on their potential plausibility within the Secret Ravine watershed; some interactions that may be typical within other watersheds were excluded based on the discussion in the meetings mentioned above.

The sources are broken down into three categories: urbanization, legacy and rural-residential. The legacy category includes sources that may not be currently present within the watershed (e.g. mining activities), but have long-term effects that may still be contributing stress to the fish.

The primary stressors are broken down into three categories: physical, chemical and biological. These primary stressors may be acting directly or indirectly on the endpoint.

The chinook salmon life stages include three categories: early life stage (which includes the egg and yolk-sac fry stages), juvenile phase and adult phase. All stressors are represented because of their potential impacts on these life stages. Some stressors may act on only one life stage whereas others affect multiple stages.

A complete list of sources and stressors is located in **Appendix F: Sources and Stressors**.

3.3 Source Descriptions

3.3.1 Urbanization

With the increase in population in western Placer County, housing developments are increasingly common and infrastructure must expand to accommodate the new influx of residents. The sources in this category reflect consequences of urbanization.

Landscape maintenance includes the maintenance of suburban lawns and gardens in new housing developments, as well as golf courses and businesses with sod lawns and terraces. This source potentially contributes fertilizers, herbicides, metals, and nutrients to the watershed. However, landscaping can also prevent erosion and buffer the effect of impervious surfaces on stream flows.

Impervious surfaces describe land uses associated with high pavement densities such as streets and driveways, roofs, and other structures that prevent water from infiltrating into the soil. This has three main effects on the stream. First, impervious surfaces decrease the time between when precipitation falls to when water enters the fluvial system, leading to changes in the flow regime (usually increasing peak flows). Second, the accumulation of fine materials on the surface coupled with increased erosion from increased peak flows can cause an increase in sediment loading to the stream. Thirdly, this source also stores contaminants between rain events. During dry periods hydrocarbons and metals collect on impervious surfaces such as roads and highways, and during rain events these contaminants wash into fluvial systems such as Secret Ravine.

Channelization is defined here as any straightening of the creek due to bank stabilization or artificial movement of the channel. One of the main causes of channelization in Secret Ravine was due to the construction of Interstate 80. Sections of the stream banks that were within a certain distance of the highway were reinforced with boulders to prevent the creek from undercutting the highway. In the process, sections of the creek lost some of their sinuosity (U.S. ACE 1997). Channelization also results from the encroachment of development into the riparian area. This process usually involves the removal of native vegetation and the artificial stabilization of the banks. Channelization can result in increased sediments, altered stream morphology and altered flow regimes.

Construction and development involves the construction of new houses and infrastructure. This source is unique in that it can result in significant loadings of sediment and alterations to riparian areas. Other stressors resulting from this source include alterations to the flow regime and morphology (increasing imperviousness) along with introductions of in-stream barriers (for water collection, fencing or crossings).

Water treatment plants exist in two locations in the headwaters of the watershed. One is near the town of Newcastle and the other as part of the Castle City Trailer park. Both facilities use an aeration basin combined with a solid storage basin (G. Lockwood, pers. comm. 2003). The sewage ponds currently have no direct connection to Secret Ravine, however in the past, the Newcastle facility was forced to chlorinate the effluent coming into the ponds and released water into Secret Ravine due to large rain events that overwhelmed capacity. This source can therefore result in increased sediments, alterations to the flow regime and increased nutrients.

Off-highway vehicles (OHVs) include any motorized vehicles (motorcycles, cars, trucks or all-terrain vehicles) that utilize the floodplain of the creek for recreation. These vehicles cause erosion and at times drive within the creek bed itself, potentially destroying invertebrate habitat and sensitive fish-spawning habitat. The most heavily used area includes the stretch from East Roseville Parkway to Greenbrae Road in Rocklin (G. Bates, pers. comm. 2003). Impacts associated with this source are: increased sediments, altered stream morphology and riparian vegetation along with a decrease in food supply for the salmon (due to habitat destruction).

3.3.2 Legacy

The history of Placer County includes activities that had significant impacts on the Secret Ravine watershed such as placer mining, orchards and introduced fishes. These sources are no longer active but their long-term impacts may still be influencing the habitat of Secret Ravine.

Mining includes major mining activity recorded by the California Department of Conservation, Division of Mines and Geology, the Bureau of Mines, U.S. Geological Survey, and Bureau of Land Management, from the time of discovery of gold in 1848 at nearby Coloma, CA, through current aggregate mining claims. This legacy source is suspected to contribute to increased sediments, altered stream morphology, altered riparian vegetation and increased metals.

Orchards dominated the Secret Ravine watershed during most of the twentieth century. The production of fruit and other agriculture products during this time period involved the use of persistent pesticides such as DDT (EPA 2002), and altered the vegetation in the riparian zone that affects salmon habitat today. A potential increase in sediments has also been associated with this source.

Introduced Fish changed aquatic species assemblages in California substantially over the last century. A wide range of activities may have introduced exotic fish to California waters including sport fishing, mosquito control, and ornamental landscape ponds (Moyle 2002). For example, spotted bass (*Micropterus punctulatus*) planting by California Division of Fish and Game occurred around 1937 to the early 1940's and again in 1973 to 1976 in reservoirs of the Central Valley to provide quality bass sport fishing. This introduction, meant to supplement bass fisheries in reservoirs far from the Dry Creek system, initiated a chain of events that allowed resident populations of spotted bass to establish in foothill streams such as Secret Ravine. Often fish introductions that led to the invasion of Secret Ravine occurred physically distant to our risk assessment area. Due to the extent of invasion and the biology of many of these species, it became necessary to limit the source value to the habitat of most concern. In consequence, fish introduction has been defined to include the riparian buffer zone surrounding Secret Ravine. This source forms the habitat for the current population of introduced fish, which may pose a risk to future generations of chinook salmon. The main impact of this source is increased predation on juvenile and early life stages of the salmon.

Beaver dams are thought to result from a combination of introductions made by fur trappers from the East during the onset of the Mining Era, as well as of beavers which are thought to have already existed in the area for many centuries (Morgan 1886).

Although the source of beaver dams is the beaver populations themselves, the distinction is no longer meaningful due to the fact that beavers have become ubiquitous throughout the regions bordering the Sierra foothills. The Stacy Li habitat study reports that 13.45% of the pools on Secret Ravine are dammed (mostly by beaver dams) (Li 1999). Beavers have long co-existed with salmon, and their presence can have both positive and negative impacts on the fish. Direct impacts of beaver dams include altered flow and reduced access for adult fish. Beaver dams - and some artificial barriers (categorized under 'Construction and Development') - affect sediment by increasing retention in second and third order streams (Naiman 1986).[7] "In several instances a small dam (4-18m^2) of wood, properly positioned, could retain 2000-6500m^3 of sediment" (Naiman 1986). Conversely, beaver dams can also exert a stabilizing effect on stream ecosystems, causing more sediment to settle out more evenly along the bed (Naiman 1986). Beaver dams - as partial barriers - can indirectly cause superimposition of redds[8] when adult migration is delayed, forcing the fish to spawn in potentially less suitable, or already used habitat. Beaver dams and other barriers, depending on flow conditions, create the opportunity for predators such as bass to congregate just downstream of barriers and prey on emigrating juveniles.

3.3.3 Rural Residential

The third category of sources includes land uses that could not be categorized under urbanization or legacy activities. The two rural residential sources that were identified within the Secret Ravine watershed include dirt and gravel roads and irrigation canals.

Dirt and gravel roads include the roads used in the watershed that have not been paved and are outside the heavily used OHV region mentioned above. Most of these roads have been created to serve rural residential structures and agriculture or are a result of OHV activities. Dirt and gravel roads differ in their contribution to flow/morphology and toxicity problems due to their different infiltration and erosion rates.

Irrigation canals operated and maintained by the Placer County Water Association (PCWA) are relics of the mining era. Today, the canal system carries water to irrigate rural residential land, supply stock ponds and to supply the water treatment plants that process most of the drinking water to the watershed. The irrigation system provides a conduit that transports water in rain events. To deal with the excess flow, PCWA has equipped the canals with spillways that allow water to leave the canal system unimpeded. The backbone of the PCWA canal system, the Boardman canal, ends in the lower part of Secret Ravine and provides water to Secret Ravine continuously throughout both the

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[7] Secret Ravine is considered a second-order stream. A second-order stream, as characterized by the "Strahler Order," is "a hierarchical ordering of streams based on the degree of branching." A second-order stream is a forked or branched stream composed of two first-order streams (Strahler 1957).

[8] Superimposition is the repeated use, or overlap, of limited spawning grounds (McNeil 1964).

summer and winter. The irrigation/canal system influences the flow and morphology of Secret Ravine.

3.4 Stressor Descriptions

3.4.1 Sediment

Sediment and its relationship to salmon health is a well-researched - yet still very complicated - issue. The condition of the sediments within the spawning redds (located in the benthos) themselves is often referred to as substrate quality while the conditions within the water column are termed turbidity (or suspended sediment). Both substrate quality and turbidity will be evaluated here under the sediment stressor.

The greatest threat to the substrate quality (and thus the benthos or early life stages) is the accumulation of fine sediments on spawning gravels and food-producing areas (Cordone and Kelley 1961). We collected data on Secret Ravine over the summer of 2002 to assess substrate quality (Ayres, Love and Vodopals 2002) (**Appendix J-1: Sediment**).

This data was then analyzed using methods developed by Tappel and Bjornn 1983 to estimate survival to emergence of the eggs to alevins. Survival to emergence usually relates negatively to percentages of small fines (Chapman 1988). A conservative estimate of average survival from a redd is estimated to be between 25% to 35% (Kondolf 2000).

K. VODOPALS COLLECTING SEDIMENT SAMPLES ON SECRET RAVINE

Increased turbidities can be injurious to fish and aquatic life, particularly if conditions of high turbidity persist for a long duration (Newcombe and MacDonald 1991). Dry Creek Conservancy (DCC) turbidity data collected from December 2000 to November 2002 was used to assess impacts to the juvenile and adult life stages (within the water column).

Effects of turbidity on salmon health were estimated using methods developed by Newcombe and Jensen (1996). Units for the turbidity data from the DCC were NTUs (nephelometric turbidity units[9]). It was necessary to make the assumption that one NTU is equal to one milligram per liter of suspended sediment in order to estimate survivability. Suspended sediment concentrations were averaged (over all years sampled) for the months where each life stage occupied the stream (e.g. juveniles are present from

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[9] A nephelometric turbidity unit is a measure of turbidity via refracted light.

February to May). Duration of exposure was assumed to apply to the entire life stage (four months for each life stage). Three sets of coefficients were given with the model to assess impacts to the three different life stages.

Suspended sediment concentrations and durations of exposure could then be used to estimate the scale of severity of ill effects[10] (Newcombe and Jensen 1996). The severity of ill effect values (SEV) range from zero to fourteen. Values from zero to three include nil and behavioral effects. Values ranging from four to eight contained the sublethal effects. SEV values of nine and ten included sublethal effects up to 20% mortality. SEV values from eleven to fourteen corresponded to mortalities of 20% up to 100%.

We assessed the impacts to the benthos utilizing the grain size distribution data (E. Ayres, J. Love and K. Vodopals 2002). The average (for all sampling sites) percentage of sediment (by weight) of sediment below 0.85 mm was 17% and 50% below 9.5 mm. The average mortality estimated from these distributions was roughly 67%.

SEV values in Secret Ravine ranged from six to 11 with an average approximately equal to a value of nine. Thus, average turbidity levels in Secret Ravine should not result in mortalities. Isolated storm events, however, could yield higher SEV values with the potential to result in mortality.

3.4.2 Flow

Risk from flow can have numerous effects on salmon. Some examples are: low flow during spawning, stranding during spawning, scour during incubation, bank erosion contributing fines to the redds, and low flow and stranding during juvenile downstream migration. General alterations to stream morphology can also occur when the flow regime is altered.

Flow data on Secret Ravine is limited. Only one storm gauge exists (located at China Garden Road, **Appendix J-2**) and was recently moved from another site. All records are suspect due to a lack of cross-sectional data at the previous site and inaccuracies of the analog device (R. Nelson, pers. comm. 2003).

Stranding was not assessed to be a problem based on observational data (G. Bates, pers. comm. 2002; R. Titus, pers. comm. 2002). Low flow was deemed not to be a problem (Swanson 2000). No data exists for bank erosion, but observational data concludes that there is a definite risk associated with this effect. General alterations to stream morphology are addressed under the “morphology” stressor. Thus, in the absence of sufficient flow data, only scour is addressed. This is the case for the MRRM. For the SDRM, however, observational flow data exists for the entire watershed and is used to assess impacts from flow.

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[10] The severity of ill effect is an index of harm to chinook due to turbidity.

Scour is the process by which peak flows disturb the streambed sediments; this can affect all three life stages along with general habitat conditions (Schuett-Hames et al. 1996). The risk of scour can be estimated based on the size of the substrate (streambed sediments). In general, smaller substrate sizes lead to increases in scour. A measure of substrate size is the D_{50}, which is the size of sediment at which 50% of the sample is less than that size by mass. The critical depth (the depth at which scour will begin) can be calculated from the D_{50} (Ritter et al. 2002).

High risk occurs when these critical depths are lower than optimal depths for migration, juvenile rearing and spawning (**Table 5.3, Section 5.1.2.2**). It should be noted that the risks to migration, juvenile rearing and spawning are not being assessed here (since sufficient flow data does not exist), rather these values are being used as baselines to assess the risk of scour. Migration is assumed to affect the adult life stage, juvenile rearing, and the early life stages.

Sediment data indicate that scour is occurring at levels below optimal flow levels for chinook migration, spawning and juvenile rearing. No flow data exists, however, to confirm this. Data from Li and Fields (1999) indicate that 27% of the habitat in Secret Ravine is unsuitable for juveniles due to poor flow conditions and 6% for adults.

3.4.3 Morphology

Gross stream morphology refers to average channel slope, approximate size of channel and floodplain width; habitat characteristics include pool/riffle sequences, sediment size, and frequency of large woody debris (University of Washington, Center for Streamside Studies 1999). For this assessment, the morphology stressor will refer to both general morphology and habitat characteristics.

In general, habitat frequency can be used to roughly gauge problems of cumulative watershed effects on streams (KRIS 2003). A stream or stream reach is rated high quality habitat if it contains more than 30% pools by length (PBL), has less than 50% embeddedness in most of its pool tail crests, and has at least 80% riparian canopy cover (KRIS 2003).

Site-specific stream morphology data exists only for the downstream reaches of Secret Ravine, based on a survey conducted by ECORP Consulting, Inc. Although substrate class size data existed in this dataset, no data existed regarding embeddedness. This risk assessment addresses canopy cover via the altered riparian vegetation stressor, thus, only chinook habitat (pools and riffles) will be addressed under morphology.

Data from ECORP (2002) and Li and Fields (1999) indicate an average deficiency (below 33%) in pools of approximately 16% and 13% for riffles.

3.4.4 Temperature

Water temperature has both direct and indirect effects upon the survival of the three life stages of chinook salmon. Such effects vary with the developmental stage of chinook salmon. Adverse conditions are intensified during drought conditions, causing water temperature to be unsuitable for maximum survival of all life stages of the fall-run chinook.

Available data suggests that none of the reaches of Secret Ravine present optimal temperatures for the various life stages of chinook throughout the entire year. However, the data is selectively relevant to each life stage due to the occupancy of the fall-run within Secret Ravine for only certain months of the year, as given by Rob Titus's determination of occupancy of different life stages in **Table 2.1**. Below are average water temperatures in Secret Ravine.

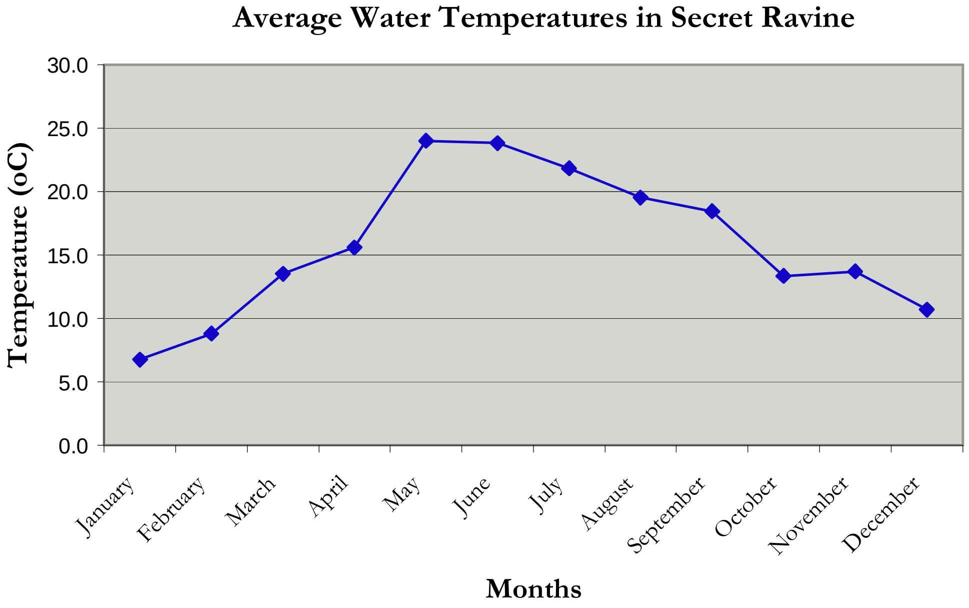


FIGURE 3.1 AVERAGE WATER TEMPERATURES IN SECRET RAVINE

Early Life Stages: Eggs & Yolk-sac Fry

Once spawning has taken place, the eggs of chinook salmon hatch in approximately two months, and the young remain in the gravel 2-3 weeks prior to emergence. Egg viability is measured by egg tolerance to both extremes of high and low temperatures. High temperatures produce abnormal physiological development during the egg stage, which prevents successful transition to active feeding in the fry stage.

Average maximum temperature during incubations should not exceed 14.5 °C. Temperatures ranging from 14.5 – 15.6 °C show reduced viability (Hicks 2000).

Additional losses are incurred when salmon are held at temperatures from 15.6 – 17.8 °C; although these conditions have not been known to incur 50% mortality (Castaneda 2000). 100% mortality was reached in eggs and fry with initial temperatures of 18.3 °C (Seymour 1956).

Juvenile Phase: Fry

After emerging from the gravels, chinook fry remain in Secret Ravine for one to two weeks. Before emigration from the stream, however, juvenile chinook may be susceptible to temperature-related factors such as predation, and smoltification effects, in addition to decreased growth rates. Juvenile mortalities can also be ascribed to indirect temperature effects, such as a loss of equilibrium that can increase their susceptibility to predation.

The maximum weekly optimal temperature for juvenile salmon is 15.6 °C (Armour 1991). Juvenile mortalities increase incrementally if temperatures exceed the maximum daily average (Brett et al. 1982).

Adult Phase

After spending three to four years in the ocean, mature fall-run chinook salmon begin their return migration to Secret Ravine to spawn. Temperatures can be a serious direct or indirect threat to migrating salmon. In addition to adult lethality, temperatures can cause adults to stop migration (cessation). These cessations can reduce the overall fitness of migrant adults.

Migrating adult salmon do not feed in freshwaters and must consequently enter freshwater with sufficient fat and muscle reserves to supply their metabolic requirements up to and through the act of spawning. Warmer waters speed up the metabolism of chinook causing them to use up stored energy reserves at a faster rate. Higher metabolic rates may result in a decrease in the quality and quantity of eggs in addition to an overall reduction in the fitness of the adult fish that need to migrate and negotiate barriers and obstacles, excavate and guard redds, and complete the act of spawning (Hicks 2000).

Stream segments used by chinook salmon for migration corridors should not exceed 16.5 °C (Hicks 2000). Partial migration cessation occurs at 18.9 °C and full cessation/direct lethality occurs at 20.0 – 21.0 °C (Hallock et al. 1970).

3.4.5 Altered Riparian Vegetation

Nearly all vegetation in Secret Ravine, both understory and overstory, has been altered since the pre-Columbian times. The first major change in Secret Ravine vegetation probably occurred during the second-half of the mining period (late 1800s). The placer miners sluiced most of the topsoil in Secret Ravine in search of gold, and other precious metals, through hydraulic and later dredge mining (Holland 2000 and Haley 1923). In Holland's 2000 survey, evidence of the extent of the mining activities is presented. Holland states that, "All but 2,000 feet of this reach (near Sierra College) shows evidence of extensive placer mining. I had not appreciated the magnitude of the forty-niner's effort. In most areas, the placer mining extends 500 to 1,000 feet away from the stream" (Holland 2000). The mining activities removed most of the topsoil found in the riparian zone and thus the understory plants associated with that soil.

Agriculture became the dominant land use in Placer County during the first part of the 1900's. During this period, 20,600 acres of the Rocklin quadrangle contained cultivated land, orchards or live stock (Holland 2000). To successfully farm orchards required productive topsoil, but the miners of the Mining Era had essentially flushed the riparian zone topsoil down Secret Ravine. Therefore, the orchards during the early part of the 1900's did not extend to the stream edge as in most agricultural areas and much of the vegetation that pioneered the mine tailings remains to the present.

Since the Mining Era, the main land use in Secret Ravine has been agriculture. During this period, the riparian area partially recovered from the Mining Era. However, the large-scale mining disturbance completely changed the overstory and understory found throughout the stream system. The grassland environments changed from native bunch grasses to non-native annual grasses, the shade tolerant shrubs were replaced with the sun-loving Himalayan Blackberry, poison oak and nettle, and the pioneer plant species, Fremont cottonwood, shared the overstory with the native oaks (Schartz 1996 and Holland 2000).

The question remains whether the altered riparian vegetation poses a modern day risk to chinook. The vegetation assemblages found historically in Secret Ravine can be divided into three basic phases: pre-Columbian, Mining Era, and present day (**Table 3.1**). The vegetation found during the pre-Columbian period represents the ideal riparian vegetation for chinook salmon, while the near de-vegetation experienced during the Mining Era could be considered the poorest kind of vegetation cover for chinook salmon.

	Current Vegetation	**Mining Era Vegetation**	**Pre-Columbian Vegetation**
Fish Cover Value	0% < X < 100%	~0	100%
Dominant Understory (Forbs*/Grasses)	Naturalized annual grasses and invasive forbs have replaced nearly all native grasses in California.	~0 cover Mining activity removed most riparian vegetation.	Native bunch grasses community largely creeping wild rye (*Leymus triticoides*).
Dominant Scrub	Early seral community and invasive species indicative of large–scale disturbance.	~0 cover Mining activity removed most riparian vegetation.	Community composed of native shade tolerant shrubs
Dominant Overstory	Oak woodland riparian habitat composed largely of Valley Oak (*Quercus lobata*) & Fremont cottonwood (*Populus fremontii*).	Only a few Valley Oaks (*Quercus lobata*) remain after mining activity.	Nearly closed canopy dominated by Valley Oak (*Quercus lobata*).

Table Plants: To understand the threat posed to chinook salmon from altered riparian vegetation, a description of the previous plant communities in Secret Ravine provides prospective on the risk to the salmon population. This table compiled information presented in *The Jepson Manual: Higher Plants of California* (Hickman, J., Ed., 1993) and Holland 2000. The Jepson Manual is a taxonomic key providing a comprehensive treatment of the flora of California and Holland developed tools to classify plant communities in California.

*A forb is a low-growing herb. The combination of forbs and grasses typically compose the ground cover in many ecosystems.

TABLE 3.1 VEGETATION ASSEMBLAGES ON SECRET RAVINE

The altered vegetation currently found on Secret Ravine includes two characteristics that may be impacting the salmon: composition of the plant community and a reduced areal extent of the riparian buffer zone along the banks of Secret Ravine.

Vegetation composition effects salmon in two direct ways: 1) by moderating water temperature through providing shade and 2) by creating bank complexity when vegetation falls into the creek that juvenile chinook use to evade aquatic predators (Li and Fields, Jr. 1999, Bishop 1997). To address cover and bank complexity the Li study of habitat suitability was used. In general, the Li study concluded that the riparian vegetation cover was fair with a median value of 38.33% by area and the overhead cover, the vegetation that moderates water temperature, was fair with a median value of 39.14% by area in 814 observations (Li and Fields, Jr. 1999). From these two index values the overall cover rating was evaluated to be approximately 40% by area, a fair value for foothill streams (Li and Fields, Jr. 1999). However, the Li study reported that the in-stream cover, the vegetation that provides fish with cover from predators was poor due to the amount of sand substrate that buried many of these structures. The issue of sand substrate will be addressed in other parts of this analysis. However it should be noted, that if in-stream cover could be augmented that cover would probably also be buried in sand due to the excess amount of sediment in Secret Ravine.

Also, vegetation composition effects salmon indirectly through hydrologically related processes such as interception of rain drops by vegetation and root stabilization of soil, thus preventing sedimentation and erosion (Bishop 1997, Li and Fields, Jr. 1999). These processes have been addressed in other stressor analyses for this risk assessment, however a change in dominant plant community can change the effectiveness of the plant community at mitigating sedimentation and erosion problems. The main change in Secret Ravine plant species composition has been due to invasive plants though these changes were not found to be a significant stressor to chinook salmon. Invasive plants in Secret Ravine have been examined in **Appendix G: Invasive Plants and Blackberry (Rubus *discolor)***, with special attention given to Himalayan blackberry (*Rubus discolor*). To evaluate the extent of the riparian area, a GIS analysis approximated the riparian buffer of 100 ft -on each side of the stream- and compared it to an estimation of actual riparian cover projected from aerial photography of Secret Ravine.

3.4.6 Reduced Access

Barriers cause reduced access on Secret Ravine, which were historically designed for human use in flood control, irrigation and agriculture (e.g. culverts, pipelines and cattle fences, respectively), and also include "natural barriers", or beaver dams. Although members of the Bren group discovered one of the last large artificial obstructions this summer for removal (a chain-link fence at Loomis Park), there are still several unscreened or inadequately screened diversions in Secret Ravine (DCC 2001). Although beaver dams are now the primary concern in terms of reduced access on Secret Ravine, reduced access and/or beaver dams convey other types of stress: decreased sediment, altered flow, superimposition of redds and increased rates of predation. Evaluations of the severity of each of these criteria are made for both models, with particular emphasis on the most egregious secondary stressor: superimposition of redds.

Total fish passage barriers have the potential to block flows that attract migrating adults and send them to non-natal tributaries (Mesick as cited in DCC 2001). Although Secret Ravine has no total barriers, partial barriers, in combination with rainfall patterns and other sources of flow, influence run timing and geographical distribution, and have the potential to send adult chinook to less suitable habitat and/or superimpose their redds, and delay juvenile emigration. Although there are several shallow passages along Secret Ravine (most notably the shallow stretch below the East Roseville Parkway Bridge, **Appendix J-6: Reduced Access**), adult chinook require a minimum water depth of only 24 cm (10 inches) for passage (Reiser and Bjornn, as cited inVanicek 1993). Thus, in the absence of the data required to construct a complete hydrological profile, we determined passage criteria based on a rule of thumb used by fish passage experts. We used different criteria to determine passability for the MRRM and SDRM models.

We took "low" and "high" flow scenarios into account in both models. Adult migration takes place from July through December, with peak spawning occurring after November 1 (DCC 2001 and R. Titus, pers. comm. 2003). However, it is important to note that until the nine-foot high Hayer Dam is opened (further downstream on Dry Creek), which usually occurs around Labor Day, adult fish are completely prevented from passing (B. Washburn, pers. comm. 2003). Juvenile rearing and smolt emigration takes place from January through June. We needed to consider many factors in order to estimate the average rates of flow for different life stages to determine passage for an unusual system such as Secret Ravine. First, there must be sufficient runoff to increase flow in the Natomas East Main Drain Canal for adults to be able to enter the Dry Creek watershed (DCC 2001). Secondly, because the headwaters of Secret Ravine are at an elevation too low to collect snowpack, as complicated by the increase in impervious surfaces, "the hydrology of the stream is dependent on rain in addition to groundwater and ag[riculture] and urban returns" (DCC 2001). Finally, change in additions to flow from Placer County Water Agency and inefficient water delivery via this canal system can result in reduced flow during fall migration. Therefore, although the incision of the channel through hydraulic mining deposits has created a high-flow floodplain that still persists today (Swanson 2001), contributing to a very "flashy" system, if rainfall occurs relatively late during the fall season, the periods that barriers will be impassible will be increased. Flow is between .5 and 2-3 cubic feet per second during the fall, with the average rainfall being 25 inches per year, with the peak occurring from December to February. Thus it is quite reasonable to expect that adults - and possibly juveniles - would frequently be subjected to low flows on this system.

Since adult fall-run chinook often immigrate after peak storm events (Thomas 2001), flow for passage was evaluated under different scenarios (with lows representing smaller initial storm events, the tapering off of a rain event, or later than average seasonal storm events). Thus, for the initial ranking, we used two flow scenarios. "Low" flows were based on adult fish migration during very low rainfall taken from ECORP data (as they were surveying in late summer and early fall, prior to the first runs); "high" flows were taken from the second storm event of the year in the just-past-peak month of spawning (Ayres, Love and Knapp 2002). In both cases, we used values to correct for depths of pools downstream of dams within different regions of the creek. **Appendix J-6: Reduced Access** contains the complete table and analysis for how passage was estimated. Juvenile passage was evaluated in a less rigorous, but supportable manner, based on the expertise of regional biologists.

Allen and Hassler (1988) determined that "chinook salmon eggs are particularly vulnerable to shock injury," most of which they believed to be caused by superimposition of redds. We looked at substrate quality, the average area needed to build a redd, the abundance of known and/or historic spawning sites between difficult-to-pass barriers and the number of adults attempting to spawn in given reaches (**Appendix J-6: Reduced Access** and **Appendix M-1: Reduced Access**) in order to assess the probability of superimposition by females on Secret Ravine. Although research indicates that superimposition of redds is positively correlated with density dependence (i.e. the likelihood of superimposition increases with increased population) and negatively related to flow (Fukushima et al. 1998 and Williams 1997), a U.S. Fish and Wildlife Service biological report confirmed work by Vronskiy (1972) and Burner (1951) that the size of the redd is inversely related to density of chinook spawners (Allen and Hassler 1988). Although the size of average adult fall-run chinook on Secret Ravine is likely smaller than chinook found on some of the larger Central Valley tributaries (R.

Titus, pers. comm. 2003), the fact that the females construct larger redds (presumably as a fitness strategy to compensate for low returns) on already substrate-limited habitat to which some of these barriers confine them, must greatly increase the probability of superimposition on this creek.

This analysis includes beaver dams that Hal Freeman and Sarah Egan of ECORP observed during their fall 2002 habitat survey, and other barriers, which group members had located and sited in previous habitat suitability assessments. The risk regions for which there was vital data from which to glean fish passage potential (e.g. dam height, downstream pool depth), include fourteen data points in the lower half of Secret Ravine. The reach from Confluence to the China Garden Gauge contains a high density of beaver dams and some artificial barriers as well as a high density of known and/or historic spawning sites that could pose a problem to fish passage. Although a later habitat survey by B. Washburn and G. Weber confirmed that, qualitatively, there were no dams of concern in upper regions, there are large boulder and large woody debris near Penryn Road. These elements tend to be associated with ideal habitat suitability, "roughness elements provide obstructions to flow allowing energy to be released at the point of contact and causing pools to scour and undercut banks to form" (Swanson 2000), and were not assessed to pose a problem to fish passage. **Appendix J-6: Reduced Access** contains photographs of several of the most problematic barriers. **Appendix B: GIS Maps** contains the GIS map with barrier sites, spawning sites and count survey reaches.

3.4.7 Toxicity

Toxicity can be characterized by the measure of contaminants in a watershed. Studies have shown that toxic substances from wastewater discharges, storm water runoff, and land-based activities both historic and current have adversely affected salmonid species. The most likely man-made contaminants include organochlorines, such as polychlorinated biphenyls and dioxins, and aromatic hydrocarbons (B. Washburn, pers. comm. 2002).

Salmonid species such as chinook may bioaccumulate chemicals that they ingest through their diet. Bioaccumulation occurs when salmonids ingest more chemicals than they can metabolize. When this happens, there is a greater likelihood for detrimental effects such as chemical modification of

S. LIEBERMAN, J. LOVE AND E. AYRES TAKING WATER AND SEDIMENT SAMPLES FOR TOXICITY AT LOOMIS PARK

DNA and the alteration of immune functions.

Water and sediment samples were taken in each of the five risk regions in Secret Ravine. These samples were tested and analyzed at the UC Davis aquatic toxicology lab. The analysis was based upon the survivability of the *Hyalella azteca* and *Ceriodaphnia dubia* in the water and sediment samples that we took.

Toxicity testing followed the 10-day static renewal procedures described in Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates (U.S. EPA 2000). It should be noted that an analysis-specific contaminants test was not conducted. Rather, the analysis measured the integrated effects of all the contaminants in the five sub-watersheds. Toxicity includes metals, pesticides, hydrocarbons and excessive nutrients in this study. **Appendix B: GIS Maps** contains the map for toxicity sampling sites.

3.4.8 Metals

The aquatic toxicity of metals is a phenomenon involving interactions between the environment and the metal pollutants of concern. Predicting the toxic effect that metals have in natural waters requires evaluating the bioavailability of the metal pollutants. The accumulation of metals in an aquatic environment has direct consequences to humans and to the ecosystem. Interest in metals like zinc and copper, which are required for metabolic activity in organisms, lies in the narrow "window" between their health values and toxicity (Skidmore 1964 and Spear 1981). Others like cadmium and lead exhibit extreme toxicity even at trace levels (Merian 1991 and DWAF 1996). Because there is a history of intensive mining activity associated with the Secret Ravine watershed, persistent metals are a concern (**Appendix A: Mining in the Secret Ravine Watershed**).

Seven metals were tested and analyzed at the University of California at Davis, based upon five samples taken in each of the five sub-watersheds identified along Secret Ravine on December 4, 2002. **Appendix B: GIS Maps** contains watershed delineations). To test for the presence of silver (Ag), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), nickel (Ni), and zinc (Zn), homogenized sediment (1200 ml) from each site was mixed with 200ml of amended control water and incubated in the original sample bucket at 23 ± 2°C. This ratio of sediment to control water (6:1) was considerably higher than the ratio used in the toxicity test (approximately 1:2). This elevated ratio was thought to better represent the concentrations of metals that might be biologically available to Hyalella azteca while residing in the upper few centimeters of the sediment. The control water was amended to match the average pH and hardness of all sample waters collected from Secret Ravine. After 48 hours, waters were decanted into pre-acidified bottles provided by the analytical laboratory, Caltest Analytical Laboratory in Napa, CA.

The metals analysis conducted at UC Davis registered values for total metals. Total metal counts were compared to the National Recommended Water Quality Criteria for Priority Toxic Pollutants. Final analyses of lead, copper, and zinc levels in Secret Ravine were done through a comparison with the Criterion Continuous Concentration (CCC). The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. The CCC is just one of the six parts of an aquatic life criterion; the other five parts are the acute averaging period, continuous maximum concentration (CMC), chronic averaging period, acute frequency of allowed exceedance, and chronic frequency of allowed exceedance. Because the aquatic life criteria are based on national guidelines, they are intended to be protective of the vast majority of the aquatic communities in the United States.

All of the aquatic life criteria CCC metals we used for comparison were dissolved metal criteria that were calculated using a hardness of 100 mg/L $CaCO_3$.

Lead

Lead and its compounds can be found in all parts of the environment, for example, in plants and animals used for food, air, drinking water, rivers, lakes, oceans, dust, and soil. At low solubilities, metals may either precipitate out of solution or bind to solid particles in a process called adsorption.

Lead is defined by the United States Environmental Protection Agency as potentially hazardous to most forms of life, and is considered toxic and relatively accessible to aquatic organisms (U.S. EPA 1986). Low lead concentrations affect salmon by causing the formation of coagulated mucous over the gills and subsequently over the entire body and thus cause the death of fish due to suffocation (DWAF 1996b). Lead is bio-accumulated by benthic bacteria, freshwater plants, invertebrates and fish (DWAF 1996b).

Copper

Copper is one of several heavy metals that is essential to life despite being as inherently toxic as non-essential heavy metals exemplified by lead and mercury (Scheinberg 1991). Copper is toxic at very low concentrations in water and is usually introduced into aqueous environments through industrial, municipal and agricultural processes and is one of the most common pollutants (Nriagu 1979 and Sadiq 1992). In the case of Secret Ravine, copper is a concern due to heavy mining activity in the watershed. Likewise, copper is an essential trace metal required in small concentrations by organisms for metabolic functions, but it is potentially very toxic when the internal available concentration exceeds the capacity of physiological/biochemical detoxification processes (Rainbow 1992).

Zinc

Zinc is an essential element for all living organisms. In natural waters, zinc occurs both in dissolved form and in natural particulates. The refining chemicals chiefly associated with placer mining were zinc and cyanide (Haley 1923). Only the dissolved fraction is thought to be toxic to fish (Finlayson and Verrue 1980). Most of the zinc introduced into the aquatic environment is eventually deposited in sediments.

At elevated levels in the environment, however, zinc may pose a threat to chinook salmon. Significant deleterious effects were observed in the most sensitive fish species at a waterborne zinc concentration of 10 mg/L (US Fish and Wildlife 1998). When larvae and alevins of rainbow trout (*Oncorhynchus mykiss*) were exposed to 10 μg Zn/L, 54 percent of them died after a 28-day exposure (Spear 1981). Acute 96-h LC50 values for salmon were observed at >1,270 μg/L (Hamilton and Buhl 1990). Both deficient and excessive amounts may cause adverse effects in all aquatic species. Zinc is most harmful to aquatic life during the early life stages in soft water where it is more water-soluble (Eisler 1993).

Trace amounts of silver were detected in the headwaters of Secret Ravine, but were deemed innocuous to chinook health. Zinc and copper levels exceeded EPA CCC recommended levels in four of the five sub-watersheds. The results of these three metals correspond highly with the degree and location of historic mining sites (**Risk Characterization for Source**, **Appendix A: Mining in the Secret Ravine Watershed**).

3.4.9 Food Supply

Only members of the juvenile life stage consume food while in Secret Ravine. Adults feed only while they are in the ocean, not while they are spawning in freshwater. Juvenile chinook of Secret Ravine are opportunistic drift feeders, eating a variety of invertebrates, which they pick out of the water column. In the Sacramento River, juveniles eat mainly terrestrial and aquatic insects such as chironomid midges, baetid mayflies, hydropsychid caddisflies (Moyle 2002), true flies, and insects from the class Homoptera (Croot and Margolis 1991). Juveniles also eat other types of invertebrates like copepods, water fleas (Croot and Margolis 1991), and amphipods (I. Werner, pers. comm. 2003).

Juveniles feed mostly during the day, and tend to feed near the edge of the stream where the invertebrates are most abundant. Foraging can occur in runs, riffles, and at the tail end of pools (Moyle 2002).

To characterize risk to juvenile salmon in Secret Ravine, three criteria were used: 1) percentage of edible invertebrates, 2) juvenile feeding habits, and 3) amount of riffle habitat available to invertebrates.

To characterize the food supply in Secret Ravine, an understanding of recent benthic macroinvertebrate populations was needed. Two studies that spanned from 1999-2001 were utilized: the Benthic Macroinvertebrate Fauna of Secret Ravine Creek, Placer

County, California (Fields, Jr. 1999) and the Benthic Macroinvertebrate Counts performed by the DCC (DCC, unpub. 2000-2001). Both studies used California Stream Bioassessment Protocol. Thus, data from both studies were combined for this analysis. An understanding of juvenile feeding habits was obtained through researching several sources (Moyle 2002 and Fields, Jr., pers. comm. 2002). An understanding of riffle habitat was obtained through several studies done in the Secret Ravine area (Li and Fields, Jr. 1999 and DCC 2001).

3.4.10 Predation by Fish

The fish assemblages of California have changed greatly over the last century. The introduction of approximately 60 species of fish for various reasons, including sport fishing, mosquito control, ornamental landscape ponds, and some accidental introductions, has lead to broad changes in fish communities (Moyle 2002, McMahon et al. 1984, Dill and Cordone 1961). In the confluence of Secret Ravine with Miners Ravine, Dr. Rob Titus, of CDFG, noted the presence of 15 exotic fish species in his emigration monitoring from November 6, 1998 to June 2, 1999 and from January 9, 2000 through June 8, 2000 (Titus 2002, Titus 2001). Of the fifteen species of exotic fish identified in the creek system eight species could potentially be competing with juvenile salmon for food or predating on salmon eggs or juvenile salmon (**Appendix H: Introduced Fish Species List**). The most influential of these fish maybe the spotted bass (*Micropterus punctulatus*) due to the abundances of this fish observed in monitoring done by screw trap and electro-fishing in 1998, 1999, and 2000 (Titus 2003). The presence of these fish is significant in two ways: it suggests that these species are present when chinook salmon are in the Secret Ravine system and that predation and competition by exotic species could be affecting chinook salmon.

The monitoring done by Dr. Titus identified two differing fish communities in Secret Ravine. The lower reach from the confluence to Sierra College, a slow moving, low gradient reach, supports a fish community dominated by spotted bass (*Micropterus punctulatus*), Sacramento pikeminnow (*Ptychocheilus grandis*) and Sacramento sucker (*Catostomus occidentalis*). The upper reach of Secret Ravine from Sierra College to the headwaters of this creek system tend to be dominated by native fishes Sacramento pikeminnow, Sacramento sucker, steelhead (*Oncorhynchus mykiss*) and Pacific lamprey (*Lampetra tridentate*) (Titus 2003). Of the dominant fish in Secret Ravine, spotted bass tend to be the species of most concern for two reasons: 1) spotted bass dominate the lower reach where the majority of chinook spawning gravel exists and 2) their introduced status means that chinook salmon did not co-evolve with spotted bass predation.

Of the three bass species found in the Secret Ravine system, spotted bass tend to prefer faster water than largemouth bass and more turbid water than smallmouth bass (Moyle 2002, McMahon et al. 1984, Smith and Page 1969, Vogele 1975). The spotted bass tends to utilize habitats of moderately sized, clear, low gradient streams (Moyle 2002, McMahon et al. 1984, Vogele 1975) that could describe most of the lower reach of Secret Ravine (Li and Fields, Jr. 1999, Holland 2000). Moyle states that spotted bass do well in streams with a summer temperature between 24-31°C (Moyle 2002), and spawn in streams with temperatures between 14-15° in early April and late March (Moyle 2002, Aasen and Henry 1981). Temperature influences growth and thus the predation activity of spotted bass in creeks such as Secret Ravine. Moyle states that "Growth rates vary with habitat; fastest rates are typically achieved in fairly new warm water reservoirs, slowest rates in cool streams" (Moyle 2002 p406). Limitations on spotted bass growth have been observed at temperatures below 10 degrees C (McMahon et al. 1984); this occurs in January and February on Secret Ravine (Weber unpublished data) (**Figure 3.1**).

The preferred food of spotted bass includes aquatic invertebrates, fish, crayfish, and terrestrial insects (Moyle 2002, McHahon et al. 1984, Mullan and Applegate 1968, Howland 1931). Crayfish and, secondarily fish, tend to comprise the majority of the spotted bass diet in streams especially as the spotted bass grow in size (Moyle 2002, McMahon et al. 1984, Howland 1931, Scalet 1977, Smith and Page 1969). Therefore spotted bass may predate on juvenile salmon given that the water temperature is sufficient to allow hunting activity. Additionally, studies of the Columbia River have found salmonid prey in the stomach contents of smallmouth bass, a close relative of spotted bass (Vigg et al. 1991). They are so close in relation, in fact, that smallmouth bass and spotted bass have been known to hybridize, and the genetic purity of spotted bass is believed to be questionable in some locations in California (Dill and Cordone 1961).

From the life histories of spotted bass and chinook salmon, one can draw the conclusion that spotted bass could potentially predate on the juvenile chinook salmon from March through June. To investigate the extent of predation of spotted bass on chinook salmon, an estimation of the biomass of black bass (small mouth, large mouth and spotted bass) for Secret Ravine was evaluated on a projected population of juvenile chinook salmon (**Appendix H: Introduced Fish Species List**). To do this a range of biomass consumptions by spotted bass was calculated and then compared to a projected population of juvenile chinook salmon for 2002. The analysis showed that spotted bass have the potential to reduce the chinook salmon population from 7% to 14%, given that salmonids comprise 1% of the spotted bass diet. The lower figure probably represents the better estimate due to the small size (26 g) of the bass in Secret Ravine and the cooler temperatures of the water during these months.

4 Risk Analysis Methods (Modified Relative Risk Model)

4.1 General Method

The Modified Relative Risk Model systematically quantifies ecological risk posed by sources and stressors in Secret Ravine. The model integrates quantitative and qualitative data by converting them to ranks, calculating a risk score using an equation that incorporates habitat, exposure and effect. A risk score can be calculated for stressors, sources, habitats, and risk regions. These risk scores capture the risk associated with each element and allow for prioritization.

To begin, all relevant data for Secret Ravine was collected. On May 17, 2002 a stakeholder meeting was held in Roseville to identify the stressors that might be affecting chinook salmon in Secret Ravine. We created the conceptual model based on synthesis of information generated at this meeting regarding the relationships between stressors, sources and effects in the system, expressed as pathways in the model. We revised and and streamlined the conceptual model throughout the project in order to better reflect our understanding of these pathways. **Appendix E: The Conceptual Model** contains the most recent incarnation.

In the MRRM process, this data is then divided up to correspond with its representative sub-watershed. Consequently, the sub-watersheds, or "risk regions", combine all data that is relevant to that area (**Appendix B: GIS Maps**). For example, data taken near the confluence of Secret Ravine and Miners Ravine is pooled together to assess risk specifically in that area. This raw data is then converted to ranks.

Allowable ranks in the MRRM are 0, 2, 4 and 6. A rank of zero indicates no or little associated risk, and six indicates large risk or mortality. To fit this scale, breaks are determined, wherever possible, using dose-response and effect estimates from scientific literature. When this information is not available, a statistical method is used to assign natural breaks in the data (**Section 4.1.2**). Ranks are relative within each stressor, not across stressors. Therefore, equivalency is not addressed, as a rank of two for temperature does not imply the same level of risk as a rank of two for morphology.

Sources that lead to these stressors are quantified using Geographic Information Systems (GIS). These are then ranked using areal extent or frequency. Habitat, or stream length, is also ranked using GIS. Once again, ranks are relative within each source or habitat, not across them. Exposure filters are also used to assess the connections between the sources and stressors, and between stressors and habitat.

The ranks for stressor, source, and habitat are combined with exposure filters, culminating in a total risk score for each risk region. These components are explained in detail below.

4.1.1 Risk Regions

The study area boundary was developed based on the land area drained by the Secret Ravine system. For the source analysis involved in the MRRM, the Secret Ravine watershed was first divided into sub-watersheds, or "risk regions", based on watershed boundaries (**Appendix B: GIS Maps)**. Dividing watersheds into subunits is a common practice in watershed analysis. Essentially, the divisions within a creek system are a function of topography; high points in the topography suggest the direction water will follow when a rain event occurs. Our sub-watersheds were adopted from a Placer

County study of flood risk (Montgomery 1992). These five risk regions are henceforth referred to as Risk Regions A, B, C, D or E. Risk Region A is the farthest sub-watershed downstream, where Secret Ravine confluences with Miners Ravine. Risk Region E is the farthest sub-watershed upstream, and encompasses the headwaters.

4.1.2 Source Ranks

To help in the identification of each source, three categories were established: urbanization, legacy, and rural residential. Each category contains multiple sources present in the Secret Ravine watershed. Each source was evaluated and assigned a rank value based on its relative impact within a risk region. Several methods assisted in establishing the extent and frequency of the various sources: aerial photography, GIS coverages describing zoning, land use, or historic landmarks, topographic maps, and personal observation. **Appendix F: Sources and Stressors** lists the twelve sources we identified for Secret Ravine and enumerates the stressors associated with each source.

Appendix I: Source Analysis and Characterization describes in detail how each source was analyzed and ranked. The traditional method of ranking all non-point sources is based on their areal extent (Hart Hayes 2002). We, however, divided by the stream length within each risk region to capture a "concentration". For example, take two sources with equal areas. The Risk Region with the smaller stream length will have the higher risk because the source is concentrated into a small length of water.

Non-point sources included landscape maintenance, impervious surfaces, construction and development, dirt and gravel roads and introduced fish. Channelization was characterized by the length of creek channelized divided by the length of stream within the respective risk regions. Since no digital maps existed, mining and orchards were characterized based on visual estimates of areal extent utilizing topographic maps and historic accounts in the literature.

Point sources (water treatment plants, irrigation canals and beaver dams) were ranked based on the number of occurrences within each risk region. In most cases, the risk region with the highest number of occurrences of that point source received the highest rank.

Once the areal extent of non-point sources or the frequency of point sources was determined, natural breaks were used to assign ranks (Landis 1997). Natural breaks finds groupings and patterns inherent in data using a statistical formula (Jenk's optimization). Jenk's optimization minimizes the sum of the variance within each of the classes. Our data was separated into four categories (0, 2, 4, 6) in accordance with the RRM.

A source is assigned one rank for each risk region. Consequently one source has five associated ranks. The source rank can be the same across all the risk regions, or vary for each risk region. Due to the nature of assigning ranks, source ranks are relative within one source, but not across different sources.

4.1.3 Habitat Ranks

"Habitat" was used as another parameter to capture the affected life stages of salmon (as opposed to conventional ecosystem-type habitats used in a regional risk assessment). Habitat in our study refers to the water column, the benthos, or both.

Potential habitat for our assessment endpoint includes only the main channel of Secret Ravine, as no data exists to indicate spawning or juvenile rearing within the tributaries (G. Bates, pers. comm. 2002 and R. Titus, pers. comm. 2002). Therefore, habitat size is defined to be the main channel stream length for a risk region. The habitat lengths were normalized using the shortest habitat length from Risk Region E. Using Jenk's optimization, these values were converted to ranks (**Table 4.1**).

	A	B	C	D	E
Habitat Length (ft)	13152	18872	5995	9009	2171
Normalized Habitat Value	6.1	8.7	2.8	4.2	1
Habitat Rank	6	6	4	4	2

TABLE 4.1 HABITAT RANKS

The longest habitat lengths (not necessarily the largest risk regions) received the highest rank of 6, and the shortest habitat length received the lowest rank of 2. The habitat length of Risk Region E was reduced to Rock Springs Road because that is the highest point salmon have been observed historically (B. Everhart via B. Washburn, pers. comm. 2003). Currently, there is no evidence of spawning or juvenile rearing above Loomis Park on the boundary between Risk Regions C and D (G. Bates, pers. comm. 2002 and R. Titus, pers. comm. 2002).

Habitat ranks were assigned to the water column or the benthos based on the life stages of salmon: early life stages (egg and alevin) occupy the benthos, while the juvenile and adult phases occupy the water column. The benthos for this analysis includes the top portion of sediment in the stream channel (Merriam-Webster 2002). Any stressor known to affect the early life stages were considered benthic habitat stressors. The water column or the open-water environment of the creek includes those environments distinct from the bed or shore that may be inhabited by freshwater organisms (EUNIS 1998). Any stressor known to affect the juvenile or adult phase were considered water column habitat stressors. Additionally, habitat ranks require that the fish be present when the relevant stressor affects a particular habitat and life stage. **Table 2.1** contains relevant time periods.

4.1.4 Effects Ranks

Effects caused by the stressor to the endpoint were given ranks of 0, 2, 4 or 6 based on dose-response curves (where data existed) or best professional judgment. A rank of zero reflects low (or no) effect and a rank of six is a highly negative effect, usually related to direct mortality. Site-specific data exists for sediments, barriers, introduced fish, temperature, invertebrate food supply, morphology, and contaminants.

4.1.5 Exposure Filters

Two exposure filters were utilized in calculating the risk score. The first exposure filter (Exposure 1) assesses whether or not the source emits the stressor. This is based on the conceptual model. A one is assigned if a direct pathway exists from the source to the stressor in the conceptual model, and a zero is assigned if no pathway exists. A value of 0.5 is assigned if there is an indirect pathway (occurring via another stressor) from the source to the stressor. **Appendix F: Sources and Stressors** differentiates between sources that are direct and indirect. We defined an indirect source as any source that generates a stressor via another stressor or relates to a source that was originally emitted many years prior to this analysis. The modeling of legacy sources, for the most part, contains an indirect exposure filter. The exception to this rule occurred with regard to the relationship between chemical stressors and mining and orchards. In this case, the literature suggested that persistent chemicals (DDT) and heavy metals (Cu), could stay biologically active, even though the emission is temporally remote. The two direct links between sources and stressors are the links between toxicity and orchards, and metals and mining. In these two cases, Exposure filters of 1 were assigned to indicate a direct link between a legacy source and a current stressor to the salmon.

The second exposure filter (Exposure 2) assesses whether or not the habitat will be exposed to the stressor. Some stressors, such as metals, affect only the water column and others are specific to the benthos. A one is assigned to both the water column and the benthos in circumstances where the stressor could be affecting both habitats.

4.1.6 Risk Scores

The main goal of this analysis is to determine the most significant stressors and the sources thereof. This is achieved by calculating risk scores. The general formula for this calculation is shown in **Equation 1**. The risk score for each stressor is calculated by multiplying together all the ranks and associated filters for that stressor and summing across risk regions. The risk score for source is calculated in a similar fashion.

$$RS = (\text{Source Rank})*(\text{Habitat Rank})*(\text{Effects Rank})*(\text{Exposure 1 filter})*(\text{Exposure 2 filter})$$

EQUATION 1 TOTAL RISK SCORE EQUATION FOR MODIFIED RELATIVE RISK MODEL

Risk scores are first calculated over each risk region. An example calculation is demonstrated below. In this calculation, the stressor is flow, the source is mining and the habitat is the water column. The resulting risk score is the relative impact that mining has on flow alterations in Risk Region A.

Stressor = Flow; Source = Mining; Habitat = Water Column

RS = (Mining Rank) * (Water Column Rank) * (Effects of Flow Rank) * (Exp1) * (Exp2)

RS = 2 * 4 * 6 * 0.5 * 1 = 24

FIGURE 4.1 EXAMPLE CALCULATION FOR RISK REGION A

Risk scores can then be summed for a specific stressor or source the entire risk region. These values represent the relative impacts that the specific stressor or source is affecting the risk region.

Finally, risk scores are generated to assess the cumulative impacts of a stressor or source. This is achieved by summing the relative risk scores for the stressor or source over all five risk regions. Another risk score is calculated to assess cumulative impacts to habitat (water column or benthos).

4.1.7 Assumptions (Modified Relative Risk Model)

The MRRM utilized assumptions that allowed the regional evaluation of risk. Each component of the model involved different assumptions with a few overarching posits that allowed these parts to be integrated into a working model.

Risk Regions

To begin, the division of the watershed into five independent risk regions required the delineation of watersheds based on topography and water movement in Secret Ravine. The model should include all areas that drain into the creek, however due to anthropogenic changes in the watershed not all these areas could be included. Specifically the canal system brings water from the neighboring Yuba/Bear watershed into the Secret Ravine system and the storm water system diverts some water from neighboring watersheds into the Secret Ravine watershed. The rerouting of water through Secret Ravine from the Yuba/Bear and movement of water through urban and rural storm water system was assumed to have a minimal effect; therefore, the risk regions did not incorporate these remote sources of Secret Ravine water. Also the risk regions should represent the actual change in drainage patterns caused by the construction of I-80, however in some cases the full extent of the tributaries that pass under the highway and the connectivity of these tributaries were not ground-truthed.

Therefore, another assumption of the model is that the extent of the risk regions includes all the area on the northwest side of I-80 that drain into Secret Ravine.

Sources

We evaluated the non-point and point sources of stressors to chinook salmon through the source analysis. In general, we assumed that the greater the extent of a possible non-point source, the higher frequency of a point source, or the smaller stream length associated with a risk region, the greater the potential stressor effect. Such source attributes as whether the source is a point or non-point source, whether the source has different types or intensity of emission than other sources or the sources ability to cause the stressor were not considered in the assigning of ranks.

The assumptions related to source come from the ranking of source within Secret Ravine and the equivalency of a certain rank for one source to that same rank for another source. The MRRM ranks each source relative to other risk regions within the watershed. For example, a 4 in Risk Region A for impervious surface may indicate that Risk Region A has a larger area of impervious surface than Risk Region B, with a rank of 2. However the confounding factor of stream length and point sources prevents a rank from being a simple comparison of land area. The area of source in each risk region is divided by the length of the stream in the risk region, so the same area of source in Risk Region A, with a stream length of 13,152 feet, may have a different rank than that same area of source in Risk Region E, with a stream length of 2,171 feet. Also, the ranking of point sources followed a completely different scheme. In the case of a point source, the number of point sources in a risk region determined the rank given.

The MRRM assumes that a rank assigned to one source is equivalent to that same rank assigned to a completely different source. Sources can be weighted equally even if they 1) differ in absolute area, 2) have different stressors emitted from them, 3) affect different stream (habitat) lengths, 4) affect different habitats (benthos or water column or both), or 5) differ in nature (point or non-point source). The consequence of this 'relative' assigning of ranks means that a certain rank can be difficult to evaluate in the context of the other sources (e.g. a rank of 4 for both channelization and impervious surfaces assumes that they pose the same risk, but that may not actually be the case).

Habitat

The stream habitat utilized by chinook salmon includes the water column and benthos of the main stem of Secret Ravine. The first assumption related to habitat is that the salmon remain in the main stem of Secret Ravine throughout their stay in the creek; use of tributaries as cover or for forage were not taken into account (G. Bates, pers. comm.2002, R. Titus, pers. comm.2002). A related assumption, that each life phase solely uses either the benthos or the water column, was necessary to divide the habitat into these two categories. An example where this assumption might be violated would be for toxicity in sediment. Adult fish, affected in the model only by water column stressors, might be exposed to benthos stressors when in the process of constructing a redd; thus adult salmon may be exposed to sediment toxicity.

Exposure

The exposure filters were based primarily on conceptual model research. The conceptual model represents the synthesis of stakeholder input during a meeting held in the spring of 2002 and the research done by the ERA team throughout the following year. Therefore, one assumption is that the experts on Secret Ravine knew enough about the creek to provide a clear picture of the on-going processes in the stream system. Another assumption is that the ERA team successfully incorporated the data of experts, stakeholders and literature to develop a conceptual model that reflects the actual processes in the creek.

Effects

The treatment for each individual stressor details the assumptions made in the evaluation of different ranks for different stressors. A few overarching assumptions that occur prevalently in the stressor effects again included the idea of equivalency. It is assumed that a stressor 'relative' rank evaluated individually for each stressor in each risk region can be comparable across stressors. A 2 for altered riparian vegetation, for example, has an equal weight as a 2 for sediment or reduced access. Another assumption is that using best professional judgment, if applied in a constant and informed manner, in the assignment of ranks can result in an accurate rank. Given the imperfect data for Secret Ravine, the use of best professional judgment allowed the inclusion of stressors that could not be quantified readily. Finally, the use of Jenk's optimization to assign rank category was assumed to be an impartial and mathematically defensible way to define categories for the five risk regions. For many stressors, the analysis only included five data points, which makes the concept of "natural breaks" rather tenuous. Nevertheless, the algorithm beneath the GIS tool allowed categories to be assigned in a consistent manner.

4.2 Uncertainty Analysis

Uncertainty analysis on Secret Ravine differs from previous relative risk model assessments. In the MRRM, we conducted a sensitivity analysis on the effects ranks to determine the resulting changes in risk scores (and thus the relative prioritizing of stressors). We then conducted an alternative ranking scheme for the habitat ranks. We based the original ranking of habitats on the absolute area of the source divided by the length of stream (habitat) in the respective risk region. The alternative habitat ranking scheme ranked habitat based purely on absolute area of sources. Changes in risk scores were then assessed.

For quantitative data, the risk predictions produced in the MRRM are point estimates based on ranks and associated filters. Uncertainty for quantitative data was determined by the following three criteria: 1) number of data points; 2) confidence of methods; and 3) natural variability of the system. Quantitative uncertainty was established for each applicable source and stressor. The analysis, results and discussion of uncertainty for the MRRM is in **Section 7**.

5 Risk Analysis and Characterization Methods (Modified Relative Risk Model)

The following section describes how risk was estimated to the salmon in terms of effects and exposure for stressors. Here, we determined the method for assigning ranks to stressors (i.e. risk analysis), and assigned stressors actual ranks values (i.e. risk characterization).

5.1 Stressors

5.1.1 Sediment

5.1.1.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Direct sources of sediment were assigned an Exposure 1 filter value of 1. These sources include impervious surfaces, OHVs, construction and development, dirt and gravel roads and channelization. All other sources (except introduced fish) are considered indirect sources of sediment and were thus assigned an Exposure 1 value of 0.5.

Exposure 2 (Habitat Exposed to Stressor filter)
Impacts from sediment affect both the water column (via turbidity) and the benthos (via fine sediment accumulations in the bedload). Therefore Exposure 2 filter values of 1 were assigned to both habitats.

5.1.1.2 Assigning Effects Ranks

In the benthos, survival to emergence based on grain size distribution (Tappel and Bjornn 1983) was estimated each risk region. Below are the criteria we used to assess ranking for sediment in the benthos.

Percent survival	**Rank**
Greater than 40%	0
30% to 40%	2
10% to 29%	4
Less than 10%	6

Table 5.1 Criteria for Ranking Sediment in the Benthos

SIEVE SHAKER AT CALIFORNIA STATE UNIVERSITY AT SACRAMENTO

Turbidity data (DCC 2003) was used to assess impacts to the water column from sediment. We calculated severities of ill effect (SEV) values for all risk regions based on methods developed by Newcombe and Jensen 1996. Below are the criteria we used to rank turbidity.

SEV (severity of ill effects)	Rank
Zero to 3	0
4 to 8	2
9 to 10	4
11 to 14	6

TABLE 5.2 CRITERIA FOR RANKING TURBIDITY

Appendix J-1: Sediment contains grain size distributions and associated mortalities for sediment in the benthos, and turbidity data used to calculate SEV values for sediment in the water column (turbidity). Summary tables of final ranks for sediment in the water column (turbidity) and the benthos are also located in this appendix.

5.1.2 Flow

5.1.2.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)

Direct sources causing alterations to the flow regime were assigned a value of 1. These include impervious surfaces, channelization, construction and development, water treatment plants, dirt and gravel roads, irrigation canals and beaver dams. All other sources (except introduced fish) were deemed indirect sources and were thus assigned a value of 0.5 for the Exposure 1 filter.

Exposure 2 (Habitat Exposed to Stressor filter)
Impacts from alterations in flow occur in both the water column (via sub-optimal velocities or depths) and the benthos (via scour or percolation). Thus, the Exposure 2 value for both habitats was assigned a value of 1.

5.1.2.2 Assigning Effects Ranks

Critical substrate depths were calculated for all risk regions based on the sediment data collected (Ayres, Love, and Vodopals 2002). These were compared with optimal (or tolerance) depths based on Allen et al 1998. The optimal (or tolerance) depth for juvenile rearing and adult migration were used to assess impacts to the water column while depths for spawning were used to assess impacts to the benthos.

Below are the criteria for ranking flow in the benthos (**Table 5.3**) and water column (**Table 5.4**)

Optimal spawning depths (cm)	Rank
Greater than 30	0
20 to 30	2
10 to 20	4
Less than 10	6

TABLE 5.3 CRITERIA FOR RANKING FLOW IN THE BENTHOS

Tolerance flow depths (cm)	Rank
Greater than 122	0
25 to 122	2
24 to 76	4
Less than 24	6

TABLE 5.4 CRITERIA FOR RANKING FLOW IN THE WATER COLUMN

Appendix J-2: Flow contains summary tables of final ranks for flow in the water column and the benthos.

5.1.3 Morphology

5.1.3.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Direct sources to changes in stream morphology include channelization, OHVs, construction and development and irrigation canals; these were assigned Exposure 1

values of 1. Excluding introduced fish, all other sources were deemed indirect sources and were thus assigned Exposure 1 values of 0.5.

Exposure 2 (Habitat Exposed to Stressor filter)
Alterations to stream morphology affect both the water column and benthos habitat. Changes, in such stream characteristics as the frequency of pools, can cause impact to the water column, while changes to the channel width and slope may alter the benthos. A 1was therefore assigned to both habitats for the Exposure 2 filter.

5.3.1.2 Assigning Effects Ranks

Percent pools by length (PBL)	Rank
Greater than 40%	0
30% to 40%	2
20% to 30%	4
Less than 20%	6

TABLE 5.5 CRITERIA FOR RANKING MORPHOLOGY IN THE BENTHOS AND WATER COLUMN

Appendix J-3: Morphology contains summary tables of final ranks for morphology in the water column and the benthos.

Appendix L contains the data we used to determine ranks for some of the morphology elements.

5.1.4 Temperature

5.1.4.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Each life stage of chinook salmon was given an exposure of 1 because each stage is susceptible to the temperature regime of each risk region. This was determined through an analysis of the conceptual model.

Exposure 2 (Habitat Exposed to Stressor filter)
Each life stage receives a 1 for their exposure to temperature in the water column. For the benthos exposure to temperature, the egg/yolk-sac fry receive a 1.

5.1.4.2 Assigning Effects Ranks

Water temperature data on Secret Ravine is only complete for Risk Region B. Risk Region B includes twelve monthly temperatures for 2002. Incomplete data (March – June) is available for the locations known as Risk Region A and Risk Region E. Rankings and implications were extrapolated for Risk Regions C and D because data was not available. This is regarded as a conservative data extrapolation because these two sub-watersheds are anchored by available data both upstream and downstream. All subsequent analyses were based upon the complete data of Risk Region B and the incomplete data of risk regions A and E.

Ranks for the three life stages and their associated habitats were established from relevant literature concerning previous studies on chinook salmon. Final ranks were determined by applying the highest (riskiest) correlate rank to each habitat. The final ranks apply to all Risk Regions (A-E).

Early Life Stages: Temperature Criteria for the Benthos

Ranks for the egg/yolk-sac fry life stage in Secret Ravine were based upon the above temperature ranges and associated percent mortalities. For the months November – February, the following ranking system applies:

Temperature Range (ºC)	Rank
< 14.5	0
14.5 – 15.6	2
15.6 – 18.0	4
> 18.0	6

TABLE 5.6 CRITERIA FOR RANKING TEMPERATURE FOR THE EARLY LIFE STAGES IN THE BENTHOS

Juvenile and Adult Phase: Ranking Criteria for the Water Column

A combination of the temperature limitations in the juvenile and adult life phases supplied the criteria for determining rank.

Juvenile Phase

For the months late January through May, the following ranking system applies to juveniles:

Temperature Range (ºC)	Rank
< 15.6	0
15.6 – 16.6	2
16.6 – 18.0	4
> 18.0	6

TABLE 5.7 CRITERIA FOR RANKING TEMPERATURE FOR THE JUVENILE PHASE (WATER COLUMN)

Adult Phase

The conservative lower threshold of 20.0 ºC was selected for correlate rank partitioning for adults.

Temperature Range (°C)	Rank
< 16.5	0
16.5 – 18.9	2
18.9 – 20.0	4
> 20.0	6

TABLE 5.8 CRITERIA FOR RANKING TEMPERATURE FOR THE ADULT LIFE STAGE (WATER COLUMN)

Appendix J-4: Temperature contains summary tables of final ranks for temperature in the water column and the benthos.

5.1.5 Altered Riparian Vegetation

5.1.5.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
The preliminary analysis, necessary to construct the conceptual model, determined that the source of altered riparian vegetation directly came from OHV activities crushing vegetation and compacting soil in the riparian zone, construction and developing clearing land for new development, landscape maintenance that changed the composition and cover of vegetation in the watershed. Indirectly, all the sources that effect hydrologic processes and the movement of toxicants influence vegetation including impervious surfaces, dirt and gravel roads, channelization, irrigation, beaver dams, mining, orchards, and water treatment plants. Eleven sources influence altered riparian vegetation either through direct or indirect processes; the indirect sources were assigned 0.5 and the direct sources 1.

Exposure 2 (Habitat Exposed to Stressor filter)
The chinook salmon of Secret Ravine require a certain water temperature, a certain amount of in-stream cover, and a riparian zone sufficient to buffer harmful substances from entering the creek. The natural services provided by the vegetation in Secret Ravine affects the benthos and water column habitats of all three life stages of chinook salmon. Therefore, each life stage of chinook salmon was assigned an Exposure 2 of 1 for each sub-watershed.

5.1.5.2 Assigning Effects Ranks

The criteria utilized to assign ranks to altered riparian vegetation utilize a combination of the historic conditions of the riparian zone and analysis of the current cover and extent of the vegetation.

Ranks	Criteria
0	Pre-Columbian vegetation with nearly 100% cover and a riparian zone extent greater than 100 ft on each side of the stream for the length of the stream.
2	A less than 1000 feet length of riparian zone with a width of less than the ascribed buffer zone of 100 ft, on both sides of the stream.
4	A larger than 1000 feet length of riparian zone with a width of less than the ascribed buffer zone of 100 ft, on both sides of the stream.
6	Near de-vegetation of Mining Era with approximately no overhead cover and few areas where the riparian zone extends beyond the ascribed buffer.

TABLE 5.9 RANKING CRITERIA FOR ALTERED RIPARIAN VEGETATION

The risk to fish on Secret Ravine, due to altered riparian vegetation, should be highest during the Mining Era. The miners, by denuding the riparian zone, would have exposed the chinook salmon to high water temperature and reduced available cover, which chinook juveniles use to evade predators. Therefore the risk for this stressor in the mining period, a worst-case scenario, should be set at 6. Conversely, the habitat that chinook salmon coevolved with existed during the pre-Columbian period of California. The habitat projected for this period of Secret Ravine should be accessed a 0. The 0 in this case would be the best-case scenario for the chinook salmon and pose nearly zero risk to the fish.

Recall from the background section, that certain risk regions have a greater or lesser extent of stream with a riparian zone less than the prescribed buffer of 100 ft on both banks of the creek. **Appendix J-5: Altered Riparian Vegetation** provides a summary of the incidences of overly small riparian zone extent by risk region. This information provided the criteria used to rank the stressors for Secret Ravine as a 2 or a 4; Risk Region A received a 4 (3,935 feet of incidence) and Risk Region B-E were assigned 2's (ranging from 201-855 feet of incidence).

5.1.6 Reduced Access

5.1.6.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Pathways, as derived from the conceptual model, exist from source (beaver dams and artificial barriers, under Construction and Development) to the following stressors: sediment, flow, predation and reduced access. Thus, we assigned '1s' to all risk regions.

Exposure 2 (Habitat Exposed to Stressor filter)
Adult chinook are potentially exposed directly to reduced access in the water column, during their upstream migration from late October through late December. Juvenile chinook are also potentially directly exposed to reduced access in the water column, during their downstream emigration from January through May, so they also received Exposure Filter 2 scores of 1. Eggs are potentially exposed to reduced access (barriers) indirectly, through the increased potential of superimposition of redds during low flows

and for the increased potential of blowout during high flows, thought these secondary stressors can result in direct mortality. Thus, eggs received a 1 for the benthos. However, impacts to the benthos cannot be evaluated easily using this model (because of multiple complex interactions), thus only the water column as it pertains to reduced access is addressed in this analysis.

The habitat ranking is applied to reduced access in the same manner as for the other stressors. The greater the stream reach, the greater potential for beavers to build dams, and thus the greater potential reduced access. This is supported by the fact that Secret Ravine undergoes very negligible grade change throughout its entirety, averaging around two percent (Swanson 2001), which topography suggests that the preferred vegetation for beavers for building dams is abundant and constant throughout all regions. This consists of softwoods such as alders, willow and cottonwood, which correspond to the broad alluvial floodplain geology of the stream reach north of Sierra College (Risk Region B, approximately where the ECORP survey ends) (Holland and Morgan 1868).

5.1.6.2 Assigning Effects Ranks

For the MRRM, experts consulted (H. Freeman, pers. comm. 2002 and C. Lee, pers. comm. 2003), concurred that in order for a barrier to be rendered "passable" the depth of the pool or riffle immediately downstream of a barrier must be at least 150% the height of the dam immediately above it (a.k.a. "the 150% rule").

Criteria for Passage - Water Column	Rank
Fish can pass during low and high flow scenarios	0
Fish can pass during low-flow scenario, but not high flow scenario	4
Fish can neither pass during low nor high flow scenarios	6

TABLE 5.10 RANKING CRITERIA FOR REDUCED ACCESS

Given the relatively unpredictable flow conditions described for Secret Ravine in Section 3.4.6, a four is assigned when the barrier would prevent the fish from passing during an average low-flow year, to render a more conservative decision. A zero indicates that fish could pass during high and low flow scenarios; that in effect, the dam has virtually no effect on passage. A six indicates that fish could pass during neither low nor high flow regimes, but not that a barrier would be impassable in the absolute sense, as counts indicate that salmon continue to migrate well into Risk Region C, despite highly obstructive barriers in Risk Region B (**Appendix M-1: Reduced Access** contains the original count data). We assigned final effects scores were based on the highest risk score determined for a barrier per risk region, consistent with the way we treated risk scores for other stressors. This ranking also helps underscore the fact that excessively high dams, particularly if they are located closely together, can compound the risk posed to fish not only in terms of passage (energy costs), which together with delays, creates density dependence downstream, limiting the amount of habitat available to the fish for spawning, and thus increasing the likelihood of straying or superimposition (SRAMP 2001).

Appendix J-6: Reduced Access contains the mathematical models used to derive ranks and a summary table of final ranks, as well as photographs of some of the problematic barriers.

5.1.7 Toxicity

5.1.7.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Direct sources of toxicity include impervious surfaces, OHVs, landscape maintenance, orchards and water treatment plants. These sources were assigned a value of 1for the Exposure 1 filter. No indirect sources were identified.

Exposure 2 (Habitat Exposed to Stressor filter)
Toxicity only affects the benthos, and consequently, the early life stages. Therefore, Exposure 2 equals 1 for the benthos and 0 for the water column.

5.1.7.2 Assigning Effects Ranks

The results showed that all of the water column tests were negative. In the sediment tests, however, *Hyalella azteca* recorded percent mortalities ranging from 21.4 to 60.0%. Since all of the water column tests came back negative, it can be concluded that there is no toxicity in the water and therefore, there is no risk posed to the juvenile and adult phases of chinook salmon. However, in the sediment a range of toxicity was found.

The results are as follows:

Site of sample taken	Risk Region	% Mean Mortality	Standard Error(%)
Confluence	A	53.5	17
Secret Court	B	21.4	18
Dias Lane	C	60	25
King Road	D	41.4	21
Rock Springs Rd.	E	22.5	17
Control	---	5.3	4

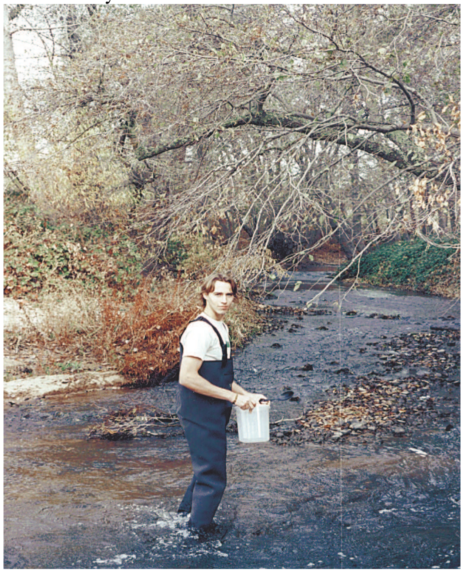
TABLE 5.11 MORTALITY RESULTS FOR TOXICITY

Below are the criteria for ranking toxicity in the benthos. Toxicity was subdivided into four ranges of percent mortality from which ranks were assigned.

Toxicity Range (% mortality)	Rank
< 5.3	0
5.3 – 22.4	2
22.5 – 40	4
> 40.0	6

TABLE 5.12 CRITERIA FOR RANKING TOXICITY IN THE BENTHOS

Appendix J-7: Toxicity contains a summary table for toxicity testing as well as a summary table of final ranks for toxicity in the benthos.



E. KNAPP WITH WATER SAMPLE AT THE CONFLUENCE.

5.1.8 Metals

5.1.8.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)

Impervious surfaces and mining directly contribute to toxicity. Therefore, they each received an Exposure filter of 1. The remaining sources received 0s.

Exposure 2 (Habitat Exposed to Stressor filter)

Metals only occur in the benthos in this analysis, thus they only affect the egg and yolk-sac fry. Therefore, the Exposure 2 filter was assigned a value of 1 for the benthos and a value of 0 for the water column.

5.1.8.2 Assigning Effects Ranks

The results obtained from the seven metals tests described above were as follows:

Risk Region	Ag	Cd	Cr	Cu	Pb	Ni	Zn
A	ND	ND	52	83	36	66	280
B	ND	ND	300	520	270	380	2300
C	ND	ND	140	230	83	210	430
D	ND	ND	110	140	56	100	210
E	9	ND	520	760	420	460	1000

*All values are based on Freshwater CMC (ug/L)

**All values within dotted lines represent concentrations exceeding the reported LC50 values

TABLE 5.13 TOTAL METALS COUNT

The results show that levels of copper, lead, and zinc exceeded the LC_{50} for *Hyalella azteca* in all Secret Ravine sediment samples. These metal concentrations represent near maximum levels that the test organisms may have been exposed to.

Of these seven metals, cadmium (Cd) was not detected in any risk region. Only 9 µg/L of silver (Ag) was detected in one risk region (E). The lack of cadmium and trace amount of silver renders these metals to be innocuous to chinook salmon in Secret Ravine. The metals chromium (Cr) and nickel (Ni) are not considered harmful to chinook in Secret Ravine because they did not represent concentrations exceeding the reported LC_{50} values.

Hardness values were concomitantly obtained from the five risk region samples using titrimetric methods (standard methods). The results for hardness are as follows:

	Total Hardness (mg/L as $CaCO_3$)		
Risk Region	**At Day 0**	**At Day 9**	**Mean of Days 0 & 9**
A	52	48	50
B	48	64	56
C	76	72	74
D	36	64	50
E	52	72	62
Mean	52.8	64	
Overall mean		**58.4**	

TABLE 5.14 TOTAL AND MEAN HARDNESS

The hardness mean of the five risk regions in Secret Ravine was 58.4 mg/L $CaCO_3$. Since toxicity decreases with increasing hardness, the toxicity of the metals in our risk regions may be higher than the results and subsequent ranks indicate. Hardness values are listed in this section to further elucidate the effect that metals may have upon Secret Ravine. Hardness values were not used for the assignment of ranks. As stated earlier, the assignment of effects ranks were based upon comparisons made between total metals and dissolved metals. Values in the risk regions, therefore, appear to be significantly higher than recommended levels. Dissolved metal comparisons were not conducted because dissolved metal testing was not performed on Secret Ravine.

Lead Criteria

We assigned a rank of 6 for all values that were greater than the EPA recommended CCC level of 2.5 ug/L for lead. Values under 2.5 ug/L received a 0.

EPA Rec. CCC (ug/L)	Ranking
> 2.5 ug/L	6
< 2.5 ug/L	0

FIGURE 5.1 CRITERIA FOR RANKING LEAD

Copper Criteria

We assigned a rank of 6 for all values that were greater than the EPA recommended CCC level of 9.0 ug/L for copper. Values under 9.0 ug/L received a 0.

EPA Rec. CCC (ug/L)	Ranking
> 9.0 ug/L	6
< 9.0 ug/L	0

FIGURE 5.2 CRITERIA FOR RANKING COPPER

Zinc Criteria

We assigned a rank of 6 for all values that were greater than the EPA recommended CCC level of 120 ug/L for zinc. Values under 120 ug/L received a 0.

EPA Rec. CCC (ug/L)	Ranking
> 120 ug/L	6
< 120 ug/L	0

FIGURE 5.3 CRITERIA FOR RANKING ZINC

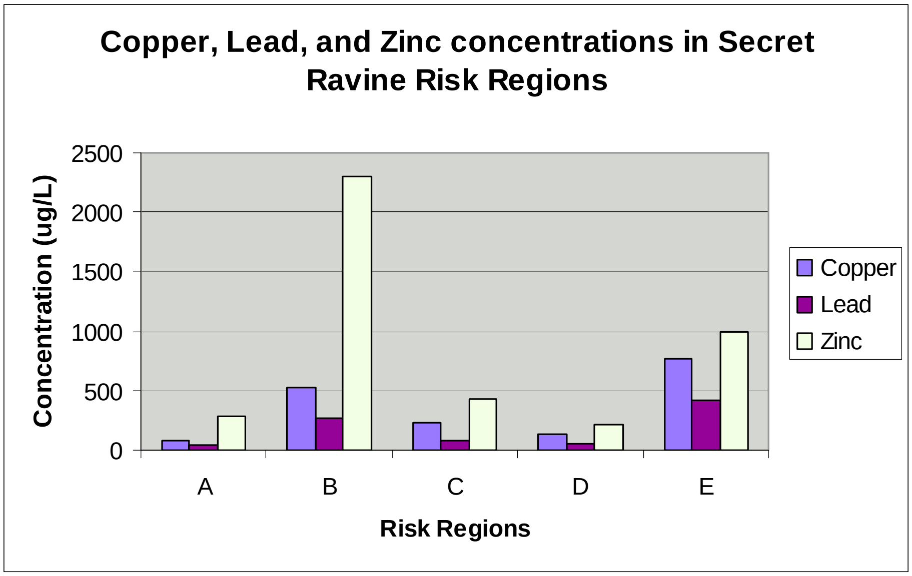


TABLE 5.15 COPPER, LEAD AND ZINC CONCENTRATIONS IN SECRET RAVINE RISK REGIONS

Appendix J-8: Metals contains a summary table of final ranks for metals in the benthos.

5.1.9 Food Supply

5.1.9.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
Food Supply is affected directly and indirectly by eleven sources. OHVs, water treatment plants, impervious surfaces, and landscape maintenance affect invertebrate populations directly, hence they were assigned an Exposure 1 filter of 1. Channelization, construction and development, dirt and gravel roads, irrigation, and beaver dams affect food supply indirectly, hence they were assigned an Exposure 1 filter of 0.5. Mining and orchards are a special case. When they were present, they would have affected food supply directly. But considering the elapsed time, the Exposure 1 was assigned as 0.5, indicating the time period and the indirect effect they presently have.

Exposure 2 (Habitat Exposed to Stressor filter)
Invertebrates that are a chinook salmon food source are found both in the benthos and the water column, but are only eaten in the water column by juveniles. Consequently, the Exposure 2 value equals 1 for water column because the juvenile stage is affected. The Exposure 2 value equals 0 for benthos.

Inherently this is incorrect because the stress of food supply is realized equally in both the water column and the sediment. But the MRRM requires the capture of life stage in this exposure filter.

5.1.9.2 Assigning Effects Ranks

We assigned a rank for food supply using three criteria: 1) percentage of edible invertebrates, 2) juvenile feeding habits, and 3) amount of riffle habitat for invertebrates (**Table 5.16**).

Rank	Criteria
0	High percentage of edible invertebrates Opportunistic feeding habits Optimal amount of riffle habitat for invertebrates
2	High percentage of edible invertebrates Opportunistic feeding habits Suitable amount of riffle habitat for invertebrates
4	Low percentage of edible invertebrates Opportunistic feeding habits Suitable amount of riffle habitat for invertebrates
6	Low percentage of edible invertebrates Opportunistic feeding habits Little riffle habitat for invertebrates

TABLE 5.16 CRITERIA FOR RANKING FOOD SUPPLY

We calculated the percentage of edible invertebrates **Appendix J-9: Food Supply** using the aforementioned list (**Section 3.4.9**). In Risk Region A 62% of the invertebrates were edible, in Risk Region B 65%, and in Risk Region C 63%. No data was collected in the upper two risk regions, therefore the average percent of edible invertebrates (63%) was used.

When looking at the percentages in each risk region, it becomes apparent that they are very similar. Notably, Fields, Jr. also indicates that species richness did not vary across his sample sites (Fields, Jr. 1999). With the guidance of our CalEPA clients, we determined that these percentages were acceptable levels for food source, and posed no or little risk to juvenile salmon. Due to the similarities across the creek, the same rank should be assigned across all risk regions.

Along with these seemingly high percentages, a look at the feeding habits of juveniles played a role in determining the rank of food supply. Juvenile chinook are "by nature opportunistic, and the riparian zone is pretty healthy, providing them with plenty of food of terrestrial origin" and with "their proclivity for eating small benthic forms and staying along the margins, they would find sufficient food of that type as well" (Fields, Jr., pers. comm. 2002). This indicates that risk due to the amount of food is minimal.

Appendix J-9: Food Supply contains a summary table of final ranks for food supply in the water column and the mathematical models used to derive those ranks.

5.1.10 Predation

5.1.10.1 Assigning Exposure Filters

Exposure 1 (Stressor from Source filter)
The only source of fish predation is introduced fish. It was therefore assigned a value of one for the Exposure 1 filter.

Exposure 2 (Habitat Exposed to Stressor filter)
Both the benthos and water column received a value of one for the Exposure 2 filter since predation occurs on both the early life (eggs and yolk-sac fry) and juvenile life stages.

5.1.10.2 Assigning Effects Ranks

To assign ranks to this stressor, the effect of spotted bass predation on chinook salmon juveniles in the water column was considered. The ranking system used to assign a weight to introduced fish for the MRRM resulted from a series of criteria (**Table 5.17**). First criteria considered whether spotted bass would predate on chinook salmon. To predate on chinook the two fish must occur in the same habitat and the temperature of the water must be above the threshold value of 10° C and salmonids must be part of the spotted bass diet. For any rank to be assigned these three criteria must be satisfied; this occurs in March through June of most years.

Ranks	Criteria
0	No predation on juvenile chinook
2	A low degree of predation, less than 5% decrease in biomass
4	Medium degree of predation, less than 25% decrease in biomass
6	High degree of predation greater than 25% decrease in biomass

TABLE 5.17 CRITERIA FOR RANKING PREDATION

6 Results (Modified Relative Risk Model)

6.1 Evaluating the Entire Watershed

6.1.1 Cumulative Stressor Risk Scores

Summing risk scores across all risk regions per stressor yields cumulative risk scores for each stressor (**Figure 6.1**). Flow scored the highest relative risk when considering both habitats (3924 cumulative risk score). Flow also had the highest cumulative risk score overall (2400 cumulative risk score in the water column).

Sediment and morphology were the next highest scoring stressors (2616 and 3816 cumulative risk score, respectively). Reduced access was the lowest-scoring stressor (96 cumulative risk score).

The reduced access and food supply stressors had cumulative risk scores only in the water column. This is due to the assumption that these two stressors affect only the life stages in the water column. This assumption is accounted for in the Exposure 2 filter.

The toxicity and metals stressors had cumulative risk scores only in the benthos based on the assumption that they only affect life stages in the benthos (also accounted for in the Exposure 2 filter).

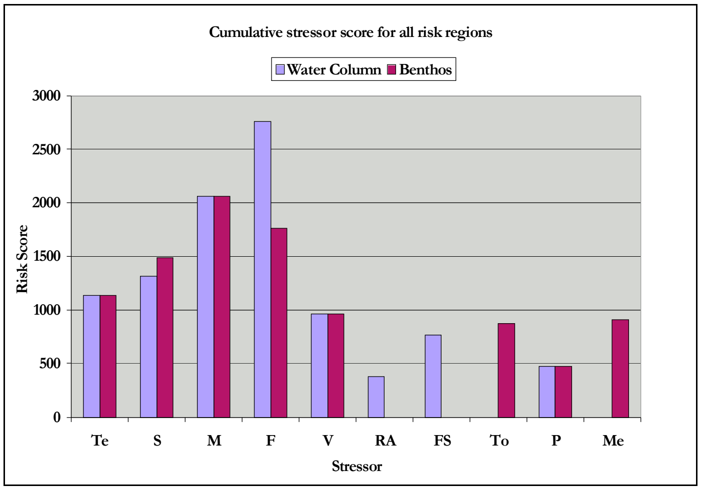


FIGURE 6.1 CUMULATIVE STRESSOR RISK SCORE FOR ALL RISK REGIONS

See **Appendix F: Sources and Stressors** for the list of stressors.

6.1.2 Cumulative Source Risk Scores

Summing across all risk regions per source yields cumulative risk scores for each source (**Figure 6.1**). The impervious surfaces source scored the highest (3104 cumulative risk score). Beaver dams, channelization and mining were the next highest scoring sources (2364, 2100 and 2072 cumulative risk scores, respectively).

Dirt and gravel roads, landscape maintenance, OHVs and irrigation canals all had cumulative source risk scores close to 1800.

Water treatment plants were the lowest scoring source (372 cumulative risk score).

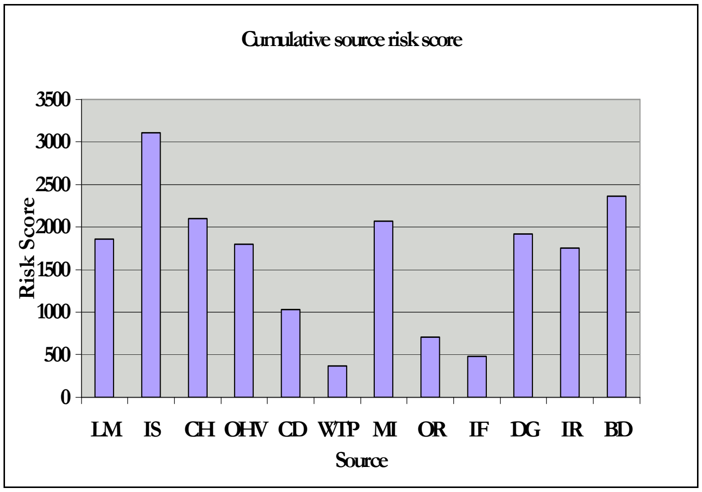


FIGURE 6.2 CUMULATIVE SOURCE RISK SCORE FOR ALL RISK REGIONS

See **Appendix F: Sources and Stressors** for the list of sources.

6.1.3 Cumulative Habitat Risk Scores

Overall, the water column scored a higher total risk than the benthos (**Figure 6.3**). The difference, however, does not seem significant.

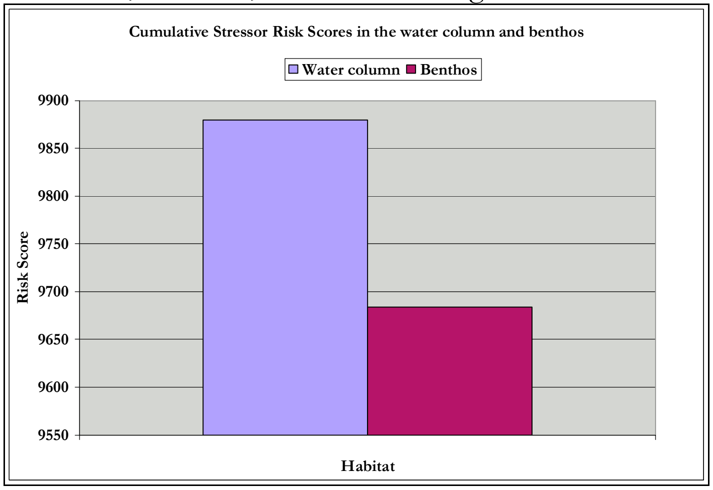


FIGURE 6.3 TOTAL RISK SCORE FOR EACH HABITAT

6.1.4 Comparing Risk Regions

Summing up all stressor scores for each risk region yields the total stressor risk score per region (**Figure 6.4**). These values can be used to compare risk from stressors among all risk regions. Risk Region A scored the highest (7308 total risk score) and Risk Region D the lowest (1840 total risk score).

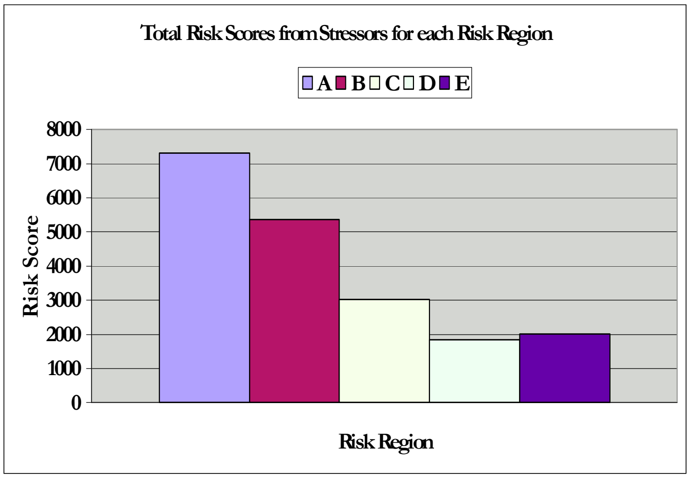


FIGURE 6.4 TOTAL RISK SCORES FROM STRESSORS FOR EACH RISK REGION

6.2 Evaluating the Individual Risk Regions

Total risk scores for stressors (or sources) per risk region can be obtained by summing across all stressors (or sources) in that risk region. These risk scores indicate the stressors (or sources) that pose the highest risk within the region being analyzed.

6.2.1 Risk Region A

6.2.1.1 Stressors in Risk Region A

The morphology and flow stressors had the highest risk scores in Risk Region A (**Figure 6.5**). Altered riparian vegetation was the next highest scoring stressor. Toxicity was the lowest scoring stressor.

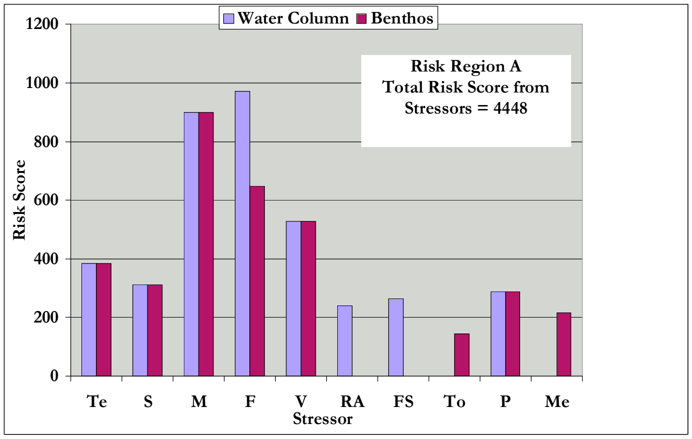


FIGURE 6.5 TOTAL RISK FROM STRESSORS IN RISK REGION A

6.2.1.2 Sources in Risk Region A

Summing risk scores across sources for Risk Region A (**Figure 6.6**) indicates that beaver dams are the source posing the most risk to that region (1404 total risk score). OHVs is the next highest scoring source (1332 total risk score) followed closely by channelization (1260 total risk score). Water treatment plants, orchards and dirt and gravel roads had total risk scores of zero in this risk region.

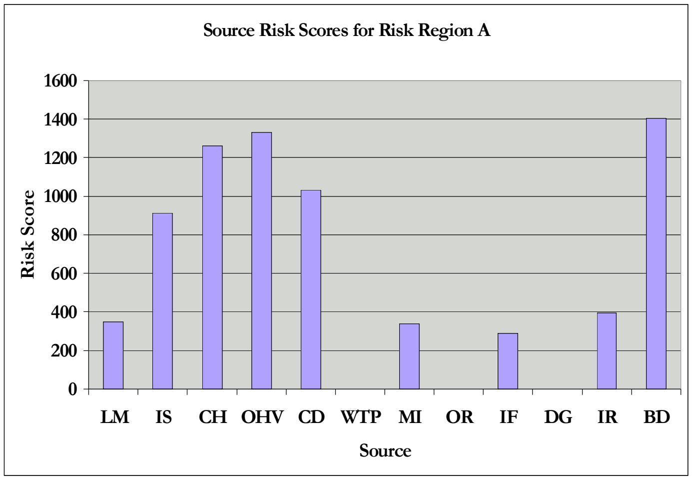


FIGURE 6.6 TOTAL RISK FROM SOURCES IN RISK REGION A

6.2.2 Risk Region B

6.2.2.1 Stressors in Risk Region B

Flow scored the highest stressor risk score (792 in the water column and 528 in the benthos) in Risk Region B (**Figure 6.7**). Sediment and morphology were the next highest scoring stressors.

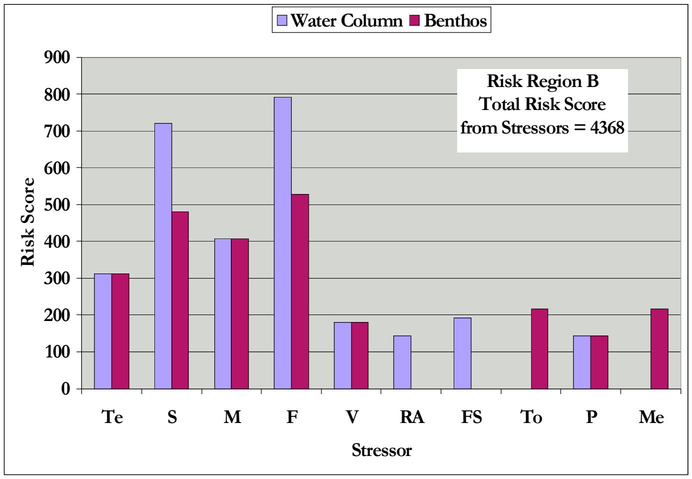


FIGURE 6.7 TOTAL RISK FROM STRESSORS IN RISK REGION B

6.2.2.2 Sources in Risk Region B

The dirt gravel roads source scored the highest (1116 total risk score) in Risk Region B (**Figure 6.8**). Beaver dams and channelization were the next highest scoring sources (960 and 840 total risk score, respectively). Construction and development, orchards and water treatment plants scored zero in this risk region.

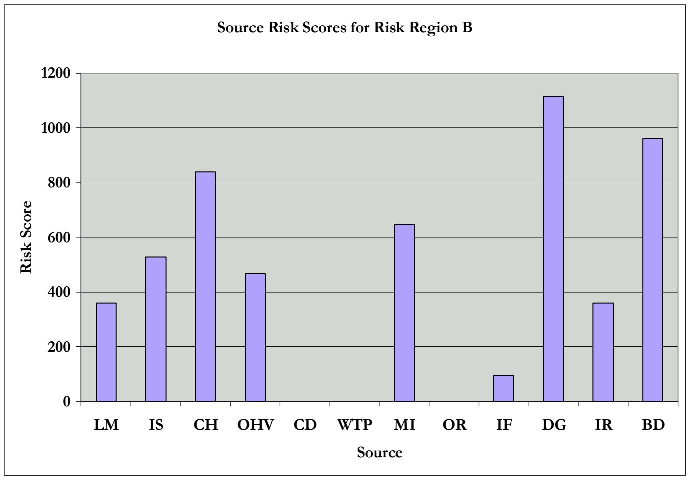


FIGURE 6.8 TOTAL RISK FROM SOURCES IN RISK REGION B

6.2.3 Risk Region C

6.2.3.1 Stressors in Risk Region C

Flow was the highest scoring stressor (384 total risk score in both the benthos and water column) for Risk Region C (**Figure 6.9**). Morphology was the next highest scoring stressor (288 total risk score in both the benthos and water column) and sediment in the benthos also had a high score (360 total risk score). Reduced access scored a zero in this risk region.

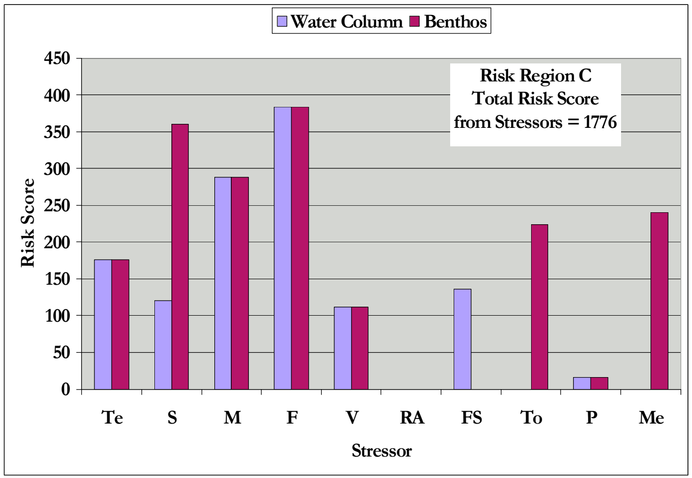


FIGURE 6.9 TOTAL RISK FROM STRESSORS IN RISK REGION C

6.2.3.2 Sources in Risk Region C

Impervious surfaces scored the highest total source risk score (1056 total risk score) in Risk Region C (**Figure 6.10**). Landscape maintenance was the next highest scoring source (720 total risk score) followed by mining (464 total risk score). Channelization, OHVs, construction and development, water treatment plants and beaver dams all scored zero for source total risk score in this risk region.

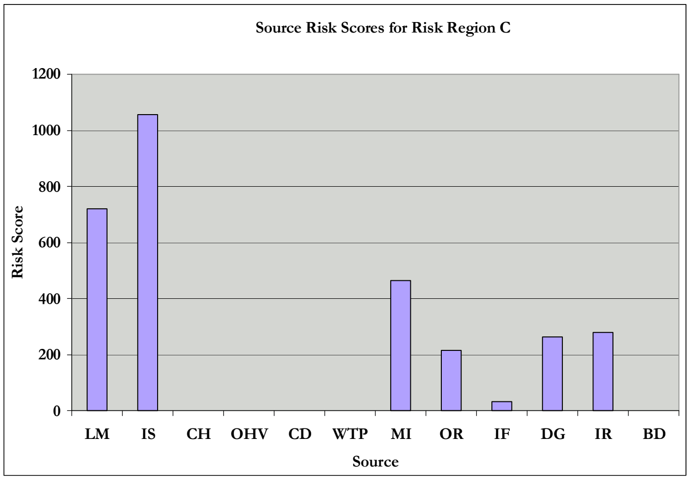


FIGURE 6.10 TOTAL RISK FROM SOURCES IN RISK REGION C

6.2.4 Risk Region D

6.2.4.1 Stressors in Risk Region D

Morphology was the highest scoring stressor (240 total risk score in both the water column and benthos) in Risk Region D (**Figure 6.11**). Flow in the water column also had a high score (288 total risk score). Reduced access scored a zero in this risk region.

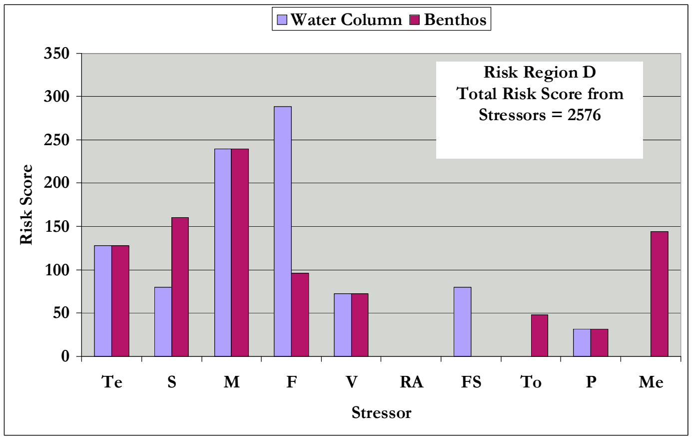


FIGURE 6.11 TOTAL RISK FROM STRESSORS IN RISK REGION D

6.2.4.2 Sources in Risk Region D

Irrigation canals scored the highest source risk score (480 total risk score) in Risk Region D (**Figure 6.12**). Mining was the next highest scoring stressor (416 total risk score). Channelization, OHVs, construction and development, water treatment plants and beaver dams scored zero for total risk in this risk region.

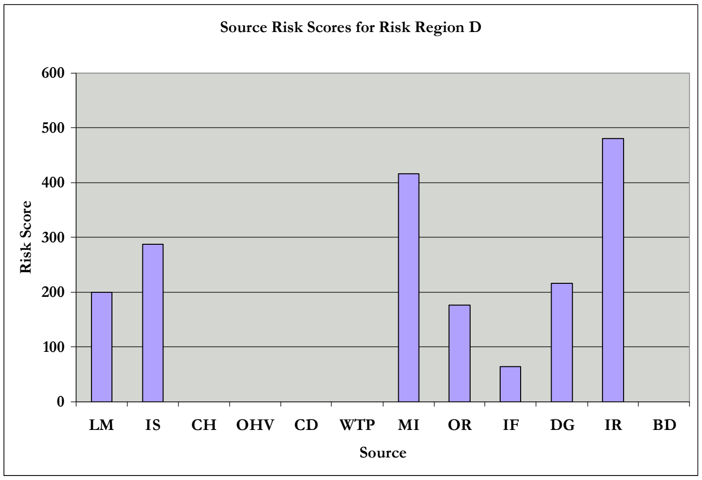


FIGURE 6.12 TOTAL RISK FROM SOURCES IN RISK REGION D

6.2.5 Risk Region E

6.2.5.1 Stressors in Risk Region E

Morphology scored the highest (228 total risk score in both the water column and the benthos) in Risk Region E (**Figure 6.13**). Flow in the water column and toxicity also scored high (324 and 240 total risk scores, respectively). Reduced access and predation scored zeroes in this risk region.

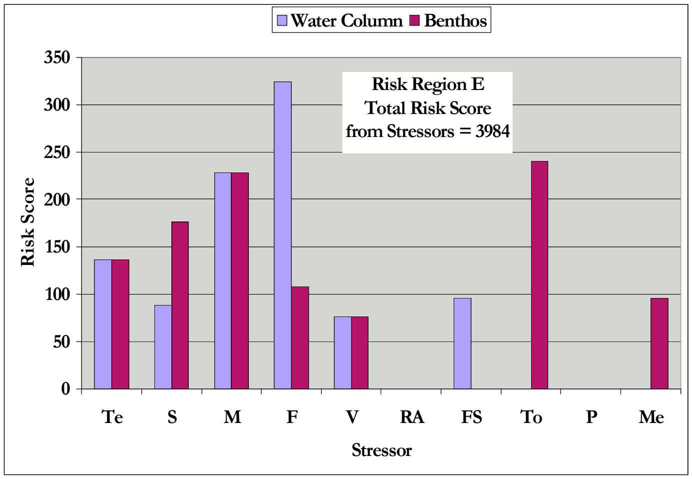


FIGURE 6.13 TOTAL RISK FROM STRESSORS IN RISK REGION E

6.2.5.2 Sources in Risk Region E

Water treatment plants scored the highest risk score (372 total risk score) in Risk Region E (**Figure 6.14**). Dirt and gravel roads, impervious surfaces and orchards were the next highest scoring sources (approximately 320 total risk score for each). Channelization, OHVs, construction and development, introduced fish and beaver dams all scored zero in this risk region.

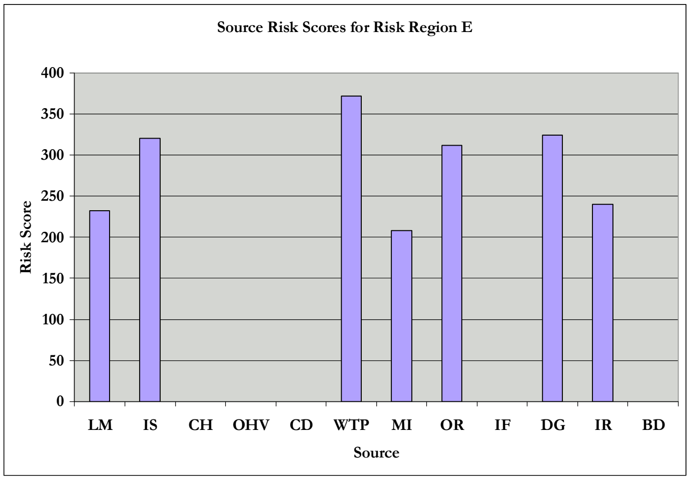


FIGURE 6.14 TOTAL RISK FROM SOURCES IN RISK REGION E

7 Uncertainty (Modified Relative Risk Model)

Uncertainty analysis for qualitative data was based on Best Professional Judgment (BPJ) and was determined by the following three criteria: 1) difficulty of evaluation; 2) confidence of evaluator; 3) number of observations (**Table 7.1** and **Table 7.2**). Qualitative uncertainty was established for each applicable source and stressor. It should be noted that best professional judgment was used for some quantitative data as well. Monte Carlo techniques were then applied for our uncertainty analyses to assess the parameters of our uncertainty in the risk predictions (**Section 7.4**).

	Data Points	**Natural Variability**	**Confidence Level**
High Uncertainty	Low # of data points	High natural variability in system	Low confidence in methods
Medium Uncertainty	Intermediate # of data points	Intermediate variability in system	Some confidence in methods
Low Uncertainty	High # of data points	Low natural variability in system	High confidence in methods

TABLE 7.1 UNCERTAINTY CRITERIA FOR QUANTITATIVE DATA

	Evaluation	Confidence Level	Observations
High Uncertainty	Very difficult evaluation	Low confidence in observer	Low # of observations
Medium Uncertainty	Moderately difficult evaluation	Some confidence in observer	Intermediate # of observations
Low Uncertainty	Relatively easy evaluation	High confidence in observer	High # of observations

TABLE 7.2 UNCERTAINTY CRITERIA FOR QUALITATIVE DATA

7.1 Uncertainty for Effects Ranks

The uncertainty associated with the effects ranks pertains to the quantity and quality of data, as mentioned above. We utilized these uncertainties to conduct a sensitivity analysis to assess whether or not changing the ranks associated with the stressor would result in a change in risk scores and how this would affect the overall prioritizing of stressors. This sensitivity analysis (Monte Carlo analysis) is summarized in **Section 7.4**. The assigned uncertainties for each stressor are described below.

Sediment

Low uncertainty was applied to the benthos for all risk regions. Many quantitative data points were accumulated for sediment in addition to significant anecdotal and observation data (Swanson 2000, Li and Fields, Jr. 1999). Medium uncertainty was applied to the water column for all risk regions. Although turbidity data does exist, it is not sufficiently detailed for accurate assessment.

Flow

High uncertainty was applied to both the benthos and the water column for all risk regions. Utility of flow data is low the scientific literature does not report robust relationships that link flow and mortality. Available data on flow is from Stacy Li percolation studies. This data exists for only three sites and records just one year of record.

Morphology

Medium uncertainty was applied to both the benthos and the water column for all risk regions. Although detailed, region specific data does exist, it is only for the two lower risk regions. Other data, Barbara Washburn survey and Stacy Li records, is limited for the rest of the risk regions.

Temperature

Medium uncertainty was applied to both the benthos and the water column for all risk regions. Sequential data was available for 12 months in risk region B. Other data points were available for risk regions A and E. Quantitative is limited by data points and was not representative of all risk regions. Extrapolation was utilized.

Altered Riparian Vegetation

High uncertainty was applied to the benthos and water column for all risk regions. All data concerning altered riparian vegetation is anecdotal and/or observational. There was no abundance data for invasive plant species and no detailed plant list exists for Secret Ravine.

Reduced Access

High uncertainty was applied to the benthos and water column for all risk regions. All available data points are located in risk regions A and B. Although the effects of beaver dams are straightforward (measured in terms of fish passage), there are numerous secondary effects that are more difficult to measure. High natural variability is associated with assessing fish passage given reduced access.

Toxicity

Medium uncertainty was applied for the benthos and the water column for all risk regions. *Hyalella* toxicity testing was performed on sediment from the Secret Ravine watersheds in December 2002 at the Aquatic Toxicology Laboratory at the University of California, Davis. Although the region specific data exists for all risk regions, samples were not taken directly after the first flush when most toxic chemicals are present. *Ceriodaphnia* toxicity testing was performed on the water column at all five risk regions and was subject to medium uncertainty for the same reason as the *Hyalella* sediment testing.

Food Supply

Uncertainty in the stressor rank was determined by the availability of data and the use of best professional judgment. There was a high confidence associated with the quality of the benthic macroinvertebrate data collected. It was collected by reliable sources (DCC), using reliable and published methods(California Stream Bioassessment Protocol), and there was a sufficient number of sampling points over a span of three years. Reliable information from a related study, Li and Fields, Jr. 1999, provided a sound basis for best professional judgment. As a result, uncertainty for this stressor was low across all risk regions for both the water column and the benthos.

Predation

High uncertainty was applied to the benthos and water column for all risk regions. Most data concerning fish predation was anecdotal and/or observational. The available population data included only one year for chinook salmon and one year for spotted bass. In addition, no data exists for both bass and salmon in the same year. Therefore much of the analysis was based on projection and best professional judgment.

7.2 Uncertainty for Sources

A sensitivity analysis similar to that conducted for the effects ranks was not conducted on the source ranks due to the fact that the source ranks were based on data that contained a relatively lower degree of uncertainty. Specifically, gross estimates of area (for non-point sources) and frequency (for point sources) could be more easily transferred into ranks than estimates of percent mortalities or habitat losses. In general, however, we concluded that risk scores associated with the legacy sources (mining and orchards) are fairly tenuous since they have not been active or abundant for a long period of time.

7.3 Uncertainty for Habitat Ranks

The alternative habitat-ranking scheme involved ranking habitat based on area of the risk region rather than stream length. The ranks underneath both schemes were as follows:

Original ranking scheme (Stream length)						
Risk Region		**A**	**B**	**C**	**D**	**E**
Stream Length (feet)		13152	18872	5995	9009	2171
Habitat	**WC**	6	6	4	4	2
	BE	6	6	4	4	2
Alternative ranking scheme (Area)						
Risk Region		**A**	**B**	**C**	**D**	**E**
Risk Region Area (Acres)		2899	3472	2724	1587	3765
Habitat	**WC**	4	6	4	2	6
	BE	4	6	4	2	6

TABLE 7.3 ALTERNATIVE RANKING FOR HABITAT

Changes in risk scores for both stressor and sources were insignificant under the alternative habitat-ranking scheme (**Figure 7.2** and **Figure 7.4**). Risk scores simply increased consistently for all stressors.

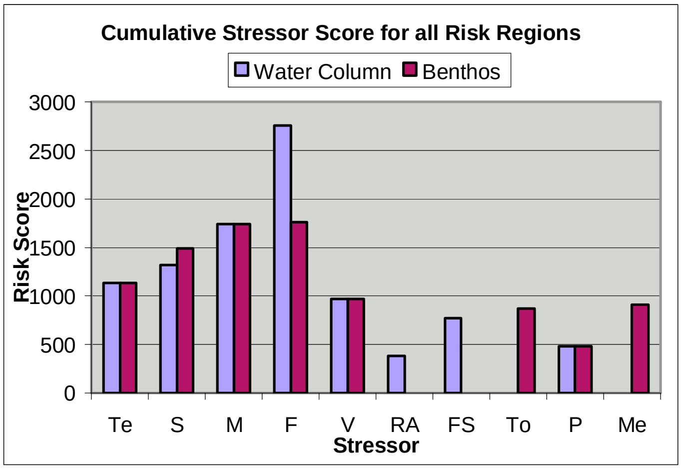


FIGURE 7.1 CUMULATIVE STRESSOR RISK SCORES (ORIGINAL)

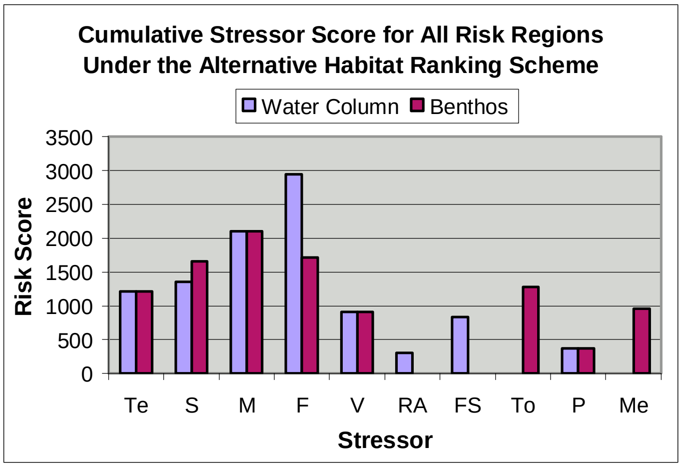


FIGURE 7.2 CUMULATIVE STRESSOR RISK SCORES (ALTERNATIVE)

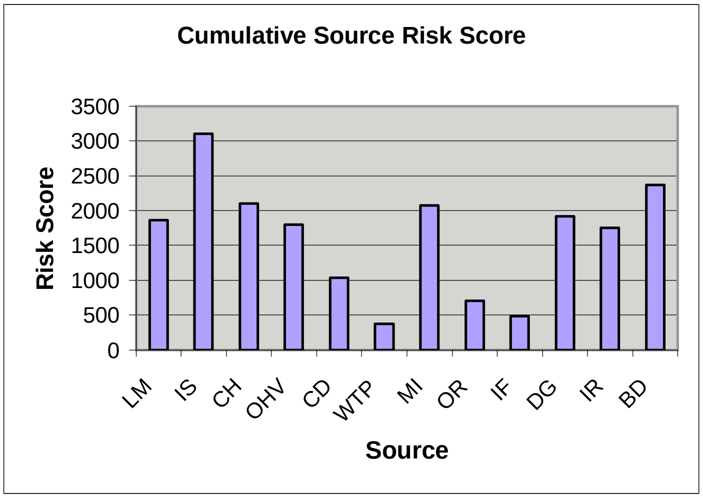


FIGURE 7.3 CUMULATIVE SOURCE RISK SCORES (ORIGINAL)

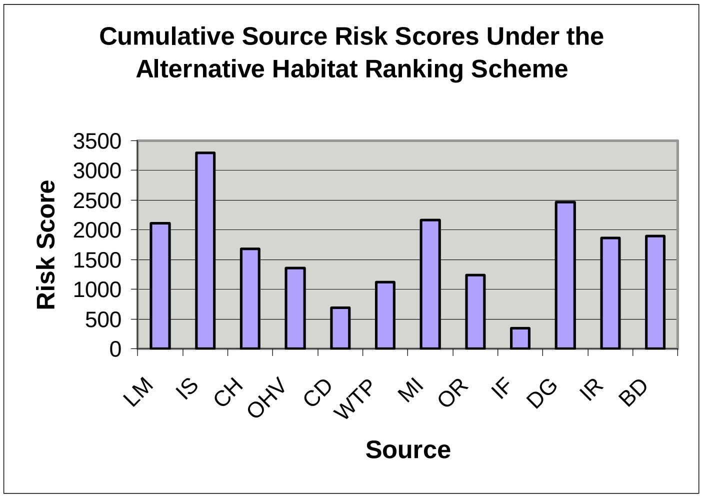


FIGURE 7.4 CUMULATIVE SOURCE RISK SCORES (ALTERNATIVE)

A similar alternative ranking scheme was applied to all non-point sources. No significant differences in stressor risk scores occurred.

7.4 Monte Carlo Analysis

Monte Carlo techniques were applied for our uncertainty analyses to assess the parameters of our uncertainty in the risk predictions. To determine output variables, Monte Carlo uncertainty analysis combines assigned probability distributions of input variables (Burmaster and Anderson 1994). In the case of the sub-watershed risk assessment, the input variables are the ranks and associated filters with high and medium uncertainty and the output variables are the corollary risk estimates.

Designations of low, medium, or high uncertainty were applied to each source, habitat rank, exposure, and effects filter based on available data and best professional judgment. We assigned discrete probability distributions to ranks and filters with medium and high uncertainty according to the criteria in the following tables.

Uncertainty Analysis Monte Carlo input distributions for ranks with medium and high uncertainty:

Assigned Rank Value	*Uncertainty*	*Assigned Probability (%) for Ranks*			
		0	**2**	**4**	**6**
0	High	60	20	20	0
0	Medium	80	10	10	0
2	High	0	60	20	20
2	Medium	0	80	10	10
4	High	0	20	60	20
4	Medium	0	10	80	10
6	High	0	20	20	60
6	Medium	0	10	10	80

TABLE 7.4 MONTE CARLO DISTRIBUTIONS FOR UNCERTAINTIES

The Monte Carlo analysis produced a variety of distributions for our stressor data. Four stressors showed means that matched the predicted risk scores exactly for either the water column or the benthos. These risk components reflected low uncertainty and high confidence for our MRRM predictions. These stressors were: sediment (BE), food supply (BE), toxicity (WC), and metals (WC).

Sediment in the benthos recorded low uncertainty due to a large number of data points, the recent collection of the data, and the peer-reviewed sampling methods that were conducted.

Food supply in the benthos showed low uncertainty due to the absence of juvenile chinook in this habitat. There is high confidence that juveniles are not affected by the food supply in the benthos.

Toxicity and metals showed low uncertainty in both the water column and the benthos. Tests at the Aquatic Toxicology Lab at UC Davis were all negative for toxicity in the water column. For the benthos, the data collection was thorough and analyses were conducted professionally.

Metals revealed narrow distributions in the water column and benthos because the metals, which adsorb to sediment particles, tested positive in the benthos and were absent in the water column.

Eight stressors had means that did not match the predicted risk score for the water column, benthos, or both. Of these eight stressors, four exhibited wide distributions with differences over 1200. The wide distributions suggested high uncertainty and low confidence. Temperature had a wide distribution in the benthos because the data was for the water column only. Temperature data was extrapolated for the benthos.

Sediment showed a wide distribution in the water column because assumptions had to be made about the duration of turbidity measured in Secret Ravine. The data stemmed from event-based sampling and did not span adequate time for robust analysis.

Flow and vegetation exhibited wide distributions for similar reasons. Neither stressor had adequate data in Secret Ravine. Without data, these stressors were highly uncertain as reflected in the Monte Carlo uncertainty analysis.

Stressor	**WC & BE**	**Risk Score**	**Mean**	**Upper C.I.**	**Lower C.I.**	***Difference***
Temperature	WC	2000	2239	2688	1792	896
	BE	2288	2239	2928	1648	1280
Sediment	WC	1840	1638	2288	912	1376
	BE	1712	1712	1712	1712	0
Morphology	WC	1968	2378	2736	1632	1104
	BE	2736	2390	2736	1760	976
Flow	WC	2464	2379	3216	1536	1680
	BE	2400	2473	3216	1680	1536
Vegetation	WC	2240	2029	2752	1296	1456
	BE	2352	2024	2864	1312	1552
Reduced Access	WC	64	67	96	32	64
	BE	32	69	96	32	64
Food Supply	WC	1360	1191	1648	912	736
	BE	0	0	0	0	0
Toxicity	WC	0	0	0	0	0
	BE	1344	1344	1344	1344	0
Introduced Fish	WC	272	327	448	192	256
	BE	304	315	480	192	288
Metals	WC	0	0	0	0	0
	BE	1872	1872	1872	1872	0

TABLE 7.5 MONTE CARLO ANALYSIS RESULTS

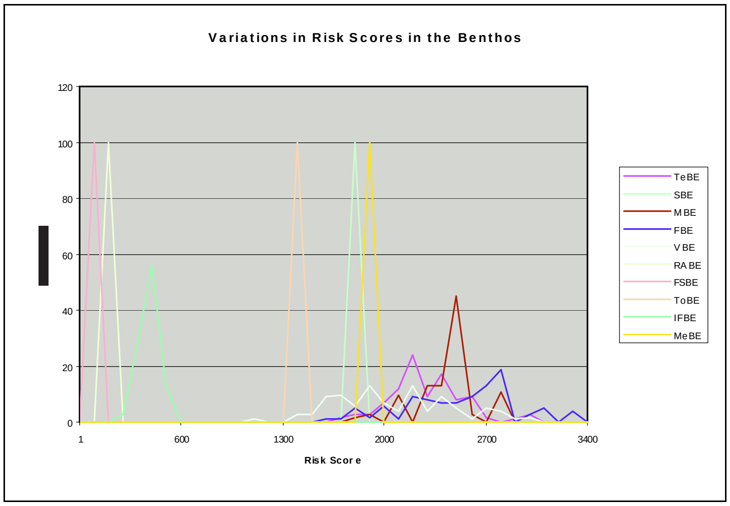


FIGURE 7.5 MONTE CARLO RESULTS FOR STRESSORS IN THE BENTHOS

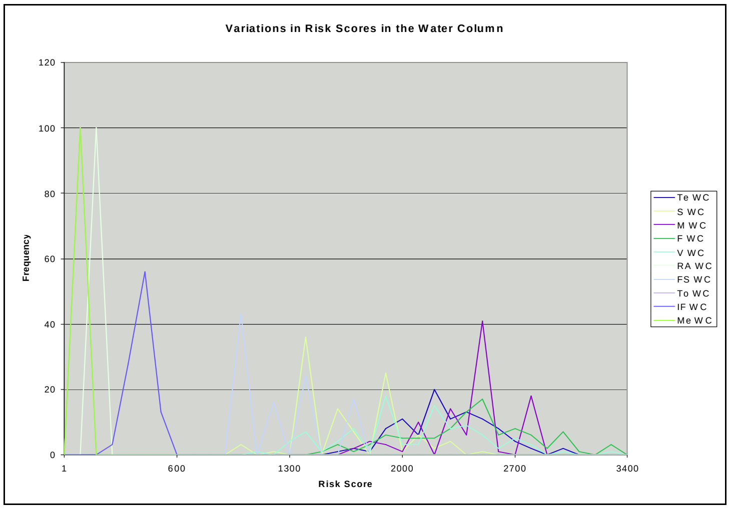


FIGURE 7.6 MONTE CARLO RESULTS FOR STRESSORS IN THE WATER COLUMN

8 Risk Analysis Methods (Stressor-Driven Risk Model)

8.1 General Methods and Modifications (SDRM)

As with the MRRM model, the main objective of the Stressor Driven Risk Model is to determine the most significant stressor and source in the Secret Ravine watershed. To attain this goal the stressor model quantifies stress in terms of effect on fish populations. The stressors produce a certain effect on the chinook salmon population. To better discern the effect of the stressor, this effect has been translated into percent mortality or percent reduction in habitat for each life stage. For the sake of flow, the 'Risk Region' delineations referred to in the MRRM are retained in the SDRM analysis

8.1.1 Evaluating Stressors

Where e = early life stage, j = juvenile and a = adult.

Percent Effect $_{\text{(per life stage per stressor)}}$ = % mortality or % habitat reduction
(Based on dose-response curves, reference values or habitat loss estimates)

$$\textbf{Total Percent Effect}_{\text{(per stressor)}} = 1 - [(1 - PE_e) \times (1 - PE_j) \times (1 - PE_a)]$$
(TPE and PE are expressed here as a number between 0 and 1.)

PE is the effect of a stressor on a particular life stage, while TPE is the integrated effect across all life stages.

*PE: Percent Effect; TPE: Total Percent Effect

EQUATION 2 TOTAL PERCENT EFFECT EQUATION (SDRM)

Once the percent effect of an individual stressor has been determined, the percent effect for each life stage was multiplied together. In essence, the product simulates the percent survival of chinook salmon through the three life stages in Secret Ravine. The percent mortality result is subtracted from one and multiplied through the three life stages. This value is subtracted again from one, rendering a total percent survival. Mortality in this model refers to mortality that is stressor-induced, above and beyond the natural mortality of the salmon.

To illustrate, consider sediment in Example A (**Figure 8.1**). The percent mortality due to sediment during the early egg and alevin phase was determined to be 67% and the percent mortality estimated for the juvenile phase is 20%. A literature search uncovered no evidence that sediment causes mortality in adult salmon, therefore the effect is considered to be 0% for this phase. The percent mortality result is subsequently subtracted from one and multiplied through the three life stages. This renders a total percent survival.

Example A:

Ranking stressors:

PE_e (sediment) = % mortality of eggs = 67%
PE_j (sediment) = % mortality of juveniles = 14%
PE_a (sediment) = % mortality of adults = 0%

TPE (sediment) = $1 - [(1 - 0.67) \times (1 - 0.14) \times (1 - 0.00)] = 0.72$
(risk score is not a rank rather a percent effect)

*PE: Percent Effect; TPE: Total Percent Effect

FIGURE 8.1 EXAMPLE A USING TOTAL PERCENT EFFECT EQUATION (SDRM)

8.1.2 Total Percent Effect Example

8.1.3 Evaluating Sources

We used the analysis described in the MRRM to identify the links between sources and stressors in the Secret Ravine watershed. However, we relaxed the assumption of the MRRM that all sources have the same intensity of effect. For the SDRM, for example, we did not assume that 1 acre of impervious surface is equal to 1 acre of historic orchard cultivation or 1 acre of dirt and gravel roads when evaluating effects on chinook salmon. Instead, each source was assigned a contribution category depending on whether that contribution per unit area (for non-point sources) or instance (for point sources) was low, medium, or high.

We limited our source analysis to sources associated with the three stressors with the most significant stressor effect. Having determined the contribution of a certain source in relation to a stressor, we next determined how much effect may be associated with each source. For each non-point source a combination of the contribution category, aerial extent, and best professional judgment was used to approximate effect for a stressor. For the point sources, the effect on a stressor was based on the degree of contribution, frequency, and best professional judgment.

8.1.4 Assumptions

In the absence of complete data sets, a few assumptions were required to construct a comprehensive ecosystem model. Two assumptions utilized in this model directly influenced the approximation of the effect that stressors had on life stages. The effect per life stage extrapolates percent effect based on data from the site; where direct data is unavailable, we use estimates available in the scientific literature. Another assumption that allowed the use of habitat loss to approximate effects is that some linear relationship exists between mortality of salmon and the loss of habitat salmon use to support integral life functions such as spawning, early growth and survival. This effectively assumes that density dependent mortality scales linearly with habitat availability, which may not be true for all processes. Finally, as in the MRMM, we assume that the full extent of the sources and stressors that effect chinook salmon in Secret Ravine have been included in the model. In particular, we do not consider the effects to the Secret Ravine salmon population when juvenile fish travel to the Pacific ocean and return via the same route to Secret Ravine. The only adult stressors considered are those that would prevent the fish from reaching or finding spawning habitat once the fish have entered the Secret Ravine watershed.

9 Risk Analysis and Risk Characterization for Stressors (SDRM)

9.1 Stressors

9.1.1 Sediment

In the SDRM, we calculated an average percent mortality to the early life stage (in the benthos) for the entire watershed using the sediment data mentioned above (**Appendix J-1: Sediment**). Grain size distributions were used to calculate percent mortalities (Tappel and Bjornn 1983) for ten sampling sites. These mortalities were then averaged to assess impacts to the entire watershed. We calculated the average percent mortality for the entire watershed to be 67% for the early life stages (eggs and yolk-sac fry).

We estimated average turbidity values for the entire watershed using the DCC turbidity data (DCC 2002, **Appendix J-1: Sediment**) to assess impacts from sediments suspended to the juvenile and adult life stages. The same assumptions as mentioned in Section 3.4.1 were made regarding duration of exposure and conversion from NTU to milligrams of suspended sediment (**Section 3.4.1**). We then calculated percent mortalities from this data set using methods developed by Allen et al 1996. The juvenile life stage was the only life stage estimated to have SEV values, as described in Section 3.4.1. These values were high enough to cause mortality. Average mortality values for the juvenile life stage were roughly 20%.

Next we calculated total percent effects (TPE) for sediment based on these two data sets with the assumption that turbidity is affecting the juvenile and adult life stages and the sediment in the benthos is affecting the early life stages. Thus, we calculated the TPE for sediment to be 74%.

9.1.2 Flow

As mentioned earlier, the lack of flow data limits the analysis of the flow stressor. In the SDRM, we calculated TPEs based on observational data specific to flow levels (Li and

Fields, Jr. 1999). This data set included observational estimates of flow depths and velocities specific to all three life stages. The percentages of depths below a minimum threshold and velocities above a maximum threshold were assumed to be equivalent to percent mortalities to the life stage being assessed. We calculated a PE of 27% for the juvenile life stage and a PE of 6% for the adult life stage yielding a TPE for flow of 31%.

9.1.3 Morphology

We used data from the entire watershed (Li and Fields, Jr. 1999) to assess alterations to stream morphology in the SDRM. The criterion used states that a stream (or stream reach) is rated high quality if it contains more than 30% pools by length (KRIS 2003). We assumed that a similar percentage of riffles and runs should exist in Secret Ravine (each being roughly one third). For the analysis, pools were regarded as juvenile habitat and riffles as early life stage habitat. Due to the limited residence time of spawning adults, and to avoid the possibility of double counting, no criteria was set for the adult life stage.

A deviation from this criterion (33% pools or riffles) indicated a loss of potential habitat and was thus the estimate of the PE. The data indicated an average percent riffles (early life stage habitat) by length of 20% and 17% for pools (juvenile habitat). Thus, the resulting TPEs were 13% for the early life stages and 16% for the juvenile life stage.

9.1.4 Temperature

In the SDRM, temperature is characterized by the number of times that Secret Ravine temperatures exceeded maximum weekly optimal temperatures. As stated in **Section 3.4.4**, maximum weekly optimal temperatures were slightly exceeded for the juvenile life stage (May) and the adult life stage (September & October). Although these temperatures exceeded maximum weekly optimal temperatures, they did not exceed the threshold for incipient mortality (Armour 1991). Since no percent mortalities were determined via dose-response curves, no life stages were affected for the SDRM.

9.1.5 Altered Riparian Vegetation

Overall, the condition of Secret Ravine in the broader context of foothill streams may be evaluated as fair. The basis of this evaluation comes from the habitat suitability study done in 1999 on Secret Ravine by Li (Li et al. 1999) (**Section 3.4.5**). The creek has a fair degree of riparian cover, a fair degree of riparian zone extent, and only a few areas where the riparian zone narrows to less than a 100-foot buffer. Within the watershed itself, however, gradations in riparian zone extent, areas with a riparian zone less than the ascribed riparian buffer of 100-ft, may indicate gradations in vegetation quality between risk regions. Therefore the percent effect on salmon habitat of altered riparian vegetation was considered the percent of the creek that were degraded due to a narrow riparian zone or approximately 10%.

Total Length of Incidence/Total Length of Stream	(5,595 ft)/(58,499 ft)=10%

EQUATION 3 CRITERIA FOR ANALYZING ALTERED RIPARIAN VEGETATION (SDRM)

9.1.6 Reduced Access

In the SDRM, Reduced Access is still embodied in the ability of a fish to pass a particular barrier, but actual counts are used to obtain more accurate estimates of the number of fish that successfully pass (**Appendix M-1: Reduced Access**). It is possible to grossly compare the average number of fish passing from risk region to risk region since barriers can be the only stressor impeding adult immigration in a single run, other than substrate quality.

Secret Ravine is not only unusually small for fall-run, but relatively distant from the Sacramento main stem for its size. Because the adult females usually move just upstream from a nest in order to build another nest within her redds, burying her eggs with excavated upstream material (Allen and Hassler 1988), it is reasonable to expect that earlier arrivals select the most downstream areas for spawning. This would make available downstream habitat increasingly limited as the fall-run season progresses. Since the count years span a range of different precipitation scenarios (1997-1998 was an El-Nino year, 1999 and 2000 were dry years), the averages of the counts also inherently contain different possibilities for flow. We mapped the survey reaches on Secret Ravine from the DCC count data (**Appendix M-1: Reduced Access**) and matched them against known barriers and spawning sites (**Appendix B: GIS Maps**). It is also reasonable to expect that the count trends reflect the reality of the creek from one fall season to another because beaver dams generally stay in the same location for several years at a time. "After a careful examination of some hundreds of these structures, and of the lodges and burrows attached to many of them, I am altogether satisfied that the larger dams were not the joint product of the labor of large numbers of beavers working together, and brought thus to immediate completion; but, on the contrary, that they arose from small beginnings, and were built upon year after year until they finally reached that size which exhausted the capabilities of the location" (Morgan 1868, p. 83).

Although there are numerous primary and secondary effects of reduced access as caused by barriers on small streams, we analyzed only those stressors associated with the potential to cause mortality to the different life stages. Superimposition of redds, predation on juveniles, exertion costs and the potential for dam blowout, were assessed in terms of percent mortalities through a combination of quantitative criteria from the literature and expertise from regional biologists.

PE(egg) was evaluated in terms of potential mortality due to superimposition and potential mortality due to blowout, as given by the formulae below.

PE(egg)= NP|(% no pass adults)*P(super)*No. females*Mort(super)

EQUATION 4 EQUATION FOR PERCENT EFFECT TO EGG AS CAUSED BY SUPERIMPOSITION

where:
P = pass via "150% rule" (supra **Section 5.1.6.2**)
NP = no pass via counts**NP|** connotes "given not having passed"
P(super) = probability of superimpostion of redds (whole watershed)
No. females = number of attempting spawning adults
Mort(super) = mortality to eggs due to superimposition

PE(egg) =NP|(% pass)*P(blow)*P(high flow)*No. females*Mort(blow)

EQUATION 5 EQUATION FOR PERCENT EFFECT TO EGG AS CAUSED BY BLOWOUT

where:
NP = no pass via counts
P(blow) = probability of blowout of beaver dams (based on no. of dams per reach)
P(high flow) = probability of high flows over one average life cycle
(whole watershed)
No. females = number of attempting spawning adults
Mort(blow) = mortality to eggs due to blowout

FIGURE 9.1 EQUATIONS FOR PERCENT EFFECT TO EGG FROM REDUCED ACCESS (SDRM)

The number of adults that did not pass per survey reach based on the 1997-2002 counts (**Appendix M-1: Reduced Access**), was multiplied by the probability of superimposition. The probability of superimposition was then multiplied by the number of females expected in the adult population (0.5), and then multiplied again by 0.33, an established estimate of the number of eggs anticipated to be lost due to superimposition of redds (McNeil 1964 and Fukushima 1998).

While there has been no direct observation of redds superimposition on Secret Ravine, the literature consensus is that it is highly likely when density dependence plays a role. While Secret Ravine does not experience density dependence per se, (the size of the creek alone could easily accommodate more than the hundred-plus average spawners), lack of quality substrate creates conditions of density dependence. Indeed, communication from Eric Gerstung via Dr. Rob Titus revealed that he "didn't think Secret Ravine would support 600 Chinook spawners anymore because of continued habitat degradation, especially in the form of decomposed granite" (R. Titus, pers. comm. 2003). And lack of available spawning habitat is one of the precursors to superimposition (Bartholow 1996). It must also be noted that the average area of the stream widths in stretches downstream of each of the barriers in this analysis is $16m^2$. This is considerably smaller than the 25 square meters average that a Central Valley fall-run chinook female uses to build her redds.

Thus, as mentioned above, substrate quality, the average area needed to build a redd, the abundance of known and/or historic spawning sites between difficult-to-pass barriers and the number of adults attempting to spawn in given reaches were used to assess the probability of superimposition by females on Secret Ravine (**Section 3.4.6**). The stretch from the Confluence to Brace Road (Loomis Park Basin) has both high density of known and/or historic spawning sites, three difficult-to-pass barriers under low flows, and poor substrate (**Appendix J-1: Sediment**). Brace Road to King Road was assessed in this appendix to have 0% survival of eggs attributed to excessively fine sediment. Thus, only the stretch from King Road to Rock Springs Road can be considered free from the conditions necessary to generate superimposition, even though negligibly few fish attempt to spawn there (**Appendix M-1: Reduced Access**). The region from Rock Springs Road to the headwaters has not been utilized at all since the 1970s for spawning (B. Washburn, pers. comm. 2002), and the reach from King Road to Rock Springs Road was assessed no potential for superimposition. Thus, the likelihood for superimposition on Secret Ravine for the entire watershed was assessed as 75% for the whole watershed.

In the McNeil study, he determined that "mortality was caused for the most part by superimposition of redds". He determined that the estimated equivalent number of females able to spawn safely (i.e. without superimposing their redds), was consistently less than the number of females spawning, when the density of females was higher than 24 per 100 meters squared. While the fish are not nearly as dense in Secret Ravine by a factor of 1,000 (an equivalent density might be reached at 24 fish per 100,000 square meters or 25 acres), chinook salmon are on average larger and longer than the pink salmon McNeil observed, and would be expected to build comparably bigger redds by a factor of 10, which the chinook females also spend more time defending (Allen and Hassler 1986). These factors, together with others mentioned above in **Section 3.4.6**, including particularly poor substrate where the highest density of fish choose to spawn, enable us to estimate mortality associated with superimposition to be 33% (as determined by McNeil, 1964 for pink salmon) for both risk regions.

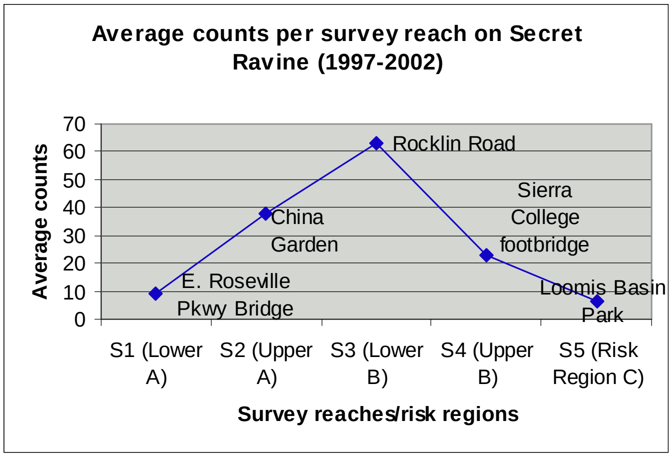


FIGURE 9.2 AVERAGE COUNTS PER SURVEY REACH ON SECRET RAVINE (1997-2002)

PE(egg) was also evaluated in terms of likelihood of blowout by beaver dams. Again, the number of adults not being able to pass was used and multiplied by beaver dams per region likely to be susceptible to high flows based on their size (threshold of three feet). This was multiplied by the number of females and the number of eggs expected to be killed during a blowout event (100%). Adult salmon live on average from 3-6 years and Chris Lee, who led a survey of habitat suitability for nearby Miners Ravine, with a similar extent of beaver dams, reported that beaver dams would probably be subject to blowout at 1or 2-year-storm events (Lee, pers. comm. 2003). Thus, 33% of the time, over the life-cycle of the fall-run we would expect the kind of high flows that cause blow out on Secret Ravine.

PE(juv) = NP | (% no pass juveniles)*P(pred)*P(low flow)*Mort(pred)

where:
NP = no pass via counts **NP |** connotes "given not having passed"
P(pred) = probability of predation by bass, given delay
P(low flow) = probability of low flows over one average life cycle
Mort(pred) = mortality to eggs due to predation

FIGURE 9.3 EQUATION FOR PERCENT EFFECT TO JUVENILES FROM REDUCED ACCESS (SDRM)

The risk to juveniles PE(juvenile) was evaluated in terms of the risk posed by predation during low flows, where bass are known to congregate in downstream pools below small dams as juvenile salmon spill over the dams (DCC 2001). Both Chris Lee of DWR and Rob Titus of CDFG estimated that juveniles would have no problems emigrating at high flows and that juveniles might become entrained behind some barriers at low flow, but that the presence of barriers of this magnitude would not exacerbate the numbers of juveniles that already emigrate relatively far into the spring season (Lee, pers. comm. 2003 and Titus, pers. comm 2003).

PE(adult) = P | (% pass adults)*M(energy)

where:
P = average percent adults, given that they pass **P |** connotes "having passed"
Mort(energy) = mortality to adults due to energy costs associated with barrier navigation

EQUATION 6 EQUATION FOR PERCENT EFFECT TO ADULTS AS CAUSED BY ENERGY COSTS (SDRM)

PE(adult) reflects energy costs associated with adult upstream migration in navigating particularly difficult to pass barriers, once passed. Although energy costs are associated with adult upstream migration against particularly hard to pass barriers, the total percent effect for adults PE(adult) was assessed to be zero in terms of direct pre-spawning mortality (i.e. they should have been able to reproduce).

9.1.7 Toxicity

In the SDRM, toxicity is still characterized by the measure of contaminants in a watershed as stated in **Section 3.4.7**. Toxicity tests were performed on samples from five sites in Secret Ravine. For the SDRM, mean mortality was calculated by averaging all the percent mortalities incurred to *Hyallela azteca*. This single numerical value represents the average mortality of the egg/yolk-sac fry stage in Secret Ravine. This value was calculated with the following equation:

$$\boxed{\frac{\text{Mean \% mortality} * \text{Length of Reach}}{\text{Total Length of Stream}}}$$

EQUATION 7 EQUATION FOR PERCENT EFFECT FOR TOXICITY (SDRM)

The percent mortality value was multiplied by the length of the reach where the sample was taken. This value was subsequently divided by the total length of the stream. This rendered a composite percent mortality number for the entire stream.

9.1.8 Metals

Metals were not analyzed separately for the SDRM. Since the toxicity tests conducted at UC Davis included the effects of metals in Secret Ravine, the percent mortalities for metals thus fell under the umbrella of toxicity in the SDRM.

9.1.9 Food Supply

To characterize percent mortality to juvenile salmon in Secret Ravine, three criteria were used: 1) percentage of edible invertebrates, 2) juvenile feeding habits, and 3) amount of riffle habitat available to invertebrates. These criteria are the same as those used for the MRRM (**Section 5.1.9**).

As mentioned in Section 5.1.9, there is little to no risk associated with the food supply in Secret Ravine. The percentage of edible invertebrates in the riffles of Secret Ravine is seemingly high (**Appendix J-9: Food Supply**). Juveniles are opportunistic feeders and capable of finding many sources of food (Fields, Jr., pers. comm. 2002). The amount and quality of riffles may be poor (Li and Fields, Jr. 1999), but there is still no indication that juveniles are limited by the amount of food in Secret Ravine. Therefore, percent mortality equals 0% for juveniles.

There are no associated percent mortalities for adults and the early life stages because they are not affected by food supply.

9.1.10 Predation

One can draw the conclusion that spotted bass could potentially predate on the juvenile chinook salmon from March through June. To investigate the predation of chinook salmon by spotted bass, an estimation of the biomass of black bass for Secret Ravine was evaluated on a projected population of juvenile chinook salmon (**Appendix J-10: Predation**). To do this a range of biomass consumptions by spotted bass was calculated and then compared to a projected population of juvenile chinook salmon for 2002. The analysis showed that spotted bass could reduce the chinook salmon population from 7% to 14%, given that salmonids comprise 1% of the spotted bass diet. The lower figure probably represents the better estimate due to the small size (26 g) of the bass in Secret Ravine and the cooler temperatures of the water during these months.

10 Results (SDRM)

10.1 Evaluating the Entire Watershed

10.1.1 Total Percent Effect for Stressors

Evaluating the influence of different sources and stressors over the entire watershed required the integration of data from Secret Ravine and information from the literature on chinook salmon. To represent these processes, a single value approximating the percent reduction in population for each stressor on a certain salmon life stage was determined. To bring these single values together in the context of the chinook salmon, the percent reductions per life stage were subtracted from one and then multiplied together. This value was subtracted again from one, rendering a total percent survival. (**Equation 2**). These percent reduction values allow the model to bring together disparate stressor effects on chinook salmon. The results of our analysis are summarized in **Table 10.1**. The construction of each of the entries in **Table 10.1** is discussed below our results. The results indicate that the cumulative impact of the nine identified stressors varies from life stage to life stage and varied between different stressors; the egg phase experienced the largest percent effect on population 92% and stressors related to sediment cause the largest total percent effect of 74%. The model approximates that the overall effect of stressors in Secret Ravine is 97%.

		Percent Effect			
		Egg	**Juvenile**	**Adult**	**Total**
Stressor	**Sediment**	67%	20%	0%	74%
	Flow	0%	27%	6%	31%
	Morphology	13%	16%	0%	27%
	Temperature	0%	0%	0%	0%
	Altered Riparian Vegetation	10%	10%	0%	19%
	Reduced Access	44%	0%	0%	44%
	Toxicity	43%	0%	na	43%
	Food Supply	na	0%	na	0%
	Predation	0%	11%	0%	11%
Percent Effect Per Life Stage		92%	60%	6%	97%

TABLE 10.1 TOTAL PERCENT EFFECTS PER LIFE STAGE PER STRESSOR

The three stressors with the largest magnitude TPE are sediment, reduced access, and toxicity with respective effects of 74%, 44% and 43%. The stressor with the next highest magnitude of effect is flow with 31%. Lower-ranking stressors were assessed lower percent effects due to either lack of effects that translated into direct mortality, or else could not be quantified in a manner equivalent to the other stressors. Thus, only the top three highest-scoring stressors will be addressed in this section, and in **Section 12.2**.

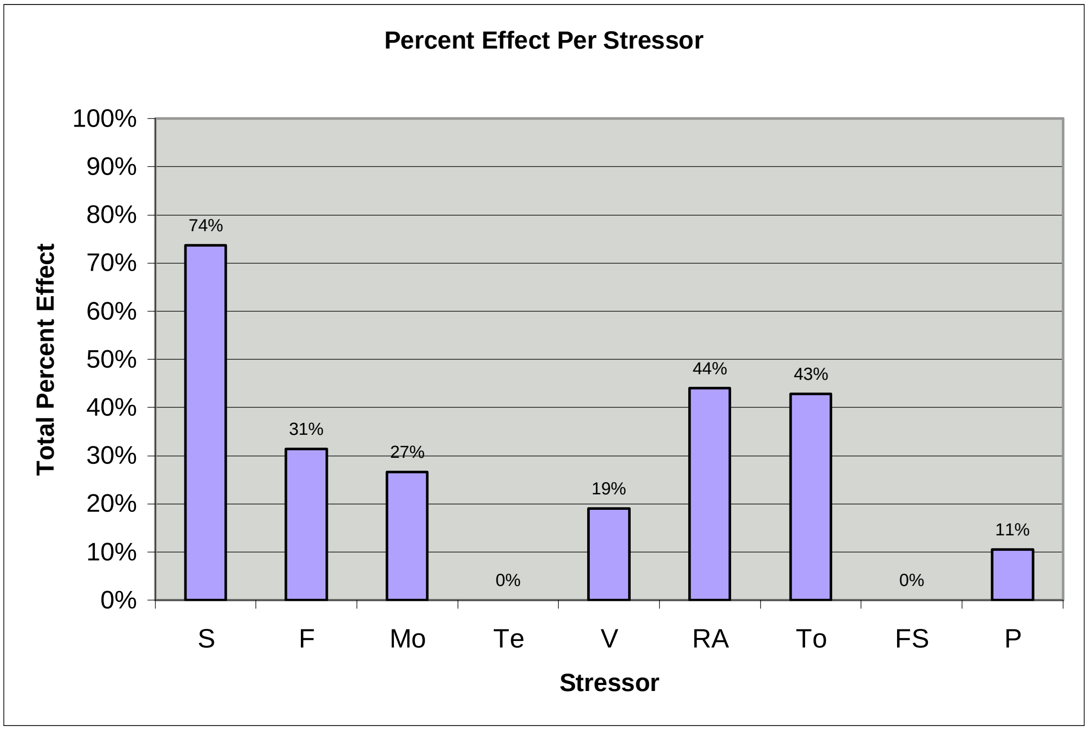


FIGURE 10.1 PERCENT EFFECT PER STRESSOR

Sediment

We used grain size distributions from ten sampling sites in Secret Ravine (**Appendix J-1: Sediment**) to calculate percent mortalities based on methods developed by Tappel and Bjornn 1983. Percent mortalities ranged from 100% to 26% with an average mortality of 67%. Thus, the mortality to the early life stages was estimated to be 67% (**Table 10.1**).

Turbidity data (DCC 2003, **Appendix J-1: Sediment**) was available over a three-year period (2000 to 2002). DCC water quality data indicated highly turbid flows during spring runoffs (approximately 1000 NTU during isolated events from February to May). This period corresponds to the peak period of residence for juveniles. Analysis based on Allen et al. 1996 estimated percent mortalities to juveniles on the order of 20% (Mortalities to the early life stages and adults were determined to be insignificant, although behavioral modifications could be occurring) (**Table 10.1**).

Reduced Access

Percent effect to egg caused by reduced access

PE(egg) = NP|(% no pass adults)*P(super)*% females*Mort(super)
NP| connotes "given not having passed"

superimposition - average high and low flow years						
	P(adults)	NP(adults)	P(super) whole watershed	Females	Egg mortality	**RS(egg)**
Confluence to China Garden Gauge	0.72	0.28	0.75	0.50	0.33	0.03
China Garden Gauge to Brace Road	0.11	0.89	0.75	0.50	0.33	0.11
						0.15

PE(egg) = NP|(% no pass adults)*P(blow)*P(high flow)*% females*Mort(blow)

blowout - high flows							
	P(adults)	NP(adults)	P(blow)	P(highflow) whole watershed	Females	Egg mortality	**RS(egg)**
Confluence to China Garden Road	0.72	0.28	0.50	0.30	0.50	1.00	0.07
China Garden Road to Brace Road	0.11	0.89	0.50	0.30	0.50	1.00	0.22
							0.29

total risk assessed to egg: **.44**

Percent effect to juvenile caused by reduced access

PE(juv)= P|(%pass juveniles)*P(predation)*(Predation rate)

total risk assessed to juvenile: **0**

Percent effect to adult caused by reduced access

PE(adult)= P|(% pass adult)*P(mortality due to energy costs)*Height of dam navigated

total risk assessed to adult: **0**

Total percent effect due to Reduced Access: 44%

FIGURE 10.2 EFFECTS ANALYSIS FOR REDUCED ACCESS

The region from Rocklin Road to the Loomis Park basin had an average of 89% adults not passing through to the next region (**Appendix M-1: Reduced Access**). The presence of many impassable barriers (three even in high flow), together with the small width of the stream and redds biology alluded to above and the poor substrate quality (**Appendix J-1: Sediment**), made the likelihood of estimated superimposition in this region extremely high and contributed to the high overall risk assessed to this secondary stressor. Likewise, half of the beaver dams in this stretch had heights above three feet, thus having the potential to contribute highly to blowout during high flows. Nevertheless, the high density of beaver dams, together with the high density of known and historic spawning sites from the Confluence region (most downstream region), also adds 10% mortality as caused by reduced access.

As with the MRRM, reduced access data was only available for the lower reaches of Secret Ravine. However, less than 4% of fish surveyed passed on average (1997-2002) north of Loomis Park. And these areas also have relatively adverse substrate quality (4s, **Appendix J-1: Sediment**). Therefore, barriers upstream of King Road, other than incident woody debris and large boulders, should have negligible impact on mortality to the fish population for all life stages.

Toxicity

Tests revealed that toxicity is present in the benthos at every sample site in Secret Ravine. These sites were strategically placed throughout Secret Ravine, so we can extrapolate that the entire creek is affected by toxicity in the benthos. Percent mortality was 38.9% for toxicity (**Equation 7**). Toxicity tests were negative for the water column. Due to this, the only life stage vulnerable to the effect of toxicity is the egg/yolk-sac fry stage. Percent mortalities for toxicity pertain only to this life stage.

10.1.2 Total Percent Effects and Sources

		Stressor									
		S	**F**	**M**	**Te**	**V**	**RA**	**To**	**Me**	**FS**	**P**
Source	**LM**	L	L	L	L	H	0	H	0	H	0
	IS	H	H	M	H	L	0	H	H	H	0
	CH	M	M	H	H	M	0	0	0	L	0
	OHV	H	L	H	M	H	0	L	0	H	0
	CD	M	M	L	M	H	H	0	M	L	0
	WTP	L	M	L	H	L	0	H	0	M	0
	MI	M	L	H	L	M	0	0	H	M	0
	OR	L	L	L	L	M	0	M	0	M	0
	IF	0	0	0	L	0	0	0	0	0	H
	DG	M	L	M	M	L	0	0	0	L	0
	IR	M	M	M	H	H	0	0	0	L	0
	BD	L	L	M	H	L	H	0	0	L	L

TABLE 10.2 RELATIVE CONTRIBUTION OF SOURCES TO STRESSORS

The source analysis for the SDRM centered on the three stressors with the highest percent effect values: sediment, reduced access and toxicity. The sources of these stressors were evaluated using both quantitative and qualitative measures. **Table 10.1.2** reports the connections between sources and stressors depicted on the conceptual model. For each of these connections the contribution per source to a particular stressor was described in three ways: H indicates a high contribution to the stressor seen in Secret Ravine, M designates a medium contribution to the stressor, L denotes a low contribution to the stressor effect, and 0 means no connection exists on the conceptual model between the source and the stressor. The contribution factor can be visualized by considering 1 acre of one category non-point source and comparing it to 1 acre of another category. For example for sediment the contribution from an acre of landscape maintenance and an acre of impervious surface would be qualitatively compared to evaluate which source would be expected to contribute more to the percent effect value. Also point sources were considered through a similar process. Each frequency of a point source was considered against other frequencies of point sources in the watershed. Once these two categories were determined, a qualitative analysis of how a high contribution point source is equivalent to a high contribution non-point source was conducted. Once this contribution factor has been determined, the extent or frequency of the source in the watershed as a whole was considered. Then the sources were space discussed in the context of what the contribution factor and the extent of the sources were in the watershed.

Sediment:
The sediment stressor had a high source contribution from impervious surfaces and OHVs. The medium contributing sources were channelization, construction and development, mining, dirt and gravel roads, and irrigation. The low contribution stressors were landscape maintenance, water treatment plants, orchards, and beaver dams.

Reduced Access:
This stressor had two high-contribution sources: construction/development and beaver dams.

Toxicity:
The high contribution sources for toxicity include landscape maintenance, impervious surface, water treatment plants, and orchards. The low contribution source was OHVs.

10.1.3 Percent Effect and Life Stage

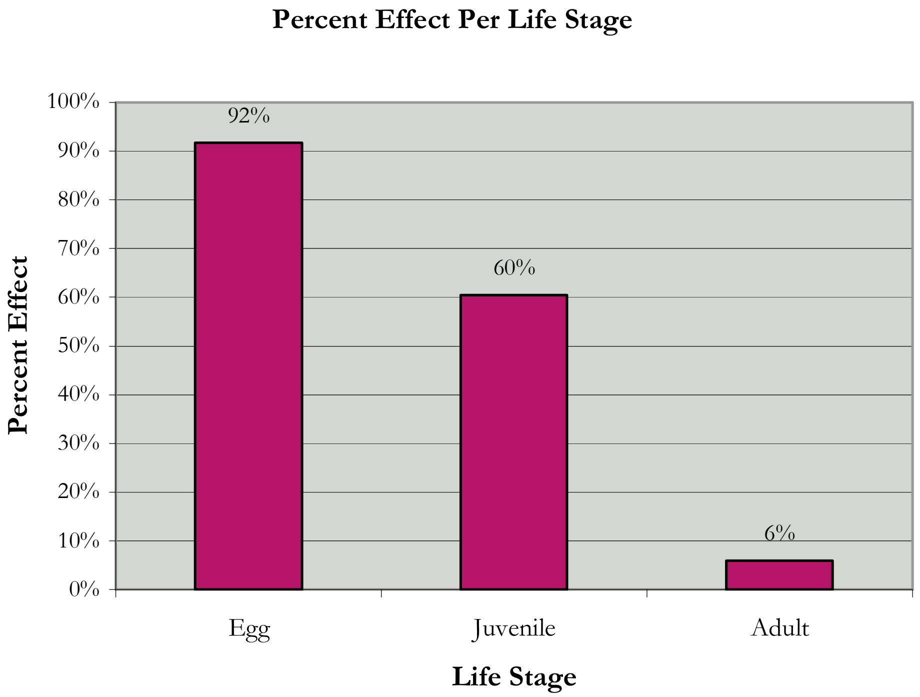


FIGURE 10.3 PERCENT EFFECT PER LIFE STAGE

The life stage with the highest percent effect was the egg phase with a percent effect of 92%. After the initial reduction in population of 92% the juvenile phase experienced a reduction of 60%, and from that surviving population, the adult phase salmon population had a simulated reduction of 6%. Integrating these effects over the three life stages, multiplying these percent reduction values together after subtracting from one for each effect, and then subtracting the resulting percent reduction from 1 again, gives a total percent reduction of approximately 97%.

11 Uncertainty (SDRM)

Uncertainty was analyzed in the SDRM for the three stressors that had the highest associated percent effect. Sediment, toxicity, and reduced access had their uncertainty calculated, each according to the respective effect of the stressor.

Sediment
We collected data from a total of ten sampling sites in order to calculate the average mortality of eggs (67%) throughout Secret Ravine due to sediments in the streambed (benthos). The standard deviation of this data was 30.7%. This yielded a standard error

of 9.8 percentage points. Thus, we are 95% confident that the mortality values for sediment (for the eggs) ranges from 47.6% to 86.7%. This large range of values implies that the data are fairly uncertain since these sampling sites were chosen based on the assumption that they were frequently used and/or historic spawning sites.

Reduced Access

Only one component (secondary effect expressed in terms of percent mortality) was quantitatively examined for reduced access in the SDRM, namely, estimated egg mortality associated with superimposition of redds. However, there is high uncertainty associated with this value, because while estimates were based on overall percent of redds superimposed (33%) for chinook salmon (Fukushima et al. 1997), while the 33% figure for mortality to the eggs themsevles was based on a study of pink salmon, which are smaller and construct much smaller redds. We have fairly high confidence in the percent mortality attributed to reduced access in terms of predation, based on the size of the fish, known flow, and the fact that predation rates were adjudged to be low in this system to begin with (**Section 3.4.10**). Although we have low confidence in the actual percent mortalities associated with the four secondary stressors, we have high confidence in their probability of occurring, as well as the life stages they effect - as well as the extent to which they affect the life stages proportionally. Therefore, there is fairly high uncertainty associated with Reduced Access as characterized by the SDRM.

Toxicity

Uncertainty was calculated in terms of percent mortality with the following formula:

$$SE = \text{sq. rt.}\ (\Sigma_i\ S_i^1)$$

i = risk region

S_i = standard error reported for region i

W_i = length of reach i / length of stream

$$S_i^1 = W_i^2 * S_i^2$$

EQUATION 8 CALCULATING UNCERTAINTY FOR TOXICITY

An uncertainty value represented by the standard error was calculated using the associated reach lengths and percent mortality for each risk region in Secret Ravine. The input used for this calculation was:

Risk Region	% Standard Error (S_i)	Reach Length (ft)	W_i	S_i^1
A	17	13152	.2673	20.63
B	18	18872	.3835	47.65
C	25	5995	.1218	9.27
D	21	9009	.1831	14.78
E	17	2171	.0441	0.56

TABLE 11.1 CRITERIA FOR ASSESSING UNCERTAINTY ASSOCIATED WITH TOXICITY

The SDRM percent mortality output for toxicity was 38.39% across the watershed. In terms of standard error, the uncertainty is 9.638%. The SDRM model thus has high uncertainty associated with toxicity.

There is high uncertainty associated with the analyses of sediment and toxicity for the SDRM - which could be assessed quantitatively - due to the high use of data extrapolation from other fish on other systems. There is also fairly high uncertainty associated with reduced access because data was for the most part extrapolated and criteria were evaluated in a completely qualitative manner. All three suffer from lack of a complete data set.

12 Discussion and Recommendations

12.1 Discussion of MRRM

12.1.1 Risk Regions

One goal of the MRRM is to determine the total risk associated with each risk region. This Total Risk Score encompasses every source and stressor present in the risk region, along with habitat and exposure. As seen in **Figure 6.4**, Risk Region A has the highest Total Risk Score, followed by B, then C, E, and D (Error! Reference source not found.).

Risk Region	Total Risk Score
A	7308
B	5376
C	3032
D	1840
E	2008

TABLE 12.1 TOTAL RISK SCORE PER RISK REGION

Several factors contributed to making Risk Region A the highest in Total Risk Score. Firstly, nine of the twelve sources were represented (**Figure 6.6**). Beaver dams scored the highest risk in this region, followed by OHVs, then channelization. Not only were these sources the highest scores in Risk Region A, they were also the highest scores of any source for a risk region in the entire watershed (**Table 12.2**). Consequently, they contributed a very large amount of risk to Risk Region A.

Construction and development ranked fourth, with a score similar to the highest source scores from Risk Region B and C (**Table 12.2)**. These sources are not surprising given the large amount of urbanization occurring in this section of the creek, and correctly reflect this area.

Secondly, all the stressors were represented in Risk Region A (**Figure 6.5**). Flow in the water column scored the highest risk in this region, followed by morphology in both the water column and the benthos. Not only were these stressors the highest scores in Risk Region A, they were also the highest scores of any stressor in the entire watershed (Error! Reference source not found.).

Top 10 Source Scores in Secret Ravine

Source	Risk Score	Risk Region
Beaver Dams	1404	A
Off Highway Vehicles	1332	A
Channelization	1260	A
Dirt and Gravel Roads	1116	B
Impervious Surfaces	1056	C
Construction & Development	1032	A
Beaver Dams	960	B
Impervious Surfaces	912	A
Channelization	840	B
Landscape Maintenance	720	C

TABLE 12.2 TOP 10 SOURCE SCORES IN SECRET RAVINE

Thirdly, the Risk Region A habitat was ranked as six, meaning it had the longest stream length. This is important when you consider two risk regions with the same exact scores for stressor, source and exposure. If these components are the same in two risk regions, the risk region with the higher habitat rank will get the higher Total Risk Score. This may not accurately reflect what is occurring in the two regions. A longer stream length does not necessarily mean a higher risk.

Yet it is not surprising that Risk Region A scored the highest. It is at the bottom of the creek, which means it captures all risk that enters the creek from above. Also, it is characterized the best because data was available for most stressors. Consequently, the Total Risk Score of this region is as accurate as possible with the MRRM.

Risk Region B had the second highest Total Risk Score (Error! Reference source not found.).

Nine of the twelve sources were represented. Dirt and gravel roads scored the highest risk, followed by beaver dams, and then channelization. All of the stressors were also represented. Flow in the water column contributed the highest risk, followed by sediment in the water column. Flow in the benthos followed, and had the same risk score as altered vegetation from Risk Region A (the fifth score in Risk Region A). Similar to Risk Region A, Risk Region B has a large amount of risk associated with it given its placement in the creek. Risk Region B also had a large amount of data associated with it, making this Total Risk Score as accurate as possible with the MRRM.

Top 10 Stressor Scores in Secret Ravine

Stressor		Risk Score	Risk Region
Flow	WC	972	A
Morphology	WC	900	A
Morphology	BE	900	A
Flow	WC	792	B
Sediment	WC	720	B
Flow	BE	648	A
Flow	BE	528	B
Altered Vegetation	WC	528	A
Altered Vegetation	BE	528	A
Sediment	BE	480	B

TABLE 12.3 TOP 10 STRESSOR SCORES IN SECRET RAVINE

Risk Region C had the third highest Total Risk Score (Error! Reference source not found.). Nine of the twelve sources were represented. Impervious surfaces scored the highest risk, which was 1.5 times larger than the second highest scoring source, landscape maintenance. Mining scored third. Nine of the ten stressors were represented. Flow in the water column and the benthos contributed the most risk, followed by morphology in the water column and the benthos, then sediment in the benthos.

Interestingly, even though the top three sources contribute largely to metals (effect rank=6) and toxicity risk (effect rank=4), these stressors scored 4th and 6th in risk score respectively. This possibly indicates a flaw in the MRRM design, because toxicity and metals data suggest a higher risk associated with these stressors.

Risk Region E had the fourth highest Total Risk Score (Error! Reference source not found.). Seven of the twelve sources were represented. Water treatment plants scored the highest risk. Dirt and gravel roads, impervious surfaces, and orchards followed, each very close to the other. Eight of the ten stressors were represented. Flow in the water column contributed the most risk, followed by morphology in the water column and the benthos, then by toxicity in the benthos. Although water treatment plants scored the highest risk, this result is questionable. It is possible for the water treatment plants to contribute toxicity and flow to Secret Ravine, but the magnitude of these inputs was small in the past, and cannot be captured accurately by the MRRM. Data for this region is the scarcest. Results in this region are based on many assumptions and extrapolations, therefore risk characterization is not as precise as the other risk regions.

Risk Region D has the lowest associated risk; four times less than Risk Region A (Error! Reference source not found.). In this risk region seven of the twelve sources were represented. Irrigation scored the highest risk, followed by mining and impervious surfaces. Nine of the eleven stressors were represented. Once again flow in the water column and morphology contributed the highest risk, but at approximately three and four times less than they did in Risk Region A. Again, results in this region are based on many assumptions and extrapolations, therefore risk characterization is not as precise as the other risk regions.

12.1.2 Stressors

Looking at both habitats (water column and the benthos), flow was the overall highest-ranking stressor from the MRRM (4524 cumulative risk score). Morphology followed with a cumulative risk score of 4128 and sediment thereafter with a score of 2808.

Sediment

Sediment was the third-highest scoring stressor overall (2808 cumulative risk score for both habitats). Effects on the benthos were higher (1488 cumulative risk score) than those in the water column (1320 cumulative risk score). Thus, impacts to the early life stages are greater than those to juveniles and adults.

Impacts in the water column were assessed via turbidity. The results indicated approximately 20% mortality to juveniles during spring flow events. Mortality from turbidity rarely occurs (Allen et al. 1996), so our estimate of mortality is a worst-case scenario that contained many assumptions about duration of exposure and actual suspended sediment concentrations. Effects such as behavioral or physiological changes, however, can be common even under lower turbidity values. Thus, the impact to juveniles via turbidity is a risk that needs to be assessed in more detail through a more rigorous sampling routine (variable duration sampling and a turbidity to suspended sediment rating curve).

Impacts of sediment in the benthos were assessed via grain size distribution analysis (E. Ayres, J. Love, and K. Vodopals 2002) and mortality estimation (Tappel and Bjornn 1983). Average mortality throughout the three risk regions sampled was approximately 70%. This value is roughly equivalent to numerous research values of average mortality rates in chinook redds (Kondolf 2000).

This is not to say, however, that overall mortalities to the early life stage due to sediment are not significant. The areas that we sampled in Secret Ravine represented a majority of the most heavily-utilized spawning habitat (Bates, pers. comm., 2002). Geographically, this area runs from the lowest point in the watershed (the confluence) up to roughly Rocklin Road, which represents approximately one-fifth of the total watershed by area. Thus, mortalities associated with the remaining habitat in Secret Ravine are unknown and are likely to be high since the area we sampled was prime spawning habitat.

Risk Region B scored the highest risk scores for sediment (720 in the water column and 480 in the benthos). The high water column risk score is due to high turbidity values on March 23, 2002 (roughly 5000 NTU). This was an event-based sample and was conducted at the request of a homeowner (DCC 2002).

Direct sources of increased sediment include impervious surfaces, channelization, OHVs, construction and development and dirt and gravel roads. All of these sources (except dirt and gravel roads) are present in Risk Region A (**Section 6.2.1.2**). Of those mentioned, OHVs had the highest risk score in Risk Region A. Efforts to curb OHV usage of the watershed in Risk Region A (near Sutter Hospital) have not been successful (Bates, pers. comm., 2002). Numerous areas were observed within this risk region where severe bank erosion and streambed disturbance were the result of OHV usage.

Sensitivity calculations for sediment indicated a high degree of uncertainty for risk scores in the water column and low uncertainty for risk scores in the benthos. The lower confidence limit for sediment was a risk score of 912 in the water column. Thus, turbidity could theoretically be ranked below temperature, altered riparian vegetation, toxicity, and metals. Uncertainties associated with sediment in the benthos were relatively less than other stressors (due to more robust data) and resulted in no variations in risk scores.

Flow

The impacts from flow were higher in the water column (2760 cumulative risk score in the water column versus 1764 in the benthos). This can be attributed to the original ranking of flow. In the water column, flow received a ranking (**Section 5.1.2.2**) of six for all risk regions based on the determination that scour is most likely occurring at flow depths below the tolerance depths associated with adult migration and juvenile rearing. As stated earlier, scour is the movement of the sediment in the streambed caused by peak flows. Thus, these results indicate that the risk of scour is greater during periods of adult migration (September to December) and juvenile rearing (February to May). Actual impacts to all life stages, however, cannot be determined without actual flow data.

Risks from flow in the benthos can be interpreted as the risk of scour affecting the early life stages (eggs and yolk-sac fry). The risk in the benthos, due to flow, was determined to be less than that in the water column. Risk in the benthos, however, is probably underestimated due to the duration of the early life stages occupying the benthos and the small size of the eggs and yolk-sac fry.

Overall, impacts from flow via scour are very high due to the dominance of fine grain sediments in Secret Ravine. Actual changes to the flow regime could not be assessed due to the lack of robust flow data. Based on numerous observations (Swanson 2000, Washburn and Webber 2003), however, it is apparent that many sections within Secret Ravine are undergoing substantial bank erosion and entrenchment of the channel, which is most likely due to alterations of the flow regime via higher peak flows and flashier floods.

Risk Region A had the highest risk score for flow (1620 total risk score for the benthos and water column combined) compared with the other risk regions. In general, discharge (total volume of flow per unit time) increases downstream (Ritter et al. 2002). Thus, the high risk score for flow in Risk Region A (the risk region furthest downstream) is in agreement with general flow processes.

Sources that contribute to changes in flow include impervious surfaces, channelization, construction and development, water treatment plants, dirt and gravel roads, irrigation canals and beaver dams (**Appendix E: The Conceptual Model**). The three highest-ranking sources in Risk Region A were beaver dams, OHVs and channelization, all of which are direct sources of flow alterations (**Section 6.1.2 Cumulative Source Risk Scores**). In general, however, impervious surfaces are the largest contributor to flow based on absolute area and have been implicated as the one of the main sources of stress to Secret Ravine via increasing pressure from urbanization (Swanson 2000, Li and Fields, Jr. 1999).

Sensitivity analysis calculations (**Section 7.4 Monte Carlo Analysis**) indicated that risk scores for flow could range from a minimum of 1536 to a maximum of 3216. This wide distribution indicates a high degree of uncertainty associated with the flow risk scores, which is expected due to the lack of detailed flow data. A risk score at the lower end in comparison with the minimum confidence limits of other stressors would result in flow being placed below temperature and metals. Thus, it could be the case that temperature and metals are more of a risk than flow.

Morphology

Morphology was the next highest-ranking stressor (4128 cumulative risk score). It was assumed that impacts from alterations to morphology would affect all life stages, thus cumulative risk scores were equal in both habitats (1944 cumulative risk score).

Criteria for ranking morphology were based on percent pools by length (PBL) and percent canopy cover (**Section 5.3.1.2 Assigning Effects Ranks**). In general, both the percentage of pools and percent canopy cover were below the threshold values. Average PBL was approximately three to ten percent below the ideal value of 30%. As stated earlier, this ideal canopy cover percentage is most likely an overestimate of ideal conditions for the Secret Ravine as it is based on forested, coastal watersheds in Northern California.

Risk Region A also had the highest risk scores for morphology (936 for both the water column and the benthos). Direct sources of alterations to morphology include landscape maintenance, channelization, OHVs, construction and development, and beaver dams. In Risk Region A, the beaver dams had the highest source risk score followed by OHVs and channelization.

Sensitivity analysis calculations for morphology also showed a wide distribution in risk scores, thus indicating a large amount of uncertainty in the final risk scores (**Section 7.4**). The lower confidence limit was at 1632 and the upper at 2736. At the lower limit, morphology would be ranked lower than temperature and metals.

12.1.3 Sources

The cumulative risk scores for each source reflect a couple of trends related to the organization of the model and the source analysis itself. The cumulative risk scores for the sources varied from 3,104 for impervious surface (IS) to 372 for water treatment plants (WTP) (**Table 12.4**). The trends in the data include the effect of the number of stressors caused by the sources in Secret Ravine, the nature of the interaction, either direct or indirect, and the location of that interaction that the source caused stress.

		Risk Regions					
		A	B	C	D	E	Totals
Source	IS	912	528	1,056	288	320	3,104
	BD	1,404	960	0	0	0	2,364
	CH	1,260	840	0	0	0	2,100
	MI	336	648	464	416	208	2,072
	DG	0	1,116	264	216	324	1,920
	LM	348	360	720	200	232	1,860
	OHV	1,332	468	0	0	0	1,800
	IR	396	360	280	480	240	1,756
	CD	1,032	0	0	0	0	1,032
	OR	0	0	216	176	312	704
	IF	288	96	32	64	0	480
	WTP	0	0	0	0	372	372
Totals		7,308	5,376	3,032	1,840	2,008	19,564

Table 12.4 Risk Scores and Totals for Sources in Each Risk Region

The sources that cause eight stressors, impervious surface (IS) and beaver dams (BD), received the two highest risk score. The propagation of equations related to source, in this case, may increase the likelihood that a source will be given a higher risk score. A new equation is generated in the MRRM whenever the source and stressor is present in the same risk region and the habitat pathway, through the water column and the benthos, exists to the endpoint (**Equation 1**, **Figure 12.1**). For example, impervious surfaces, with a total of 65 individual equations, had a cumulative risk score of 3,104 (**Equation 9**). The average non-zero equation in the MRRM model had a risk score of 46 risk points, so sources that had higher numbers of source-stressor interactions in many different risk regions generally had higher risk scores (**Table 12.4**). Ecologically, this reflects the complexity of the chinook salmon ecosystem. Often sources have many different and spatially diffuse effects that could be a risk for the salmon. However, the propagation of equations can lead to a process where a source with more conceptual connections may be evaluated as a higher risk regardless of the actual rank of the source.

Equation 1: Basic Risk Score Equation: The total RSsource comes from the additive sum of equations generated for stressor-source association and per risk region where these interactions occur.

RSsource = (Source Rank)* (Habitat Rank)* (Effects Rank)* (Exposure 1 filter) * (Exposure 2 filter)

Figure 12.1 Total Risk Score Equation for Modified Relative Risk Model

		Risk Score Totals (from highest to lowest risk score)	Stressors Caused by Sources	Indirect Sources (all .5 equations)	Risk Regions	Number of Equations
Source	IS	3,104	8	30	A, B, C, D, E	65
	BD	2,364	8	18	A, B,	28
	CH	2,100	6	40	A, B,	22
	MI	2,072	7	10	A, B, C, D, E	60
	DG	1,920	6	55	B, C, D, E	44
	LM	1,860	7	28	A, B, C, D, E	60
	OHV	1,800	7	8	A, B,	24
	IR	1,756	6	35	A, B, C, D, E	55
	CD	1,032	7	3	A,	12
	OR	704	7	33	C, D, E,	36
	IF	480	1	0	A, B, C, D,	8
	WTP	372	7	8	E	12

TABLE 12.5 INFLUENCES ON THE OUTCOME OF RISK SCORES

$$\boxed{\begin{aligned} NumberofEquations &= ((8*2)-3)*5 \\ NumberofEquations &= 65 \end{aligned}}$$

EQUATION 9 NUMBER OF IMPERVIOUS SURFACE EQUATIONS IN THE CUMULATIVE RISK SCORE

Number of Stressor/ Source Interactions = 8	Se, F, M, Te, V, RA, To, Me, FS, P
Number of Habitats = 2	water column and benthos
Minus number of Exp2 equaling zero = 3	where stressor does not effect endpoint
Number of Risk Regions with source = 5	all five Risk Regions A, B, C, D, E

Also, the counter positive can be true. If a source has only a few equations associated with its risk, then the total risk score may be low. Several examples of this were Introduced Fish (IF) and Water Treatment Plants (WTP) that respectively have 12 and 8 equations associated with their risk scores; these two sources have the lowest risk scores of the 10 sources in the analysis.

The exposure filter 2 described the presence of the endpoint in a habitat where a source could generate a stressor. Exposure 2 could have one of three values 0, 1, or .5: 0 denotes no interaction the 1 expressed a connection between a stressor and source, and the .5 represented an indirect effect. The source analysis included a total 426 different equations; of these equations 268 or 63% were determined to be indirect. An indirect source was defined as any source that generated a stressor via another stressor or related to a source that was originally emitted many years prior to this analysis. The modeling of legacy sources, for the most part, contained an indirect exposure filter. In the case of mining (MI) as a source, the indirect exposures moderated the effect of the number of equations (60 equations) associated with the source. The 12 indirect filters associated with mining reduced the cumulative risk score by approximately 1,600 risk points and moved mining from the source with the second largest risk score to the source with the fourth largest risk (**Table 12.6**).

Analysis without Indirect Sources	
	Risk Score Totals
LM	4,040
MI	3,688
BD	3,360
LM	3,032
DG	2,680
CH	2,592
IR	2,360
OHV	2,232
OR	1,288
CD	1,152
WTP	552
IF	480
	27,456

TABLE 12.6 ANALYSIS WITHOUT INDIRECT SOURCES

The other category of indirect sources contributed to stressors through a series of intermediate processes; an example of this type of source was landscape maintenance (LM). The production of this source occurs today when water is used to maintain a garden or lawn. In this case, the landscape maintenance source can induce changes in sediment, flow, and morphology, though secondary processes remote from the actual practice of watering a lawn.

The designation of landscape maintenance as an indirect source decreases the risk score by 1,200 risk points and drops the relative position of landscape maintenance from the source with the fourth largest risk score to the sixth largest risk score (Error! Reference source not found. and Error! Reference source not found.). The indirect source designation allows some differentiation of legacy and sources acting through a series of processes. However the arbitrary halving of source risk source may not reflect the actual natural attenuation of legacy sources and the actual influence of sources working though a series of intermediate processes.

The location of the interactions between source and stressor also played a part in the risk score associated with the source. The habitat rank in each risk region hold sway over the total risk score seen in the model. The habitat rank for each region came from the relative assessment of the length of the stream in each region.

Analysis with Indirect Sources	
	Risk Score Totals
IS	3,104
BD	2,364
CH	2,100
MI	2,072
DG	1,920
LM	1,860
OHV	1,800
IR	1,756
CD	1,032
OR	704
IF	480
WTP	372
	19,564

TABLE 12.7 ANALYSIS WITH INDIRECT SOURCES

For this reason the lower regions, Risk Regions A and B both received a habitat ranking of 6 due to the fact that these risk regions encompass the largest portion of Secret Ravine. However for each equation associated with a source a habitat rank value is part of the multiplicative (**Equation 1**). Therefore a rank of risk for Risk Region A or B, with a habitat rank of 6, generates 3 times the risk associated with Risk Regions E, with the same habitat rank.

	Stressors Caused by Source	Indirect Filters (all .5 filters)	Total Risk Score	Total Risk with No Indirect Effect
Construction & Development CD)	7	4	1,032	1,152
Water Treatment Plants (WTP)	7	8	372	552

TABLE 12.8 COMPARISON OF CONSTRUCTION & DEVELOPMENT AND WATER TREATMENT PLANT

An example of how location effect creates larger risk scores can be seen when comparing construction and development (CD) and water treatment plants (WTP) **Table 12.8**). For both these sources, the source only effects one risk region and the number of equations that generates the risk score is 12 (**Table 12.5**). The difference between these two sources come from the number of indirect filters (four indirect filters for construction and development and eight indirect filters for water treatment plants), the risk regions ranked (A and E) and ranking of the sources effect (construction and development effect Risk Region A with a lower rank of 4 than water treatment plants with a source rank of 6). To investigate the effect of only the location of the source ranking, one can pull the risk scores from the Table Analysis without Indirect Effects (Error! Reference source not found.); this table reports the risk scores that would be expected if the no indirect filter existed. In this case, CD received a risk score of 1,152 and the risk evaluated for WTP was 552. So even though water treatment plants received a higher rank of 6 the risk associated with water treatment plants was less than half the risk associated with construction and development with a rank of 4. This suggests that a strong location effect exists. Sources such as beaver dams (RS=2,364) and channelization (RS=2,100), the second and third ranked source may exhibit this effect. Both of these sources have six source-stressor relationships in the model, suggesting that they should fall lower on the risk score list. However, beaver dams and channelization both have high ranks for both Risk Region A and B, which compensates for the lower number of source-stressor association and any indirect filters associated with the sources. This location effect could be interpreted so that the habitat value of a larger portion of stream should be assigned a higher rank due to the larger capacity of the stream to support salmon.

In this case, the argument is made that a higher potential for risk exists for larger habitat. However, if the same amount of source moves into a smaller section of stream it would be expected to increase the risk to the fish in the stream due to the increase in source intensity.

Some fine grain differences do present themselves in the source results. In general, sources that are present in all five risk regions have a higher risk score and those sources with more than one rank of 6 or 4 tend to have higher risk scores. But the assignment of ranks tends to be less influential than the trends mentioned previously. Indeed the only source with two ranks of 6, dirt and gravel roads falls fifth on the list of total risk score. In consequence, these three general trends, larger number of equation equals a larger risk score, indirect versus direct exposure filters, and downstream effects in Risk Region A and B, influence the source analysis.

To collaborate the observation of these trends in the source data a regression analysis compared the three factors, larger number of equation equals a larger risk score, indirect versus direct exposure filters, and location effects in Risk Region A and B, influence the source analysis, with the total risk score. The regression analysis found that all three trends significant and returned an R-squared value of .767 (adjusted R squared of .604). These results suggest that the three trends may be a significant influence on the total source risk score and that much of the source risk score variability can be explained by the structure of the model.

Regression Variable	**Description**	**P-Value**
Total Number of Equations in the Risk Score	(# of source-stressor interactions equations)	0.002
'Location Effect	(# of equations with 4 or 6 in Risk Region A or B)	0.022
Indirect sources	(# of equations including an indirect source)	0.051

TABLE 12.9 REGRESSION ANALYSIS RESULTS FOR SOURCE

12.1.4 Habitat

The highest risk score was generated for the water column habitat at 9,880 risk points, while the benthos habitat scored 9,684 points. The similar magnitudes of these two values suggest that risk on Secret Ravine is disseminated approximately equally between the two habitats. The slightly larger value of the water column habitat may mean that this habitat could be slightly more at risk. However the difference of only 196 risk points may reflect no appreciable difference in risk between the two habitats. Implicate in this risk score, the risk to the egg phase habitat (benthos) and the juvenile/adult phase habitat (water column) appear to be approximately equal in magnitude. The assessment of the benthos and water column as having approximately equal risk seems counterintuitive due to the several distinctions in the way stressors effect different chinook salmon life stages. Possible overriding factors such as the source analysis, the ranking of habitat, and the interaction of stressors and sources may have overwhelmed the mathematical distinctions made to reflect different stressor effects per salmon habitat or there could simply be the same risk to egg phase habitat and juvenile/adult habitat.

Habitat	**Total Risk Score**
Water Column	9,880
Benthos	9,684

TABLE 12.10 TOTAL RISK SCORE FOR HABITAT

	Risk Region	A	B	C	D	E
Habitat	**Water Column**	6	6	4	4	2
	Benthos	6	6	4	4	2

TABLE 12.11 HABITAT RANKS FOR WATER COLUMN AND BENTHOS PER RISK REGION

12.2 Discussion of Stressor-Driven Risk Model (SDRM)

12.2.1 Top Three Stressors (SDRM)

Sediment

Overall, the highest mortalities estimated were due to sediment. 67% mortality was estimated for the early life stages and 20% for the juvenile life stage. Twelve sites total were sampled with ten of those being frequently-used spawning areas (Bates, pers. comm., 2002). Percent mortalities ranged from a minimum of 30% to a maximum of 100%. Numerous laboratory and field experiments indicate, however, an average survival rate of approximately 30% (mortality, therefore, equals 70%) in a typical chinook redd (Kondolf 2000). Thus, the average mortality in the redds sampled in Secret Ravine is approximately the same as the average mortality in other studied redds. As mentioned earlier, however (**Section 12.1.2**), overall mortality throughout the watershed is probably much higher due to the dominance of fine grain sand

As stated in the MRRM results, risks from turbidity were highest during spring flows but more robust sampling routines need to be developed to obtain more accurate estimates of mortality or behavioral modifications.

Numerous observations have been made (Swanson 2000, Li and Fields, Jr. 1999, Montgomery 1992) implicating fine sediments as the main cause of stress to the Secret Ravine watershed. Our data indicates that the most heavily utilized spawning areas have mortalities roughly similar to other researched redds. Other sites that we sampled had much higher mortalities (usually 90% and above). Thus, given that the poorer sites represent the majority of the potential spawning sites, it is evident that there is a deficiency in the overall abundance of prime spawning and rearing habitats.

Reduced Access

Reduced access was the second highest ranked stressor in the SDRM, with almost 50% mortality across life stages attributed to it. Although reduced access is directly an issue for adults in terms of upstream migration, eggs are subject to the consequences if adults are prevented from swimming as far upstream as it takes them to find suitable spawning habitat. Although each of the secondary effects explored in this analysis are hypothetical, there is strong evidence that each occurs. Blowout is seen yearly, and it contributed the highest impact relative to the other secondary stressors (29%). Superimposition of redds (15%), although not directly observed - or even investigated - on our system, is practically inevitable given how coveted downstream spawning sites are and how limited good substrate is in these areas and given literature that supports this. We have confidence in the suitability of the other two secondary stressors and their lack of apparent adverse effects to the creek.

Toxicity

Toxicity ranked as the third most highly ranked stressor in the SDRM. Total percent effect of toxicity was 43% in Secret Ravine. Although toxicity can theoretically harm all life stages of Chinook, it appears to only be adversely affecting the egg/yolk-sac fry life stage. Tests conducted at the Aquatic Toxicology Lab at UC Davis were negative for toxicity in the water column. Therefore, there is no risk to the adult and juvenile life stages. In the benthos, however, all of the five sampling points tested positive for toxicity. The mean percent effect across all the sampling points was 38.39%. This percent effect is derived from total mortality caused to *Hyallela azteca* in the toxicity tests. The toxicity tests conducted on Secret Ravine were measures of total toxicity and thus included the effects of metals in the SDRM model. Although a separate metals analysis was performed, it was not included in the SDRM model. The most likely anthropogenic contaminants include organochlorines, such as polychlorinated biphenyls and dioxins, and aromatic hydrocarbons. Toxicity ranked as the third highest percent effect in the SDRM model and is a likely threat to the egg/yolk-sac fry. But the extent of the effect of contaminants in Secret Ravine is unclear as evidenced by the high uncertainty value that is shown in **Section 11**.

12.2.2 Sources of Stressors (SDRM)

Sediment

We estimate that impervious surfaces and OHVs are the two sources contributing the highest potential concentration of sediment (**Table 10.2**). Impervious surfaces overwhelmingly exceed OHVs in terms of absolute area and should thus be considered the largest source of sediment to the watershed. The mechanism for delivery of sediment, however, is unclear and needs further research. Observations by Swanson (2000) as to the main sources of sediment include widely disturbed sources of channel erosion, historical disturbance and unfavorable channel morphology. Thus, the combination of an overabundance of introduced fine sediments (from placer mining and other historical uses) and poor channel hydraulics has created a system that is unable to rid itself of the excess fine sediments. Sections with deeply entrenched channels (rectangular with high banks) are unable to deposit fine sediments overbank. Furthermore, increased alterations of the flow regime due to increasing impervious surfaces further exacerbates problems associated with bank erosion and entrenchment.

The other significant sources most likely contributing to the sedimentation (medium concentration estimates in Table 10.2) problem include irrigation canals, dirt and gravel roads, channelization, construction and development and mining. Legacy impacts from mining are not well researched. It is still unclear whether areas of concentrated delivery of unconsolidated granite exist or if the issue is simply too widespread throughout the watershed.

Relationships between the remaining significant sources and individual sediment concentrations are not well understood. A detailed source analysis of these relationships should be the focus of any further studies into this issue.

Reduced Access

The two sources associated with reduced access - beaver dams and artificial barriers (via construction and development) - were assessed high direct effect to these stressors. The criteria used to determine total percent effects for the SDRM, in contrast to the MRRM, clearly demonstrate that factors other than whether fish can pass or not, must be taken into consideration when evaluating the impact of barriers. But whereas artificial barriers have the potential to confer mostly negative secondary impacts - with perhaps the exception of the formation of deep holding pools for adults - (C.D. Vanicek 1993), it must be remembered that beaver dams have the potential to confer other positive benefits. These include expediting materials transport downstream, maintaining water levels during low flows, increasing retention of organic matter and improving nutrient recycling, in addition to also creating first class pools (R. Naiman 1986). Indeed, R. Naiman emphasizes the role of beavers in second and third order streams as a keystone species for the system's "biogeochemical economy," benefiting plants, invertebrates and the fish themselves (R. Naiman 1986).

The high percent effects associated with the stream reach from the gauge at China Garden Road to Brace Road largely reflect the nature of the barriers (height, downstream pool depth, artificial versus natural), relative to the number of adults that attempt to spawn in this region, rather than simply the number of barriers in the region. With the exception of the triplicate fence at Sierra College Road, which obviously confers no benefits to migrating spawners, the benefits of beaver dams in terms of improved salmon habitat must be weighed against the adverse consequences of obstructed fish passage on a subshed-by-subshed basis. Secret Ravine is not particularly long to require a great frequency of deep holding pools. Furthermore, the most obstructive beaver dams over the past few years have been found in the downstream regions where substrate quality is still decent and where fish have been known to spawn most frequently historically - leading to the potentially high values for superimposition and blowout we received. Finally, it is important to remember that the prohibitively high Hayer Dam (further downstream on Dry Creek), also completely prevents adult fish from passing, thus lessening the overall magnitude of fish that should return to Secret Ravine to spawn by an unspecified amount (B. Washburn, pers. comm. 2003). Because the PCWA canal system helps maintain flows during summer, managers should err on the side of breaching the most obstructive dams, timed with upstream salmon migration, once beaver activity has been carefully monitored.

Toxicity

Toxicity recorded a high percent mortality due to the large number of direct sources that may be contributing toxic substances into Secret Ravine. These sources are a combination of both legacy and current sources. Most of the sources causing the high percent mortalities for toxicity reflect the consequences of urbanization due to the increasing number of housing developments and infrastructure in western Placer County. Although toxicity can kill chinook directly, it is more likely that toxicity in Secret Ravine is causing indirect harm by impairing reproduction, reducing the survivability of eggs/yolk-sac fry, restricting migration, and/or causing behavioral changes that limit survival.

In the SDRM source analysis, landscape maintenance, waste treatment plants, and impervious surfaces all received 'high' values for their respective contributions to the total toxicity. Orchards received a 'medium' value and OHVs registered a 'low' input. Of these sources, only the waste treatment plants are a point source; all the others are non-point.

Two waste treatment plants exist near the headwaters of Secret Ravine in Risk Region E. One plant, near the town of Newcastle, exists on the north side of Risk Region E and the other, part of the Castle City Trailer park, is on the south side. Since both plants use aeration basins combined with solid storage basins, there is no direct connection to Secret Ravine. In large rain events in the past, the Newcastle facility has chlorinated the effluent coming into its sewage ponds and been forced to release it into Secret Ravine to prevent flooding. Such events may increase toxicity in Secret Ravine in the form of increased nutrients. Some infrastructure improvements have occurred. However, with the increase in residential development, the water treatment plant will need to keep pace with the expanding population. Infrastructure designed to minimize the effects of heavy rain events must be implemented at these two waste treatment plants and Secret Ravine must be safeguarded from effluent spills and releases.

Impervious surfaces affect Secret Ravine by decreasing the time between when precipitation falls to when water enters the fluvial system, often associated with the alteration of peak flows. This tends to accrue fine materials (hydrocarbons and metals) on the surface. Heavy rain events flush these fine materials and contaminants into the stream in concentrated pulses. In areas where impervious surfaces are extensive, bio-filtration devices should be installed to minimize the effects of peak flow runoff.

Orchards contribute a legacy effect on Secret Ravine. During most of the twentieth century, orchards dominated the watershed and many agricultural products during this period involved the use of persistent pesticides such as DDT. Since orchards represent a legacy source, there are few best management practices suitable to offset these malignant effects. The effect of pejorative practices associated with historical orchards around

Secret Ravine continues to diminish as residual pesticides are broken down and filtered out.

Off-highway vehicles include all motorcycles, cars, trucks or all-terrain vehicles that utilize the floodplain of Secret Ravine for recreation. Oftentimes, these vehicles drive in the creek itself and contribute hydrocarbons and metals directly into the waters. OHV use needs to be restricted in and around Secret Ravine to inhibit further contamination and maintain the riparian vegetation within the buffer zone.

12.2.3 Affected Life Stages and Implications for Secret Ravine (SDRM)

Percent mortalities for sediment, reduced access and toxicity were averaged over the entire watershed and each rendered percent mortalities to the egg/yolk-sac fry stage, with 67%, 44% and 38%, respectively. Reduced access and toxicity only resulted in effects to the early life stages, although effects to the other two life stages were investigated, while sediment also yielded percent mortality to the juvenile life stage through turbidity (20%).

Despite high levels of uncertainty for all three stressors, these results are significant because the standards used to measure the effects for these particular stressors were related to direct potential mortality (as opposed to metabolic or behavioral effects or other chronic effects measured by some of the other stressors). Approximately 15,000 juveniles leave the system every year (after being corrected for observation error in the Predation stressor analysis (**Appendix J-10**). Assigning each female (half of the 160 figure) the average number of eggs fall-run females can be expected to lay in the Sacramento tributaries (5,000) having built the minimum number of redds (one), the number of juvenile offspring projected from these counts (400,000) would already drop the survival rate from egg to outmigrating smolt to 4%. This closely approximates our total percent effect value estimated from the SDRM (with perhaps 1% attributed to indirect or chronic mortality, such as temperature and flow effects, as moderated by factors such as riparian vegetation).

There are about 100 juveniles for every spawning adult, and the number of adults spawning on average in Secret Ravine has been relatively constant (hovering at 100) for the last decade. Because one adult is needed to return to Secret Ravine in completing the 3-5 year life cycle in order to maintain this population, we can estimate that approximately 3% of mortality to the salmon can be attributed to the ocean phase (.03 mortality from Secret Ravine x .03 mortality from the ocean = total mortality for the Secret Ravine population throughout their life-cycle). Overall, one can glean from these data that fall-run chinook experience on average a 0.001-0.0002 percent survival rate from egg to adult.

Taken together, these results imply two important trends. Firstly, that we can roughly estimate that the stressors on Secret Ravine contribute to approximately half of the mortality associated with the salmon engaged in the Secret Ravine life cycle. Depending on the role that density dependence plays in the ocean, this means that management targeted to our 37-square-mile watershed could, indeed, positively impact the future of the salmon population migrating through Secret Ravine. Of course, because we have already determined that because of pervasive substrate problems, density dependence also plays a role on Secret Ravine, for as many added salmon as we hope to see spawn in the future on Secret Ravine, improvements to substrate quality will have to be made in step. These results also show that because the egg life stage is implicated in half the mortality associated with Secret Ravine - which represents what we think is about half of the total mortality contributing to the population counts for the Secret Ravine fish - egg mortality represents almost half (46%) of the total mortality associated with this population. (The juvenile life stage was estimated to contribute 10%: 20% from SDRM x 50% of life cycle mortality). This information indicates that not only could the egg stage play a proportionally high role in perpetuating the fall-run life cycle, but that extra attention should be given to the mitigation of sources associated with the stressors causing mortality to the egg stage.

12.3 Comparing the Models

Modified Relative Risk Model

There were many positive and appropriate aspects of the Modified Relative Risk Model that helped in our analysis of Secret Ravine. The MRRM is a peer-reviewed method that gave us a systematic way to quantify ecological risk posed by sources and stressors in Secret Ravine. Risk can still be quantified with an incomplete data set, which was the case in Secret Ravine. For example, with altered vegetation we lacked plant lists and abundances, but we were still able to examine its effects on the salmon in Secret Ravine. We were also able to use literature references to fill in data gaps, and to make better decisions on how rank should be assigned. This made applying ranks more robust than the RRM method, which relied solely on GIS. Most importantly, the MRRM prioritized risk regions, sources and stressors using calculated risk scores.

But there are also flawed aspects of the MRRM. Converting data to ranks poses the biggest problem. Scientific importance is lost, and precision is thrown by the wayside. Determining actual ranks can also be arbitrary. Although ranks were based mostly on references from biology literature, sometimes this was not the case and Jenk's optimization was used. This weakens the analysis by ignoring important biological factors. Additionally, criteria for assigning ranks can be rather nebulous. The difference between a rank of two or a rank of four can be unclear, and therefore arbitrary. For example, what makes a toxicity level a two, versus a four? This distinction may have relied too heavily on best professional judgment. Moreover, the relativity of the MRRM lies within a source or a stressor, but cannot be applied across sources or stressors. For example, a rank of two for temperature does not imply the same level of risk as a rank of two for morphology. The separation of the watershed into risk regions also weakened the analysis. This required that data was present in every risk region, but this was not always the case. More often than not, data was missing in the top two risk regions, requiring extrapolation. A risk score in those regions is less accurate than a risk score in the lower regions because of the lack of data. Similarly, the delineation of these risk regions is somewhat arbitrary. Sub-watershed boundaries are based on the landscape, but regrouping sub-watersheds results in different risk regions. Different risk regions can mean different results, and there is no "correct" way to group them. Source estimation using areal extent also posses a problem. Big source does not equal big stress in most cases. Likewise, point sources have a small areal extent, but can emit a large stress. We rectified this problem with point sources by using frequency, but whether this is the best way to analyze point sources is not clear. Baseline risk is ignored in the MRRM. There is no accounting for natural risk that can occur in a system without stressors. Lastly, the MRRM is a poor communication tool. A rank or a Total Risk Score has less meaning than an actual effect, i.e. percent mortality. It is difficult to communicate a stressors effect on the salmon population merely by producing an arbitrary number that can only be understood in relation to other arbitrary numbers.

Stressor-Driven Risk Model

The development of the Stressor-Driven Risk Model rectifies some of the shortcomings of the MRRM, but still falls short of accurately analyzing the effect of sources and stressors to chinook salmon. The SDRM dealt structurally with stressors and habitat through the evaluation of percent reduction in population for the whole ecosystem. In the SDRM, the whole ecosystem could be analyzed as a unit; this placed importance on the system as a whole opposed to spatial units such as risk regions. Given the scale of Secret Ravine, 37 square miles, dividing the watershed into smaller units may be imposing arbitrary divisions on an area with more similarities than differences. Additionally, the analysis of risk on an ecosystem-wide scale allowed for greater statistical power, where dividing data into five risk regions often required the projection of data into regions of the watershed that were not characterized in the original data collection. Also, the SDRM allowed for the analysis of the salmon population via life stage, not through the often arbitrary division of water column and benthos habitat. For example, the food supply stressor affected the juvenile chinook salmon. Juvenile salmon primarily utilize the water column as habitat, however the food supply of the juveniles often originates in the benthos of a stream. So juvenile salmon depend on both water column and benthos and risk to either habitat should be important to overall risk to chinook salmon. Furthermore, the SDRM used the concept of percent reduction of population to characterize effect. The percent reduction in population eliminates the ambiguity in assigning ranks and decreases the amplifying of imprecision caused by multiplying rank by rank.

The shortcomings of the SDRM include three major hurdles: the source characterization was problematic, reduction in population does not address carrying capacity, and no baseline mortality evaluation was possible. The limited source characterization for the SDRM utilized a semi-quantitative approach for describing the average emission of a stressor by a source and discussed in a qualitative manner the sources for the three stressors with the most influence in the ecosystem. This approach allowed for the discussion of source in the SDRM analysis, but the source analysis could have been improved if a mathematical relationship between source and the stressor effect could have been generated. This type of model could be developed but the limitation of resources prevented the SDRM from including a more comprehensive treatment of source. However, compared with the source analysis in the MRRM, the SDRM addressed this data gap in a more straightforward manner. Another drawback of the model comes from the relationship between carrying capacity and percent reduction in population. The carrying capacity of an ecosystem defines the number of individual organisms an ecosystem can support. We do not know the carrying capacity of Secret Ravine, so a percent reduction in population may be greater than the carrying capacity of the creek. However no density dependence seems to be in evidence in Secret Ravine, therefore neglecting carrying capacity may not be a drawback of the model. Another drawback that limits the utility of the model is baseline mortality. In all ecosystems, even during the pre-Columbian time period, some baseline mortality occurred. The separation of anthropogenic and baseline mortality cannot be accurately approximated. However by concentrating on effects of stressors and not the actual survival rate some of this ambiguity between baseline and anthropogenic mortality was avoided.

Which Model is More Appropriate For Our Creek?
We determined that the Stressor-Driven Risk Model is a more appropriate model for evaluating risk to Secret Ravine chinook salmon. Its ability to assess risk in an ecosystem, coupled with its scientific relevance, makes it a better tool to analyze and communicate risk.

12.3.1 Reduced Access, Toxicity and the MRRM

Neither reduced access nor toxicity, high-scoring stressors in the SDRM, ranked highly in the MRRM. In the following section, we attempt to explain why this may be the case.

Reduced Access
With the MRRM model, there was little way of accounting for the secondary effects of some of the stressors, although they were identified in the Conceptual Model or in breaking down relationships among the stressor itself. Effects to only one life stage could be assessed at a time using the 'habitat' criterion in the ranking scheme. Since percent mortalities could be evaluated based on the effects of several stressors (secondary, in this case), values for these could be multiplied together to derive more refined results.

Reduced access was determined to be the lowest ranking stressor in terms of cumulative risk summed over the entire watershed in the MRRM. It was the third-lowest ranking stressor in Risk Region A and the lowest ranking stressor in Risk Region B. However, it was the second most highly ranked stressor in the SDRM, with almost 50% mortality across life stages attributed to it. This discrepancy is largely explained by the fact that reduced access only had two sources associated with it in the MRRM (beaver dams and construction and development), even though these two sources were given medium rankings based on the moderate areal extents they were associated with. Although beaver dams were assessed the highest source risk in Risk Region A (relative to the other risk regions), and received the highest source ranking for this region relative to the other sources, number of sources associated with stressors determined whether the stressor would exert an impact on the fish. However, it is interesting to note that the 150% passage rule employed in the MRRM yielded approximate the same results in terms of relative effects as the actual counts.

Nevertheless, while attempts were made to make beaver dams - a point source - equivalent to the impact that non-point sources would exert, areal extent is not a reliable way to infer beaver dams impacts. Barriers are by nature, best considered in terms of their cumulative impact to the fish: their navigation costs adults energy and their complete impassability during low flows limits already limited spawning grounds. Subjecting a source of this nature to comparison per risk region is especially erroneous using this type of analysis. In the grossest sense, barriers need to be evaluated in terms of the amount of delay they impart to the adult and juvenile life stages, which makes salmon susceptible to a host of other more extreme stressors (G. Marsh, pers. comm. 2003). Arbitrary breaking up of the watershed (and the barriers, themselves) for the purposes of barriers analysis does not allow the full picture to be revealed in terms of when and where fish are allowed to spawn given so many obstacles along the way.

The effects rankings were so low in the MRRM because only one life stage could be addressed at a time. But perhaps more importantly, the effects criteria used are simply wrong in terms of their characterization of barriers on salmon health. Passage does not necessarily imply that the adult will successfully spawn or even attempt to reproduce; and non-passage does not imply that an adult will not attempt to spawn. Indeed, Chris Lee of the DWR reported that, "salmon will do whatever it takes to try and spawn. ...they will definitely turn tail and go back downstream to find suitable substrate if a barrier is blocking upstream migration" (C. Lee, pers. comm. 2003). Thus, the potential effects associated with not passing/passing scenarios were analyzed using the SDRM.

Reduced access is the only stressor that deals directly with the potential consequences of delay, and delay (in adult spawning with early rains, in juvenile exit prior to temperature increases), has particularly egregious consequences for fall-run chinook. This is especially true given their large size and high rates of metabolic activity, in a stream of this nature (so far from the estuary). Thus, it is reasonable to conclude that reduced access would rank as one of the highest-ranking sources, rather than one of the lowest. Thus, although the MRRM is helpful in terms of comparing risk among regions in terms of reduced access, the SDRM is capable of the same and provides much more scientifically believable results for the entire watershed.

Toxicity

There were three reasons that toxicity did not appear in the MRRM. The most important reason is that toxicity had far fewer sources associated with it than did sediment, flow, and morphology. Toxicity had seven contributing sources whereas sediment, flow, and morphology had 11 contributing sources.

The second reason toxicity did not appear in the MRRM is that toxicity registered a "0" for the water column exposure filter. This occurred because the toxicity tests were negative for the water column. This worked to cut the effect of toxicity in half for the MRRM.

The third reason toxicity did not appear in the MRRM is because of the nature of one of its sources. Waste treatment plants registered as point sources. Due to this, waste treatment plants only affected the one risk region that they were located in. In the MRRM, waste treatments were found only in Risk Region E. This risk region received a "6" while all the others received ranks of "0," respectively.

12.3.2 Flow, Morphology and the SDRM

The MRRM indicated that flow and morphology were two of the three highest-ranking stressors. These stressors, however, did not rank in the top three for the SDRM. Some reasons for this as follows.

The lack of robust flow data for Secret Ravine required alternative methods for estimating risks associated with that stressor. In the MRRM, the risk of scour was the basis for estimating impacts of flow. Thus, in the MRRM, the flow stressor is not a true estimate of the risk from flow. It is more of a reflection of the condition of excess sand within the substrate. In the SDRM, actual observational estimates of flow depth and velocities (Li and Fields, Jr. 1999) were used to estimate risk. We did not use these data in the MRRM because they were not risk region specific. Therefore, the main reason that the flow stressor did not rank so high in the SDRM is because it does not consider scour.

In the MRRM, criteria for ranking morphology were based on the percentage of pools. We determined that most risk regions were deficient in the frequency of pools and therefore received high rankings. We determined, using the same data set in the SDRM that the loss of pool and riffle habitat resulted in a loss of roughly 27% of the habitat. According to the SDRM, this is not a high-ranking stressor, relatively. Thus, the MRRM, due to ambiguities in the criteria for ranking, may be overestimating the risk associated with this stressor.

Overall, it is apparent that fine grain sediments are a major stress on the Secret Ravine system. These sediments can lead to disruptions in both flow and morphology due to the complex nature of fluvial systems. Moreover, alterations to the flow regime and morphology can lead to changes in sediment fluxes. It is impossible to determine what the root cause of the problem is with this model. The SDRM, however, is better suited to estimate risk due to the data constraints and structural improvements to the model.

12.3.3 MRRM, SDRM and the Conceptual Model

Although we have noted glaring differences between the models in terms of how their structures emphasize certain key components and relationships of each, the conceptual model ultimately drives both. While the SDRM defines well the stressor-to-endpoint relationship without taking redundant pathways into account, the MRRM focuses strictly on magnitude - of source, habitat length, and effects to quantify stressor risk score magnitude. The MRRM helps express the complex number of ecosystem interactions that could occur to render certain effects; the SDRM helps elucidate the need to "work backwards" from the assessment endpoint to the stressor in order to determine the source that should be highly targeted for management. The difference was how the conceptual model was used (source to endpoint vs. endpoint to source). The latter (endpoint to source) seems more biologically believable; the former perhaps more easily implementable from a management perspective. However, both suffer from lack of being able to substantiate the source-to-stressor relationship source analysis.

12.4 Management Recommendations

Management recommendations for Secret Ravine were generated in light of the strengths of the MRRM and SDRM, respectively, based on the sources associated with the top-ranking stressors. While we concluded that both models are better suited to assess preliminary risk to fall-run chinook in this type of ecosystem, and as a data-needs assessment, management recommendations are also possible for different aspects of the study. It is important to keep in mind that by "management" we are referring to the potential to manage the sources of stress according to their biological, physical and chemical impacts to the fish but that any full-blown management plan for fall-run chinook salmon be accompanied by a cost-benefit analysis.

12.4.1 MRRM Management Recommendations

The MRRM analysis implicated the most harmful stressors in Secret Ravine to be flow, morphology and sediment. We determined that all three of these stressors, due to their complex ecological interactions, had eleven out of the twelve possible sources associated with them. Only direct sources, with the potential to contribute large amounts of the stressor, will be discussed here. Management recommendations for sediments will be discussed in the next section (**Section SDRM** Management Recommendations) since it was also one of the three highest-scoring stressors in that model.

The flow stressor had seven direct sources associated with it. Of these seven, impervious surfaces was determined to be the source most likely causing most of the stress (**Figure 6.2**). This source was also the highest-scoring source overall within Secret Ravine. Numerous management recommendations exist for this source and many are discussed in association with the sediment stressor. Direct mitigations for impervious surface alterations to flow include the standard practices of detention basins and floodplain protection. These practices need to be supplemented with accurate flow data, especially given the complex issues associated with the excess sand supply and habitat requirements for chinook.

This data would also be useful in helping to shed light on the flow inputs from the PCWA canal system. Direct sources of the morphology stressor include four sources. As stated earlier, OHV impacts on morphology are obvious in the downstream sections of Secret Ravine and should be immediately dealt with by gating off known access areas combined with a stakeholder-based public awareness program.

Planned structural alterations for flood control (including channelization) need to be researched in depth to determine impacts to morphology by taking into account the complex sediment loading issues. Little effort has been made to understand these issues (Bates, Pers. Comm., 2003). Introductions of large woody debris and roughness elements (boulders) to improve salmon habitat have already been recommended (Swanson 2001).

Numerous studies (Li and Fields, Jr. 1999, Swanson 2000, DCC 2001) have alluded to the legacy impacts associated with mining in Secret Ravine. No detailed information exists, however, concerning pre-mining conditions or predictions for sediment transport. Such information would be of great utility in determining whether the excess sediment supply issue could be dealt with expeditiously or if it is a long-term issue that cannot be solved via standard management practices.

12.4.2 SDRM Management Recommendations

The SDRM analysis revealed that sediment, toxicity, and reduced access are the three most harmful stressors in regards to chinook percent effect. Because we have more confidence in the scientific methods used to infer the relationship between the stressors and our biological endpoint, fall-run chinook population viability, we can also have confidence in the targeting of their associated sources for management actions, relative to the MRRM. Because our method for determining the relative contribution of sources was the weakest link in our SDRM analysis, however, and because there are many source the potentially contribute to the effects given by sediment and toxicity, the overlap in sources among the top stressors should be investigated in order to focus management efforts. In addition, those sources should be targeted that were associated with the highest magnitudes.

Sediment had eleven total contributing sources. Of these sources, two registered high contributions, five registered medium contributions, and four registered low contributions. Impervious surfaces and off-highway vehicles were the leading sources causing increased sediments in Secret Ravine. Impervious surfaces often alter the peak flows in Secret Ravine by decreasing the time between when precipitation falls to when water enters the fluvial system. In heavy rain events, impervious surfaces alter the flow regime by increasing peak flows. This increase accelerates erosion that can cause an increase in sediment loading in the stream. Both non-structural and structural best management practices should be implemented to prevent sediment loading.

Non-structural recommendations would include the concentration of development and the maintenance of open space. Zoning regulations requiring the inclusion of greenways and open spaces in new developments would further accomplish this. Existing impervious surfaces ought to be separated or disconnected with vegetated areas. Permeable pavements ought to be installed as an alternative to concrete and asphalt.

Structural best management practices that should be considered for Secret Ravine would be the installation of dry and extended detention basins. Such detention basins would control peak storm water discharges and provide temporary storage of storm water runoff with gradual release to minimize flooding. Dry and extended detention basins would offer a corollary benefit to reducing the impervious surface contribution to toxicity by promoting the settling of suspended solids and associated pollutants. Some pollutant removal would also occur through infiltration and vegetative uptake.

Off-highway vehicles are the other major contributor to sediment loading in Secret Ravine. Off-highway vehicles include all motorcycles, cars, trucks or all-terrain vehicles that utilize the floodplain of Secret Ravine for recreation. It is highly recommended that OHV use be restricted in and around Secret Ravine to inhibit further erosion and maintain the riparian vegetation within the buffer zone.

Toxicity poses another leading threat to chinook in Secret Ravine in terms of percent effect. Of the five contributing sources to toxicity, impervious surfaces, landscape maintenance and waste treatment plants are the highest potential contributors.
As stated in Section 9.1.1, impervious surfaces affect Secret Ravine by decreasing the time between when precipitation falls to when water enters the fluvial system, often associated with the alteration of peak flows. This tends to accrue fine materials (hydrocarbons and metals) on the surface. Heavy rain events flush these fine materials and contaminants into the stream in concentrated pulses. In areas where impervious surfaces are extensive, bio-filtration devices should be installed to minimize the effects of peak flow runoff. Hydrologists recommend implementing seeded or sodded grassed "infiltrating conveyances" as part of a design for storm-water management systems. These open, vegetated portions of the storm water system slow the rate of overland storm water flow. This allows sediment and other particulates to deposit themselves onto the vegetation thus slowing movement toward Secret Ravine. Such interaction with the biological (primarily microbial) component of the grass system would serve to decompose or chemically convert various pollutants, thus removing their component from the storm water. Trenches, dry wells, leaching catch basins and infiltration islands are other recommendations that could be installed to provide a holding area for runoff to allow infiltration into the soil profile and added pollutant removal. Such structural devices would also benefit Secret Ravine by promoting ground water recharge, and reducing the temperature of storm water runoff. In all other areas, buffer zones need to

be created and maintained around Secret Ravine. In these buffer zones, riparian vegetation should be protected to assist in contaminant filtration.

Toxicity from landscape maintenance may be in the form of fertilizers, herbicides, metals, and nutrients that are reaching Secret Ravine. Due to encroaching urbanization, there are many lawns and gardens in new housing developments, as well as golf courses and businesses with sod lawns and terraces. To protect chinook, individual homeowners must phase out their use of pesticides and herbicides in their homes, gardens, lawns, and workplaces. To encourage this, Placer County needs to develop a comprehensive pesticide use reporting system with publicly accessible data. To reduce levels of toxicity, Placer County ought to provide consumers with information about alternatives to pesticides and herbicides through educational opportunities, brochures, and media advertising. Restrictions involving the use of pesticides near Secret Ravine are also advisable. Lastly, comprehensive water monitoring ought to be made more vigorous for a fuller understanding of Secret Ravine's status in regards to toxicity.

In regards to waste treatment plants, infrastructure designed to minimize the effects of heavy rain events must be implemented at the two waste treatment plants at Newcastle and Castle City Trailer Park thus safeguarding Secret Ravine from accidental effluent spills and emergency releases.

Reduced access in Secret Ravine registered as the second most deleterious stressor to Secret Ravine. Again, this is not surprising, given that this is the only stressor to directly address the issue of timing delay in terms of migration, an important factor for anadromous fish on any system. Construction and development - in the form of artificial barriers - needs to be addressed mainly in terms of the direct impacts of reduced access. With the exception of the old concrete aprons at the Confluence and near China Garden Road, for their ability to create deep holding pools, only the fence at Sierra College Road remains an almost complete obstruction on Secret Ravine, and should be breached as soon as possible. And while the benefits of beaver dams, in terms of the requirements of this particular creek, seem to be outweighed by the costs of reduced access itself, the monitoring and breaching of particularly problematic beaver dams needs to be undertaken in a very cautious manner. There is an unusually high number of beavers in the Dry Creek watershed, particularly on nearby Miners, which has over 80 beaver dams.

According to Chris Lee, because of the rapid urbanization in the Dry Creek watershed area, the number of beavers found is probably higher than in less disturbed watersheds throughout Placer County and the Sierran foothills, because there are lower concentrations of beavers's natural predators in the region. So while certain dams should be breached during upstream adult migration periods, the area must be brought back into equilibrium in terms of limiting the take of natural predators to repopulate the area to some extent. Because the rise of development in this area makes this prospect unrealistic, mitigation of overly large beaver dams should occur. DWR also plans to remove the prohibitively high Hayer Dam downstream on Dry Creek, which should slightly increase the magnitude of adult fish returning to spawn in Secret Ravine (B. Washburn, pers. comm. 2003). Afterwards, as little breaching as possible should take place, as beavers should be integrated into resource management plans. The canal system must be considered in the planning process for Secret Ravine, because, depending on changes to the system, flows may be too high for beavers to want to build dams on this creek. Thus, management recommendations that target the sources of other stressors related to improved riparian health, including those addressing flow and sediment, should also help naturally control beaver populations and maintain flows high enough so that dams do not pose as much of a threat in terms of reduced access.

12.5 Conclusion

The chinook salmon is renowned for its preeminence in California for its economic and ecological value. To maintain the remaining population of chinook salmon, we recommend that the results of the Stressor-Driven Risk Model be appropriated for Secret Ravine. The SDRM utilizes scientific relativity to assess risk making it a more appropriate model to both analyze and communicate the risk posed to chinook salmon.

The SDRM functions to analyze risk by evaluating "…the likelihood that adverse ecological effects may occur, or are occurring, as a result of exposure to one or more stressors" (U.S. EPA 1998). The SDRM functions as a sound ecological risk assessment by incorporating available data and information to help understand and predict the links between sources, stressors, and their resulting ecological effects. These findings can then be used to prioritize environmental decisions (U.S. EPA 1998). With the SDRM, we have used the era process as defined by the U.S. EPA. In so doing, we have assessed the physical, chemical, and biological stressors on the fall-run chinook salmon in Secret Ravine. We have concluded that the MRRM and SDRM are good tools for preliminary risk assessment. However, the source component of the models is still greatly limited by insufficient data. With further research and data gathering, we believe this limitation can be overcome. It is our hope that this endeavor has prioritized sources and stressors in such a way that local and state organizations can protect the future viability of chinook salmon.

13 References

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Appendix A: Mining in the Secret Ravine Watershed

History

Placer County is located along the old "Mother Lode Belt" in one of the state's most historically active regions for mining. Gold was discovered at Sutter's Mill in Coloma, California in 1848 in adjacent El Dorado County, and was the predominant commodity mined in Placer County, from its peak in the 1850s through its eventual decline in the 1960s (Haley 1923). The geology of this region dictated not only the types of commodities mined, but the types of mining methods employed. The alluvial deposits of the western Sierra Nevada, which contributed more than 40% of California's total gold output, are divisible into the Tertiary (older, 65-million-years) deposits, which consist predominantly of quartzitic gravels, and Quaternary deposits, which are in and adjacent to the present stream channels. The Tertiary channel deposits - which correspond to the higher gradient drainages upstream of Secret Ravine - including the Bear and Yuba Rivers - were exploited primarily by hydraulic and drift mining, while the greatest yields from Quaternary deposits - the type found directly along the low-gradient Secret Ravine basin - purportedly yielded the most efficient output through dredge mining.

Hydraulic mining came to prominence because of an abundance of cheap water and sufficient grade for the disposal of tailings (Haley 1923). Indeed, the Yuba contained "undoubtedly the largest single body of commercial hydraulic gravel in the State of California" by 1921 (Haley 1923). It was eventually recognized, however, by the early 1870s, that hydraulic mining was disruptive to other land interests. "Where irrigation canals are fed from rivers below the dumping ground of the mine, it is quite possible that these canals may be silted by mining operations; which would naturally result in trouble for all concerned" (Haley 1923). At the same time land primarily used by miners as dumping grounds, started increasing in value and agricultural interests overtook mining interests in the form of the 1893 Caminetti Act. (California State Mining Bureau 1916). The Act outlawed the practice of hydraulic mining, but made exceptions with the allowance of debris-restraining dams if they were shown to mitigate the sedimentation of streams by hydraulic mining, thus it continued through the 1920s. All-told, hydraulic mining was estimated to have been responsible for 1.295 billion cubic yards of gravel washed into tributaries of the Sacramento River during this time period (Haley 1923).

The shifts in geography and commodity, not to mention economy, corresponded to the concurrent chronological and physical shifts from panning of surface placer golds to hydraulic mining of gold from quartz veins to drift and dredge mining of the river gravels (i.e. methods increasingly more adverse to stream morphology) through the early part of the 20th century. Indeed, these changes are reflected in microcosm on the Secret Ravine watershed.

All-told, hydraulic mining was estimated to have been responsible for 1.295 billion cubic yards of gravel washed into tributaries of the Sacramento River during this time period. (Haley 1923). The shifts in geography and commodity, not to mention economy, corresponded to the concurrent chronological and physical shifts from panning of surface placer golds to hydraulic mining of gold from quartz veins to drift and dredge mining of the river gravels through the early part of the 20th century. Indeed, these changes are reflected in microcosm on the Secret Ravine watershed.

Risk Characterization for Source

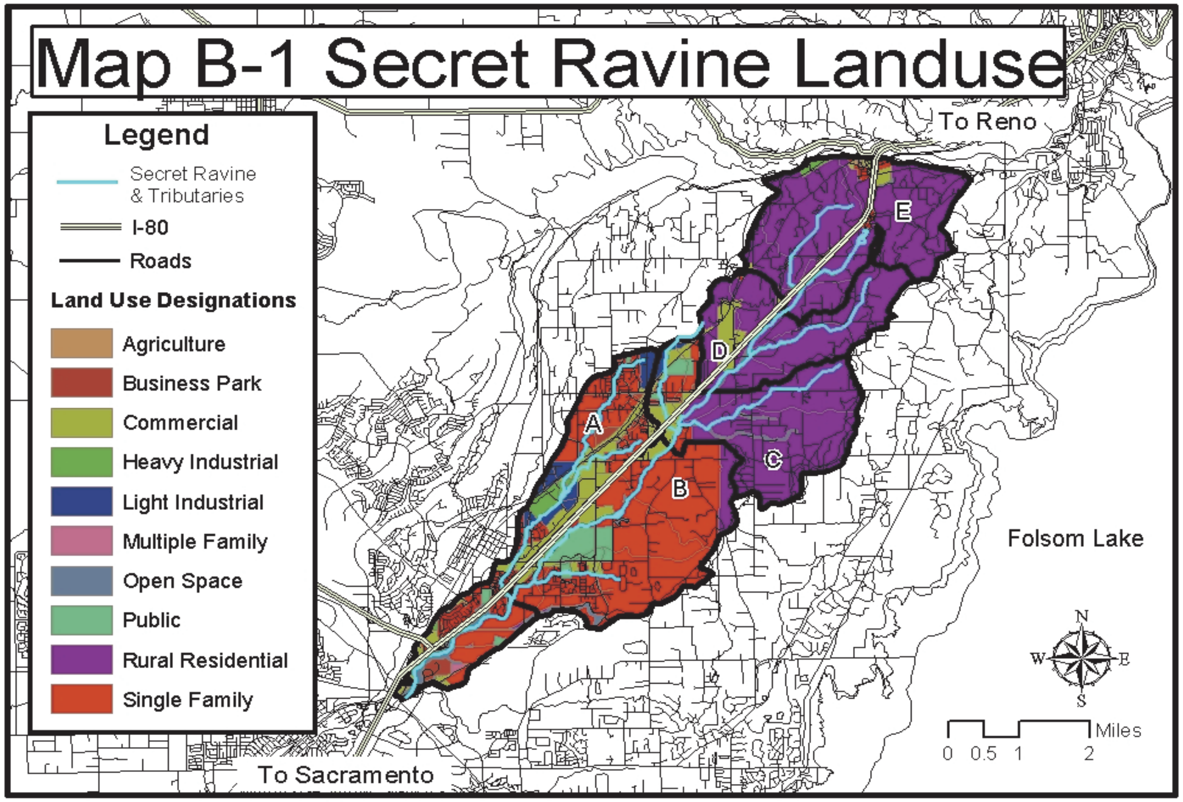
Risk characterization for mining was loosely based on a calculus of commodity mined (in terms of persistence chemical impacts), intensity of mining activity (or mining type) and mining duration. The refining chemicals chiefly associated with placer mining were zinc and cyanide (Haley 1923), and the tailings were primarily in the form of mercury.

The entire watershed was most likely exposed to the hydraulic runoff from the lower Yuba and Bear Rivers via the canal system (the Boardman Canal, in particular), constructed during the turn of the century to transport foothill Sierra water to the agricultural lands surrounding Secret Ravine. (Meadow Vista Vegetation Management Project 2001). This produced a period of channel aggradation, which disrupted the stream morphology of the system so severely, that the stream is still not considered recovered (Swanson 2001). For this, a baseline of 2 is warranted across all risk regions. Secondly, Rocklin district (an area encompassing present day Risk Regions B and C) was the epicenter of granite quarry mining in Placer County in the early 20th century (for mining of quartz and feldspar, and for direct use in the construction of buildings, curbstone, paving bricks and riprap) (California State Mining Bureau 1916). The Lee Drift Mine (one of the principle placer gold mines), was also located squarely where Sierra College is presently located, and was dredge-mined through the late 1950s. Perhaps most famous of all were the Alabama and Mary Len mines (located on the border of Risk Regions D and E). Alabama reaped $1 million in profits from the sale of gold, silver, granite and quartz, Mary Len, $500,000 (California State Mining Bureau 1916). Risk Region E also had several limestone quarries. Thus, the upper four risk regions, based not only on pervasive hydraulic runoff from upper drainages, but on their documented accounts of major - although short-term mining operations and commodities and persistent refining chemicals, received 4s in relation to Risk Region A, where, according to the records consulted, there were no major mining operations. These chemicals may have had, and may still have, chronic toxicity implications for the fish, and they include zinc, copper and chrome.

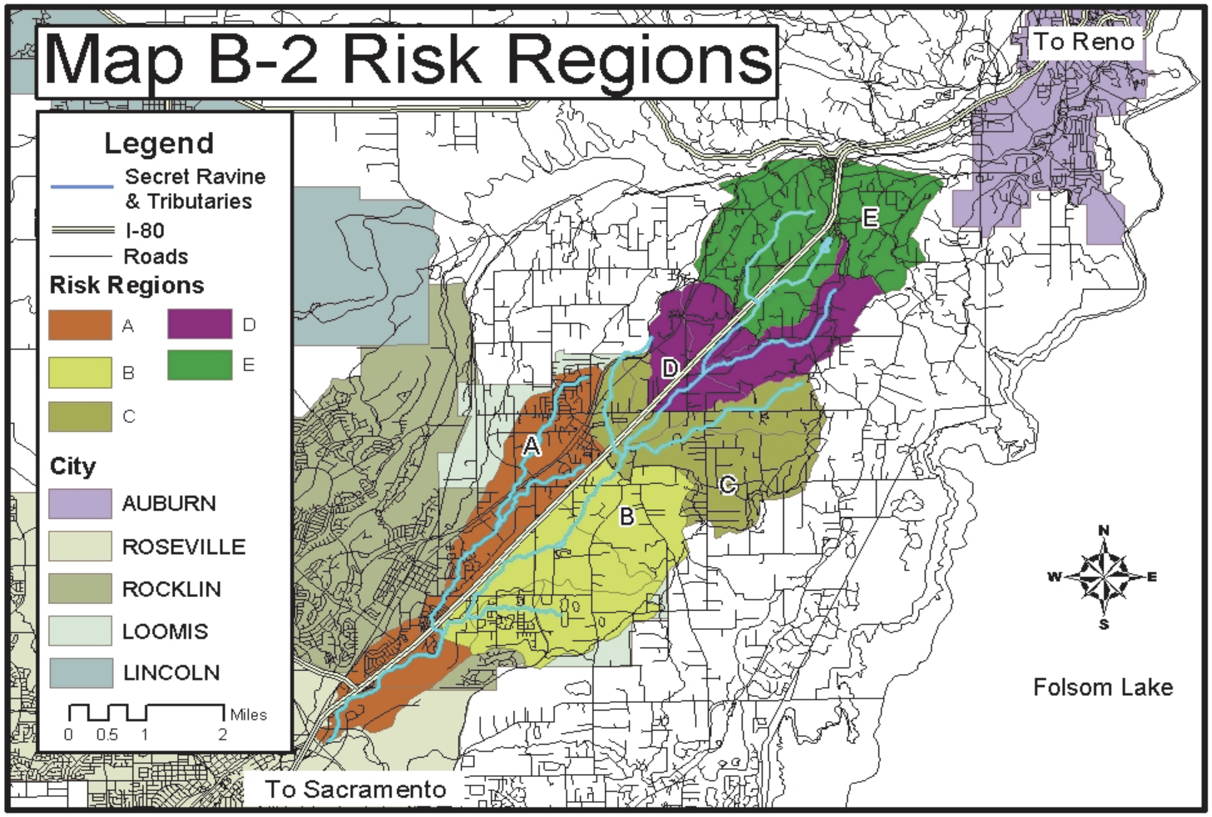
Dredging operations in the area were curtailed during World War II due to increasing costs, depletion of dredging grounds and changing land values. The last dredging operation shut down in Folsom in 1962. There are currently no known mining activities within or remotely near the Secret Ravine watershed, although there is high aggregate demand throughout southwestern Placer County (particularly in alluvial sand, gravel and crushed granite), and there are still active gold mines in eastern Placer County (The Mineral Industry Handbook 1999).

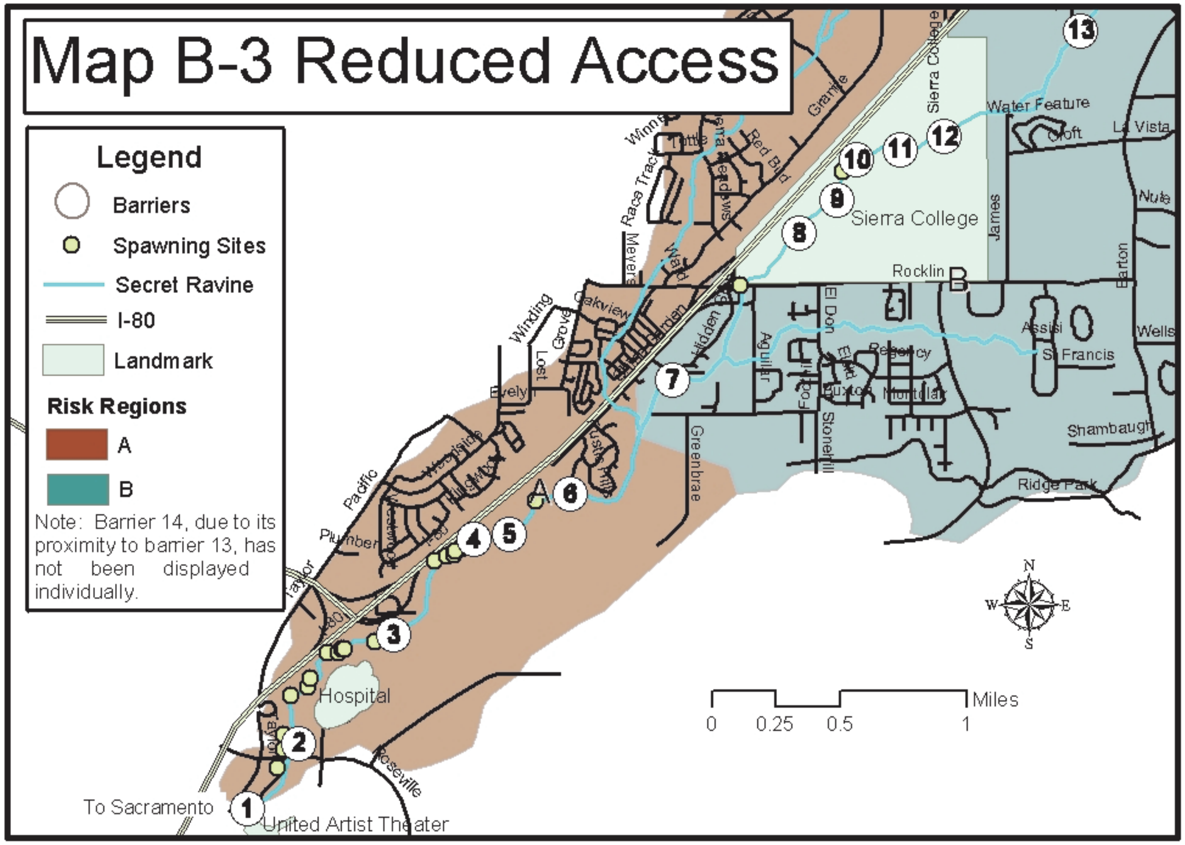
Appendix B: GIS Maps

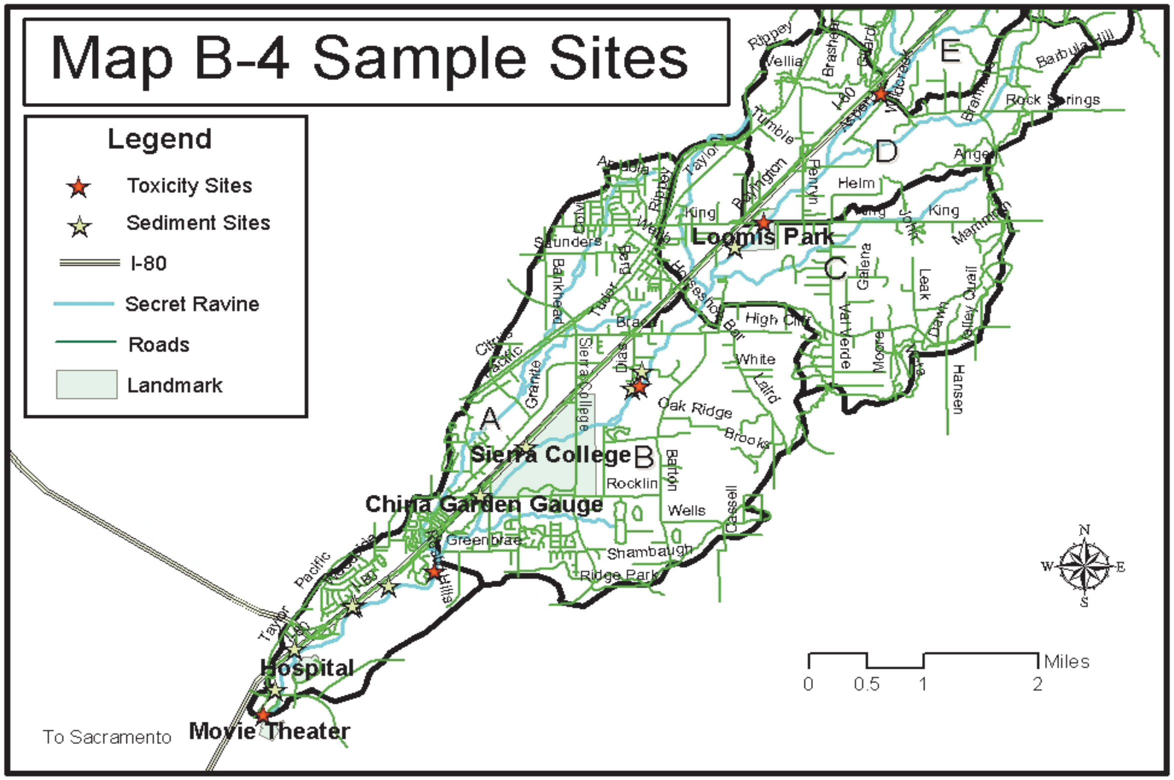
The following pages contain GIS Maps B-1 through B-4.



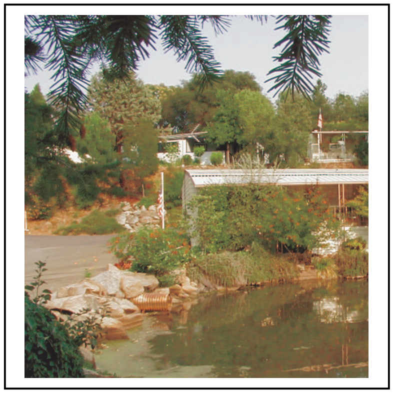
Map B-1 Secret Ravine Landuse


Map B-2 Risk Regions
Legend
Secret Ravine & Tributaries
I-80
Roads
Risk Regions
A
B
C
D
E
City
AUBURN
ROSEVILLE
ROCKLIN
LOOMIS
LINCOLN
0
0.5
1
2
Miles
To Reno
To Sacramento
Folsom Lake
N
S
E
W
A
B
C
D
E


Map B-3 Reduced Access
Legend
Barriers
Spawning Sites
Secret Ravine
I-80
Landmark
Risk Regions
A
B
Note: Barrier 14, due to its proximity to barrier 13, has not been displayed individually.
1
2
3
4
5
6
7
8
9
10
11
12
13
A
B
Sierra College
Hospital
To Sacramento
United Artist Theater
Rocklin
Water Feature
Croft
La Vista
Nute
Barton
Wells
Assisi
St Francis
Shambaugh
Ridge Park
James
Regency
Montclair
Buxton
El Don
Aguilar
Stonehill
Greenbrae
Hidden
Oakview
Grove
Winding
Lost
Evely
Pacific
Plumber
Taylor
Roseville
Granite
Race Track
Meyers
Tottle
Red Bird
Miles
0
0.25
0.5
1
N
S
E
W


Map B-4 Sample Sites
Legend
Toxicity Sites
Sediment Sites
I-80
Secret Ravine
Roads
Landmark
A
B
C
D
E
Loomis Park
Sierra College
China Garden Gauge
Hospital
Movie Theater
To Sacramento
N
S
E
W
Miles
0
0.5
1
2

Appendix C: Images of Secret Ravine Today



Trailer Park Ponds in Castle City Trailer Park

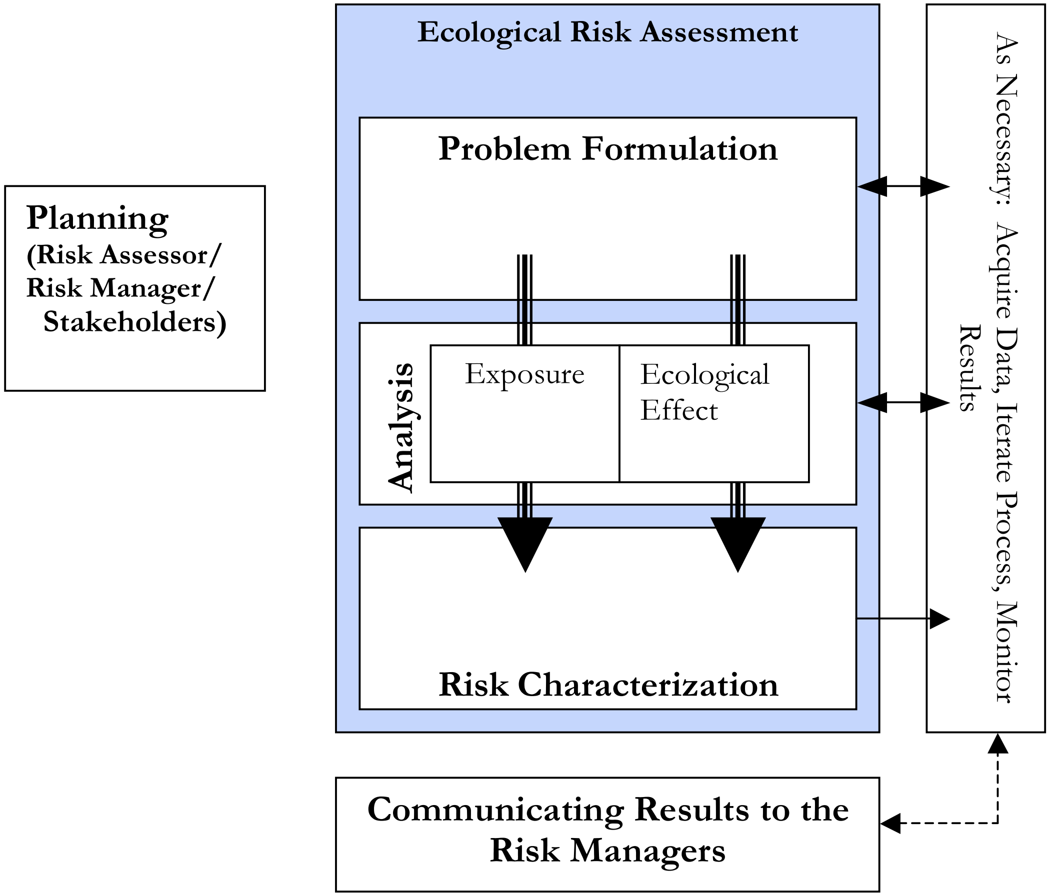
Eutrophication at Newcastle

Pumps, Pipes and Garbage Near Penryn Road (Photo Courtesy B. Washburn)

Tree Frog

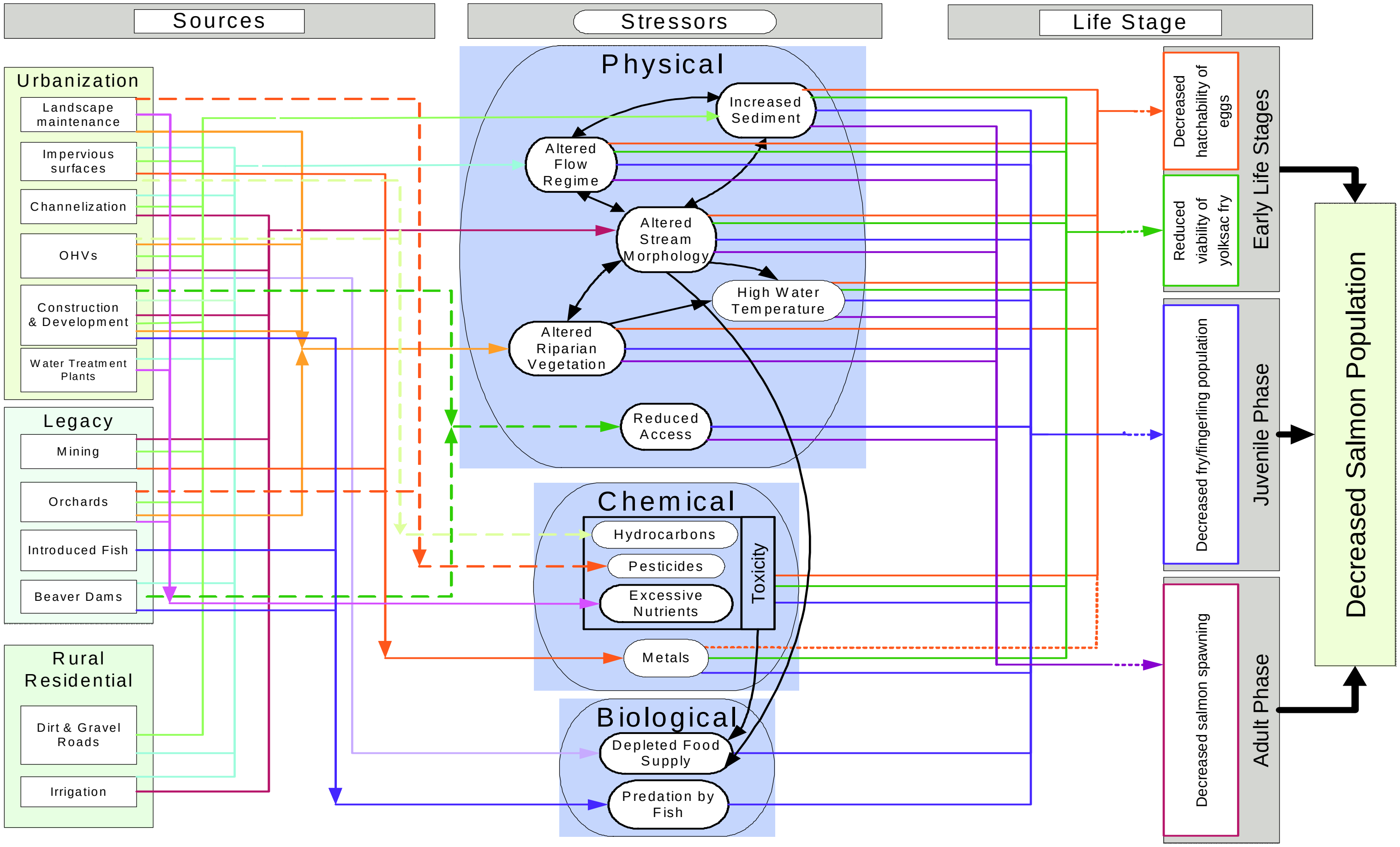
Adult Fall-Run Chinook in Secret Ravine (Photo Courtesy M. Posehn)

Appendix D: The Framework for Ecological Risk Assessment



Appendix E: The Conceptual Model

Conceptual Model - Stressors on Chinook Salmon - Secret Ravine



Appendix F: Sources and Stressors

Sources

LM	Landscape Maintenance
IS	Impervious Surface
CH	Channelization
OHV	Off Highway Vehicles
CD	Construction & Development
WTP	Water Treatment Plants
MI	Mining
OR	Orchards
IF	Introduced Fishes
BD	Beaver Dams
DG	Dirt & Gravel Roads
IR	Irrigation

Stressors

S	Sediment
F	Flow
M	Morphology
Te	Temperature
V	Altered Riparian Vegatation
RA	Reduced Access
To	Toxicity
Me	Metals
FS	Food Supply
P	Predation by Fish

Stressors		Direct Sources	Indirect Sources	# of Sources
PHYSICAL	**Sediment**	IS, OHV, CD, DG, CH	IR, WTP, BD, LM, MI, OR	11
	Flow	IS, CH, CD, WTP, DG, IR, BD	OHV, MI, OR, LM	11
	Morphology	CH, OHV, CD, IR	WTP, IS, OR, DG, BD, LM, MI	11
	Temperature		LM, IS, CH, OHV, CD, WTP, MI, OR, BD, DG, IR	11
	Altered Riparian Vegetation	OHV, CD, LM	IS, CH, WTP, MI, IR, DG, BD, OR	11
	Reduced Access	CD, BD		2
CHEMICAL	**Toxicity**	IS, OHV, LM, OR, WTP		5
	Metals	IS, MI		2
BIOLOGICAL	**Food Supply**	OHV, WTP, IS, LM	CH, CD, MI, IR, OR, DG, BD	11
	Predation by Fish	IF, BD		2

Appendix G: Invasive Plants and Blackberry (*Rubus discolor*)

Invasive plant species can be divided into two categories, those plant species that alter ecosystem processes and replace native species or those plants that just displace native species. According to Randall and Hoshovsky 'the invasive species that cause the greatest damage are those that alter ecosystem processes such as nutrient cycling, intensity and frequency of fire, hydrological cycles, sediment disposition, and erosion (Randall 2000). None of the plants observed in the Secret Ravine stream system exhibit this type of biology.

The second category of invasive plant displaces native vegetation. Within Secret Ravine (as with other areas of California) this displacement has four effects: invasive plants "outcompete native species, suppress native recruitment, alter community structure, degrade or eliminate habitat for native animals, and provide food and cover for undesirable non-native animals"(Randall 2000). In Secret Ravine, examples of how these effects currently influence the stream can be observed in the biology of the six listed invasive species (CalEPPC 1999): medusa grass (*Taeniatherum caput-medusae*), star thistle (*Centurea solstitialis*), Himalayan blackberry (*Rubus discolor*), edible fig (*Ficus carica*), tree-of-heaven (*Ailanthus altissima*), and fennel (*Foeniculum vulgare*) (Holland 2000, per comm. S. Egan). The Medusa head and yellow star thistle are currently replacing the non-native annual grasses, that a century ago replaced the native perennial bunch grasses. Recruitment of native plant species has all but been eliminated in the grassland environment of the California Central Valley and has experienced complete shifts in community structure (Holland 2000, Randall 2000).

STAR THISTLE ON SECRET RAVINE

Another example, the edible fig, tree-of heaven and fennel, have in some locations of the Sierra Nevada dominated the canopy in the riparian zone changing community structure and degrading or eliminating habitat for native animals (Randall 2000). Currently, the invasion of edible fig, tree-of heaven and fennel have not progressed to this extent in Secret Ravine, but the management of these invasions should be a top management priority. Additionally, Himalayan blackberry, a shrub seen throughout Secret Ravine can provide nesting habitat to black rat (*Ratus ratus*), an exotic animal species and disease vector (City of San Francisco 2000, Hickman 1996, Dutson 1974).

	Today's Vegetation	**Mining Era**	**Pre-Columbian**
Dominant Grasses & Forbs	Naturalized annual grasses and invasive forbs have replaced nearly all native grasses in California: Soft chess (*Bromus hordaceus*), Ripgut brome (*Bromus diandrus*), Medusa grass [A1] (*Taeniatherum caput-medusae*), Filaree (*Erodium botrys*) Wild lettuce (*Lactuca serriola*) & Yellow star thistle[A1] (*Centurea solstitialis*)	Mining activity in the riparian zone removed most pre-Columbian vegetation and provided ample opportunity for invasive plant introductions.	Native bunch grasses predominately Creeping wild rye (*Leymus triticoides*)
Dominant Scrub	Early seral community and invasive species indicative of disturbance including: Himalayan blackberry [A1] (*Rubus discolor*), Button willow (*Cephalanthus occidentalis*), Nettles (*Urtica dioica holosericea*)	Mining activity in the riparian zone removed most pre-Columbian vegetation and provided ample opportunity for invasive plant introductions.	Shade tolerant shrubs include: Ashes (*Fraxinus latifolia*), Box elder (*Acer negundo var. californicum*), Walnut (*Juglans hindsii*), & Wild grape (*Vitis california*)
Dominant Overstory	Valley oak (*Quercus lobata*) Fremont cottonwoods (*Populus fremontii*) White alder (*Alnus rhombifolia*) Species of Concern: Edible fig [A2] (*Ficus carica*) Tree-of-heaven [A2] (Ailanthus altissima) Fennel [A1] *(Foeniculum vulgare)*	Few Valley oaks (*Quercus lobata*)	Nearly closed canopy dominated by Valley Oak (*Quercus lobata*)

A1 - Medusa grass (*Taeniatherum caput-medusae*), Himalayan blackberry *(Rubus discolor*) star thistle (*Centurea solstitialis*) & fennel (Foeniculum vulgare) have a class A1 exotic pest plant designation, meaning they are invasive in three Jepson Regions or the more than half of California.

A2 – Edible Fig *(Ficus carica)* & Tree-of-heaven (*Ailanthus altissima)* have a class A2 exotic pest plant designation, meaning they are invasive in three Jepson Regions or the more than half of California.

A Jepson Region describes the floristic provinces within California as described by *The Jepson Manual: Higher Plants of California* (Hickman, J., Ed., 1993). The Jepson Manual is a taxonomic key providing a comprehensive treatment of the flora of California.

* - A forb is a low growing herb and the combination of forbs and grasses typically compose the ground cover in many ecosystems.

CHANGES IN DOMINANT VEGETATION IN RIPARIAN CORRIDOR OF SECRET RAVINE

We focused our analysis on Himalayan blackberry because these woody plants dominant the banks of Secret Ravine, creating most of the near shore fish cover for chinook salmon (Bishop 1997, Holland 2000, as per comm. S. Egan, Ecorp). However, the effects of blackberry were mixed between the habitat value it provides Secret Ravine salmon and the possible erosion caused by the replacement of native flora with blackberry. Therefore the decision was made not to include it in the overall risk calculation.

Himalayan blackberry (*Rubus discolor*)

The cultivation of Himalayan blackberry in California began in 1885 (Bailey 1945). Originally from Western Europe (Munz and Keck 1973), *Rubus discolor* had naturalized on the west coast of the North America by 1945 (Bailey 1945). Today, on the west coast of North America, *Rubus* discolor is considered an invasive weed and has been classified by CalEPPC as an A1 invasive weed (CalEPPC 1999). *Rubus discolor* is a woody shrub with prickly canes or brambles which produce black, berry-like fruit (Hickman 1996). The Himalayan blackberry reproduces via vegetative reproductions and sexual reproduction. Vegetative reproduction occurs when the canes root at the apices[11] of the cane stem and produce new stems (Amor 1974a). Typically this is how established brambles of *Rubus discolor* reproduced, however some sexual reproduction does occur. *Rubus discolor* produces berries that ripen in the summer and fall; sexual reproduction occurs via these berries. However seedlings require a sunny wet location to germinate which often does not include the area directly adjacent to the mature blackberry bramble. Experimentally it was determined that seedlings receiving less than 44 percent full sun died (Amor 1974a). This indicates that most reproduction by *Rubus discolor* maybe through vegetative regeneration and that sexual reproduction may occur primarily during pioneering of new sites.

Himalayan blackberries supplies a food source for foraging birds and mammals, including people, as well as providing nesting habitat for birds and small mammals (Hoshovsky 2001, Hickman 1996). Among the small mammals that utilize *Rubus discolor* for food and shelter includes the roof rat (*Ratus ratus*). This introduced mammal favors blackberry brambles and can transmit disease (City of San Francisco 2000, Hickman 1996, Dutson 1974).

In Secret Ravine, invasive plants crowd out native flora that would, to a greater degree prevent erosion and stabilize banks. However the greater stabilization afforded by native flora compared to the current plant assemblages found in Secret Ravine is unknown.

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[11] An apices is a growing tip of a shoot. This includes the ends of canes and stems in the case of Rubus discolor.

But given this caveat, the blackberry brambles do prevent and decrease some soil erosion (Bishop 1997). "Vegetation can prevent soil erosion by 1) interception of raindrops 2) restraint of the soil particles by root systems 3) providing physical roughness slows water down 4) enhanced infiltration and 5) uptake (of water)" (Hickin 1984). Blackberry to some extent prevents erosion through all five of these processes. Also blackberry provides habitat value to other animal species such as birds and mammals in the riparian zone. In addition to the habitat value to terrestrial animals, chinook salmon directly utilize the overhanging branches of the blackberry as fish cover and habitat complexity. Secret Ravine has essentially no large woody debris (Li 1999). Therefore these overhangs are a main component of fish habitat complexity within the creek. The question as to why Secret Ravine does not have a lot of woody debris is complex: related to the species composition of the riparian area and the amount of small sediment in the creek system. In any case, many streams with heavy infestation of blackberry have higher rates of woody debris. In consequence, the habitat complexity of blackberry provides a benefit to chinook salmon using Secret Ravine.

Given both the benefits and the costs of allowing *Rubus discolor* to dominant the ecosystem has been weighted by more comprehensive studies of the vegetation on Secret Ravine. Both Holland and Bishop suggest that Secret Ravine may benefit through the removal of blackberry (Holland 2000, Bishop 1997). This may well be the case, however, it should be stressed that before any management initiatives attempt to remove blackberry the question of what will replace the species as the dominant shrub in the ecosystem should be investigated and how the removal will be performed should be detailed. Other A1 weeds in Sierra Nevada foothills cause detrimental effects that do change basic ecosystem function such examples as tall white top (*Lepidium latifolium*), arundo (*Arundo donax),* tamarisks *(Tamarix chinensis, T. ramosissima, T. pentandra, T. parviflora)* can reduce actual water available to fish or can choke a stream with plants so fish cannot pass (Randall 2000). If a management approach replaced the blackberry infestation with an even more detrimental invasive species then perhaps this would not be the correct strategy. Also the process by which the plants are removed can cause more harm than good. The removal recommended must be done carefully; removal of vegetation from stream banks can destabilize banks and cause significant sediment input if not protected during the rainy season (Holland 2000, Bishop 1997). A well thought out program may gain much for the Secret Ravine ecosystem, but a second best management effort may be to prevent new invasions by exotic weeds, than to fight invasive weeds fully entrenched in the Secret Ravine ecosystem (Randall 2000).

Appendix H: Introduced Fish Species List

Common Name	Family	Feeding Strategy	Preferred Habitat	Effect on salmon	Status/Year of Introduction to California
Golden shiner, *Notemigonus crysoleucas* (Mitchill)	Minnow family (Cyprinidae)	Surface and midwater feeders, feed on zooplanton and zooplanters	Warm shallow ponds, lakes, and sloughs often associated with aquatic plants	Little effect due to poor adaptation to Secret Ravine	IIE, 1891(?)
Common carp, *Cyprinus carpio* (Linnaeus)	Minnow family (Cyprinidae)	Omnivorous bottom feeders, feed predominately on algae and aquatic insect larvae however fish larvae and eggs also eaten when available	Warm turbid water at low elevations but can survive in trout streams	Predation of fish eggs	IIE, 1872
Fathead minnow, *Pimephales promelas* (Rafinesque)	Minnow family (Cyprinidae)	Omnivorous bottom feeders, feed predominately on filamentous algae, diatoms, small invertebrates including chironomid larvea, and organic matter	Pools in small, muddy, streams and ponds	Competition with juveniles	IIE, 1953(?)
Black bullhead, *Ameiurus melas* (Rafinesque)	Catfish family (Ictaluridae)	Omnivorous bottom feeders, feed predominately on fish, amphipods, isopods, snails, and other invertebrates including chironomid larvae	Ponds, small lakes, river backwaters, and sloughs and pools of low gradient streams with muddy bottoms, warm turbid water	Competition with juveniles	IID, 1930s
Brown bullhead, *Ameiurus natalis* (Lesueur)	Catfish family (Ictaluridae)	Omnivorous bottom feeders, feed predominantly on amphipods, isopods, crayfish, and chironomid larvea	Highly adapted to cold and warm water including trout streams, also found in lakes, sloughs and river pools, with sluggish, low-gradient reaches and high turbidity, beds of aquatic plants and soft substrate	Competition with juveniles	IID, 1874
White catfish, *Ameiurus natalis* (Linnaeus)	Catfish family (Ictaluridae)	Carnivorous bottom feeders, feed predominately on invertebrates and fishes	Slow-current river habitat with water depths of 3-10 m	Little effect due to poor adaptation to Secret Ravine	IID, 1874
White crappie, *Pomoxis annularis* (Rafinesque)	Sunfish family (Centrarchidae)	Opportunistic predator, feed predominately on planktonic crustaceans and small fish	Warm turbid lakes, reservoirs, and river backwater	Little effect due to poor adaptation to Secret Ravine	IID, 1891 or 1908
Green sunfish, *Lepomis cyanellus* (Rafinesque)	Sunfish family (Centrarchidae)	Opportunistic predator, predominately on small fish and invertebrates including chironomids	Small, warm streams, ponds, and lake edges	Predation on juveniles and competition with juveniles	IIE/IID, 1891 or 1908

Common Name	Family	Feeding Strategy	Preferred Habitat	Effect on salmon	Status/Year of Introduction to California
Warmouth, *Lepomis gulosus (Cuvier)*	Sunfish family (Centrarchidae)	Opportunistic predators, feed predominately on opossum shrimp, amphipods, and aquatic insects but larger fish eat crayfish and fish	Abundant cover in warm, turbid, muddy-bottomed sloughs and backwater of the Sacramento and Colorado River	Little effect due to poor adaptation to Secret Ravine	IIC, 1891(?)
Redear sunfish, *Lepomis microlophus* (Gunther)	Sunfish family (Centrarchidae)	Omnivorous bottom feeders predominately on hard shelled invertebrates and aquatic plants	Deeper waters of warm, quiet ponds, lakes, and river backwater and sloughs with substantial beds of aquatic vegetation	Little effect due to poor adaptation to Secret Ravine	IID, 1950 & 1954
Bluegill, Lepomis macrochirus (Rafinesque)	Sunfish family (Centrarchidae)	Opportunistic predators, aquatic insect larvae, planktonic crustaceans, flying insects, snails, small fish and fish eggs.	Warm, shallow lakes, reservoirs, ponds, streams, and sloughs at low elevation	Predation on eggs and competition w/ juveniles	IID, 1908
Largemouth bass, *Micropterus salmoides* (Lacepede)	Sunfish family (Centrarchidae)	Opportunistic predators, feed largely on threadfin shad, golden shiners, and bluegill though in Bay Delta predate on juvenile salmon and native minnows	Warm shallow waters <6 M in depth can include farm ponds, lakes, reservoirs, sloughs, and river backwaters	Predation on juvenile salmon though Secret Ravine not ideal habitat	IID, 1891 or 1895
Smallmouth bass, *Micropterus dolomieu* (Lacepede)	Sunfish family (Centrarchidae)	Opportunistic predators, feed largely on crayfish also an introduced species	Clear lakes, clear streams with abundant cover and cool summer temperature (elevation between 100 and 1000M)	Good habitat for these fish, however prefer crayfish	IID, 1874
Spotted bass, *Micropterus punctulatus* (Rafinesque)	Sunfish family (Centrarchidae)	Opportunistic predators of larger invertebrates and fish; they feed largely on aquatic invertebrates, fish, crayfish, and terrestrial insects	Moderately sized, clear, low-gradient sections of rivers and reservoirs, like faster water than large mouth bass and more turbid water than small mouth bass	Most abundant fish seen in Secret Ravine, predation on juvenile fish	IIE, 1936
Western Mosquitofish, *Gambusia affinis* (Baird and Girard)	Livebearer family (Poeciliidae)	Opportunistic omnivore, predominately feed on what organisms are most abundant including aquatic invertebrate insects such as mosquito larvae and pupae, algae, zooplankton, and terrestrial insects	Wide range of conditions including warm ponds, lakes, and streams	Little effect due to preference for mosquitoes	IIE, 1922

<table>
<tr><th>Common Name</th><th>Family</th><th>Feeding Strategy</th><th>Preferred Habitat</th><th>Effect on salmon</th><th>Status/Year of Introduction to California</th></tr>
<tr><td colspan="6">Status: Describes abundance trends and management needs. This is the status found in Moyle’s Inland Fishes of California, 2002.
I. Alien Species
C. **Localized likely to become more widespread or already** widespread but not abundant in most areas. Alternately, it may be fairly common but is declining. The species is usually a recent introduction and is just starting to expand its range, or it is a long-established species that is only regionally abundant.
D. **Widespread and stable**. The species is widely distributed but seems to have reached the limits of its range. Presumably such species are integrated into local ecosystems.
E. **Widespread and expanding**. These fish are aggressive invaders that are still expanding their range to all suitable habitats in the state.</td></tr>
</table>

Appendix I: Source Analysis and Characterization

Category	Source	Analysis	Characterization				
			Risk Region				
			A	B	C	D	E
Urbanization	Landscape Maintenance	Ranks for both landscape maintenance and impervious surfaces were developed using land-use maps from the Sacramento Area Council of Governments (SACOG). Standard percent impervious surface values were applied based on literature reviews (percent landscape maintenance values were estimated based on BPJ). Audra Heinzel, Cal-EPA intern, then spot-checked these values specifically in the Secret Ravine watershed. Adjustments were made accordingly and areas were calculated for each land use category.	2	2	6	2	4
	Impervious Surfaces		4	2	6	2	4
	Channelization	Habitat data from ECORP indicated areas where rip-rap was present (channelized) in the stream and associated lengths for those sections. These stream lengths were summed for the risk region. A buffer of 100 feet was then applied to I-80 (from the PLTIGERV map). Stream lengths within that buffer were also considered channelized. Such sections only existed in risk regions A and B, but channelization most likely exists in other risk regions.	6	4	0	0	0

Urbanization	Construction & Development	Construction and development sites were digitized from a 2002 aerial photo Only one large construction site existed in Risk Region A.	4	0	0	0	0
	Water Treatment Plants	The Newcastle and Castle City sewage plants were digitized from a 2002 aerial. Both of these treatment plants in Risk Region E.	0	0	0	0	6
	OHVs	The extent of OHV trails was digitized from a 2002 aerial photo. From stakeholder information and direct observation it was determined that substantial OHV use occurs only in one large area within sections of risk regions A and B.	6	2	0	0	0

<table>
<tr>
<td>Legacy</td>
<td>Mining</td>
<td>The number of data points for current and historic quarries, shaft mines, dredge and hydraulic operations was determined using historic source data and previously mapped mining sites. Mining as a source was evaluated in terms of the physical: intensity and/or duration of the activity (which also embodies mining method), and in terms of chemical impacts: whether or not the metal was persistent or non-persistent. Following are the criteria we used in determining the ranks for this point source:
<table>
<tr><th>Criteria for Ranking</th><th>Rank</th></tr>
<tr><td>No historic record of mining</td><td>0</td></tr>
<tr><td>Low duration activity and/or non-persistent metal</td><td>2</td></tr>
<tr><td>Low duration activity and persistent metal</td><td>4</td></tr>
<tr><td>High duration or current activity and/or persistent metal</td><td>6</td></tr>
</table>
Although the upper four risk regions experienced some of the most intensive mining in Placer County, indirect exposure filters were applied to all stressors with the exception of metals, because they caused legacy effects are not currently manifested in the watershed (Section 4.1.5). See Appendix A: Mining in the Secret Ravine Watershed for a more complete description of some of the major recorded mining activity in the area and how the ranks were assigned.</td>
<td>2</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
</table>

	Orchards	The extent of orchards came from estimates bases on a USGS topographic map from 1981. Approximate areas were estimated according to the icons associated with orchard use. No digital data existed for this source.	0	0	2	2	6
	Introduced Fish	Fish introduction has been defined to include the riparian buffer zone surrounding Secret Ravine	6	2	2	4	0
	Beaver Dams	Beaver dams were surveyed and mapped by ECORP for the first four miles from the Confluence. Additional beaver dams noted anecdotally were digitized in ArcMap as point sources. Because dams potentially block habitat (Stoecker et al. 2002) and restrict it in the form of energy costs - "source" was calculated by measuring the percent area of the watershed upstream of a particular beaver dam. **Appendix J-6: Reduced Access** contains the data used to estimate source.	6	4	0	0	0
Rural Residential	Dirt & Gravel Roads	2002 aerial photographs were used to determine locations of dirt and gravel roads within the floodplain (excluding those within the OHV region mentioned above).	0	6	2	2	6
	Irrigation/Canals	CAD files from PCWA depicting the canal system was analyzed for the number of spillways in each Risk Region.	2	2	2	4	4

Appendix J: Stressor Risk Analysis and Characterization (MRRM)

Appendix J-1: Sediment

Risk Characterization for Sediment (MRRM)

Sediment Rankings (Benthos)

Risk region C had an average of 0% survival, so a risk ranking of six was given. Risk region B received a ranking of four since it had a 29% average survival and Risk region A was assigned 2 since it had a 35% survival. Risk Regions D and E were both given fours based on observations (B. Washburn and G. Webber, pers. comm. 2003). A conservative ranking of four was chosen since fine sediments are abundant, but actual spawning potential in these upper risk regions is most likely decreased due to higher slopes (Swanson, 2000).

Risk Region	Rank (benthos)
A	2
B	4
C	6
D	4
E	4

FINAL RANKS FOR SEDIMENT IN THE BENTHOS

Raw Data and Mathematical Models for Characterizing Sediment in the Benthos

Secret Ravine Grain Size Distribution and Mortality Analysis (early life stages in benthos)

Ayres, E., J. Love and K. Vodopals 2002 (unpublished)

Site Name	% fines < 0.85 mm	% fines < 6.5 mm	% fines < 9.5mm	Estimated Percent Survival [Tappel and Bjornn (1983)]	Negative percent survivals were assumed to be 0% survivals	Percent mortality = 1 - Percent Survival	Risk Region
IC01	18.16	54	66.78	-43.71	0.00	100.00	B
IC02	16.96	47	48.77	17.59	17.59	82.41	B
LM01A	19.31	55	59.00	-26.68	0.00	100.00	C
RO02	11.66	51	54.83	29.21	29.21	70.79	B
SC01	10.15	33	35.95	70.27	70.27	29.73	B
SP04	9.49	30	34.87	73.55	73.55	26.45	A
SP08	13.63	38	41.65	49.06	49.06	50.94	A
SP18	16.95	45	49.01	16.94	16.94	83.06	A
SP18_DS	9.19	32	36.41	71.75	71.75	28.25	A
SP20	45.43	93	75.13	-314.37	0.00	100.00	A
					Average mortality:	67.16	

GRAIN SIZE DISTRIBUTIONS AND ASSOCIATED MORTALITIES

Sediment Rankings (Water Column - Turbidity)

Risk Region	Rank (water column)
A	2
B	6
C	2
D	2
E	2

FINAL RANKS FOR SEDIMENT IN THE WATER COLUMN

All risk regions scored SEV values of either six or seven except for Risk Region B. This resulted in a risk ranking of two for all risk regions besides Risk Region B. These SEV values indicate that no (or very low) levels are occurring but that moderate physiological stress and impaired homing may be affecting salmon migration and development. Risk Region B contained turbidity levels that had the potential to result in approximately 30% mortality to juvenile salmon. Thus, a risk rank of six was assigned to Risk Region B.

Risk Regions D and E did not have turbidity data and were thus assigned a rank of 2 based on the fact that the average SEV value for the other three risk regions was less than nine (average SEV equals eight).

Raw Data and Mathematical Models for Analyzing Sediment in the Water Column (Turbidity)

Assumptions:

1 NTU = 1 mg/L, Maximum duration of exposure = 2688 hours

Dates of residence:

Adults	Juveniles	Eggs
September to December	February to May	November to February

RISK REGION	Site ID	Sample Location	Start Date	TURB (NTU)
C	DC6	Secret Ravine @ Loomis Park	12/12/00	3.5
C	DC6	Secret Ravine @ Loomis Park	12/12/00	1.4
C	DC6	Secret Ravine @ Loomis Park	1/17/01	4.3
C	DC6	Secret Ravine @ Loomis Park	2/13/01	12.7
C	DC6	Secret Ravine @ Loomis Park	3/8/01	4.5
C	DC6	Secret Ravine @ Loomis Park	4/10/01	4.5
C	DC6	Secret Ravine @ Loomis Park	6/1/01	2.6
C	DC6	Secret Ravine @ Loomis Park	6/26/01	3.6
C	DC6	Secret Ravine @ Loomis Park	7/11/01	1.9
C	DC6	Secret Ravine @ Loomis Park	8/23/01	2.9
C	DC6	Secret Ravine @ Loomis Park	9/28/01	2.2
C	DC6	Secret Ravine @ Loomis Park	10/17/01	2.7
C	DC6	Secret Ravine @ Loomis Park	11/26/01	2.4
B	Sierra College	First Flush	11/13/01	13.9
B	SR at Miners Ravine	First Flush	11/13/01	16.1
B	5	Secret Ravine above Rocklin Road	3/9/02	8.0
B	A	Near Greenbrae Rd - Barrington Hills Drain	3/23/02	5010.0
B	A	Near Greenbrae Rd - Barrington Hills Drain	3/23/02	4970.0
B	5	Secret Ravine above Rocklin Road	5/19/02	14.5
B	5	Secret Ravine above Rocklin Road	5/21/02	28.2
B	A	Near Greenbrae Rd - Barrington Hills Drain	5/21/02	2020.0
B	5	Secret Ravine above Rocklin Road	6/15/02	2.3
B	5	Secret Ravine above Rocklin Road	6/15/02	3.2
B	5	Secret Ravine above Rocklin Road	6/18/02	2.2
B	5	Secret Ravine above Rocklin Road	10/15/02	1.1
B	5	Secret Ravine above Rocklin Road	10/15/02	1.0
A	6	Secret Ravine at Miner's Ravine	3/9/02	10.8
A	6	Secret Ravine at Miner's Ravine	3/9/02	10.8
A	6	Secret Ravine at Miner's Ravine	5/19/02	9.2
A	6	Secret Ravine at Miner's Ravine	6/15/02	1.9

A	6	Secret Ravine at Miner's Ravine	6/15/02	2.0
A	AA	Secret Ravine below Sewer Crossing	6/18/02	1010.0
A	6	Secret Ravine at Miner's Ravine	10/5/02	2.2
A	6	Secret Ravine at Miner's Ravine	11/8/02	51.7

RISK REGION	**Site ID**	**Sample Location**	**Start Date**	**TURB (NTU)**
A	SR at Miner's Ravine	First Flush	11/8/02	51.7
A	Miner's Ravine at SR	First Flush	11/8/02	29.5
unknown		Secret Ravine above Smaller Side Stream	12/11/01	2.6
unknown		Smaller Stream above Lower Pipe X-ing	12/11/01	81.3
unknown		Secret Ravine above Larger Side Stream	12/19/01	3.4
unknown		Secret Ravine 20' below Side Stream	12/19/01	27.6
unknown		Larger Side Stream below Lower Pipe X-ing	12/19/01	191.0
unknown		Secret Ravine above Smaller Side Stream	12/19/01	2.8
unknown		Secret Ravine below Lower Side Stream	12/19/01	10.6
unknown		Smaller Stream above Lower Pipe X-ing	12/19/01	178.0
unknown	B	Secret Ravine ~ 50M Below Ditch Outfall	3/23/02	45.0
unknown	B	Secret Ravine ~ 50M Below Ditch Outfall	3/23/02	46.0
unknown	C	Secret Ravine Beyond Sediment Trail	3/23/02	24.0
unknown	D	Secret Ravine ~ 5Mm Below Ditch Outfall	3/23/02	160.0
unknown	D	Secret Ravine ~ 5Mm Below Ditch Outfall	3/23/02	156.0
unknown	E	Secret Ravine ~ 1M Below Ditch Outfall	3/23/02	1925.0
unknown	E	Secret Ravine ~ 1M Below Ditch Outfall	3/23/02	1910.0
unknown	A	Near Greenbrae Rd - Barrington Hills Drain	5/19/02	3710.0
unknown	E	Secret Ravine ~ 1M Below Ditch Outfall	5/19/02	3010.0
unknown	B	Secret Ravine ~ 50M Below Ditch Outfall	5/21/02	32.2
unknown	E	Secret Ravine ~ 1M Below Ditch Outfall	5/21/02	182.0

Sediment in the Water Column (Turbidity) Data

$$\text{SEV (severity of ill effects)} = a + b*(\log_e x) + c*(\log_e y)$$

The a, b and c values are constants specific to the life stage; x is duration of exposure (in hours) and y is concentration of suspended sediment (in mg/L).

Constants	**Adult**	**Juvenile**	**Eggs**
a	1.68	0.73	3.75
b	0.48	0.70	1.09
c	0.76	0.71	0.31
SEV values			
Risk Region	**Adult**	**Juvenile**	**Eggs**
A	8	7	8
B	7	11	7
C	6	7	6
D	No data	No data	No data
E	No data	No data	No data

SEV VALUES FOR TURBIDITY

Appendix J-2: Flow

Risk Characterization for Flow (MRRM)

Flow Rankings (Benthos and Water Column)

All risk regions had critical depths below 24 cm (ranging from 4.95 cm in risk region C to 22.25 cm in risk region B) and thus were assigned a rank of six for the water column.

Risk Regions D and E had calculated critical depths of 15.82 cm. They were both assigned a rank of four in the benthos based on the optimal spawning depths (Allen et al. 1998). Risk Region C received a rank of six for the benthos since the estimated critical depth (4.95 cm) was well below 10 cm. Risk Regions A and B both had relatively high critical depths (20.27 cm and 22.25 cm respectively) and were thus assigned risk ranks of two.

Risk Region	Rank (water column)	Rank (benthos)
A	6	4
B	6	4
C	6	6
D	6	2
E	6	2

FINAL RANKS FOR FLOW

Appendix J-3: Morphology

Risk Characterization for Morphology (MRRM)

Morphology Rankings (Benthos and Water Column)

Risk Regions A and B both had percent pools by length (PBL) between 20% and 30%. A risk rank of 6 was therefore assigned to both the water column and benthos for these risk regions. Ranks for Risk Regions C, D and E were extrapolated from the percent pools reported for Risk Regions A and B. The average percent pools by length was estimated to be very low (16%). This resulted in a risk rank of 6 for all three of the upper risk regions.

Risk Region	**Rank**
A	6
B	6
C	6
D	6
E	6

FINAL RANKS FOR MORPHOLOGY FOR THE BENTHOS AND WATER COLUMN

Appendix J-4: Temperature

Risk Characterization for Temperature (MRRM)

Temperature Rankings (Benthos and Water Column)

The available data for Risk Region B reveals that water temperatures have not risen to temperatures high enough to threaten egg development and survivability for chinook salmon. Risk Region B indicates that the temperature range for November through February ranges from 6.1 – 11.2 ºC. This indicates that Secret Ravine temperatures are well under the 14.5 ºC threshold, and thus receive a rank of zero for the egg/yolk-sac fry life stage. The final rank for the benthos habitat of this life stage is zero, or no risk. The available data for Risk Region B reveals that water temperatures have not risen to temperatures high enough to threaten juvenile development and survivability for chinook salmon for the months of February, March, and April. All of these months show temperatures below the maximum weekly temperature of 15.6 ºC. In May, however, the mean temperature of Risk Regions A and E is 17.4 ºC. This value indicates risk to the juvenile life stage in Secret Ravine. Also the available data for Risk Region B reveals that water temperatures have risen to temperatures high enough to threaten adult migration and survivability for chinook salmon. Risk Region B indicates that the temperature range for September through November is 11.2 – 19.0 ºC, while October has a temperature of 17.9 ºC and thus receives a rank of 2. September has a temperature of 19.0 ºC and thus receives a rank of 4. To generate the rank for the water column habitat, the most conservative monthly rank for the adult and juvenile life phase was assigned. The final rank for the water column habitat is 4.

Life Stage	Final Rank
Egg/Fry	0
Juvenile	4
Adult	4

SUMMARY TABLE OF FINAL RANKS FOR TEMPERATURE

Site	**Sub-watershed**	**E**	**J**	**A**
Confluence	A	0	4	4
Secret Court	B	0	4	4
Dias Lane	C	0	4	4
King Road	D	0	4	4
Rock Springs Rd.	E	0	4	4

SUMMARY TABLE OF FINAL RANKS ACROSS THE RISK REGIONS

Appendix J-5: Altered Riparian Vegetation

Risk Characterization for Altered Riparian Vegetation (MRRM)

Altered Riparian Vegetation Rankings (Benthos and Water Column)

In the context of the temporal condition of Secret Ravine, the vegetation composition has changed considerably over the last century and the quality of the habitat has been degraded in comparison to pre-Columbian California. Overall, the condition of Secret Ravine in the broader context of foothill streams maybe evaluated as fair. The creek has a fair degree of riparian cover, a fair degree of riparian zone extent, and only a few areas where the riparian zone narrows to less than a 100-foot buffer. Within the watershed itself, however, gradations in riparian zone extent, areas with a riparian zone less than the ascribed riparian buffer of 100-ft, may indicate gradations in vegetation quality between risk regions. Assigning of ranks used these gradation in riparian buffer to evaluate whether the risk region had a 2 or 4 rank.

Risk Region	**Incidences of <100 ft**	**Length of Incidence (feet)**	Ranks
A	3	3935	4
B	1	323	2
C	1	281	2
D	3	855	2
E	1	201	2
		5595	

SUMMARY OF INCIDENCES OF OVERLY SMALL RIPARIAN ZONE EXTENT

Appendix J-6: Reduced Access

Risk Characterization for Reduced Access (MRRM)

Reduced Access Rankings (Water Column)

Risk Region B received a six because it contains several beaver dams that are difficult to pass for most fish in both high and low flow conditions, in addition to what is considered a very prohibitive barrier in terms of reduced access for adult fish. This barrier consists of "cattle wire fencing strung across [the Sierra College Boulevard underpass] in triplicate in most places" with 4x4-inch holes not lined up with each other, making it impossible for a fish with the ability to weigh up to sixty kilograms, to navigate through (B. Washburn pers. comm. 2003). Surveyors confirm that they have seen salmon aggregating downstream of this obstruction behind Sierra College, north of Rocklin Road (G. Bates and B. Washburn, pers. comm. 2002). Indeed, the count records for the past six years seem to reflect this trend, as given below. Complete count data is located in **Appendix M-1: Reduced Access**.

Risk Region A contains a higher density of closely spaced beaver dams, but only two that pose problems under low flow conditions. However, Risk Region A contains several barriers, including an old concrete apron, responsible for creating one of "the more noteworthy deep [1st class] pools throughout the reach" (Vanicek 1993). This risk region also contains the highest concentration of known spawning sites.

We assigned Risk Regions C, D and E '0s' based on lack of available data, although there are anecdotal accounts that beaver dams were seen up in the lower extremes of Risk Region E in the fall season (Lieberman, S. pers. account, Rock Springs Road toxicity sampling site, 2002). Big boulders and large woody debris also characterize the upper risk regions, factors that would normally yield excellent flow conditions, if it were not for meager suitable substrate. Below are the tables that we used to determine passage via the '150%' rule.

Risk Region	Rank
A	4
B	6
C	0
D	0
E	0

FINAL RANKS FOR REDUCED ACCESS

Raw Data and Mathematical Models for Analyzing Sediment in the Benthos

Dam site	**Risk region**	**Type of barrier**	**Photo(s)**	**Coordinates**	**Stream types (downstream)**	**Downstream pool depth (average)**	**Date data taken**	**Height of dam**
1	A	concrete dam (G. Marsh)	**PS03**	2212380, 398824	pool	2	2001	3
2	A	not a dam, but an underpass; danger in very low flows	**SR27, 26, PS09**	221332, 400152	n/a	0.4	7/25/2002	n/a
3	A	fallen log (12" above water)	SR91-88	221529, 402384	run, riffle, run	1	8/13/2002	n/a
4	A	beaver dam	SR143-139	221704, 404344	pool, run, riffle	2.1	8/17/2002	2
5	A	beaver dam (submerged)	**SR157-156**	221769, 404447	pool, riffle, pool	3.8	8/17/2002	3
6	A	beaver dam (instream)	SR176-175	2218846, 405295	riffle, run, pool	1.2	8/17/2002	3
7	B	concrete dam (C.D. Vanicek)	none	2221064, 407554	pool	2	1993	3
8	B	beaver dam	**SR296-294**	2223690, 410663	run, riffle	0.9	10/26/2002	4
9	B	beaver dam	SR304-302	2224470, 411349	riffle, run, riffle	0.6	10/26/2002	1
10	B	beaver dam	SR319-320	2225170, 412169	riffle, pool	1.3	10/26/2002	3
11	B	beaver dam (G. Bates)	SR320	2225513, 412382	run, riffle, pool	2.2	10/26/2002	2
12	B	Sierra College Blvd. fence (B. Washburn, Bren students)	**PS18**	2226622, 412799	n/a	n/a	2002	
13	B	beaver dam	none	2235416, 423111	pool	1	12/6/2002	2.75
14	B	beaver dam	none	2239758, 424016	pool	0.87	12/6/2002	1.58

CRITERIA FOR ASSESSING REDUCED ACCESS

Low flow scenario/(early fall)	High flow scenario/ (late fall)	Area downstream from barrier (square feet)	Total area downstream from barrier (square feet)	Percent area upstream (square feet)	Source rank (2,4 or 6)	Habitat rank (constant)	Exp2	Effects rank (0,4, or 6)	Exposure rank (0 or 1)	Final Risk Score
1.50	0.86	0	**0**	**1.00**	**6**	**4**	**1**	**4**	1	**96**
n/a	n/a	3647623	3647623	**0.99**	6	4	**1**	0	1	**0**
n/a	n/a	10995125	14642748	**0.98**	6	4	**1**	0	1	**0**
0.95	0.54	13158434	27801182	**0.96**	6	4	**1**	0	1	**0**
0.79	0.45	1093549	28894731	**0.95**	6	4	**1**	0	1	**0**
2.50	1.43	5232983	34127714	**0.95**	6	4	**1**	4	1	**96**
1.50	0.86	36124588	70252302	**0.89**	**6**	**6**	**1**	**4**	1	**144**
4.44	**2.54**	47668088	117920390	**0.81**	4	6	**1**	6	1	**144**
1.67	0.95	8772245	126692635	**0.80**	4	6	**1**	4	1	**96**
2.31	1.32	14212081	140904716	**0.78**	4	6	**1**	4	1	**96**
0.91	0.52	3172838	144077554	**0.77**	4	6	**1**	0	1	**0**
		3685449	147763003	**0.77**	4	6	**1**	6	1	**144**
2.75	**1.57**	36484346	184247349	**0.71**	**2**	**6**	**1**	**6**	1	**72**
1.82	1.04	2914536	187161885	**0.70**	**2**	**6**	**1**	**4**	1	**48**

629310892 total s.r. area

1.75 stream depth at China Gd Road 12/6/02

1 average depth for ECORP stream-type values downstream of barriers

1.75 correction factor using only pool depth associated with barriers

CRITERIA FOR ASSESSING REDUCED ACCESS

The first column of data refers to the barrier site, ranging from 1-14. Barrier "1" is the most downstream barrier, "14," the most upstream barrier. The barriers are also referred to using these numbers on the GIS map in **Appendix B: GIS Maps**. The Risk Region refers to the risk region in which the barrier is located. The photos column indicates barriers for which photographs were taken and analyzed. The photographs in bold are located the photographs section below. Coordinates refer to UTM coordinates in GIS.

The ratio of downstream average pool depth to height of barrier immediately upstream of that pool (or other stream type) was used to assess whether or not the fish could be expected to pass (by the 150% rule, the height of the downstream pool needed to be at least 150% of the barrier immediately upstream of it). Low flow scenarios reflect fairly low flow averages as the depths associated with the pools (or other stream types) at the time ECORP conducted the survey were taken during the late summer/early fall. High flow depths used the depth estimated from the flow data taken by group members in December 2002 at the China Garden Road Gauge, following the second major storm event of the year.

Area upstream of a particular barrier was measured for the source analysis for the MRRM. We drew polygons in ArcMap in order to estimate the square-foot area upstream of each barrier and divided this by the total area of the watershed. Hence, the further downstream a particular barrier, the greater potential for an adult migrating upstream to encounter potential passage problems.

Source ranks, habitat ranks, exposure filter ranks and final ranks for reduced access are included in this spreadsheet in order to be able to determine how different factors affected the final outcome for risk scores per risk region.

Appendix J-6: Reduced Access

Photographs for Reduced Access

Concrete Dam at Confluence (Barrier #1 on GIS Map)

Interstate I-80 Underpass (Barrier #2 on GIS Map)

Cattle Fence on Secret Ravine

Fence Underneath Sierra College Boulevard (Barrier #12 on GIS Map)

Pool Below Beaver Dam Looking Upstream (Barrier #5 in GIS Map)

Run and Beaver Dam looking Upstream (Barrier #8 in GIS Map)

Appendix J-7: Toxicity

Risk Characterization for Toxicity (MRRM)

Toxicity Rankings (Benthos and Water Column)

Risk Region	Rank (water column)	Rank (benthos)
A	0	2
B	0	6
C	0	4
D	0	2
E	0	6

SUMMARY TABLE OF FINAL RANKS FOR TOXICITY

Raw Data for Characterizing Toxicity in the Benthos

Summary of 10-day *Hyalella* sediment toxicity test conducted on Dry Creek samples collected 5 December 2002.[1]

Treatment	Growth[2] (mg/surv indiv)		Mortality[2] (%)	
	x	se	x	se
Laboratory Control	0.121[P]	0.012	6.3[P]	4.0
Confluence Eureka & Sunrise Road	0.213	0.016	22.5	17.0
Secret Court	0.173	0.025	41.4	21.0
Dias Street	0.192	0.021	60.0	25.0
King Road	0.188	0.020	21.4	18.0
Rock Springs Road	0.179	0.047	52.5	17.0

Quality Assurance Sample

Treatment	Growth[2] (mg/indiv)		Mortality[2] (%)	
	x	se	x	se
Control Duplicate: DIEPAMHR	0.119	0.022	7.1	4.0

1. Test initiated on 24 December 2002.
2. Highlighted areas indicate a significant increase in mortality or decrease in growth when compared to the laboratory control. The growth and mortality endpoints were analyzed with Dunnett's Test ($p<0.05$).

P. The laboratory control met the criteria for test acceptability.

SUMMARY TABLE FOR TOXICITY TESTING

Appendix J-8: Metals

Risk Characterization for Metals (MRRM)

Metals Rankings (Benthos)

Lead

Since all the risk regions exhibit Pb values well over the National Recommended Water Quality Criteria for freshwater (2.5 μg/L), all of the risk regions pose a chronic threat to chinook salmon. All risk regions therefore receive a rank of 6.

Risk Region	Pb (ug/L)	EPA Rec. CCC (ug/L)	Rank
A	36	2.5	6
B	270	2.5	6
C	83	2.5	6
D	56	2.5	6
E	420	2.5	6

FINAL RANKS FOR LEAD

Copper

Since all the risk regions exhibit Cu values well over the EPA's National Recommended Water Quality Criteria for chronic exposure to copper (9.0 μg/L), all of the risk regions pose a chronic threat to chinook salmon. All risk regions therefore receive a rank of 6.

Risk Region	Amount Cu (ug/L)	EPA Rec. CCC (ug/L)	Rank
A	83	9.0	6
B	520	9.0	6
C	230	9.0	6
D	140	9.0	6
E	760	9.0	6

FINAL RANKS FOR COPPER

Zinc

Since all the risk regions exhibit Zn values well over the EPA's National Recommended Water Quality Criteria for chronic exposure to copper (120 μg/L), all of the risk regions pose a chronic threat to chinook salmon. All risk regions therefore receive a rank of 6.

Risk Region	Zn (ug/L)	EPA Rec. CCC (ug/L	Rank
A	280	120	6
B	2300	120	6
C	430	120	6
D	210	120	6
E	1000	120	6

FINAL RANKS FOR ZINC

Appendix J-9: Food Supply

Risk Characterization for Food Supply (MRRM)

Food Supply Rankings (Water Column)

The amount of riffle habitat available to invertebrates is also important. Riffles are the most important habitat for benthic invertebrates because they are produced there and live there (DCC 2001). In Secret Ravine riffles have been characterized as low in abundance and in quality across the entire creek (Li and Fields, Jr. 1999). Consequently, risk to salmon is increased if suitable invert habitat is not available. Due to the similarities across the creek, the same rank should be assigned across all risk regions.

In light of the above analysis, food supply was ranked as 2 for all risk regions. The percentage analysis and feeding habits of juveniles indicated that food supply should be ranked as zero because there is minimal risk associated. But the quality and abundance of riffles in Secret Ravine increases the risk of a depleted food supply. Subsequently, all risk regions were given a rank of 2 for food supply.

From the sampled invertebrate assemblages, the percentage of edible invertebrates was calculated (**Table 2**). In Risk Region A 62% of the invertebrates were edible, in Risk Region B 65%, and in Risk Region C 63%. No data was collected in the upper two risk regions, therefore the average percent of edible invertebrates (63%) was used.

	Risk Region A			Risk Region B			Risk Region C			R.R. D	R.R. E
	2001	2000	1999	2001	2000	1999	2001	2000	1999		
# of invertebrates found	945	317	1158	891	no data collected	1169	no data collected	no data collected	1216	no data collected	no data collected
# of edible invertebrates	485	214	672	590		747			761		
% edible invertebrates	62%			65%			63%			63%	63%
subsequent rank	2			2			2			2	2

PERCENTAGE OF EDIBLE INVERTEBRATES ACCORDING TO RISK REGION

Raw Data and Mathematical Models for Characterizing Food Supply in the Water Column

To characterize the food supply in Secret Ravine, an understanding of recent benthic macroinvertebrate populations was needed. Two studies that spanned from 1999-2001 were utilized: The benthic macroinvertebrate fauna of Secret Ravine Creek, Placer County, California (Fields, Jr. 1999) and the Benthic Macroinvertebrate Counts performed by the Dry Creek Conservancy (unpub. DCC 2001). W.C. Fields, Jr. performed his study on September 3, 1999, where he analyzed six sites throughout Secret Ravine. The Dry Creek Conservancy performed their studies in 2000 and 2001, where four sites in total were analyzed. Both counts were conducted using California Stream Bioassessment Protocol, therefore all samples were taken within the riffles of Secret Ravine. Consequently, data from both studies were combined for this analysis.

Sampled sites were separated into groups according to their appropriate subsection of the creek (**Table 1**). Risk Region A had 5 sample sites, Risk Region B had 3 sample sites, Risk Region C had 2 sample sites, and Risk Region D and E had no sample sites.

	Dry Creek Conservancy		**Fields, Jr.**
	2001	**2000**	**1999**
Risk Region	**Sampled Sites**	**Sampled Sites**	**Sampled Sites**
A	Secret Ravine at Miners Ravine	Secret Ravine at Miners Ravine	Upstream of Miners Ravine
		Gravel site at hospital	Meadow near end of China Garden Rd
B	Sierra College		Downstream of Dominguez Rd
			Behind Sierra College
C			Horseshoe Bar Rd
			Loomis Basin Park
D			
E			

LOCATION OF SITES SAMPLED FOR BOTH STUDIES

For each risk region of the creek, invertebrate counts from all representative sites were combined.

It was determined which of the sampled invertebrates were a food source for juvenile chinook. Of the aforementioned food sources, all were found except copepods and water fleas.

From the sampled invertebrate assemblages, the percentage of edible invertebrates was calculated. In Risk Region A 62% of the invertebrates were edible, in Risk Region B 65%, and in Risk Region C 63%. No data was collected in the upper two risk regions, therefore the average percent of edible invertebrates (63%) was used.

In order to characterize each risk region further, it was proposed to normalize each edible invertebrate percentage by the percentage of riffle found in that risk region. This idea proved to be ineffectual because percent riffle could only be calculated for Risk Region A and Risk Region B. An average percent riffle would have to be used for the upper three regions.

Essentially every region would be multiplied by the same factor, not helping in the characterization process.

Appendix J-10: Predation

Risk Characterization for Predation (MRRM)

Predation Rankings (Water Column)

Spotted bass have been found throughout the Secret Ravine watershed meaning that no risk region will be assigned a value of 0 for fish predation. The upper sections of Secret Ravine (Risk Region C, Risk Region D, and Risk Region E) tended to have local abundances of bass and sunfish, however the habitat quality for spotted bass decreases as the stream decreases in size and increases in slope (Swanson 2000, Titus 2003 unpublished). For this reason and the direct observation of this change in fish community by Rob Titus, the rank for fish predation was given a 2 for Risk Region C, Risk Region D, and Risk Region E.

Having established that the creek located closest to the confluence tends to contain more abundant spotted bass, these risk regions may be the location where the majority of predation by fish occurs. Therefore, Risk Region A and Risk Region B were evaluated using a "snap shot in time" of the predation of spotted bass on juvenile chinook (See Appendix P). The predation model predicted a 7% to 14% percent reduction in salmon biomass given two separate population scenarios based on fish count numbers from 1999 and 2002. Though rough estimates, these numbers indicate that for those areas of Secret Ravine where spotted bass are abundant a ranking of 4 should be assigned.

Risk Regions	Rank Assigned for Water Column Habitat
A	4
B	4
C	2
D	2
E	2

FINAL RANKS FOR PREDATION

Raw Data and Mathematical Models for Characterizing Predation in the Water Column

Possible Predation of Juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) by Spotted Bass (*Micropterus punctulatus*)

The data provided by Dr. Rob Titus of the California Fish and Game contained a biomass estimation of spotted bass and a population study of out-migrating chinook salmon. The results of his study of Secret Ravine are summarized in Table 1 and Table 2.

"Biomass of Sacramento pikeminnow and black bass – primarily spotted bass – was estimated in a 30 m (177 m^2) section of Secret Ravine upstream from the East Roseville Parkway crossing on 28th October 2002. This work was done as a field exercise with the California State University, Sacramento fishery biology class. Abundance of these species was estimated with the two-pass removal method with use of electrofishing. Abundance estimates were then multiplied by the observed mean weight of each species to estimate biomass" (Attributed to Titus 2003).

Biomass of Spotted Bass Oct. 2002 *(Micropterus punctulatus)*	
The section of Secret Ravine studied	30 m (177 m^2)
Number of spotted bass	96
Average mass of bass observed	26 g
Total biomass of the stream section	2506 g
Biomass density of spotted bass	14.2 g/ m^2

BIOMASS OF SACRAMENTO PIKEMINNOW AND BLACK BASS

"The gear to catch juvenile salmon was a 5-foot diameter rotary screw trap, located at the confluence of Secret Ravine and Miners Ravine and fished from November 6, 1998 through June 2, 1999, and from January 9, 2000 through June 8, 2000" (Attributed to Titus 2003).

	Juvenile Salmon Caught	
	1999	2000
January	0	5
February	658	103
March	1038	52
April	1375	57
May	1513	184
June	4	0

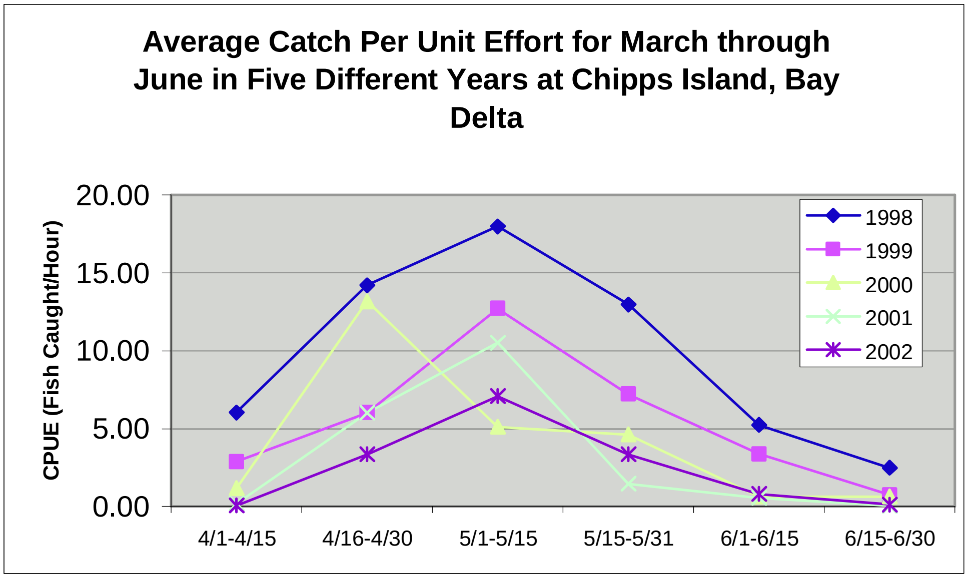
SCREW TRAP CATCH OF JUVENILE SALMON

These data sets provided the basis of the analysis of predation on salmon by non-native fish. The analysis concentrated on non-native fish for two reasons: spotted bass dominate the lower region of the watershed where the majority of the spawning habitat exists and salmon coevolved with the native fish in this environment and presumably have effective behaviors to minimize the consequences of this predation. The data sets, on the juvenile salmon and spotted bass population in Secret Ravine, are incomplete therefore projections filled some data gaps for the sake of this snap shot in time analysis. The analysis calculates three projected values the amount of chinook salmon hatched in Secret Ravine, the amount of biomass these salmon would grow in Secret Ravine, and the amount of biomass the number of spotted bass observed in the creek would be expected to consume.

Projecting Juvenile Salmon Biomass for 2002:

The screw trap study on Secret Ravine contained two years of data on the creek. One of these years 2000 was further investigated to see whether the crash in the Secret Ravine population was consistent with trends in the larger system. The Chipps Island data sampled the population of fish that the Secret Ravine salmon joined in the Bay Delta estuary and this data represents the most complete information readily available on the estuary. The salmon population in 1999 in the Bay Delta system appeared to reflect trends emergent in four out of the last five years (Figure 1), while the 2000 data seems to be indicative of a population crash in the salmon stocks. Therefore, the 2000 population were excluded from the analysis. This created a problem. With only one year of data and no way to quantify the population of salmon in Secret Ravine in 2002, the analysis could only investigate one year of data 1999 and the bass population was unknown. To overcome this problem a projection of juvenile chinook for 2002 was generated.

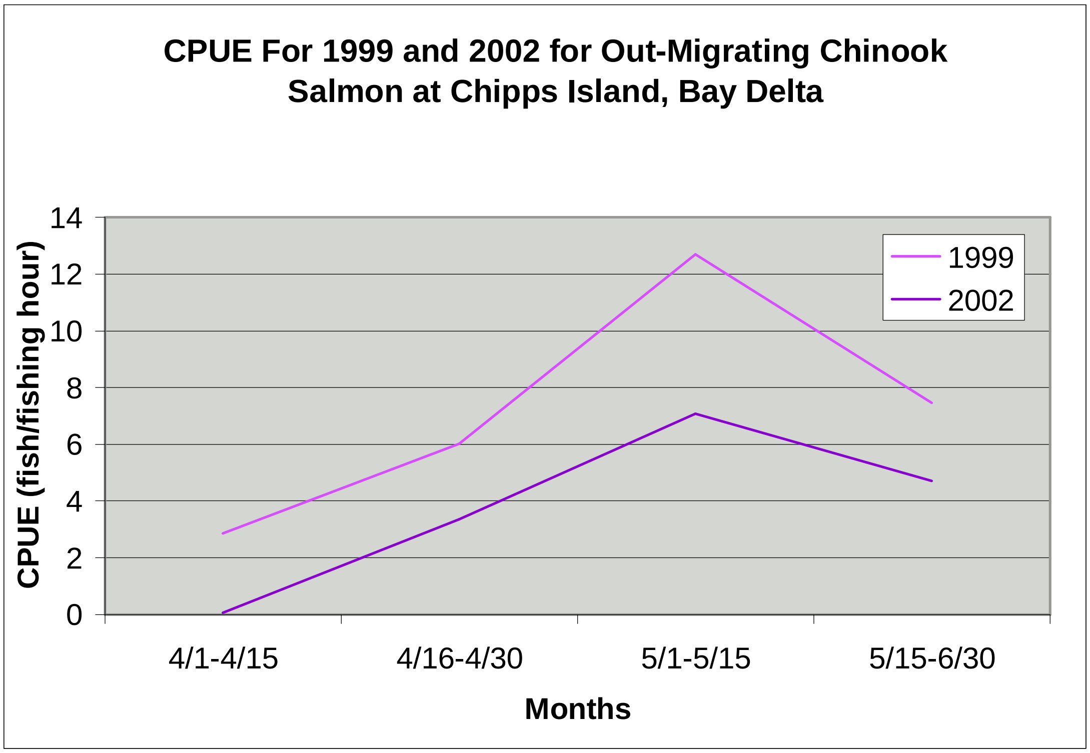
Two populations of animals in the same ecosystem may not always exhibit the same trends in abundance from year to year. However resident populations tend to remain more stable in comparison to migrating populations. For this reason the population estimate of spotted bass in 2002 was projected back to 1999, but direct use of the salmon population of 1999 for 2002 did not seem wise. So in consequence, it was decided to try and project the juvenile salmon biomass for Secret Ravine in 2002 using a larger system, Bay Delta estuary, with data in 2002 as a model.



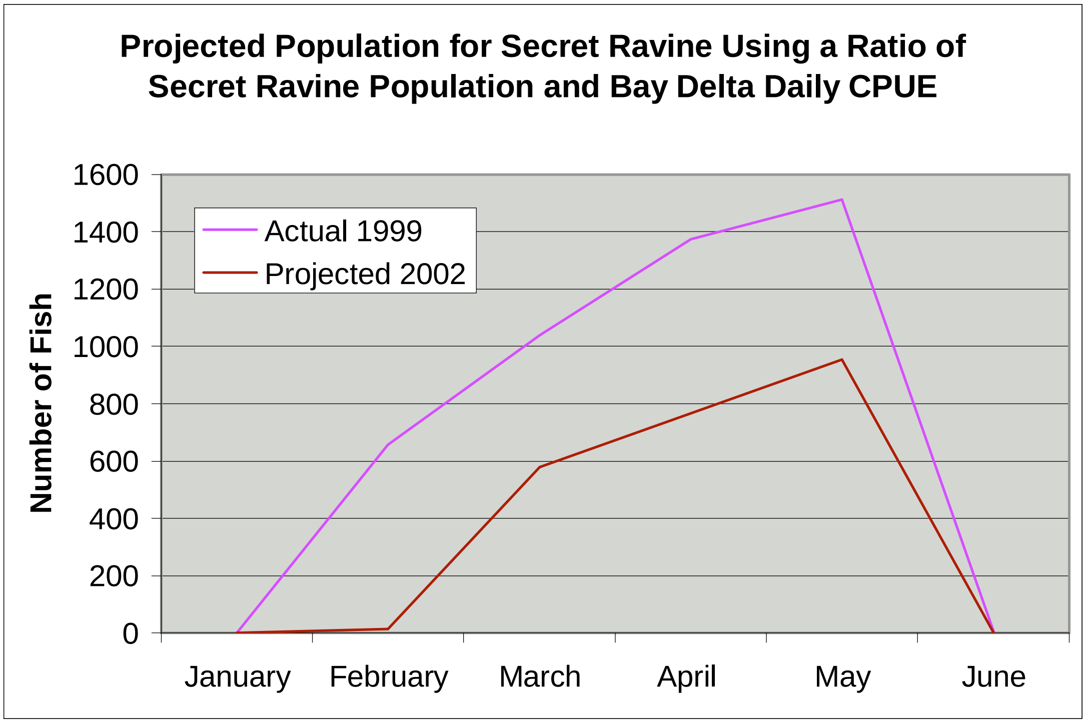
REAL TIME MONITORING DATA FROM DEPARTMENT OF FISH AND GAME, BAY DELTA BRANCH

Figure 2 shows the real time monitoring data from Department of Fish and Game, Bay Delta Branch. The real time system provided the fishing statistics, catch per unit effort, for Chipps Island from March to June for 1998 to 2002. Trawling has been conducted at Chipps Island since 1976, in most years from April through June during peak fall run out-migration. The Chipps Island data sampled the population of fish that the Secret Ravine salmon joined in the Bay Delta estuary and this data represents the most complete information readily available.

We used the ratio between the population values observed in Secret Ravine in 1999 compared to the larger system of the Bay Delta to translate the population numbers for the Bay Delta in 2002 into estimates of the number of out-migrating chinook salmon in 2002 in Secret Ravine. Figures 2 and 3 show the data trends at the estuary and the data simulated in Secret Ravine for 2002. Comparing the peak out-migration period in Secret Ravine to the peak out-migration period in the estuary generated the ratios used to translate migration at the Bay Delta to estimates on Secret Ravine. Then by working back from the peak out-migration, two-week averages for the Chipps Island data was correlated to the preceding month in Secret Ravine.



AVERAGE CATCH PER UNIT EFFORT FOR 1999 AND 2002 FOR CHIPPS ISLAND, BAY DELTA FROM THE REAL TIME DATA SET.



ACTUAL AND PROJECTED INITIAL POPULATIONS OF OUT-MIGRATING JUVENILE SALMON FOR SECRET RAVINE IN 1999 AND 2002.

Salmon Biomass

The projected biomass of salmon in the stream during the spring months of March to June came from the integration of five different types of data: screw trap data from the confluence of Secret Ravine in 1999, projection data from 2002, a growth function from the San Francisco estuary, monitoring data of out-migrating juvenile numbers from daily monitoring done by midwater trawl by California Fish and Game, and Bay Delta branch and juvenile survival rates developed by National Marine Fisheries for sub-yearling chinook salmon.

So the Secret Ravine screw trap data from 1999 and the projected 2002 data was used to estimate the numbers of juvenile fish hatched in Secret Ravine. The raw screw trap and projected screw trap data was then corrected for the size of the trap and the hours of operation (Table 3). Roughly these correction factors mean that the monthly screw trap sample represented one eighth of the juvenile salmon out-migrating from Secret Ravine.

Gear	Secret Ravine Conditions	Correction Factor
Screw Trap Diameter = 5ft	Creek Width = 15ft	2 * screw trap sample
Fished 40 Hours a Week	Continuous Migration	4 * screw trap sample

TO ESTIMATE THE POPULATION OF OUT-MIGRATING SALMON A CORRECTION FACTOR DUE TO GEAR SIZE AND HOURS OF OPERATION WAS USED.

To project the initial numbers of fish emergent in Secret Ravine, a survival of sub-yearling salmon from the Draft Biological Opinion conducted by NMFS on the Columbia River was necessary (NMFS 2000). This value of .599 came from the mean survival of fish from 1994 to 1999 through the pool reach prior to any dam passage. By dividing the corrected screw trap sample numbers by this survival value, an initial number of fish was approximated.

$$\text{INITIAL POPULATION}_{\text{CHINOOK SALMON}} = \text{CORRECTED SCREW TRAP NUMBERS}/.599$$

EQUATION 10: DETERMINING INITIAL POPULATION OF CHINOOK SALMON IN SECRET RAVINE (NMFS 2000)

Table 4 reports the initial population of fish in Secret Ravine for 1999 using the corrected screw trap values and the survival value. The next step in the salmon biomass assessment was to determine the median age of the fish in Secret Ravine. The MacFarlane study indicates that the average age of a salmon entering the San Francisco estuary was 136±2 days and given that it takes approximately a month for the fish to reach the estuary, the median fish age in the creek is 106 days (MacFarlane 2002). Once the median age was determined the initial population was 'grown'. Using Equation 2 developed by MacFarlane relating growth rate to age, the biomass of the initial population was determined.

$$\text{Mass of Salmon} = 2.68 + .029 * (\text{Age in Days})$$

EQUATION 11: JUVENILE CHINOOK SALMON GROWTH RATE (ATTRIBUTED MACFARLANE 2002)

	1999 Sample	Corrected Sample	Initial Population	Age(d)	Weight(g)	Biomass(g)
February	658	5264	8782	15	3.115	27,356
March	1038	8304	13854	45	3.985	55,208
April	1375	11000	18352	76	4.884	89,630
May	1513	12104	20194	106	5.754	116,194
					Total:	288,387

SAMPLE VALUES, CORRECTED VALUES, AND INITIAL POPULATION VALUES FOR 1999.

	2002 Projected Sample	Corrected Sample	Initial Population	Age(d)	Weight(g)	Biomass(g)
February	14	116	193.4109	15	3.115	602
March	578	4627	7719.116	45	3.985	30,761
April	766	6130	10226.13	76	4.884	49,944
May	953	7625	12721.47	106	5.754	73,199
					Total:	154,591

PROJECTED VALUES, CORRECTED VALUES, AND INITIAL POPULATION VALUES FOR 2002.

Biomass Consumed by Spotted Bass

The consumption of salmon by spotted bass utilize several sources of information, the biomass survey on Secret Ravine from the Titus survey and consumption rates of salmonids by bass based on weight from a study by Vigg. The amount of juvenile salmon consumed by small mouth bass on the Columbia River ranged from 1% to 7% of the overall diet of the fish and the overall diet of the fish is .0287of prey per day per gram of body weight (Vigg 1991). The spotted bass, a closely related fish, exhibits similar biology to the small mouth bass; indeed, in some California streams, the small mouth and spotted bass hybridize, so the use of these values seems justified (Dill 1997). Given the weight of the spotted bass and the 97 fish in the 30 meters of Secret Ravine surveyed, the consumption of the spotted bass was calculated (Table 1). The section surveyed, of Secret Ravine, only includes a small section of the lower reach of Secret Ravine where spotted bass is the dominant predator. In consequence to estimate the consumption value for the entire lower reach the biomass consumed was normalized for the 9,763 meters of the lower reach or risk regions A and B.

	Spotted Bass Consumption of Salmonids (g)		
	1%	4%	7%
March	7,302	29,210	51,117
April	7,067	28,268	49,468
May	7,302	29,210	51,117
June	7,067	28,268	49,468

CONSUMPTION OF SALMONIDS BY SPOTTED BASS GIVEN THE PROJECTED ABUNDANCE OF BASS IN SECRET RAVINE.

Percent of Juvenile Chinook Salmon Consumed By Spotted Bass

Once the consumption rates and the biomass of salmon have been calculated, the reduction of chinook salmon can be estimated. For the 1999 population of salmon, the effect of the 2002 population of bass would be approximately 8% to 53% reduction. Additionally, if the salmon population of 2002 followed the same trends as observed in 1999, which the real time out-migration data seem to indicate, then the rate of consumption could be from 14% to 98% of the total population.

	Salmon Consumed/Biomass Juvenile Salmon	
Consumption Rate	1999	2002
1%	8%	14%
4%	30%	56%
7%	53%	98%

THE PERCENT REDUCTION OF JUVENILE SALMON BY SPOTTED BASS PREDATION 1999 & 2002

Discussion

For the MRRM and the SDRM, the lowest percent consumption rate (1%) by spotted bass seems appropriate for two reasons: the relatively small size of the spotted bass (26 g) mean that the amount of larger prey should be a low percent of the bass diet and the cool temperatures of the creek that tend to depress bass activity. This rate was calculated for the years of 1999 and 2002 and compared with the estimated initial biomass of chinook salmon to produce the 8-14% rates reported in Table 7.

Appendix K: Stressor Risk Characterization

Category	Stressor	Filter	**Characterization**				
			Risk Region				
			A	**B**	**C**	**D**	**E**
Physical	Sediment	Water Column=1	2	6	2	2	2
		Benthos=1	2	4	6	4	4
	Flow	Water Column=1	6	6	6	6	6
		Benthos=1	4	4	6	2	2
	Morphology	Water Column=1	6	4	6	6	6
		Benthos=1	6	4	6	6	6
	Temperature	Water Column=1	4	4	4	4	4
		Benthos=1	4	4	4	4	4
	Altered Riparian Vegetation	Water Column=1	4	2	2	2	2
		Benthos=1	4	2	2	2	2
	Reduced Access	Water Column=1	4	6	0	0	0
		Benthos=1	4	6	0	0	0
Chemical	Toxicity	Water Column=0	0	0	0	0	0
		Benthos=1	2	6	4	2	6
	Metals	Water Column=0	0	0	0	0	0
		Benthos=1	6	6	6	6	6
Biological	Food Supply	Water Column=1	2	2	2	2	2
		Benthos=0	2	2	2	2	2
	Predation by Fish	Water Column=1	4	4	2	2	2
		Benthos=1	4	4	2	2	2

Appendix L: ECORP Habitat Survey Data

This data was used in the analyses for Morphology (MRRM and SDRM) and Reduced Access (MRRM).

Date	ID	Type	Length	Average Depth
7/25/2002	srf001	RIF	75.5	0.50
7/25/2002	srf002	RUN	38.9	0.87
7/25/2002	srf003	RIF	33.3	0.33
7/25/2002	srf004	RUN	15.1	1.07
7/25/2002	srf005	POOL	56.5	1.07
7/25/2002	srf006	RIF	43.9	0.43
7/25/2002	srf007	POOL	42.7	1.03
7/25/2002	srf008	RUN	222.9	0.37
7/25/2002	srf009	RIF	87	0.70
7/25/2002	srf010	RUN	35.7	0.63
7/25/2002	srf011	POOL	42	2.20
7/25/2002	srf012	POOL	60.7	2.57
7/25/2002	srf013	RUN	600.8	0.37
7/25/2002	srf014	RIF	44.3	0.53
7/25/2002	srf015	RUN	39.8	0.73
7/25/2002	srf016	POOL	25.8	2.23
7/25/2002	srf017	RIF	199.1	0.63
7/25/2002	srf018	POOL	30.8	1.00
7/25/2002	srf019	RIF	32.1	0.40
7/25/2002	srf020	RIF	75.2	0.43
7/25/2002	srf021	RUN	180.3	0.73
7/25/2002	srf022	POOL	25.1	2.20
7/25/2002	srf023	RIF	208.1	0.47
7/25/2002	srf024	RUN	289.8	0.80
7/25/2002	srf025	POOL	20.4	1.57
7/25/2002	srf026	RUN	615.7	0.40
7/25/2002	srf027	RIF	72.2	1.13
7/25/2002	srf028	POOL	15	1.23
7/25/2002	srf029	RIF	80.4	0.73
7/25/2002	srf030	RUN	263.3	0.83
7/28/2002	srf031	POOL	21.4	1.63
7/28/2002	srf032	RUN	190.7	0.93
7/28/2002	srf033	RIF	21.1	0.43
7/28/2002	srf034	RUN	164.5	0.60

Date	ID	Type	Length	Average Depth
7/28/2002	srf035	POOL	25	1.50
7/28/2002	srf036	RIF	33.6	0.43
7/28/2002	srf037	RUN	112.8	0.50
7/28/2002	srf038	POOL	28.6	2.10
7/28/2002	srf039	RIF	45.7	0.50
7/28/2002	srf040	RUN	158.3	0.87
7/28/2002	srf041	POOL	78.9	2.00
7/28/2002	srf042	RUN	50.8	0.73
7/28/2002	srf043	RIF	22.6	0.63
7/28/2002	srf044	RUN	54	1.03
7/28/2002	srf045	RIF	15.4	0.50
7/28/2002	srf046	RUN	128.7	0.80
7/28/2002	srf047	RIF	28	0.47
7/28/2002	srf048	RUN	194	0.60
7/28/2002	srf049	RIF		0.43
7/28/2002	srf050	RUN	293.7	0.60
7/28/2002	srf051	RIF	26	0.47
7/28/2002	srf052	RUN	241.2	0.83
7/28/2002	srf053	RIF	91.1	0.47
7/28/2002	srf054	RUN	23.4	0.87
7/28/2002	srf055	RIF	83.3	0.47
7/28/2002	srf056	POOL	39.6	2.13
7/28/2002	srf057	RUN	56.7	0.63
7/28/2002	srf058	POOL	23.4	1.63
7/28/2002	srf059	RIF	36.2	0.60
8/13/2002	srf060	POOL	22.2	1.07
8/13/2002	srf061	RIF	115.5	0.67
8/13/2002	srf062	POOL	14.3	0.93
8/13/2002	srf063	RIF	69.9	0.57

8/13/2002	srf064	RIF	29.5	0.43
8/13/2002	srf065	POOL	18.6	2.03
8/13/2002	srf066	RUN	49.6	0.90
8/13/2002	srf067	POOL	30.5	1.70
8/13/2002	srf068	RIF	18.5	1.33

Date	ID	Type	Length	Average Depth
8/13/2002	srf069	RUN	144.4	0.70
8/13/2002	srf070	POOL	34.8	2.07
8/13/2002	srf071	RIF	32.3	0.33
8/13/2002	srf072	RUN	16	0.70
8/13/2002	srf073	POOL	22.7	1.30
8/13/2002	srf074	RUN	82.3	0.53
8/13/2002	srf075	POOL	17.5	1.53
8/13/2002	srf076	RUN	96.7	0.90
8/13/2002	srf077	POOL	39.8	2.07
8/13/2002	srf078	RUN	141.4	1.00
8/13/2002	srf079	RIF	20.4	0.50
8/13/2002	srf080	POOL	24.6	1.17
8/13/2002	srf081	RIF	99.2	0.57
8/13/2002	srf082	RUN	77.7	0.60
8/13/2002	srf083	RIF	9	0.33
8/13/2002	srf084	RUN	20.6	0.70
8/13/2002	srf085	RIF	96.4	0.50
8/13/2002	srf086	RUN	153.9	1.00
8/13/2002	srf087	P0OL	16.1	1.03
8/13/2002	srf088	RIF	65.3	0.47
8/13/2002	srf089	RUN	70.3	0.57
8/13/2002	srf090	RIF	29.1	0.50
8/13/2002	srf091	RUN	475.4	0.57
8/13/2002	srf092	POOL	27.6	1.47
8/13/2002	srf093	RIF	47.1	0.57
8/13/2002	srf094	RUN	151.2	1.47
8/13/2002	srf095	RIF	42.4	0.40
8/13/2002	srf096	RUN	71.3	0.77
8/13/2002	srf097	RIF	34.5	0.83
8/13/2002	srf098	RUN	44	0.70
8/13/2002	srf099	POOL	171.9	1.40
8/13/2002	srf100	RIF	8.2	0.70
8/13/2002	srf101	POOL	27.1	1.30
8/13/2002	srf102	RIF		0.73
8/13/2002	srf103	RUN	37.8	0.93
8/13/2002	srf104	RIF	31.1	0.37
8/13/2002	srf105	RUN	24.9	0.87
8/13/2002	srf106	POOL	17.4	1.20
8/13/2002	srf107	RIF	10.5	0.43
8/13/2002	srf108	POOL	17.4	2.13
8/13/2002	srf109	RIF	12	0.77
8/13/2002	srf110	POOL	33	1.57
8/13/2002	srf111	RUN	48.8	1.30
8/13/2002	srf112	RIF	33.4	0.37

Date	ID	Type	Length	Average Depth
8/13/2002	srf113	RUN	48.2	1.07
8/13/2002	srf114	RIF	55.8	0.47
8/13/2002	srf115	RUN	23.1	0.73
8/13/2002	srf116	POOL	44.6	1.43
8/13/2002	srf117	RUN	45.9	1.27
8/13/2002	srf118	RIF	24.5	0.53
8/13/2002	srf119	RUN	32.9	1.03
8/13/2002	srf120	POOL	22.2	1.67
8/13/2002	srf121	RUN	108.2	1.10
8/13/2002	srf122	RIF	65.6	0.47
8/13/2002	srf123	RUN	42.9	0.73
8/13/2002	srf124	RIF	61.6	0.47
8/17/2002	srf125	RUN	94.5	1.23
8/17/2002	srf126	POOL	45.3	2.03
8/17/2002	srf127	RIF	61.9	0.70

Date	ID	Type	Length	Average Depth
8/17/2002	srf128	POOL	47.9	1.77
8/17/2002	srf129	RIF	30.1	0.50
8/17/2002	srf130	RUN	62	0.83
8/17/2002	srf131	POOL	26.8	1.83
8/17/2002	srf132	RIF	62.4	1.07
8/17/2002	srf133	POOL	99.9	1.83
8/17/2002	srf134	RIF	68.7	0.50
8/17/2002	srf135	POOL	96.6	1.50
8/17/2002	srf136	RIF	116.4	0.53
8/17/2002	srf137	RUN	29.4	1.17
8/17/2002	srf138	POOL	76.3	2.63
8/17/2002	srf139	RUN	49.7	0.63
8/17/2002	srf140	POOL	31.4	1.70
8/17/2002	srf141	RIF	39.7	0.57
8/17/2002	srf142	POOL	94.9	2.07
8/17/2002	srf143	RIF	25.2	0.53
8/17/2002	srf144	RUN	47.8	0.83
8/17/2002	srf145	POOL	108.6	1.70
8/17/2002	srf146	RUN	154.6	0.80
8/17/2002	srf147	RIF	120.1	0.73
8/17/2002	srf148	POOL	41.8	1.37
8/17/2002	srf149	RIF	39.6	0.47
8/17/2002	srf150	POOL	19.1	1.17
8/17/2002	srf151	RUN	37.7	0.87
8/17/2002	srf152	POOL	55	1.67
8/17/2002	srf153	RIF	92.7	0.57
8/17/2002	srf154	RUN	47.4	1.13
8/17/2002	srf155	POOL	58.1	1.50
8/17/2002	srf156	RIF	26.6	0.57
8/17/2002	srf157	POOL	39.8	3.80
8/17/2002	srf158	POOL	53.7	1.20
8/17/2002	srf159	RUN	584	1.03
8/17/2002	srf160	POOL	28.2	1.53
8/17/2002	srf161	RUN	244.7	0.83
8/17/2002	srf162	POOL	45.2	1.27
8/17/2002	srf163	RUN	100.6	0.50
8/17/2002	srf164	POOL	41.6	2.33
8/17/2002	srf165	RIF	56.1	0.73
8/17/2002	srf166	RUN	84.1	0.57
8/17/2002	srf167	POOL	42.4	1.23
8/17/2002	srf168	RIF	90.6	0.43
8/17/2002	srf169	POOL	35.7	1.53
8/17/2002	srf170	RIF	26.4	0.37
8/17/2002	srf171	RUN	26.2	0.70
8/17/2002	srf172	POOL	25	1.67
8/17/2002	srf173	RUN	67	0.97
8/17/2002	srf174	POOL	17	1.30
8/17/2002	srf175	RUN	22.8	0.70
8/17/2002	srf176	POOL	16.9	1.23
8/17/2002	srf177	RUN	73.1	0.40
8/25/2002	srf178	RIF	29	0.73
8/25/2002	srf179	POOL	33	1.40
8/25/2002	srf180	POOL	108	1.80
8/25/2002	srf181	RUN	31.2	1.23
8/25/2002	srf182	POOL	40.1	2.27
8/25/2002	srf183	RIF	47.5	0.63
8/25/2002	srf184	RUN	34.5	0.87
8/25/2002	srf185	RIF	43.3	0.47
8/25/2002	srf186	POOL	34.5	2.37
8/25/2002	srf187	RIF	63.8	0.60
8/25/2002	srf188	RUN	484.9	0.97
8/25/2002	srf189	POOL	32.6	1.17
8/25/2002	srf190	RUN	28.2	0.83
8/25/2002	srf191	RIF	24.1	0.60
8/25/2002	srf192	RUN	25.7	0.60

8/25/2002	srf193	POOL	37.6	1.57
8/25/2002	srf194	RUN	45	0.60
8/25/2002	srf195	POOL	65.3	1.60
8/25/2002	srf196	RIF	37.8	0.73
8/25/2002	srf197	POOL	42.3	2.10
8/25/2002	srf198	POOL	23.8	2.00
8/25/2002	srf199	RUN	80.9	1.00
8/25/2002	srf200	RIF	33.2	0.63
Date	**ID**	**Type**	**Length**	**Average Depth**
8/25/2002	srf201	RUN	35.9	0.67
8/25/2002	srf202	POOL	20.8	1.40
8/25/2002	srf203	RUN	42.5	0.83
8/25/2002	srf204	POOL	7.6	1.40
8/25/2002	srf205	RIF	13.2	0.43
8/25/2002	srf206	POOL	140.8	2.37
8/25/2002	srf207	POOL	51.1	1.30
8/25/2002	srf208	POOL	49.7	1.77
8/25/2002	srf209	POOL	32	1.53
8/25/2002	srf210	POOL	65.8	2.00
8/25/2002	srf211	POOL	22.3	1.63
8/25/2002	srf212	RUN	36	1.57
8/25/2002	srf213	POOL	69.8	3.47
8/25/2002	srf214	RUN	16.5	1.30
8/25/2002	srf215	POOL	97.6	1.83
8/25/2002	srf216	POOL	41.9	1.37
8/25/2002	srf217	RIF	13.7	0.47
8/25/2002	srf218	RUN	34	0.97
8/25/2002	srf219	POOL	24.2	1.90
8/25/2002	srf220	RUN	29.3	0.83
8/25/2002	srf221	POOL	66.7	1.90
8/25/2002	srf222	RIF	23.3	0.60
8/25/2002	srf223	POOL	46	1.47
8/25/2002	srf224	POOL	42.7	2.03

8/25/2002	srf225	RUN	24.4	1.30
8/25/2002	srf226	POOL	113.8	2.30
8/25/2002	srf227	RUN	15.6	1.00
8/25/2002	srf228	POOL	72.5	2.90
8/25/2002	srf229	RIF	42.8	0.97
8/25/2002	srf230	POOL	11.1	1.77
8/25/2002	srf231	RIF	26.1	1.30
8/25/2002	srf232	RIF	29.5	0.57
8/25/2002	srf233	RIF	28.9	0.90
8/25/2002	srf234	POOL	46	1.67
8/25/2002	srf235	RIF	99.6	0.67
END OF RISK REGION A				
8/25/2002	srf236	RUN	51	0.97
8/25/2002	srf237	POOL	39.1	1.37
8/25/2002	srf238	RIF	37.7	0.93
8/25/2002	srf239	POOL	20.5	1.63
8/25/2002	srf240	RUN	38.8	0.97
8/25/2002	srf241	POOL	69.5	2.73
8/25/2002	srf242	RUN	87	1.20
8/25/2002	srf243	RIF	60.8	0.40
Date	**ID**	**Type**	**Length**	**Average Depth**
8/25/2002	srf244	POOL	46.7	1.13
8/25/2002	srf245	RIF	29.6	0.70
8/25/2002	srf246	POOL	83.2	2.73
8/25/2002	srf247	RUN	31	0.43
8/25/2002	srf248	RIF	52.5	0.67
8/25/2002	srf249	POOL	33.4	3.30
8/25/2002	srf250	RUN	27	0.53
8/25/2002	srf251	POOL	82.7	2.50
8/25/2002	srf252	RUN	25.4	1.30
10/10/2002	srf253	POOL	60	2.63
10/10/2002	srf254	RIF	35.3	1.10
10/10/2002	srf255	RUN	63.6	0.80

Date	ID	Type	Length	Average Depth
10/10/2002	srf256	RIF	40.7	0.80
10/10/2002	srf257	POOL	46.6	1.90
10/10/2002	srf258	RUN	164.1	1.30
10/10/2002	srf259	POOL	149.9	2.57
10/10/2002	srf260	RUN	22.5	1.40
10/10/2002	srf261	POOL	26.8	2.83
10/10/2002	srf262	RUN	42.2	1.03
10/10/2002	srf263	POOL	24.8	2.30
10/10/2002	srf264	RUN	31.5	1.87
10/10/2002	srf265	POOL	71.7	2.73
10/10/2002	srf266	POOL	60	1.70
10/10/2002	srf267	RUN	26.6	1.53
10/10/2002	srf268	POOL	33.1	2.67
10/10/2002	srf269	RUN	29.4	1.03
10/10/2002	srf270	POOL	15	2.00
10/10/2002	srf271	RIF	67.6	1.10
10/10/2002	srf272	POOL	24.2	2.03
10/10/2002	srf273	RIF	10.6	0.73
10/10/2002	srf274	POOL	33.9	2.13
10/10/2002	srf275	POOL	23.5	2.27
10/10/2002	srf276	RUN	39.2	1.57
10/10/2002	srf277	RIF	92.8	0.67
10/10/2002	srf278	RUN	101.2	1.07
10/10/2002	srf279	POOL	56.7	1.83
10/10/2002	srf280	POOL	65.7	2.33
10/10/2002	srf281	RUN	93.8	1.50
10/10/2002	srf282	POOL	49.8	2.13
10/10/2002	srf283	RUN	26.3	0.73
10/10/2002	srf284	POOL	33	1.77
10/10/2002	srf285	RIF	54.5	1.17
10/10/2002	srf286	POOL	50.8	1.53
10/10/2002	srf287	RIF	49.3	0.90
10/10/2002	srf288	RUN	61.9	1.20
10/10/2002	srf289	POOL	83.9	1.77
10/10/2002	srf290	RUN	57.8	1.60
10/10/2002	srf291	POOL	130	2.93
10/10/2002	srf292	RIF	38.1	1.13
10/10/2002	srf293	RUN	130.3	1.33
10/10/2002	srf294	POOL	62.1	2.37
10/10/2002	srf295	RUN	45.1	0.83
10/10/2002	srf296	POOL	37.4	2.23
10/10/2002	srf297	RUN	41.7	0.73
10/10/2002	srf298	POOL	26.4	1.90
10/10/2002	srf299	RIF	106.2	1.07
10/10/2002	srf300	RUN	70	1.10
10/10/2002	srf301	POOL	41.5	2.13
10/10/2002	srf302	RUN	66.9	1.07
10/10/2002	srf303	POOL	26.3	2.13
10/10/2002	srf304	RIF	107.6	0.73
10/10/2002	srf305	POOL	39.2	2.70
10/10/2002	srf306	POOL	41.6	2.40
10/10/2002	srf307	RIF	51.5	1.13
10/10/2002	srf308	RUN	37.8	1.93
10/10/2002	srf309	RIF	29.4	0.77
10/10/2002	srf310	POOL	49.6	2.40
10/10/2002	srf311	RIF	50.6	0.93
10/12/2002	srf312	RUN	49.3	1.13
10/12/2002	srf313	RIF	9.3	0.50
10/12/2002	srf314	RUN	51.7	1.50
10/12/2002	srf315	RIF	14.6	0.70
10/12/2002	srf316	RUN	46	1.17
10/12/2002	srf317	POOL	39.8	1.63
10/12/2002	srf318	RUN	37.1	1.63
10/12/2002	srf319	RIF	12.8	0.37

10/12/2002	srf320	POOL	59.6	2.17
10/12/2002	srf321	RIF	43.9	0.53
10/12/2002	srf322	RUN	87.5	0.77
10/12/2002	srf323	POOL	26.3	1.83
10/12/2002	srf324	RIF	38.3	0.60
10/12/2002	srf325	RUN		0.83
10/12/2002	srf326	POOL		1.90
10/12/2002	srf327	RUN	27.9	1.20
10/12/2002	srf328	RIF	11.1	0.47
10/12/2002	srf329	RUN	35.6	1.33
10/12/2002	srf330	POOL	40.9	1.67

Date	**ID**	**Type**	**Length**	**Average Depth**
10/12/2002	srf331	RUN	40.8	0.87
10/12/2002	srf332	POOL	13.9	1.60
10/12/2002	srf333	RIF	57.7	0.63
10/12/2002	srf334	RUN	67.7	1.23
10/12/2002	srf335	POOL	29.6	1.67
10/12/2002	srf336	RIF	27.6	0.73
10/12/2002	srf337	RUN	37.7	0.73
10/12/2002	srf338	RIF		0.43
10/12/2002	srf339	RUN		1.17
10/12/2002	srf340	RIF	85.4	1.17
10/12/2002	srf341	POOL	47.6	2.27
10/12/2002	srf342	RIF	22.9	0.47
10/12/2002	srf343	RUN	84.8	1.10
10/12/2002	srf344	POOL	21.2	2.17
10/12/2002	srf345	RIF	20.7	0.67
10/12/2002	srf346	POOL	20.8	2.17
10/12/2002	srf347	RIF	20.9	0.63
10/12/2002	srf348	RUN	41.9	1.27
10/12/2002	srf349	POOL	22.1	1.83
10/12/2002	srf350	RIF	19.2	0.70
10/12/2002	srf351	POOL	31.5	1.23
10/12/2002	srf352	RUN	53.1	1.20
10/12/2002	srf353	POOL	19.3	1.93
10/12/2002	srf354	RUN	35.5	1.77
10/12/2002	srf355	RIF	50.2	0.43
10/12/2002	srf356	RUN	159.8	0.83
10/12/2002	srf357	POOL	21.6	2.40
10/12/2002	srf358	RIF	24.6	0.50
10/12/2002	srf359	RUN	252.5	0.83
10/12/2002	srf360	POOL	36.8	1.60
10/12/2002	srf361	RUN	276.1	0.90
10/26/2002	srf362	POOL	54.6	1.20
10/26/2002	srf363	RIF	143.1	0.83
10/26/2002	srf364	RUN	64.8	0.77
10/26/2002	srf365	POOL	39.8	2.97
10/26/2002	srf366	RUN	73.6	0.93
10/26/2002	srf367	RIF	42.1	0.40
10/26/2002	srf368	RUN	39	0.87
10/26/2002	srf369	RIF	23.2	0.33
10/26/2002	srf370	RUN	65.8	0.67
10/26/2002	srf371	POOL	19	1.80
10/26/2002	srf372	RIF	49	0.43
10/26/2002	srf373	RUN	70.5	0.90

Date	**ID**	**Type**	**Length**	**Average Depth**
10/26/2002	srf374	POOL	34.172	1.97
10/26/2002	srf375	RUN	375	0.87
10/26/2002	srf376	POOL	18.6	1.43
10/26/2002	srf377	RUN	297.1	0.67
10/26/2002	srf378	RIF	89.5	0.47
10/26/2002	srf379	RUN	102	0.53
10/26/2002	srf380	RIF	58.3	0.70
10/26/2002	srf381	RUN	30.2	0.90
10/26/2002	srf382	RIF	51.7	0.37
10/26/2002	srf383	RUN	19.7	1.03

10/26/2002	srf384	RIF	30.1	0.63
10/26/2002	srf385	POOL	31.2	1.50
10/26/2002	srf386	RUN	57.3	0.70
10/26/2002	srf387	POOL	43.7	2.13
10/26/2002	srf388	RUN	62.6	0.40
10/26/2002	srf389	RIF	91.2	0.43
10/26/2002	srf390	POOL	40.1	1.17
10/26/2002	srf391	RIF	13.9	0.37
10/26/2002	srf392	POOL	24	1.40
10/26/2002	srf393	RIF	57	0.47
10/26/2002	srf394	POOL	30.4	1.23
10/26/2002	srf395	RIF	28.2	0.40
10/26/2002	srf396	RUN	46.7	1.03
10/26/2002	srf397	POOL	34.9	1.13
10/26/2002	srf398	RUN	32.1	0.83
10/26/2002	srf399	POOL	12.6	1.27
10/26/2002	srf400	RIF	19.2	0.80
10/26/2002	srf401	RUN	23.2	0.77
10/26/2002	srf402	RIF	57.2	0.77
10/26/2002	srf403	RUN	94	0.53
10/26/2002	srf404	RIF	49.5	0.30
10/26/2002	srf405	RUN	98.4	0.57
10/26/2002	srf406	POOL	31.7	1.70
10/26/2002	srf407	RUN	36.5	0.73
10/26/2002	srf408	RIF	28.6	0.43
10/26/2002	srf409	POOL	18.3	1.63
10/26/2002	srf410	RIF	111.1	0.53
10/26/2002	srf411	POOL	45	0.63
10/26/2002	srf412	RIF	26.4	0.27
10/26/2002	srf413	POOL	16.2	1.13
10/26/2002	srf414	RIF	26.5	0.70
10/26/2002	srf415	POOL	40.6	0.93
10/26/2002	srf416	RIF	13.5	0.50
10/26/2002	srf417	POOL	40.4	1.27

Date	**ID**	**Type**	**Length**	**Average Depth**
10/26/2002	srf418	RIF	40.4	0.63
10/26/2002	srf419	POOL	381.6	2.20
10/26/2002	srf420	RIF	9.9	0.60
10/26/2002	srf422	RIF	10.9	0.57
10/26/2002	srf421	RUN	30.2	0.73
10/26/2002	srf423	POOL	128	1.50
10/26/2002	srf424	RUN	53	0.77
10/26/2002	srf425	POOL	33.9	1.80
10/26/2002	srf426	RUN	86.7	0.50
10/26/2002	srf427	RIF	20.4	0.57
10/26/2002	srf428	RUN	19.4	0.80
10/26/2002	srf429	RIF	21.8	0.40
10/26/2002	srf430	POOL	31.5	1.00
10/26/2002	srf431	RIF	20.1	0.53
10/26/2002	srf432	RUN	26.6	0.83
10/26/2002	srf433	RIF	25	0.40
10/26/2002	srf434	RUN	94.6	0.37
10/26/2002	srf435	RIF	16.9	0.27
10/26/2002	srf436	RUN	30.8	1.03
10/26/2002	srf437	RIF	89.9	0.40
10/26/2002	srf438	RUN	54.6	0.83
10/26/2002	srf439	RIF	13.1	0.53
10/26/2002	srf440	RUN	56.7	0.80
10/26/2002	srf441	RIF	47.5	0.40
10/26/2002	srf442	RUN	42.6	0.73
10/26/2002	srf443	RIF	78	0.37
10/26/2002	srf444	RUN	34.9	0.63
10/26/2002	srf445	RIF	51.7	0.47
10/26/2002	srf446	RUN	40.6	0.93
10/26/2002	srf447	RIF	50.9	0.30
10/26/2002	srf448	RUN	46.4	0.77

10/26/2002	srf449	RIF	24.4	0.37
10/26/2002	srf450	RUN	51	0.67
10/26/2002	srf451	RIF	23.2	0.53

Appendix M: Stressor Risk Analysis and Characterization (SDRM)

Appendix M-1: Reduced Access

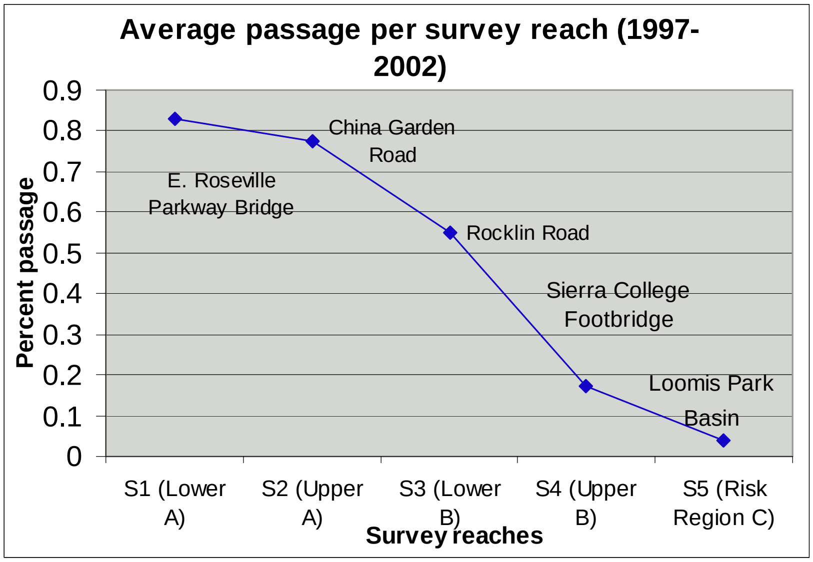
Risk Characterization for Reduced Access (SDRM)

Raw Data and Mathematical Models for Characterizing Reduced Access

Total counts (carcass +live)					
1997	54				
1998	115				
1999	114				
2000	344				
2001	no data				
2002	213				
average	168				
Risk region averages (1997-2002, live only)					
S1 (Lower A)	9				
S2 (Upper A)	38				
S3 (Lower B)	63				
S4 (Upper B)	23				
S5 (Risk Region C)	6				
Average occupancy per month (1997-2002, live only)					
Late October	0				
Early November	27				
Late November	26				
Early December	48				
Late December	2				
Yearly counts per survey reach (1997-2002, live only)					
	1997	**1998**	**1999**	**2000**	**2002**
S1	8	5	3	31	0
S2	7	29	46	63	43
S3	0	0	0	40	86
S4	0	0	15	10	44
S5	0	5	0	14	0
Average passage (1997-2002, live only)	P	NP			
through S1	0.83	0.17			
through S2	0.77	0.23			
through S3	0.55	0.45			
through S4	0.17	0.83			
through S5	0.04	0.96			

Average passage ('Risk Region A')	0.72	0.28
Average passage ('Risk Region B')	0.11	0.89
Average passage ('Risk Region C')	0.04	0.96

Adult Count Data for Secret Ravine (1997-2002)



Average Adult Passage Per Survey Reach (1997-2002)