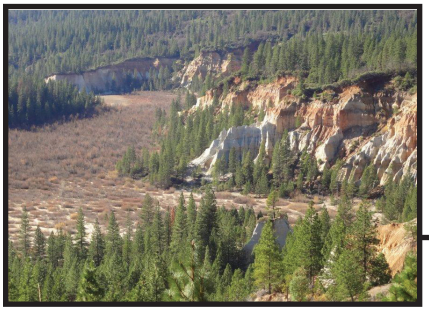

6 CABY Mercury and Sediment Abatement Initiative

ATTACHMENTS

6. CABY Mercury and Sediment Abatement Initiative

The following attachments are provided in PDF form as supplemental materials to this proposal (unless otherwise noted):

- In the online package reference documents are grouped into three PDFs that are uploaded as part of Attachment 7, entitled:
  - **Att7_IG2_TechJust_6MercRefs1_9of12.pdf** (containing references A-M)
  - **Att7_IG2_TechJust_6MercRefs2_10of12.pdf** (containing references N-R)
  - **Att7_IG2_TechJust_6MercRefs3_11of12.pdf** (containing references S-Y)

- In the hard copy package these documents are provided as separated PDFs in the folder entitled **"6 - Mercury Initiative Project."**

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MAPS

AA. Project Map

BB. Combie Project Maps and Figures

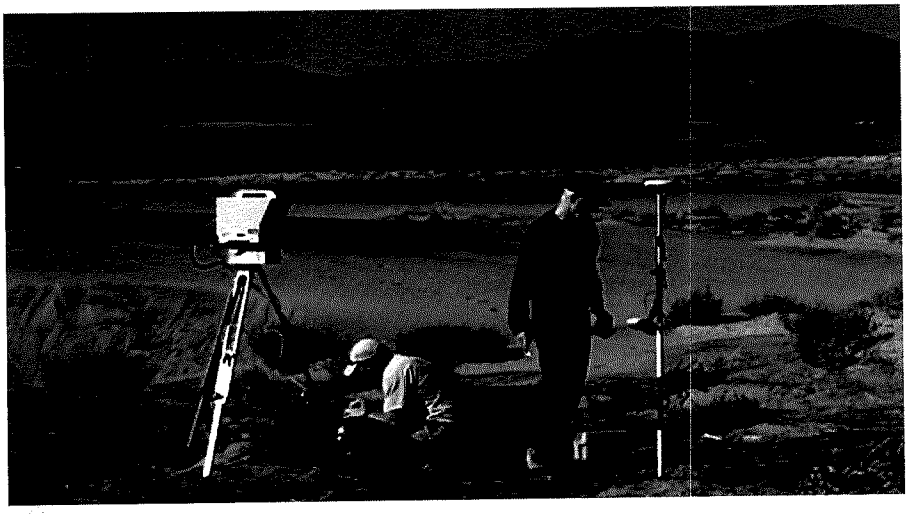
CC. Relief Hill Site Map

USGS
science for a changing world

RESEARCH AT THE USGS WESTERN GEOGRAPHIC SCIENCE CENTER

Using Terrestrial Light Detection and Ranging (Lidar) Technology for Land-Surface Analysis in the Southwest

Emerging technologies provide scientists with methods to measure Earth processes in new ways. One of these technologies—ultra-high-resolution, ground-based light detection and ranging (lidar)—is being used by USGS Western Geographic Science Center scientists to characterize the role of wind and fire processes in shaping desert landscapes of the Southwest United States.



USGS Western Geographic Science Center scientists are using terrestrial lidar to understand the consequences of landscape change in the desert Southwest. In this photograph a terrestrial lidar scanner and high-precision GPS are being used to investigate how wind processes influence erosion patterns and sediment transport in the Navajo Nation. (USGS photo by Miguel Velasco.)

Until relatively recently, aerial-photo interpretation and traditional surveying techniques were the primary methods used to conduct three-dimensional (3- D) analysis of the Earth's surface. Such analyses were significantly improved with the advent of airborne lidar and highly accurate Global Positioning System (GPS) data and instruments, which allow scientists to study areas of the Earth's surface at a finer scale and higher precision. These technologies have continued to evolve and improve the quality of scientific work, but in recent years they have also given rise to new scientific tools, specifically terrestrial lidar.

In contrast to airborne systems, terrestrial lidar instruments are portable, mounted on tripods, and provide higher-precision measurements. They are active sensors that emit pulses of light and use the time delay of the reflection of light from target surfaces to measure distance. Terrestrial lidar can provide very precise data (millimeter accuracy) to enable scientists to build high-resolution three- to four-dimensional models of objects of interest. The fourth dimension is a measurement of point intensity, which can be useful for characterizing land-surface properties and to classify land use or land cover. Terrestrial lidar units have advantages over traditional surveying techniques and airborne instruments, including:

- Less expensive to deploy, schedule, and operate.
- Able to provide a significant increase in spatial resolutions.
- Able to map features otherwise obscured from the air, such as overhanging cliff faces, caves, and forest understory.
- Optimal for rapid damage assessments, long-term geomorphic change monitoring, and precision modeling.

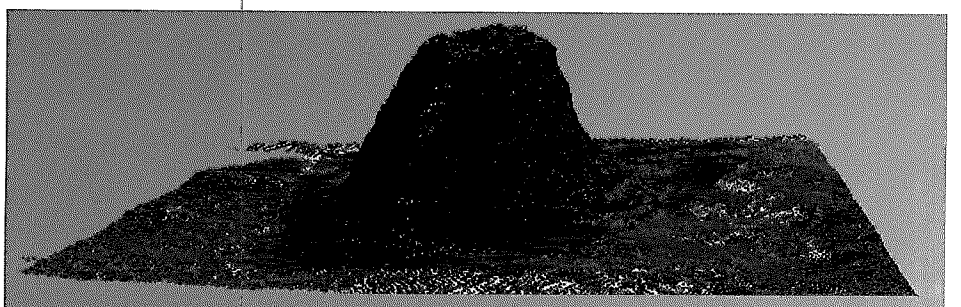
Using Lidar

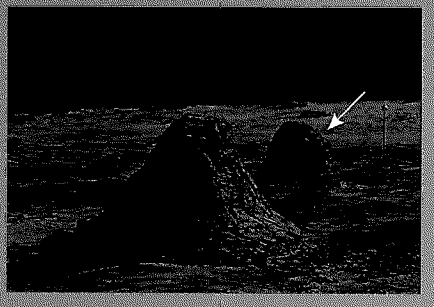
Terrestrial lidar scanners are highly automated devices, based on laser rangefinding systems, and are often mounted on robotic pan-and-tilt heads. Data is generally collected from an instrument mounted on a stationary tripod, and the instrument can automatically survey as much as a 360-degree field of view around the instrument out to a distance of 1,500 m (~1 mile). It is often necessary to perform multiple scans from various locations to collect information from the shadows and backsides of objects in a scene. Sophisticated software for aligning scan data—a series of coordinates called "point clouds"—is required to assemble multiple clouds from different vantage points into a single coherent scene.

Once completed, the alignment of scans can provide a 3-D model of the object of interest with subcentimeter precision. Terrestrial scans not only have ultrafine spatial resolutions, but also allow data collection at enhanced temporal resolutions. By rescanning a scene or an object over a period of time, information on the morphology of physical features (size, shape, or location) can be collected and analyzed to understand how natural systems and processes of change are influencing the landscape and environment.

CABY Headwaters Resilience and Adaptation Plan - March 2015
Attachment 7 - CABY Mercury Initiative References 3 of 3

U.S. Department of the Interior
Fact Sheet 2011–3017
March 2011





Repeat data collections with terrestrial lidar allow surface dimensions and movements to be tracked over time. In some areas, wind erosion leaves relic "yardangs" where sand dunes used to exist. Yardangs are made up of cohesive rock material that persists after softer material is eroded away by wind processes. USGS scientists are using repeat data collection to understand how continued wind abrasion weathers these rare geologic features. This image shows a raw lidar "point cloud" of a yardang from the Mojave Desert of Arizona (see arrow on photo; USGS photo by Rian Bogle).

Measuring Sand-Dune Movement in the Southwest

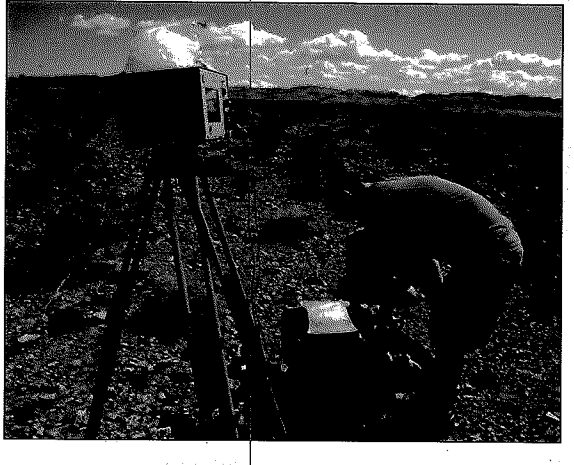
Scientists with the U.S. Geological Survey's (USGS) Western Geographic Science Center are using terrestrial lidar to measure sand-dune movement in the Southwestern United States. Arid lands in the Southwest can be very sensitive to climate changes. These landscapes, which are often largely comprised of fine-grained sand, are prone to wind mobilization when not stabilized by soil crusts or plant cover. Because of warming and drying trends from a changing climate or long-term drought, the interconnections between plant cover, precipitation, temperature, and sediment movement change over time. Consequently, the features found in arid regions can enter a cycle of increasing sediment mobility and decreasing plant-cover stabilization. These factors can lead to a constantly moving landscape with little or no plant cover, conditions that could have long-term and potentially significant impacts on agriculture, transportation, and human health for the Southwest.

Terrestrial lidar surveys are an effective approach to precisely measure and record the mobilization and geomorphic change of sand dunes in the desert Southwest. Ground-based lidar instruments make it possible to create detailed volumetric models of sampled dunes and compare the magnitudes and forms of change over short periods of time. These morphological studies can be integrated into detailed models of plant cover and climatic variability, and help predict potential future vulnerabilities in the landscape to drought or long-term changes in climate patterns.

Recording Desert-Soil Microtopography

In desert shrublands, soil mounds surrounding perennial shrubs are important because they are nutrient rich and contain organic matter, serving as sources of plant fertility. Fire can change the chemical composition of the soils in these mounds, but the resulting changes in the microtopography and volume of soils has not been quantified previously due to technological limitations. In the Pakoon Basin of the Mojave Desert in Grand Canyon-Parashant National Monument, Arizona, terrestrial lidar is being used by USGS scientists to quantify the differences between burned and unburned areas by creating a series of high-resolution bare-earth surface models for sample plots. Lidar scans were collected from unburned and previously burned sites with similar vegetation and soil-landform characteristics 10 years after experimental fires were conducted. Mound measurements indicate that the presence of fire affects the volume and surface roughness of mounds in the Pakoon Basin. Observations also show that the reduction in plant canopy cover in previously burned areas has contributed to a larger reduction in mound volume as a result of water and wind erosion. Through this research, ground-based lidar is helping determine how fires are shaping desert shrubland landscapes in the Southwest.

The work of Western Geographic Science Center (WGSC) scientists using terrestrial lidar for land-surface analysis in the desert Southwest is only part of the WGSCs efforts to better understand the causes and consequences of land-cover change. WGSC, supported by the USGS Geographic Analysis and Monitoring Program, is also working with communities to help provide them the crucial geographic, economic, and natural hazards information they need to make decisions about interactions between people and their environment to reduce unnecessary risk.



Using terrestrial lidar, Western Geographic Science Center scientists scanned unburned and previously burned study plots in the Grand Canyon-Parashant National Monument, Arizona. Plots were scanned from different positions to get a 360-degree view of the surface and vegetation, resulting in more than 4 million point measurements per plot. Vegetation was separated from the bare-earth surface points using advanced software to create unique mound and plant measurements. Mound volumes and plant dimensions were found to be reduced in previously burned plots. (USGS photo by Dave Bedford.)

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This Fact Sheet and any updates to it are available online at http://pubs.usgs.gov/fs/2011/3017/

Statewide Mercury Policy and Mercury Control Program for Reservoirs

Summary for CEQA Scoping Meetings March 2012

Mercury is negatively impacting the waters of the state. More than 180 water bodies in California are designated as impaired by mercury by the U.S. Environmental Protection Agency. Many fish in these waters have mercury concentrations that pose a risk for humans or wildlife that eat the fish. The number of mercury-impaired waters is expected to increase substantially when additional, recently collected monitoring data are evaluated.

The State Water Resources Control Board and Regional Water Quality Control Boards ("Water Boards") are in the early stages of developing a Statewide Mercury Policy (Policy) to control mercury in California's waters. The Policy would define an overall structure for adopting water quality objectives; general implementation requirements; and control plans for mercury impaired water bodies.

Please visit http://www.waterboards.ca.gov/water_issues/programs/mercury/ for information about this project and the extent of the mercury problem in California.

The first phases of program development will include:

- Development of water quality standards to protect people and wildlife that eat fish. These could include water quality objectives expressed as concentrations of mercury in the water column or in the tissues of fish; beneficial use designations; and antidegradation provisions
- Establishment of a control program designed to attain the new water quality objectives in our state's mercury-impaired reservoirs. An associated implementation plan will likely include:
    - Control actions for a variety of point and nonpoint sources, such as runoff from mine sites, atmospheric deposition, and discharges from wastewater treatment plants and urban stormwater
    - Changes in approaches to reservoir management that will modify water chemistry to reduce creation of the most biologically available form of mercury
    - Changes in fisheries management practices to limit populations of the types of stocked fish that often have high levels of mercury in their tissues

Future phases may include development of control plans specific to other mercury-impaired water bodies such as creeks, rivers, bays, and estuaries.

This document has been prepared for public workshops and “scoping meetings” as required by the California Environmental Quality Act (CEQA; California Public Resources Code section 21000 et seq.) and the Water Boards’ regulations for compliance with CEQA (California Code of Regulations, Title 23, Division 3, Chapter 27). The purpose of the document – and the scoping meetings – is to provide stakeholders and members of the public with a basic understanding of the project and the types of actions that may be required for compliance, so that interested parties and concerned California residents may provide comments and suggestions to the Water Boards early in the project development process. We welcome comments about potential harmful impacts of the project on the environment, and mitigation measures that will lessen those impacts. *This document is not intended to present an exhaustive analysis of mercury sources, or a detailed explanation of potential mercury control options.* Later in the process, full documentation will be made available for formal public comment.

A public scoping meeting has already taken place to discuss the development of mercury fish tissue objectives. Therefore, the remainder of this document and the public scoping meetings anticipated in early 2012 will focus on the development of a Policy structure and reservoir control program.

CEQA Scoping

The scoping process is designed to enlist the public in the Water Boards’ effort to identify:

- Concerns of government agencies and other stakeholders
- A reasonable range of project alternatives and actions, including different regulatory vehicles the Water Boards may use to control mercury in our state’s waters; and preferred options
- Reasonably foreseeable methods of compliance with a new Policy or other regulatory program
- Potential significant harmful impacts to the environment -- including cumulative impacts if any -- related to potential implementation actions
- Potential mitigation measures to reduce potential impacts to a less than significant level

CEQA defines “environment” broadly. Comments are welcome in the following topic areas:

- Aesthetics
- Agriculture and forest resources
- Air quality
- Biological resources
- Cultural resources
- Geology and soils
- Greenhouse gas emissions
- Hazards and hazardous materials
- Hydrology and water quality
- Land use and planning
- Mineral resources
- Noise
- Population and housing
- Public services
- Recreation
- Transportation and traffic
- Utility and service delivery systems

Need for a new Mercury Policy, and a mercury control program for reservoirs in California

Harmful levels of mercury in fish are a statewide (indeed nationwide) problem. Reservoirs containing potentially harmful amounts of mercury are found throughout California. The Colorado River, Santa Ana, and San Diego regions have the fewest reservoirs impaired by mercury; while the Central Valley Region has over 100. A map and complete list of impaired reservoirs is posted on the State Water Board's Mercury Program web page, at http://www.waterboards.ca.gov/water_issues/programs/mercury/reservoirs/.

A statewide Mercury Policy will provide the framework for implementing a consistent approach to controlling mercury in California's inland waters. A statewide mercury control program for reservoirs is needed because the Water Boards must address impairments in an efficient and timely manner.

The project under consideration at the public scoping meetings is development and adoption by the State Water Resources Control Board of 1) a statewide Mercury Policy that will provide the framework for control programs for mercury in California's inland waters, and 2) a control program for mercury-impaired reservoirs. The reservoir control program should be based on the efficient use of the Water Board's existing regulatory authority. The final structure of the control program could include a total maximum daily load (TMDL) for mercury in reservoirs along with an implementation plan to achieve the TMDL; or an implementation plan that does not rely on a TMDL. Whatever the vehicle, the mercury control program will need to be developed to ensure achievement of the objectives established for methylmercury in the tissues of fish, in accordance with the Porter-Cologne Water Quality Control Act of 1972 (CA Water Code, Division 7, section 13242).

CEQA Scoping: Project elements under consideration

The Water Boards are considering alternatives to adoption of a Mercury Policy, and to key elements of a reservoir control program. In addition, CEQA requires that we identify both harmful impacts that may result from implementation, and actions or strategies that can be included in the program which will mitigate or reduce potential impacts. When considering alternatives, the Water Board must consider and analyze a "no action" alternative.

We invite the public to comment on these alternatives and to suggest additional options.

Elements 1 and 2, and the potential implementation actions described later in this document, will be discussed at the public scoping meetings.

Element 1: Adoption of a statewide Mercury Policy

Alternative 1: No action

No action to develop a Statewide Mercury Policy to reduce mercury in California's waters would leave policies and practices as they currently exist.

Mercury-impaired water bodies would continue to be addressed by each Regional Water Board on an individual basis through the ongoing development of statewide fish tissue mercury objectives, site specific mercury water quality objectives, the TMDL process, site cleanup orders, waste discharge requirements, conditional waivers of waste discharge requirements, and NPDES permits – without an over-arching statewide structure.

Alternative 2: Establish a statewide Mercury Policy to control mercury in California's waters

A new statewide Policy would incorporate statewide water quality objectives for mercury, which are currently under development. A Policy would present a coordinated and tiered approach to developing control plans for mercury-impaired water bodies in a timely and effective manner. Such control plans could eventually include specific requirements for point and nonpoint sources that discharge to all water bodies in the state.

As has been previously mentioned, establishment of fish tissue objectives for mercury and a statewide reservoir mercury control program are expected to be the first completed elements of the broader Policy. The reservoir control program could incorporate requirements for parties responsible for point and nonpoint sources of inorganic mercury and methylmercury in reservoirs, as well as parties responsible for land and water management activities that affect methylmercury production and loss processes, mercury transport, and bioaccumulation.

Future elements of a Policy could include control programs for the following waters and mercury sources, among others:

- Other California reservoirs identified in the future as containing fish with unsafe levels of mercury in their tissues
- Rivers, creeks, streams, enclosed bays, and coastal bays, estuaries, and lagoons impaired by mercury
- Point sources including NPDES-permitted wastewater and stormwater sources
- Nonpoint sources including timber harvest activities, mining, and agriculture including irrigation and grazing

Element 2: A statewide control program for mercury in reservoirs

Alternative 1: No action

No action to develop a control program for mercury in reservoirs would leave policies and practices as they now exist, with no statewide program of actions to achieve either the new statewide fish tissue objectives for methylmercury that are currently under development, or the existing narrative bioaccumulation objectives. As required by the federal Clean Water Act, the Regional Water Boards would need to address California's 74 reservoirs listed by the United States Environmental Protection Agency on the 2010 Clean Water Act section 303(d) list of impaired waters as impaired by mercury, and other reservoirs designated as impaired by mercury in the future, on an individual basis – for example through the total maximum daily load (TMDL) process for individual water bodies. Future TMDLs would be implemented through individual site cleanup orders, waste discharge requirements, waiver

programs for waste discharge requirements, NPDES permits, and other enforcement actions as appropriate. Future 303(d) listings for mercury would also be required to be addressed by future TMDLs.

Alternative 2: Statewide mercury control program for reservoirs

A statewide control program for mercury in reservoirs would address mercury impairments in the 74 reservoirs on the 2010 303(d) list, and potentially other mercury-impacted reservoirs. Such a program could incorporate requirements for parties responsible for point and nonpoint sources of inorganic mercury and methylmercury, and parties responsible for land and water management activities that affect methylmercury production and loss processes, mercury transport, and bioaccumulation. A reservoir control program could be designed within a TMDL framework, or could rely on other regulatory approaches. Implementation requirements would likely be similar, regardless of the regulatory framework employed.

CEQA Scoping: Potential implementation actions under consideration

A key purpose of CEQA scoping is for the lead agency (in this case, the Water Boards) to receive comments from the public about the range of project actions and alternatives, reasonably foreseeable means of compliance, significant (and any cumulative) impacts of the project to be analyzed, and ways to eliminate or mitigate those impacts.

The table on the following pages provides examples of implementation actions responsible parties might take to comply with a mercury control program for the state's reservoirs. "Responsible parties" include both regulatory agencies and the entities they regulate. This list is a starting point for evaluating potential environmental impacts; it is not intended to restrict the scope of possible actions to be evaluated or implemented. While many of these potential actions are already common practice, implementation of an effective statewide control program may require broader, more comprehensive application of such approaches and technologies.

After receiving comments on possible impacts and mitigation actions, the State Water Board will prepare project documentation including draft staff reports, a CEQA checklist, and a draft water quality control plan or Policy. These documents will be circulated for public comment.

Potential Implementation Actions

Sources	Potential Responsible Parties	Implementation Actions (examples)
Mine sites where mercury was mined or used, e.g., mercury mines in the Coast Range and gold mines and dredging in the Sierra Nevada and Trinity Mountains: • Tailings, over burden, waste rock, and other mercury contaminated wastes at mine sites • Hydraulic mining debris and dredge tailings downstream of gold mine sites	Private mine site property owners and mine operators Public agencies that own or manage mine sites, such as U.S. Bureau of Land Management	Site cleanup to prevent mercury transport from tailings piles, waste rock, sluices, and other mining features, such as: • Erosion control (grading, runoff controls, revegetation) • Excavation of mercury-contaminated wastes and burial onsite or in an engineered landfill; installation of erosion controls in excavated area Onsite pollution prevention measures, such as: • Protection of erosive areas from vehicles, grazing, etc. • Construction of downstream settling basins to collect and sequester contaminated sediment • Restoration of temporary or unmaintained roads and trails to native forest conditions with natural hydrologic function (recontouring, soil restoration, seeding, block vehicle access) • Dust suppression during earth-moving operations
Water chemistry in reservoirs	Private reservoir owners and operators, such as water suppliers and irrigation companies Public reservoir owners and operators, for example: • Federal agencies such as the U.S. Army Corps of Engineers, U.S. Bureau of Reclamation • State agencies, such as the Department of Water Resources • Municipalities and local agencies, such as water suppliers and flood control districts	Develop and implement reservoir management plans to reduce methylmercury concentrations in reservoir fish Implement and evaluate methods for reducing methylmercury in reservoirs, such as: • Water aeration and circulation to increase oxygen • Removal or capping of mercury-contaminated sediment in the reservoir and in upstream tributaries • Monitoring to identify areas within reservoir where mercury accumulates in sediment; develop sediment management plans to reduce releases of mercury during reservoir maintenance • Modification of channel geometry to direct flows away from mercury-contaminated areas • Where possible, modification of water storage and discharge patterns to reduce methylmercury production

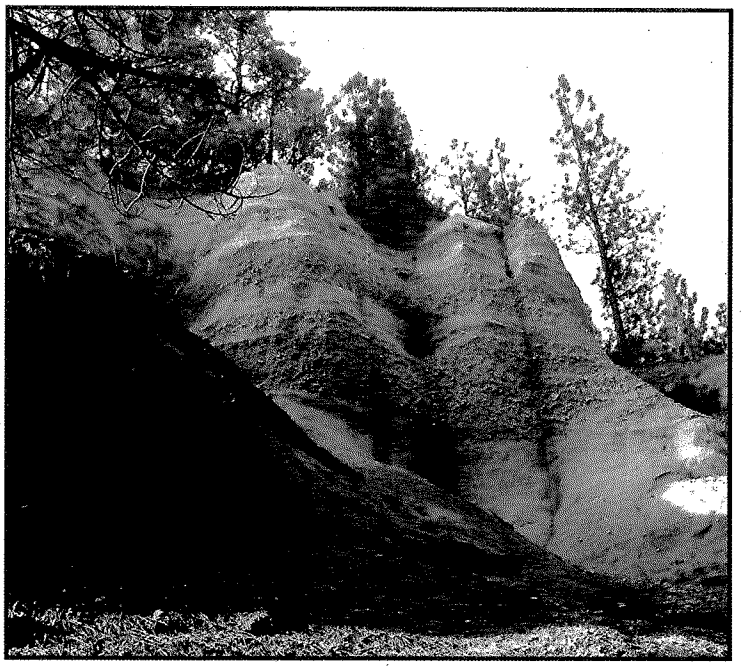
Sources	Potential Responsible Parties	Implementation Actions (examples)
Fisheries management in reservoirs	Public and private fisheries managers Reservoir owners and operators U.S. Fish and Wildlife Service State agencies such as the Department of Water Resources, Department of Fish and Game	Promote abundance of species and sizes of reservoir fish that accumulate smaller amounts of mercury in their tissues, for example: • Encourage native anadromous fisheries such as salmon and steelhead, and landlocked species such as rainbow trout and kokanee salmon, which have lower mercury levels than introduced species • Reduce stocking of introduced species such as bass and brown trout • Promote intensive fishing of species with higher mercury levels, which would enhance the individual fish growth rates of the remaining fish and consequently reduce their methylmercury levels Manage nutrients/algae to improve production (at the base of the food web) and reduce fish methylmercury concentrations
Upland earthmoving projects that disturb mercury-contaminated soils and In-stream projects (in- or near-channel activities) that disturb sediment or soil downstream of mercury sources	Public agencies, municipalities that regulate grading projects Private landowners Forest owners and managers, timber harvesters Parties seeking Clean Water Act Section 401 certification of dredge-and-fill or construction projects from the Water Board Operators/managers of municipal stormwater pollution prevention programs Habitat restoration and conservation project managers	Minimize erosion of mercury-contaminated soils and sediments, for example: • Stabilize and revegetate road shoulders • Preserve existing vegetation, or revegetate • Stabilize stream banks • Encourage/promote landscaping practices that contain erosion • Increase filtration by reducing impervious surface cover • Keep livestock out of mercury-contaminated areas • Install retention basins or other features to reduce erosion • Minimize earth disturbance from logging activities adjacent to mercury or gold mine sites, or mine waste piles Ensure adequate soil moisture or other dust suppression techniques during earth-moving operations Install and maintain features that direct, contain, or filter mercury from stormwater runoff, such as: • Infiltration trenches and prefabricated infiltration systems, silt fences • Slope drains, water velocity dissipators, check dams • Constructed wetlands, detention basins, drainage swales

Sources	Potential Responsible Parties	Implementation Actions (examples)
Urban stormwater sources upstream of reservoirs (primarily in southern California)	Operators/managers of municipal stormwater pollution prevention programs	Reduce mercury in urban stormwater by employing appropriate actions described previously for "Upland earthmoving and In-stream projects", and additional actions such as: vacuum street sweeping, stormwater vaults with media filters, and sediment traps Implement mercury-specific pollution prevention measures, for example: • Thermometer exchange and fluorescent lamp recycling programs • Education of auto dismantlers on how to remove, store, and dispose of mercury switches • Expand hazardous waste collection programs for mercury-containing products, including thermometers, batteries, fluorescent lamps, switches, and thermostats
Wastewater treatment plants and other NPDES-permitted dischargers that discharge into or upstream of reservoirs	Municipal owners and operators of wastewater treatment facilities, and other publicly owned treatment works Industrial wastewater dischargers	Develop and implement programs to minimize total mercury in sewage, for example: • Implement mercury-specific pollution prevention measures (see examples listed in the "Urban stormwater" section above) • Install amalgam separators at dental offices Improve wastewater treatment to reduce particle-bound methylmercury and total mercury, and/or promote demethylation of methylmercury, for example: • Increase retention in aeration tanks or retention ponds • Filtration • Ultraviolet disinfection • Nitrification/denitrification and other treatments used to reduce ammonia • Increase effluent disposal to land

Sources	Potential Responsible Parties	Implementation Actions (examples)
Atmospheric deposition from California industrial sources	Regulatory agencies: • U.S. EPA • California Air Resources Board • Local air quality management districts Industrial facilities	Use emissions control technology to reduce emissions of mercury from industry, such as: • Cement plants • Geothermal power plants • Petroleum refineries • Waste incinerators Implement mercury source reduction strategies, where feasible
Atmospheric deposition from global industrial sources	U.S. EPA U.S. Department of State	Negotiate international treaties to reduce global industrial emissions

FINAL
ENGINEERING EVALUATION/COST ANALYSIS

RELIEF HILL HYDRAULIC MINE
NEVADA COUNTY, CALIFORNIA



Prepared For

TAHOE NATIONAL FOREST
NEVADA CITY, CALIFORNIA

U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE REGION 5

June 2007

Prepared By

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Rancho Cordova, California, 95670

FINAL
ENGINEERING EVALUATION/COST ANALYSIS

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ACRONYMS AND ABBREVIATIONS

°F	Degree Fahrenheit
µg/L	Microgram per liter
AQMD	Air Quality Management District
ARAR	Applicable or relevant and appropriate requirement
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient water quality criterion
bgs	Below ground surface
BLM	U.S. Department of the Interior, Bureau of Land Management
CCR	California Code of Regulations
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CSM	Conceptual site model
CTR	California Toxics Rule
CWA	Clean Water Act
EE/CA	Engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ET	Ecotox Threshold
Forest Service	U.S. Department of Agriculture Forest Service
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
O&M	Operation and maintenance
OHV	Off-highway vehicle
OSHA	Occupational Safety and Health Administration
PA/SI	Preliminary assessment/site inspection
PRAG	Preliminary removal action goal
PRAO	Preliminary remedial action objective

PRG	Preliminary remediation goal
PRP	potentially responsible party
RCA	Riparian conservation area
RCRA	Resource Conservation and Recovery Act
Relief Hill	Relief Hill Hydraulic Mine
SAIC	Science Applications International Corporation
SDWA	Safe Drinking Water Act
SMARA	California Surface Mining and Reclamation Act
SMCRA	Surface Mining Control and Reclamation Act
SWRCB	State Water Resources Control Board
TBC	To be considered
tech memo	Technical memorandum
Tetra Tech	Tetra Tech EM Inc.
TSS	Total suspended solids
USC	United States Code
USGS	U.S. Geological Survey
Water Board	California Regional Water Quality Control Board, Central Valley Region
WQO	Water quality objective
yd^3	Cubic yards

EXECUTIVE SUMMARY

Relief Hill Hydraulic Mine (Relief Hill) is an inactive historic hydraulic gold mine located on public land administered by the U.S. Department of Agriculture Forest Service (Forest Service). The mine site comprises approximately 86 acres of land located 2.6 miles west of the town of Washington, California, within the south half of Section 4 and the north half of Section 9, Township 17 North, Range 10 East of the Mount Diablo Base and Meridian.

Site Description

Hydraulic mining occurred at Relief Hill from the early 1850s to the late 1880s, and small-scale underground mining still occurs on active mine claims at the site. Liquid mercury was used during hydraulic mining to facilitate gold recovery, and an estimated 21,000 to 64,000 pounds of mercury was lost to the environment at Relief Hill (Science Applications International Corporation [SAIC] 2004).

The site has numerous physical features associated with hydraulic mining that include remnant ground sluices, at least five drain tunnel systems, numerous drain tunnel inlets, depressions that fill with rain water to form pit lakes, and large piles of cobbles and boulders ringing sluices and pit lakes. Precipitation that falls on Relief Hill flows from the site though the ground sluice and drain tunnel networks designed to drain the site (and recover gold) during hydraulic mining. Surface runoff from the site is released into three defined drainages including Logan Canyon, an unnamed central drainage, and Union Canyon. All three water sources drain into the South Yuba River, which is used for recreation, freshwater habitat (including spawning and migration), and municipal and domestic water supply (California Regional Water Quality Control Board, Central Valley Region 2004).

Site Conditions

Results from previous investigations indicate that mercury is present in surface water and sediment at Relief Hill. Mercury is believed to remain at the base of ground sluices and pit lakes, which filled with sediment after hydraulic mining ceased. Biota sampling showed that bioaccumulation of mercury at Relief Hill is low relative to 44 mine and stream sites throughout the South Yuba River, Bear River, and Greenhorn Creek watersheds. A poor vegetative cover, susceptibility of on-site geologic materials to erosion, and sluice system for rapid surface water drainage lead to significant sediment transport from Relief Hill during storm events. Sediment released from the site flows to Logan and Union canyons and the unnamed central drainage, and ultimately into the South Yuba River. There are currently no engineering controls at Relief Hill to prevent erosion and migration of sediment and mercury during storm events. Thus, precipitation at Relief Hill causes a negative impact on downstream water quality. Based on investigation findings and preliminary risk screening, the Forest Service is exercising its authority as lead agency under the Comprehensive Environmental Response, Compensation, and

Liability Act (CERCLA) to undertake a removal action at Relief Hill to control the release of sediment (including particulate-bound mercury) to the environment.

Risk Characterization

Mercury concentrations in water and sediment at Relief Hill pose a threat to human health and ecological receptors. Highly mobile sediment in the hydraulic mine pit and ground sluice and drain tunnel networks is released from the site through storm water runoff and deposited in the three defined off-site drainages and the South Yuba River. A biological evaluation encompassing the Relief Hill area determined numerous special status plant and animal species may be present at the site; the foothill yellow-legged frog (a State of California species of concern) was reportedly observed on site during the preliminary assessment/site inspection (SAIC 2004). The South Yuba River, located less than one mile downstream from Relief Hill along the three defined drainages, has been identified as a fishery (SAIC 2004).

Removal Action Alternatives

This Engineering Evaluation/Cost Analysis (EE/CA) presents a detailed analysis of removal action alternatives that the Forest Service and appropriate regulatory agencies can use for decision-making at Relief Hill. The EE/CA identifies, screens, and evaluates technologies that may be implemented to reduce releases of sediment and mercury to the environment. Tetra Tech EM Inc. prepared this EE/CA in accordance with the U.S. Environmental Protection Agency (EPA) "Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA" (EPA 1993a) and "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study" (EPA 2000). Cost estimates were prepared in substantial accordance with EPA guidelines (EPA 2000) using engineer's estimates, historic costs for similar projects, and vendor quotes.

Based on the results of the human health and ecological risk screening, three preliminary removal action objectives were developed for Relief Hill:

- Minimize site runon and runoff to reduce migration of suspended sediment and mercury from the mine pit, flood areas, ground sluices, and drain tunnels to nearby drainages and the South Yuba River.
- Minimize the potential for exposure and release of mercury that may be present at the base of ground sluices.
- Improve public awareness of on-site objective dangers due to previous mining activities.

Attaining these objectives is expected to result in protection of human and ecological receptors and water quality at Relief Hill. The following removal action alternatives are proposed and evaluated for Relief Hill:

- Alternative 1: No Action – No action would be taken.
- Alternative 2: Land Use Controls and Access Restrictions – Identify land use consistent with allocation of the area as a riparian conservation area. Prevent land use that could lead to mobilization of sediment through access restriction. Access for private property and existing mining interests must not be compromised.
- Alternative 3: Selective Engineering Controls, Land Use Controls, and Access Restrictions: In addition to the measures included in Alternative 2, Alternative 3 will divide site into watershed units roughly corresponding to sluice systems. Within each watershed unit, implement surface water runon/runoff controls, sediment detention structures, erosion controls, and revegetation to minimize migration of sediment off site.
- Alternative 3a: Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions – In addition to the measures included in Alternative 3, Alternative 3a will include check dams constructed within open and accessible sluice tunnel inlets to provide additional sediment retention capacity.

Recommended Removal Action

The recommended removal action alternative to control erosion and release of sediment and particulate-bound mercury from Relief Hill is Alternative 3a. Alternative 3a includes engineering controls to reduce erosion and retain mobilized sediment on site, and land use controls to reduce erosion caused by certain site uses (including off-highway vehicle traffic), encourage the growth of soil-stabilizing vegetation, and reduce direct human contact with contaminants.

Alternative 3a was determined to provide the highest degree of protection for human and ecological receptors, would comply with ARARs, provides long-term effectiveness and permanence, and greatly reduces the mobility and off-site migration of sediment and particulate-bound mercury. The engineering controls in Alternative 3a (including rock armoring of spillways, and capture of new sediment in detention basins built in sluices) would further entomb mercury that may remain at the base of former ground sluices. The additional burial of potentially contaminated sediment would reduce human and ecological exposure to on-site mercury in sediment, surface water, and dust particles. The likelihood of a large storm exposing mercury potentially remaining below sluice infill sediment would also be reduced by improved storm water and erosion controls. The removal action would be implemented during one field season, with operation and maintenance activities consisting of: ensuring success of revegetation

efforts, sediment detention basin cleanout, sign and gate replacement/repair, and periodic monitoring.

Alternative 3a would be implemented at a total present worth cost of $529,000, based on an estimated capital cost of $392,000 and periodic and annual operation and maintenance costs totaling $138,000 for a conservative 30-year period. In accordance with EPA guidance (EPA 1993a, 2000), these engineering costs are estimates that are expected to be within plus 50 ($794,000) to minus 30 percent ($370,000) of the actual project cost (based on year 2006 dollars). Most (over 80 percent) of the operation and maintenance cost is slated for the vegetation effort that will be performed during the second and third years after the removal action.

1.0 INTRODUCTION

Tetra Tech EM Inc. (Tetra Tech) is under contract to the U.S. Department of Agriculture Forest Service (Forest Service) Region 5 to prepare an Engineering Evaluation/Cost Analysis (EE/CA) for the non-time critical removal action of mercury affected sediment in ground sluices, pit lakes, and drain tunnels at the Relief Hill Hydraulic Mine (Relief Hill) located in the Tahoe National Forest, Nevada County, California. This work is being performed under Contract Number 53-91S8-03-PUF11 (Regional Environmental Response Action), Task Order Number 53-9A63-4-1139. Site investigation activities were conducted by the U.S. Geological Survey (USGS), Science Applications International Corporation (SAIC), and Tetra Tech between 1999 and 2005 to determine if mercury was present at Relief Hill, to support human health and ecological risk screening, and to collect data in support of removal action alternatives to be evaluated in this EE/CA. The results of these activities are documented in a site characterization and risk screening technical memorandum (tech memo) (Tetra Tech 2006b).

1.1 Background

Relief Hill is a historic hydraulic gold mine located in the Tahoe National Forest, Nevada County, California. The mine site comprises approximately 86 acres of land located 2.6 miles west of the town of Washington, in the south half of Section 4 and the north half of Section 9, Township 17 North, Range 10 East (see Figures 1 and 2). Hydraulic mining in the North Bloomfield Mining District occurred primarily between 1853 and 1884, when the Sawyer Decision prohibited this method of mining. It is estimated that at least 10 million cubic yards of auriferous gravel were processed and that 21,445 to 64,336 pounds of mercury were lost during processing activities over the operational life of Relief Hill (SAIC 2004). Currently, underground gold mining operations are being conducted at Relief Hill at Dan Jasper's mine. The terrain is very hummocky and there are numerous depressions fed by overland runoff that collects in the pit lakes, ground sluices, and sluice tunnels before discharging to three defined drainages including Logan Canyon, an unnamed central drainage, and Union Canyon, which feed into the South Yuba River. Previous investigations have demonstrated that mercury is present in surface water and sediment at Relief Hill. Mercury is believed to remain at the base of ground sluices and pit lakes, which filled with sediment after hydraulic mining ceased. Biota sampling showed that bioaccumulation of mercury at Relief Hill is "moderate" relative to 44 mine and stream sites throughout the South Yuba River, Bear River, and Greenhorn Creek watersheds.

Most of the surface area at Relief Hill is exposed and weathered bedrock, poorly developed soil, recently deposited sediment derived from exposed bedrock, and piles of rock. Significant un-vegetated areas still exist at the site due to historic hydraulic mining. Revegetation appears to be inhibited by the nutrient-poor bedrock and soils, steep and weakly consolidated sluice walls and pit high walls, and large piles of cobbles and boulders. The poor vegetative cover, susceptibility of on-site geologic materials to erosion, and sluice system for rapid surface water drainage lead to significant sediment transport from Relief Hill during storm events. Sediment released from

the site flows to Logan Canyon, an unnamed central drainage, and Union Canyon, which feed into the South Yuba River. Thus, precipitation at Relief Hill could cause a negative impact on downstream water quality.

1.2 Purpose

The purpose of this EE/CA is to present a detailed analysis of removal action alternatives that the Forest Service and appropriate regulatory agencies can use for decision-making. This EE/CA identifies, screens, and evaluates technologies that may be implemented to reduce the amount of sediment migrating from Relief Hill through storm water runoff and reduce the potential for re-exposure and release of mercury that may currently be buried below infill sediment in ground sluices, pit lakes, and wetlands. The technologies evaluated in this report will facilitate long-term attainment of the water quality standards applicable to surface water discharged from Relief Hill, minimize the potential for re-exposure and release of mercury, and allow ecological restoration of the disturbed site.

1.3 Organization

This EE/CA presents background information, site investigation findings, risk screening results, an evaluation of applicable or relevant and appropriate requirements (ARAR), preliminary removal action objectives (PRAO) and preliminary removal action goals (PRAG), and the development and screening of removal action alternatives. The remaining parts of this EE/CA are organized into nine sections. The contents of Sections 2.0 through 9.0 are briefly described below.

Section 2.0, Site Background - briefly describes the Relief Hill location and topography, mine history and features, climate, geology and soils, hydrology and hydrogeology, vegetation and wildlife, land use and population, significant cultural and archeological features, and property ownership and mineral rights.

Section 3.0, Site Investigation Summary - summarizes site investigation findings and presents a conceptual site model (CSM) for Relief Hill.

Section 4.0, Preliminary Risk Screening - summarizes the human health and ecological risk screening methodology and results, and recommends removal actions based on risk findings.

Section 5.0, Applicable or Relevant and Appropriate Requirements - presents the state and federal chemical-, location-, and action-specific ARARs that may be relevant to a removal action at Relief Hill.

Section 6.0, Removal Action Objectives And Goals - presents the PRAOs and PRAGs.

Section 7.0, Identification And Screening of Response Actions, Technology Types, and Process Options - identifies and describes general response actions, technologies, and process options; screens technologies, and develops removal action alternatives.

Section 8.0, Detailed Analysis of Removal Action Alternatives - presents the detailed analysis of removal action alternatives using effectiveness, implementability, and cost criteria.

Section 9.0, Comparative Analysis of Removal Action Alternatives - presents a comparative analysis of removal action alternatives for consistency with the effectiveness, implementability, and cost criteria; summarizes analysis findings; and presents a recommended removal action alternative.

Section 10.0, References – presents a list of sources used in preparation of this EE/CA.

Figures and tables are presented after the report text.

This EE/CA also includes the following appendices:

- Appendix A, Site Photographs
- Appendix B, Mine Claim Records
- Appendix C, Laboratory Analytical Data

2.0 SITE BACKGROUND

This section presents Relief Hill background information pertinent to the development of an EE/CA. The information presented includes a description of the mine location and topography, mine history and features, climate, geology and soils, hydrology and hydrogeology, vegetation and wildlife, land use and population, significant cultural and archeological features, and property ownership and mineral rights. Much of the information in this section was obtained from the preliminary assessment/site inspection (PA/SI) for Relief Hill (SAIC 2004).

2.1 LOCATION AND TOPOGRAPHY

Relief Hill is a historic hydraulic gold mine located in the Tahoe National Forest, Nevada County, California. The mine site comprises approximately 86 acres of land located 2.6 miles west of the town of Washington, in the south half of Section 4 and the north half of Section 9, Township 17 North, Range 10 East (see Figure 1).

Relief Hill features numerous piles of large weathered cobbles, boulders, and bedrock ringing open pit lakes; and remnant ground sluices and sluice tunnels. The terrain is very hummocky and there are numerous depressions fed by overland runoff that collects in the pit lakes, ground sluices, and sluice tunnels before discharging to three defined drainages including Logan Canyon, an unnamed central drainage, and Union Canyon, which feed into the South Yuba River.

2.2 HISTORY AND FEATURES

Mining began at Relief Hill as early as 1853. By 1856, the settlement had attained a population of 75 people, one general store, two salons, one butcher shop, two boarding houses, one blacksmith shop, and several dwellings. The town steadily increased in size and importance until 1858, at which time the population exceeded 100 people. It then began to rapidly decline, but in 1862 it was revived and remained a thriving mining camp for several years. The population, circa 1880, was 75 (SAIC 2004). Hydraulic mining in the North Bloomfield Mining District lasted until 1884, when the Sawyer Decision prohibited this method of mining. It is estimated that at least 10 million cubic yards of auriferous gravel were processed and that 21,445 to 64,336 pounds of mercury were lost during processing activities over the operational life of Relief Hill (SAIC 2004). Currently, underground gold mining operations are being conducted at Relief Hill at Dan Jasper's mine.

Vast tertiary gravel deposits from the Graniteville and Omega Channel of the ancestral rivers within the Sierra Nevada gold belt contained large quantities of placer gold. Relief Hill was strategically located to allow miners to remove the volcanic cap rock from mountain saddles where it was thinner. An extensive water transfer system of ditches, canals and vertical pipes provided the sustained water pressure necessary for hydraulic mining. Typically, two monitors (hydraulic nozzles) were used. The first monitor would hydraulically cut the benches. The second monitor would then sweep and route the cut auriferous gravels through sluices. Liquid

mercury was added to the sluices to enhance gold recovery. Laborers would remove the large cobbles and extract the gold; cobbles were piled beside the sluices. The mercury-laden process water and sediment was then washed down adjacent ravines using diversion tunnels and pipes. As mining progressed into deeper gravels, tunnels were constructed to facilitate drainage and to remove debris from the bottom of the hydraulic mine pits.

2.3 CLIMATE

The climate of the Relief Hill region (elevation 4,000 feet above mean sea level) is characterized by mild spring and fall months, warm summers, and cold, wet winters. Annual precipitation at nearby Lake Spaulding, (elevation 5,160 feet above mean sea level) the nearest weather station located approximately 12 miles east-southeast of Relief Hill averaged 68.5 inches of water from 1914 to 2003 and comes mostly in the form of winter snow and rainfall. Rain and snow falls frequently during the winter months (November through February) in the Relief Hill region. Precipitation at Relief Hill is slightly less and occurs more frequently as rain due to the elevation difference. Average maximum and minimum daily temperatures from 1914 to 2003 at Lake Spaulding were 61 and 34 degrees Fahrenheit (°F), respectively. Maximum high and minimum low temperatures from 1914 to 2003 were 104 and -14 °F, respectively, at Lake Spaulding. Low temperatures at Relief Hill are likely more moderate due to the lower elevation.

2.4 GEOLOGY AND SOILS

Local geology is described by Lindgren (1900, 1911). In summary, ancient ocean-floor sediments (clay, sand, limestone) were subducted beneath the continental plate where pressure and heat transformed them into metasedimentary rock (slate, schist, and quartzite) that were then accreted onto the continental edge. The ocean crust sank, heated up, and melted. The melted continental crust rose toward the surface and, as it cooled, formed the Sierra Nevada Batholith, an underground expanse of granite. The batholith was exposed over time as overlying rock gradually eroded away. During the Tertiary period, the region was drained by a river system transporting sediment westward toward an inland sea (where the Sacramento Valley now lies). This sediment, including auriferous gravel, was deposited in a broad flood plain encompassing the area of the Washington Mining District. During the late Tertiary Period, tectonic forces resulted in block uplifting, intermittent volcanism, and volcanic ash and mudflows over the much of the region. The uplifting produced deep canyons with high-energy watersheds. Pleistocene Epoch ice ages between 1.5 and 2 million years ago resulted in the cyclic advance and retreat of glaciers that scraped away much of the volcanic cap rock and left smooth polished granite boulders in the channel of the South Yuba River.

The geology of the South Yuba River watershed is typical of the western slope Sierran drainages and is comprised of metasedimentary rocks, metavolcanic rocks, channel deposits and volcanic flows overlying granitic bedrock. The bedrock is divided into two primary groups: the subjacent (basement) series is dominated by deformed Paleozoic and Mesozoic marine sedimentary and volcanic rocks intruded by granite batholiths, which are the result of tectonically emplaced

accretionary terrains. The metamorphic rocks, largely phyllite and slate from the Calaveras and Shoo Fly formations, are intruded by quartz veins, which provide a significant source of gold through the region (Yarnell 2000). The superjacent series is comprised of undeformed rocks in gently dipping beds. The earlier deposits are Cenozoic auriferous gravels, while the later beds are rhyolytic volcanic rocks overlain by andesitic flows.

Spanning from the present-day Feather River basin south to the upper edges of the American River basin, the ancestral Yuba system drained about half of the northern proto-sierra range. The current remains of this large drainage crop out in various locations within the Yuba, Bear, and North Fork American basins, but the main ancestral Yuba channel, including the confluence of two major tributary rivers, crop out on the divide between the South and Middle Yuba Rivers. The ancestral Yuba deposits are comprised of two distinct gravel units named for their position within the ancient valley basin: the upper or bench gravels are primarily aggraded floodplain sediments and the lower gravels are coarser channel deposits. The bench gravel contains primarily highly weathered milky-white quartz and quartzite clasts, which fine upwards from boulders and cobbles to an abundance of silt and clay beds. The lower gravel is coarser grained, less well-sorted, and due to its low position within the channel, has a higher density of gold. Miners further distinguished the lower gravel into red and blue gravels based on color. The blue gravel has a blue-grey color cast, which results from the reducing conditions below the groundwater table, while the red gravel has been highly oxidized. All the gravel deposits contain gold derived from the surrounding bedrock, but the amount of gold progressively increases in the deeper units (Yarnell 2000).

2.5 HYDROLOGY AND HYDROGEOLOGY

The metasedimentary bedrock complex underlying Relief Hill generally has low porosity and low recharge capacity. No information is available pertaining to groundwater flow direction; however, it can be surmised that groundwater flow underlying Relief Hill generally follows the orientation of the metasedimentary bedrock/overburden contact and trends south towards the South Yuba River. Groundwater also preferentially follows unmineralized fractures and faults within the metasedimentary bedrock complex. Thus, a limited quantity of groundwater occurs in bedrock fractures while most local groundwater occurs within the fluvial deposits of the South Yuba River channel and its tributaries, situated approximately ¼ mile lower in elevation than Relief Hill. Groundwater to surface water expression is common throughout the mountainous terrain. Several prominent springs (Coleman, Big Lick, Dempsey, Willow, Derbec, Upper Derbec) located within 4 miles of the Relief Hill have been mapped (SAIC 2004).

It is probable that residual mercury in shallow subsurface soils is mobilized by infiltrating surface water. The residual mercury could then migrate along the bedrock/overburden contact, bedrock fractures, or manmade water diversion/drainage tunnels to the channels of nearby perennial streams and the South Yuba River.

2.6 VEGETATION AND WILDLIFE

Ground sluices and plugged tunnel inlets form depressions that collect direct precipitation and surface runoff to form seasonal ponds. During the spring and early summer, several wetland indicators (vegetation type, visible hydrology, and the presence of hydric soils) are associated with these areas (SAIC 2004). Some of the depressions likely meet the criteria of palustrine, emergent, seasonally or semipermanent wetlands. However, the U.S. Fish and Wildlife Service has not classified the wetlands at this site using wetland delineation technical guidelines developed by the U.S. Army Corps of Engineers.

Vegetation in the watershed surrounding Relief Hill (between middle and south forks of the Yuba River, Humbug Creek, and Poorman Creek) includes a diversity of vegetation typical of montane hardwood-conifer habitats (Forest Service 2004b). The most common tree species within proposed units are Ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), Douglas-fir (*Pseudotsuga menziesii*), incense cedar (*Calocedrus decurrens*), California black oak (*Quercus kelloggii*), tan oak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*). Tree canopies vary throughout the watershed and can exceed 50 percent. Other species native to the area include northern starflower, cow parsnip, buckbrush, sedges, rushes, wild azalea, manzanita, gray pine, white fir, broad leaf maple, and incense cedar (SAIC 2004).

Areas associated with the three off-site drainages and the South Yuba River provide crucial breeding and foraging areas for a variety of wildlife (SAIC 2004). The area provides habitat for mammals, fish, amphibians, reptiles, and insects. Though there is no direct evidence that any threatened or endangered plant or animal species occurs along any segment of the surface water migration pathway, the area of the site is potential (elevation) habitat for the federally threatened California red-legged frog (*Rana aurora draytonii*). The area also provides potential (elevation) habitat for the endangered bald eagle and California spotted owl, in addition to many other resident and migratory birds. Newts, salamanders, and tree frogs are also common. The foothill yellow-legged frog (*Rana boylii*), a State of California species of concern, was observed during field sampling activities. The area of the site is also habitat for other sensitive aquatic species including the hardhead (*Mylopharadon conocephalus*) and Northwestern pond turtle (*Clemmys marmorata*).

The Forest Service completed a biological evaluation in the Washington and North Bloomfield area in 2004 (Forest Service 2004b). The purpose of the biological evaluation was to document analysis of the potential effects of the Washington Fuels Reduction Project on a list of threatened and sensitive bird, mammal, amphibian, reptile, invertebrate and fish species and their habitats potentially present within the study area. Special status animal species identified in the biological evaluation and that may be present in the Relief Hill area are listed in Table 1.

The Forest Service completed a weed risk assessment at Relief Hill in 2004 (Forest Service 2004d). Two invasive, non-native plant species were identified on site: fewer than five plants of bull thistle (*Cirsium vulgare*) and 12 plants of Klamath weed (*Hypericum perforatum*). Both

species proliferate in disturbed areas and can be controlled or replaced by dense cover of native vegetation.

2.7 LAND USE AND POPULATION

Presently, an active, small-scale gold mining operation is located on a portion of Relief Hill. The mine is operated by Mr. Dan Jasper who employs two full-time caretakers. Several pieces of large mining equipment remain on the property. These include a Pelton Wheel, a monitor, a jaw crusher, and a grizzly. The mine features a large pit and lake where there are indications of recreational swimming (a diving board), target shooting, and off-highway vehicle (OHV) use (SAIC 2004).

Recreational activities in the South Yuba watershed include fishing, swimming, sun bathing, hiking, camping, mountain biking, and gold mining. All of these activities place people in close contact with water and sediment that may be impacted by releases from Relief Hill. Recreational gold miners engage in suction dredging and underwater sampling that places them in direct contact with mercury. During Tetra Tech's sampling activities in October 2004 and March 2005, the field crew also observed a number of motorcycle riders on the access road between the town of Washington and site; Tetra Tech did not observe any additional evidence of recreational use at the site. The site photographs (Appendix A, Photographs A-1 through A-40) depict various site features and sample locations at Relief Hill.

Existing beneficial uses for the Yuba River include the following (California Regional Water Quality Control Board, Central Valley Region [Water Board] 2004):

- Municipal and domestic water supply
- Irrigation and stock watering
- Power generation
- Recreation
- Freshwater habitat
- Migration for striped bass, sturgeon, shad, salmon, and steelhead
- Spawning for striped bass, sturgeon, shad, salmon, and steelhead
- Wildlife habitat

2.8 SIGNIFICANT CULTURAL AND ARCHEOLOGICAL FEATURES

The Forest Service completed an archeological inventory at Relief Hill in 2004 (Forest Service 2004c). During the field inventory, the Forest Service identified and recorded a number of artifacts and artifact concentrations at the mine, most of which are located on private property.

The location of an archeological site on Forest Service land at Relief Hill is shown on Figure 3. Artifacts identified at Relief Hill included segments of penstock (water pipelines used during hydraulic mining), water ditches, ponds, rock dam remnants, mine tunnel openings, and various mining and domestic debris (such as bottle glass, ceramic, and metal fragments). Drain tunnels constructed during historic hydraulic mining are ubiquitous features at the numerous hydraulic mines in the region, and therefore are not considered contributing elements to the potential National Register eligibility of the Relief Hill. Most artifacts, except for the drain channels, holding or settling ponds, drain shafts and tunnels, are located on high ground and will not be disturbed as a result of anticipated removal activities. The inventory report concluded that a removal action consisting of surface water controls, sediment stabilization, and contour grading will have no effect on heritage resources. The report noted there is a possibility that additional heritage resources will be located as a result of removal activities. Any response actions undertaken at Relief Hill should be coordinated with the Forest Service archeologist.

2.9 PROPERTY OWNERSHIP AND MINERAL RIGHTS

The Relief Hill mine encompasses both public and private land, as shown on Figure 3. As discussed in Section 2.7, small-scale gold mining is occurring on mine claims at the site under an authorized plan of operations. The U.S. Department of the Interior, Bureau of Land Management (BLM) mine claim database shows two unpatented mine claims, recorded as the Jasper and Jasper #2 claims, are active within Section 4 (see Appendix B). Removal action alternatives evaluated in this EE/CA are limited to public land administered by the Forest Service; activity on private land is not addressed in this report.

3.0 SITE INVESTIGATION SUMMARY

Site investigation and sampling activities have been conducted at Relief Hill by USGS, SAIC, and Tetra Tech from 1999 to 2005. Each of these investigations is summarized below. The investigations are discussed in greater detail in the tech memo (Tetra Tech 2006b).

3.1 PREVIOUS INVESTIGATIONS

Prior to the EE/CA, USGS and SAIC conducted site investigations and sampling at Relief Hill. Results of these investigations are summarized below. Analytical data from the previous investigations are presented in Appendix C.

3.1.1 U.S. Geological Survey Sampling

Surface water and sediment samples were collected by the USGS during three separate sampling events that occurred on May 20, 1999; September 1, 1999; and July 30, 2002. During the sampling event on September 1, 1999, biota samples were also collected. Four surface water samples were collected and analyzed for field parameters, total and dissolved metals (including total and methyl mercury), anions, nutrients, and suspended solids. Four sediment samples were collected and analyzed for total and methyl mercury. Three biota samples were collected and analyzed for total and methyl mercury. USGS sample locations are shown on Figure 2. Results of mercury analyses by USGS are summarized below and listed in Table 2.

- **Surface Water:** Total mercury concentrations in unfiltered samples ranged from 0.0008 to 0.299 microgram per liter (µg/L). Dissolved mercury concentrations in filtered samples ranged from less than 0.0001 to 0.0688 µg/L. Methyl mercury concentrations in unfiltered samples ranged from less than 0.000025 to 0.0001 µg/L. Methyl mercury concentrations in filtered water samples were only analyzed in two samples, one from location BY94 and a second from location BY95; results at both locations were less than 0.00004 µg/L. The highest concentrations of total mercury (0.299 µg/L) and methyl mercury (0.0001 µg/L) reported by USGS were in water samples from the Cliff tunnel outlet (BY94 on Figure 2).

- **Sediment:** Sediment samples were collocated with surface water samples to assess the amount of total mercury at location BY94 and methyl mercury at all three locations. Total mercury concentrations in sediment samples ranged from 0.02 to 0.409 milligram per kilogram (mg/kg), and methyl mercury concentrations ranged from 0.0002 to 0.0015 mg/kg. The highest concentrations of total mercury (0.409 mg/kg) and methyl mercury (0.0015 mg/kg) reported by USGS were detected in a sample from the Cliff tunnel outlet (see BY94 on Figure 2) collected on September 1, 1999.

- **Biota:** Three biota samples were collected to assess the amount of total and methyl mercury in invertebrates at Relief Hill. Biota samples included hellgrammites and

water striders from location BY94 and water striders from location BY95. All three biota samples were collected on September 1, 1999. The hellgrammite sample from location BY94 was analyzed for total mercury; analytical results showed the sample contained 0.048 mg/kg (wet weight) of total mercury. All three biota samples were analyzed for methyl mercury; concentrations ranged from 0.047 mg/kg (wet weight) to 0.094 mg/kg. The highest reported methyl mercury concentration (0.094 mg/kg) was in the water strider sample from the Cliff tunnel outlet (BY94).

Results of USGS sampling showed minimal uptake of mercury in invertebrates at Relief Hill. Analytical results for invertebrate samples show that bioaccumulation at the pit pond is low relative to 44 mine and stream sites throughout the South Yuba River, Bear River, and Greenhorn Creek watersheds (Alpers 2000).

3.1.2 Science Applications International Corporation Preliminary Assessment/Site Inspection

As a follow-up to USGS sampling activities, the Forest Service contracted SAIC in 2003 to conduct a combined PA/SI for Relief Hill to assess the relative risk posed by the site to human health and the environment and to gather sufficient information to support a decision regarding the need for further action under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (SAIC 2004). Seven colocate surface water and sediment samples were collected where surface water was pooled or flowing. Three sediment samples were collected at stations found to be dry. SAIC sample locations are shown on Figure 2. Results of mercury analyses by SAIC are summarized below and listed in Table 3.

- **Surface Water:** Mercury concentrations in all seven surface water samples were below the detection limit of 0.20 µg/L.
- **Sediment:** Mercury concentrations in all but one of the sediment samples were below the detection limit of 0.1 mg/kg. The single detection was 0.1 mg/kg at the Cliff tunnel outlet.

Based on PA/SI findings, SAIC concluded that 1) mercury may be mobilized during high-flow, turbid, runoff events; 2) open, accessible, mercury-bearing sluice remnants, acidic pit lakes, unsupported drainage tunnels and adits, high walls, and steep/loose tailings piles pose physical hazards to unwary locals and tourists; and 3) threatened and endangered species may be present at the site.

3.2 CURRENT INVESTIGATION

The Forest Service contracted Tetra Tech to complete an EE/CA for Relief Hill, which included additional field sampling activities to fill data gaps and gain a better understanding of site dynamics. Tetra Tech conducted two sampling events to determine the mercury levels during both "undisturbed" dry season conditions (October 2004) and "disturbed" conditions during a

saturated runoff event (March 2005) to document mercury migration while contaminants were being flushed from the site. Tetra Tech also identified surface water flow patterns and mapped significant mine features including high walls, ground sluices, drain tunnels, pit lakes, and flood areas. Results of EE/CA field sampling are presented and evaluated in the tech memo (Tetra Tech 2006b) and are summarized in this section.

Sluice Survey

Approximately 20,800 feet of sluices were surveyed or interpreted in five distinct tunnel systems. The Cliff, New, Middle, and Waukesha tunnels were surveyed from the outlets and through the network of sluices and significant sub-sluices. The Union sluice system was interpreted from an historical mining map. The ground sluices were estimated to contain 49,150 cubic yards (yd^3) of infill sediment (see Table 4). The actual volume of infill sediment could be substantially greater because the sediment may be thicker than the minimum estimate used in the volume calculations (the sediment thickness could not be accurately determined). Site features and drainage patterns are shown on Figure 3.

Surface Water Sampling

Tetra Tech collected surface water samples at six locations during the undisturbed event and 15 locations during the disturbed event. Surface water samples were analyzed for low-level total and methyl mercury, dissolved mercury (at standard detection limits), total suspended solids (TSS), and field parameters (pH, specific conductance, oxidation-reduction potential, temperature, and dissolved oxygen). Detection limits for mercury in water samples under the current investigation were 0.00015 µg/L for total mercury, 0.000025 µg/L for methyl mercury, and 0.2 µg/L for dissolved mercury. Figure 3 show the sampling locations for both sampling events. Analytical data for surface water samples are presented in Table 5. Findings from surface water sampling include the following:

- Concentrations of total mercury ranged from 0.00421 to 0.078 µg/L during the undisturbed event and 0.00324 to 1.88 µg/L during the disturbed event. Total concentrations were highest in samples collected from the Waukesha South Inlet No. 4, the Waukesha South Tunnel Outlet, and the Middle Tunnel North Inlet No. 2 during the disturbed event. The highest total mercury concentrations were detected in the Cliff tunnel during the undisturbed event.

- Methyl mercury concentrations were below the detection limit (0.000025 µg/L) in samples from the Cliff and Waukesha South tunnel outlets, and ranged from 0.000031 to 0.000704 µg/L in the remaining samples during the undisturbed event. During the disturbed event, methyl mercury concentrations were below the detection limit (0.000025 µg/L) in five samples, and ranged from 0.000039 to 0.000318 µg/L in the remaining samples. Methyl mercury concentrations were highest in samples collected from the Waukesha South Inlet No. 4, the Waukesha South Tunnel Outlet, and the Middle Tunnel North Inlet No. 2 during the disturbed event and in the Waukesha Inlet Pond during the undisturbed event.

- Concentrations of TSS in four of the six surface water samples collected during the undisturbed event were below the detection limit of 10 milligrams per liter (mg/L). Concentrations of TSS were 150 mg/L and 18 mg/L in samples from the Cliff Tunnel Inlet No. 6 and the Waukesha Inlet Pond samples, respectively. These two locations also contained the highest concentrations of total and methyl mercury relative to the other undisturbed event water samples, which suggests mercury may be associated with suspended particles. Surface water samples collected during the disturbed event generally had similar concentrations of TSS to undisturbed event samples. The majority of disturbed event water samples were collected after rainfall ceased, when standing water and near-surface groundwater were draining from the site. TSS concentrations ranged from less than 5.0 mg/L (in nine samples) to 2,200 mg/L. The highest concentrations (2,200 mg/L and 510 mg/L) were measured in samples collected from the Waukesha sluice system. These concentrations are at least one order of magnitude greater than all the other disturbed event samples (47 mg/L or less). High TSS concentrations in Waukesha sluice system samples are attributed to a small landslide that occurred recently at the head of the sluice system and do not appear to represent normal runoff conditions. However, these observations illustrate that sediments on site are susceptible to erosion and off-site migration.

Solid Matrix Sampling

Tetra Tech collected solid matrix samples at 15 locations during the undisturbed event and eight locations during the disturbed event. During the undisturbed event, surface samples (less than 6 inches below ground surface [bgs]) were collected to assess potentially mobile sediment and subsurface samples (up to 66 inches bgs) were collected as close as possible to the base of the ground sluices where elemental mercury was expected to accumulate. Disturbed event samples were collected from the surface to 4 inches bgs to assess mercury concentrations in recently mobilized sediment. Sediment samples were analyzed for total and methyl mercury. Detection limits for mercury in solid matrix samples under the current investigation were 0.00045 mg/kg for total mercury and 0.00002 to 0.000028 mg/kg for methyl mercury. Figure 3 show the sampling locations for both sampling events. Analytical data for sediment samples are presented in Table 6. Findings from sediment sampling include the following:

- Concentrations of total mercury, as determined by low-level analytical methods, ranged from 0.0169 to 1.92 mg/kg during the undisturbed event and from 0.00259 mg/kg to 0.579 mg/kg during the disturbed event. Concentrations in aliquots analyzed by standard methods were similar, ranging from 0.011 to 5.9 mg/kg during the undisturbed event; samples were not analyzed for total mercury by standard analytical methods during the disturbed event. The sample from the Middle Tunnel Inlet No. 1 had the highest total mercury concentration during the disturbed event (0.579 mg/kg) as well as the undisturbed event (1.92 mg/kg and 5.9 mg/kg, depending on the analytical method).

- Concentrations of methyl mercury were below the detection limit (0.00002 mg/kg) in nine samples, and ranged from 0.000024 to 0.000779 mg/kg in five samples during the undisturbed event. Methyl mercury concentrations were below the detection limit (0.00002 to 0.00028 mg/kg) in four samples, and ranged from 0.000041 mg/kg to 0.000836 mg/kg in five samples during the disturbed event. The Waukesha Inlet Pond sample contained the highest concentration of methyl mercury during the undisturbed event. The sample from the Cliff Tunnel Inlet No. 7 contained the highest methyl mercury concentration during the disturbed event.

- Results of total mercury analysis and the estimated volumes of infill sediment were used to calculate a mass of mercury remaining in on-site sediments. The mass of mercury was estimated to be 59.4 pounds. More than 86 percent of the mercury estimated to remain on site is within the Middle sluice system. The average mercury concentration used for the Middle sluice system (1.97 mg/kg) was more than 20 times the average concentration in the four other sluice systems (0.055 to 0.087 mg/kg) because of a high concentration of mercury in the Middle Tunnel Inlet sample in October 2004 (1.92 mg/kg by low-level analysis and 5.9 mg/kg by standard analysis). The calculated mass of mercury on site is thought to be a minimum estimate because the thickness (and therefore volume) of infill sediment could be greater than the value used in the calculation, and because mercury that accumulated at the base of ground sluices does not appear to be accounted for in the sediment sample results.

3.3 SUMMARY OF SAMPLING RESULTS

The previous and current investigations at Relief Hill show that mercury is present on site, but concentrations at most surface water and sediment sample locations are relatively low (generally only detectable by low-level analysis). Results of biota sampling at Relief Hill did not show bioaccumulation of methyl mercury above background concentrations in the South Yuba and Bear rivers. Detection of mercury in sediment from tunnel outlets at Relief Hill indicate mercury may be released from the site through the surface water system. The documentation of thick infill sediment in ground sluices, pit lakes, and flood areas on site with low mercury concentrations indicates that elemental mercury remaining at Relief Hill is buried with sediment deposited since hydraulic mining ended. The slightly lower overall concentrations of mercury Tetra Tech documented during the disturbed event suggest that either geologic material currently being eroded, or susceptible to erosion, contains less mercury than the material that was eroded

and deposited on site in the past or the disturbed event samples were being diluted by precipitation. Field observations and analytical data show that sediment mobility at Relief Hill is a concern. The poor vegetative cover, susceptibility of on-site geologic materials to erosion, and sluice system's design for rapid surface water drainage lead to significant sediment transport from Relief Hill during storm events. Though the active mobilization and on-site deposition of sediment helps encapsulate mercury, sediment transported off site has a negative effect on water quality in receiving water bodies including the South Yuba River.

3.4 CONCEPTUAL SITE MODEL

Based on the findings of previous environmental investigations, a CSM was developed for Relief Hill (Figure 4). The CSM addresses the mine workings of Relief Hill and identifies five potential primary sources of mercury and increased turbidity:

1. Pit floor and high walls
2. Flood areas
3. Ground sluices
4. Sluice tunnels
5. Plunge pools below the sluice tunnel outlets

Five primary release mechanisms for release of sediment and mercury to the environment are identified in the CSM. One or more of the primary release mechanisms may operate at Relief Hill on any of the potential primary sources to mobilize sediment and mercury to the environment. Primary release mechanisms that may be operating on individual primary sources at Relief Hill include the following:

1. Storm Water Runoff – Sediment and mercury may be released and transported away from any of the primary sources by storm water runoff. Mercury can also methylate and enter the food chain when moist or wet.
2. Dissolution – Mercury can be entrained in sediment and released from any of the primary sources while inundated with surface water, dissolve into the water column, or methylate and enter the food chain.
3. Slope Failure – Sediment and mercury may be released by failure of sluice side walls and high walls, which can aid dissolution into the water column, migration of airborne particles and dust (when dry), and volatilization. Slope failure and erosion can also increase turbidity during runoff events.
4. Particles/Dust – Sediment and particulate-bound mercury from exposed ground surfaces on the pit floor, high walls, flooded areas, and ground sluices can be released by migration of airborne particles and dust during the dry season.

5. Volatilization – Mercury entrained in either sediment or surface water from any of the primary sources can volatilize and become airborne.

In addition, as presented in the CSM, two secondary sources of mercury and their associated release mechanisms include the following:

1. Surface Water – Mercury in surface water may be methylated leading to accumulation in the food chain. Mercury can also volatilize or evade from the water column to the atmosphere.

2. Ambient Air – Ambient air also acts as a reservoir for mercury and is an exposure pathway that does not require a secondary release mechanism. Mercury in air occurs on dust and particulates and as mercury vapor (volatilization). Mercury on dust particles may also deposit in surface water bodies and methylate.

Based on an evaluation of primary and secondary sources, release mechanisms, and environmental data, three direct exposure media for potential receptors have been identified. Potential receptors may be exposed to mercury or methyl mercury in this media through inhalation, ingestion, and dermal contact.

1. Surface Water – Exposure routes for recreational visitors and fauna include ingestion of and dermal contact with surface water from Relief Hill. A number of water samples were found to exceed screening criteria for drinking water (Marshack 2003). However, it should be noted that the mine is not a source for drinking water and substantial ingestion is unlikely. One of the water samples collected from Relief Hill exceeded the U.S. Environmental Protection Agency (EPA) Ambient Water Quality Criterion (AWQC) for the protection of fresh water aquatic life (Marshack 2003), aquatic life being the most likely receptor in the area. Ingestion of or dermal contact with surface water from the mine pit is one of three completed pathways identified at this time based on field observations and existing analytical data. Residential receptors were not considered because the miners and caretakers do not live at the site full time.

2. Sediment – Exposure routes for recreational visitors and fauna include ingestion of and dermal contact with sediment from Relief Hill. None of the sediment samples collected from Relief Hill exceeded BLM risk criteria for humans under a number of exposure scenarios (Ford 1996). The sediment sample collected from the Middle Tunnel Inlet No. 1 during previous field work exceeded BLM risk management criteria for a robin. Residential receptors were not considered because the miners and caretakers do not live at the site full time.

3. Ambient Air – Ambient air is also a potentially completed pathway for human visitors, terrestrial, and aquatic receptors because mercury has a low vapor pressure and is easily volatilized. Mercury vapor is a potential concern in areas of stagnant air where temperatures are moderate to high. Air samples were not collected at Relief Hill to demonstrate path completion. However, based on the low levels of mercury and methyl mercury in sediment and surface water samples, the potential exposure to area receptors is considered low. Residential receptors were not considered because the miners and caretakers do not live at the site full time.

While each of the media and associated exposure routes may lead to adverse effects on humans or wildlife, a significant concern is biomagnification of mercury in the food chain and exposure of upper trophic level fauna and humans through consumption of mercury-containing organisms. For example, humans may eat fish or frogs containing mercury; or birds of prey may consume frogs or fish that have accumulated mercury from ingestion of mercury-containing insects.

An evaluation of environmental data suggests the following scenario regarding mercury fate and transport at Relief Hill. Mercury is believed to be present at the base of ground sluices, pit lakes, and wetlands. A portion of the loose geologic material mobilized by precipitation and storm water runoff appears to be deposited in the sluices and depressions, further entombing the remaining mercury. Though the active mobilization and on-site deposition of sediment helps encapsulate mercury, sediment transported off site likely has a negative effect on water quality in receiving water bodies including the South Yuba River.

4.0 PRELIMINARY RISK SCREENING

The completed pathways shown in the CSM (Figure 4) identify the media and routes of exposure evaluated in human health and ecological risk screening presented in this section. Potential risks to human health and ecological receptors of mercury were evaluated by comparison to soil and drinking/tap water screening criteria. Sediment mercury concentrations are compared to risk-based screening criteria for soils because generally applicable sediment screening criteria are not available for all receptors. The exposure of humans and fauna to mercury in sediment at Relief Hill is similar to exposure of fauna and humans to soil for the purposes of risk screening. Soil screening criteria are generally more conservative than sediment screening criteria. Threats to water quality will also be described.

Potential risks to human health and ecological receptors of methyl mercury were evaluated by comparison to background results from the Bear River and a compilation of samples collected from background locations, mine sites and downstream of mine sites in the South Yuba River, Bear River, and Greenhorn Creek Watersheds and water quality criteria compiled by Marshack (2003).

4.1 HUMAN HEALTH RISK SCREENING

Potential risks to human health have been evaluated by comparison of mercury concentrations reported in surface water and sediment at Relief Hill to screening criteria. The paragraphs below identify the criteria used for human health risk screening and present the risk screening results. The discussion is organized by sample media.

Analytical results for surface water samples collected at Relief Hill were compared with human health risk screening criteria established by EPA and the State of California. The screening criteria were developed for sources of drinking water and are therefore considered very conservative when applied to water samples from Relief Hill. Analytical results and screening criteria values for surface water samples are listed in Table 7 and shown graphically on Figure 5. Screening criteria for surface water samples are summarized below and described in greater detail in Section 5.2.1.

- EPA maximum contaminant level (MCL) (2 µg/L for total mercury)
- California Public Health Goal in Drinking Water (1.2 µg/L for total mercury)
- California Toxics Rule (CTR) criterion for human consumption of water and aquatic organisms (0.05 µg/L for total mercury)
- EPA Region IX preliminary remediation goal (PRG) for tap water (11 µg/L for total mercury and 3.6 µg/L for methyl mercury)

The mercury concentration in six surface water samples from Relief Hill (0.0637 to 1.88 µg/L) exceeds the CTR criterion (0.05 µg/L). Thus, humans who frequently use mine pit water as a source of drinking water may have an increased health risk due to mercury contamination. However, this is the most conservative screening criterion identified and recreational users and site workers are not expected to ingest mine pit water on a continual basis. Site visitors are known to swim in the pit lake and might consume pit water, but not at the frequency and volume assumed in the drinking water criteria calculations. Thus, the screening criteria may overestimate actual risk to human receptors. None of the water samples collected from Relief Hill exceeded the EPA PRG for methyl mercury in tap water (3.6 µg/L), the most conservative screening criterion identified (Smucker 2004).

Analytical results for solid matrix (both sediment and soil) samples collected at Relief Hill were compared with human health risk screening criteria established by BLM and EPA. Sediment samples from Relief Hill were compared with screening criteria for soil because exposure scenarios are similar and soil screening values are generally lower. BLM developed human risk management criteria for metals at mining sites for several exposure scenarios (Ford 1996), of which the camper scenario is most applicable to Relief Hill. The BLM human risk management criterion for mercury under a camper exposure scenario is 40 mg/kg. The EPA Region IX industrial PRG (310 mg/kg for mercury) was also used for human health risk screening. The industrial PRG is calculated based on an industrial use scenario (for humans working at a site), which is routinely thought to reflect exposures greater than recreational exposures. The industrial exposure calculation assumes exposure of five 8-hour days per week for 50 weeks per year for 25 years. This is likely a greater exposure time than would be selected for recreational exposures. Therefore, use of the industrial PRG likely overstates the potential risk for recreational visitors. Neither the BLM nor EPA screening criteria include values for methyl mercury. Analytical results and screening criteria values for solid matrix samples are listed in Table 8 and shown graphically on Figure 6.

Concentrations of total mercury in solid matrix samples from Relief Hill (up to 5.9 mg/kg) do not exceed even the lowest of the selected screening criteria (40 mg/kg). The highest measured concentration of methyl mercury was 0.0015 mg/kg. However a screening benchmark concentration has not been promulgated for methyl mercury. This indicates that humans who use Relief Hill for recreation activities or work at the site will not be exposed to mercury or methyl mercury in sediment at concentrations that present a significant health risk.

4.2 ECOLOGICAL RISK SCREENING

Potential risks to ecological receptors have been evaluated by comparing mercury concentrations at Relief Hill to screening criteria, and by comparing the results of biota sampling at Relief Hill to results of biota sampling throughout nearby watersheds. The paragraphs below identify the criteria used for ecological risk screening and present the risk screening results. The discussion is organized by sample media.

Analytical results for surface water samples collected at Relief Hill were compared with the EPA AWQC for the protection of freshwater aquatic life, continuous concentration (4-day average). The AWQC criterion for total mercury is 0.77 µg/L; a criterion for methyl mercury has not been established. Analytical results and screening criteria values for surface water samples are listed in Table 7 and shown graphically on Figure 5. The concentration of total mercury in one surface water sample from Relief Hill (1.88 µg/L at the Waukesha South Inlet No. 4 during the disturbed event) exceeded the AWQC. Most mercury in this sample appeared to be associated with sediment particles; the concentration of dissolved mercury was 0.2 µg/L. This surface water sample was affected by a small landslide that recently occurred upstream; sediment and mercury load in this sample does not appear to represent normal runoff conditions.

Analytical results for solid matrix samples collected at Relief Hill were compared with ecological risk screening criteria developed by BLM and EPA. BLM developed wildlife and livestock risk management criteria for 12 animal species (Ford 1996); screening values for mercury in soil include 1 mg/kg for a robin, 4 mg/kg for a mallard, 9 mg/kg for a mule deer, and 15 mg/kg for a cotton tail. Ford (1996) suggests that concentrations exceeding the risk screening criteria by a factor of 1 to 10 represent a moderate risk, exceedances by a factor of 10 to 100 represent a high risk, and exceedances by more than a factor of 100 represent an extremely high risk. The EPA Office of Solid Waste and Emergency Response Ecotox Threshold (ET) value for mercury in sediment (0.15 mg/kg) was also used for preliminary risk screening (EPA 1996). The EPA reference describes ETs as "media-specific contaminant concentrations above which there is sufficient concern regarding adverse ecological effects to warrant further site investigation. ETs are meant to be used for screening purposes only; they are not regulatory criteria, site-specific cleanup standards, or remediation goals." The ET for mercury is based on the lower 10th percentile concentration associated with the observation of biological effects in species that are most susceptible to mercury contamination. The ET for mercury is considered especially conservative when applied to sediment at Relief Hill. Note that the average concentration of mercury in California background soils (0.26 mg/kg) (Bradford and others 1996) is almost double the ET for mercury. Analytical results and screening criteria values for solid samples are listed in Table 8 and shown graphically on Figure 6.

Concentrations of total mercury in five solid matrix samples from Relief Hill (up to 5.9 mg/kg) exceed the ecological risk screening benchmarks, as described below:

- A sediment sample collected at the Waukesha Inlet Pond during the undisturbed sampling event contained 0.179 mg/kg of total mercury.
- A sediment sample collected at the Union Tunnel Outlet during the undisturbed sampling event contained 0.221 mg/kg of total mercury.
- A sediment sample collected at the Middle Tunnel Inlet No. 1 during the undisturbed sampling event contained 5.9 mg/kg of total mercury.

- A second sediment sample collected at the Middle Tunnel Inlet No. 1 location during the disturbed sampling event contained 0.579 mg/kg of total mercury.
- A sample collected by the USGS at the Cliff Tunnel Outlet (location BY94) in September 1999 contained 0.409 mg/kg of total mercury. A sample collected at the same location in July 2002 contained 0.02 mg/kg of total mercury (below the ecological risk screening criterion).

Of the exceedances described above, only the one sample contained mercury (5.9 mg/kg in sediment from the Middle Tunnel Inlet No. 1 during the undisturbed sampling event) above the range of mercury in California background soils (0.10 to 0.90 mg/kg) (Bradford and others 1996). In accordance with BLM guidance (Ford 1996), the mercury concentration in the Middle Tunnel Inlet No. 1 sediment sample is considered to pose a moderate risk to robins and mallards.

An alternative way to evaluate potential ecological risk is to compare mercury concentrations detected in biota at Relief Hill to biota throughout nearby watersheds. Sample results and comparison criteria are presented in Table 9. Sample locations are presented in Figures 2 and 3. Mercury concentrations in hellgrammites and water striders collected at Relief Hill by USGS were compared to biota from the Bear River, South Yuba River, and Greenhorn Creek watersheds. Biota samples collected at Relief Hill include a hellgrammite sample from the Cliff tunnel outlet (BY94) and water strider samples from the Cliff tunnel outlet (BY94) and the pit pond at the Cliff tunnel inlet (BY95) (Alpers 2000). The biota data set also includes background samples from baseline reference sites in the Bear and South Yuba Rivers that USGS reported to be upstream of known mining effects. The baseline reference stations include the Bear River at Highway 20 near Emigrant Gap (BY199) and the South Yuba River at Eagle Lakes near Emigrant Gap (BY117).

The concentration of total mercury in the pit pond water strider sample (0.048 mg/kg) was similar to concentrations in background samples from the Bear River (0.028 to 0.070 mg/kg). The concentration of methyl mercury (0.047 mg/kg) was similar to background concentrations in one sample from the South Yuba River (0.050 mg/kg) and four samples from the Bear River (0.027 to 0.050 mg/kg). The methyl mercury concentration in one water strider sample from the Cliff tunnel outlet (0.094 mg/kg) was twice as high as concentrations measured in water strider samples from the pit pond and background concentrations in the South Yuba and Bear rivers. Methyl mercury concentrations in water striders at Relief Hill (0.047 and 0.094 mg/kg) were low to moderate compared to 35 samples collected throughout the South Yuba and Bear river watersheds (the 10 percent concentration is 0.05 mg/kg; the median concentration is 0.084 mg/kg; and the 75 percent concentration is 0.1 mg/kg) and high compared to 56 samples collected throughout the Greenhorn Creek watershed (the 90 percent concentration is 0.027 mg/kg). The methyl mercury concentration in one hellgrammite sample from the Cliff tunnel outlet (0.053 mg/kg) was slightly higher than the concentration in one background sample from the South Yuba River (0.031 mg/kg) and three background samples from the Bear River

(0.029 to 0.040 mg/kg). Based on the analytical results of invertebrates, bioaccumulation at the Relief Hill pit ponds is considered low (Alpers 2000).

4.3 THREATS TO WATER QUALITY

Conditions at Relief Hill might affect the quality and usability of surface water downstream from the site. As a result, water sample data was also compared to criteria related to beneficial use of surface water as defined by the California Regional Water Quality Control Board, Central Valley Region Basin Plan (Water Board 2004), which includes CTR and EPA PRG criteria. Results for water sampling performed at Relief Hill do not show a substantial increase in concentrations of total or methyl mercury as water flows from the mine pit through the ground sluices, and out of the drain tunnels. Concentrations of total mercury in six surface water samples (0.0637 to 1.88 µg/L), including two samples of water discharging from the site (0.299 and 0.413 µg/L), exceed the CTR criterion for human consumption of water and organisms (0.05 µg/L). None of the water samples collected from Relief Hill exceeded EPA PRGs for tap water for either total mercury (11 µg/L) or methyl mercury (3.6 µg/L) (Smucker 2004).

Field observations and analytical data from the disturbed sampling event show that mercury-bearing geologic materials at Relief Hill are susceptible to erosion and transport through the sluice systems. The maximum concentration of total mercury in surface water samples (1.88 µg/L at the Waukesha South Inlet No. 4 during the disturbed event) appears to be associated with a small landslide that occurred recently upgradient from the sluice (see Photographs A-21 and A-23 in Appendix A). The landslide originated from the hillside west of the sluice, directly above Dan Jasper's mine entrance. Tetra Tech does not have reason to believe that substantial amounts of mercury were used above the sluices or above Dan Jasper's Mine, unless this was a storage area at some time. Due to the recent slide, the water at the sample location was extremely turbid as evidenced by the elevated TSS reading of 2,200 mg/L. Most mercury in this sample (1.88 µg/L) appeared to be associated with sediment particles; the concentration of dissolved mercury was 0.2 µg/L. The sediment and mercury load in this sample does not appear to represent normal runoff conditions. However, these observations illustrate that soil on site is susceptible to erosion, which can lead to transport of mercury through the sluice systems. Concentrations of total mercury (0.413 µg/L) and TSS (510 mg/kg) in surface water at the Waukesha South Outlet were approximately one-fourth of the concentration at the inlet. This suggests that mobilized sediment is a source of mercury in surface water, and sediment released by the landslide settled from the water column within the sluice system before discharging from the drain tunnel outlet. Sediment mobilized from the site may be discharged into the South Yuba River, thereby affecting turbidity and sediment load.

4.4 BASIS FOR REMOVAL ACTION

Concentrations of mercury at Relief Hill were found to exceed the human health screening benchmark in six surface water samples, including two samples collected where water flowed off

site. Surface water with mercury at concentrations above the CTR criterion for human consumption of water and organisms (0.05 µg/L) include the following:

- Cliff Tunnel Inlet No. 6 sample collected by Tetra Tech in October 2004 (0.078 µg/L)
- Waukesha South Outlet sample collected by Tetra Tech in March 2005 (0.413 µg/L)
- Middle Tunnel Inlet No. 1 sample collected by Tetra Tech in March 2005 (0.0637 µg/L)
- Waukesha South Inlet No. 4 sample collected by Tetra Tech in March 2005 (1.88 µg/L)
- Middle Tunnel North Inlet No. 5 sample collected by Tetra Tech in March 2005 (0.269 µg/L)
- Cliff Tunnel Outlet (BY94) sample collected by USGS in September 1999 (0.299 µg/L)

One sediment sample collected during the undisturbed sampling event contained mercury at a concentration that exceeded the ecological screening benchmark. The mercury concentration in a sample from the Middle Tunnel Inlet No. 1 was 1.92 mg/kg by low-level analysis and 5.9 mg/kg by standard analysis. These concentrations exceed the BLM risk management criteria for robins (1 mg/kg) and mallards (4 mg/kg) and may represent a moderate risk to these receptors.

Near-surface sediment (up to 66 inches bgs) in ground sluices at Relief Hill was not found to contain total or methyl mercury at concentrations above the human health or ecological screening benchmarks. Material at the base of the sluices could not be sampled due to greater than anticipated sediment thickness and equipment limitations. However, elemental mercury, if present at the site, would likely have accumulated near the original bottom of the sluice channel. Results of disturbed event sampling indicate sediment mobilized during storm water runoff events generally contains low concentrations of mercury (0.579 mg/kg or less). Deposition of this sediment in ground sluice channels, flood areas, and plunge pools during each storm event appears to bury elemental mercury potentially remaining at the base of ground sluices under relatively clean sediment. Therefore, exposure of humans and wildlife to potentially elevated mercury concentrations at the base of ground sluices is unlikely. Visual observations and analytical data from disturbed event sampling at the Middle sluice system showed that slope failure can significantly increase the concentrations of total mercury and TSS in surface water flowing through the sluice systems. Surface water controls to limit runon and runoff could further reduce the potential for migration of mercury found on site.

Bioaccumulation of mercury on site is considered low in the pit pond at the Cliff Tunnel Inlet (BY95) and moderate at the Cliff Tunnel Outlet (BY94) based on fauna sampled. One water strider sample from the pit pond (0.048 mg/kg total mercury and 0.047 mg/kg methyl mercury) did not show bioaccumulation above background concentrations in the South Yuba and Bear

rivers (up to 0.070 mg/kg of total mercury and up to 0.050 mg/kg of methyl mercury). Water strider and hellgrammite samples from the Cliff Tunnel Outlet had methyl mercury concentrations of 0.094 and 0.053 mg/kg, respectively. These concentrations are slightly elevated compared to maximum concentrations of methyl mercury measured in background samples from the South Yuba River (0.050 mg/kg for water striders and 0.031 mg/kg for hellgrammites) and the Bear River (0.050 mg/kg for water striders and 0.040 mg/kg for hellgrammites). The methyl mercury concentration in the Cliff Tunnel Outlet water strider sample was comparable to the 75 percent concentration level for 35 samples throughout the South Yuba River watershed (0.10 mg/kg) and above the 90 percent concentration level for 56 samples throughout the Greenhorn Creek watershed (0.027 mg/kg). Potential impacts to human and ecological receptors due to exposure to mercury from Relief Hill are described below, followed by a summary of removal action criteria from the National Oil and Hazardous Substance Pollution Contingency Plan (NCP) that are met at Relief Hill.

Potential Human Impacts of Mercury Exposure. The potential human impacts of mercury exposure are summarized from Agency for Toxic Substances and Disease Registry (ATSDR) (1999). Exposure to high levels of metallic, inorganic, or organic mercury can permanently damage the brain, kidneys, and developing fetus. Mercury's harmful effects that may be passed from the mother to the fetus include brain damage, mental retardation, lack of coordination, blindness, seizures, and inability to speak. Children poisoned by mercury may develop problems of their nervous and digestive systems, and kidney damage. Effects of exposure to mercury on brain functioning may result in irritability, shyness, tremors, changes in vision or hearing, and memory problems. Methyl mercury and metallic mercury vapors are more harmful than other forms, because mercury in these forms more readily reaches the brain. Short-term exposure to high levels of metallic mercury vapors may cause effects including lung damage, nausea, vomiting, diarrhea, increases in blood pressure or heart rate, skin rashes, and eye irritation.

Potential Ecological Impacts of Mercury Exposure. Potential ecological impacts of mercury exposure are summarized from "Toxicological Profile for Mercury." (ATSDR 1999) and "Handbook of Ecotoxicology" (Wiener and others 2003). In the environment, inorganic mercury can be methylated by microorganisms to produce methyl mercury. Methyl mercury will accumulate in the tissues of organisms. The animals at the top of the food chain tend to accumulate the most methyl mercury in their bodies. Any source of mercury release to the environment may, therefore, lead to increased levels of methyl mercury in tissues of large fish, reptiles, birds, and mammals (ATSDR 1999). Mercury affects the reproduction and foraging ability of fish and is neurotoxic to fish. Exposure to mercury can impair reproduction of birds, cause mortality of bird eggs, and is related to the impaired feeding ability of birds. Exposure effects of mammals to mercury are similar to effects in humans and include lethargy, tremors, convulsions, and mortality (Wiener and others 2003).

Potential Safety Concerns. Mine tunnels, ground sluices and high walls may cause unsafe conditions on publicly accessed land. Mine tunnels, known to exist at the Relief Hill, are connected to numerous open and collapsed inlets throughout the site, creating fall or cave-in

hazards. Similarly, high walls and ground sluice walls could fail near the steep embankments causing a site visitor to fall or be buried by loose material unexpectedly sloughing off due to natural or human triggered erosion. The site is currently used for mining and recreational activities. There are currently no controls to minimize the physical hazards to site visitors.

NCP Removal Action Criteria. The potential risks to humans and ecological receptors described above document attainment of the following NCP removal action factors found at 40 *Code of Federal Regulations* (CFR) Section 300.415(b)(2):

- Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants.
- Actual or potential contamination of drinking water supplies or sensitive ecosystems.
- Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released.

Based on these three NCP factors, a removal action is warranted at Relief Hill to minimize human and ecological exposure to mercury, to minimize migration of sediment and mercury through storm water runoff, and to minimize accumulation of mercury in the food chain.

Field observations and analytical data collected during the disturbed sampling event show that non-vegetated areas at Relief Hill are subject to slope failure and erosion during storm events. Mercury was found to be associated with mobile sediment particles. Sediment mobilized by storm water runoff is released from the site and contributes to the sediment load in receiving waters, particularly the South Yuba River.

5.0 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section summarizes the Forest Service analysis of potential federal and State of California ARARs and the resultant identification of potential ARARs for each removal action alternative retained for detailed analysis in this EE/CA. Section 5.1 summarizes the definitions and concepts pertinent to ARAR determinations. The three categories of ARARs, chemical-, location- and action-specific, are described in Sections 5.2, 5.3, and 5.4, respectively. Section 5.5 follows the ARAR discussion and provides an analysis of the exemption of mining wastes from regulation as a hazardous waste under Section 3001(a)(3)(A)(ii) of the Resource Conservation and Recovery Act (RCRA) (Bevill Amendment exemption) and under the California Health and Safety Code, Section 25143.1(b)(1) and (2). Section 5.6 is a discussion of other issues that could affect the removal action.

The Forest Service has primary responsibility for identifying federal ARARs at Relief Hill. The Forest Service has identified the following federal and state ARARs for Relief Hill.

5.1 SUMMARY OF COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT AND NATIONAL OIL AND HAZARDOUS SUBSTANCES POLLUTION CONTINGENCY PLAN REQUIREMENTS

Section 121(d) of the CERCLA of 1980 (42 *United States Code* [USC] Section 9621[d]), as amended, states that remedial actions on CERCLA sites must attain (or the decision document must justify the waiver of) any federal or more stringent state environmental standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate.

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. The requirement is applicable if the jurisdictional prerequisites of the law or regulation directly address the circumstances at the site. An applicable federal requirement is an ARAR. An applicable state requirement is an ARAR only if it is more stringent than federal ARARs.

If the requirement is not legally applicable, then the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations similar to the circumstances of the proposed removal action and are well suited to the conditions of the site (EPA 1988). A requirement must be determined to be both relevant <u>and</u> appropriate to be considered an ARAR.

To qualify as a state ARAR under CERCLA and the NCP, a state requirement must be a promulgated law, substantive, consistently applied, and more stringent than a federal requirement. Provisions of generally relevant federal and state statutes and regulations that were determined to be procedural or nonenvironmental, including permit requirements, are not

considered to be ARARs. Nonpromulgated advisories or guidance issued by federal or state governments are not legally binding and do not have the status of ARARs. However, such requirements may be useful, and are "to be considered" (TBC) for guiding decisions regarding cleanup levels or methodologies when regulatory standards are not available.

Three categories of ARARs are used to assist in the identification of ARARs: (1) chemical-specific, (2) location-specific, (3) and action-specific ARARs. EPA guidance recognizes that some requirements do not fall neatly into these three categories. These three categories and two additional categories of ARARs (mining waste regulations and other issues) are described in the following sections.

5.2 CHEMICAL-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDEREDS

Chemical-specific ARARs are generally health- or risk-based numerical values or methodologies applied to site-specific conditions that result in the establishment of a cleanup level. The media of potential concern at Relief Hill are surface water and sediment. Potential ARARs for these media are evaluated below.

5.2.1 Applicable or Relevant and Appropriate Requirements for Surface Water

Identification of surface water ARARs depends on the beneficial uses of the water. Beneficial uses of surface waters in California are identified in water quality control plans, known as Basin Plans. Basin Plans are adopted and amended by regional water boards with input from the public, environmental review by the state, and approval by the Water Board (Water Board 2004). Basin Plans are regulatory references for meeting the state and federal requirements for water quality control. The Basin Plan for the Central Valley Region does not specifically identify the existing beneficial uses for Logan Canyon, the unnamed central drainage, and Union Canyon. However, the Basin Plan identifies a beneficial use of municipal domestic supply for water bodies not specifically identified unless the criteria of Resolution 88-63 are exceeded. Logan, Union, and the unnamed central canyons meet the federal and state criteria for sources of drinking water. These water bodies are tributaries to the South Yuba River. Beneficial uses for the Yuba River include municipal domestic supply, agriculture, industry, recreation, warm and cold freshwater habitat, migration, potential spawning, and wildlife habitat. Potential federal surface water ARARs for tributaries to the Yuba River are the Safe Drinking Water Act (SDWA) and the Clean Water Act (CWA) regulations. Potential state ARARs for tributaries to the Yuba River are the State of California MCL, the Basin Plan, and Resolutions 68-16 and 92-49.

5.2.1.1 Safe Drinking Water Act

The SDWA, 42 USC Section 300(f), sets limits on the concentrations of certain hazardous materials in drinking water. MCLs are applied at the tap to water that is delivered directly to 25 or more people or to 15 or more service connections. Under the SDWA, EPA has also designated MCL goals (MCLG), which are health-based goals, generally more stringent than MCLs. CERCLA Section 1211(d)(2)(B) provides that response actions "shall require a level of standard or control which at least attains MCLGs established under the Safe Drinking Water

Act." Section 300.430(f)(5) of the NCP provides that remedial actions must generally attain MCLs or non-zero MCLGs if water is a current or potential source of drinking water. EPA has adopted the following MCLs (40 CFR 141.62(b)) and MCLGs (40 CFR 141.51) for solids and mercury in tributaries to the Yuba River:

EPA MAXIMUM CONTAMINANT LEVELS

Substance	MCL	MCLG
Mercury	2 µg/L	2 µg/L
Turbidity*	Less than 1 NTU; must not exceed 0.3 NTU in 95% of daily samples in any month	Not promulgated

Notes:

*	Applies to water treatment systems that use conventional or direct filtration
µg/L	Microgram per liter
%	Percent
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
NTU	Nephelometric turbidity unit

5.2.1.2 State Safe Drinking Water Act

The State of California has adopted primary and secondary MCLs for public drinking water under the California SDWA of 1976. Some state MCLs may be more stringent than the corresponding federal MCL, in which case the state MCL would generally be the ARAR. The MCLs are set forth in Title 22 *California Code of Regulation* (CCR) Sections 64431 and 64449(a). The state MCLs for solids and mercury in tributaries to the Yuba River are as follows:

CALIFORNIA MAXIMUM CONTAMINANT LEVELS

Substance	MCL	MCLG
Mercury	2 µg/L	Not promulgated
Turbidity*	Less than 1 NTU; must not exceed 0.3 NTU in 95% of daily samples in any month	Not promulgated

Notes:

*	Proposed value. Applies to water treatment systems that use conventional or direct filtration
µg/L	Microgram per liter
%	Percent
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
NTU	Nephelometric turbidity unit

5.2.1.3 Clean Water Act Water Quality Standards

On December 22, 1992, EPA promulgated federal water quality standards under the authority of CWA Section 303(c)(2)(B) to establish water quality standards where the State of California had failed to do so. Priority toxic pollutants for California inland surface waters are contained in

40 CFR Section 131.38(a). Criteria for solids and mercury in tributaries to the South Yuba River are as follows:

EPA CALIFORNIA TOXICS RULE WATER QUALITY CRITERIA

Substance	Freshwater		Human Health	
	Maximum Concentration (µg/L)	Continuous Concentration (µg/L)	Consumption of water and organisms (µg/L)	Consumption of organisms (µg/L)
Mercury	Not promulgated	Not promulgated	0.050*	0.051*
Solids/Turbidity	Not promulgated	Not promulgated	Not promulgated	Not promulgated

Notes:

* Total recoverable concentration

µg/L Microgram per liter

5.2.1.4 Clean Water Act Ambient Water Quality Criteria

Section 121 of CERCLA states that remedial actions shall attain federal water quality criteria where they are relevant and appropriate under the circumstances of the release. AWQC are non-enforceable guidance developed by EPA and used by the state to establish water quality standards. Generally, AWQC are considered potentially relevant and appropriate for surface water considered a potential source of drinking water only in the absence of promulgated MCLs or MCLGs. However, if the surface water's designated beneficial use includes protection of aquatic life, the AWQC may be more stringent than the MCL or MCLG. The AWQC for solids and mercury within tributaries to the South Yuba River are as follows:

EPA AMBIENT WATER QUALITY CRITERIA

Substance	Freshwater		Human Health	
	Maximum Concentration (µg/L)	Continuous Concentration (µg/L)	Consumption of water and organisms (µg/L)	Consumption of organisms (µg/L)
Mercury	1.4	0.77	Not promulgated	Not promulgated
Solids/Turbidity	*	Not promulgated	Not promulgated	Not promulgated

Notes:

* Increased color, in combination with turbidity (suspended and settleable solids) should not reduce the depth of the compensation point for photosynthetic activity by more than 10 percent from the seasonally established norm for aquatic life

µg/L Microgram per liter

5.2.1.5 *Clean Water Act Effluent Limitations*

There are no effluent limitations specifically identified for inactive placer gold mines. There are limitations for active placer gold mines, which are found at 40 CFR Sections 440.140 through 440.148. Because the problems of mine drainage from abandoned placer gold mines are similar to the problems of active placer gold mines, these effluent limitations are potentially relevant and appropriate. The CWA established effluent limitations according to whether the discharge is from a new or existing source and whether the pollutant is conventional, toxic, or a non-conventional, non-toxic pollutant. Existing sources were initially required to achieve best practicable technology and later best available technology economically achievable. The instantaneous maximum effluent limitation for settleable solids at placer gold mines is 0.2 milliliters per liter.

5.2.1.6 *Central Valley Water Quality Control Plan (Basin Plan)*

The Basin Plan identifies MCLs as the standard for surface water drinking sources. The Basin Plan also includes narrative water quality objectives (WQO) for surface water within the region. The WQOs potentially pertinent to the removal action at Relief Hill are as follows (Water Board 2004):

> *Sediment: The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.*
>
> *Settleable Material: Waters shall not contain substances in concentrations that result in the deposition of material that causes nuisance or adversely affects beneficial uses.*
>
> *Suspended material: Waters shall not contain suspended material in concentrations that cause nuisance or adversely affect beneficial uses.*
>
> *Toxics: Water shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal, or aquatic life.*
>
> *Turbidity: Waters shall be free of changes in turbidity that cause nuisance or adversely affect beneficial uses.*

5.2.1.7 *State Water Resources Control Board Resolution 68-16*

State Water Resources Control Board (SWRCB) Resolution 68-16, Statement of Policy With Respect to Maintaining High Quality Waters in California, establishes the policy that high quality waters of the state "shall be maintained to the maximum extent possible" consistent with the "maximum benefit to the people of the state." It requires the maintenance of high quality waters until it has been demonstrated that any change will be consistent with maximum benefit to the people of the state, will not unreasonably affect beneficial uses of such water, and will comply with applicable water quality control policies. It further requires that any discharge of waste to

high quality waters comply with requirements resulting in best practicable treatment or control to prevent pollution or nuisance.

5.2.1.8 State Water Resources Control Board Resolution 92-49

SWRCB Resolution 92-49 contains policies and procedures that the regional boards apply to all investigations and cleanup and abatement activities for all types of discharges subject to California Water Code Section 13304. Section III.G of the Resolution requires attainment of background water quality, or if background cannot be restored, the best water quality that is reasonable.

5.2.2 Applicable or Relevant and Appropriate Requirements for Sediment

Section 3001(b) of the RCRA temporarily prohibited EPA from regulating solid waste from the "extraction, beneficiation, and processing of ores and minerals" as hazardous waste pending further study. EPA has since determined that regulation of many of the wastes from mineral extraction do not warrant regulation as hazardous waste. Specifically, 22 CCR Section 66261.4(b)(5)(A) excludes "solid waste from the extraction, beneficiation, and processing of ores and minerals" from the definition of hazardous waste. All of the wastes generated at Relief Hill relate in some manner to historic or current mining operations. Therefore, the mining wastes at Relief Hill are not subject to RCRA Subtitle C regulation or to regulation as hazardous wastes under the California Hazardous Waste Control Law. The wastes would, however, be regulated under the provisions of California Water Code Section 13172. The level of control required under state law will depend on whether the wastes are classified as Group A, B, or C wastes (see Section 5.4.4).

5.3 LOCATION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDEREDS

Location-specific ARARs are restrictions on the conduct of activities solely because they are in specific locations. Special locations include floodplains, wetlands, historic places, and sensitive ecosystems, or habitats. The Endangered Species Act of 1973 (ESA), the Archeological and Historic Preservation Act, the Fish and Wildlife Coordination Act, the Migratory Bird Treaty Act, and various California natural resource laws are potential ARARs. Each is summarized below.

5.3.1 Endangered Species Act of 1973

The ESA, 16 USC Chapter 35, was enacted to protect the ecosystems upon which endangered and threatened species depend, and to conserve and recover endangered and threatened species. The ESA applies to actions taken or funded by Federal agencies. Though there is no direct evidence that any threatened or endangered plant or animal species occurs along any segment of the surface water migration pathway, the area of the site is potential (elevation) habitat for

numerous special status species (see Table 1), including the threatened California red-legged frog (*Rana aurora draytonii*). The area also provides potential (elevation) habitat for the endangered bald eagle and California spotted owl, in addition to many other resident and migratory birds. Newts, salamanders, and tree frogs are also common. The foothill yellow-legged frog (*Rana boylii*), a State of California species of concern, was observed during field sampling activities. The area of the site is also habitat for other sensitive aquatic species including the hardhead (*Mylopharadon conocephalus*) and Northwestern pond turtle (*Clemmys marmorata*).

5.3.2 Archeological and Historic Preservation Act

The Archeological and Historic Preservation Act, 16 USC Section 469, establishes procedures to provide for preservation of historical and archeological data that might be destroyed through alteration of terrain as a result of a federal construction project or a federally licensed activity or program. If any removal action would cause irreparable loss or destruction of significant scientific, prehistoric, historical, or archeological data, it will be necessary to follow the procedures in the statute to provide for data recovery and preservation activities. An archeological inventory was completed at Relief Hill (Forest Service 2004c). During the field inventory, the Forest Service identified and recorded a number of artifacts and artifact concentrations at the mine, most of which are located on private property. The location of an archeological site on Forest System land at Relief Hill is shown on Figure 3. Most artifacts, except for the drain channels, holding or settling ponds, drain shafts and tunnels, are located on high ground and will not be disturbed as a result of anticipated removal activities. The inventory report concluded that a removal action consisting of surface water controls, sediment stabilization, and contour grading will have no effect on heritage resources. The report noted there is a possibility that additional heritage resources will be located as a result of removal activities. Any response actions undertaken at Relief Hill should be coordinated with the Forest Service archeologist.

5.3.3 Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act, 16 USC Section 661, was enacted to protect fish and wildlife when federal actions result in the control or structural modification of a nature stream or body of waste. The statute requires federal agencies to take into consideration the effect that water-related projects would have on fish and wildlife and then take action to prevent loss or damage to these resources.

5.3.4 Migratory Bird Treaty Act

The Act, 16 USC Section 703, establishes federal responsibility for the protection of international migratory bird resources. It prohibits at any time, using any means or manner, the pursuit, hunting, capturing, killing or attempting to take, capture, or kill any migratory bird. No migratory birds have been identified at the site.

5.3.5 California Natural Resource Laws

Two potential location-specific ARARs were identified and are discussed below.

5.3.5.1 California Wildlife Statutes

The foothill yellow-legged frog, a State of California species of concern, was reportedly observed at Relief Hill (SAIC 2004). California Fish and Game Code Section 3005 prohibits the taking of any mammal or bird with poison. California Fish and Game Code Section 5650 makes it unlawful to "deposit in, permit to pass into, or place into waters of the state … substances or materials deleterious to fish, plant life, or bird life."

5.3.5.2 California Lake and Streambed Alteration Program

California Fish and Game Code Sections 1600 through 1616 prohibit alteration of streambeds or impeding natural flow in streambeds absent an agreement with the California Department of Fish and Game (CDFG).

5.4 ACTION-SPECIFIC APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS AND TO BE CONSIDEREDS

Action-specific ARARs are technology- or activity-based requirements of limitations on actions taken with respect to hazardous substances. These requirements are triggered by the particular remedial activities selected. This section summarizes the general action-specific ARARs for the alternatives. A more detailed discussion of the action-specific ARARs as they apply to each alternative is included in Section 8.0, as part of the detailed analysis of the alternatives.

For alternatives that involve the excavation, treatment, or disposal of contaminated media, the following regulations were evaluated as ARARs.

5.4.1 Northern Sierra Air Quality Management District Regulations

Northern Sierra Air Quality Management District (AQMD) rules and regulations include standards for dust controls and nuisances. Specifically, rules that set standards for discharges of particulate matter from sources other than combustion sources; and prohibit the discharge of air contaminants causing nuisances. A dust control plan must be submitted to the AQMD for construction activities that disturb more than 1 acre of land surface.

5.4.2 Clean Water Act

The CWA contains permit requirements for discharges to waters of the United States. For those alternatives that would involve discharge to surface water, the substantive requirements of 40 CFR Part 122 are potential ARARs.

5.4.3 Clean Water Act Permit Requirements for Storm Water Discharges

Any on-site discharge of storm water runoff associated with construction of the proposed remedy must meet the substantive requirements of the General National Pollutant Discharge Elimination System Permit for Storm Water Discharges Associated with Construction Activity, Order 99-08-DWQ, issued by the SWRCB pursuant to its delegated authority under the CWA. In addition, the substantive requirements of the General Permit for Storm Water Discharges associated with Industrial Activities, Order 97-03-DWQ, may be potential ARARs because inactive mines are considered to be an industrial activity for purposes of the permit.

5.4.4 Off-Site Disposal of Mine Waste

Off-site disposal of mine wastes would require compliance with California and Federal transportation requirements and compliance with relevant disposal criteria. In particular, RCRA land disposal restrictions require that wastes be analyzed for the potential to create leachate using the toxicity characteristics leaching procedure prior to off-site disposal.

5.5 MINING WASTE REGULATIONS

All of the soil wastes at Relief Hill are the result of mineral extraction or beneficiation at the site. Under RCRA Section 3001(a)(3)(A)(ii), 42 USC 6921(a)(3)(A)(ii) (also known as the "Bevill Amendment"), EPA has exempted most mining wastes from regulation as hazardous waste. Exempted material includes waste generated from the extraction and beneficiation of minerals, and some mineral processing wastes (including amalgam) (see 40 CFR Section 261.4(b)(7)). Surface water drainage from Relief Hill is not exempt from RCRA regulation. Treatment process wastes, including precipitates and sludges, are not excluded from RCRA regulation.

5.5.1 State Exclusion of Mining Waste from Regulation as Hazardous Waste

California's Health and Safety Code recognizes the Bevill Amendment exclusion, so that wastes that would otherwise be regulated by the California Hazardous Waste Control Law, the California analogue to RCRA, are instead subject only to the requirements of Water Code Section 13172, detailed in 27 CCR Section 22470. Under Health and Safety Code Section 25143.1(b)(1 and 2) as stated below:

> "Wastes from the extraction, beneficiation, and processing of ores and minerals that are not subject to regulation under Subchapter III (commencing with Section 6921) of Chapter 82 of Title 42 of the United States Code are exempt from the requirements of this chapter, except the requirements of Article 9.5 (commencing with Section 25208) and Chapter 6.8 (commencing with Section 25300)... The wastes subject to this subdivision are subject to Article 9.5 (commencing with Section 25208) and Chapter 6.8 (commencing with Section 25300) if the wastes would otherwise be classified as hazardous wastes pursuant to Section 25117 and the regulations adopted pursuant to Section 25141."

5.5.2 Surface Mining Control and Reclamation Act

The Surface Mining Control and Reclamation Act (SMCRA), 30 USC Section 1201, establishes a nationwide program for the protection of human health and the environment from the adverse effect of surface coal mining operations. Although SMCRA addresses abandoned coal mines, it may be relevant and appropriate to cleanup of other types of mining sites. In its CERCLA Compliance with Other Laws Manual, EPA explained that SMCRA may be relevant and appropriate at (1) sites with sulfide-containing geologic materials and where there is a release or threat of release of acid and at (2) sites subject to erosion and thus releases are contaminated by heavy metals. The following regulations, which provide guidelines for post-mining rehabilitation and reclamation of surface mines (Part 816) and underground mines (Part 817) may be potentially relevant and appropriate (EPA 1988):

- 30 CFR 816.43/817.43 – standard for diversions of flow from disturbed areas
- 30 CFR 816.56/817.56 – post mining rehabilitation of sedimentation ponds, diversions, and impoundments
- 30 CFR 816.97/817.97 – protection of fish and wildlife
- 30 CFR 816.111/817.11, 816.114/817.114, and 816.116/817.116 – revegetation requirements

5.5.3 California Surface Mining and Reclamation Act of 1975

Pursuant to the State Surface Mining and Reclamation Act (SMARA), the California Department of Conservation, Office of Mine Reclamation has adopted reclamation standards for mining operations in Article 9, Title 14. These standards do not apply to operations that completed reclamation prior to January 15, 1993, or had an approved reclamation plan prior to January 15, 1993. Pertinent requirements include provisions of the follow regulations:

- 14 CCR 3703 – protection standards for wildlife habitat
- 14 CCR 3704 – performance standard for backfilling, regrading, slope stability, and recontouring
- 14 CCR 3705 – performance standards for revegetation
- 14 CCR 3706 – performance standards for drainage, diversion structures, waterways, and erosion control
- 14 CCR 3710 – performance standards for stream protection
- 14 CCR 3713 – performance standards for closure of surface openings

5.5.4 California Mining Waste Regulations

Pursuant to California Water Code Section 13172, the State of California has adopted regulations designed to address the management of mining waste. These regulations are found at 27 CCR 22470 through 22510. The regulations establish three groups of mining waste:

- Group A – mining waste that must be managed as hazardous waste provided the Water Board finds that such mining wastes pose a significant threat to water quality.
- Group B – mining wastes that consist of or contain hazardous wastes that qualify for a variance, provided that the Water Board finds that such mining wastes pose a low risk to water quality, or mining wastes that consist of or contain nonhazardous soluble pollutants of concentrations that exceed WQOs for, or could cause, degradation of waters of the state.
- Group C – wastes from which any discharge would be in compliance with the applicable water quality control plan, including WQOs other than turbidity.

Classification of the mining waste as hazardous under the Hazardous Waste Control Act is used to determine which group designation is appropriate. Contaminated sediments from Relief Hill may be classified as either Group B or Group C wastes, depending on hazardous characteristic and the level of threat to water quality. The regulations contain specific requirements on siting, construction, monitoring, and closure and post-closure maintenance of existing and new units. These requirements are ARARs for alternatives that involve the creation of an on-site disposal unit or closure of existing units.

5.6 OTHER ISSUES

Property ownership is another issue that could potentially affect the removal action at Relief Hill. Any response action undertaken for the site should take into account the rights of private property owners, including active mining operations under an approved plan of operations. Tetra Tech is not aware of a potentially responsible party (PRP) search completed for Relief Hill. Thus no PRPs have been identified that should be pursued for cost recovery if a response action is taken at Relief Hill.

6.0 REMOVAL ACTION OBJECTIVES AND GOALS

The goal of the EE/CA process at Relief Hill is to develop and select remedies in accordance with CERCLA criteria. These criteria require that remedies be protective of human health and the environment and comply with ARARs (see Section 5.0). PRAOs and PRAGs have been developed for Relief Hill in consideration of CERCLA criteria. The removal action objectives and goals identified in this EE/CA are typical of those used for cleanup actions at abandoned mine sites. They will be refined and updated as additional information becomes available. The final removal action objectives and final removal action goals will be identified in the action memorandum.

6.1 PRELIMINARY REMOVAL ACTION OBJECTIVES

PRAOs are intended to remove the site conditions that trigger NCP criteria for a removal action. These factors are as follows:

- **Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances or pollutants or contaminants.** Mercury concentrations in a sediment sample from the Middle Tunnel Inlet No. 1 exceeded screening criteria and represent a moderate risk to ecological receptors (Ford 1996). Ecological receptors may be exposed to moderate levels of mercury when they disturb sediment from Middle Tunnel Inlet No. 1.

- **Actual or potential contamination of drinking water supplies or sensitive ecosystems.** Water from sluice tunnel outlets discharges to drainages that join the South Yuba River. The Water Board identified numerous beneficial uses for the Yuba River, including drinking water, irrigation and stock watering, recreation, fresh water habitat, and fish migration and spawning (Water Board 2004). Six water samples, including two collected at drain tunnel outlets where water flows off site, contained mercury at concentrations above screening criteria for the protection of human health or the environment.

- **Weather conditions that may cause hazardous substances or pollutants or contaminants to migrate or be released.** Much of the ground surface at Relief Hill is loose, non-vegetated soil and weathered bedrock that is highly susceptible to slope failure and erosion during storm events. A small landslide above Dan Jasper's mine released sediment and mercury to the downstream sluice system. Storm events may cause off-site migration of sediment and mercury.

- **Other situations or factors that may pose threats to public health or welfare or the environment.** Objective hazards caused by hydraulic mining activity could pose a substantial threat to site visitors. The site is currently used for mining and recreational activities. These activities place site visitors in close proximity to high walls, ground sluices walls, tunnels and tunnel inlets that could fail unexpectedly causing burial or entrapment. Vehicle traffic and other site recreational activities may

contribute to soil instability by inhibiting the growth of soil-stabilizing vegetation. Sediment eroded from the mine is transported to drainages that are tributaries to the South Yuba River. The South Yuba River is used for numerous recreational activities, including fishing, swimming, sun bathing, and placer mining. These activities place people in close contact with water and sediment that may be impacted by releases from Relief Hill.

Based on these NCP removal action factors the following PRAOs are identified for Relief Hill:

- *Minimize site runon and runoff to reduce migration of suspended sediment and mercury from the mine pit, flood areas, ground sluices, and drain tunnels to nearby drainages and the South Yuba River.*
- *Minimize the potential for exposure and release of mercury that may be present at the base of ground sluices.*
- *Improve public awareness of on-site objective dangers due to previous mining activities.*

Attaining these objectives is expected to result in mitigation of NCP removal action factors, protection of human and ecological receptors, and protection of water quality at Relief Hill.

6.2 PRELIMINARY REMOVAL ACTION GOALS

There are no known specific cleanup levels applicable to sediment or mercury at Relief Hill; therefore, it is recommended that the removal action address off-site sediment migration in storm water flows. Measures that address the mobility of sediment are also expected to mitigate factors leading to the release of mercury from the site. Management of surface flows can minimize sediment release and reduce the potential for re-exposure and release of mercury that may currently be buried below infill sediment in ground sluices, pit lakes, sluice tunnels, and plunge pools.

In meeting these qualitative goals, long-term risk reduction for potential human and ecological receptors may be attained. A human health and ecological risk assessment for Relief Hill has not been prepared; therefore, risk screening criteria presented in Section 4.0 have been used to identify long-term risk reduction goals at the mine. Tables 10 and 11 present long-term risk reduction goals for surface water and sediment, respectively. Reduction of off-site sediment transport through storm water runoff is consistent with attaining long-term risk reduction goals. Residual waste materials generated during construction of the removal action, if any, will be hauled off site for proper disposal.

7.0 IDENTIFICATION AND SCREENING OF RESPONSE ACTIONS, TECHNOLOGY TYPES, AND PROCESS OPTIONS

Selection of the appropriate removal action alternatives for Relief Hill depends on the following: (1) the scope of the proposed removal action; (2) the nature and types of source materials; (3) the source material volume and location; (4) the mobility of sediment from source areas; (5) the concentration of mercury in the source materials; (6) the effectiveness of the potentially applicable technology and process options; and (7) property ownership.

The removal action alternative selection process involves five steps that include (1) identification of general response actions, technologies, and process options; (2) initial technology screening and alternative development; (3) detailed analysis of alternatives; (4) analysis of implementability of identified alternatives; and (5) comparative analysis of alternatives. General response actions, technologies, and process options are identified in Section 7.1. The results of the initial technology screening and alternative development process for Relief Hill are described in Section 7.2. A detailed analysis of the alternatives is presented in Section 8.0. A comparative analysis of alternatives and recommendation of a site strategy is presented in Section 9.0.

7.1 IDENTIFICATION OF GENERAL RESPONSE ACTIONS, TECHNOLOGIES, AND PROCESS OPTIONS

The first step in the removal action alternative selection process is identifying general response actions that may satisfy the PRAOs. General response actions are then progressively refined into technology types and process options. The process options are then screened in Section 7.2 and the retained technologies and process options are combined into potential removal action alternatives. The purpose of the initial screening is to eliminate process options that are not feasible from further consideration and retain those process options that are potentially feasible.

Sources of sediment erosion and off-site migration identified at Relief Hill that would be addressed by a removal action include: (1) exposed soil and weathered bedrock on non-vegetated ground surfaces (high walls, sluice walls, the mine pit floor, and existing roads); (2) loose sediment in ground sluices, pit lakes, and wetlands; and (3) sediment in drain tunnels. General response actions, technologies, and process options potentially capable of meeting the PRAOs for these sources of sediment are identified in Table 12. Measures that address the mobility of sediment will also mitigate factors leading to the release of particulate-bound mercury from the site.

7.2 TECHNOLOGY SCREENING SUMMARY AND DEVELOPMENT OF REMOVAL ACTION ALTERNATIVES

The purposes of technology and process option screening, the second step in the removal action alternative development process, are to: (1) evaluate the identified technologies and process

options based on the NCP criteria of effectiveness, implementability, and relative costs; and (2) eliminate technologies and process options to reduce the number of alternatives developed and carried forward for detailed analysis in Section 8.0. A technology or process option can be eliminated from further consideration if it does not meet the effectiveness or implementability criteria. Also, a technology or process option can be eliminated if its cost is substantially higher than other technologies or process options, and at least one other technology or process option is retained that offers equal protectiveness. A summary of general response actions for the site is presented in Table 12 and an initial screening of technologies and process options for controlling sediment and particulate-bound mercury is provided in Table 13.

The technologies and process options that were retained have been combined into the four removal action alternatives shown in Table 14. In accordance with guidance from the Forest Service, the four alternatives include no action plus two removal alternatives and one sub-alternative that appear to be most feasible for the site. Because the number of alternatives is not unreasonably high and none of these alternatives could obviously be eliminated through an additional screening step, all of these alternatives will be carried through to the detailed analysis in Section 8.0.

8.0 DETAILED ANALYSIS OF REMOVAL ACTION ALTERNATIVES

The purpose of the detailed analysis is to evaluate the removal action alternatives for their effectiveness, implementability, and cost in order to control and reduce off-site migration of sediment and mercury from Relief Hill. The removal action alternatives that were retained after the technology and process option identification and screening processes performed in Section 7.0 are included in the detailed analysis.

As suggested in "Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA" (EPA 1993a), removal action alternatives that were retained after the technology and process option identification and screening processes will be evaluated individually against the following three broad criteria: effectiveness, implementability, and cost. Descriptions of the qualitative evaluation criteria are provided in the following paragraphs.

Effectiveness Evaluation. During an evaluation of the effectiveness of a removal action alternative, the ability of the process to protect human health and the environment is reviewed (EPA 1993a). Protection is achieved by reducing the toxicity, mobility, and/or volume of metals in surface water over a short-term and long-term time frame while complying with ARARs.

Effectiveness relates to the potential of an alternative to achieve the PRAOs considering the chemical and physical characteristics of the source and the site conditions. Potential impacts to human health and the environment during the construction and implementation phase as well as the reliability of the process with respect to the site conditions are also considered. For the purposes of this evaluation, effectiveness is considered as low, moderate, high, or uncertain.

Implementability Evaluation. During an evaluation of the implementability of a removal action alternative, the technical and administrative feasibility of constructing, operating, and maintaining the alternative is measured (EPA 1993a). Technical feasibility takes into account whether or not the removal action alternative is applicable to the site and can be properly constructed and operated at the site. The evaluation considers long-term operation, maintenance, and monitoring of the implemented alternative. Administrative feasibility considers regulatory approval and scheduling constraints, as well as the availability of disposal services, disposal locations, and the necessary construction expertise and equipment. For the purposes of this evaluation, implementability is considered as easy, moderately difficult, or difficult.

Cost Evaluation. The types of costs that will be assessed include the following:

- Capital costs, including both direct and indirect costs
- Annual operation and maintenance (O&M) costs, including long-term effectiveness monitoring cost
- Net present worth of capital, O&M costs, and periodic costs

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In accordance with EPA guidance (EPA 1993a, 2000), these engineering costs are estimates that are expected to be within plus 50 to minus 30 percent of the actual project cost (based on year 2006 dollars). Cost estimates were prepared in accordance with EPA guidelines (EPA 2000) using engineer's estimates, historic costs for similar projects, and vendor quotes. Because of unique characteristics for many elements of the remedial alternatives, it was not possible to use published unit construction costs or cost estimating software. The costs of these elements were estimated using vendor quotes and were evaluated and adjusted as necessary to account for inflation and differences between the sites. Changes in the cost elements are likely to occur as a result of new information and data collected during the removal action design. The present worth of each removal action alternative provides the basis for the cost comparison. The present worth cost represents the amount of money that, if invested in the initial year of the removal action at a given interest rate, would provide the funds required to make future payments to cover all costs associated with the removal action over its planned life.

Capital Costs. Capital costs include direct and indirect costs. Costs incurred for equipment, material, labor, construction, development and implementation of remedial technologies are included as direct costs. Indirect costs include health and safety items, site supervision, engineering and mobilization/demobilization costs are listed as separate line items while overhead and profit are included in the estimate as a percentage of the direct capital cost.

Professional/Technical Services Costs. Professional/capital services costs include project management, remedial design, and construction management. Costs for these services were based on engineering estimates and costs for projects of similar complexity that were conducted in the past. The estimated costs are slightly higher than those based on percentage of construction costs as presented in "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study" due to project complexity and remote location (EPA 2000).

Annual Operation and Maintenance and/or Periodic Costs. Annual O&M costs include costs incurred after construction. These costs are necessary to assure the effectiveness of a remedial action. Annual O&M costs typically include operating labor, consumable materials, equipment replacement, maintenance, and site reviews.

Periodic costs occur once every few years or once during the entire O&M period. Examples include 5-year sign replacement and gate maintenance.

Present Value Analysis. Remedial action projects typically involve construction costs that are expended at the beginning of a project (capital costs) and costs in subsequent years (operation and maintenance and/or periodic costs). Present value analysis is a method to evaluate expenditures which occur over different periods of time. This standard methodology allows for cost comparisons of different remedial alternatives on the basis of a single cost figure for each alternative. This single value, referred to as the present value, is the amount needed to be set aside at the initial point in time (base year) to assure that funds will be available in the future as

they are needed. Present value analysis uses a discount rate and period of analysis to calculate the present value of each expenditure.

Discount Rate. A discount rate is similar to an interest rate and is used to account for the time value of money. A dollar is worth more today than in the future because, if invested in an alternative use today, the dollar would earn interest. If the capital were not employed in a specific use, it would have a productivity value in alternate uses. The choice of a discount rate is important because the selected rate directly impacts the present value of a cost estimate, which is then used in making a remedy selection decision.

EPA policy on the use of discount rates for remedial investigation and EECA cost analysis is stated in the preamble to the National Oil and Hazardous Substances Pollution Contingency Plan (Title 55 *Federal Register* Section 8722) and in Office of Solid Waste and Emergency Response Directive 9355.3-20 (EPA 1993b). Discount rates used in economic analysis by the federal government are specified in the Office of Management and Budget Circular A-94. The current real discount rate for a 30-year stream of payments is a real discount rate of 3.0 percent (Office of Management and Budget 1993). This discount rate assumes a federal site where the Forest Service takes the lead and pays for the remediation.

Contingency Allowance. Contingency is factored into a cost estimate to cover unknowns, unforeseen circumstances, or unanticipated conditions that are not possible to evaluate from the data on hand at the time the estimate is prepared. The two main types of contingency are scope and bid. Scope contingency covers unknown costs resulting from scope changes that may occur during design. Bid contingency covers unknown costs associated with constructing or implementing a given project scope. A 25 percent contingency (15 percent scope and 10 percent bid) is applied to the construction costs and the operations and maintenance costs. Contingency percentage rates are based on the early stages of the design process and the scope of work, which includes a combination of surface grading, minimal excavation, and sign construction in accordance with guidance provided in "A Guide to Developing and Documenting Cost Estimates During the Feasibility Study" (EPA 2000). Bid contingency rates are also based on contractor availability and scheduling work early enough in the construction season to avoid weather delays.

The final step of this analysis is to conduct a comparative analysis of the removal action alternatives. The comparative analysis, presented in Section 9.0, will discuss each alternative's relative strengths and weaknesses with respect to each criterion. Once completed, the findings of the comparative analysis will be used to identify preferred removal action alternative(s).

8.1 ALTERNATIVE 1: NO ACTION

Under the No Action alternative, no treatment or removal action would occur at Relief Hill. Consequently, potential human health, ecological, and water quality impacts associated with sediment mobility and mercury exposure are assumed to remain unchanged. The No Action alternative is used as a baseline against which other removal action alternatives are compared.

The No Action alternative is applicable to all media at Relief Hill. The No Action alternative will be retained through the detailed analysis of alternatives.

8.1.1 Effectiveness

The No Action alternative is considered to have low effectiveness for achieving PRAOs. This alternative would not minimize the transport of sediment or mercury from the site. Sediment migration through storm water runoff would be unchanged. This alternative would provide no control of sediment transport and no reduction in risk to human health or the environment. Therefore, increased protection of human health and the environment would not be achieved under the No Action alternative.

A comprehensive list of federal and state ARARs for Relief Hill is presented in Section 5.0. ARARs are divided into contaminant-specific, location-specific, and action-specific requirements. Under the No Action alternative, sediment and mercury would not be treated, removed, or actively managed. Consequently, no location- or action-specific ARARs apply to the No Action alternative. Storm water runoff from Relief Hill would continue to release sediment to receiving surface water bodies; therefore, the No Action alternative would not comply with chemical-specific ARARs.

Under the No Action alternative, no controls or long-term measures would be implemented to control sediment or mercury at the site; consequently, this alternative provides no long-term effectiveness. Therefore, the No Action alternative would not be effective at improving water quality. The No Action alternative would provide no reduction in toxicity, mobility, or volume of mercury contaminated soil at the site. In the short-term, the No Action alternative would pose no reduction in the threat to the community or the environment than exists under the current site conditions.

8.1.2 Implementability

The No Action alternative would be readily implementable and administratively feasible. No permits would be required to implement this alternative. No services or materials would be needed for the implementation of this alternative.

8.1.3 Cost

There are no foreseen costs associated with the No Action alternative.

8.2 ALTERNATIVE 2: LAND USE CONTROLS AND ACCESS RESTRICTIONS

Alternative 2 combines land use controls and access restrictions to minimize impacts of site recreational uses on continued erosion of previously disturbed areas and to allow revegetation to stabilize loose soils and sediment on site and reduce the migration of sediment and particulate-

bound mercury. Alternative 2 will rely primarily on natural processes to vegetate disturbed areas on site. Over time, the establishment of ground cover will minimize the erosion and transport of soil through storm water runoff and airborne dust, further encapsulate mercury that might remain buried in sluices, and reclaim unauthorized user-created trails. Limitations on public use at Relief Hill will also minimize surface disturbances that can cause erosion (such as OHV use).

Land use controls are used primarily to reduce erosion caused by certain site uses (including OHV traffic), encourage the growth of soil-stabilizing vegetation, and reduce direct human contact with contaminants. The Forest Service can control the use of public land in accordance with the Sierra Nevada Forest Plan Amendment, referred to by the Forest Service as the "Framework." The Framework is an integrated strategy for vegetation management (Forest Service 2004a). The Framework defines goals, strategies, and desired conditions for a number of ecosystems and territories that can be designated as land allocations. The land allocations have associated sets of desired conditions, intents, and objectives that provide direction to land managers for designing and developing vegetation management projects. Under the authority provided in the Framework, the Forest Service may define a set of riparian conservation areas (RCA) (a type of land allocation) on Forest System land at Relief Hill. The Forest Service does not have jurisdiction over private land or active mine claims and therefore cannot designate such lands within the RCA. The active mine claims will be incorporated into the RCA after the current authorized plan of operation expires and the claimant completes mine reclamation. RCAs include buffer areas of 300 feet on each side of lakes, wetlands, and perennial streams (150 feet for intermittent and ephemeral streams). The proposed RCA buffer area is shown on Figure 7.

Desired conditions are statements describing a common vision for a specific land area (Forest Service 2004a). The Framework identifies a number of desired conditions for RCAs, including the following:

- Water quality meets the goals of the CWA and SDWA; it is fishable, swimmable, and suitable for drinking after normal treatment.
- Soils with favorable infiltration characteristics and diverse vegetative cover absorb and filter precipitation and sustain favorable conditions of stream flows.
- The physical structure and condition of stream banks and shorelines minimizes erosion and sustains desired habitat diversity.
- Meadows are hydrologically functional. Sites of accelerated erosion, such as gullies and headcuts are stabilized or recovering. Vegetation roots occur throughout the available soil profile. Meadows with perennial and intermittent streams have the following characteristics: (1) stream energy from high flows is dissipated, reducing erosion and improving water quality, (2) streams filter sediment and capture bedload, aiding floodplain development, (3) meadow conditions enhance floodwater retention

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and groundwater recharge, and (4) root masses stabilize stream banks against cutting erosion.

Site use within an RCA must be to the benefit of the land allocation. Negative impacts are allowable in the short term under the condition that long-term improvement is achieved. For example, existing vegetation in a stream channel that was created during hydraulic mining and is highly susceptible to erosion can be removed in order to armor the stream channel, amend the exposed soil, and establish a healthy vegetative cover. The Forest Service has authority to evaluate and permit site use within the RCA.

Under Alternative 2, land use controls would be supplemented with access restrictions on Forest System land to provide physical deterrence for highly impacting recreational use. Access restrictions include signs posted at sensitive or high-traffic areas and maintenance of the site entrance gate (currently maintained by the active mine operation) after the mine's existing plan of operations expires and the claimant completes mine reclamation.

Under Alternative 2, the volume and toxicity of mercury in the environment would remain unchanged. However, Alternative 2 would reduce the mobility of sediment and mercury at Relief Hill, thereby reducing the human health and ecological risk associated with a release to the watershed. Land use controls are appropriate in remote areas where substantial direct human contact is not a primary concern. Land use controls and access restrictions are considered feasible alternatives for reducing site traffic.

Land use controls and access restrictions could be implemented as a stand-alone remedy or in combination with other alternatives. Implementation of this alternative will involve the activities described below and shown on Figure 7. The item number assigned to each activity corresponds to the cost summary presented in Table 15.

1. The Forest Service will complete administrative tasks to designate Relief Hill as an RCA. Administration of land use restrictions within the RCA (including vehicular traffic) will support the CERCLA response action objectives by reducing erosion, conserving the current habitat, and facilitating growth of soil-stabilizing vegetation. Portions of Relief Hill that are privately owned or under active mining claims are not under Forest Service jurisdiction and will not be included in the RCA designation.

2. The existing mine's authorized plan of operations will expire and the Forest Service will be responsible for issuing a mine closure order (Forest Service 2006). After the mining is completed and the claimant reclaims the site, Tetra Tech understands that the Forest Service will maintain the site gates and signs (Tetra Tech 2006a). Tetra Tech does not know precisely when or how the existing mine's authorized plan of operations will be terminated, and for cost purposes assumes the Forest Service will begin maintenance of the access gate beginning with year 5 of the remedy implementation.

3. Equipment necessary to implement Alternative 2 will be mobilized to the site. Equipment will include two work trucks, a skid steer (Bobcat), and hand tools. No more than 5 working days will be required during one calendar week of work.

4. Signs will be placed at potential access points to the site describing the RCA access restrictions implemented as a component of a CERCLA response action. Signage will also be developed and placed to educate the public as to the reasons for and benefits from the use restrictions. Thirty signs will be constructed of metal and posted on 8-foot wooden 4-inch by 4-inch sign posts.

Maintenance

- Long-term maintenance will include:
  - Annual site visits to inspect response action measures.
  - Repairs to signs and gates every 5 years (beginning in year 5).
  - Collection and analysis (low-level total mercury and TSS) of four surface water samples (one at each of the known tunnel outlets) to evaluate the effectiveness of the response action. Sampling would be conducted annually in years 1 through 5; semi-annually in years 7 through 15; and in years 20, 25, and 30.
  - Forest Service project management for O&M.

Assumptions included in this alternative are listed below.

- Signage will include 30 signs posted at approximately 100-foot intervals.
- One quarter of the signs will require replacement after 5 years due to theft and vandalism.
- Work plan and completion report will not be written under this alternative.
- The Forest Service will manage O&M tasks. All maintenance and sampling activities are assumed to coincide with the annual site visit.
- Estimated costs are provided for O&M field tasks, including site inspections, sign and gate repairs, and sampling. Cost associated with administrative tasks related to RCA land use enforcement will be absorbed by the Forest Service and are not included as part of this EE/CA.

8.2.1 Effectiveness

The implementation of this alternative would reduce erosion caused by certain site uses (including OHV traffic) on Forest System land and encourage the growth of soil-stabilizing vegetation. These measures would reduce the release of sediment and mercury to the South Yuba River watershed where it may affect humans and wildlife. These measures would also

reduce dust generated during the dry season. The volume and toxicity of mercury in the environment would remain unchanged. The threat of human exposure due to on-site ingestion of contaminated sediment and surface water, dermal contact with contaminated sediment and surface water, and inhalation of dust and mercury vapors would be reduced by minimizing human traffic on portions of the site under Forest Service jurisdiction.

Land use controls and access restrictions are considered feasible alternatives for addressing human exposure to and off-site transport of sediment and mercury. Recreational use of Forest System land at Relief Hill, can erode sediment and discourage vegetative cover on bare soil. The natural establishment of ground cover will minimize the erosion and transport of soil through storm water runoff and airborne dust, further encapsulate mercury that might remain buried in sluices, and reclaim unauthorized user-created trails. Limitations on public use at Relief Hill will also minimize surface disturbances that can cause erosion (such as OHV use). However, the permanence and effectiveness of land use controls and access restrictions depend on enforcement and maintenance activities. Alternative 2 will protect human health on Forest System land by removing humans from the area as recreational receptors. Furthermore, the natural site reclamation allowed under Alternative 2 would provide a low degree of reduction in the transport of particulate-bound mercury by stabilizing loose soil. The resulting reduction of sediment and mercury released from Relief Hill to Logan Canyon, the unnamed central drainage, Union Canyon, and the South Yuba River would reduce the threat to ecological receptors downstream from the mine. However, Alternative 2 would not provide a significant reduction in the threat to on-site ecological receptors.

Land use controls and access restrictions would lead to a limited reduction in contaminant and sediment loads from the site. Alternative 2 does not address sediment once it has been mobilized by storm water runoff; future monitoring would be necessary to prove if activities associated with Alternative 2 reduces contaminant and sediment concentrations to levels that meet the criteria listed in Tables 10 and 11.

Location-specific ARARs may not be met under Alternative 2. The riparian communities on site would be protected by enforcement of land use restrictions within the RCA. However, stream banks and beds may continue to be eroded due topographic and drainage features created by historical hydraulic mining. Habitat for the foothill yellow-legged frog and other special status species potentially inhabiting Relief Hill would be preserved under Alternative 2. Alternative 2 would not affect the protected heritage resources identified at Relief Hill during the archeological inventory (Forest Service 2004c), but the response action should be coordinated with the Forest Service archeologist. Areas disturbed by the removal activities would be revegetated in accordance with Tahoe National Forest guidelines, including selection of native seed mixtures and use of certified weed-free plant materials for erosion control.

Action-specific ARARs would be met under Alternative 2. Storm water generated during field activities, though not anticipated, will be managed in accordance with the CWA. Northern Sierra AQMD nuisance dust suppression and control requirements are not applicable for the access

restriction measures (signs and gate maintenance) included in Alternative 2. Occupational Safety and Health Administration (OSHA) requirements would be met by requiring appropriate safety training for all on-site workers during the field phase.

The construction phase for Alternative 2 would be accomplished within one field season; therefore, impacts associated with construction would likely be short-term and minimal. On-site workers would be adequately protected by using appropriate personal protective equipment and by following safe work practices. Short-term risks of physical injury would exist for site workers during construction. Increased truck traffic required to transport construction material to the site would have a short-term impact on local air quality and traffic safety.

8.2.2 Implementability

Alternative 2 is technically feasible, but only partially administratively feasible. Portions of the site are on private property or held under current mine claims and actively mined under an authorized plan of operations. Land use controls and access restrictions must consider the rights of the private property and mining interests, including maintaining limited access to the site. Upon closure and reclamation of the active mine, the Forest Service will assume responsibility for maintaining access restriction measures (signs and gates). All necessary actions could be implemented within one field season. In accordance with the Framework (Forest Service 2004a), the Forest Service has the authority to designate RCAs on Forest System land at Relief Hill through administrative procedures. Sign posting and gate maintenance require conventional construction practices; materials are readily available. Design methods are well documented and understood. Equipment, materials, and labor would be available through the local market.

Enforcement of land use controls may prove to be problematic. By nature, OHV use is not easily controlled. The site is relatively remote making it difficult to observe trespassers and enforce the controls.

8.2.3 Cost

The total present worth cost for Alternative 2, land use controls and access restrictions, is estimated to be $76,000 and are expected to be within plus 50 percent ($114,000) and minus 30 percent ($53,000) of actual project costs as per EPA guidance for costs estimates (EPA 2000). Table 15 presents a summary of the costs associated with implementing Alternative 2. The total present worth cost includes the present value of capital costs and 30 years of O&M. Internal Forest Service costs for designation of the land as an RCA and the enforcement of land use controls are not included. Changes in the cost elements are not likely to occur as a result of new information and data collected during the removal action design.

8.3 ALTERNATIVE 3: SELECTIVE ENGINEERING CONTROLS, LAND USE CONTROLS, AND ACCESS RESTRICTIONS

Alternative 3 will consist of selective engineering controls in addition to the land use controls and access restrictions described in Section 8.2. Selective engineering controls will consist of surface controls and revegetation. Surface controls are used primarily to reduce contaminant mobility and direct contact by humans and wildlife. Surface controls are appropriate in remote areas where direct human contact is not a primary concern. Human and ecological risks associated with mercury would be decreased downstream of the site due to a reduction in sediment mobility and volume of impacted water discharged from Relief Hill. Surface controls are considered a feasible alternative for managing erosion in and surface water runoff from the site, for capturing mobile sediment containing particulate-bound mercury. Surface control process options include grading, erosion control and protection, revegetation, runon and runoff controls, diversion, and construction of detention/infiltration basins. Land use controls (designation of areas within the mine as RCAs) and access restrictions (sign and gate maintenance after mine closure) will be implemented to provide physical deterrence for highly impacting recreational use.

For Alternative 3, Relief Hill was divided into four sluice systems as illustrated in Figure 8, the Union sluice system is not part of Relief Hill and will not be discussed further in this report. Selective engineering controls would allow the Forest Service to prioritize each sluice system based on cost and overall benefit. Sluice systems were based on confirmed and assumed hydraulic properties observed during sampling events. Each sluice system depicts the assumed on-site sediment migration pattern and is intended to illustrate off-site watershed patterns that do not affect the migration of potentially contaminated site sediment.

The major features of the engineering controls described below are shown on Figure 8. Alternative 3 includes removal activities in all four sluice systems, but costs are provided separately for each sluice system so that partial implementation of Alternative 3 can be evaluated. The item number assigned to each activity corresponds to the cost summary presented in Table 16.

1. The Forest Service will complete administrative tasks to designate Relief Hill as an RCA. Administration of land use restrictions within the RCA (including vehicular traffic) will support the CERCLA response action objectives by reducing erosion, conserving the current habitat, and facilitating growth of soil-stabilizing vegetation. Portions of Relief Hill that are privately owned or under active mining claims are not under Forest Service jurisdiction and will not be included in the RCA designation.

2. The existing mine's authorized plan of operations will expire and the Forest Service will be responsible for issuing a mine closure order (Forest Service 2006). After the mining is completed and the claimant reclaims the site, Tetra Tech understands that the Forest Service will maintain the site gates and signs (Tetra Tech 2006a). Tetra Tech does not know precisely when or how the existing mine's authorized plan of operations will be terminated, and assumes the Forest Service will begin maintenance of the access gate beginning with year 5.

3. Equipment necessary to implement Alternative 3 will be mobilized to the site. Equipment includes four work trucks, an excavator, a backhoe, two OHVs, an office trailer, a portable storage shed, a generator, fire suppression equipment, and hand tools. No more than 61 working days will be required during 14 calendar weeks of work to be completed between May 1 and October 15.

4. Signs will be placed at potential access points to the site describing the RCA access restrictions implemented as a component of a CERCLA response action. Signage will also be developed and placed to educate the public as to the reasons for and benefits from the use restrictions. Thirty signs will be constructed of metal and posted on 8-foot wooden 4-inch by 4-inch sign posts.

Waukesha Tunnel System

5. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above WTI-1.

6. Vegetate a 0.3-acre area within S-WTI-1 sediment detention basin.

7. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above WTI-2.

8. Vegetate a 0.3-acre area within S-WTI-2 sediment detention basin.

9. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin in the west fork of the WTI-3 sluice.

10. Vegetate a 0.3-acre area within S-WTI-3 west fork sediment detention basin.

11. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin in the east fork of the WTI-3 sluice.

12. Vegetate a 0.3-acre area within WTI-3 sediment detention basin.

13. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above S-WTI-1.

14. Vegetate a 0.3-acre area within S-WTI-1 sediment detention basin.

15. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above S-WTI-3.

16. Vegetate a 0.3-acre area within S-WTI-3 sediment detention basin.

Middle Sluice System

No removal actions are proposed for the Middle sluice system.

New Sluice System

17. Construct a rock armored spillway near the S-NTI-1 inlet to divert flow from the flood zone to the existing ravine south of the sluice.

18. Construct a rock armored spillway near the S-NTI-2 inlet to divert flow from the flood zone to the existing ravine south of the sluice.

19. Improve 900 feet of the existing OHV trail to allow access to the New Sluice System.

20. Reclaim 900 feet of OHV trail in the New Sluice System.

Cliff Sluice System

21. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above CTI-1.

22. Vegetate a 0.3-acre area within CTI-1 sediment detention basin.

23. Improve an additional 500 feet of the existing OHV trail to allow access to the Cliff Sluice System. The initial 900 feet of OHV trail will be improved under the New Sluice System portion of the removal action. If the New Sluice items are not completed, then the costs under item 22 in the cost estimate would need to be added to this cost.

24. Reclaim 500 feet of OHV trail in the Cliff Sluice System.

Maintenance

- Long-term maintenance will include:
  - Annual site visits to inspect response action measures.
  - Repairs to signs and gates every 5 years (beginning in year 5).
  - Cleanout of the sedimentation basins each of the first three years and every five years after that (beginning in year 5)

- Collection and analysis (low-level total mercury and TSS) of four surface water samples (one at each of the known tunnel outlets) to evaluate the effectiveness of the response action. Sampling would be conducted annually in years 1 through 5; semi-annually in years 7 through 15; and in years 20, 25, and 30.
- Forest Service project management for O&M.

Assumptions included in this alternative are listed below.

- Mobilization must commence by August 1 to allow sufficient time to complete work before onset of the rainy season. Work must be scheduled early enough in the season so that it can be completed in a single mobilization.
- Subcontractor oversight will be required for no more than 40 percent of the days construction work is scheduled. Oversight and construction management will be performed by an appropriate prime contractor. Construction will be completed in no more than 61 days.
- Site security will be required 24 hours a day, seven day a week for construction equipment. Total calendar days equipment is on site will not exceed 73 days.
- Additional time for weather delays is not included in this cost estimate.
- Revegetation will be performed on land disturbed by construction activities and within sediment detention basins. Revegetation will be difficult on the weathered bedrock and loose soil areas; complete revegetation at Relief Hill would be a labor- and resource-intensive process. Selective revegetation will be performed to initiate plant growth in areas that are most critical for minimizing erosion and where the chances for successful revegetation are best. Revegetation will include reducing some slopes and scarifying the soil surface to provide selected areas with reduced surface water runoff and increased moisture to enhance the establishment of the native grasses and shrubs. In addition, the roughened surface will provide pockets and pits where the native seeds and fertilizer can collect. The prepared scarified surface will be hydroseeded with a mixture of native species, wood-fiber mulch, and fertilizer. If possible, existing shrubs could be salvaged from other locations on the mine site and transplanted to selected locations within the reclaimed areas. Entire multi-shrub "islands" can be excavated along with the live root wads, and transplanted to previously excavated holes. Finally, native, site-adapted shrubs and trees could be purchased from a nursery (either in cone-tainers or as bare-root stock) and planted in selected areas where they stand the best chance to survive. Revegetation methods and seed selection will be done in accordance with Tahoe National Forest guidelines.

- Removal action work performed on private land will be limited to temporary improvement of the existing OHV trail for access to the Cliff and New sluice systems. After site activities are completed, including revegetation activities for 3 years, the OHV trail will be reclaimed. This EECA assumes there will be no additional administrative or use costs associated with use of the OHV trail during the removal action.

- All necessary rock will be borrowed from on-site sources along the sluices.

- All necessary fill dirt used on site will be borrowed from on-site sources, generally at the tops of sluice cuts where it will decrease existing slope angle to aid natural revegetation. An average depth of 2 feet by 10 feet of sluice face for a length of 65 to 130 linear feet of sluice cut (if both sides of the sluice cut are used for fill) would provide the necessary 100 to 200 cubic yards of material needed to construct each dam.

- Actual dam size and shape may be adjusted based on actual field conditions to best fit individual ground sluices and maximize retention time to the extent practicable. Specific dam size and position should be determined during the design phase of the removal action.

- Additional runon controls will not be implemented above the northern high wall. The area above the high wall has established vegetation that limits erosion from above the site. Furthermore, it is located primarily on private land.

- Revegetation activities will be required for 3 years. Half of the revegetation area will require reseeding after each of the first 3 years. Revegetation activities would also include inspection for and eradication of noxious weeds in the construction areas.

- The Forest Service will manage O&M tasks. All maintenance and sampling activities are assumed to coincide with the annual site visit.

8.3.1 Effectiveness

The implementation of Alternative 3 would reduce the mobility of sediment and particulate-bound mercury from Relief Hill, promote the growth of soil-stabilizing vegetation, and reduce human exposure to on-site contaminants. The reduction in mobility would be achieved by creating storm water detention and diversion to settle the majority of the mobile sediment from surface runoff and contain it on site; by grading, installing wattles, and revegetating disturbed areas to reduce erosion; and by minimizing highly impacting recreational uses through access restrictions and designation and enforcement of RCAs. Storm water detention basins are designed to reduce sediment mobility by reducing flow velocity and increasing settling times for particulate matter to the extent practical based on site conditions. The basins will not be designed to hold all surface runoff from large rain events.

Alternative 3 would reduce human and ecological exposure to sediment and mercury in surface water downstream from the site (including the South Yuba River), reduce mercury loading to the South Yuba River, reduce direct contact with contaminated sediment, and reduce inhalation of dust during the dry season. Furthermore, mercury believed to remain on site is likely to exist at the base of ground sluices, pit lakes, and wetlands. The engineering controls in Alternative 3 (including rock armoring of sluices and capture of new sediment in detention basins built in sluices, pit lakes, and wetlands) would further entomb the remaining mercury. The additional burial of potentially contaminated sediment would reduce human and ecological exposure to on-site mercury in sediment, surface water, and dust particles. The likelihood of a large storm exposing mercury potentially remaining below sluice infill sediment would also be reduced by improved storm water and erosion controls. The volume and toxicity of mercury in the environment would remain unchanged.

Engineering controls are considered a feasible alternative for managing surface water runoff from and erosion in the mine pit, for capturing mobile sediment potentially containing mercury, and for diverting of surface water around the ground sluices. The permanence of surface controls alone for reducing sediment and particulate-bound mercury migration to surface water and the threat of human health and ecological exposure depends on maintenance activities. Alternative 3 would likely decrease the mercury load leaving the site but would not reduce the total amount of mercury on site. However, mercury on site appears to be buried and is unlikely to cause substantial risks to human health and the environment. Land use controls and access restrictions are also considered feasible alternatives for reducing erosion and human exposure, though the permanence and effectiveness of land use controls and access restrictions depend on enforcement and maintenance activities.

Engineering controls in Alternative 3 would reduce contaminant and sediment loads from Relief Hill and would meet long-term goals listed in Tables 10 and 11.

Location-specific ARARs would be met under Alternative 3. The riparian communities on site would be protected by enforcement of land use restrictions within the RCA. Habitat for the foothill yellow-legged frog and other special status species potentially inhabiting Relief Hill would be preserved under Alternative 3. Alternative 3 would not affect the protected heritage resources identified at Relief Hill during the archeological inventory (Forest Service 2004c), but the response action should be coordinated with the Forest Service archeologist. Areas disturbed by the removal activities would be revegetated in accordance with Tahoe National Forest guidelines, including selection of native seed mixtures and use of certified weed-free plant materials for erosion control.

Action-specific ARARs would be met under Alternative 3. Storm water generated during construction activities, though not anticipated, will be managed in accordance with the CWA. Northern Sierra AQMD nuisance dust suppression and control requirements are applicable because greater than 1 acre of land will be disturbed during grading and erosion control activities. OSHA requirements would be met by requiring appropriate safety training for all on-site workers

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during the construction phase. Revegetation would be carried out in a manner to comply with 30 CFR 816.111. The California Fish and Game Code Sections 1600 through1616 prohibit alteration of streambeds or impeding natural flow in stream beds. Under the code, an existing fish or wildlife resource can not be substantially adversely affected. Alternative 3 will not likely adversely affect resources. However, the CDFG should be notified prior to beginning construction activities. Construction activities within the newly defined RCA would be coordinated with Forest Service biologists to ensure the long-term benefit of riparian areas.

The construction phase for Alternative 3 would be accomplished within one field season; therefore, impacts associated with construction would likely be short-term and minimal. Construction of surface controls would meet the standards for diversion of flow from disturbed areas and revegetation requirements contained in SMCRA and SMARA. In addition, standards for drainage, diversion structures, waterways, and erosion control contained in SMARA would also be met. Storm water generated during construction activities, though not anticipated, will be managed in accordance with the CWA. Northern Sierra AQMD nuisance dust suppression and control requirements are applicable for construction and earth-moving activities associated with this alternative for the control of fugitive dust emissions; these requirements would be met through water application to roads receiving heavy vehicular traffic and to construction or excavation areas, if necessary. OSHA requirements would be met by requiring appropriate safety training for all on-site workers during the construction phase. Short-term risks of physical injury would exist for site workers during construction. Increased truck traffic required to transport construction material to the site would have a short-term impact on local air quality and traffic safety.

8.3.2 Implementability

Alternative 3 is technically feasible, but only partially administratively feasible. Portions of the site are held under current mine claims and actively mined under an authorized plan of operations. Land use controls and access restrictions must consider the rights of the private property owners and authorized mining interest, including maintaining limited access to the site. Upon closure of the active mine, the Forest Service will assume responsibility for maintaining access restriction measures (signs and gates). All necessary actions could be implemented within one field season. In accordance with the Framework (Forest Service 2004a), the Forest Service has the authority to designate RCAs on Forest System land at Relief Hill through administrative procedures. Excavation, trenching, construction, grading, and revegetation require conventional construction practices; materials are readily available. Design methods, construction practices, and engineering requirements for installation of berms, ditches, diversions, rock dissipaters, and detention ponds are well documented and understood. Equipment, materials, and labor would be available through the local market.

Excavation and grading work would require the use of heavy equipment including excavators, loaders, dozers, and haul trucks. Controlling fugitive dust emissions and storm water discharge (if generated) during excavation and grading activities would be required.

Long-term monitoring and maintenance would be required but would be limited primarily to gate and sign repair and regular inspections. Due to the size and depth of the sediment detention basins cleanout is expected to be fairly infrequent. Detention pond capacity should be monitored during regular inspections. Cleanout cost is not included in this EECA but would be comparable to costs for Alternative 3A and thus would not influence alternative selection.

Enforcement of land use controls may prove to be problematic. By nature, OHV use is not easily controlled. The site is relatively remote making it difficult to observe trespassers and enforce the controls.

8.3.3 Cost

The total present worth cost for Alternative 3, selective engineering controls, land use restrictions, and access restrictions, is estimated to be approximately $390,000 and are expected to be within plus 50 percent ($585,000) and minus 30 percent ($273,000) of actual project costs as per EPA guidance for costs estimates (EPA 2000). Table 16 presents a summary of the costs associated with implementing Alternative 3. The total present worth cost includes the present value of capital costs and 30 years of O&M. Internal Forest Service costs for designation of the land as an RCA and the enforcement of land use controls are not included. Changes in the cost elements are likely to occur as a result of new information and data collected during the removal action design.

8.4 ALTERNATIVE 3A: SELECTIVE ENGINEERING CONTROLS INCLUDING CHECK DAMS IN OPEN SLUICE TUNNELS, LAND USE CONTROLS, AND ACCESS RESTRICTIONS

Alternative 3a will consist of constructing check dams in open sluice tunnels in addition to the selective engineering controls, land use controls, and access restrictions described for Alternative 3 in Section 8.3. As described previously, selective engineering controls will consist of surface controls and revegetation to reduce the contaminant mobility and direct contact by humans and wildlife. Land use controls (designation of areas within the mine as RCAs) and access restrictions (signage) will be implemented to provide physical deterrence for highly impacting recreational use. In addition to these measures, Alternative 3a includes construction of check dams in the open sluice tunnels to slow the flow of storm water through the tunnels. The reduced energy of storm water flow will allow sediment and particulate-bound mercury mobilized from upstream in the sluice system to be deposited behind the check dams instead of discharging from the site. Selective engineering controls, land use controls, and access restrictions are considered feasible and are appropriate in remote areas where direct human contact is not a primary concern. Human and ecological risk associated with sediment and particulate-bound mercury would be decreased downstream of the site due to a reduction in overall sediment mobility, volume of impacted water discharged from Relief Hill, and human traffic on site. The volume and toxicity of mercury in the environment would remain unchanged.

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For Alternative 3a, Relief Hill was divided into four sluice systems as illustrated in Figure 9, the Union sluice system is not part of Relief Hill and will not be discussed further in this document. Selective engineering controls would allow the Forest Service to prioritize each sluice system based on cost and overall benefit. The basis for dividing the four systems was described under Alternative 3 in Section 8.3.

The major features of the engineering controls described below are shown on Figure 9. Alternative 3a includes removal activities in all four sluice systems, but costs are provided separately for each watershed so that partial implementation of Alternative 3a can be evaluated. The item number assigned to each activity corresponds to the cost summary presented in Table 17.

1. The Forest Service will complete administrative tasks to designate Relief Hill as an RCA. Administration of land use restrictions within the RCA (including vehicular traffic) will support the CERCLA response action objectives by reducing erosion, conserving the current habitat, and facilitating growth of soil-stabilizing vegetation. Portions of Relief Hill that are privately owned or under active mining claims are not under Forest Service jurisdiction and will not be included in the RCA designation.

2. The existing mine's authorized plan of operations will expire and the Forest Service will be responsible for issuing a mine closure order (Forest Service 2006). After the mining is completed and the claimant reclaims the site, Tetra Tech understands that the Forest Service will maintain the site gates and signs (Tetra Tech 2006a). Tetra Tech does not know precisely when or how the existing mine's authorized plan of operations will be terminated, and assumes the Forest Service will begin maintenance of the access gate beginning with year 5.

3. Equipment necessary to implement Alternative 3A will be mobilized to the site. Equipment includes four work trucks, an excavator, a backhoe, two OHVs, an office trailer, a portable storage shed, a generator, fire suppression equipment, and hand tools. No more than 85 working days will be required during 19 calendar weeks of work to be completed between May 1 and October 15.

4. Signs will be placed at potential access points to the site describing the RCA access restrictions implemented as a component of a CERCLA response action. Signage will also be developed and placed to educate the public as to the reasons for and benefits from the use restrictions. Thirty signs will be constructed of metal and posted on 8-foot wooden 4-inch by 4-inch sign posts.

<u>Waukesha Tunnel System</u>

5. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above WTI-1.

6. Vegetate a 0.5-acre area within WTI-1 sediment detention basin.

7. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above WTI-2.

8. Vegetate a 0.5-acre area within S-WTI-2 sediment detention basin.

9. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin in the west fork of the WTI-3 sluice.

10. Vegetate a 0.5-acre area within S-WTI-3 west fork sediment detention basin.

11. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin in the east fork of the WTI-3 sluice.

12. Vegetate a 0.5-acre area within wti-3 sediment detention basin.

13. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above S-WTI-1.

14. Vegetate a 0.5-acre area within S-WTI-1 sediment detention basin.

15. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above S-WTI-3.

16. Vegetate a 0.5-acre area within S-WTI-3 sediment detention basin.

Middle Sluice System

17. Construct three check dams just above N-MTI-4.

18. Vegetate a 0.5-acre area above check dams.

New Sluice System

19. Construct three check dams just above N-NTI-1.

20. Vegetate a 0.5-acre area above check dams.

21. Construct a rock armored spillway near the S-NTI-1 inlet to divert flow from the flood zone to the existing ravine south of the sluice.

22. Construct a rock armored spillway near the S-NTI-2 inlet to divert flow from the flood zone to the existing ravine south of the sluice.

23. Improve 900 feet of the existing OHV trail to allow access to the New Sluice System.

24. Reclaim 900 feet of OHV trail in the New Sluice System.

Cliff Sluice System

25. Construct three check dams just above CTI-4.
26. Vegetate a 0.5-acre area above CTI-4 check dams.
27. Construct three check dams just above CTI-5.
28. Vegetate a 0.5-acre area above CTI-5 check dams.
29. Build an approximately 7-foot high by 40-foot long dam, based on site features, to create the largest practicable sediment detention basin just above CTI-1.
30. Vegetate a 0.5-acre area within CTI-1 sediment detention basin.
31. Improve an additional 500 feet of the existing OHV trail to allow access to the Cliff Sluice System. The initial 900 feet of OHV trail will be improved under the New Sluice System portion of the removal action. If the New Sluice items are not completed, then the costs under item 22 in the cost estimate would need to be added to this cost.
32. Reclaim an additional 500 feet of the existing OHV trail to allow access to the Cliff Sluice System.

Maintenance

- Long-term maintenance will include:
  - Annual site visits to inspect response action measures.
  - Repairs to signs and gates every 5 years (beginning in year 5).
  - Cleanout of the sedimentation basins each of the first three years and every five years after that (beginning in year 5).
  - Collection and analysis (low-level total mercury and TSS) of four surface water samples (one at each of the known tunnel outlets) to evaluate the effectiveness of the response action. Sampling would be conducted annually in years 1 through 5; semi-annually in years 7 through 15; and in years 20, 25, and 30.
  - Forest Service project management for O&M.

Assumptions included in this alternative are listed below.

- Mobilization must commence by July 1 to allow sufficient time to complete work before onset of the rainy season. Work must be scheduled early enough in the season so that it can be completed in a single mobilization.

- Subcontractor oversight will be required for no more than 40 percent of the days construction work is scheduled. Oversight and construction management will be performed by an appropriate prime contractor. Construction will be completed in no more than 84 days.

- Site security will be required 24 hours a day, seven day a week for construction equipment. Total calendar days equipment is on site will not exceed 104 days.

- Additional time for weather delays is not included in this cost estimate.

- Revegetation will be performed on land disturbed by construction activities and within sediment detention basins. Revegetation will be difficult on the weathered bedrock and loose soil areas; complete revegetation at Relief Hill would be a labor- and resource-intensive process. Selective revegetation will be performed to initiate plant growth in areas that are most critical for minimizing erosion and where the chances for successful revegetation are best. Revegetation will include reducing some slopes and scarifying the soil surface to provide selected areas with reduced surface water runoff and increased moisture to enhance the establishment of the native grasses and shrubs. In addition, the roughened surface will provide pockets and pits where the native seeds and fertilizer can collect. The prepared scarified surface will be hydroseeded with a mixture of native species, wood-fiber mulch, and fertilizer. If possible, existing shrubs could be salvaged from other locations on the mine site and transplanted to selected locations within the reclaimed areas. Entire multi-shrub "islands" can be excavated along with the live root wads, and transplanted to previously excavated holes. Finally, native, site-adapted shrubs and trees could be purchased from a nursery (either in cone-tainers or as bare-root stock) and planted in selected areas where they stand the best chance to survive. Revegetation methods and seed selection will be done in accordance with Tahoe National Forest guidelines.

- Removal action work performed on private land will be limited to temporary improvement of the existing OHV trail for access to the Cliff and New sluice systems. After site activities are completed, including revegetation activities for 3 years, the OHV trail will be reclaimed. This EECA assumes there will be no additional administrative or use costs associated with use of the OHV trail during the removal action.

- All necessary rock will be borrowed from on-site sources along the sluices.

- All necessary fill dirt used on site will be borrowed from on-site sources, generally at the tops of sluice cuts where it will decrease existing slope angle to aid natural revegetation. An average depth of 2 feet by 10 feet of sluice face for a length of 65 to 130 linear feet of sluice cut (if both sides of the sluice cut are used for fill) would provide the necessary 100 to 200 cubic yards of material needed to construct each dam.

- Actual dam size and shape may be adjusted based on actual field conditions to best fit individual ground sluices and maximize retention time to the extent practicable. Specific dam size and position should be determined during the design phase of the removal action.

- Additional runon controls will not be implemented above the northern high wall. The area above the high wall has established vegetation that limits erosion from above the site. Furthermore, it is located primarily on private land.

- Revegetation activities will be required for 3 years. Half of the revegetation area will require reseeding after each of the first 3 years. Revegetation activities would also include inspection for and eradication of noxious weeds in the construction areas.

- The Forest Service will manage O&M tasks. All maintenance and sampling activities are assumed to coincide with the annual site visit.

8.4.1 Effectiveness

The implementation of Alternative 3a would reduce the mobility of sediment and particulate-bound mercury from Relief Hill, promote the growth of soil-stabilizing vegetation, and reduce human exposure to on-site contaminants. The reduction in mobility would be achieved by: creating storm water detention (including check dams) and diversion to settle the majority of the mobile sediment from surface runoff and contain it on site; by grading, installing wattles, and revegetating disturbed areas to reduce erosion; and by minimizing highly impacting recreational uses through access restrictions and designation and enforcement of RCAs. Storm water detention basins are designed to reduce sediment mobility by reducing flow velocity and increasing settling times for particulate matter to the extent practical based on site conditions. The basins will not be designed to hold all surface runoff from large rain events.

Alternative 3a would reduce human and ecological exposure to sediment and mercury in surface water downstream from the site (including the South Yuba River), reduce mercury loading to the South Yuba River, reduce direct contact with contaminated sediment, and reduce inhalation of dust during the dry season. Furthermore, mercury believed to remain on site is likely to exist at the base of ground sluices, pit lakes, and wetlands. The engineering controls in Alternative 3a (including rock armoring of sluices, and capture of new sediment in detention basins built in sluices, pit lakes, and sluice tunnels) would further entomb the remaining mercury. The additional burial of potentially contaminated sediment would reduce human and ecological exposure to on-site mercury in sediment, surface water, and dust particles. The likelihood of a large storm exposing mercury potentially remaining below sluice infill sediment would also be reduced by improved storm water and erosion controls. The volume and toxicity of mercury in the environment would remain unchanged.

Engineering controls are considered a feasible alternative for managing surface water runoff from and erosion in the mine pit, and for capturing mobile sediment potentially containing mercury.

The permanence of surface controls alone for reducing sediment and particulate-bound mercury migration to surface water and the threat of human health and ecological exposure depends on maintenance activities. Alternative 3a would likely decrease the mercury load leaving the site but would not reduce the total amount of mercury on site. However, mercury on site appears to be buried and is unlikely to cause substantial risks to human health and the environment. Land use controls and access restrictions are also considered feasible alternatives for reducing erosion and human exposure, though the permanence and effectiveness of land use controls and access restrictions depend on enforcement and maintenance activities.

Engineering controls in Alternative 3a would reduce contaminant and sediment loads from Relief Hill and would meet long-term goals listed in Tables 10 and 11.

Location-specific ARARs would be met under Alternative 3. The riparian communities on site would be protected by enforcement of land use restrictions within the RCA. Habitat for the foothill yellow-legged frog and other special status species potentially inhabiting Relief Hill would be preserved under Alternative 3a. Alternative 3a would not affect the protected heritage resources identified at Relief Hill during the archeological inventory (Forest Service 2004c). However, the response action should be coordinated with the Forest Service archeologist. Areas disturbed by the removal activities would be revegetated in accordance with Tahoe National Forest guidelines, including selection of native seed mixtures and use of certified weed-free plant materials for erosion control.

Action-specific ARARs would be met under Alternative 3a. Storm water generated during construction activities, though not anticipated, will be managed in accordance with the CWA. Northern Sierra AQMD nuisance dust suppression and control requirements are applicable because greater than 1 acre of land will be disturbed during grading and erosion control activities. OSHA requirements would be met by requiring appropriate safety training for all on-site workers during the construction phase. Revegetation would be carried out in a manner to comply with 30 CFR 816.111. The California Fish and Game Code Sections 1600 through 1616 prohibit alteration of streambeds or impeding natural flow in stream beds. Under the code, an existing fish or wildlife resource can not be substantially adversely affected. Alternative 3 will not likely adversely affect resources. However, the CDFG should be notified prior to beginning construction activities. Construction activities within the newly defined RCA would be coordinated with Forest Service biologists to ensure the long-term benefit of riparian areas.

The construction phase for Alternative 3a would be accomplished within one field season; therefore, impacts associated with construction would likely be short-term and minimal. Construction of surface controls would meet the standards for diversion of flow from disturbed areas and revegetation requirements contained in SMCRA and SMARA. In addition, standards for drainage, diversion structures, waterways, and erosion control contained in SMARA would also be met. Storm water generated during construction activities, though not anticipated, will be managed in accordance with the CWA. Northern Sierra AQMD nuisance dust suppression and control requirements are applicable for construction and earth-moving activities associated with

this alternative for the control of fugitive dust emissions; these requirements would be met through water application to roads receiving heavy vehicular traffic and to construction or excavation areas, if necessary. OSHA requirements would be met by requiring appropriate safety training for all on-site workers during the construction phase. Short-term risks of physical injury would exist for site workers during construction. Increased truck traffic required to transport construction material to the site would have a short-term impact on local air quality and traffic safety.

8.4.2 Implementability

Alternative 3a is technically feasible, but only partially administratively feasible. Portions of the site are held under current mine claims and actively mined under an authorized plan of operations. Land use controls and access restrictions must consider the rights of the mine claimant, including maintaining limited access to the site. Upon closure of the active mine, the Forest Service will assume responsibility for maintaining access restriction measures (signs and gates). All necessary actions could be implemented within one field season. In accordance with the Framework (Forest Service 2004a), the Forest Service has the authority to designate RCAs on Forest System land at Relief Hill through administrative procedures. Excavation, trenching, construction, grading, and revegetation require conventional construction practices; materials are readily available. Design methods, construction practices, and engineering requirements for installation of berms, ditches, diversions, rock dissipaters, and detention ponds are well documented and understood. Equipment, materials, and labor would be available through the local market.

Excavation, grading, and check dam construction work would require the use of heavy equipment including excavators, loaders, dozers, and haul trucks. Controlling fugitive dust emissions and storm water discharge (if generated) during excavation and grading activities would be required.

Long-term monitoring and maintenance would be required but would be limited primarily to gate and sign repair and regular inspections. Due to the size and depth of the sediment detention basins cleanout is expected to be fairly infrequent. Detention pond capacity should be monitored during regular inspections. Cleanout cost is not included in this EECA but would be comparable to costs for Alternative 3 and thus would not influence alternative selection.

Enforcement of land use controls may prove to be problematic. By nature, OHV use is not easily controlled. The site is relatively remote making it difficult to observe trespassers and enforce the controls.

8.4.3 Cost

The total present worth cost for Alternative 3a, selective engineering controls including check dams, land use restrictions, and access restrictions, is estimated to be approximately $529,000

and are expected to be within plus 50 percent ($794,000)and minus 30 percent ($370,000) of actual project costs as per EPA guidance for costs estimates (EPA 2000). Table 17 presents a summary of the costs associated with implementing Alternative 3a. The total present worth cost includes the present value capital costs and 30 years of O&M. Internal Forest Service costs for designation of the land as an RCA and the enforcement of land use controls are not included. Changes in the cost elements are likely to occur as a result of new information and data collected during the removal action design.

9.0 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

This section compares the removal action alternatives retained for detailed analysis at Relief Hill. The comparison focuses on the effectiveness, implementability, and cost of each alternative. The following sections present the comparative analysis, a summary of analysis findings, and the recommended removal action alternative based on analysis findings.

9.1 COMPARATIVE ANALYSIS

The final step of an EE/CA is to conduct a comparative analysis of the removal action alternatives. The analysis will discuss each alternative's relative strengths and weaknesses with respect to each comparison criterion. Once completed, the analysis will be used to select the recommended removal action alternative(s). A press release in local newspapers will inform the public where the recommended removal action alternative can be viewed and will provide a forum for oral and written comments. All significant comments will be addressed in writing. The preferred removal action alternative will then be documented in an action memorandum.

The purpose of the analysis is to compare the relative effectiveness, implementability, and cost of the removal action alternatives in controlling and reducing the release of sediment and mercury from Relief Hill. The effectiveness comparison includes consideration of the following criteria: (1) protectiveness of human health and the environment; (2) compliance with ARARs; (3) long-term effectiveness and permanence; (4) reduction of toxicity, mobility, and volume; (5) short-term effectiveness of each alternative; (6) implementability, and (7) cost. The cost comparison will include consideration of the estimated total present worth cost of each alternative.

Each criterion is presented and compared for each removal action alternative in Table 18. Supporting agency acceptance and community acceptance are additional criteria that will be addressed in the action memorandum after the state agency and the public review the evaluation process and the recommended removal action alternative.

9.2 SUMMARY OF FINDINGS

A summary of the comparative analysis of the four removal action alternatives is presented in this section.

Overall Protectiveness

Baseline conditions at Relief Hill as represented by Alternative 1, the No Action alternative. Under Alternative 1, erosion and off-site transport of sediment and particulate-bound mercury to the environment would continue, and therefore is not protective of human health and the environment. Alternative 2 would protect human health and the environment by reducing off-site transport of sediment and particulate-bound mercury by limiting highly impacting recreational activities in areas susceptible to erosion. Alternatives 3 and 3a would protect human health and the environment by reducing off-site transport of sediment and particulate-bound

mercury by stabilizing material susceptible to erosion, capturing sediment that has been mobilized in storm water runoff, and limiting highly impacting recreational activities in areas susceptible to erosion. ***Alternative 3a is considered to be most protective of human health and the environment because it includes all of the measures from Alternatives 2 and 3, and includes check dams in open sluice tunnels as an additional sediment capture measure.*** Alternative 2 is considered to be less protective of human health and the environment than Alternatives 3 and 3a because it does not address sediment once it has become mobile in surface runoff.

Compliance with ARARs

No ARARs apply to Alternative 1, No Action. Alternative 2 would only reduce the potential for erosion on site and, as a result, surface water discharged from the site may not meet chemical-specific ARARs. Alternatives 3 and 3a would comply with chemical-specific ARARs by reducing the potential for erosion on site and limiting the amount of sediment and particulate-bound mercury released from the site. Alternatives 2 may not comply with location-specific ARARs because stream banks and beds may continue to be eroded due topographic and drainage features created by historical hydraulic mining. Alternatives 3 and 3a would comply with location-specific ARARs. Issues such as private property boundaries and areas of archeological protection must be taken into account for Alternatives 2, 3, and 3a. Specifically, the potential removal actions cannot prohibit mining activity on patented and unpatented claims on site that is conducted under the existing authorized plan of operations. ***Alternatives 2, 3, and 3a would comply with action-specific ARARs through proper implementation.***

Long-Term Effectiveness and Permanence

Alternative 1, No Action, is not considered to have long-term effectiveness for addressing the migration of sediment and mercury from the site. None of the alternatives would alter the volume or toxicity of mercury in the environment. Alternatives 2, 3, and 3a would reduce the mobility of sediment and mercury. Alternatives 3 and 3a would also further minimize the off-site transport of sediment and particulate-bound mercury indefinitely as long as the engineering controls are adequately maintained and site use limitations are enforced. The rock-lined channels, sediment detention basins, and check dams (Alternative 3a only) would require periodic inspection; debris removal may also occasionally be necessary to ensure proper flow. Revegetation activities included in Alternatives 3 and 3a would reduce erosion in the long term by stabilizing loose geologic materials. Alternative 2 would have long-term effectiveness, but over a longer timeframe and to a lesser degree than Alternatives 3 and 3a. Alternative 2 would include revegetation only along obliterated roads and would rely primarily on natural processes for revegetation in other sections of the site. Therefore, Alternative 2 would take longer to stabilize loose geologic materials than Alternatives 3 and 3a. ***Alternative 3a would have the greatest long-term effectiveness due to the additional check dams creating greater redundancy of to reduce off sit emigration pathways.***

Reduction in Toxicity, Mobility, and Volume

None of the alternatives would reduce the volume or toxicity of mercury at the site. Alternative 2 would slightly reduce the mobility of sediment by decreasing erosion caused by site visitors and allow revegetation at a natural pace. Alternatives 3 and 3a would further reduce off-site transport of sediment and particulate-bound mercury by slowing high velocity runoff and allowing particulate to settle on-site, thus further burying potential mercury containing sediment. ***Due to the additional sedimentation measures included in Alternative 3a it would be most effective at reducing mobility of contaminated sediment.***

Short Term Effectiveness

Alternative 1, No Action, is not considered to have short-term effectiveness. ***Alternatives 2, 3, and 3a are considered to have short-term effectiveness because they would all be implemented in one field season.*** Establishment of RCAs on the mine site is an administrative task that can be completed by the Forest Service when appropriate staff are available. There are qualified contractors capable of accomplishing construction tasks described in Section 8.0, and equipment and materials are commercially available for the implementation of Alternatives 2, 3, and 3a. Short-term effects of construction would be minimized through application of water to construction surfaces and employment of adequate storm water control measures. There would be increased heavy traffic in the local area; however, appropriate traffic control would be used to minimize these effects.

Costs

Alternative 1 is the least expensive alternative because no cost is incurred. ***Costs for Alternatives 2, 3, and 3a are $76,000, $390,000, and $529,000, respectively.*** Internal Forest Service costs for designation of the land as an RCA and the enforcement of land use controls are not included in this EE/CA. These engineering costs are estimates that are expected to be within plus 50 percent to minus 30 percent of the actual project cost (based on year 2006 dollars). Changes in the cost elements are likely to occur as a result of new information and data collected during engineering design and construction pre-bid and walk-through meetings.

9.3 RECOMMENDED REMOVAL ALTERNATIVE

The recommended removal action alternative to control erosion and release of sediment and particulate-bound mercury from Relief Hill is Alternative 3a. Alternative 3a includes engineering controls to reduce erosion and retain mobilized sediment on site, and land use controls to reduce erosion caused by certain site uses (including OHV traffic), encourage the growth of soil-stabilizing vegetation, and reduce direct human contact with contaminants.

Alternative 3a was determined to provide the highest degree of protection for human and ecological receptors, would comply with ARARs, provides long-term effectiveness and

permanence, and greatly reduces the mobility and off-site migration of sediment and particulate-bound mercury. The engineering controls in Alternative 3a (including rock armoring of drainages, and capture of new sediment in detention basins built in sluices) would further entomb mercury that may remain at the base of former ground sluices. The additional burial of potentially contaminated sediment would reduce human and ecological exposure to on-site mercury in sediment, surface water, and dust particles. The likelihood of a large storm exposing mercury potentially remaining below sluice infill sediment would also be reduced by improved storm water and erosion controls. The removal action would be implemented during one field season, with operation and maintenance activities limited to ensuring success of revegetation efforts and clean out of sediment detention basins and diversion channels until vegetation is established. Alternative 3a would be implemented at an approximate total present worth cost of $529,000, which are expected to be within plus 50 percent ($794,000) and minus 30 percent ($370,000) of actual project costs as per EPA guidance for costs estimates (EPA 2000). The total costs include estimated capital cost of $392,000. Thirty years of operations and maintenance costs include costs for annual site inspections and costs to repair the gate, replace vandalized signs, collect confirmation monitoring samples and cleanout the sedimentation basins approximately every five years and appropriately manage the site. Operations and maintenance cost is $138, 000 for 30 years of operations and maintenance at a real discount factor of 3.0 percent.

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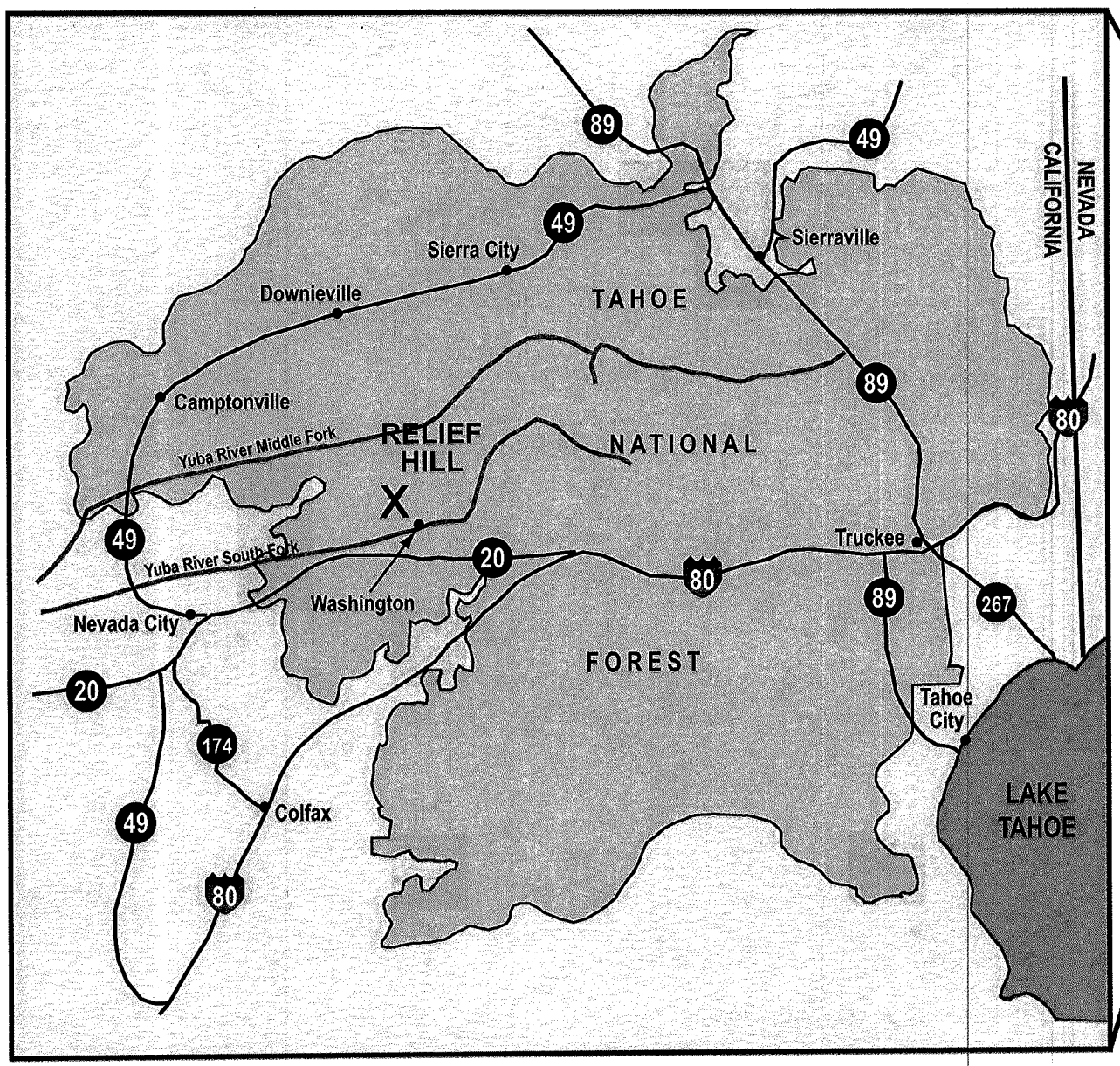
FIGURES



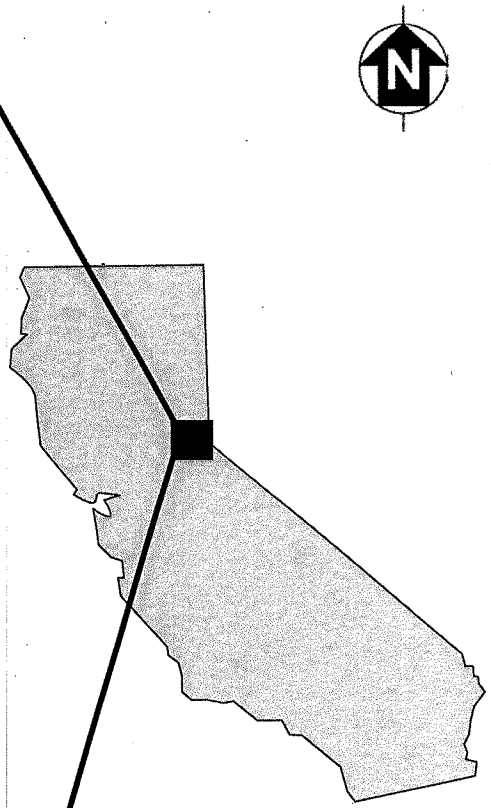
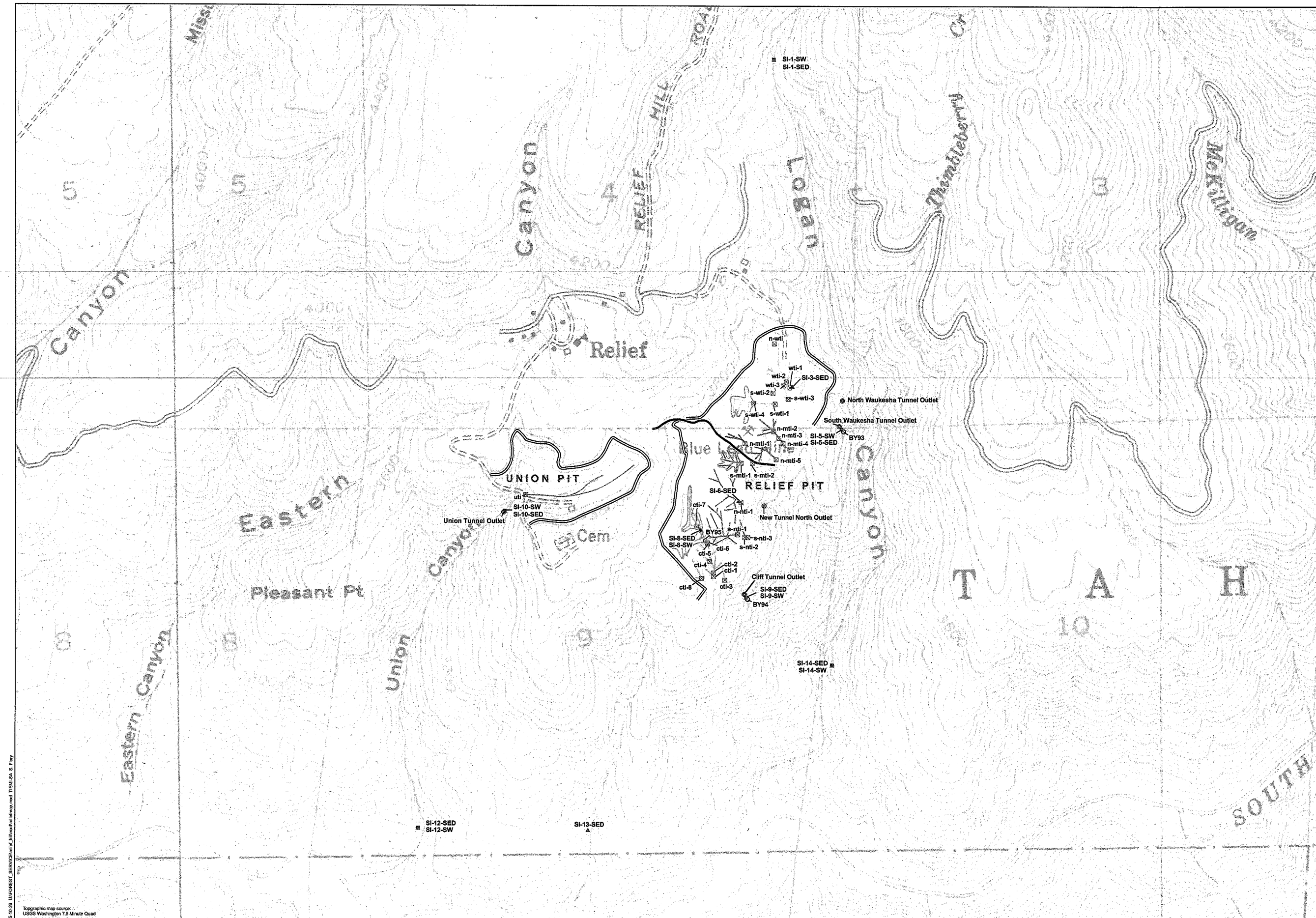


FIGURE 1

Site Location Map

Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.



▲ SAIC SEDIMENT SAMPLES
■ SAIC SURFACE WATER SAMPLES
USGS SAMPLE LOCATIONS
TUNNEL INLETS
DRAIN TUNNEL OUTLETS
GROUND SLUICE
HIGHWALL
ROAD
FLOOD ZONES

Sluice Systems

Cliff Sluice System
Middle Sluice System
New Sluice System
Waukesha Sluice System
Union Sluice System

N

0 250 500
Scale in Feet

Notes:

Previous sample locations are depicted on this figure based on location descriptions and topographic interpretation, and may be slightly different from historic coordinates.

SAIC Science Applications International Corporation

USGS U.S. Geological Survey

Locator Map

FIGURE 2

Previous Sampling Locations

Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.

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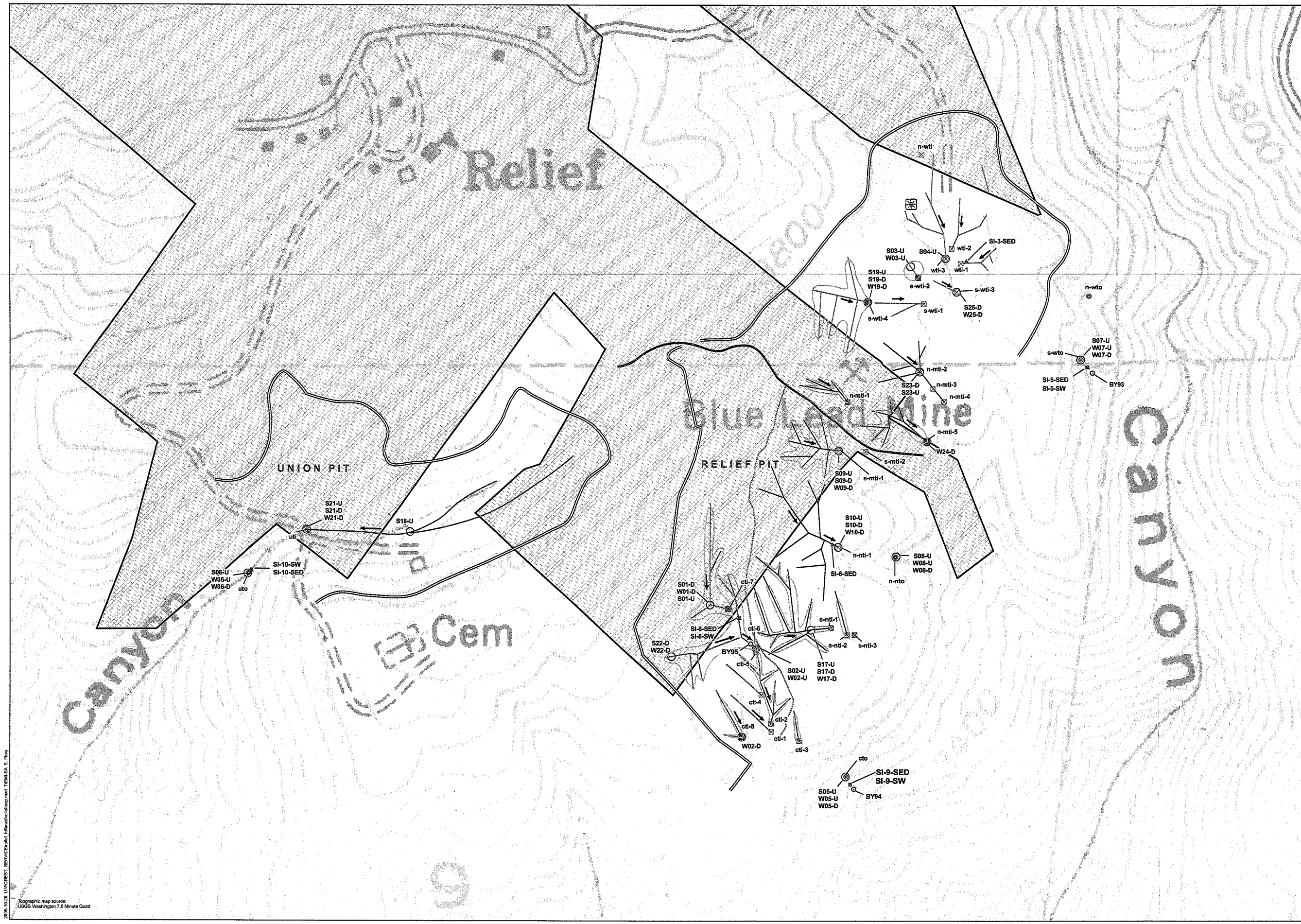

Topographic map source:
USGS Washington 7.5 Minute Quad

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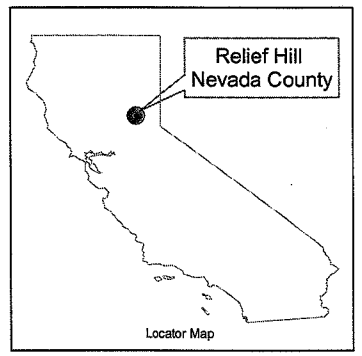
TETRA TECH SAMPLE LOCATION
SAIC SEDIMENT SAMPLES
SAIC SURFACE WATER SAMPLES
USGS SAMPLE LOCATIONS
OPEN TUNNEL INLET
TUNNEL INLET EXISTING PLUG
DRAIN TUNNEL OUTLETS
CHECK DAM
HISTORIC SITE
GROUND SLUICE
HIGHWALL
ROAD
FLOOD ZONES
PRIVATE PROPERTY

Sluice Systems

Cliff Sluice System
Middle Sluice System
New Sluice System
Waukesha Sluice System
Union Sluice System

Note: Previous sample locations are depicted on this figure based on location descriptions and topographic interpretation and may be slightly interpreted from historic coordinates



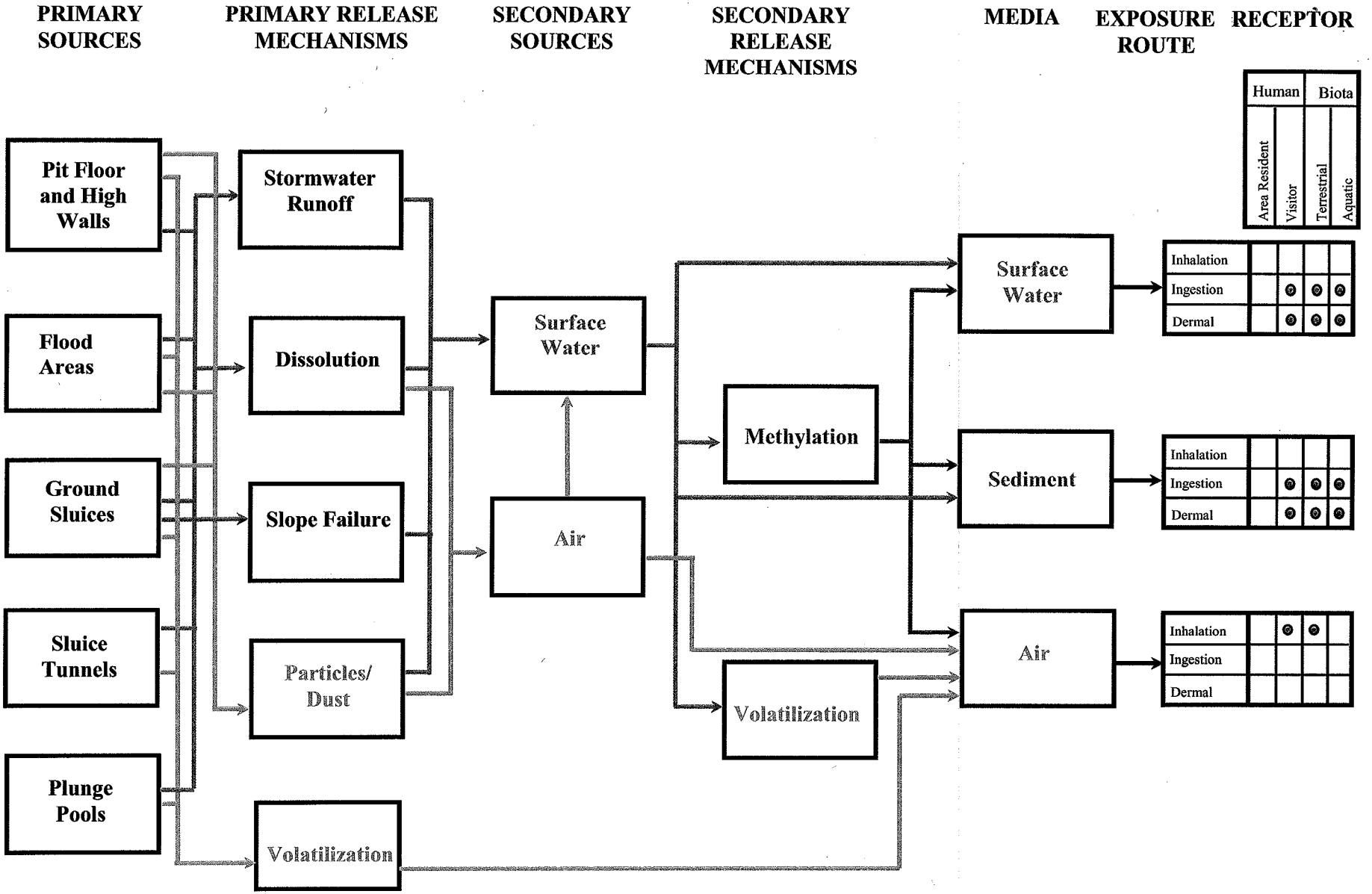
Locator Map

FIGURE 3

Site Features And Sampling Locations

Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.



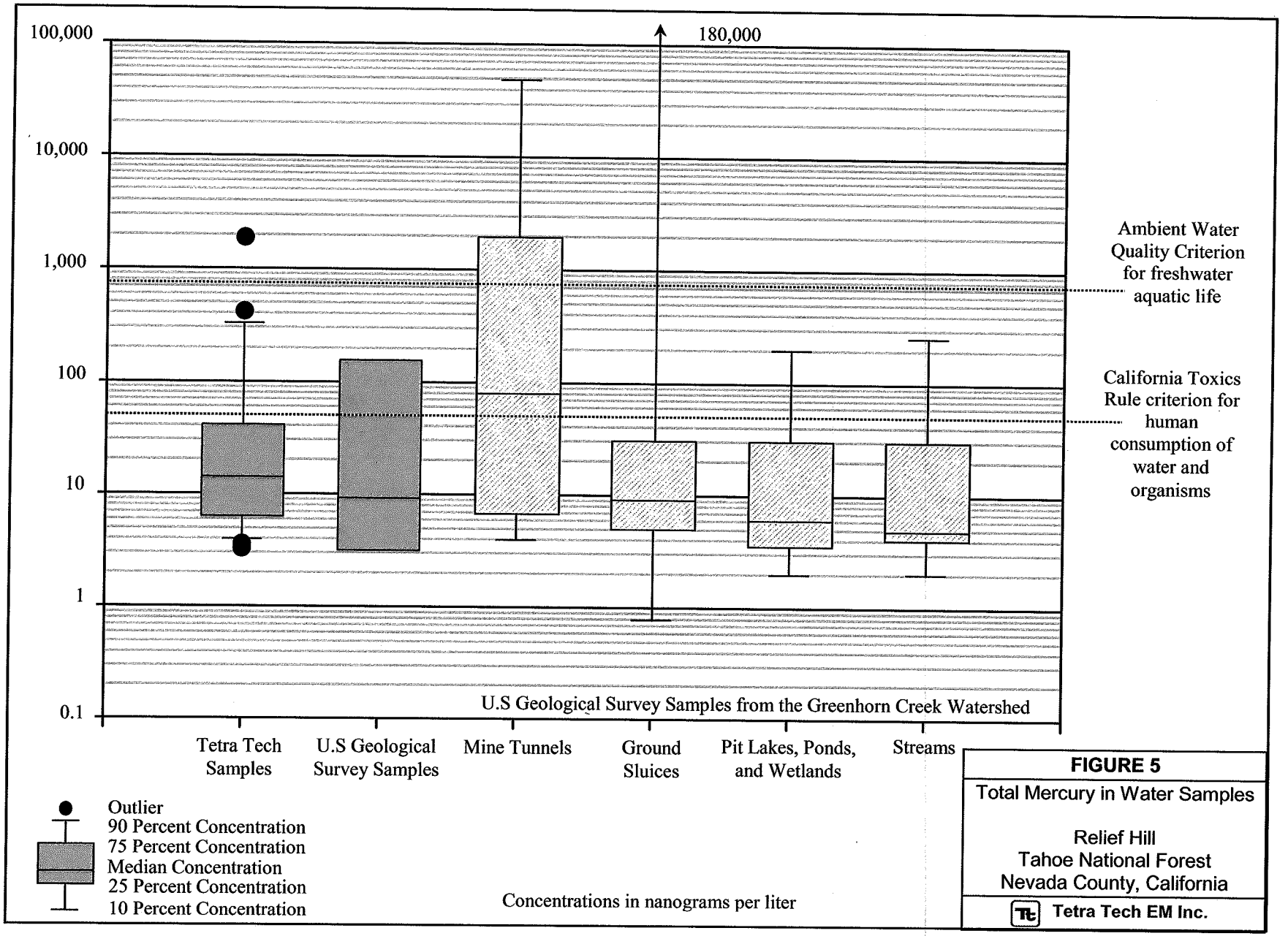
Sources and mechanisms occurring in surface water
Sources and mechanisms occurring in air
Mechanisms occurring by methylation
Residential receptors were not considered because the miners and caretaker do not live at the site full time.

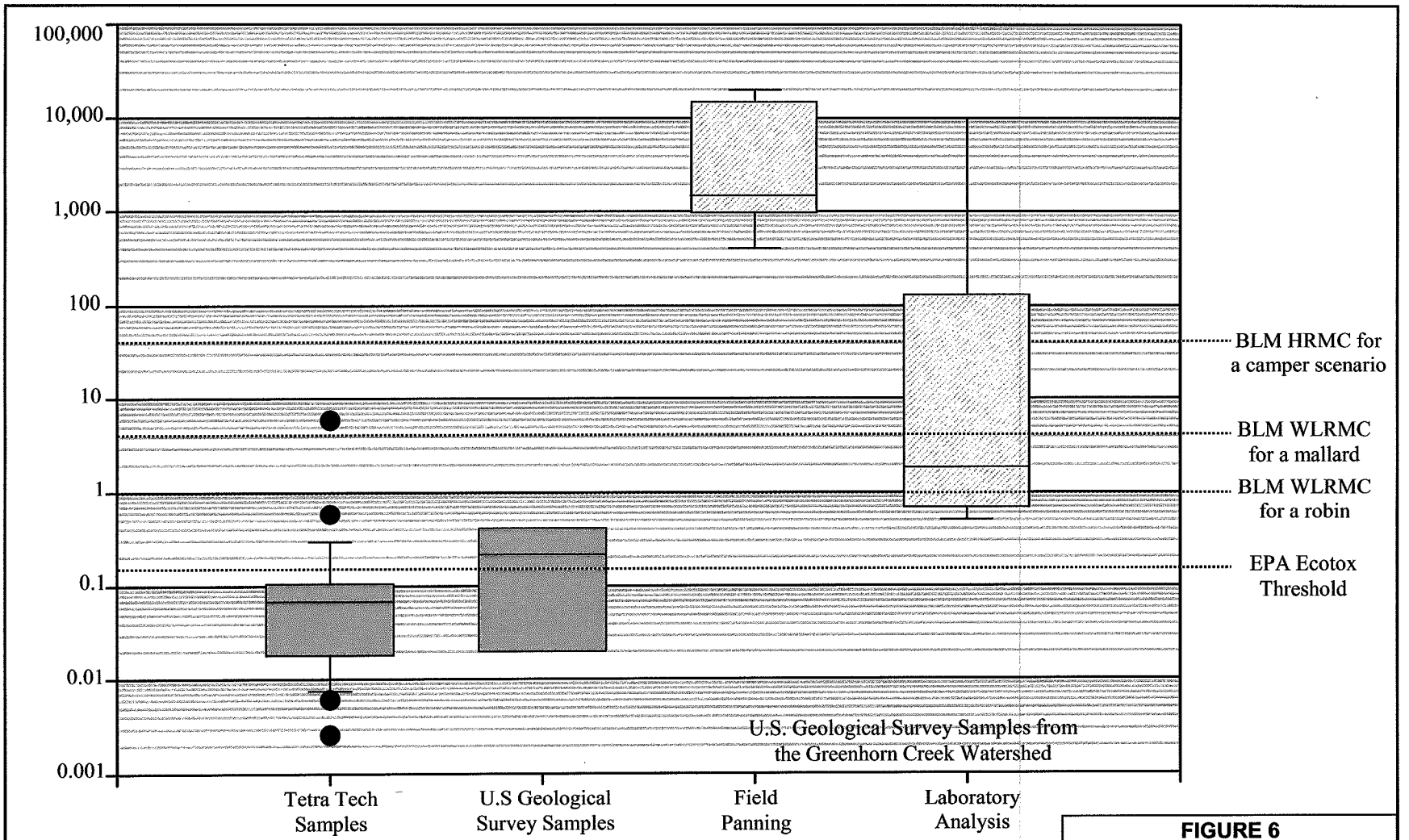
FIGURE 4

Conceptual Site Model

Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.


100,000
10,000
1,000
100
10
1
0.1
180,000
Ambient Water Quality Criterion for freshwater aquatic life
California Toxics Rule criterion for human consumption of water and organisms
U.S Geological Survey Samples from the Greenhorn Creek Watershed
Tetra Tech Samples
U.S Geological Survey Samples
Mine Tunnels
Ground Sluices
Pit Lakes, Ponds, and Wetlands
Streams
Outlier
90 Percent Concentration
75 Percent Concentration
Median Concentration
25 Percent Concentration
10 Percent Concentration
Concentrations in nanograms per liter
FIGURE 5
Total Mercury in Water Samples
Relief Hill
Tahoe National Forest
Nevada County, California
Tetra Tech EM Inc.



Outlier
90 Percent Concentration
75 Percent Concentration
Median Concentration
25 Percent Concentration
10 Percent Concentration

BLM Bureau of Land Management
EPA U.S. Environmental Protection Agency
HRMC Human risk management criteria
WLRMC Wildlife and livestock risk management criteria
Concentrations in milligrams per kilogram

FIGURE 6

Total Mercury in Sediment

Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.

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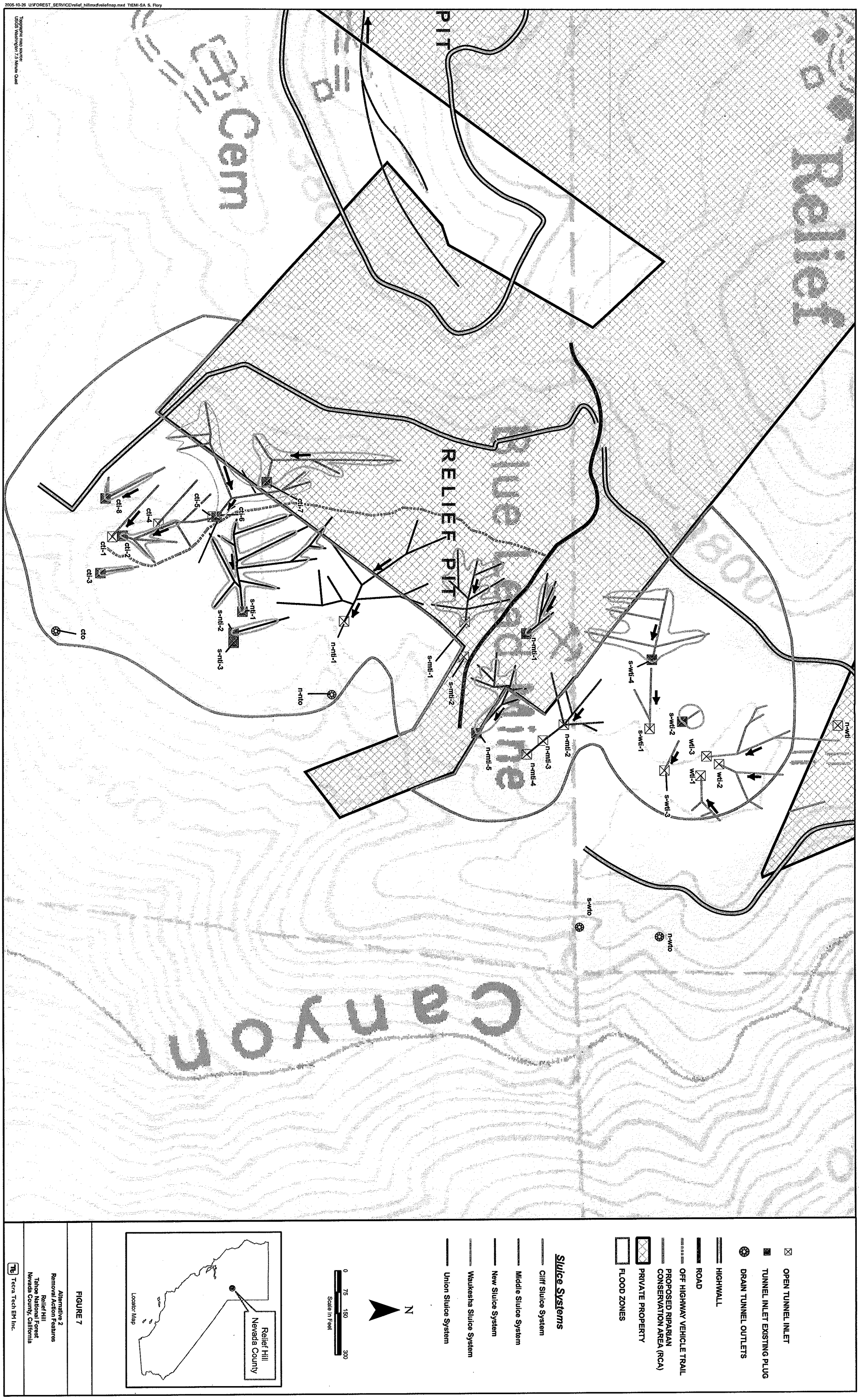
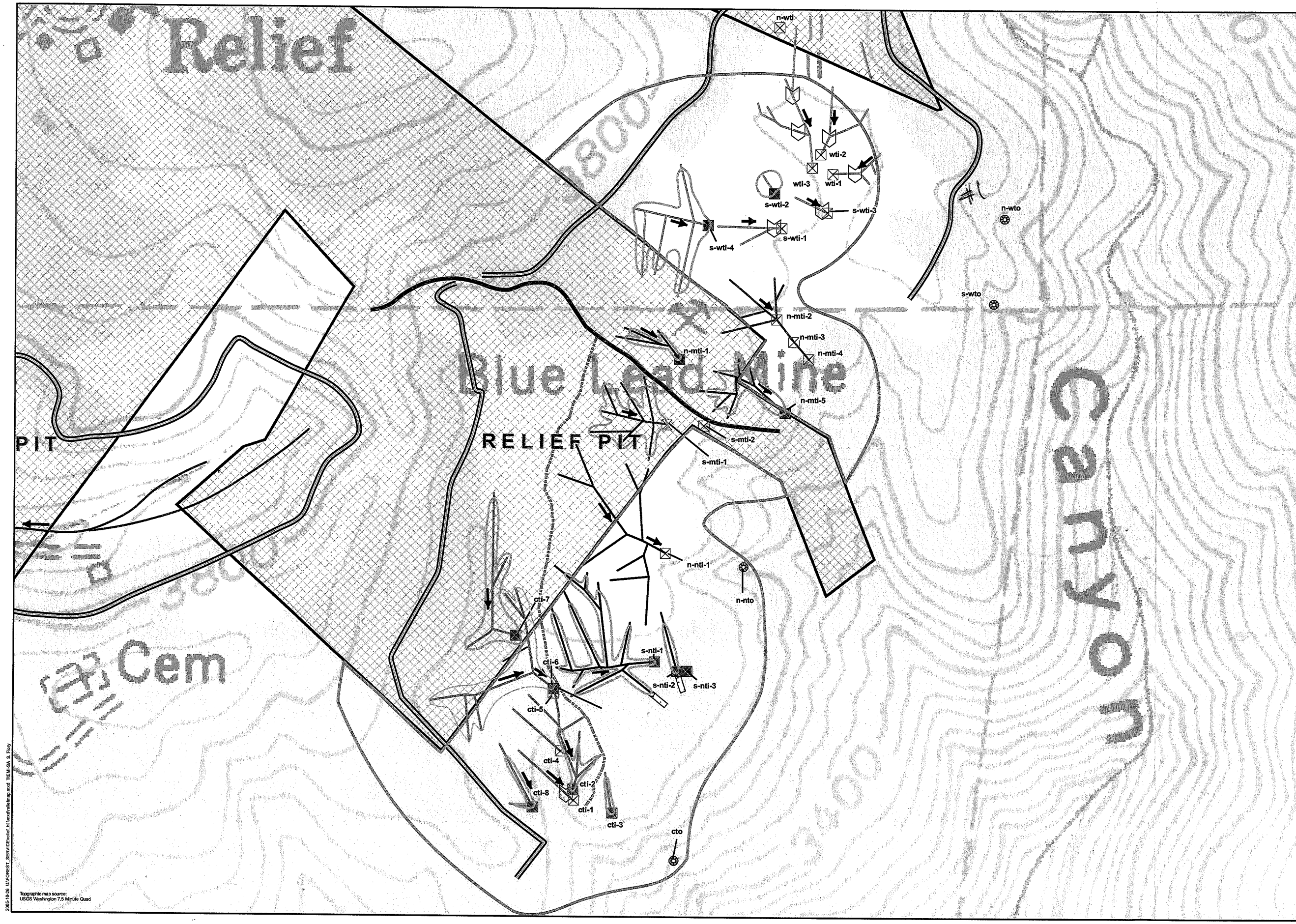


FIGURE 7

Alternative 2
Removal Action Features
Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.



OPEN TUNNEL INLET
TUNNEL INLET EXISTING PLUG
DRAIN TUNNEL OUTLETS
CHECK DAM
GROUND SLUICE
HIGHWALL
ROAD
OFF HIGHWAY VEHICLE TRAIL
PROPOSED RIPARIAN CONSERVATION AREA (RCA)
PRIVATE PROPERTY
FLOOD ZONES
ROCK ARMORED SPILLWAY

Sluice Systems

Cliff Sluice System
Middle Sluice System
New Sluice System
Waukesha Sluice System
Union Sluice System

N

0 75 150 300
Scale In Feet

FIGURE 8

Alternative 3
Removal Action Features

Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.

2005-10-26 U:\FOREST_SERVICE\relief_hill\mxd\reliefmap.mxd TIEMI-SA S. Flory

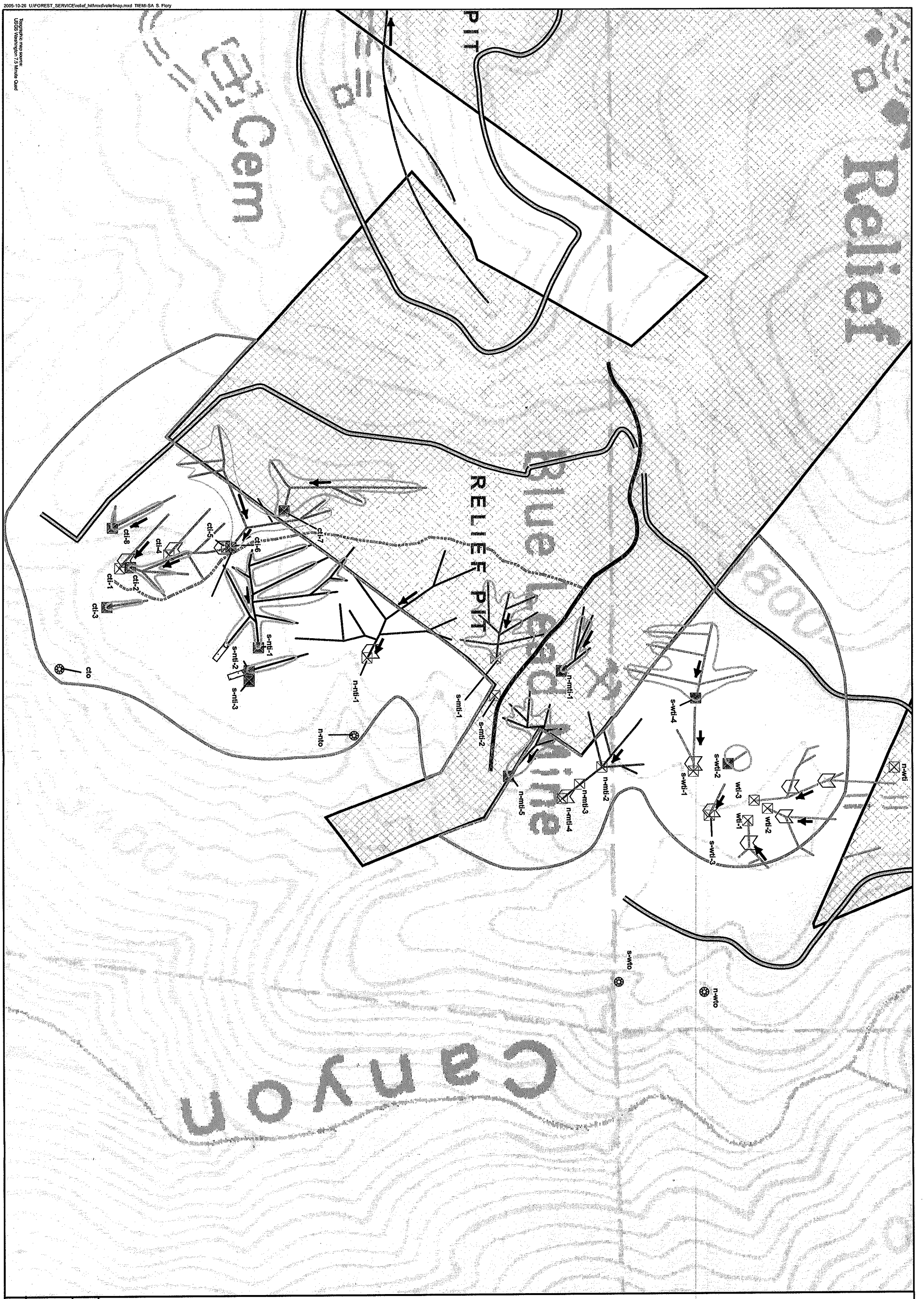


FIGURE 9

Alternative 3A
Removal Action Features
Relief Hill
Tahoe National Forest
Nevada County, California

Tetra Tech EM Inc.

TABLES

Table 1. Special Status Plant and Animal Species Potentially Present at Relief Hill

Common Name	Scientific Name
Threatened Species	
Bald eagle	*Haliaeetus leucocephalus*
California red-legged frog	*Rana aurora draytonii*
Valley elderberry longhorn beetle	*Desmocerus californicus dimorphus*
Lahontan cutthroat trout	*Oncorhynchus clarki henshawi*
Sensitive Species	
American peregrine falcon	*Falco peregrinus anatum*
California spotted owl	*Strix occidentalis occidentalis*
Great gray owl	*Strix nebulosa*
Northern goshawk	*Accipter gentilis*
Willow flycatcher	*Empidonax trailii*
Greater sandhill crane	*Grus canadensis tabida*
Pacific fisher	*Martes pennanti*
Marten	*Martes americana*
Sierra Nevada red fox	*Vulpes vulpes necator*
California wolverine	*Gulo gulo luteus*
Pallid bat	*Antrozous pallidus*
Townsend's big-eared bat	*Corynorhinus townsendii*
Western red bat	*Lasiurus blossevillii*
Northwestern pond turtle	*Clemmys marmorata marmorata*
Foothill yellow-legged frog	***Rana boylii***
Mountain yellow-legged frog	*Rana muscosa*
Northern leopard frog	*Rana pipiens*
Great Basin rams-horn snail	*Helisoma newberryi newberryi*
Lahontan Lake tui chub	*Gila bicolor pectinifer*
Hardhead	*Mylopharodon conocephalus*
Candidate Species and Species of Concern	
Mount Lyell salamander	*Hydromantes platycephalus*
California horned lizard	*Phyronosoma coronatum frontale*
Northern sagebrush lizard	*Sceloporus graciosus graciosus*
Western spadefoot toad	*Spea hammondii*
American dipper	*Cinclus mexicanus*
California thrasher	*Toxostoma redivivum*
Black swift	*Cypseloides niger*
Flammulated owl	*Otus flammeolus*
Harlequin duck	*Histrionicus histrionicus*

Table 1. Special Status Plant and Animal Species Potentially Present at Relief Hill

Common Name	Scientific Name
Candidate Species and Species of Concern (Continued)	
Lewis woodpecker	*Melanerpes lewis*
Loggerhead shrike	*Lanius ludovicianus*
Long-billed curlew	*Numenius americanus*
Oak titmouse	*Baeolophus inornatus*
Rufous hummingbird	*Selasphorus rufus*
Sage grouse	*Centrocercus urophasianus*
White-headed woodpecker	*Picoides albolarvatus*
Tricolored blackbird	*Agelaius tricolor*
Sierra Nevada showshoe hare	*Lepus americanus tahoensis*
Pale Townsend's big-eared bat	*Plecotus townsendii pallescens*
Yuma myotis bat	*Myotis yumanensis*
Fringed myotis bat	*Myotis thysanodes*
Greater western mastiff-bat	*Eumops perotis californicus*
Long-eared myotis bat	*Myotis evotis*
Long-legged myotis bat	*Myotis volans*
Small-footed myotis bat	*Myotis ciliolabrum*
Spotted bat	*Euderma maculatum*
Amphibious caddisfly	*Desmona bethula*
Cold Spring caddisfly	*Lepidostoma ermanae*
Lake Tahoe benthic stonefly	*Capnia lacustra*
Sagehen Creek goeracean caddisfly	*Goeracea oregona*
Shirttail Creek stonefly	*Megaleuctra sierra*
Long-tailed caddisfly	*Faula praelonga*
Spiny rhyacophilan caddisfly	*Rhyacophila spinata*
Green sturgeon	*Acipenser medirostris*
Longfin smelt	*Spirinchus thaleichthys*

Notes:

Source: Forest Service 2004b
Bold text indicates species was reportedly observed at Relief Hill.

Table 2. Total and Methyl Mercury Concentrations in Samples Collected by the U.S. Geological Survey from 1999 to 2002

Station Number/Map ID	Location	Date	Total Mercury Concentration	Methyl Mercury Concentration
	Unfiltered Surface Water			
392126120510201/BY93[a]	Relief Hill Deep Blue Tunnel Outflow Near North Bloomfield	5/20/1999	5 ng/L 5.5 ng/L	0.07 ng/L
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	9/1/1999	299 ng/L 59 ng/L	<0.025 ng/L
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	7/30/2002	13 ng/L NA	0.1 ng/L
392119120512201/BY95[c]	Relief Hill Pond Near Relief, California	7/30/2002	0.8 ng/L 0.8 ng/L	<0.04 ng/L
	Filtered Surface Water			
392126120510201/BY93[a]	Relief Hill Deep Blue Tunnel Outflow Near North Bloomfield	5/20/1999	0.5 ng/L 0.7 ng/L	NA
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	9/1/1999	49.2 ng/L 68.8 ng/L	NA
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	7/30/2002	2.3 ng/L 2.5 ng/L	<0.04 ng/L
392119120512201/BY95[c]	Relief Hill Pond Near Relief, California	7/30/2002	<0.1 ng/L <0.1 ng/L	<0.04 ng/L
	Sediment			
392126120510201/BY93[a]	Relief Hill Deep Blue Tunnel Outflow Near North Bloomfield	5/20/1999	NA	0.0002 mg/kg
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	9/1/1999	0.409 mg/kg	0.0015 mg/kg
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	7/30/2002	0.02 mg/kg	0.00031 mg/kg
392119120512201/BY95[c]	Relief Hill Pond Near Relief, California	7/30/2002	NA	0.00031 mg/kg
	Biota			
	Hellgramite			
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	9/1/1999	NA	0.053 mg/kg*
	Water Strider			
392111120511301/BY94[b]	Relief Hill Hydraulic Pit Mine Drain Tunnel Outflow Near North Bloomfield	9/1/1999	NA	0.094 mg/kg*
392119120512201/BY95[c]	Relief Hill Pond Near Relief, California	9/1/1999	0.048 mg/kg*	0.047 mg/kg*

Notes: Sources: Science Applications International Corporation 2004; U.S. Geological Survey unpublished data
Gray shading indicates highest concentration of this constituent for this sample media

a Location is is believed to be the feature referred to as the Waukesha south outlet in Tetra Tech's investigation
b Location is is believed to be the feature referred to as the Cliff tunnel outlet in Tetra Tech's investigation
c Location is is believed to be the feature referred to as the Cliff tunnel inlet No. 5 and No. 6 in Tetra Tech's investigation
* Wet weight
ID Identification
mg/kg Milligram per kilogram
NA Not analyzed
ng/L Nanogram per liter

Table 3. Total Mercury Concentrations in Historical Samples Collected by Science Applications International Corporation in September 2003

Sample ID	Location	Date	Total Mercury Concentration
	Surface Water		
R-PA/SI-1-SW	Background - Logan Canyon	9/11/2003	<0.20 µg/L
R-PA/SI-5-SW	Waukesha Drainage Tunnel Outlet	9/11/2003	<0.20 µg/L
R-PA/SI-8-SW	Large Pit Lake	9/11/2003	<0.20 µg/L
R-PA/SI-9-SW	Cliff Tunnel Drainage Outlet	9/11/2003	<0.20 µg/L
R-PA/SI-10-SW	Union Canyon Drainage Tunnel Outlet	9/11/2003	<0.20 µg/L
R-PA/SI-12-SW	Union Canyon at intersection with South Yuba Trail (near confluence with South Yuba River)	9/8/2003	<0.20 µg/L
R-PA/SI-14-SW	Logan Canyon at interstction with South Yuba Trail (near confluence with South Yuba River)	9/8/2003	<0.20 µg/L
	Sediment		
R-PA/SI-1-SED	Background - Logan Canyon	9/11/2003	<0.10 mg/kg
R-PA/SI-3-SED	Waukesha Drainage Tunnel Intlet	9/11/2003	<0.10 mg/kg
R-PA/SI-5-SED	Waukesha Drainage Tunnel Outlet	9/11/2003	<0.10 mg/kg
R-PA/SI-6-SED	Cliff Tunnel Inlet	9/11/2003	<0.10 mg/kg
R-PA/SI-8-SED	Large Pit Lake	9/11/2003	<0.10 mg/kg
R-PA/SI-9-SED	Cliff Tunnel Drainage Outlet	9/11/2003	0.1 mg/kg
R-PA/SI-10-SED	Union Canyon Drainage Tunnel Outlet	9/11/2003	<0.10 mg/kg
R-PA/SI-12-SED	Union Canyon at intersection with South Yuba Trail (near confluence with South Yuba River)	9/8/2003	<0.10 mg/kg
R-PA/SI-13-SED	Central Drainage at intersection with South Yuba Trail (near confluence with South Yuba River)	9/8/2003	<0.10 mg/kg
R-PA/SI-14-SED	Logan Canyon at intersection with South Yuba Trail (near confluence with South Yuba River)	9/8/2003	<0.10 mg/kg

Notes: Source: Science Applications International Corporation 2004
Gray shading indicates highest concentration of this constituent for this sample media
µg/L Microgram per liter
ID Identification
mg/kg Milligram per kilogram
PA/SI Preliminary assessment/site inspection

The leader for sample IDs on Figures 2 and 3 was truncated for readability. "120611" was omitted from Tetra Tech sample IDs and "R-PA/" was omitted from Science Applications International Corporation sample IDs.

Table 4. Estimated Ground Sluice Dimensions

Sluice System	Depth (ft)	Width (ft)	Length (ft)	Volume (ft^3)	Volume (yd^3)
Cliff	6	12	2,963	213,336	7,901
New	5	12	3,675	220,500	8,167
Middle	5	12	4,251	255,060	9,447
Waukesha	6	12	8,160	587,520	21,760
Union	2.5	12	1,688	50,640	1,876
Total Relief Hill			20,737	1,327,056	49,150
Total Relief Hill (Cubic Yards)				49,150	1,820

Notes: Sluice system locations are shown on Figure 3.

ft Foot

ft^3 Cubic foot

yd^3 Cubic yard

Sluice depths are estimated based on results of subsurface sample collection and sluice profiling. The original sluice surface was only encountered in one sample location within the Union sluice system; depths in the table reflect the minimum sluice sediment thickness. Actual sediment thickness (and therefore, total sediment volume) may be significantly greater than values listed in the table.

Table 5. Results of Water Sampling in October 2004 and March 2005

	Sample Identification	Location	Date	Time	Total Mercury (ng/L)[a]	Methyl Mercury (ng/L)[b]	Dissolved Mercury (ng/L)[c]	TSS (mg/L)	Temp. (°C)	pH	SC (µS/cm)	Eh (mV)	DO (mg/L)	Flow (gpm)	Comments
Undisturbed Sampling Event	120611W02U	Cliff Tunnel Inlet No.6 (lagoon)	10/7/2004	12:00	78.0	0.041	NA	150	NR	3.9	5.8	242	5.03	0	Standing water (groundwater) about 6 inches bgs.
	120611W03U	Waukesha Inlet Pond	10/6/2004	16:50	18.9	0.704	NA	18	19.8	7.2	23	128	7.5	0	Ponded water.
	120611W05U	Cliff Tunnel Outlet	10/5/2004	17:45	21.1	<0.025	NA	<10*	13.3	3.2	654	479	8.2	0	Standing water in pools and just below sediment surface.
	120611W06U	Union Tunnel Outlet	10/6/2004	11:30	6.80	0.031	NA	<10	12	6.78	326	112	8.7	1.5 gpm	Flowing water.
	120611W20U	(Field Duplicate)	10/6/2004	12:30	7.93	<0.025	NA	NA	NA	NA	NA	NA	NA		
	120611W07U	Waukesha South Outlet	10/5/2004	12:20	12.3	<0.025	NA	<10*	12.5	5.6	871	124	8.6	2-4 gpm	Flowing water.
	120611W08U	New Tunnel North Outlet	10/5/2004	14:30	4.21	0.031	NA	<10*	12.4	1.86	1,609	632	8.83	0	Standing water in pools and just below sediment surface.
	120611FB	Field Blank	10/6/2004	15:15	<0.15	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	Nanopure water poured into sample container.
	120611ER	Equipment Rinsate	10/6/2004	15:15	<0.15	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	Nanopure water poured over a new sediment sample scoop and into a sample container.
Disturbed Sampling Event	120611W01D	Cliff Tunnel Inlet No.7 (wetland)	3/24/2005	11:50	13.9	0.081	250**	5	7.6	6.5	56	148	10.8	0	Plugged inlet, sluice contains vegetation in upper, shallow reaches. CTI- 7 sluices are flooded. Water had risen up to notch in bedrock and is flowing toward CTI-6.
	120611W20D	(Field Duplicate)	3/24/2005	11:50	13.8	0.070	960**	<5	NA	NA	NA	NA	NA		
	120611W02D	Cliff Tunnel Inlet No.8 (alternate location)	3/24/2005	14:10	7.05	<0.025	680**	<5	7.8	5.03	9	279	10.3	0	Sample collected due to access concerns at CTI-6 and water at CTI-6U is same as CTI-6. Water sample only collected at end of the sluice near the high wall. No flow measurement.
	120611W05D	Cliff Tunnel Outlet	3/25/2005	12:00	9.17	0.048	<200	<5	10.9	5.2	94	223	11.1	80-100	Tunnel outlet.
	120611W06D	Union Tunnel Outlet	3/25/2005	13:55	7.09	0.051	<200	10	8.7	6.2	118	217	10.9	1,484	Sample collected from 5-inch pool just down stream of tunnel outlet.
	120611W07D	Waukesha South Outlet	3/24/2005	16:45	413	0.21	<200	510	4.3	5.95	76	266	12	1,123	Outlet partially blocked by slide. Water discharging from top and bottom of slide. Most discharge is from pool below falls. Water at outlet is turbid, similar to inlet (WTI-3).
	120611W08D	New Tunnel North Outlet	3/23/2005	16:15	14.5	0.048	<200	<5	3.5	3.17	140	488	10.7	449	none
	120611W09D	Middle Tunnel Inlet No.1	3/24/2005	15:00	63.7	0.039	430**	<5	7.0	4.45	30	311	11.1	0	Plugged inlet. Very fine, dry sediment. No vegetation. Inlet is plugged. Water is standing and blue/green. Water has flooded lower portions of sluices. Sample location is vertically above undisturbed sample location.
	120611W10D	New Tunnel North Inlet	3/23/2005	15:30	16.7	0.076	<200	<5	3.3	3.33	93	501	11.5	239	Open inlet to vertical shaft. Coarse, dry slate sediment. No vegetation. Steady flow of 3-inch depth into inlet.
	120611W17D	New Tunnel South Inlet	3/24/2005	14:45	4.70	<0.025	<200	<5	7.9	3.95	131	338	9.9	0	Plugged inlet. Very fine, dry sediment. No vegetation. Inlet is plugged, water is standing and clear. Water does not extend up sluices so tunnel inlet must have a slow leak.
	120611W19D	Waukesha South Inlet No.4	3/24/2005	16:50	1,880	0.288	200	2,200	3.4	5.3	41	288	10.8	265	Plugged inlet. Fine to medium, dry sediment. Vegetation. Shallow extremely turbid flow into inlet potentially originating from land slide above drift mine entrance.
	120611W21D	Union Pond Outlet	3/25/2005	14:25	3.58	0.062	<200	<5	9.0	6.8	118	221	10.3	1,926	Fine to very fine, wet sediment. Sediment is approximately 6 inches deep of white sandy silt with some quartz underlaid by black organic matter mostly decaying leaves. Standing water in large wetland area just upstream of the tunnel inlet. Vegetated.

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Table 5. Results of Water Sampling in October 2004 and March 2005

	Sample Identification	Location	Date	Time	Total Mercury (ng/L)[a]	Methyl Mercury (ng/L)[b]	Dissolved Mercury (ng/L)[c]	TSS (mg/L)	Temp. (°C)	pH	SC (µS/cm)	Eh (mV)	DO (mg/L)	Flow (gpm)	Comments
Disturbed Sampling Event (continued)	120611W22D	Cliff Tunnel Inlet No.6 (upper wetland area)	3/24/2005	12:10	5.02	<0.025	1,600**	10	7.6	4.6	65	208	10.6	0	Plugged inlet. No vegetation or detritus. Coarse, wet slate sediment. CTI 6U wetland and lower sluices are flooded. Water has risen to notch and spilled into CTI 6. Sample collected at east end of wetland just before notch.
	120611W23D	Middle Tunnel North Inlet No.2	3/24/2005	16:15	3.24	<0.025	4,100**	<5	5.2	4.1	101	304	9.1	15-20	Inlet is partially blocked. Water is standing in sluices. Flow at other side in collapsed area between MTI-N3 and MTI-N4. Water is clear.
	120611W24D	Middle Tunnel North Inlet No.5	3/24/2005	15:15	269	0.318	2,400**	<5	5.0	5.22	14	246	10.7	0	Inlet is plugged and water is pooled. Lower portion of sluices are flooded. Water is green/brown.
	120611W25D	Waukesha Tunnel Inlet No.3	3/23/2005	15:00	32.6	<0.025	<200	47	4.4	6.58	39	198	11.4	1,397	Open inlets feeding into a central shaft. Steady stream flowing into inlet 1.4 feet wide and 4 inches deep.
	120611FB01D	Field Blank	3/25/2005	13:15	<0.15	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	Nanopure water poured into sample container.
	120611ER01D	Equipment Rinsate	3/25/2005	13:20	<0.15	<0.025	NA	NA	NA	NA	NA	NA	NA	NA	Nanopure water poured over a new sediment sample scoop and into a sample container.

Notes:

	Gray shading indicates highest concentration (or lowest pH) of this constituent in real samples for this sampling event
a	Analyzed by Frontier GeoSciences, Inc. standard operating procedure 069.
b	Analyzed by Frontier GeoSciences, Inc. standard operating procedure 070.
c	Analyzed by SW-846 Method 7470.
*	Sample was analyzed beyond the EPA recommended holding time.
**	Results of dissolved mercury analysis are higher than results of total mercury analysis. This issue is discussed in the Disturbed Event under Section 3.3.3 Surface Water Sampling.
***	Calculated flow rates appear to be high due to bias in the velocity meter. Visual flow rate estimates are provided in parentheses.
<	Less than
°C	Degree Celsius
µS/cm	MicroSiemen per centimeter
bgs	Below ground surface
DO	Dissolved oxygen
EPA	U.S. Environmental Protection Agency
gpm	Gallon per minute
mg/L	Milligram per liter
mV	Millivolt
NA	Not analyzed
ng/L	Nanogram per liter
Eh	Oxidation-reduction potential
SC	Specific Conductance
Temp.	Temperature
TSS	Total suspended solids

The leader for sample identifcations (ID) on Figures 2 and 3 was truncated for readability. "120611" was omitted from Tetra Tech EM Inc. sample IDs and "R-PA/" was omitted from Science Applications International Corporation sample IDs.

Table 6. Results of Solid Matrix Sampling in October 2004 and March 2005

	Sample ID	Location	Date	Time	Low-level Total Mercury (mg/kg)[a]	Low-level Methyl Mercury (mg/kg)[b]	Total Mercury (mg/kg)[c]	Sample Depth (inches)	Comments
Undisturbed Sampling Event	120611S01U	Cliff Tunnel Inlet No.7 (western sluice)	10/7/2004	10:45	0.0692	<0.00002	0.066	36	Plugged inlet, sluice contains vegetation in upper, shallow reaches. Fine, dry sediment.
	120611S02U	Cliff Tunnel Inlet No.6 (lagoon)	10/7/2004	12:00	0.0631	<0.00002	0.060	36	Plugged inlet. No vegetation or detritus. Coarse, wet slate sediment.
	120611S03U	Waukesha Inlet Pond	10/6/2004	17:00	0.179	0.000779	NA	Surface	Plugged inlet. Ponded water. Very fine sediments. No vegetation in pond. Vegetation in upstream sluice. Some detritus in sediment.
	120611S04U	Waukesha Inlet No. 1, 2, 3 (composite)	10/7/2004	16:45	0.0191	<0.00002	0.024	66	Open inlets feeding into a central shaft. No standing water. Fine to medium, dry sediment over coarse slate.
	120611S05U	Cliff Tunnel Outlet	10/5/2004	18:00	0.0243	<0.00002	0.089	6	Open outlet. Fine to medium, wet sediment. No flow.
	120611S06U	Union Tunnel Outlet	10/6/2004	11:45	0.221	0.000232	0.063	Surface	Open outlet. Tunnel filled about 2/3 full of sediment. Roof collapse just upstream from portal. Sediments are fine to coarse.
	120611S20U	(Field Duplicate)	10/6/2004	11:45	0.263	0.000674	NA		
	120611S07U	Waukesha South Outlet	10/5/2004	12:20	0.0169	0.000024	0.029	6	Collapsed outlet. Flowing water. Fine sediment. No vegetation. Some detritus.
	120611S08U	New Tunnel North Outlet	10/5/2004	14:45	0.0471	<0.00002	0.081	24	Open outlet. No flow. Wet sediments. Fine to medium sediments over coarse slate.
	120611S09U	Middle Tunnel Inlet No.1	10/7/2004	16:55	1.92	0.000108	5.9	60	Plugged inlet. Very fine, dry sediment. No vegetation.
	120611S10U	New Tunnel North Inlet	10/7/2004	17:10	0.132	<0.00002	0.11	36	Open inlet to vertical shaft. Coarse, dry slate sediment. No vegetation.
	120611S17U	New Tunnel South Inlet	10/7/2004	18:00	0.0738	<0.00002	0.079	36	Plugged inlet. Very fine, dry sediment. No vegetation.
	120611S18U	Union Sluice	10/6/2004	14:00	NA	NA	0.011 J	24	Medium to coarse, wet sand. Gleying in overlying fines.
	120611S19U	Waukesha South Inlet No.4	10/8/2004	10:20	0.0697	<0.00002	0.078	36	Plugged inlet. Fine to medium, dry sediment. Vegetation.
	120611S21U	Union Pond Outlet	10/6/2004	14:30	NA	NA	0.012 J	Surface	Fine to very fine, wet sediment. Black with lots of detritus. Standing water in large wetland area just upstream of the tunnel inlet. Vegetated.
	120611S23U	Middle Tunnel North Inlet No.2	10/8/2004	12:00	0.0449	<0.00002	0.031	36	Partially plugged inlet. Fine to very fine, dry sediments. No vegetation.
Disturbed Sampling Event	120611S01D	Cliff Tunnel Inlet No.7 (western sluice)	3/24/2005	11:50	0.107	0.000836	NA	Surface	Plugged inlet, sluice contains vegetation in upper, shallow reaches. Cliff Tunnel Inlet No.7 sluices are flooded. Water had risen up to notch in bedrock and is flowing toward Cliff Tunnel Inlet No.6.
	120611S20D	(Field Duplicate)	3/24/2005	11:50	0.0827	0.00041	NA		
	120611S09D	Middle Tunnel Inlet No.1	3/24/2005	15:00	0.579	0.000122	NA	Surface	Plugged inlet. Very fine, dry sediment. No vegetation. Inlet is plugged. Water is standing and blue/green. Water has flooded lower portions of sluices. Sample location is vertically above undisturbed sample location.
	120611S10D	New Tunnel North Inlet	3/23/2005	15:30	0.0185	<0.00002	NA	3	Open inlet to vertical shaft. Coarse, dry slate sediment. No vegetation. Steady flow of 3-inch depth into inlet.
	120611S17D	New Tunnel South Inlet	3/24/2005	14:45	0.00779	<0.000028	NA	Surface	Plugged inlet. Very fine, dry sediment. No vegetation. Inlet is plugged, water is standing and clear. Water does not extend up sluices so tunnel inlet must have a slow leak.
	120611S19D	Waukesha South Inlet No.4	3/23/2005	16:50	0.102	0.000538	NA	3	Plugged inlet. Fine to medium, dry sediment. Vegetation. Shallow extremely turbid flow into inlet potentially originating from land slide above drift mine entrance.
	120611S21D	Union Pond Outlet	3/25/2005	14:25	0.00605	<0.000025	NA	4	Fine to very fine, wet sediment. Sediment is approxiamtely 6 inches deep of white sandy silt with some quartz underlaid by black organic matter mostly decaying leaves. Standing water in large wetland area just upstream of the tunnel inlet. Vegetated.
	120611S22D	Cliff Tunnel Inlet No.6 (upper wetland area)	3/24/2005	12:10	0.00259	<0.000028	NA	Surface	Plugged inlet. No vegetation or detritus. Coarse, wet slate sediment. Cliff Tunnel Inlet No.6U wetland and lower sluices are flooded. Water has risen to notch and spilled into Cliff Tunnel Inlet No.6. Sample collected at east end of wetland just before notch.
	120611S25D	Waukesha Tunnel Inlet No.3	3/23/2005	15:00	0.0181	0.000041	NA	4	Open inlets feeding into a central shaft. Steady stream flowing into inlet 1.4 feet wide and 4 inches deep.

Notes:
All sample results are by dry weight.
Italics font indicates sample was analyzed by Method 7471 (not low-level).
Gray shading indicates highest concentration (or lowest pH) of this constituent in real samples for this sampling event.
a Analyzed by Frontier GeoSciences, Inc. standard operating procedure 069.
b Analyzed by Frontier GeoSciences, Inc. standard operating procedure 070.
c Analyzed by SW-846 Method 7471.

ID Identification
< Less than
J Value is less than the reporting limit.
mg/kg Milligram per kilogram
NA Not analyzed

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Table 6. Results of Solid Matrix Sampling in October 2004 and March 2005

The leader for sample IDs on Figures 2 and 3 was truncated for readability. "120611" was omitted from Tetra Tech EM Inc. sample IDs and "R-PA/" was omitted from Science Applications International Corporation sample IDs.

Table 7. Total and Methyl Mercury Concentrations in Water Samples Collected from 1999 to 2005

Sample ID	Location	Total Mercury Concentration (ng/L)	Methyl Mercury Concentration (ng/L)
Tetra Tech EM Inc. "Undisturbed" EE/CA Sampling Event			
120611W02U	**Cliff Tunnel Inlet No.6 (lagoon)**	**78**	0.041
120611W03U	Waukesha Inlet Pond	18.9	0.704
120611W05U	Cliff Tunnel Outlet	21.1	<0.025
120611W06U	Union Tunnel Outlet	6.80	0.031
120611W07U	Waukesha South Outlet	12.3	<0.025
120611W08U	New Tunnel North Outlet	4.21	0.031
Tetra Tech EM Inc. "Disturbed" EE/CA Sampling Event			
120611W01D	Cliff Tunnel Inlet No.7 (wetland)	13.9	0.081
120611W02D	Cliff Tunnel Inlet No.8 (alternate location)	7.05	<0.025
120611W05D	Cliff Tunnel Outlet	9.17	0.048
120611W06D	Union Tunnel Outlet	7.09	0.051
120611W07D	**Waukesha South Outlet**	**413**	0.21
120611W08D	New Tunnel North Outlet	14.5	0.048
120611W09D	**Middle Tunnel Inlet No.1**	**63.7**	0.039
120611W10D	New Tunnel North Inlet	16.7	0.076
120611W17D	New Tunnel South Inlet	4.7	<0.025
120611W19D	**Waukesha South Inlet No.4**	**1,880**	0.288
120611W21D	Union Tunnel Inlet (aka Union Pond Outlet)	3.58	0.062
120611W22D	Cliff Tunnel Inlet No.6 (upper wetland area)	5.02	<0.025
120611W23D	Middle Tunnel North Inlet No.2	3.24	<0.025
120611W24D	**Middle Tunnel North Inlet No.5**	**269**	0.318
120611W25D	Waukesha Tunnel Inlet No.3	32.6	<0.025
U.S. Geological Survey Data			
392126120510201 (BY93)	Waukesha South Outlet	5.5	0.07
392111120511301 (BY94)	**Cliff Tunnel Outlet (September 1, 1999)**	**299**	<0.025
392111120511301 (BY94)	Cliff Tunnel Outlet (July 30, 2002)	13	0.1
392119120512201 (BY95)	Pit Pond at the Cliff Tunnel Inlet	0.80	<0.04
Mine tunnels in the Greenhorn Creek Watershed (16 total mercury samples; 14 methyl mercury samples)	90 percent concentration	50,000	5
	75 percent concentration	2,000	0.8
	50 percent concentration	80	0.13
	25 percent concentration	7	0.02
	10 percent concentration	4	NR
Ground sluices in the Greenhorn Creek Watershed (7 samples)	90 percent concentration	180,000	NR
	75 percent concentration	30	0.3
	50 percent concentration	9	0.1
	25 percent concentration	5	0.02
	10 percent concentration	0.8	NR
Pit lakes, ponds, or wetlands in the Greenhorn Creek Watershed (6 total mercury samples; 5 methyl mercury samples)	90 percent concentration	200	NR
	75 percent concentration	30	0.37
	50 percent concentration	6	0.05
	25 percent concentration	4	0.03
	10 percent concentration	2	NR

Table 7. Total and Methyl Mercury Concentrations in Water Samples Collected from 1999 to 2005

Sample ID	Location	Total Mercury Concentration (ng/L)	Methyl Mercury Concentration (ng/L)
U.S. Geological Survey Data (Continued)			
Streams in the Greenhorn Creek Watershed (16 total mercury samples; 14 methyl mercury samples)	90 percent concentration	250	0.14
	75 percent concentration	30	0.08
	50 percent concentration	5	0.05
	25 percent concentration	4	0.02
	10 percent concentration	2	NR
Median concentration in Greenhorn Creek Watershed (44 total mercury samples; 40		9.6	0.07
Screening Levels			
EPA Maximum Contaminant Level		2,000	NP
California Public Health Goal in Drinking Water		1,200	NP
EPA National Recommended Ambient Water Quality Criteria for Freshwater Aquatic Life Protection, Continuous Concentration (4-day average)		**770***	NP
California Toxics Rule Criteria for Inland Surface Waters, Human Health		**50****	NP
EPA Preliminary Rediation Goal for tap water		11,000	3,600

Notes: Sources: Science Applications International Corporation 2004; Alpers and others 2005; U.S. Geological Survey (USGS) unpublished data
Bold font indicates analyte in real sample exceeds one or more criteria (criteria exceeded also noted in bold).
Gray shading indicates highest concentration of this constituent measured at Relief Hill

*	Expressed as dissolved mercury
**	Primary screening criteria used for this document.
<	Less than
aka	= Also known as
EE/CA	Engineering evaluation/cost analysis
EPA	U.S. Environmental Protection Agency
ID	Identification
ng/L	Nanogram per liter
NP	Not promulgated
NR	Not reported

The leader for sample IDs on Figures 2 and 3 was truncated for readability. "120611" was omitted from Tetra Tech sample IDs and "R-PA/" was omitted from Science Applications International Corporation sample IDs.

Table 8. Total and Methyl Mercury Concentrations in Solid Matrix Samples Collected from 1999 to 2005

Sample ID	Description	Total Mercury Concentration (mg/kg)	Methyl Mercury Concentration (mg/kg)
Tetra Tech EM Inc. "Undisturbed" EE/CA Sampling Event			
120611S01U	Cliff Tunnel Inlet No.7 (western sluice)	0.0692 / *0.066*	<0.00002
120611S02U	Cliff Tunnel Inlet No.6 (lagoon)	0.0631 / *0.06*	<0.00002
120611S03U	**Waukesha Inlet Pond**	**0.179**	0.000779
120611S04U	Waukesha Inlet No. 1, 2, 3 (composite)	0.0191 / *0.024*	<0.00002
120611S05U	Cliff Tunnel Outlet	0.0243 / *0.089*	<0.00002
120611S06U	**Union Tunnel Outlet**	**0.221 / 0.063**	0.000232
120611S07U	Waukesha South Outlet	0.0169 / *0.029*	0.000024
120611S08U	New Tunnel North Outlet	0.0471 / *0.081*	<0.00002
120611S09U	**Middle Tunnel Inlet No.1**	**1.92 / 5.9**	0.000108
120611S10U	New Tunnel North Inlet	0.132 / *0.11*	<0.00002
120611S17U	New Tunnel South Inlet	0.0738 / *0.079*	<0.00002
120611S18U	Union Sluice	0.011 J	NA
120611S19U	Waukesha South Inlet No.4	0.0697 / *0.078*	<0.00002
120611S21U	Union Pond Outlet	0.012 J	NA
120611S23U	Middle Tunnel North Inlet No.2	0.0449 / *0.031*	<0.00002
Tetra Tech EM Inc. "Disturbed" EE/CA Sampling Event			
120611S01D	Cliff Tunnel Inlet No.7 (western sluice)	0.107	0.000836
120611S09D	**Middle Tunnel Inlet No.1**	**0.579**	0.000122
120611S10D	New Tunnel North Inlet	0.0185	<0.00002
120611S17D	New Tunnel South Inlet	0.00779	<0.000028
120611S19D	Waukesha South Inlet No.4	0.102	0.000538
120611S21D	Union Pond Outlet	0.00605	<0.000025
120611S22D	Cliff Tunnel Inlet No.6 (upper wetland area)	0.00259	<0.000028
120611S25D	Waukesha Tunnel Inlet No.3	0.0181	0.000041
Science Applications International Corporation PA/SI Sampling (Detected results only)			
R-PA/SI-9-SED	Cliff Drainage Tunnel Outlet	0.10	NA
U.S. Geological Survey Data			
392126120510201 (BY93)	Waukesha South Outlet	NA	0.0002
392111120511301 (BY94)	**Cliff Tunnel Outlet (September 1, 1999)**	**0.409**	0.0015
392111120511301 (BY94)	Cliff Tunnel Outlet (July 30, 2002)	0.02	0.00031
392119120512201 (BY95)	Pit Pond at the Cliff Tunnel Inlet	NA	0.00031
Sediment from the Greenhorn Creek Watershed by field panning method (14 samples)	90 percent concentration	20,000	NA
	75 percent concentration	15,000	NA
	50 percent concentration	1,500	NA
	25 percent concentration	1,000	NA
	10 percent concentration	400	NA
Sediment from the Greenhorn Creek Watershed by lab methods (10 total mercury samples; 9 methyl mercury samples)	90 percent concentration	10,000	0.009
	75 percent concentration	11	0.005
	50 percent concentration	0.18	0.0007
	25 percent concentration	0.007	0.00004
	10 percent concentration	0.005	0.00001

Table 8. Total and Methyl Mercury Concentrations in Solid Matrix Samples Collected from 1999 to 2005

Sample ID		Description	Total Mercury Concentration (mg/kg)	Methyl Mercury Concentration (mg/kg)
Screening Levels				
Concentrations in California background soils[a]		Minimum	0.10	NR
		Maximum	0.90	NR
		Average	0.26	NR
Human Health Screening Benchmarks	EPA Preliminary Remediation Goal (Industrial)[b]		310	NP
	BLM Risk Management Criteria[c]	Camper	40	NP
		Human Worker	60	NP
		Surveyor	480	NP
		ATV Driver	550	NP
Ecological Screening Benchmarks	**EPA Ecotox Threshold[d]**		**0.15**	NP
	BLM Risk Management Criteria[c]	**Robin**	**1**	NP
		Cotton Tail	15	NP
		Mule Deer	9	NP
		Mallard	**4**	NP

Notes: Sources: Science Applications International Corporation 2004; Alpers and others 2005; U.S. Geological Survey (USGS) unpublished data
Bold font indicates analyte in real sample exceeds one or more criteria (criteria exceeded also noted in bold).
Italics font indicates sample was analyzed by method 7471 (not low-level)
Gray shading indicates highest concentration of this constituent measured at Relief Hill

[a] Source: Bradford and others 1996
[b] Source: Smucker 2004
[c] Source: Ford 1996
[d] Source: EPA 1996

ATV All terrain vehicle
BLM U.S. Department of the Interior, Bureau of Land Management
EE/CA Engineering evaluation/cost analysis
EPA U.S. Environmental Protection Agency
ID Identification
mg/kg Milligram per kilogram
NA Not analyzed
NP Not promulgated
NR Not reported
PA/SI Preliminary assessment/site inspection

The leader for sample IDs on Figures 2 and 3 was truncated for readability. "120611" was omitted from Tetra Tech sample IDs and "R-PA/" was omitted from Science Applications International Corporation sample IDs.

Table 9. Total and Methyl Mercury Concentrations in Invertebrate Samples Collected from 1999 to 2002

Common Name	Sample Location	Date	Live Weight (gram)	Moisture (Percent)	Total Mercury (mg/kg)	Methyl Mercury (mg/kg)
Hellgrammite	**Cliff Tunnel Outlet (BY94)**	**9/1/1999**	**0.86**	**80.3**	**NA**	**0.053**
	Background South Yuba River (BY117)[a]	9/30/1999	0.99	78.4	NA	0.031
	Background Bear River (BY199)[b]	9/12/2000	1.52	74.9	0.035	0.038
	Background Bear River (BY199)[b]	9/15/2001	0.61	79.6	0.041	0.040
	Background Bear River (BY199)[b]	9/15/2001	3.48	75.7	0.040	0.029
Water Strider	**Cliff Tunnel Outlet (BY94)**	**9/1/1999**	**0.6**	**58.3**	**NA**	**0.094**
	Pit Pond at the Cliff Tunnel Inlet (BY95)	**9/1/1999**	**1.85**	**55.3**	**0.048**	**0.047**
	Background South Yuba River (BY117)[a]	9/30/1999	1.42	55.2	NA	0.050
	Background Bear River (BY199)[b]	10/1/1999	1.07	57.2	NA	0.027
	Background Bear River (BY199)[b]	9/21/2000	1.3	76.1	0.028	0.027
	Background Bear River (BY199)[b]	9/15/2001	1.3	64.7	0.070	0.050
	Background Bear River (BY199)[b]	8/23/2002	1.4	63.0	0.045	0.041
	South Yuba and Bear River Watersheds[c] (35 samples): 90 percent concentration					0.16
	South Yuba and Bear River Watersheds[c] (35 samples): 75 percent concentration					0.10
	South Yuba and Bear River Watersheds[c] (35 samples): median concentration					0.084
	South Yuba and Bear River Watersheds[c] (35 samples): 25 percent concentration					0.07
	South Yuba and Bear River Watersheds[c] (35 samples): 10 percent concentration					0.05
	Greenhorn Creek Watershed[d] (56 samples): 90 percent concentration					0.027
	Greenhorn Creek Watershed[d] (56 samples): 75 percent concentration					0.018
	Greenhorn Creek Watershed[d] (56 samples): 50 percent concentration					0.011
	Greenhorn Creek Watershed[d] (56 samples): 25 percent concentration					0.009
	Greenhorn Creek Watershed[d] (56 samples): 10 percent concentration					0.007

Notes: Sources: Science Applications International Corporation 2004; Alpers and others 2005; U.S. Geological Survey (USGS) unpublished data

BOLD **Bold** font indicates sample was collected at Relief Hill

Gray shading indicates highest concentration of this constituent for this sample media at Relief Hill

a Sample was collected from a background location at the South Yuba River at Eagle Lakes near Emigrant Gap.

b Sample was collected from a background location at the Bear River at Highway 20 near Emigrant Gap.

Table 9. Total and Methyl Mercury Concentrations in Invertebrate Samples Collected from 1999 to 2002

c	All samples collected from the South Yuba and Bear river watersheds between May and October 1999. Data include samples collected at background locations, on mine sites, and at downstream locations.
d	All samples collected from the Greenhorn Creek watershed during 1999 through 2001. Data include samples collected at background locations, on mine sites, and at downstream locations.
mg/kg	Milligram per kilogram
NA	Not analyzed

Table 10. Long-Term Risk Reduction Goals for Surface Water

Chemical of Potential Concern	Human Health Protection	Unit	Source	Ecological Protection	Unit	Source
Mercury	0.050	µg/L	a	0.77	µg/L	b
Suspended Sediment	*	*	c	*	*	c

Notes:

a U.S. Environmental Protection Agency California Toxics Rule water quality criteria based on total recoverable mercury
b U.S. Environmental Protection Agency ambient water quality criteria based on dissolved mercury
c California Regional Water Quality Control Board, Central Valley Region, Water Quality Control Plan (Basin Plan) for the Sacramento River Basin and the San Joaquin River Basin
* No numeric concentration; solids in surface water should not cause nuisance or adversely affect beneficial uses.
µg/L Microgram per liter

Table 11. Long-Term Risk Reduction Goals for Sediment

Chemical of Potential Concern	Human Health Screening Concentration	Unit	Source	Ecological Screening Concentration	Unit	Source
Mercury	40[a]	mg/kg	[b]	1[c]	mg/kg	[b]

Notes:

a Camper exposure scenario
b U.S. Department of the Interior, Bureau of Land Management (BLM) risk management criteria for metals at BLM mining sites (Ford 1996)
c Robin receptor
mg/kg Milligram per kilogram

Table 12. General Response Actions, Technology Types, and Process Options

General Response Action	Technology Type	Process Options
No Action	None	None
Institutional Controls	Access Restrictions	Fencing/Barrier
		Land Use Control
		Water Use Control
Engineering Controls	Surface Water Controls	Sediment Detention Structure
		Surface Diversion
	Sediment Controls	Grading
		Revegetation
		Road Obliteration
		Erosion and Flood Control
	Sediment Containment	Consolidation
		Earthen Cover
		Sediment Sealing and Earthen Cover
Treatment	Physical/Chemical Treatment of Surface Water	Settling or Filtration

Table 13. Technology Screening Comments Summary

General Response Actions	Technology	Process Options	Description	Screening Comment
No Action	None	Not applicable	No action.	Not applicable.
Institutional Controls	Access Restrictions	Fencing/ Barrier	Install fence around site access points and areas susceptible to erosion.	Partially effective. Vandalism and penetration of the barriers is likely. May facilitate natural revegetation in the long term, but short-term improvements in sediment stability are minimal. Potentially effective in conjunction with other technologies. Readily implementable.
		Land Use Control	Implement restrictions to control current and future land use.	Partially effective. Use of the site could be limited through policy measures such as zoning or special land allocation. Physical restriction measures may not be feasible due to access rights of existing private property and mining interests. Establishment and implementation of policy measures might require increased on-site enforcement. Potentially effective in conjunction with other technologies. Policy measures are readily implementable.
		Water Use Control	Implement restrictions to control current and future water use.	Partially effective for on-site waters; however, beneficial uses of off-site water cannot be readily changed. Not readily implementable.
Engineering Controls	On-Site Surface Water Controls	Sediment Detention Structure	Install sediment detention basins or check dams to capture mobile sediment discharged from ponds, ground sluices, and drain tunnels.	Very effective for capturing mobile sediment and reducing downstream entrainment of sediment (reduces velocity). Readily implementable.
		Surface Diversion	Install surface drains or ditches to capture and divert run-on and run-off around areas susceptible to erosion.	Very effective for bypassing surface flows around areas susceptible to erosion. Readily implementable.
		Tunnel Plugging	Install plugs at drain tunnel inlets and/or outlets to minimize surface water flow through the tunnels.	Very effective for minimizing the release of sediment from tunnel networks. Creates dramatic and unknown effects on site hydrology. May create large ponds that methylate mercury and negatively affect private property and existing mining interests. Readily implementable but more challenging to construct than other engineering controls.
	On-Site Sediment Controls	Selective Grading	Grade selected areas to reduce gradients in drainages (reducing surface run off energy) and eliminate steep surfaces susceptible to erosion (such as sluice walls).	Very effective for reducing sediment mobility. Grading would leave bare ground that would require stabilization measures. Would also require soil stabilization measures. Readily implementable.

Table 13. Technology Screening Comments Summary

General Response Actions	Technology	Process Options	Description	Screening Comment
Engineering Controls (Continued)	On-Site Sediment Controls (Continued)	Site-wide Grading	Grade the entire area disturbed by hydraulic mining to reduce surface runoff energy and eliminate steep surfaces susceptible to erosion.	Very effective for reducing sediment mobility. Grading would leave bare ground that would require stabilization measures. Would also require soil stabilization measures. Would provide similar protection as selective grading at a higher construction, revegetation, and maintenance costs. Readily implementable.
		Revegetation	Add amendments to disturbed areas and seed with appropriate vegetative species to establish an erosion-resistant ground surface.	Very effective for stabilizing bare soil in many areas on site that are currently susceptible to erosion. Would also require measures to minimize sediment transport in areas where revegetation is not practical, such as existing sluice and drainage systems where vegetation may be washed away or buried. Readily implementable.
		Road Obliteration	Obliterate existing dirt roads on site by ripping the surfaces and placing obstructions (such as boulders) to prevent future road use.	Very effective for minimizing large vehicle traffic on site, which compacts soil, inhibits growth of soil-stabilizing vegetation, and generates dust that may be mobilized in storm water runoff. Only applies to a small portion of the site and would require additional process options that address other portions of the site. The roads that provide vehicular access to the site are on private property or support current mining on site; access for private interests cannot be compromised. Readily implementable.
		Erosion and Flood Control	Install drainage ditches and sediment detention basins to manage surface water run on, infiltration, run off, erosion, and off-site sediment transport. (Equivalent to surface water controls described above.)	Very effective for capturing mobile sediment, reducing downstream entrainment of sediment (reduces velocity), and bypassing surface flows around areas susceptible to erosion. Readily implementable.
	Sediment Containment	Consolidation	Excavate geologic materials susceptible to erosion place them in an on-site repository. Sediment in drain tunnels may be classified as a hazardous or designated waste, and require special handling and disposal.	Partially effective. Excavation of sediment in ground sluices, pit lakes, wetlands, and drain tunnels may expose mercury that has accumulated at the base of the sediment, potentially leading to a release of mercury from the site. Excavation of sluice walls and pit high walls susceptible to erosion would leave bare ground that would require stabilization measures. Readily implementable.
		Earthen Cover	Fill ground sluices with soil and establish vegetative cover to stabilize the surface. Similar to, but less encompassing than the grading process options discussed above.	Partially effective. Sediment erosion would be reduced. Not applicable for features that retain water for much of the year (pit lakes, wetlands, and drain tunnels). Would also require soil stabilization measures in covered areas. Readily implementable.

Table 13. Technology Screening Comments Summary

General Response Actions	Technology	Process Options	Description	Screening Comment
Engineering Controls (Continued)	Sediment Containment (Continued)	Sediment Sealing and Earthen Cover	Seal sediment in ground sluices in place, then fill ground sluices with soil and establish vegetative cover to stabilize the surface.	Partially effective. Sediment erosion would be reduced. Not applicable for features that retain water for much of the year (pit lakes, wetlands, and drain tunnels). Would also require soil stabilization measures in covered areas. Anticipated to provide equal protectiveness to the earthen cover process option but at a higher cost. Readily implementable.
Treatment	Physical/ Chemical Treatment of Surface Water	Settling or Filtration	Construct an on-site treatment facility that separates suspended solids from storm water flows with a settling basin or fine sand filter.	Moderately effective at fine sediment removal. Effectiveness is also questionable given variability in dosage required to address changing influent flow rates during storm events. Greater long-term operation and maintenance commitment than engineering controls discussed above. Process is not readily implementable because of the lack of electrical infrastructure.

Note: Eliminated alternatives are shaded.

Table 14. Removal Action Alternatives Summary

Alternative Number	Alternative Description
Alternative 1	No Action
Alternative 2	Land Use Controls and Access Restrictions *Identify land use consistent with allocation of the area as a riparian conservation area. Prevent land use that could lead to mobilization of sediment through access restriction after termination of the existing mine's plan of operations. Access for private property and existing mining interests must not be compromised.*
Alternative 3	Selective Engineering Controls, Land Use Controls, and Access Restrictions *Divide site into watershed units roughly corresponding to sluice systems. Within each watershed unit, implement surface water runon/runoff controls, sediment detention structures, erosion controls, and revegetation to minimize migration of sediment off site. Identify land use consistent with allocation of the area as a riparian conservation area. Prevent land use that could lead to mobilization of sediment through access restriction after termination of the existing mine's plan of operations. Access for private property and existing mining interests must not be compromised.*
Alternative 3a	Selective Engineering Controls including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions *In addition to Alternative 3 engineering controls, check dams will be constructed within open and accessible sluice tunnel inlets to provide additional sediment retention capacity.*

Table 15. Cost Estimate for Alternative 2: Land Use Controls and Access Restrictions

Cost Item	Quantity	Unit	Unit Cost	Unit MH Cost	Unit Equipment Cost	Unit Material Cost	Cost
Item 1: Designation as a Riparian Conservation Area							*
Item 2: Assume Control of the Access Gate							*
Item 3: Equipment Mobilization/Demobilization							**$ 590**
Job Trucks	2	EA	$95	$0	$95	$0.00	$ 190
Bobcat	1	EA	$400	$0	$750	$0.00	$ 400
Item 4: Sign Placement for Access Restriction						**$**	**5,100**
Sign, Wooden 4x4 pole	30	EA	$70	$0	$0	$ 71	$ 2,100
Sign Placement	30	MH	$100	$65	$35	$ -	$ 3,000
Subtotal Construction Costs							**$ 6,000**
Construction Contingencies	Percent of Construction Costs		25%	*(15% bid + 10% scope contingencies)*			**$ 1,500**
Project Management						**$**	**2,100**
Construction Contractor Project Management	20	MH	$105	$105	$0	$0.00	$ 2,100
Construction Management						**$**	**2,000**
Health and Safety Oversight - CIH	3	MH	$120	$120	$0	$0.00	$ 360
Engineering Oversight	16	MH	$75	$75	$0	$0.00	$ 1,200
Per Diem and Vehicle for Oversight Personnnel	2	Day	$214	$214	$0	$0.00	$ 428
Bonding and Insurance	**4% of Construction Cost**						**$ 200**
TOTAL CAPITAL COSTS							**$ 11,800**
Site Maintenance						**$**	**64,400**
Present Worth of O&M Costs Based on 30 Year Life and 3.0% Discount Rate							
Replace 7 Signs Every 5 Years	35	EA	$170				$ 4,100
Repair Gate Every 5 Years (beginning Year 5)	6	EA	$1,000				$ 3,400
Annual Site Inspections	30	EA	$1,000				$ 18,400
Post-Removal Sampling (During Inspections)	30	EA	$1,000				$ 9,200
Forest Service Project Management	328	MH	$80				$ 16,400
O&M Contingencies	Percent of O&M Costs		25%	*(15% bid + 10% scope contingencies)*			$ 12,900
TOTAL PRESENT WORTH							**$ 76,000**

Notes:

Costs were prepared in accordance with U.S. Enviromental Protection Agency (2000) guidelines and are based on engineers estimates, historical costs for similar projects, and vendor quotes. In accordance with EPA guidance (EPA 1993, 2000), these engineering costs are estimates that are expected to be within plus 50 to minus 30 percent of the actual project cost (based on year 2006 dollars). ***As a result, cost range for Alternative 2 is approximately $53,000 to $114,000.***

Construction costs include environmental prime contractor markup of 18% and environmetal prime contractor oversight and project management.

*	Internal or administrative costs to the Forest Service were not included in the calculation.
%	Percent
EA	Each
LS	Lump sum
MH	Man hour
O&M	Operation and maintenance
OHV	Off-highway vehicle

Table 16. Cost Estimate for Alternative 3: Selective Engineering Controls, Land Use Controls, and Access Restrictions

Cost Item	Quantity	Unit	Unit Cost	Unit MH Cost	Unit Equipment Cost	Unit Material Cost	Cost
Item 1: Designation as a Riparian Conservation Area							*
Item 2: Assume Control of the Access Gate							*
Item 3: Equipment Mobilization/Demobilization							**$ 4,480.00**
Job Trucks	4	EA	$95	$0.00	$95	$0.00	$ 380
Excavator	1	EA	$750	$0.00	$750	$0.00	$ 750
Shed	1	EA	$500	$0.00	$500	$0.00	$ 500
ATV	2	EA	$500	$0.00	$500	$0.00	$ 1,000
Generator	1	EA	$200	$0.00	$200	$0.00	$ 200
Fire Suppression Equipment	1	EA	$500	$0.00	$500	$0.00	$ 500
Office Trailer	1	EA	$200	$0.00	$200	$0.00	$ 200
Water Truck	1	EA	$200	$0.00	$200	$0.00	$ 200
Backhoe	1	EA	$750	$0.00	$750	$0.00	$ 750
Item 4: Sign Placement for Access Restriction					**$**		**5,100**
Sign, Wooden 4x4 pole	30	EA	$70	$0.00	$0.00	$ 71	$ 2,100
Sign Placement	30	MH	$100	$64.90	$35.40	$ -	$ 3,000
Item 5: Build 7-foot Dam to Create WTI-1 Sediment Detention Basin					**$**		**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 6: Vegetate WTI-1 Sediment Detention Basin					**$**		**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 7: Build 7-foot Dam to Create WTI-2 Sediment Detention Basin					**$**		**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 8: Vegetate WTI-2 Sediment Detention Basin					**$**		**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 9: Build 7-foot Dam to Create WTI-3 West Fork Sediment Detention Basin					**$**		**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 10: Vegetate WTI-3 West Fork Sediment Detention Basin					**$**		**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 11: Build 7-foot Dam to Create WTI-3 Sediment Detention Basin					**$**		**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 12: Vegetate WTI-3 Sediment Detention Basin					**$**		**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 13: Build 7-foot Dam to Create S-WTI-1 West Fork Sediment Detention Basin					**$**		**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 14: Vegetate S-WTI-1 West Fork Sediment Detention Basin					**$**		**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 15: Build 7-foot Dam to Create S-WTI-3 West Fork Sediment Detention Basin					**$**		**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 16: Vegetate S-WTI-3 West Fork Sediment Detention Basin					**$**		**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 17: Construct a Rock Armored Spillway at the South Fork of S-NTI-1					**$**		**5,000**
Rock Armor Spillway	1	EA	$5,000		$0.00	$ 5,000	$ 5,000
Item 18: Construct a Rock Armored Spillway at S-NTI-2					**$**		**5,000**
Rock Armor Spillway	1	EA	$5,000		$0.00	$ 5,000	$ 5,000
Item 19: Improve 900 Feet of Existing OHV Trail for New Sluice System					**$**		**7,009**
Improve Existing OHV Trail	900	LF	$8	$0.00	$7.79	$ -	$ 7,009

Table 16. Cost Estimate for Alternative 3: Selective Engineering Controls, Land Use Controls, and Access Restrictions

Cost Item	Quantity	Unit	Unit Cost	Unit MH Cost	Unit Equipment Cost	Unit Material Cost	Cost
Item 20: Reclaim 900 Feet of OHV Trail for New Sluice System						$	**7,009**
Improve Existing OHV Trail	900	LF	$8	$0.00	$7.79	$ -	$ 7,009
Item 21: Build 7-foot Dam to Create CTI-1 Sediment Detention Basin						$	**6,500**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 22: Vegetate CTI-1 Sediment Detention Basin						$	**10,450**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 23: Improve 500 Feet of Existing OHV Trail for Cliff Sluice System						$	**3,900**
Improve Existing OHV Trail	500	LF	$8	$0.00	$7.79	$ -	$ 3,900
Item 24: Reclaim 500 Feet of OHV Trail						$	**3,600**
Reclaim Improved Road after 3rd year reseeding at 3.0% discount rate	500	LF	$8	$0.00	$7.79	$ -	$ 3,600
Subtotal Construction Costs							**$ 160,000**
Construction Contingencies	Percent of Construction Costs		25%	*(15% bid + 10% scope contingencies)*			**$ 40,000**
Project Management						$	**6,300**
Construction Contractor Project Management	60	MH	$105	$105.00	$0.00	$0.00	$ 6,300
Construction Management						$	**34,300**
Health and Safety Oversight - CIH	27	MH	$120	$120.00	$0.00	$0.00	$ 3,300
Health and Safety Oversight - General	99	MH	$75	$75.00	$0.00	$0.00	$ 7,400
Engineering Oversight	99	MH	$75	$75.00	$0.00	$0.00	$ 7,400
Site Security Officer	73	Day	$150	$150.00	$0.00	$0.00	$ 11,000
Per Diem and Vehicle for Oversight Personnnel	24	Day	$214	$214.00	$0.00	$0.00	$ 5,200
Design							**$ 21,500**
Contingency	1	LS	$3,000	$0.00	$0.00	$3,000.00	$ 3,000
Project Work Plan	1	LS	$7,500	$0.00	$0.00	$7,500.00	$ 7,500
Completion Report	1	LS	$11,000	$0.00	$0.00	$11,000.00	$ 11,000
Bonding and Insurance	**4% of Construction Cost**						**$ 6,400**
TOTAL CAPITAL COSTS							**$ 268,500**
Item 25: Site Maintenance						$	**121,400**
Present Worth of O&M Costs Based on 30 Year Life and 3.0% Discount Rate							
Replace 7 Signs Every 5 Years	35	EA	$170				$ 4,400
Repair Gate Every 5 Years (beginning Year 5)	6	EA	$1,000				$ 3,700
Cleanout Sedimentation Basins First 3 Years and Every 5 Years beginning Year 5	8	EA	$8,500				$ 42,400
Annual Site Inspections	30	EA	$1,000				$ 19,600
Post-Removal Sampling (During Inspections)	30	EA	$1,000				$ 9,600
Forest Service Project Management	328	MH	$80				$ 17,400
O&M Contingencies	Percent of O&M Costs		25%	*(15% bid + 10% scope contingencies)*			$ 24,300
TOTAL PRESENT WORTH							**$ 390,000**

Notes:

Costs were prepared in accordance with U.S. Enviromental Protection Agency (2000) guidelines and are based on engineers estimates, historical costs for similar projects, and vendor quotes. In accordance with EPA guidance (EPA 1993, 2000), these engineering costs are estimates that are expected to be within plus 50 to minus 30 percent of the actual project cost (based on year 2006 dollars). ***As a result, cost range for Alternative 3 is approximately $273,000 to $585,000.***

Construction costs include environmental prime contractor markup of 18% and environmetal prime contractor oversight and project management.

* Internal or administrative costs to the Forest Service were not included in the calculation.

% Percent

AC Acre

EA Each

LS Lump sum

MH Man hour

O&M Operation and maintenance

OHV Off-highway vehicle

Table 17. Cost Estimate for Alternative 3a: Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions

Cost Item	Quantity	Unit	Unit Cost	Unit MH Cost	Unit Equipment Cost	Unit Material Cost	Cost
Item 1: Designation as a Riparian Conservation Area							*
Item 2: Assume Control of the Access Gate							*
Item 3: Equipment Mobilization/Demobilization							**$ 4,480.00**
Job Trucks	4	EA	$95	$0.00	$95	$0.00	$ 380
Excavator	1	EA	$750	$0.00	$750	$0.00	$ 750
Shed	1	EA	$500	$0.00	$500	$0.00	$ 500
ATV	2	EA	$500	$0.00	$500	$0.00	$ 1,000
Generator	1	EA	$200	$0.00	$200	$0.00	$ 200
Fire Suppression Equipment	1	EA	$500	$0.00	$500	$0.00	$ 500
Office Trailer	1	EA	$200	$0.00	$200	$0.00	$ 200
Water Truck	1	EA	$200	$0.00	$200	$0.00	$ 200
Backhoe	1	EA	$750	$0.00	$750	$0.00	$ 750
Item 4: Sign Placement for Access Restriction					**$**		**5,100**
Sign, Wooden 4x4 pole	30	EA	$70	$0.00	$0.00	71	$ 2,100
Sign Placement	30	MH	$100	$64.90	$35.40	-	$ 3,000
Item 5: Build 7-foot Dam to Create WTI-1 Sediment Detention Basin					**$**		**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	6,500	$ 6,500
Item 6: Vegetate WTI-1 Sediment Detention Basin					**$**		**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	-	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Item 7: Build 7-foot Dam to Create WTI-2 Sediment Detention Basin					**$**		**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	6,500	$ 6,500
Item 8: Vegetate WTI-2 Sediment Detention Basin					**$**		**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	-	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Item 9: Build 7-foot Dam to Create WTI-3 West Fork Sediment Detention Basin					**$**		**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	6,500	$ 6,500
Item 10: Vegetate WTI-3 West Fork Sediment Detention Basin					**$**		**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	-	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Item 11: Build 7-foot Dam to Create WTI-3 Sediment Detention Basin					**$**		**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	6,500	$ 6,500
Item 12: Vegetate WTI-3 Sediment Detention Basin					**$**		**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	-	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Item 13: Build 7-foot Dam to Create S-WTI-1 West Fork Sediment Detention Basin					**$**		**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	6,500	$ 6,500
Item 14: Vegetate S-WTI-1 West Fork Sediment Detention Basin					**$**		**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	-	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Item 15: Build 7-foot Dam to Create S-WTI-3 West Fork Sediment Detention Basin					**$**		**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	6,500	$ 6,500
Item 16: Vegetate S-WTI-3 West Fork Sediment Detention Basin					**$**		**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	-	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	-	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	-	$ 700
Item 17: Construct 3 Check Dams Above N-MTI-4					**$**		**7,500**
Construct 3 Check Dams	3	LS	$3,000	$0.00	$0.00	3,000	$ 9,000

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Table 17. Cost Estimate for Alternative 3a: Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions

Cost Item	Quantity	Unit	Unit Cost	Unit MH Cost	Unit Equipment Cost	Unit Material Cost	Cost
Item 18: Vegetate above N-MTI-4 Check Dams						**$**	**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 19: Construct 3 Check Dams Above N-NTI-1						**$**	**7,500**
Construct 3 Check Dams	3	EA	$3,000	$0.00	$0.00	$ 3,000	$ 9,000
Item 20: Vegetate Area Above N-NTI-1 Check Dams						**$**	**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 21: Construct a Rock Armored Spillway at the South Fork of S-NTI-1						**$**	**4,950**
Rock Armor Spillway	1	EA	$5,000		$0.00	$ 5,000	$ 5,000
Item 22: Construct a Rock Armored Spillway at S-NTI-2						**$**	**4,950**
Rock Armor Spillway	1	EA	$5,000		$0.00	$ 5,000	$ 5,000
Item 23: Improve 900 Feet of Existing OHV Trail for New Sluice System						**$**	**7,009**
Improve Existing OHV Trail	900	LF	$8	$0.00	$7.79	$ -	$ 7,009
Item 24: Reclaim 900 Feet of OHV Trail for New Sluice System						**$**	**7,009**
Improve Existing OHV Trail	900	LF	$8	$0.00	$7.79	$ -	$ 7,009
Item 25: Construct 3 Check Dams Above CTI-4						**$**	**7,500**
Construct 3 Check Dams	3	EA	$3,000	$0.00	$0.00	$ 3,000	$ 9,000
Item 26: Vegetate above CTI-4 Check Dams						**$**	**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 27: Construct 3 Check Dams Above CTI-5						**$**	**7,500**
Construct 3 Check Dams	3	EA	$3,000	$0.00	$0.00	$ 3,000	$ 9,000
Item 28: Vegetate above CTI-5 Check Dams						**$**	**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 29: Build 7-foot Dam to Create CTI-1 Sediment Detention Basin						**$**	**6,000**
Construct Dam	1	EA	$6,500	$0.00	$0.00	$ 6,500	$ 6,500
Item 30: Vegetate CTI-1 Sediment Detention Basin						**$**	**11,850**
Hydroseed Sediment Detention Basin and Berm	0.5	AC	$10,000	$0.00	$10,000	$ -	$ 5,000
Wattles	300	LF	$2.50	$1.25	$0	$ 1.25	$ 750
Year 2 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,400
Year 2 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Year 3 Reseed at 3.0 % Discount Rate	0.25	AC	$10,000	$0.00	$10,000	$ -	$ 2,300
Year 3 Sedimentation Basin Cleanout at 3.0 % Discount	1.00	LS	$750	$0.00	$750	$ -	$ 700
Item 31: Improve 500 Feet of Existing OHV Trail for Cliff Sluice System						**$**	**3,900**
Improve Existing OHV Trail	500	LF	$8	$0.00	$7.79	$ -	$ 3,900
Item 32: Reclaim 500 Feet of OHV Trail						**$**	**3,600**
Reclaim Improved Road after 3rd year reseeding at 3.0% discount rate	500	LF	$8	$0.00	$7.79	$ -	$ 3,600
Subtotal Construction Costs							**$ 243,000**
Construction Contingencies	Percent of Construction Costs		25%	*(15% bid + 10% scope contingencies)*			**$ 60,800**
Project Management						**$**	**8,400**
Construction Contractor Project Management	80	MH	$105	$105.00	$0.00	$0.00	$ 8,400
Construction Management						**$**	**48,100**
Health and Safety Oversight - CIH	38	MH	$120	$120.00	$0.00	$0.00	$ 4,600
Health and Safety Oversight - General	138	MH	$75	$75.00	$0.00	$0.00	$ 10,300
Engineering Oversight	138	MH	$75	$75.00	$0.00	$0.00	$ 10,300
Site Security Officer	104	Day	$150	$150.00	$0.00	$0.00	$ 15,600
Per Diem and Vehicle for Oversight Personnnel	34	Day	$214	$214.00	$0.00	$0.00	$ 7,300
Design							**$ 21,500**
Contingency	1	LS	$3,000	$0.00	$0.00	$3,000.00	$ 3,000
Project Work Plan	1	LS	$7,500	$0.00	$0.00	$7,500.00	$ 7,500
Completion Report	1	LS	$11,000	$0.00	$0.00	$11,000.00	$ 11,000
Bonding and Insurance	**4% of Construction Cost**						**$ 9,700**
TOTAL CAPITAL COSTS							**$ 391,500**
Item 33: Site Maintenance						**$**	**137,600**
Present Worth of O&M Costs Based on 30 Year Life and 3.0% Discount Rate							
Replace 7 Signs Every 5 Years	35	EA	$170				$ 4,400
Repair Gate Every 5 Years (beginning Year 5)	6	EA	$1,000				$ 3,700
Cleanout Sedimentation Basins First 3 Years and Every 5 Years beginning Year 5	9	EA	$8,500				$ 55,400
Annual Site Inspections	30	EA	$1,000				$ 19,600
Post-Removal Sampling (During Inspections)	30	EA	$1,000				$ 9,600
Forest Service Project Management	328	MH	$80				$ 17,400
O&M Contingencies	Percent of O&M Costs		25%	*(15% bid + 10% scope contingencies)*			$ 27,500
TOTAL PRESENT WORTH							**$ 529,000**

Table 17. Cost Estimate for Alternative 3a: Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions

Cost Item	Quantity	Unit	Unit Cost	Unit MH Cost	Unit Equipment Cost	Unit Material Cost	Cost

Notes:

Costs were prepared in accordance with U.S. Enviromental Protection Agency (2000) guidelines and are based on engineers estimates, historical costs for similar projects, and vendor quotes. In accordance with EPA guidance (EPA 1993, 2000), these engineering costs are estimates that are expected to be within plus 50 to minus 30 percent of the actual project cost (based on year 2006 dollars). **As a result, cost range for Alternative 3a is approximately $370,000 to $794,000.**

Construction costs include environmental prime contractor markup of 18% and environmetal prime contractor oversight and project management.

*	Internal or administrative costs to the Forest Service were not included in the calculation.
%	Percent
AC	Acre
EA	Each
LS	Lump sum
MH	Man hour
O&M	Operation and maintenance
OHV	Off-highway vehicle

Table 18. Comparative Analysis of Alternatives

Assessment Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls and Access Restrictions	Alternative 3 Selective Engineering Controls, Land Use Controls, and Access Restrictions	Alternative 3a Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions
Overall Protectiveness				
Public Health, Safety, and Welfare	No reduction in risk.	Reduces sediment and mercury concentrations in on-site surface water and in the heavily used South Yuba River downstream from the site. The release of sediment and particulate-bound mercury would be addressed by limiting human activity in areas susceptible to erosion. Limits site uses (such as OHV use), which reduces potential exposure of site visitors to residual mercury. Provides a lower level of protection than Alternatives 3 and 3a because this alternative does not address sediment once it has become mobile in surface runoff.	Reduces sediment and mercury concentrations in on-site surface water and in the heavily used South Yuba River downstream from the site. The release of sediment and particulate-bound mercury would be addressed by stabilizing material susceptible to erosion, capturing sediment that has been mobilized in storm water runoff, and limiting human activity in areas susceptible to erosion. Limits site uses (such as OHV use), which reduces potential exposure of site visitors to residual mercury. Provides overall protection greater than Alternative 2. Overall protection is slightly lower than Alternative 3a because Alternative 3a includes additional sediment capture measures.	Reduces sediment and mercury concentrations in on-site surface water and in the heavily used South Yuba River downstream from the site. The release of sediment and particulate-bound mercury would be addressed by stabilizing material susceptible to erosion, capturing sediment that has been mobilized in storm water runoff, and limiting human activity in areas susceptible to erosion. Limits site uses (such as OHV use), which reduces potential exposure of site visitors to residual mercury. Provides overall protection greater than Alternatives 2 and 3.
Environmental Protectiveness	No protection offered.	Reduces off-site transport of sediment and particulate-bound mercury by limiting human activity in areas susceptible to erosion. Site uses would be managed in order to maintain desirable riparian conditions. Provides a lower level of protection than Alternatives 3 and 3a because this alternative does not address sediment once it has become mobile in surface runoff.	Reduces off-site transport of sediment and particulate-bound mercury by stabilizing material susceptible to erosion, capturing sediment that has been mobilized in storm water runoff, and limiting human activity in areas susceptible to erosion. Provides overall protection greater than Alternative 2. Overall protection is slightly lower than Alternative 3a because Alternative 3a includes additional sediment capture measures.	Reduces off-site transport of sediment and particulate-bound mercury by stabilizing material susceptible to erosion, capturing sediment that has been mobilized in storm water runoff, and limiting human activity in areas susceptible to erosion. Provides overall protection greater than Alternatives 2 and 3.
Overall Protectiveness Rating	Unacceptable	Acceptable	Good	Very Good
Compliance with ARARs				
Chemical-Specific	None apply.	Chemical-specific ARARs may be met. Meeting chemical-specific ARARs is less certain than with Alternatives 3 and 3a because this alternative does not address sediment once it has become mobile in surface runoff.	Chemical-specific ARARs would be met.	Chemical-specific ARARs would be met.
Location-Specific	None apply.	Location-specific ARARs may not be met because stream banks and beds may continue to be eroded due topographic and drainage features created by historical hydraulic mining.	Location-specific ARARs would be met.	Location-specific ARARs would be met.
Action-Specific	None apply.	Action-specific ARARs would be met.	Action-specific ARARs would be met.	Action-specific ARARs would be met.
Compliance with ARARs Rating	Not applicable	Acceptable	Very Good	Very Good
Long-Term Effectiveness and Permanence				
Magnitude of Residual Risk	No reduction in erosion and off-site transport of sediment and particulate-bound mercury.	Reduction in mobilization of sediment and particulate-bound mercury. Limited reduction in off-site transport of contaminants; impact of release to watershed might be reduced but would not be eliminated.	Reduction in mobilization and off-site transport of sediment and particulate-bound mercury. Mercury potentially remaining at the base of ground sluices, pit lakes, and wetlands would be further entombed beneath mobilized sediment that settles on site.	Reduction in mobilization and off-site transport of sediment and particulate-bound mercury. Mercury potentially remaining at the base of ground sluices, pit lakes, wetlands, and sluice tunnels would be further entombed beneath mobilized sediment that settles on site.
Adequacy and Reliability of Controls	No controls implemented; no reliability.	Access restrictions could effectively reduce vehicle traffic in areas susceptible to erosion. Would require a presence on site by enforcement staff to prevent unauthorized uses. On-site maintenance is expected to be minimal.	Would continue to minimize the off-site transport of sediment and particulate-bound mercury indefinitely as long as the engineering controls are adequately maintained. Rock-lined channels and sediment detention basins would require periodic inspection; debris removal may also occasionally be necessary to ensure proper flow. Periodic inspections would be needed to prevent recreational users from developing trails again. Would require a presence on site by enforcement staff to prevent unauthorized uses.	Would continue to minimize the off-site transport of sediment and particulate-bound mercury indefinitely as long as the engineering controls are adequately maintained. Rock-lined channels, sediment detention basins, and check dams would require periodic inspection; debris removal may also occasionally be necessary to ensure proper flow. Periodic inspections would be needed to prevent recreational users from developing trails again. Would require a presence on site by enforcement staff to prevent unauthorized uses.
Long Term Effectiveness and Permanence Rating	Acceptable	Acceptable	Good	Very Good

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Attachment 7 - CABY Mercury Initiative References 3 of 3

Table 18. Comparative Analysis of Alternatives

Assessment Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls and Access Restrictions	Alternative 3 Selective Engineering Controls, Land Use Controls, and Access Restrictions	Alternative 3a Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions
Reduction of Toxicity, Mobility, and Volume through Treatment				
Treatment Process Used and Materials Treated	None.	None.	None.	None.
Volume of Contaminated Materials Treated	None.	None.	None.	None.
Expected Degree of Reduction	None.	Mobility of sediment and particulate-bound mercury would be reduced, but to a lesser degree than Alternatives 3 and 3a. No change in the toxicity or volume of contaminants.	Mobility of sediment and particulate-bound mercury would be reduced. No change in the toxicity or volume of contaminants.	Mobility of sediment and particulate-bound mercury would be reduced to a greater degree than Alternative 3. No change in the toxicity or volume of contaminants.
Reduction of Toxicity, Mobility and Volume through Treatment Rating	Unacceptable	Unacceptable	Acceptable	Good
Short-Term Effectiveness				
Protection of Community During Remediation	Not applicable.	Fugitive dust emissions control may be required during construction. Increased truck traffic may be a concern during transport of construction material to treatment areas.	Fugitive dust emissions control may be required during construction. Increased truck traffic may be a concern during transport of construction material to treatment areas.	Fugitive dust emissions control may be required during construction. Increased truck traffic may be a concern during transport of construction material to treatment areas.
Protection of On-Site Workers During Remediation	Not applicable.	Expected to be sufficient. On-site workers must be adequately protected by using appropriate personal protective equipment and by following proper operating and safety procedures.	Expected to be sufficient. On-site workers must be adequately protected by using appropriate personal protective equipment and by following proper operating and safety procedures.	Expected to be sufficient. On-site workers must be adequately protected by using appropriate personal protective equipment and by following proper operating and safety procedures.
Time Until Preliminary Remediation Measure Objectives are Achieved	Not applicable.	Meets surface water PRMOs after implementation of physical measures (such as road obliteration) and establishment and effective enforcement of land use policies. Growth of soil-stabilizing vegetation would take years in areas that are not revegetated as part of the removal action.	Meets surface water PRMOs after construction of erosion and sediment controls, revegetation, and establishment and effective enforcement of land use policies. Would achieve goals in a shorter timeframe than Alternative 2 because the majority of areas susceptible to erosion would be revegetated during construction.	Meets surface water PRMOs after construction of erosion and sediment controls, revegetation, and establishment and effective enforcement of land use policies. Would achieve goals in a shorter timeframe than Alternative 2 because the majority of areas susceptible to erosion would be revegetated during construction.
Short Term Effectiveness Rating	Unacceptable	Unacceptable	Good	Good
Implementability				
Ability to Construct and Operate	No construction or operation involved.	The "Framework" (Forest Service 2004) authorizes the Forest Service to establish RCAs on public lands it administers. RCA establishment is considered an administrative task to be completed by the Forest Service.	The "Framework" (Forest Service 2004) authorizes the Forest Service to establish RCAs on public lands it administers. RCA establishment is considered an administrative task to be completed by the Forest Service. Constructing erosion and sediment controls, obliterating dirt roads, and revegetating bare areas on site would require the services of a contractor experienced in the proper construction procedures. Existing roads to the site may limit access by large construction and transport vehicles.	The "Framework" (Forest Service 2004) authorizes the Forest Service to establish RCAs on public lands it administers. RCA establishment is considered an administrative task to be completed by the Forest Service. Constructing erosion and sediment controls, obliterating dirt roads, and revegetating bare areas on site would require the services of a contractor experienced in the proper construction procedures. Existing roads to the site may limit access by large construction and transport vehicles.
Ease of Implementing More Action if Necessary	This measure does not inhibit implementation of other actions.	Implementation of future measures would be controlled by policy rather than physical conditions at the site. Future actions would have to meet goals and objectives for RCAs as defined by the "Framework" (Forest Service 2004).	Implementation of future measures would be controlled more by policy than by physical conditions at the site. Future actions would have to meet goals and objectives for RCAs as defined by the "Framework" (Forest Service 2004). Physical conditions on site after the removal action would not significantly change the ease of implementing future measures from current conditions.	Implementation of future measures would be controlled more by policy than by physical conditions at the site. Future actions would have to meet goals and objectives for RCAs as defined by the "Framework" (Forest Service 2004). Physical conditions on site after the removal action would not significantly change the ease of implementing future measures from current conditions.
Availability of Services and Capacities	Not applicable.	Establishment of RCAs requires designation by a Forest Service hydrologist and would depend entirely on staff availability. Construction services are available locally and within the state. Enforcement of land allocation policies would depend entirely on Forest Service enforcement staff availability.	Establishment of RCAs requires designation by a Forest Service hydrologist and would depend entirely on staff availability. Construction services are available locally and within the state. Enforcement of land allocation policies would depend entirely on Forest Service enforcement staff availability.	Establishment of RCAs requires designation by a Forest Service hydrologist and would depend entirely on staff availability. Construction services are available locally and within the state. Enforcement of land allocation policies would depend entirely on Forest Service enforcement staff availability.
Availability of Equipment and Materials	Not applicable.	Available locally and within the state.	Available locally and within the state.	Available locally and within the state.

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Attachment 7 - CABY Mercury Initiative References 3 of 3

Table 18. Comparative Analysis of Alternatives

Assessment Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls and Access Restrictions	Alternative 3 Selective Engineering Controls, Land Use Controls, and Access Restrictions	Alternative 3a Selective Engineering Controls Including Check Dams in Open Sluice Tunnels, Land Use Controls, and Access Restrictions
Implementability (Continued)				
Estimated Present Worth Cost with 30 Years of Operation and Maintenance[a]	$0	$76,000 ($53,000-$114,000)[b]	$390,000 ($273,000-$585,000)[b]	$529,000 ($370,000-$794,000)[b]
Implementability Rating	Good	Good	Good	Good
Overall Rating	**Unacceptable**	**Acceptable**	**Good**	**Very Good**

Notes: Source: Forest Service 2004. "Sierra Nevada Forest Plan Amendment, Final Supplemental Environmental Impact Statement, Record of Decision." January.

a Does not include internal Forest Service costs for RCA establishment and land use control enforcement

b Costs were prepared in accordance with U.S. Environmental Protection Agency (2000) guidelines and are based on engineers estimates, historical costs for similar projects, and vendor quotes. In accordance with EPA guidance (EPA 1993, 2000), these engineering costs are estimates that are expected to be within plus 50 to minus 30 percent of the actual project cost, shown in parentheses below the cost estimate (based on year 2006 dollars).

ARAR Applicable or relevant and appropriate requirement
Forest Service U.S. Department of Agriculture Forest Service
OHV Off-highway vehicle
PRMO Preliminary remediation measure objective
RCA Riparian conservation area

Rating Scale:

Unacceptable…Acceptable…Good…Very Good…Excellent

APPENDIX A
SITE PHOTOGRAPHS
(Presented in Hard Copy and on Compact Disc)

Photograph A-1

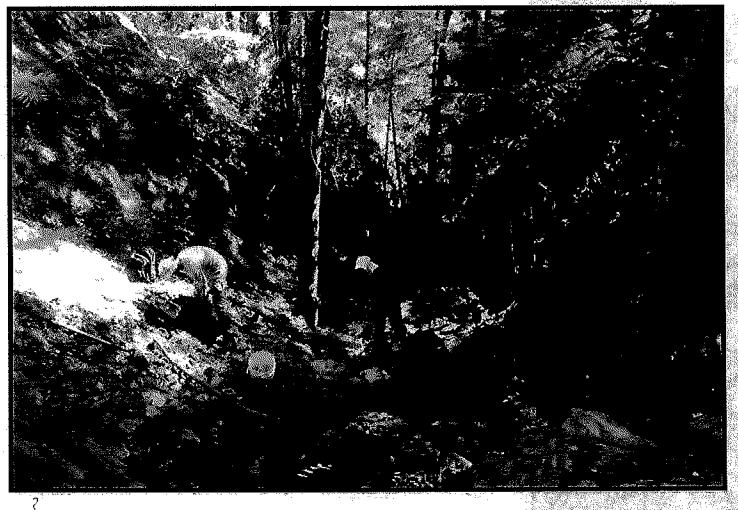
Monitor pipes found at Relief Hill mine pit. Facing northeast.

October 4, 2004

Photograph A-2

Waukesha tunnel outlet – south of sample location during the undisturbed sampling event. Facing west.

October 5, 2004



Photograph A-3

Drainage channel below Waukesha tunnel outlet. Facing east.

October 5, 2004

CABY Headwaters Resilience and Adaptability Program - March 2013
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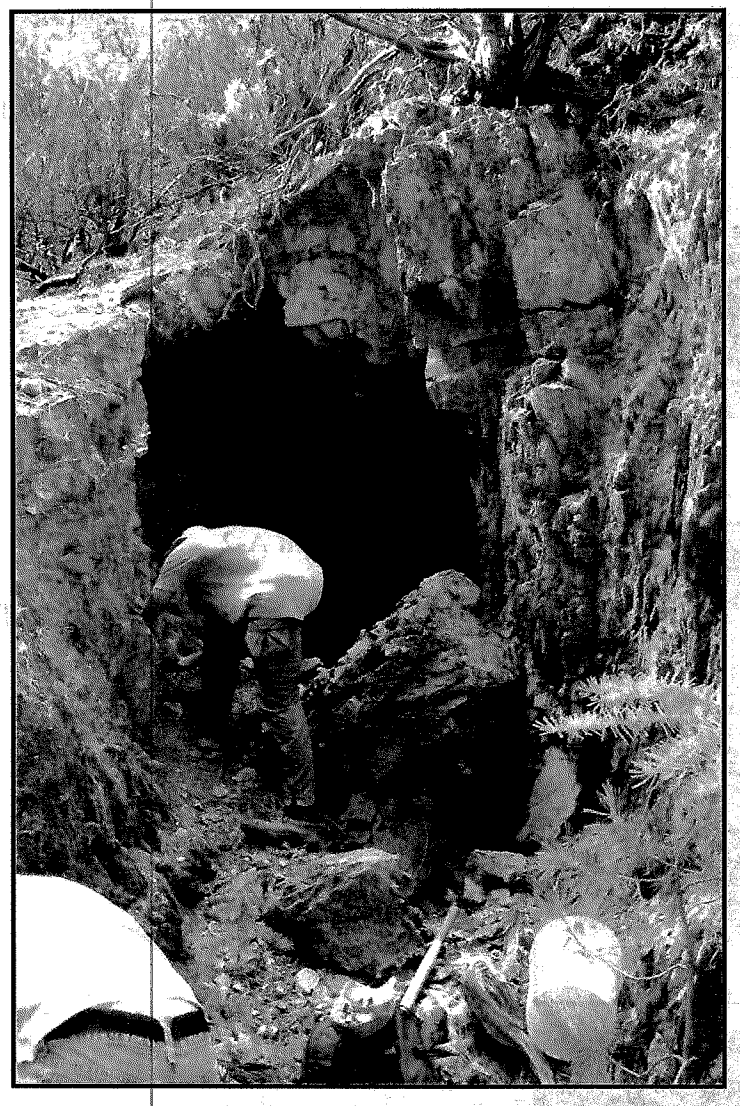
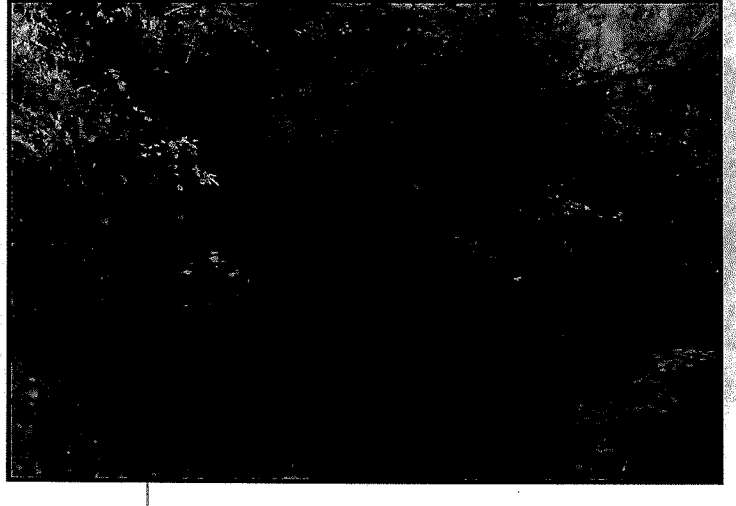


Photograph A-4

New tunnel outlet during the undisturbed sampling event. Facing west.

October 5, 2004



Photograph A-5

Union tunnel outlet. Facing northeast.

October 6, 2004

Photograph A-6

Drainage channel below the Union tunnel outlet Facing southwest.

October 6, 2004

Photograph A-7

Union sluice sample location during undisturbed sampling event. Sluice timbers were located approximately 2 feet below ground surface. Facing east.

October 6, 2004

Photograph A-8

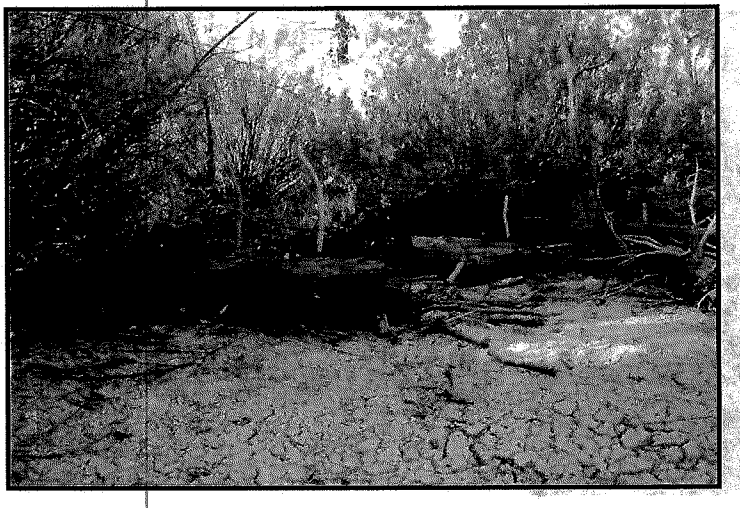
Union tunnel inlet near the Union sluice sample location. Facing west.

October 6, 2004

Photograph A-9

Waukesha tunnel inlet No. 2 sample location during the undisturbed sampling event. Facing southeast.

October 6, 2004

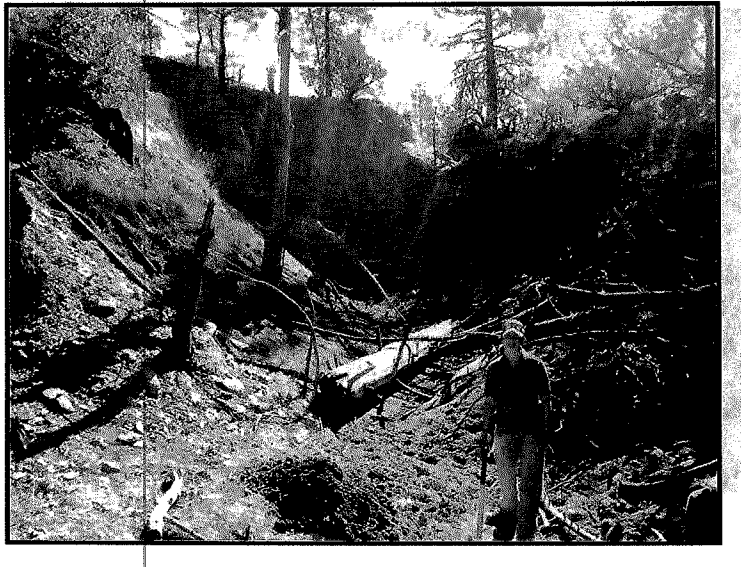


Photograph A-10

Dried cracked mud outside of the Waukesha tunnel inlet No. 2 pond. Photograph taken during the undisturbed sampling event.

Facing northeast.

October 6, 2004



Photograph A-11

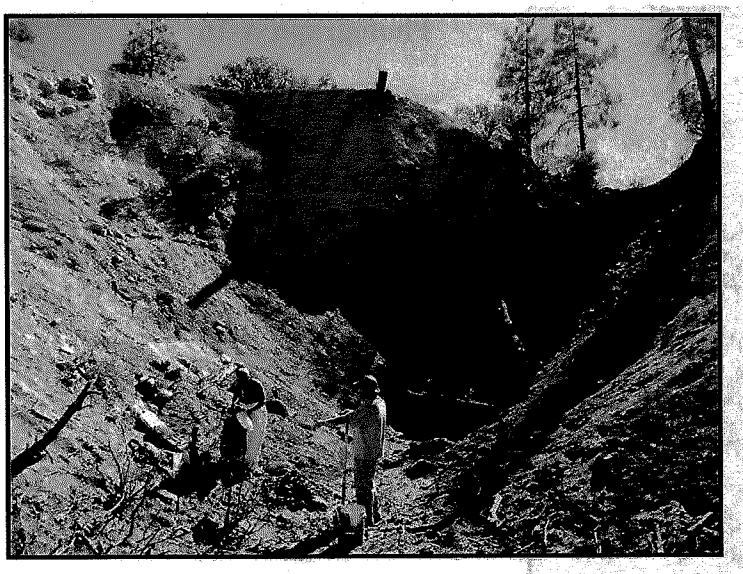
Ground sluice leading to Cliff tunnel inlet No. 7. Sample S01 was collected here during the undisturbed sampling event. Facing south.

October 7, 2004

Photograph A-12

Ground sluice just up stream of Cliff tunnel inlet No. 6. Also known as the "Blue Lagoon." Facing northwest.

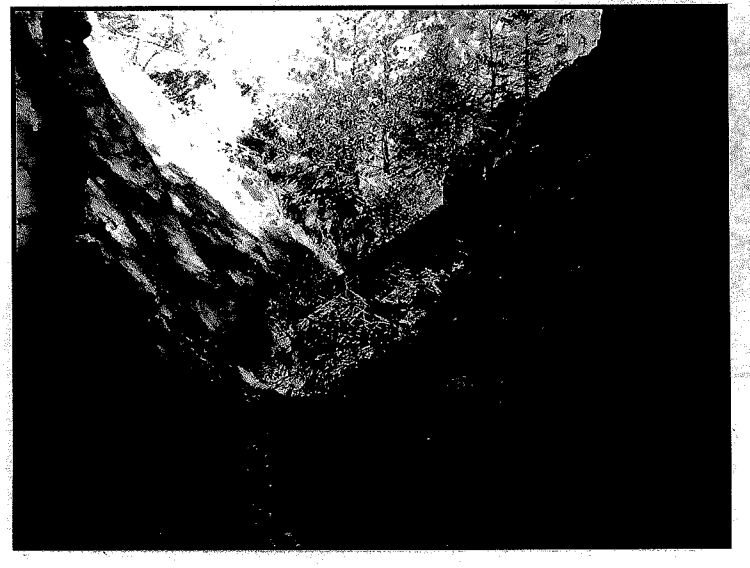
October 7, 2004



Photograph A-13

Cliff tunnel inlet No. 6 sample location (W02-U) Also known as the "Blue Lagoon." Facing southeast.

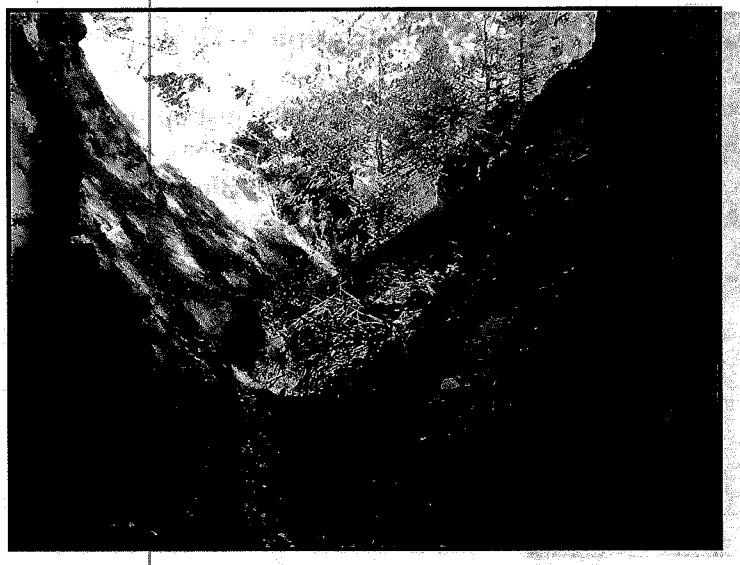
October 7, 2004



Photograph A-14

Ground sluice upstream of Waukesha tunnel inlet No. 2. Facing north.

October 7, 2004



Photograph A-15

Ground sluice upstream of Waukesha tunnel inlet No. 2. Facing north.

October 7, 2004

Photograph A-16

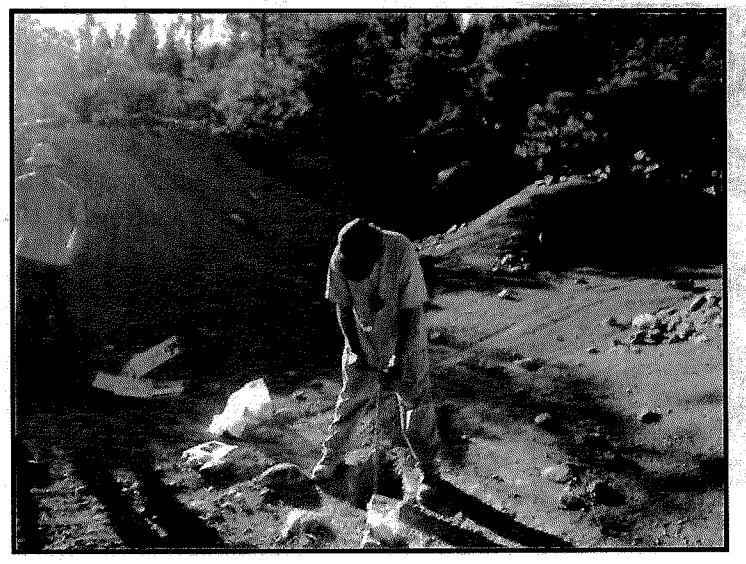
Waukesha tunnel inlet No. 2. Facing south.

October 7, 2005

Photograph A-17

Ground sluice upstream from Waukesha tunnel inlet No. 3. Facing north.

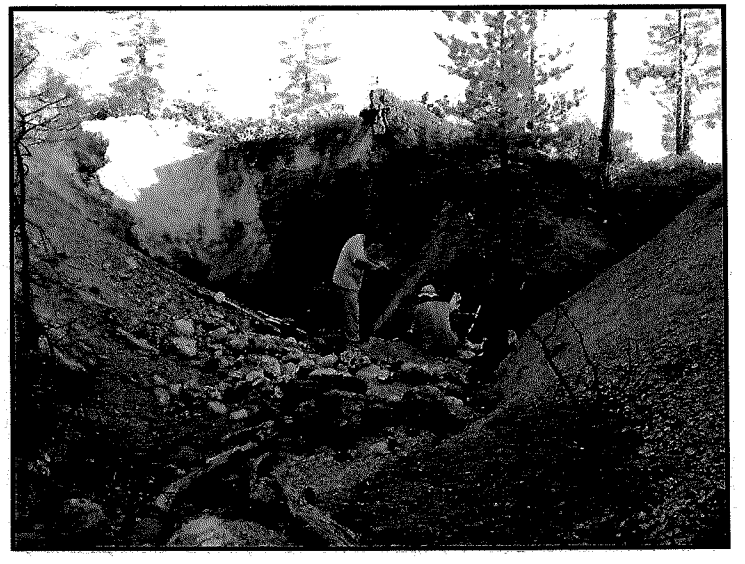
October 7, 2004



Photograph A-18

Middle tunnel inlet No. 1 (S09-U) sample location. Sample collected during undisturbed sampling event. Facing north.

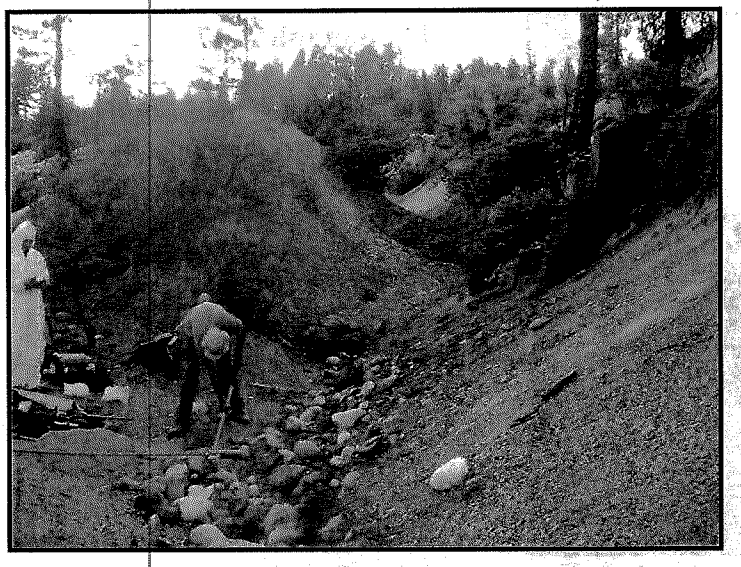
October 7, 2005



Photograph A-19

Sample location S10-U near north-New tunnel inlet; sample collected during the undisturbed sampling event. Facing southeast.

October 7, 2004



Photograph A-20

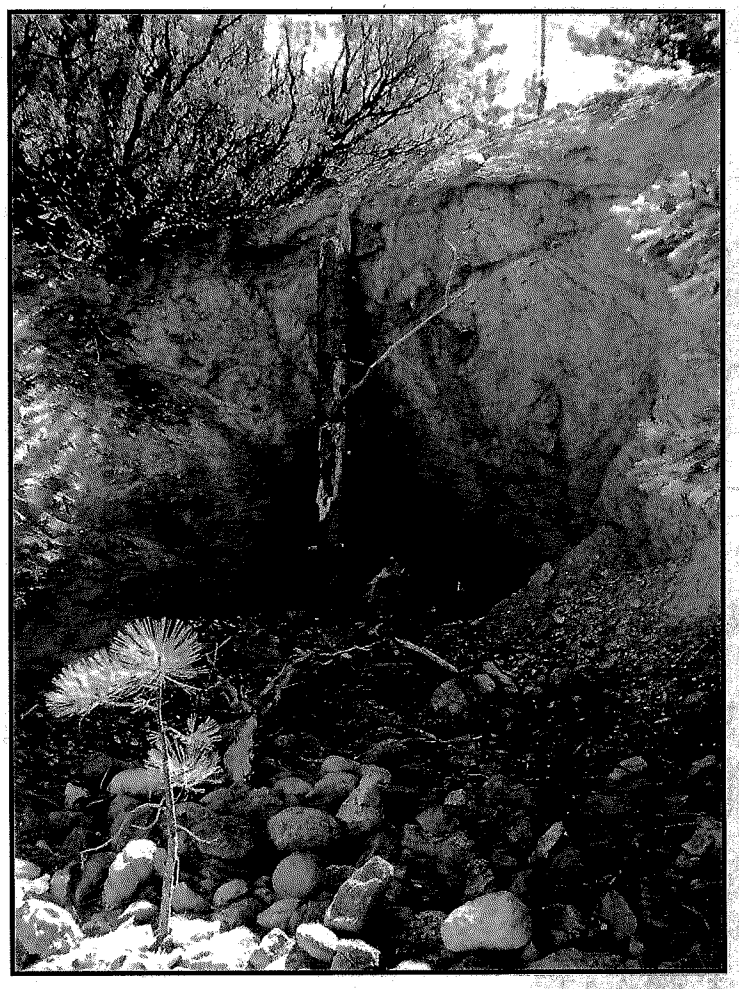
Sample location S17-U near south-New tunnel inlet; sample collected during the undisturbed sampling event. Facing west.

October 7, 2004

Photograph A-21

Close-up view of sediment and turbidity from Jasper Mine landslide above Waukesha tunnel inlet No. 4 sample location (W19-D). Facing down.

March 24, 2005



Photograph A-22

Sample location S23-U near north–Middle tunnel inlet No. 2, sample collected during the undisturbed sampling event. Facing south.

October 8, 2004

Photograph A-23

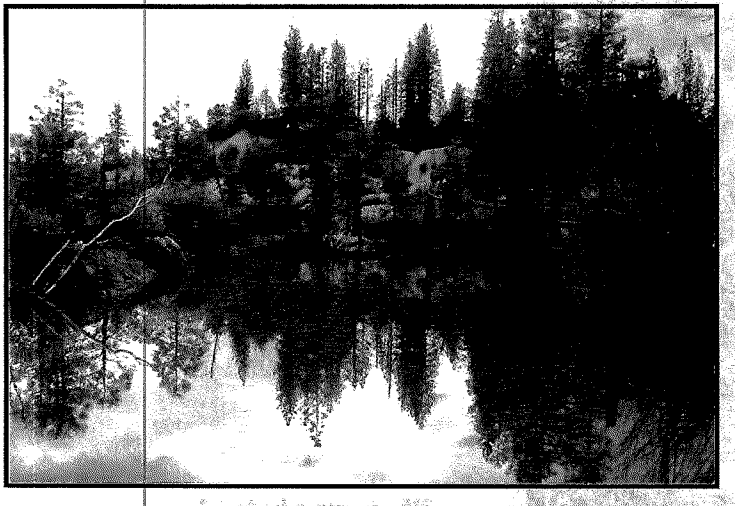
Land slide and runoff from above Jasper Mine above Waukesha tunnel inlet No. 4, sample location (W19-D). Facing northwest.

March 24, 2005

Photograph A-24

Land slide and runoff from above Jasper Mine above Waukesha tunnel inlet No. 4, sample location (W19-D). Facing northwest.

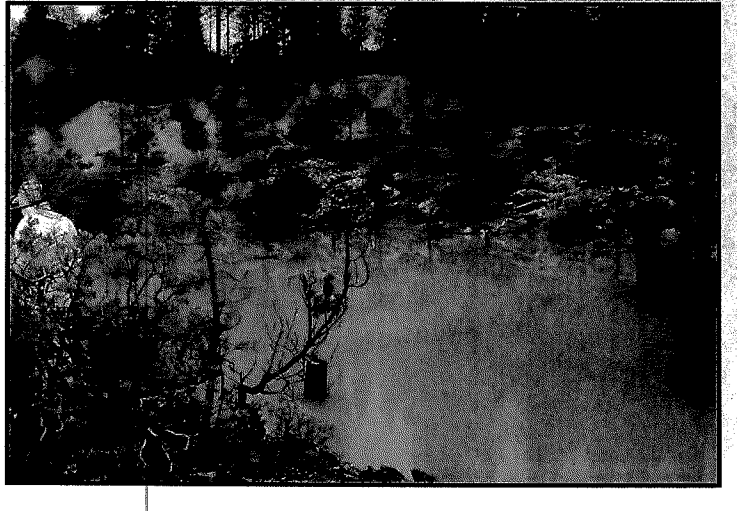
March 24, 2005



Photograph A-25

Cliff tunnel inlet No. 7 sample location (W01-D). Sample collected from flooded sluice upstream of plugged inlet. Facing east.

March 24, 2005



Photograph A-26

Cliff tunnel inlet No. 6U, sample location (W22-D). Sample collected at east end of wetland just before the notch to the "Blue Lagoon." Wetland and lower sluices are flooded. Facing east.

March 24, 2005

Photograph A-27

View from the Cliff tunnel inlet No. 7 notch to the "Blue Lagoon." Facing east.

March 24, 2005

Photograph A-28

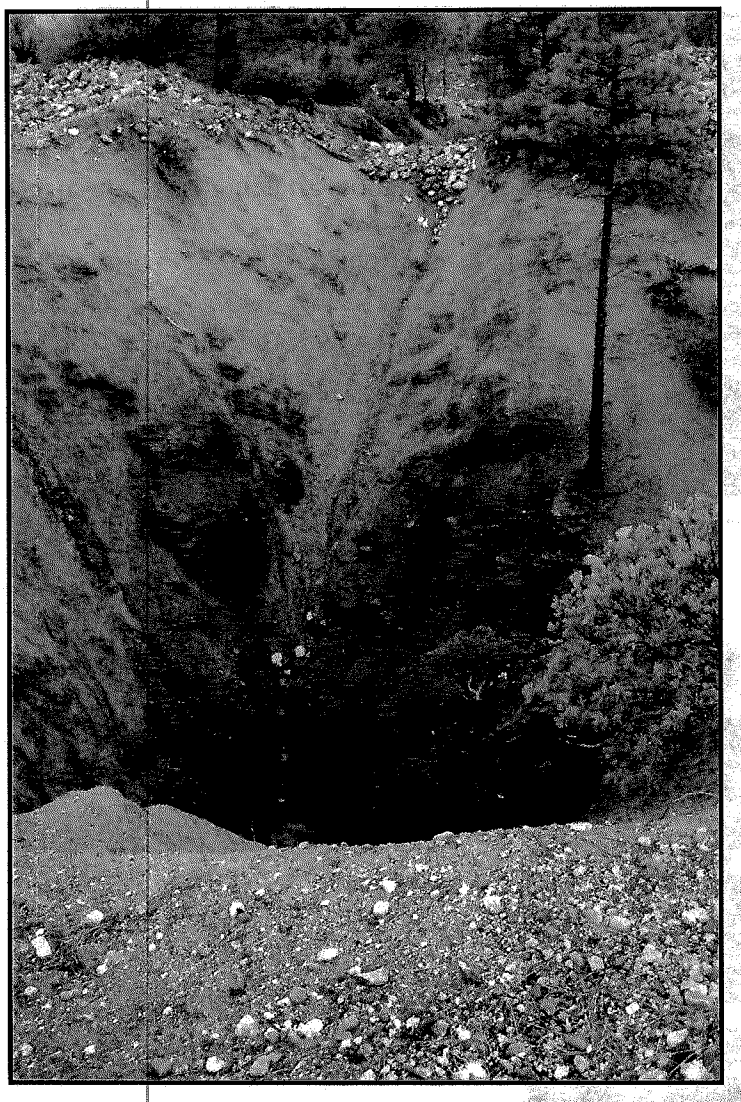
Cliff tunnel inlet No. 6 also known as the "Blue Lagoon." Sample location (W22-D). Compare to undisturbed sample event photo on Figure A-7.

March 24, 2005

Photograph A-29

View of Cliff tunnel inlet No. 8 looking towards Cliff tunnel inlet No. 1. Facing east.

March 24, 2005



Photograph A-30

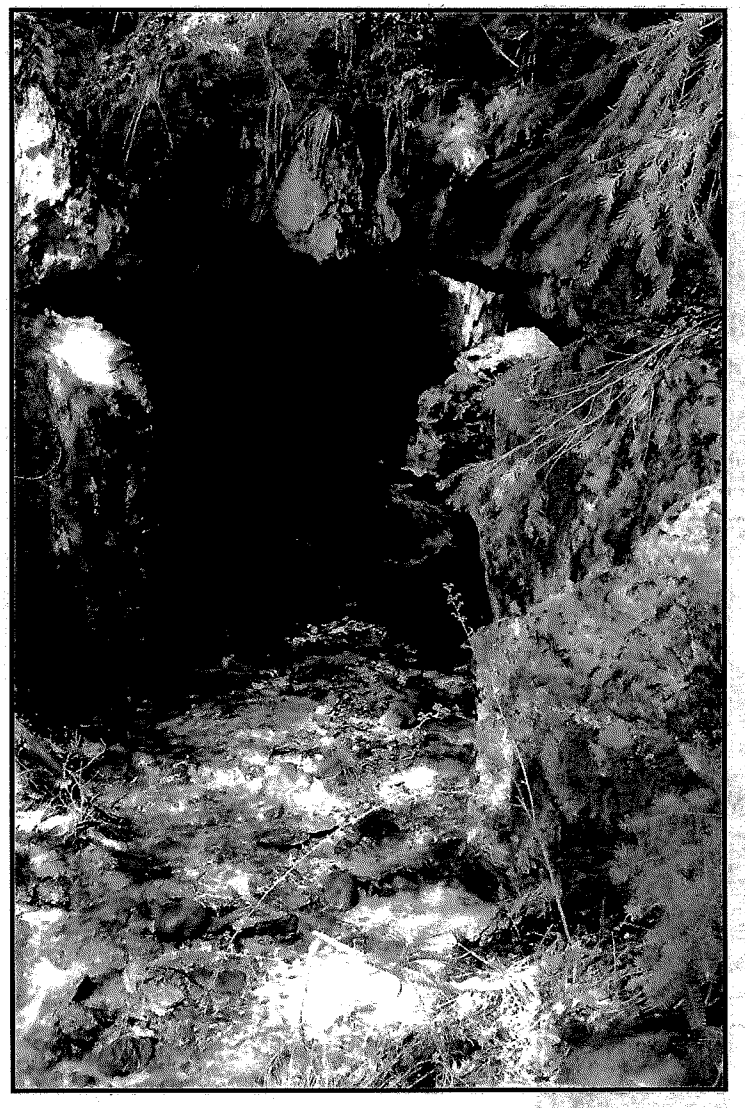
Seepage from flooded Cliff tunnel inlet No. 8 to Cliff tunnel inlet No. 1. Facing west.

March 25, 2005

Photograph A-31

View of New tunnel south inlet and pool during sampling. Sample location W17-D during disturbed sampling event. Facing north.

March 24, 2005



Photograph A-32

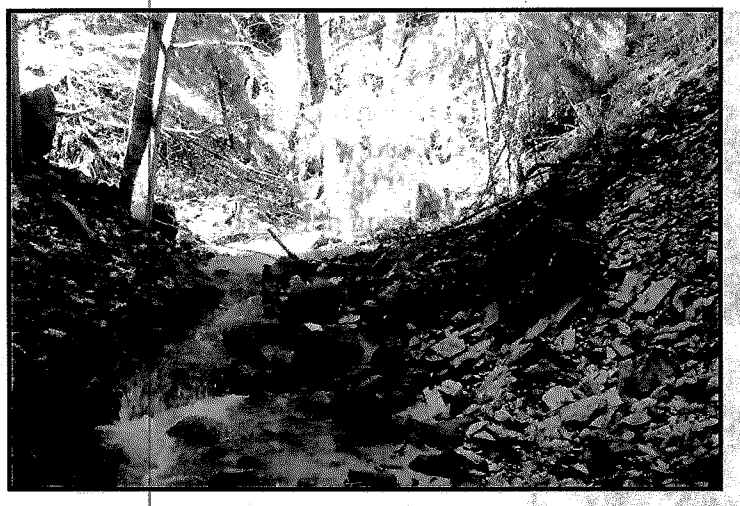
Union tunnel outlet sample location (W06-D). Note collapse 150 feet back from tunnel outlet. Facing northeast.

March 25, 2005

Photograph A-33

Union tunnel inlet sample location during disturbed sampling event (W21-D). Note water clarity. Facing northeast.

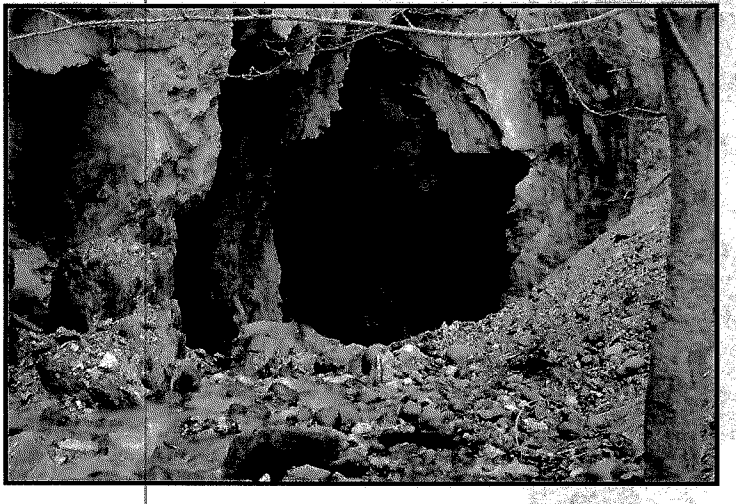
March 25, 2005



Photograph A-34

Ground sluice upstream of Union tunnel inlet. Facing east.

March 25, 2005



Photograph A-35

Union tunnel inlet sampling location (W21-D) during disturbed sampling event. Facing west.

March 25, 2005

Photograph A-36

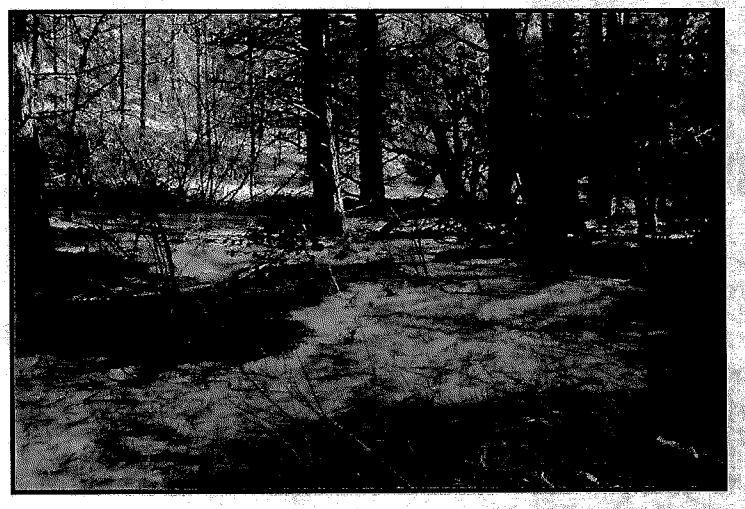
Explosives depot found in Union Pit during site reconnaissance.

March 25, 2005

Photograph A-37

Tracked crane in Union Pit, located during site reconnaissance. Facing west.

March 25, 2005



Photograph A-38

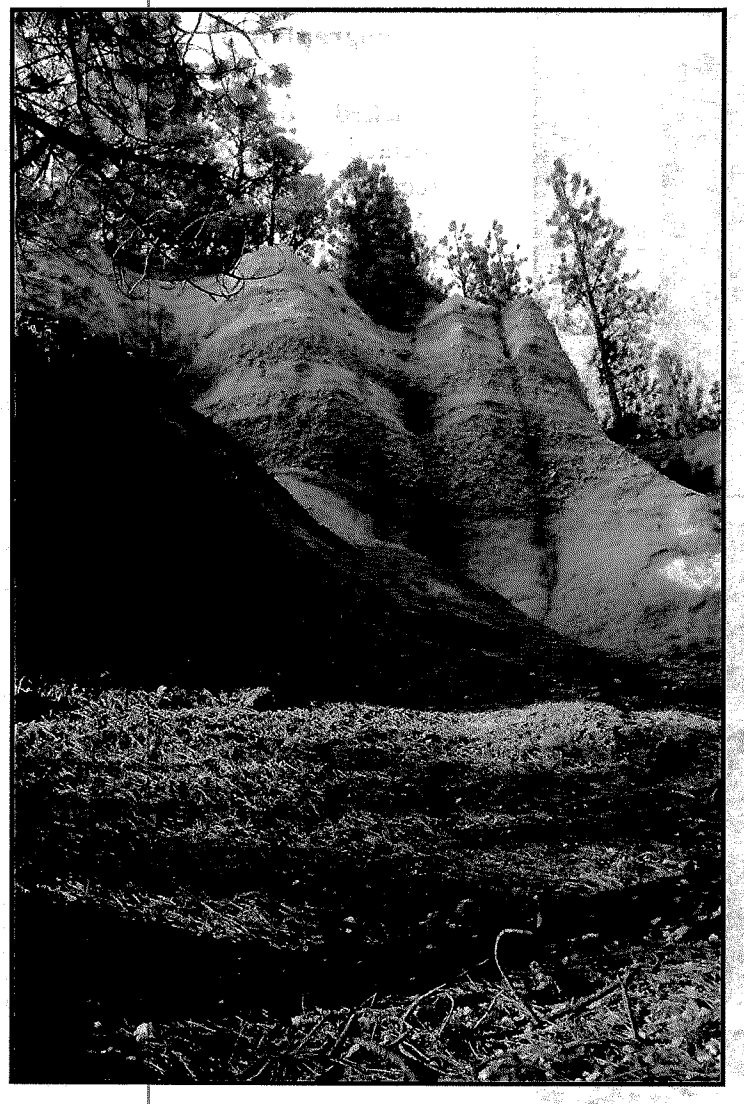
Sediment deposits on Union Pit floor. Facing northeast.

March 25, 2005

Photograph A-39

Eroded sediment from Union Pit high wall. Facing southwest.

March 25, 2005



Photograph A-40

High wall at Relief Hill. Facing east.

March 25, 2005

APPENDIX B
MINE CLAIM RECORDS
(Presented in Hard Copy and on Compact Disc)

Run Time: 02:01 PM

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
MINING CLAIM GEOGRAPHIC REPORT
LIST OF MINING CLAIMS BY SECTION

MER TWP RNG SEC
21 0170N 0100E 004

Serial Num	Quad	Claim Name/Number	Claimant(s)	Lead File	Case Type	Status	Loc Dt	Last Assessment
CAMC1651	NE SE	JASPER	FETTERMAN KEITH	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1651	NE SE	JASPER	GARRETT DENNIS R	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1651	NE SE	JASPER	GARRETT DIDGIE L	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1651	NE SE	JASPER	JASPER CHARLES	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1651	NE SE	JASPER	JASPER DANNY V	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1651	NE SE	JASPER	JASPER LINDA S	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1651	NE SE	JASPER	JASPER MARY L	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	FETTERMAN KEITH	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	GARRETT DENNIS R	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	GARRETT DIDGIE L	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	JASPER CHARLES	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	JASPER DANNY V	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	JASPER LINDA S	CAMC1651	384201	ACTIVE	03/10/1975	2006
CAMC1652	NE NW	JASPER #2	JASPER MARY L	CAMC1651	384201	ACTIVE	03/10/1975	2006

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APPENDIX C
LABORATORY ANALYTICAL DATA
(Presented on Compact Disc)

GOLD COUNTRY ANGLER SURVEY

A Pilot Study to Assess Mercury Exposure from Sport Fish Consumption in the Sierra Nevada

MAY 2011

THE SIERRA FUND

ABOUT THE SIERRA FUND

The Sierra Fund is the only nonprofit community foundation dedicated to the Sierra Nevada. Our mission is to increase and organize investment in the region's natural resources and communities. We pursue this mission three ways: through *Advocacy* to bring public funding to the region, *Philanthropy* to provide a vehicle for private funding, and *Strategic Campaigns* that pursue critically needed programs in the Sierra.

Since 2006, the **Reclaiming the Sierra Initiative** has been our primary strategic campaign. The goal of this Initiative is to assess and address mining's toxic legacy: the ongoing cultural, environmental and human health impacts of toxins left over from the Gold Rush.

In 2009, The Sierra Fund initiated two pilot studies to learn whether people who live, work, or recreate in the Sierra Nevada are being exposed to legacy mining toxins including mercury, arsenic, lead, asbestos and chromium. Results of the 2009-2010 *Gold Country Angler Survey* are presented here. The *2009 Recreational Trails and Abandoned Mines Assessment*, which looks at levels of contaminated mine waste on recreational trails near abandoned mines, was released in June 2010. Copies may be obtained online at *www.sierrafund.org* or by contacting The Sierra Fund directly.

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[*] *Created in 1992 as a private, independent foundation, TCWF's mission is to improve the health of the people of California by making grants for health promotion, wellness education, and disease prevention.*

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ABSTRACT

The purpose of the *Gold County Angler Survey* was to stimulate awareness, research, and policy reform to address the issue of mercury-contaminated fish in the Sierra Nevada. Potential mercury exposure and health hazard awareness of people fishing at mercury-contaminated water ways was determined based on their responses to a standard interview. The questionnaire used was based on one developed by the California Department of Public Health for a survey of anglers in the San Francisco Bay/Delta. The Gold Country Angler Survey was administered by trained volunteers at 12 fishing water ways in the Sierra in the summers of 2009 and 2010. A total of 69 interviews were completed during the 2009 season and 82 interviews were completed during the 2010 season, for a total of 151 interviews. The majority of the interviews were from Rollins Lake (n=33), Upper Scotts Flat (n=23), Camp Far West (n=21), Lake Englebright (n=17), Nimbus Dam (n=16), and Lake Wildwood (n=15).

The most popular fish eaten were bass (largemouth, smallmouth and striped) and trout (rainbow and brown). Bass and brown trout are predatory fish, that often have elevated mercury concentrations and are the subject of numerous fish consumption advisories in the Sierra. Survey respondents indicated that their most trusted sources of health information was their healthcare providers, however it is known that Sierra clinics do not routinely provide information about mercury exposure from eating locally caught fish. Posted fish consumption advisories were not observed at the vast majority of targeted water bodies.

Over 90% of respondents reported eating fish that were caught by themselves or by someone they know. Approximately half (47%) the anglers interviewed planned to eat the fish they caught that day, and the majority of those (73%) planned to feed the fish to their families. Significant numbers of anglers (50%) feed the fish they catch to children under the age of 18, women of child bearing age (54%) and, to a lesser extent, pregnant women in their household (6%). These groups are most at risk from the health impacts of eating mercury-contaminated fish.

Estimated mercury exposure indicates that some respondents eat more fish and are likely exposed to more mercury than amounts considered to be safe by OEHHA. When individuals' mercury exposure was calculated, 9% of anglers interviewed consumed more mercury than state guidelines recommend. The maximum mercury exposure level from sport fish consumption calculated from the survey responses was 90 micrograms (µg) of methylmercury (MeHg) per day, more than four times the recommended safe level of 21µg MeHg/day (based on a 70kg body weight). This person was a Caucasian man between the ages of 18 and 34 fishing at Nimbus Dam on the American River, who reported eating bass five times in the last month and also crappie one time in the last month. His typical serving size was two or three 7.5 oz portions each meal.

These results indicate that people are consuming locally-caught sport fish from mercury-contaminated water ways in amounts that exceed safe levels, and that in general there is limited understanding of the associated health hazards from eating mercury-contaminated fish. Collection of fish mercury data from local water ways, additional angler surveys, and immediate posting of existing fish consumption advisories are highly recommended.

INTRODUCTION

Exposure to mercury through sport fish consumption may be the single most significant route by which people are exposed to mining toxins in the Sierra Nevada Foothills, however little is known about the true extent of human exposure in the region. This study provides some insight into the extent of mercury exposure, and identifies an urgent need for a full characterization of mercury exposure to vulnerable populations.

The purpose of the Gold Country Angler Survey was to stimulate awareness, research, and policy reform to address the issue of mercury-contaminated fish in the Sierra Nevada. A survey of anglers in the Sierra Nevada Foothills, also known as the Gold Country, was conducted to provide an assessment of potential human exposure to mercury through sport fish consumption. Sport fish are fish that people catch rather than buy at a store or restaurant. The survey was performed during the late Spring through the Fall of 2009 and repeated in the Summer of 2010.

This report summarizes the Gold County Angler Survey methods, results, and recommendations for action, and provides lessons learned to encourage and improve future angler surveys.

Gold Mining and Mercury

The primary source of mercury in Sierra Nevada water ways was historic placer and hard rock gold mining activities during the 19th century. Mercury binds with gold to form an amalgam which enhances gold recovery. Mercury was used in sluice boxes to recover placer gold and also during stamp milling of hard rock ore. An estimated 26 million pounds of mercury were used in the Sierra Nevada during the California Gold Rush (Alpers, et al. 2005). Of these, an estimated 10 million pounds were lost to the environment in placer or hydraulic mining operations and another 3 million pounds were lost from hard rock mining (Churchill, 2000). Discharging both mercury-contaminated stamp mill sands and hydraulic mining debris into rivers and streams was common and thus, mercury entrained in mining waste was washed into streams and rivers.

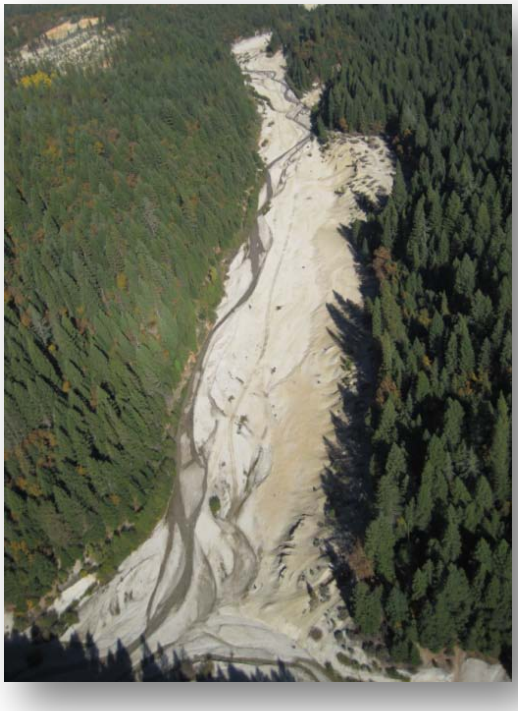


Figure 1: Greenhorn Creek, a tributary to Rollins Reservoir - Photo taken in 2010 shows the creek channel still choked with hydraulic mining debris. (Photo: Nevada Irrigation District)

Today, mercury remains in Sierra Nevada water ways. Elemental mercury can still be seen with the naked eye and mercury in fine sediment in these watersheds is at least 10 times higher than background levels. Mercury-laden sediment from historic mining has built up in the region's reservoirs. Other sources of mercury contamination include atmospheric deposition from coal burning and other industrial sources, and effluent released from waste water treatment facilities, but these sources pale compared to legacy mercury from historic gold mining in the Sierra Nevada.

Methylmercury

Mercury was originally used at mine sites in elemental form or "quicksilver" but can exist in many different forms in the environment. Elemental mercury can be converted by microbial action to methylmercury, the form most readily incorporated into biological tissues. Methylmercury is what people who eat mercury-contaminated fish are exposed to, and it is toxic. Methylmercury bioaccumulates in living organisms, increasing in concentration in tissue at each trophic level from bacteria and algae to invertebrates, fish, and people who eat mercury-contaminated fish. Biomagnification of mercury results in exponentially higher levels of mercury each step up the food chain. This is illustrated by the example of a large predatory fish that in its lifetime has eaten many smaller fish. Consequently, larger predatory fish such as bass and brown trout, which are both highly sought after as sport fish, are of particular concern because they have much higher mercury levels than fish lower on the food chain.

Figure 2: Methylmercury in the food chain

Health Effects of Mercury

Although fish should be part of a healthy diet, the negative health effects of eating mercury-contaminated fish are profound and may outweigh health benefits. Health effects of mercury include brain, nervous system, kidney, and immune system damage. Symptoms of mild mercury poisoning include tingling of the lips, fingers, and toes. More severe poisoning causes headaches, memory loss, vision and coordination difficulties, muscle spasms, pain and stiffness in joints, and heart disease.

The health effects of mercury on developing children and fetuses are of highest concern. High doses of mercury during pregnancy can cause birth defects and mental retardation in children. The effects of mercury exposure during childhood include slow development, language and memory impairment, delayed walking, and attention disorders. Children and fetuses are especially vulnerable to low levels of mercury exposure since their nervous systems are still developing and mercury easily passes through the placental barrier and the blood-brain barrier.

At-Risk Populations

Some demographic or ethnic groups such as Native Americans who traditionally eat sport fish may be disproportionately impacted by mercury contamination of the fish. The Native Peoples of the Sierra Nevada were decimated by the Gold Rush, and the presence of mercury in fish perpetuates the cultural devastation today. Additionally, low-income people may view fishing as an inexpensive way to feed

their families, and may not be aware of the potentially serious health effects. The California Department of Public Health (CDPH) has tried to educate communities about mercury and fish consumption by providing small grants to community groups that conduct educational activities that are culturally and linguistically appropriate for specific ethnic communities (Cambodian, Vietnamese, Latino, etc.). CDPH and county agencies have also posted signs in the Delta at fishing locations. CDPH has trained and distributed educational materials through food stamp education programs, WIC programs (Women, Infants, Children), and other organizations that serve lower income populations.

Previous Angler Survey Efforts

CDPH interviewed over 1,000 anglers in the San Francisco Bay Area in 1998-1999 (SFEI, 2001b). CDPH also completed a smaller Pilot Angler Survey in the San Joaquin River and Delta area in 2005 (CDPH, 2005). The Healthy Fish Coalition, which includes UC Davis researchers and students, performed angler surveys in 2005 through 2008 in the Sacramento River and Delta (Shilling, et al., 2010).

Despite the growing interest in mercury exposure from sport fish consumption in the California Bay/Delta, comparatively little attention has been paid to the upper watershed. The only survey conducted in the Sierra was a creel survey at Lake Englebright in 2003 and 2004 (Upper Yuba River Studies Program, 2006). The creel survey identified the number of species and size of fish that were caught and retained but did not collect data regarding fish consumption patterns, demographics or level of health hazard awareness. No other angler surveys or fish consumption surveys related to mercury have been conducted in the Sierra Nevada Foothills to date, therefore the effect that consumption of mercury-contaminated fish has had on the health of communities in this region is unknown. The Gold County Angler Survey is the first survey that focuses primarily on consumption of mercury-contaminated fish in the Sierra Nevada foothills.

Mercury Regulations: Fish Consumption Advisories and Water Quality

Mercury is highly regulated, both as a health concern and a water quality pollutant. The United States Food and Drug Administration (FDA) and Environmental Protection Agency (EPA) recommend that sensitive populations including young children, woman who are pregnant or could become pregnant, and nursing mothers limit their exposure to mercury. The FDA and EPA recommend that sensitive populations avoid certain high mercury species and limit consumption of commercial fish to no more than 12 ounces (uncooked weight, with smaller servings for children) a week, and for fish caught by family and friends, local advisories should be followed. If no local advisory is available, sensitive populations should limit consumption of locally caught fish to six ounces a week (FDA, 2004).

The California Office of Environmental Health Hazard Assessment (OEHHA) has issued fish consumption advisories for several northern Sierra water ways based on mercury levels in fish (OEHHA, 2009). In 2003, OEHHA issued an interim fish advisory for water bodies in the Sierra Nevada, and in 2009 OEHHA updated this advisory. In the advisory update process, the criteria for what constituted enough data for a fish advisory changed and more fish samples were required in order to issue a human health advisory (OEHHA, 2009). Because of limited fish samples from several Sierra Nevada locations, safe eating guidelines were eliminated. The OEHHA advisories that existed in 2003 but not in 2009 reflect the need for more data rather than an improved fishery. It should be noted that regardless of the status of the OEHHA advisory, the federal advisory is in place for all water bodies that do not have local (country or state) advice.

Under section 303(d) of the 1972 Federal Clean Water Act, States, Territories, and authorized Tribes are required to develop lists of impaired waters which do not meet water quality standards. The California EPA has issued 303(d) listings for mercury contamination of multiple water ways in the Sierra Foothills, Sacramento-San Joaquin Delta, and San Francisco Bay regions. Table 1 (below) indicates the status of 303(d) listing according to data from the Central Valley Regional Water Quality Control Board (CVRWQCB) and the 2003 and 2009 OEHHA fish advisories.

Table 1: Regulatory Status of Mercury-Impacted Water Ways in the Yuba and Bear Watersheds

Mercury-Impacted Water Way	303(d) Listed as impaired by mercury (CVRWQCB 2010)	Fish Consumption Advisory 2003 (OEHHA 2003)	Fish Consumption Advisory 2009 Update (OEHHA 2009)
Deer Creek	X*	X	**
Upper Scotts Flat Lake	X	X	**
Lower Scotts Flat Lake			
Lake Wildwood	X		
Bear River	X	X	**
Rollins Lake	X	X	X
Lake Combie	X	X	X
Camp Far West Reservoir	X	X	X
South Yuba River	X	X	**
North Yuba River	X		
Lake Englebright	X	X	X
Lower Yuba River (below Englebright)	X		
Lower American River (below Nimbus Dam)	X	X	X

* 303(d) listings have been issued for Little Deer Creek, a tributary to Deer Creek.
** Removed from the fish advisory during the 2009 update due to insufficient number of samples

SCOPE

The survey was conducted at twelve target reservoirs and rivers in the Gold Country. A map of all water ways included in the study can be found on page 10 and detailed descriptions of the major water ways are included in Appendix C. The interview locations were within the Yuba, Bear, American and Deer Creek watersheds in Nevada, Yuba and Placer Counties approximately one to two hours east of Sacramento, California.

These reservoirs and rivers were chosen because they were well known fishing areas, and contaminated by mercury from historic mining activities. They were also within a one-hour radius of the Grass Valley/Nevada City area, a feasible distance considering the resources of the study. The selected locations are listed as impaired for mercury by the Clean Water Act section 303(d) and some also have fish consumption advisories, the only exception being Lower Scotts Flat which is contiguous with Upper Scotts Flat Reservoir and Deer Creek.

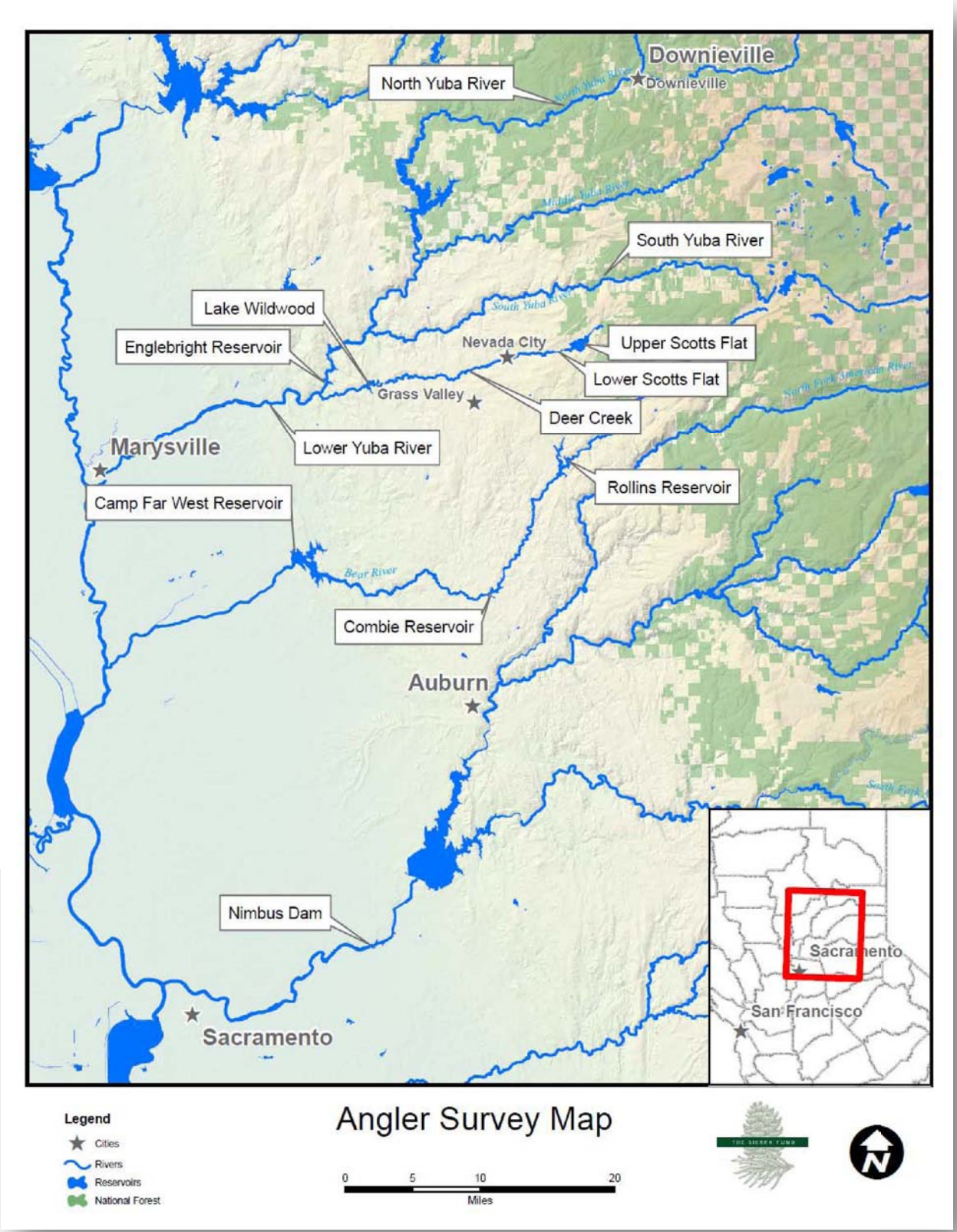


Figure 3: Map of Angler Survey Locations – Interviews were completed at water bodies known to be contaminated with mercury and within one to two hours of Nevada City, CA.

METHODOLOGY

The Gold Country Angler Survey was based on the Sacramento River Angler Survey that was conducted by the University of California (UC). Gold Country Angler Survey volunteers were trained by Healthy Fish Coalition collaborators, namely Dr. Fraser Shilling at UC Davis, to conduct the angler interview according to the protocol developed by UC Davis and CDPH. The format of the questionnaire and interview was kept the same as previous CDPH angler survey except for minor changes such as the names of locations and fish species. This was done to promote consistency between the surveys and facilitate cross-regional comparison of the survey results.

The survey was designed to collect information through face-to-face interviews with anglers encountered at fishing locations. Interviewing anglers at water bodies (rather than only residents) allowed the survey to include populations that may be consuming fish from Gold Country water bodies, but that do not necessarily live in the immediate area.

Questions were asked orally by a trained interviewer, who then recorded answers on a standard paper form. The entire interview was designed to take 10 minutes or less. A interviewer would record the date of the interview, their name, the start and end time of each interview, the location of the interview and the gender of the person interviewed. Then the interviewer would proceed to ask the standardized questions, in the established order.

Interview questions covered the following categories: fishing location and frequency, fish species sought or caught, and fish consumption patterns (e.g., how much locally caught fish is eaten, how much is store-, restaurant-, or cafeteria-bought, and who eats the fish). No personal identifiers such as name or address were collected, however the interview did include questions about the level of health hazard awareness, household demographics, ethnicity and age. To prompt accurate responses about serving sizes, interviewers presented plastic models of fish fillets (7.5 oz, 4.5 oz and 1.5 oz) and asked the angler to identify the size of their uncooked serving. A copy of the Gold Country Angler Survey questionnaire is included in Appendix D, and a summary of interview questions is provided in the box on the following page.

Interviewers followed a standard protocol (see Appendix B) in choosing and approaching anglers for an interview. All anglers encountered were approached to participate. Interviews were performed from shore or at boat ramps when anglers were putting in or taking out their boats. If a group of anglers was encountered, interviewers tried to interview as many as would cooperate, and attempted to interview individual anglers in private so that their answers did not influence other members of the group. Interviewers were to approach anglers in a calm, friendly manner to avoid alarming them. Interviewers were encouraged to memorize key interview questions so they could approach anglers in a casual manner and move quickly through the interview. Upon completion of the interview, anglers were offered laminated fish species identification cards, free tackle (spinners, hooks, worms and weights) and OEHHA fish advisories.

Interview locations were pre-determined based on popularity and the presence of known mercury contamination. Interview times of day and days of the week were flexible throughout the survey period. This allowed the survey to be adapted according to seasonal conditions and local fishing habits. The goal of this approach was to conduct approximately 30 interviews from each targeted location across a

range of times of day and days of the week so that a range of fishing activity was represented in the data collected.

Gold Country Angler Survey Questions

0) Would you mind participating in this short ten minute survey about fishing?
   a. If no then the reason for their decline is recorded.
1) Have you ever been interviewed before?
2) What are you trying to catch today?
3) Are you going to eat the fish you catch today?
   a. If yes, are you going to feed it to your family?
   b. If no, what are you going to do with the fish you catch?
   c. Do you ever eat fish that you or someone you know catches?
4) About how many times did you go fishing in the last 30 days?
5) a. Do you eat (catfish, largemouth bass, smallmouth bass, striped bass, sunfish, bluegill, crappie, rainbow trout, brown trout, kokanee salmon, other fish) that you or someone you know catches?
   b. How many times did you eat (species listed above) in the last 30 days?
   c. How much of the (species listed above) did you eat in one meal? (Used plastic models of uncooked fish fillets at sizes 1.5, 4.5 and 7.5 oz (provided by CDPH).)
   d. Where was the (species listed above) caught?
6) In the last 30 days, have you eaten fish that came from stores, markets, restaurants, or cafeterias?
7) If yes, in the last 30 days how many times did you eat commercially bought fish? How many times? How much? Where was it bought?
8) In the past year, have any children under 18 in your household eaten fish that you or someone you know catches?
9) In the past year, have any women between ages 18 and 49 in your household eaten fish that you or someone you know catches?
10) In the past year, have any women expecting a child or who have a baby in your household eaten fish that you or someone you know catches?
11) Have you ever heard or seen any health warnings about eating fish?
    a. If yes, do you remember what the warning said? (record exact response)
12) Do you remember where you saw or heard this warning?
13) Where do you get information about your health, about what is good or bad for you, that you trust?
14) If you don't mind, could you tell me how best to describe your race or ethnicity?
15) If you don't mind me asking, what is your age?
16) What zip code do you live in?
17) (Record gender)
18) If you don't mind me asking, what is your weight? (Or record weight category)

SURVEY RESULTS AND DISCUSSION

Completed Interviews and Effort Spent

The survey was conducted in 2009 and repeated in 2010. For the 2009 survey, volunteer interviewers were recruited in late winter and early spring. Two trainings were held in Spring 2009 prior to conducting the survey. A total of eleven volunteers were trained and participated in the 2009 Angler Survey. Dr. Fraser Shilling from UC Davis and the Healthy Fish Coalition trained four people who then trained the other seven volunteers. Several members of a local fly fishing organization, Gold Country Fly Fishers, participated as volunteers. Two summer interns from National University and California State University, Chico were trained for the summer of 2010 field season.

Figure 4: 2010 Angler Survey Interns
James Worthy and Alan Rhoades

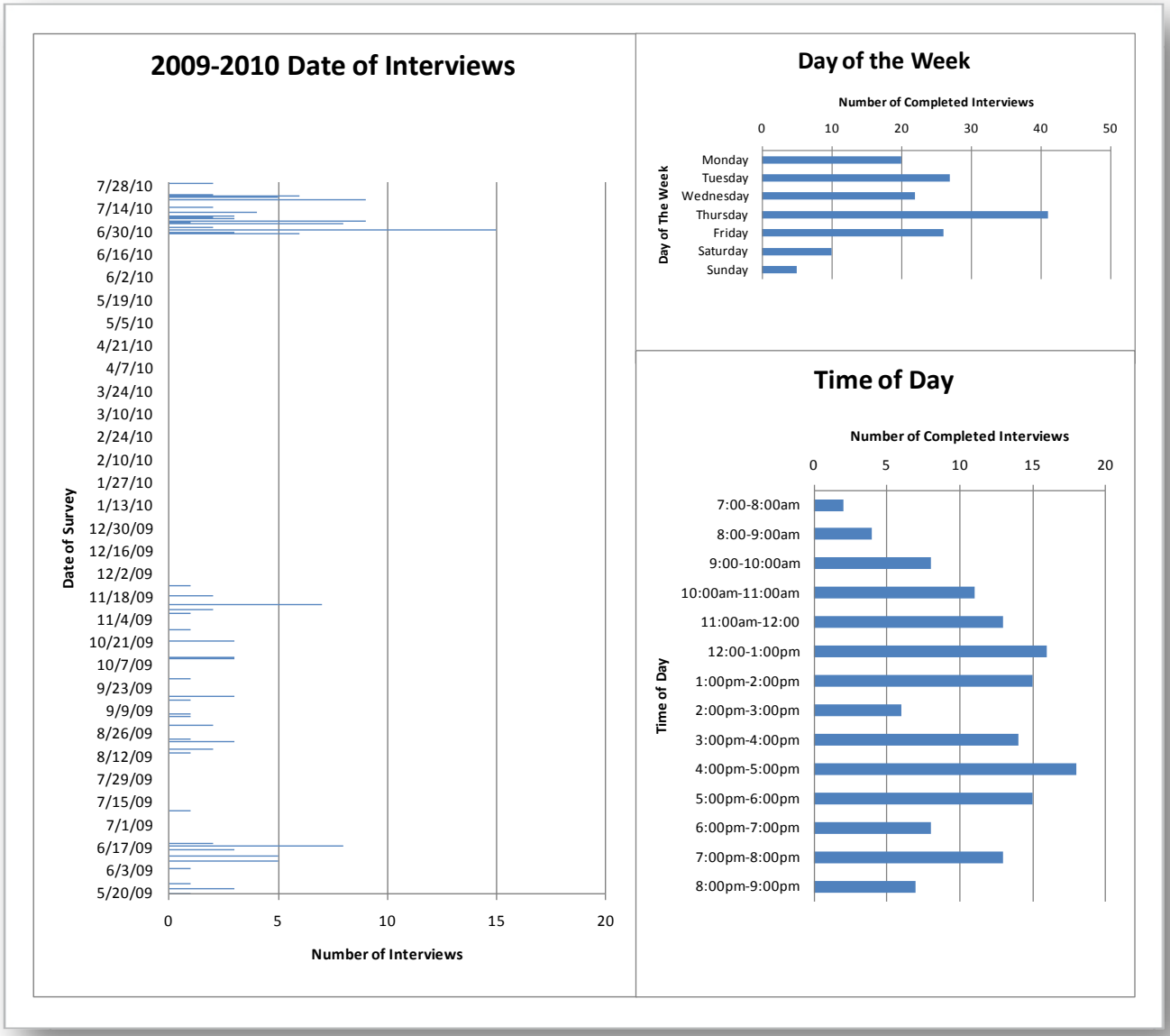
During the course of the survey, efforts were made to obtain an equal distribution of completed questionnaires from each of the target water ways. This was difficult during 2009 due to the nature of using volunteer interviewers who conducted interviews when they were either already in the field or went into the field when it was most convenient for them to do so. Due to difficulties locating anglers in the field, in 2009 a limited number of questionnaires were completed by interviewing anglers off of water ways. In these cases, anglers were asked to base their responses on their most recent fishing trip. However, in 2010 with two interns who were dedicated to conducting interviews it was possible to fill many gaps in the data set.

A total of 69 interviews were completed during the 2009 season. Volunteer interviewers visited 12 locations approximately 48 times (many of which were unproductive). Exactly how many visits were unsuccessful is difficult to calculate because volunteers did not log unsuccessful attempts, only time spent in the field. It was estimated that interviewers spent approximately 78 hours in the field searching for anglers on the shore and waiting for anglers at various boat ramps, and when they found them conducting the interviews. This translates to an average of less than two completed questionnaires per field visit and approximately 1.15 hours of field time spent per completed questionnaire.

In 2010 a total of 82 interviews were completed. The two interns worked to conduct interviews from areas and during times of day that were not covered during the 2009 season. Their efforts were focused on reservoirs for which there were less than 10 interviews completed in 2009, in particular, Rollins Reservoir, Camp Far West Reservoir, Lake Wildwood and Lake Englebright. Interviewers visited a single location until they had approximately 30 interviews from that site for the 2009 and 2010 season. In general it took three to six visits to a single site to accomplish this. Between 6 and 24 interviews were completed for each site in 2010. Visits took place at different times of the day that varied by site depending on the fishing conditions at each site. In general about two interviews per hour in the field (not including driving time) was typical.

Gold Country Angler Survey interviewers spent significantly more field time per completed questionnaire compared to similar surveys conducted in the Sacramento River, Delta and San Francisco Bay Areas. This is likely due to the broader geographic area covered by the survey, and because Sierra Foothills anglers seem to be more spread out at specific water ways making locating anglers in the field more difficult. It should be noted that it was difficult to find anglers at river or creek locations and thus, fewer questionnaires were completed from those locations.

In general, single and groups of two anglers were encountered during the survey. Most anglers were cooperative and interested in the survey. None said they had been interviewed before in the Gold Country or Delta region.



Figures 5: Interview Date, Time, and Day of Week – Interviews were conducted in May through November 2009 and again in July 2010. Interviews were completed at a variety of times of day. Interviews were completed on every day of the week, however more often on weekdays.

Location of Interviews

The majority of the completed questionnaires were obtained from the major reservoirs that are easily accessible from the Nevada City-Grass Valley area. Rollins Reservoir (22%), Upper Scotts Flat Reservoir (15%), Camp Far West Reservoir (14%), Lake Englebright (11%), the American River at Nimbus Dam (11%), and Lake Wildwood (10%) had the most completed interviews (Figure 6). A small number of interviews (1%) were conducted at other locations including Clear Creek in Butte County and Collins Reservoir in Yuba County. Native American anglers were interviewed at Indigenous Peoples Days in Nevada City in October 2009.

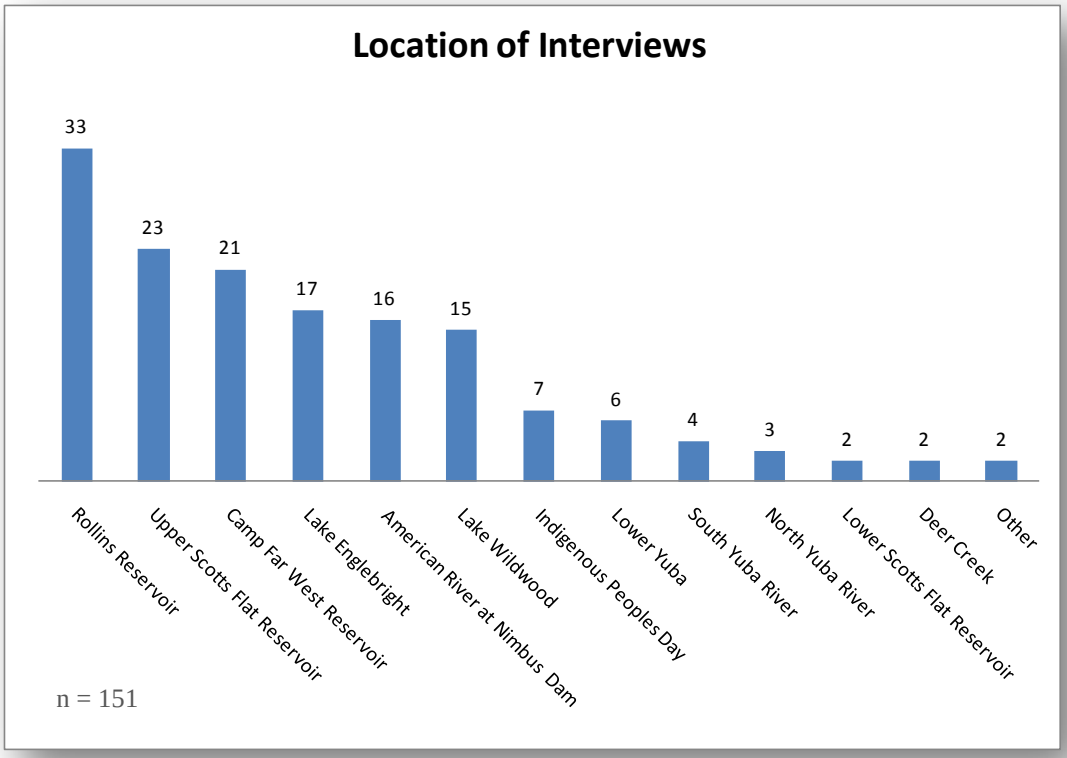


Figure 6: Locations where interviews were conducted - Rollins Reservoir (n=33), Upper Scotts Flat Reservoir (n=23), Camp Far West Reservoir (n=21), Lake Englebright (n=17), American River at Nimbus Dam (n=16), Lake Wildwood (n=15), Indigenous Peoples Day (n=7), Lower Yuba River (n=6), South Yuba River (n=4), North Yuba River (3), Lower Scotts Flat Reservoir (n=2), Deer Creek (n=2) and other locations (n=2) which included Clear Creek in Butte County and Collins Reservoir in Yuba County.

Interviews conducted along the Lower Yuba River, and to a lesser extent the South Yuba also took more effort per completed questionnaire, most likely because fishing activity was more sparse than on lakes and spread out over a larger area. No interviews were successfully completed from the Bear River or Lake Combie.

Survey Question Results

The following sections reflect individual survey questions and summary of the results for each question, as well as in some cases follow-up calculations that were made using survey response answers, in particular the methylmercury exposure calculation. Results are grouped under three general categories:

1. Demographics
2. Health Hazard Awareness
3. Fish Consumption

1. Demographics

Ethnicity of Anglers Surveyed

Anglers were asked their ethnicity or what ethnicity they identified most with (Figure 7). The majority of people surveyed (78%) considered themselves Caucasian, which is generally parallel with the population of Nevada and Placer Counties. The only other surveyed ethnic group of significant size was Native Americans (7%), who were specifically sought out at cultural events during the 2009 survey efforts. Consequently, the 10 Native Americans interviewed were not representative of anglers encountered in the field since these questionnaires were obtained at Indigenous Peoples Day events.

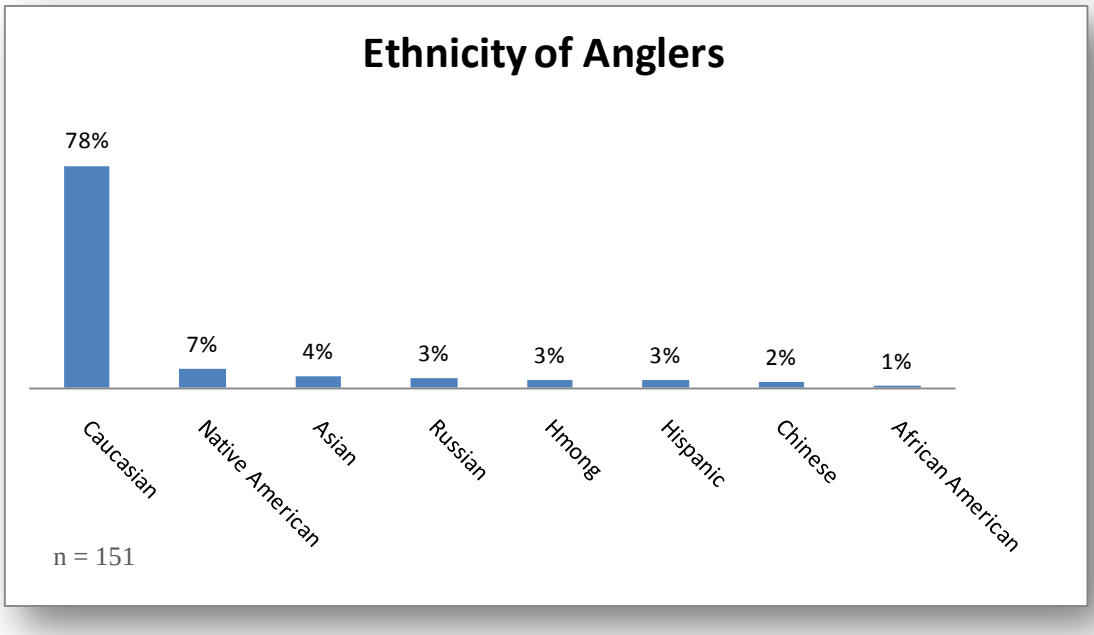


Figure 7: Ethnicity of anglers interviewed - Caucasian (n=118), Native American (n=10), Asian (n=6), Russian (n=5), Hmong (n=4), Hispanic (n=4), Chinese (n=3) and African American (n=1)

Based on anecdotal evidence, the study was expected to encounter more Latino and Asian anglers at Foothills reservoirs who reportedly travel up from Central Valley communities to fish, however during the 2009-2010 Survey, few individuals from non-Caucasian ethnic groups were interviewed. This may be in part due to language barriers. Future surveys should make efforts to target these populations because ethnic Southeast Asians from the Marysville and Central Valley areas may be the most at risk fishing populations due to their cultural practices, which include eating a large amount of wild caught

fish, and because they may have limited fluency in English and thus may not be aware of fish consumption advisories.

An interviewer did approach a group of five Hmong people fishing at the Lake Wildwood Dam but they spoke limited English and could not or would not participate in the survey. Capturing the practices of Hmong groups would be an important aspect of a follow up survey in the future and is clearly not captured in the current survey due to the limited number of individuals interviewed in this study, only four of which were Hmong.

Age Groups of Anglers

One of the survey questions targeted the age bracket of each survey participant. The interviewer would typically place the participant in the age group that seemed appropriate and would not ask directly, unless the interviewer felt there was significant uncertainty and a polite way of doing so. The largest age group was those between 18 and 34 years old (35%), followed by over 49 years (30%), and 35-49 years old (28%) (Figure 8).

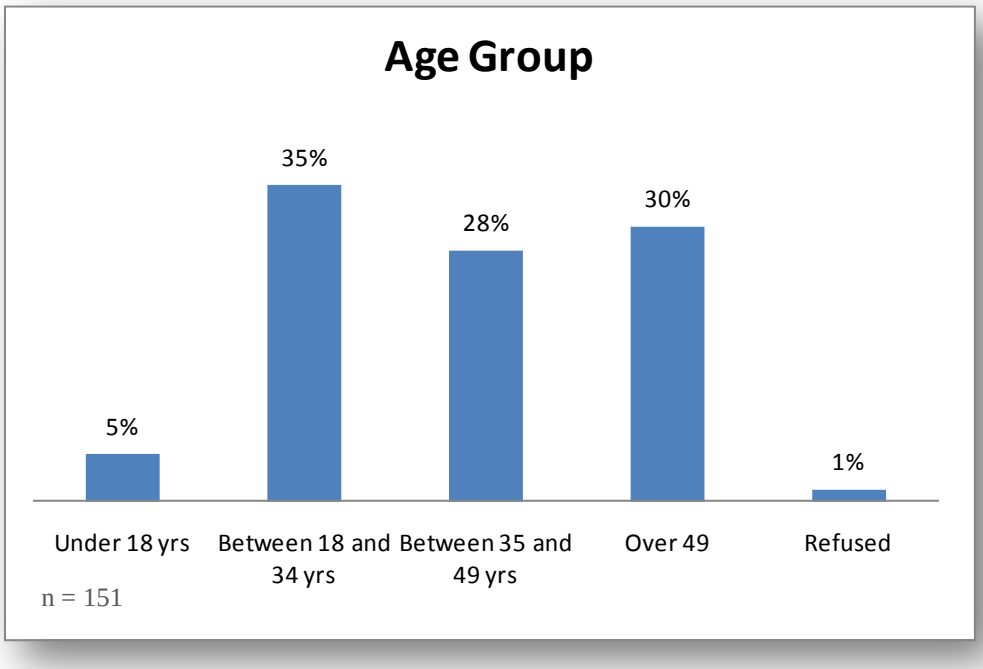


Figure 8: Apparent Age Group of interviewed anglers, Under 18 years old (n=8), between 18 and 34 years old (n=53), between 35 and 49 years old (n=42), and over 40 years old (n=46). Two questionnaires were left blank, meaning that the interviewer did not record the participant's age.

The relatively high number of anglers in the 18-35 year old group and the over 49 age group may indicate that younger and perhaps less employed and/or older or retired people have more time to fish, especially during business hours when the majority of the interviews were conducted. Comparatively few anglers were under 18 years of age. Interviewers were trained to not question people under 18 years of age. Those who were interviewed appeared at least 18 and their exact age was only learned at the end

of the interview. These individuals were included in the results due to the limited sample size and because information from young anglers is important because they are a sensitive population for mercury exposure. The majority of anglers encountered were men. Out of 151 individuals interviewed only 16 were of women, or 11%.

2. Health Hazard Awareness

Accuracy of Health Hazard Awareness Response

Anglers were asked if they had heard or seen any health warnings about eating fish. Interviewers were trained not to prompt the respondent at any time during the interview, especially when asking about awareness. Responses were recorded word for word and the level of health hazard awareness was later evaluated by reviewing responses to determine how many specific health issues were recalled. In analysis of answers, three specific health issues considered representative of accurate health hazard awareness were considered: species of fish for which warnings had been issued, demographic groups most at risk from mercury, and the recommended maximum number of meals of mercury-impacted fish species which can be safely eaten per month.

Results of this type are always difficult to interpret because respondents may not have told the interviewer everything they know. These results were analyzed in the same way that the Healthy Fish Coalition analyzed the responses to this question. A single scientist reviewed all questionnaires and coded them according to the accuracy of the response to the three aspects of health issue: species of fish, sensitive populations, and frequency of meals. For example, a response was given one point if their answer included some indication of pollution awareness, in the water, from mercury, or of the fish. A second point was given if a response included something related to children or pregnant women (eg. sensitive population). A third point was given if the response included some indication of how much should be eaten, such as two meals a month, or even “not very often.” Most respondents’ replies included one of these three issues, but very few included information on all three issues. If a response did not relate to any of these three issues or was inaccurate then it was included as “not accurate.”

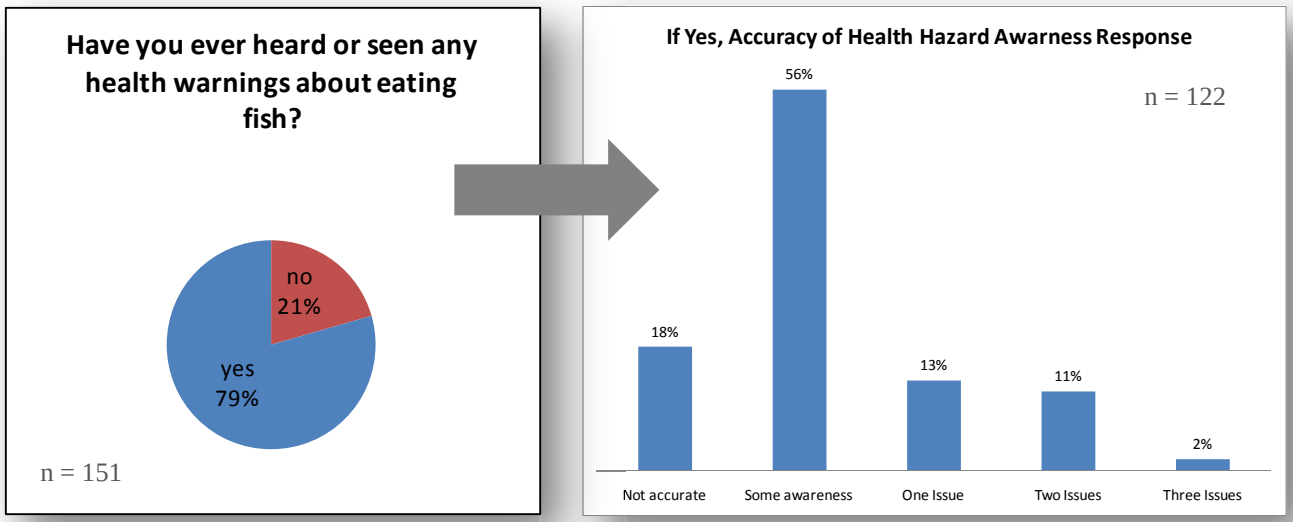


Figure 9: Level of Awareness of Health Warnings Regarding Sport Fish Consumption - Of all survey respondents (n=151) ,21% reported that they had never heard of seen any health warning about eating fish (n=31). When asked to provide details about the health warning, only 2% of respondents could correctly recall three aspects of the health warning (n=2). 18% could not accurately recall any aspect of the health warning (n=22), 56% had some level of awareness (n=68), 13% could correctly recall one aspect of the health warning (n=16), and 11% could correctly recall two aspects of the health warning (n=14).

Most people surveyed (79%) reported that they had heard or seen some type of health related warnings concerning fish consumption (Figure 9). Compared to other studies, 79% general awareness is relatively high. It was only 61% in the San Francisco Bay study, and 63% in the 2005 Delta pilot survey.

Figure 10: Fish Consumption Advisory at Lake Wildwood – This sign, erected by property owners, is posted near the dam at Lake Wildwood, the only public fishing access. It is one of only two fish consumption postings observed at targeted water bodies.

When asked to specify their knowledge, 56% of the respondents had some level of health hazard awareness such as awareness of mercury contamination, but did not identify any of the three specific issues looked for. Thirteen percent identified awareness of one of the three issues correctly. Twelve percent reported two issues correctly and only two percent reported three issues correctly. Eighteen percent of the responses were completely inaccurate.

Survey results regarding the level of accuracy of health hazard awareness indicate most respondents had some level of awareness of potential health hazards from fish consumption. However, the more detailed the level of awareness looked for, the fewer correct responses were provided. This indicates that Sierra anglers lack the specific information needed to make informed decisions to balance the benefits of eating fish with the risks of eating too much contaminated fish.

Trusted Health Information Sources

Survey respondents were asked where they get trusted information about health and what is good and bad for them. The most trusted source of information was health care providers, reported by 57% of respondents. In a 2006 survey of Sierra health clinics (and follow up interviews in 2011), The Sierra Fund found that none of the clinics surveyed used environmental health history forms or typically discussed fish mercury issues with patients, including maternal health patients (TSF, 2006). This may be because health care providers tend to be overworked or overwhelmed by other issues or have not been trained on this issue. After health providers, trusted sources included friends and family members, posted signs, fishing regulation handbooks, and to a lesser extent internet and television.

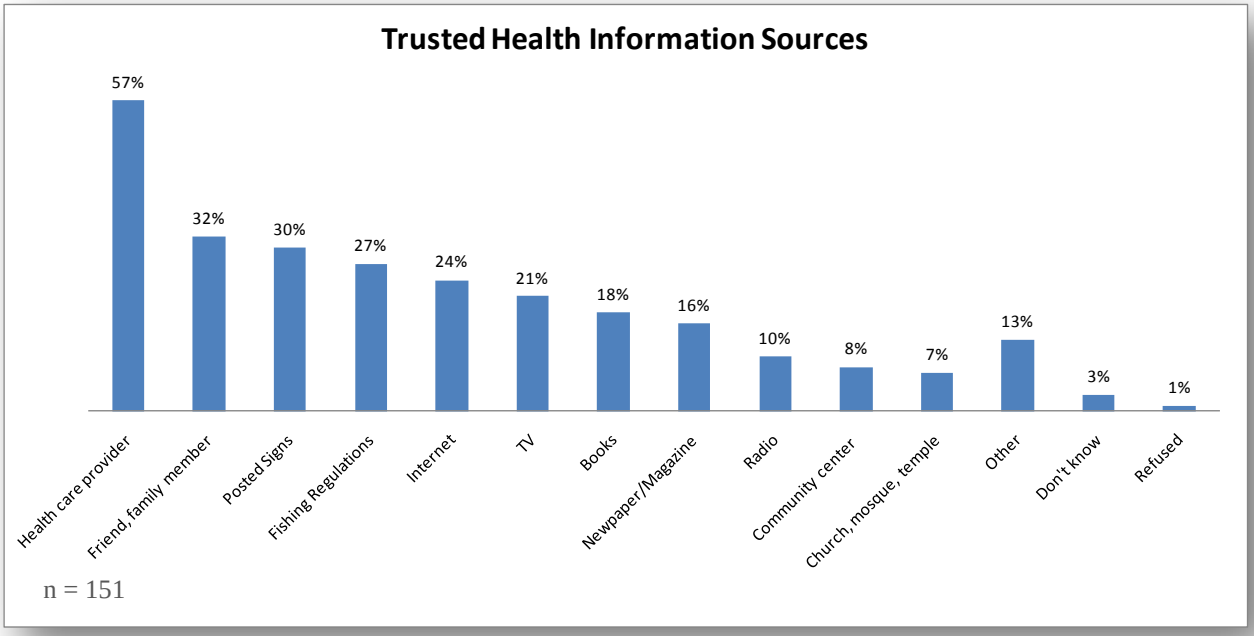


Figure 11: Sources of trusted health information - Out of the 151 survey participants, 86 trusted health care providers, 48 trusted friends and family, 46 posted signs, 41 fishing regulations, 36 trusted the internet, 32 trusted the TV, 27 books, 24 newspapers and magazines, 15 trusted the radio, 12 community centers, 11 church/mosque/temple, 20 said other sources than these, 4 said they did not know, and 2 refused to answer the question.

3. *Fish Consumption*

Consumption of Sport Fish

Nearly half (47%) of the people surveyed reported that they intended to eat the fish they caught that day. Of those who intended to eat the fish, 73% said they would also feed the fish to their families (Figure 12). Catch-and-release fisherman accounted for 51% of the survey respondents.

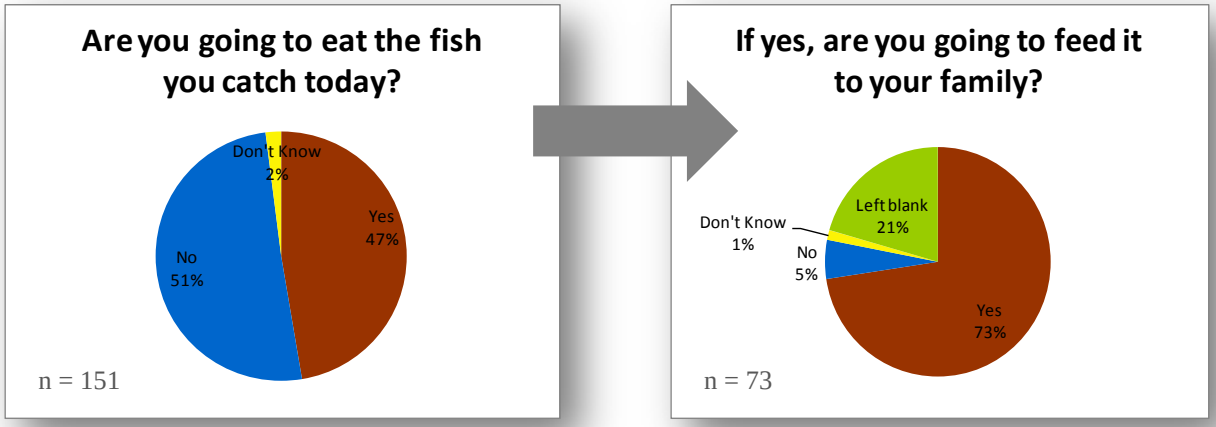


Figure 12: Fish Consumption vs. Catch and Release - Yes (n=71), No (n=76), three said they did not know, and one questionnaire was left blank. The follow up question "Are you going to feed it to your family?" was answered by 73 individuals: Yes (n=53), No (n=4), don't know (n=1), and blank (n=15).

The percentage of anglers who intended to eat the fish they caught (47% of those surveyed) was only slightly less than that found by other angler surveys conducted in the state. This may be because more catch and release anglers (51% of those surveyed) fish the Gold Country water ways. These results may also show some sample bias since many of the volunteers conducting the survey in 2009 were members of a fly fishing group and may have preferentially interviewed at locations where they (and other catch and release anglers) like to fish.

Of the 76 people who reported that they were not going to eat the fish they caught that day, 56 answered yes to the question: "Do you ever eat fish that you or someone you know catches?" The total number of people who reported ever eating sport fish was 132 out of 144 (seven questionnaires were left blank) or 92% of the people responding (Figure 13). This percentage includes sport fish caught in the Sierra as well as those caught elsewhere.

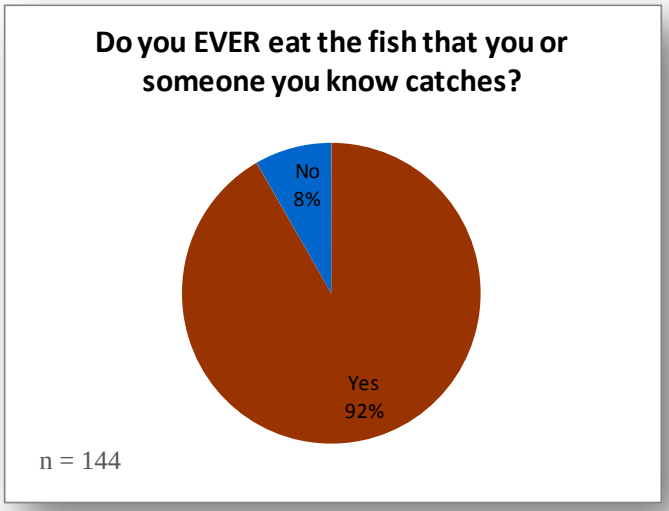


Figure 13: Sport Fish Consumption - All anglers, even those who were not going to eat the fish they caught that day, were asked if they ever ate sport fish that they caught or that was caught by others. Of the people who answered this question (n=144, because 7 surveys were left blank) 132 said yes (n=132, or 92%) and 12 said no (n=12, or 8%).

Fish Consumption by Species

Anglers who reported eating sport fish that either they or someone they know caught (total of 132 respondents or 92%) were asked to identify the species of sport fish they ate. Anglers were shown a color printed card to assist in accurately identifying fish species and could select more than one species.

The most popular reported species of fish eaten from Sierra Foothills water ways was trout (77% of respondents) and the second most popular was some species of bass (65%). The category "any species of bass" was added during the 2010 survey effort for people who did not know or distinguish which kind of bass they caught and was also selected for all anglers who mentioned eating one or more of the species of bass listed. Both bass and brown trout have relatively high mercury concentrations and are the subject of many fish consumption advisories. Other popular species included catfish (39%), kokanee salmon (39%), and crappie (28%). Percentages are out of 132, the number of survey respondents who answered yes to eating sport fish that either they or someone they knew caught (Figure 14).

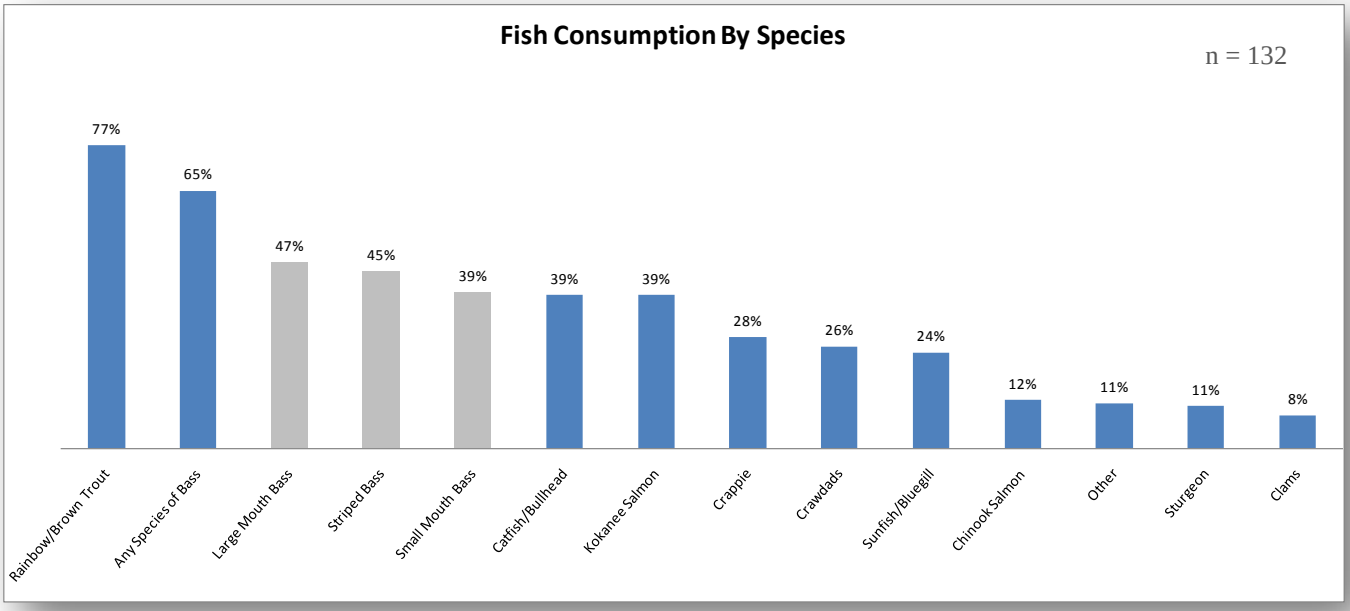


Figure 14: Fish Consumption by Species - Rainbow/brown trout (n=101), any species of bass (n=86), largemouth bass (n=62), striped bass (n=59), smallmouth bass (n=52), catfish (n=51), kokanee salmon (n=51), crappie (n=37), crawdads (n=34), sunfish/bluegill (n=32), chinook salmon (n=16), other (n=15), sturgeon (n=14), and clams (n=11). Percentages are out of 132, the number of respondents who said they ate fish that either they or someone they know caught.

For the 2010 survey effort the distinction between rainbow trout and brown trout was introduced and 52 of the 78 surveys collected in 2010 reported eating brown trout, for an estimated 67% of anglers. This is significant because unlike rainbow trout, brown trout are predatory and therefore typically have higher levels of mercury than rainbow trout.

For each type of fish that an angler reported eating, follow up questions were asked about the amount of fish consumed, and where that fish was caught. This allowed the survey to consider the angler's mercury exposure, and whether that exposure was from eating fish caught in the Gold Country.

Portion Sizes and Amount of Sport Fish Consumed Per Person

Anglers were asked how much fish they ate per meal and how many meals they ate in the last 30 days. Thirty days was considered the time range that most people could accurately remember what they had eaten and was commonly used in other angler surveys. OEHHA fish consumption guidelines are calculated based on an 8 oz (uncooked) serving size. To determine typical serving sizes, interviewers showed anglers plastic models of uncooked fish fillets and asked participants to identify their typical serving size of uncooked fish. The plastic models were provided by CDPH and were made from the same molds used in their 2005 study. The models represented uncooked fish in 1.5 oz, 4.5 oz and 7.5 oz serving sizes.

Some anglers reported eating large portion sizes, as much as 15 to 22.5 oz at one meal, which is two or three 7.5 oz fish portions, but the average reported meal size of all anglers was 6.9 ounces, within the OEHHA guidelines of six to eight ounces. High consumption anglers were identified by the survey as those who ate considerably more meals per month than are consistent with OEHHA guidelines and thus may be exposed to greater amounts of mercury than is considered safe (Figure 15).

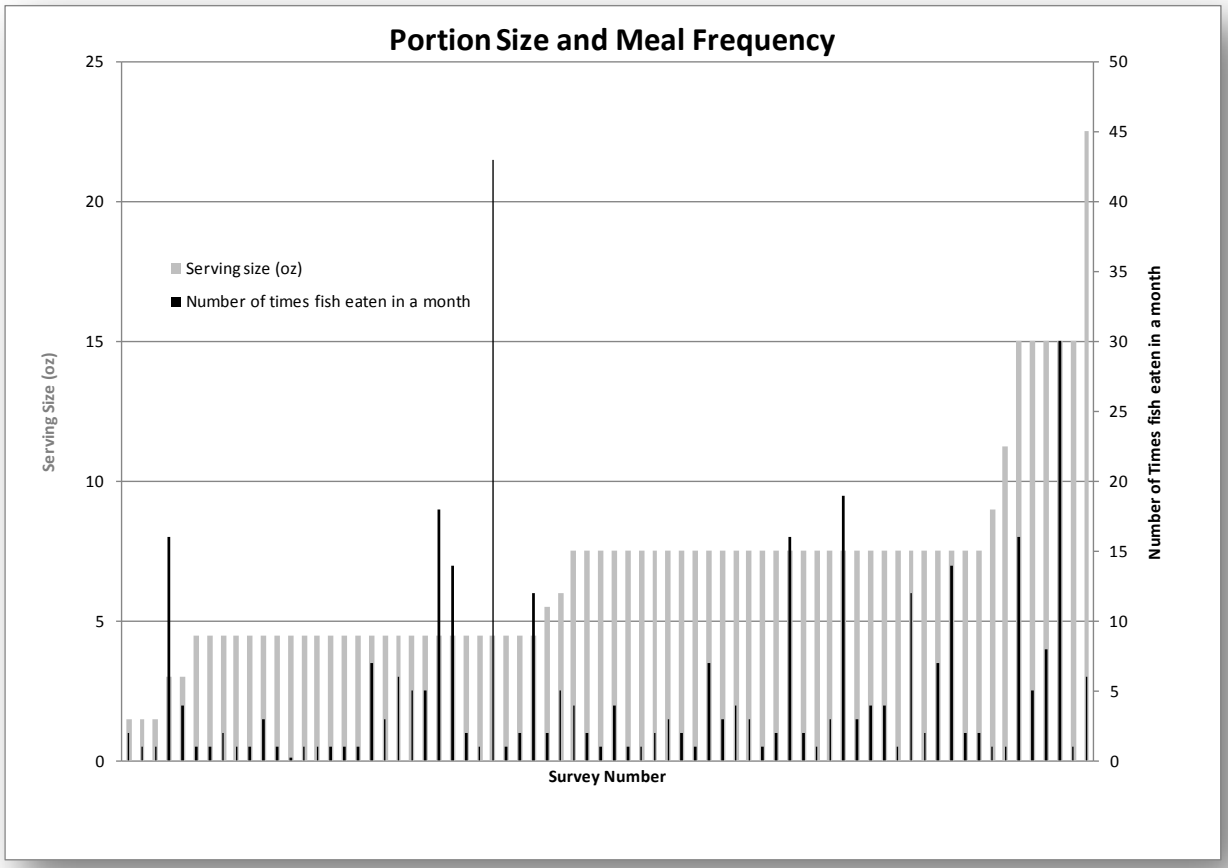


Figure 15: Portion Size and Meal Frequency - Gray bars represent serving size of fish portions (oz) of each surveyed individual. The largest reported serving size was 22.5 oz. Thin black bars represent number of meals the participant reported eating during the previous month. The greatest number of meals was 40 in a month.

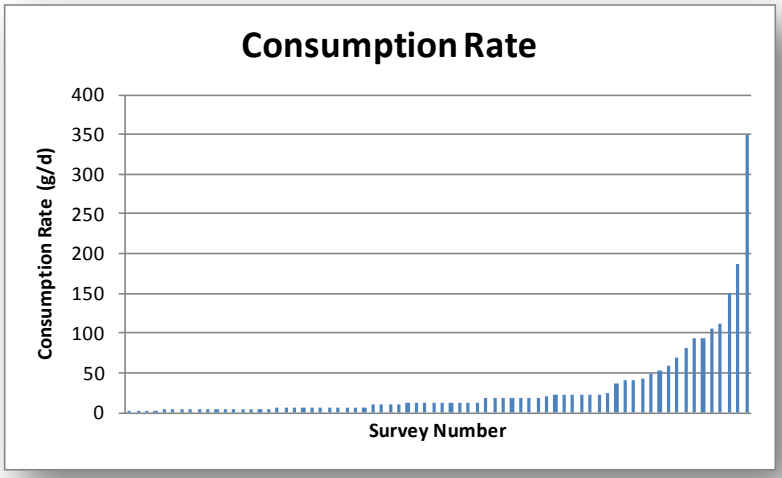


Figure 16: Consumption Rates (g/day) - Consumption rate is the combination of meal size (g of fish/meal) and meal frequency (meals/month) into a more commonly used metric of grams/day. The highest consumption rate was 350 g/day (15 oz/day). The average consumption rate was 30g/day.

The number of meals per month varied greatly among anglers. One angler ate 40 sport fish meals in a month, but the majority ate fish one to two times a week or four to eight times a month. The combination of these two variables is captured in Figure 16, Consumption Rate in grams per day, a more common measurement for public health professionals. The average consumption rate was 30 g/day, and the maximum was 390 g/day, an individual who reported eating 15 ounces in a day, every day over the course of a month.

Household Consumption Information

Anglers who answered yes to eating sport fish that they or someone they knew caught were asked a series of questions regarding which demographic groups in their household had also eaten fish they or someone they know had caught in the past year. Survey results indicate a relatively large percentage (50%) of anglers who eat the fish they catch also feed the fish to children in their household under the age of 18. A slightly larger percentage (54%) feed the fish they caught to women of childbearing age in their household. Just six percent had fed the fish they catch to pregnant or nursing mothers in the past year (Figure 17). This may reflect a greater awareness about the dangers of fish consumption for pregnant and nursing mothers.

These results are of concern since these three groups have the greatest health risk from mercury exposure. The results suggest there is a low level of awareness of the dangers associated with eating mercury-contaminated fish especially for children and women of child bearing age.

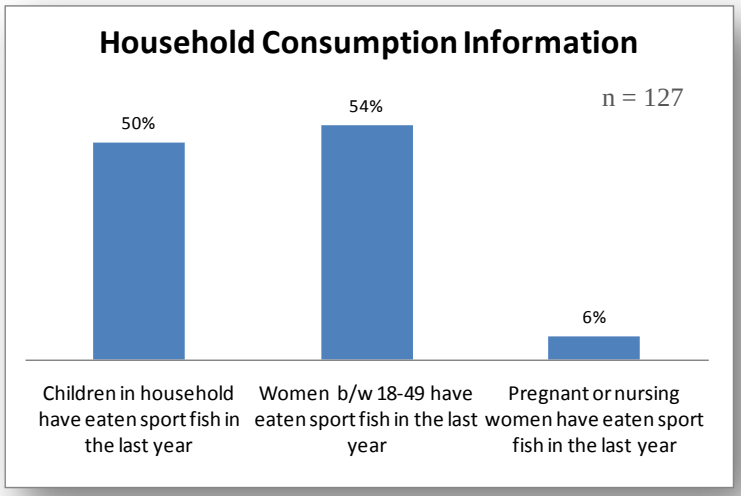


Figure 17: Household Demographics and Sport Fish Consumption - From anglers who eat the fish they or someone they know catches (n=127), the number who reported children in their household that also eat sport fish is 50% (n=64), women between the ages of 18-49 is 52% (n=69), and pregnant or nursing women is 6% (n=7).

Methylmercury Exposure from Sport Fish

In order to learn if anglers were eating fish within safe exposure guidelines an estimated amount of methylmercury in each species of fish was compiled, and used to calculate the approximate exposure of each survey participant based on answers to questions about fish consumption in the past 30 days.

To complete this analysis, the following three steps were followed:

1. Determine methylmercury levels in each species of sport fish
2. Calculate exposure of each survey participant
3. Compare results to OEHHA safe levels

1. Determine Methylmercury Levels in Sport Fish

Fish contamination data provided by the Central Valley Regional Water Quality Control Board (CVRWQCB) current database was used to estimate the level of methylmercury in Gold Country sport fish (Table 2). The database was populated with fish mercury data from the State Water Board's Surface Water Ambient Monitoring Program (SWAMP), FERC relicensing projects, and other projects. These data were also used in the 2008-2010 303(d) listing process.

Table 2: CVRWQCB 2010 Average Fish Mercury Concentrations for Gold Country Angler Survey Water bodies

Fish Species	**n**	**Mean** (ppm)	**SD**	**Length** (inches)	**Location of fish samples (**CFW=Camp Far West; LWW=Lake Wildwood; Yuba= Lower Yuba, North Fork, and/or South Fork)
Bluegill	12	0.19	0.09	> 6	Folsom, CFW, Combie, Rollins, Scotts Flat
Brown Trout[1]	146	0.22	0.18	>6	American, Bear, Deer Creek, Yuba, and Feather Watersheds
Catfish	31	0.75	0.28	> 6	Folsom, CFW, Rollins
Chinook Salmon	11	0.59	0.27	>6	Folsom
Crappie[2]	5	0.31	0.10	>8	Delta, Lower Sacramento River
Largemouth Bass	95	0.64	0.20	>6	Folsom, CFW, Combie, Rollins, Scotts Flat, LWW, Englebright
Rainbow Trout	76	0.14	0.09	>6	Folsom, Combie, Deer Creek, Scotts Flat, Englebright, Yuba
Smallmouth Bass	33	0.65	0.15	>6	Folsom, CFW, Rollins, Englebright, Yuba
Spotted Bass	53	0.73	0.18	>6	Folsom, CFW, Rollins, Englebright, Yuba
Striped Bass[3]	18	0.89	0.49	>6	American River below Nimbus, Lower Feather
Sturgeon[4]	11	0.27	0.24	>48	Lower Sacramento River
Sunfish	4	0.17	0.13	>6	Folsom, Scotts Flat, Englebright

[1] Because of limited brown trout data for targeted water bodies, the average value in Table 2 is taken from data covering a much larger region in the Sierra Nevada.
[2] The only crappie data from the targeted water bodies was a single fish from Rollins Reservoir which has a value of 0.31ppm, therefore the value used was from Shilling et al. 2010.
[3] Although striped bass are uncommon in the targeted Gold Country water bodies, anglers reported eating it. This value is taken from CVRWQCB data in the lower American and Feather River watersheds.
[4] There were no data for sturgeon in the targeted water bodies. The value in Table 2 was used from Shilling et al. 2010.

Table 2 includes data compiled by CVRWQCB from almost 30 years of measurements of mercury in various fish species up to 2010. To construct this table, CVRWQCB calculated average total mercury concentrations (parts per million or micrograms/gram) for each target species. Of the total amount of mercury found in fish muscle tissue, methylmercury comprises more than 95 percent (ATSDR, 1999; Bloom, 1992). For the purpose of this exposure analysis it was assumed that 100 percent of the mercury in fish tissue is in the form of methylmercury.

Best professional judgment was used to select the most appropriate fish mercury concentration for use in this exposure analysis since there is a relatively limited data set for surveyed water bodies, and to a lesser extent the Sierra Nevada region. For brown trout, no data were provided from target water bodies, so the mercury value was an average of brown trout data provided by the CVRWQCB for the greater Sierra Nevada region. This included data from the American, Bear, Deer Creek, Yuba and Feather River watersheds for a total of 146 samples. For crappie and sturgeon, values were used for fish caught in the Delta and Lower Sacramento River, since data from the Sierra Nevada region was not available.

In an effort to promote regional comparisons and relate findings of this study to other research efforts, fish mercury averages from targeted Gold Country water bodies were also compared to the fish mercury levels used in the similar angler survey effort in the San Francisco Bay/Delta, published by Shilling et al. 2010. Table 3 compares the two sets of data. With the exception of bluegill and largemouth bass, Gold Country averages were higher than those from Bay/Delta water bodies.

Table 3: Fish Mercury Data from Targeted Water Bodies Compared to the Bay/Delta

Fish Species	**Gold Country Fish Mercury Data** (CVRWQCB)				**Bay/Delta Fish Mercury Data** (Shilling et al., 2010)			
	n	**Mean** (ppm)	**SD**	**Length** (inches)	**n**	**Mean** (ppm)	**SD**	**Length** (inches)
Bluegill	12	0.19	0.09	> 6	10	.208	.125	>6
Brown Trout	146	0.22	0.18	>6				
Catfish	31	0.75	0.28	> 6	44	.424	.251	>12
Chinook Salmon	11	0.59	0.27	>6	25	.09	.03	>26
Crappie	5	0.31	0.10	>8	5	0.309	0.104	>8
Largemouth Bass	95	0.64	0.20	>6	63	.774	.324	>12
Rainbow Trout	76	0.14	0.09	>6	12	.061	.014	>18
Smallmouth Bass	33	0.65	0.15	>6				
Spotted Bass	53	0.73	0.18	>6				
Striped Bass	18	0.89	0.49	>6	47	.545	.318	>18
Sturgeon	11	0.27	0.24	>48	11	.271	.241	>48
Sunfish	4	0.17	0.13	>6	14	.182	.097	>8

The small sample size and high range of variability in fish mercury levels, even among the water bodies targeted by this survey, indicate that more fish data are needed from Gold Country water bodies to accurately calculate the methylmercury exposure from sport fish consumption. This high variability could be the result of site history (mining intensity) of the water bodies and/or due to different life history patterns of fish. For example, resident salmon in Folsom Reservoir have an average mercury concentration of 0.78 ppm, whereas anadromous salmon below Nimbus Dam would likely have an

average mercury concentration similar to Delta salmon, or 0.09 ppm. Additionally the average value for largemouth bass in Lake Combie was 0.907 ppm whereas Lake Englebright had an average of 0.35 ppm.

2. Calculate Exposure of Gold Country Angler Survey Participants

The Gold Country Angler Survey included the following questions in order to determine the methylmercury exposure of individual survey respondents:

- How much sport fish he or she consumed in the last 30 days
- Which species of sport fish were consumed
- Where the fish had been caught[5]
- Typical serving sizes

The 2010 survey also included the following questions:

- How much of what kinds of commercially bought fish he or she consumed in the last 30 days
- Participant's body weight

To calculate the methylmercury exposure from sport fish, the number of times the survey participant reported eating a particular species of sport fish in the last 30 days was multiplied by reported portion sizes and the average mercury concentration determined for that species (as indicated in Table 2). This calculation was performed for each species of fish the participant reported eating in the last 30 days. Resulting values were added to achieve a cumulative total. The result was the approximate amount of mercury consumed by the individual, measured in micrograms per day.

An example calculation for an individual who reported eating two 7.5 oz meals of rainbow trout and one 7.5 oz meal of largemouth bass in the last 30 days:

TROUT: 7.5 oz/meal * 2 meals / 30 days * 28.35 g/oz * 0.14 µg Hg/g = 1.98 µg Hg /day
BASS: 7.5 oz/meal * 1 meal / 30 days * 28.35 g/oz * 0.64 µg Hg/g = 4.54 µg Hg /day

TOTAL: 1.98 µg Hg /day of trout + 4.54 µg Hg /day of bass = **6.52 µg Hg /day**

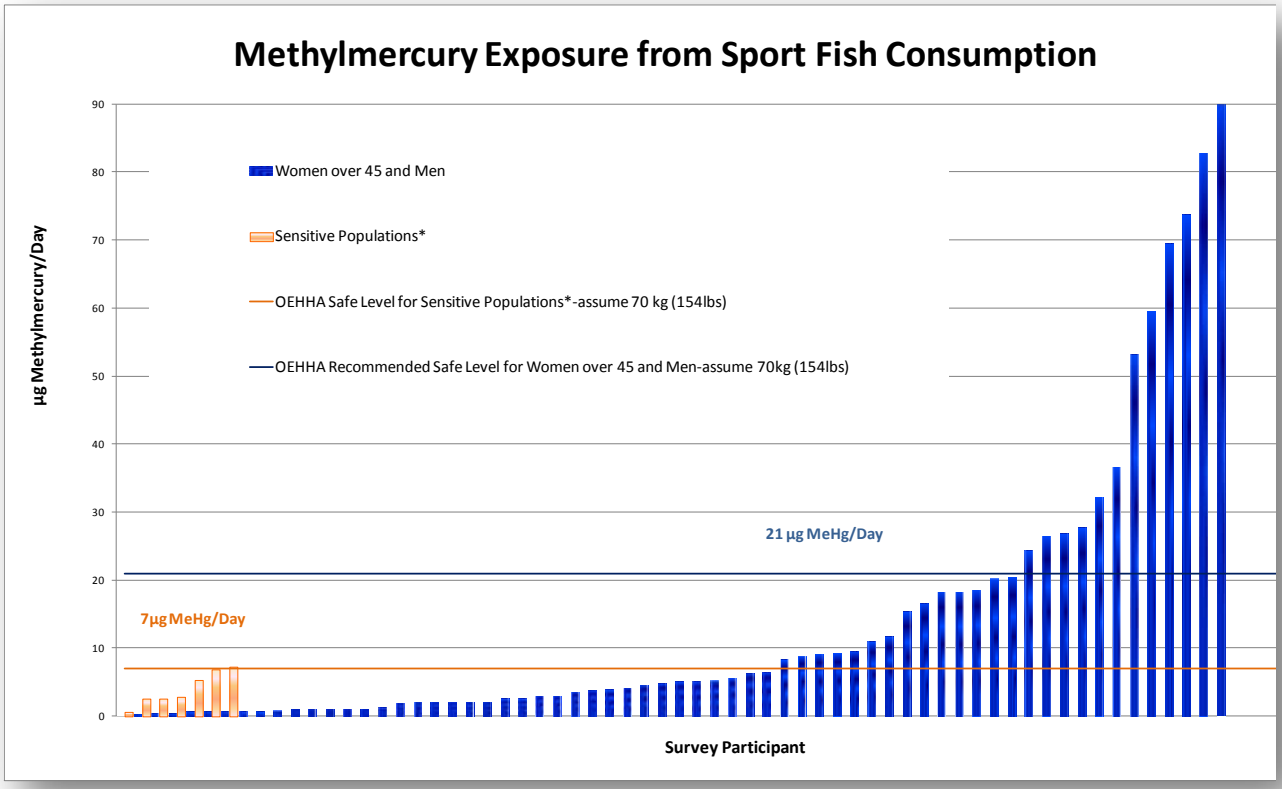
3. Compare Participants' Exposure to OEHHA Safe Consumption Levels

According a 2008 OEHHA report on the development of sport fish advisories, the OEHHA recommended safe levels of methylmercury exposure are 0.1 µg of mercury/kg of body weight per day for women aged 18 to 45 years and children under 17 years, and 0.3 µg of mercury/kg of body weight per day for women over 45 years and men (OEHHA, 2008). The safe level of exposure depends on each individual's body weight.

[5] Although anglers were asked where the fish were caught, this information was not used in the calculation of methylmercury exposure because of the limited site-specific data.

In order to compare calculated levels of methylmercury exposure from this survey to OEHHA standards, a standard body weight was assigned of 70 kg (154 lbs) for all adults, and children were assigned half that weight or 35 kg (77 lbs). OEHHA fish advisories are based on these weights. There are separate safe exposure levels for men as compared to women of child bearing age and children because developing fetuses and children are more sensitive to the harmful effects of methylmercury than adults.

Adult weight was used for mercury exposure calculations for all participants. Therefore, the safe exposure level assuming a body weight of 70 kg (or 154 lbs) is 21 µg of mercury/day for women over 45 years or men, and 7 µg of mercury/day for women under the age of 45. A child's safe exposure level must be calculated using the standard weight of 35 kg (or 77lbs) and only 0.1 µg of mercury per kg of body weight, resulting in a limit of 3.5 µg of mercury/day for children. This level is not shown in Figure 18, because children were not surveyed.



* Sensitive Populations are considered by OEHHA to be women aged 18 to 45 and children under 17.

Figure 18: Methylmercury exposure from Sport Fish - This graph displays the calculated methylmercury exposure for all anglers who reported eating sport fish in the previous 30 days. The majority of the anglers were within the safe eating limits, while thirteen anglers were above safe eating limits, and one person was more than four times the recommended safe exposure level. One member of the sensitive populations (orange bars) was above the recommended safe exposure level.

In Figure 18, each bar represents the calculated exposure level of a single survey respondent. Men and women over 45 who were surveyed are represented in dark blue bars. Women younger than 45 or all individuals under the age of 18 (of which there was one) are represented in light orange bars. The

OEHHA recommended safe level of exposure for men is the dark blue line at 21 µg Hg/day. The OEHHA recommended safe level for women under 45 is the orange line at 7 µg Hg/day.

Results of this evaluation suggest that the majority of the Gold Country Angler Survey respondents are not exposed to dangerous levels of methylmercury through eating sport fish, however the exposure potential remains high. Calculations show that 9% of the surveyed anglers (n=151) consumed more mercury than state and federal guidelines recommend. Although the sample size is small, these results clearly point to the need for more surveys, especially from sensitive populations, and more outreach to the fishing population.

The highest calculated exposure to methylmercury from sport fish consumption was 90 µg methylmercury/day, more than four times higher than the recommended exposure level, the next highest was 83 µg methylmercury/day, also four times higher than the recommended level. The highest level of mercury exposure was from a man interviewed at Nimbus Dam on the American River in July 2010. He was a Caucasian who ate bass five times in the last month and also crappie one time in the last month. His typical serving size was two or three 7.5oz portions each meal. The second highest level of mercury exposure was from a Native American man interviewed at the South Yuba River in 2009. He had eaten chinook salmon eight times in the last month and rainbow trout eight times in the last month. His typical serving size was two 7.5 oz portions.

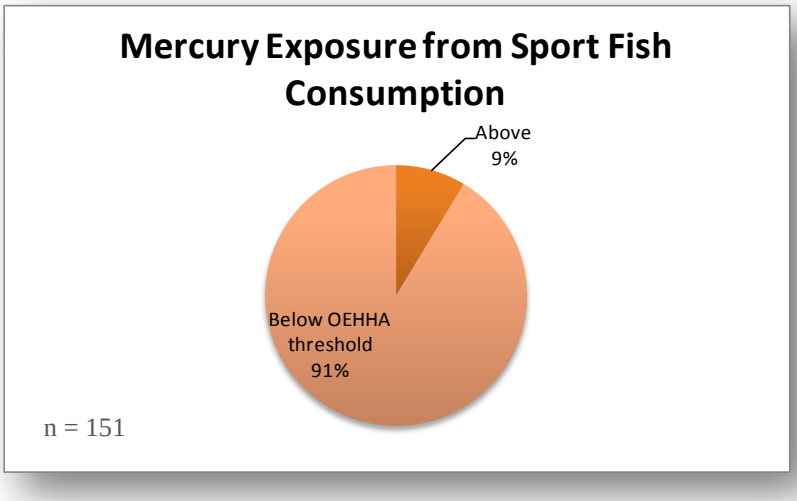


Figure 19: Mercury Exposure from Sport Fish Consumption Results of all surveyed anglers (n=151) indicated that 9% (n=13) were exposed to methylmercury from sport fish consumption at levels that were above OEHHA safe eating guidelines of 21µg/day (women over 45 and men) or 7µg/day (sensitive population s including women younger than 45 and men younger than 18).

The next four highest exposure levels from sport fish consumption (74, 70, 60, and 53 µg MeHg/day), between two and four times the recommended levels, were from individuals interviewed at Nimbus Dam on the American River. They were all males 170-200 lbs, three were Caucasian and one was Hmong. They all ate bass, and one ate sunfish/bluegill and crappie every day and another ate 15 oz of rainbow trout every day.

Almost as high (37 µg methylmercury/day) was a single fisherman at Scotts Flat Reservoir who reported eating bass, sunfish/bluegill and trout more than six times a month and ate a single 7.5 oz as a typical serving.

The highest level of exposure calculated from the 2009 survey responses was 21.94 micrograms of methylmercury per day, just over the recommended safe level. This person was a Hmong man between

the ages of 39 and 45 fishing at Lake Wildwood, who reported eating largemouth bass at least four times a month. He was observed fishing with a group of five Hmong men and women who had caught a stringer of large-sized largemouth bass which they indicated they planned to eat.

Additional Calculation: Methylmercury Exposure from Commercial Fish

Exposure to methylmercury through the consumption of commercial fish was not considered in the above analysis, therefore participants' actual methylmercury exposure may be higher still. In an effort to learn whether participants' total mercury exposure was within safe levels, the 2010 survey effort added questions to quantify commercial fish consumption. Of the 72 interviews conducted in 2010, 34 answered yes to eating commercially bought fish, almost 50%.

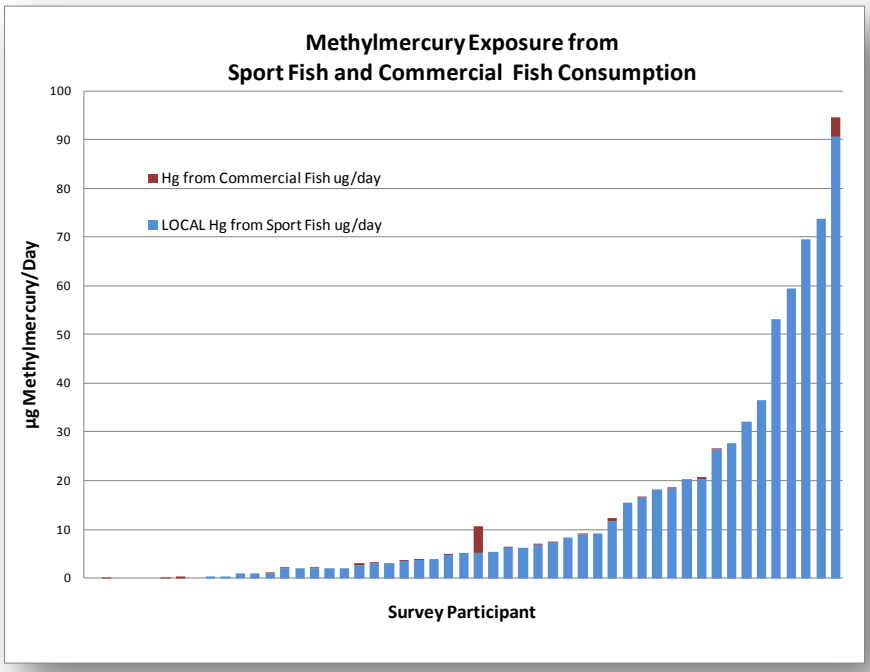


Figure 20: Mercury exposure from sport fish and commercially bought fish – This graph shows mercury exposure of individuals surveyed in 2010 field season only, and only the top 50 exposure levels from 2010 are displayed here.

The responses from 2010 survey participants show that the commercial fish most commonly eaten among those surveyed were albacore and canned tuna, salmon, fish sticks (cod), and halibut. The mercury levels in these fish (Table 4) were obtained from the GotMercury.org online mercury calculator (http://www.gotmercury.org). It should be noted that chunk light tuna typically has less mercury (0.118 ppm) compared to canned albacore (0.353 ppm). Results of calculations of participants' mercury exposure considering both commercial and sport fish (Figure 20) show that the majority of exposure was from sport fish, but commercial fish consumption is an important factor in determining whether individuals who eat sport fish are exposed to dangerous levels of mercury.

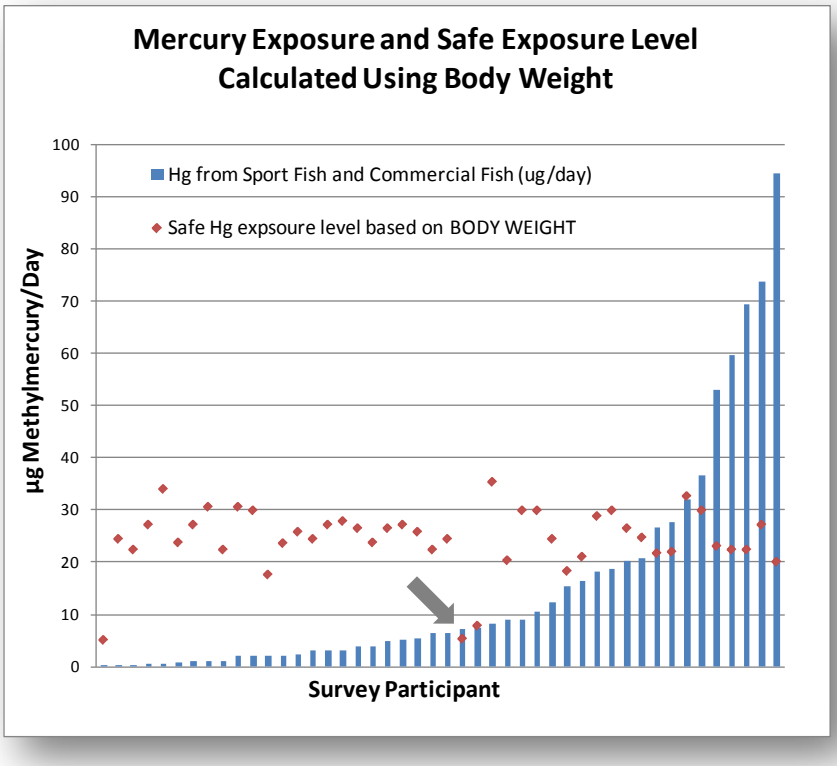
Table 4: Average Mercury Concentrations in Commercial Fish (GotMercury.org)

Commercial Fish	Hg (ppm)
Albacore	0.357
Canned Tuna	0.353
Salmon	0.014
Sticks	0.095
Halibut	0.252

Additional Calculation: Mercury Exposure Based on Weight

Calculating an individual's mercury exposure based on a default weight is problematic in some cases, particularly for women. If adults were less than 154 lbs then they may be exposed to methylmercury above recommended levels, because OEHHA uses this default weight for their calculations. The reported weight of anglers was recorded during 2010 survey efforts in order to determine if this was a potential issue.

In the 2010 survey effort, respondents were asked their body weight and it was recorded as an exact weight rather than a category. Using this information, the OEHHA safe exposure level was calculated for each individual. This calculation used OEHHA recommended safe levels of methylmercury exposure of 0.1 µg of mercury/kg of body weight per day for women aged 18 to 45 years and children under 17 years, and 0.3 µg of mercury/kg of body weight per day for women over 45 years and men (OEHHA, 2008).



These calculations show that fish consumption advisories based on the default weight of 70 kg are for the most part protective of public health. One exception (indicated by the arrow) was a young woman who weighed 120 lbs. Her safe exposure level using her body weight was 5.4ug/day, less than the default safe exposure level of 7 µg/day, while her mercury exposure from fish consumption was 7.9 µg/day.

Figure 21: Mercury Exposure and Safe exposure level calculated using body weight - Mercury exposure from fish consumption compared to safe consumption guidelines calculated using participants' bodyweight. Results are presented for the top 50 exposure levels from 2010 survey respondents.

SUMMARY AND RECOMENDATIONS

The *Gold Country Angler Survey* was a project of The Sierra Fund's Reclaiming the Sierra Initiative. Its purpose was to stimulate awareness, research and policy reform to address the issue of mercury-contaminated fish in the Sierra Nevada. Interviews were conducted to learn whether people who eat sport fish caught in Sierra Nevada waters are being exposed to mercury from historic mining activities. Survey results indicate that a significant percentage (92%) of Sierra anglers are consuming the fish they catch, and some (9%) are consuming methylmercury at levels above the OEHHA safe eating guidelines. Collection of additional local fish mercury levels and angler survey data is warranted in order to more accurately quantify methylmercury exposure from sport fish consumption.

Results Summary

Anglers were encountered and interviewed at all targeted water ways with the exception of the Bear River and Lake Combie. Between 15 and 33 interviews were conducted at Rollins Lake, Scotts Flat Reservoir, Camp Far West Reservoir, Lake Englebright, the American River below Nimbus Dam, and Lake Wildwood. Completion of interviews in the Sierra Nevada was time intensive compared with more populous areas since anglers were often spread out and seldom fish in groups. With a total of 151 interviews this study should not be considered a comprehensive overview of anglers in the Gold County, but is more accurately considered a pilot study. Because the participant cohort was small, it is difficult to make regional conclusions, especially in regards to sensitive populations.

The results of the survey questions can be summarized into three categories:

- Angler Demographics
- Advisory Awareness
- Fish consumption

Demographics Results Summary

The ethnicity of the anglers surveyed was predominantly Caucasian and nearly equally split among age groups 18-34, 35-49, and 49 and over. Notable exceptions were the groups of Hmong anglers fishing at Lake Wildwood and Nimbus Dam, and Native Americans who were interviewed at the Indigenous Peoples Day event in Nevada City.

Advisory Awareness Results Summary

Although most respondents had some level of awareness of health hazards associated with sport fish consumption and mercury exposure, reported knowledge of specific factors tended to be vague or inaccurate. These results suggest a lack of awareness of the specific information needed to make informed health decisions to balance the benefits of eating fish with the risks of eating too much mercury-contaminated fish.

Posted fish consumption advisories were not observed at most of the water ways where consumption advisories were in effect and interviews were conducted. The two postings observed (at Lake Wildwood and Lake Englebright) were either difficult to understand, lacking in specific information, or were relatively small and inconspicuous.

The most commonly reported trusted sources of health hazard information were health care providers, followed by friends and family and posted signs. Recent research suggests that health care providers in the Sierra Nevada region do not typically disseminate information regarding the health risks from consuming sport fish contaminated with mercury and generally do not ask their patients about their fish consumption habits (TSF, 2006). Survey results point to health care providers as the most trusted way to increase health hazard awareness among people who eat locally caught fish.

Fish Consumption Results Summary

Over 90% of the anglers surveyed reported eating the fish they catch. Of those who were planning to eat the fish they caught that day, nearly three quarters (73%) of those intended to feed the fish to their families: approximately half said they feed the fish they catch to children under the age of 18 (50%), and/or to women of child bearing age (54%). These groups are most at risk from the health impacts of eating mercury-contaminated fish. One of the most popular fish eaten was bass, which tends to have elevated mercury concentrations and is the subject of numerous fish consumption advisories. People reported eating fish from all the water ways where interviews were conducted, particularly from the larger reservoirs such as Rollins Reservoir, Camp Far West, Upper Scotts Flat Reservoir, and Lake Englebright.

Fish portion sizes reportedly eaten by survey respondents were generally consistent with portion sizes used by OEHHA to develop fish consumption advisories (average 6.9 oz). However, certain anglers reported eating significantly larger portions, as much as 15 to 22 ounces in a single meal, and certain anglers reported eating more meals per month (up to 40 per month) than the advisories recommend.

Results of calculations performed to estimate the amounts of mercury consumption by specific survey respondents show that 9% of anglers exceeded state guidelines for mercury intake, and some anglers were exposed to four times safe levels. Results of this evaluation suggest that the majority of the Gold Country Angler Survey respondents are not exposed to dangerous levels of methylmercury through eating sport fish, however the exposure potential remains high.

Recommendations

Based on the results of the Gold Country Angler Survey, The Sierra Fund has developed five recommendations for action that will help protect the public and reduce consumption of contaminated fish:

1. Post signs at fishing locations
2. Collect fish mercury data
3. Conduct additional angler surveys
4. Increase funding for outreach to better inform the public about risks
5. Reduce mercury in aquatic ecosystems by remediating abandoned mines

1: Post Signs at Fishing Locations

Post existing fish consumption advisories. Fish consumption advisories need to be posted as signs at all popular fishing locations on water ways where OEHHA advisories are in effect. Posting efforts should include partnerships with property owners, fishing groups and state and local government agencies and should be sensitive to all concerned parties. Signs should be clear and understandable, and presented in English as well as other languages if non-English speakers are known to fish at that location.

Clarify jurisdiction for posting fish consumption advisories. Although posting existing fish consumption advisories is a simple, relatively inexpensive and extremely important task, it has not been done because it is currently unclear which entity, agency or department is responsible for posting fish advisories in the field. A policy mandate and budget is needed for either a state or local agency to implement posting of existing advisories.

Provide information in areas where advisories do not yet exist. Information also needs to be present in areas where fish consumption advisories have not yet been established, due to insufficient fish data. A general fish consumption guideline based on existing knowledge could be developed for the Sierra region, where the presence of mercury from historic mining is widespread, and generally the same species of fish are found. This general advisory should be posted at any and all Sierra water bodies were anglers are present in order to improve awareness. Landowners should be encouraged to post through education and incentives.

2: Collect Fish Mercury Data

Collect fish data to complete fish consumption advisories. More fish need to be tested from Sierra Nevada water ways so that fish advisories can be issued for all relevant species of fish. Fish sampling should be conducted in all the water bodies where fish are caught and eaten. Enough fish samples should be taken of each species and from each location to learn whether OEHHA fish advisories are warranted.

Use water body-specific fish data to calculate human exposure. Additional fish data from Sierra water bodies will improve estimates of mercury exposure for Sierra anglers, since fish from these water bodies may have different mercury levels than those from other areas of the state or region. This information is important for human health research, as well as providing a basis for remediation projects, and mercury regulations including TMDLs.

3: Additional Angler Surveys

Collect more surveys. Additional angler surveys are needed from the Sierra Nevada region to substantiate these results. A larger number of survey participants (200-300) would enable a more accurate assessment of fish consumption patterns at specific locations and estimates of methylmercury exposure. Lessons learned from this process (see Appendix A) should be considered in planning other survey efforts. Future surveys should focus on the following locations and populations:

- **Target reservoirs.** Survey results suggest that reservoirs have the highest concentrations of anglers and the most anglers likely to be eating the fish they catch. Future survey efforts should concentrate on reservoirs to increase their efficiency. In particular, more effort should be spent in the American River watershed since some of the highest consumers of mercury found by this study were fishing below Nimbus Dam. Conducting more surveys early in the spring, in the early morning hours, and from boats would provide more representative data from reservoirs.

- **Expand geographical scope.** Additional angler surveys should be conducted in other areas of the Sierra Nevada in order to determine if the impacts identified in the Northern Sierra region are present in other areas where similar historic mining activities and demographic conditions exist. Locations for future surveys should include water ways downstream of historic hydraulic mining that therefore have the potential for mercury contamination. Other areas where historic mining impacts are known but where fish advisories have not yet been developed (possibly due to insufficient data) should be considered, including the upper American, Cosumnes and Mokelumne River watersheds in El Dorado, Amador and Calaveras Counties.

- **Target sensitive populations.** Not enough individuals from sensitive populations were contacted by this study to draw conclusions about their mercury exposure from sport fish. A different approach may be needed to gauge exposure of sensitive populations since findings show that there are relatively few women present at fishing locations. Additionally, to gauge exposure of children, specific questions would need to be directed to parents. This population could be targeted through an interview conducted door-to-door or at health clinics that asked most of the same questions.

- **Target ethnic groups.** During future surveys, more effort should be made to identify fishing activities by non-Caucasian ethnic groups. Interviewers should be recruited who are bilingual in Spanish, Hmong or other languages. During future surveys it would be advisable to request help from the Southeast Asian Assistance Center in contacting at risk groups and translating the questionnaire.

Calculate mercury exposure with water body-specific values for Sierra fish. Water body-specific fish mercury data would improve the accuracy of future exposure calculations for anglers. Average fish mercury levels created using small data sets from multiple water ways do not accurately represent exposure because of significant regional variability. This variability warrants water body-specific exposure calculation, rather than region-wide averages. More fish data are needed from local water ways to complete the data set for Sierra fish.

Coordinate with other research efforts. Expanded and future surveys should coordinate with ongoing or proposed research in associated areas including:

- Development of Total Maximum Daily Loads (TMDLs)
- Assessments of mercury concentrations in specific fish species from individual water ways
- Assessments of mercury levels in humans

Information from these and other sources as well as improved survey techniques, such as increasing survey participation (greater number of completed interviews), a consistent design for covering

locations, times of day and days of the week, and structural/content improvements to the questionnaire as described in the lessons learned (Appendix A), will allow better estimates of actual mercury exposure from a statistically representative population, and document a critical pathway in the fate and transport of mercury from the environment to human exposure.

4: Increase funding for outreach to better inform the public about risks

Increase overall public awareness. In order to address the general lack of health hazard awareness identified in this survey, additional public outreach should be performed to increase awareness of the health risks associated with eating fish high in mercury. Health care providers should be informed and assisted in providing accurate information. An education program in local schools and Public Service Announcements for television, radio and internet may improve public awareness in the long term. Region-specific educational programs should be coordinated with additional survey efforts.

Increase awareness of policymakers. Local, state and tribal leaders need to know about the problems existing from historic gold mining, particularly the dangers of eating mercury-contaminated fish and the fact that a large population of people are eating these fish. Policymakers need to take action to encourage cleanup of water ways, public education efforts, and additional data collection.

Advocate for funding. Funding is critically needed for the outreach programs described above. Funding is needed for posting of existing advisories, fish data collection for development of comprehensive advisories, and public education and posting efforts.

5: Reduce Mercury in Aquatic Ecosystems by Remediating Abandoned Mines

The sources of most of the mercury in Sierra Nevada waters are abandoned mine lands that in most cases were abandoned more than 100 years ago. Cleaning up these sources of mercury could have a significant impact on reducing mercury contamination in area fish. Increased collaboration among local, state and federal agencies is essential in order to assess and address legacy mining issues in ways that will have a positive impact on water quality and supply, and human health.

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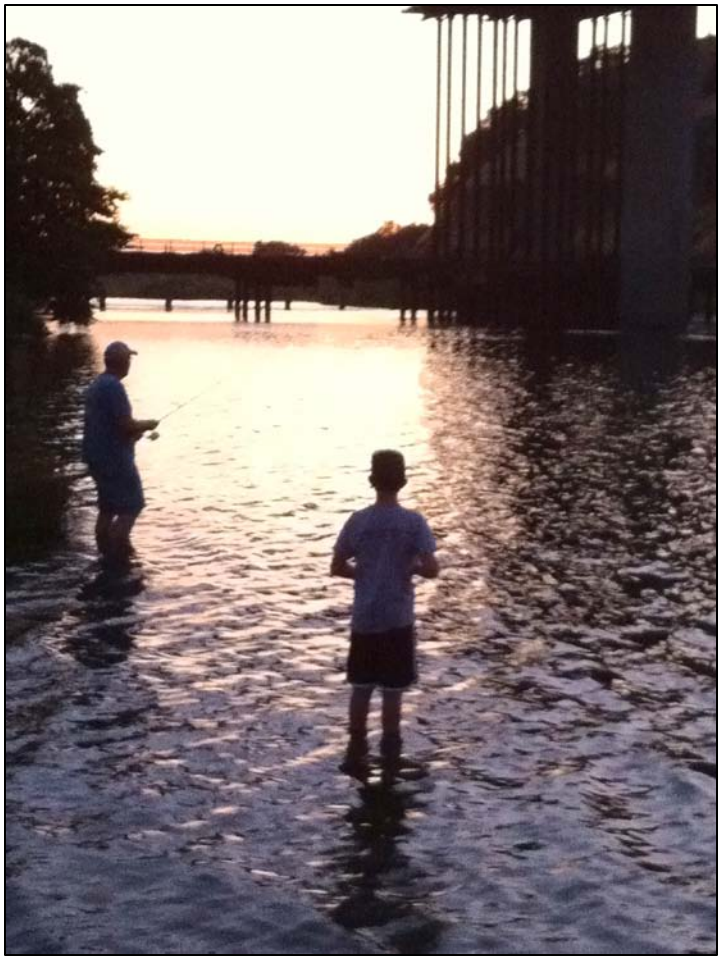
APPENDICES



Appendix A: Angler Survey Lessons Learned

Appendix B: Angler Survey Protocol

Appendix C: Gold Country Angler Survey Target Water Bodies

Appendix D: Gold Country Angler Survey Questionnaire

Appendix E: Sierra Nevada Sport Fish Species

Appendix F: Fish Portion Model

Appendix G: OEHHA 2003 Health Advisory for Northern Sierra Nevada Foothills

Appendix H: OEHHA 2009 Update of California Sport Fish Advisories

APPENDIX A

Lessons Learned

The following paragraphs present some of the lessons learned which should inform future angler survey efforts in the Sierra Nevada region. The lessons learned are grouped into two categories: suggestions for improving survey implementation and suggestions for improving the questionnaire itself.

Survey Implementation

Focus study design and scope. A focused plan for conducting interviews at a limited number of targeted locations should be completed before interview efforts begin, in order to ensure a statistically representative population in the survey results. This could be accomplished by first characterizing fishing activities such as angling intensity, catch per unit effort, and fishing preferences. The study design should include times of day that interviewers will visit each location, and how often the location should be visited.

Use dedicated, coordinated interviewers. Interviewer availability and the nature of the volunteer effort during the 2009 season limited the number of completed interviews and limited the selection of fishing times and locations. The 2009 volunteer interviewers reported that they generally attempted to conduct interviews as their time permitted and during times when in their opinion most fishing was likely to occur. The single most important improvement during the 2010 survey season was obtaining more interviews that better represented the population of anglers. The reason for this improvement is attributed to working with just two dedicated volunteer interns who took a coordinated approach to interview completion efforts. They would repeatedly visit a single location until the designated numbers of interviews were completed.

Talk to anglers informally after the interview. In 2010, interns made an effort to talk to anglers after the questionnaire was completed to learn about other potential locations to conduct interviews, and the best time of day to catch anglers. Through these efforts, unique "spots" at targeted locations were found, specifically areas low-income anglers frequented because they did not require entrance fees.

Include educational materials as part of survey. After completing the survey questionnaire, some interviewees were given a printed OEHHA fish mercury advisory brochure. This practice should be part of all surveys administered, and interviewers could be better trained to inform anglers and provide more specific information to fishermen.

Provide "thank you" tokens. In 2010, interviewers assembled a tackle box of common fishing gear (hooks, worms, spinners, weights) and would offer a few pieces to anglers after completion of the interview. Anglers were very appreciative of this gesture. This proved an inexpensive and effective way of building trust and general good will with anglers.

Track refusal rate. The number and location of people who were encountered in the field, but declined to participate in the survey should be recorded, and when appropriate the reason for their refusal.

Review questionnaires daily. Completed questionnaires should be reviewed by other team members the day that interviews were conducted to check for completeness and to ensure that the interviewer understands the importance of obtaining accurate, detailed information for all categories so that exposure calculations can be made and no sections are left blank.

Calculate exposure based on water body-specific fish mercury levels. Mercury concentrations in fish vary by species and by water way. For this effort, fish mercury levels in the exposure calculations were in some cases based on fish data from across the Sierra Nevada, or from Sacramento Delta and San Francisco Bay locations. Analysis of future surveys should include fish mercury values based entirely on fish from target water bodies in order to more accurately calculate specific exposure levels.

Questionnaire Improvements/Revisions

Reposition household demographic questions. The structure of the angler survey questionnaire used in 2009 (based on the Sacramento River angler survey) placed the questions regarding household demographics after questions regarding health hazard awareness. This could create a bias if interviewees became embarrassed to admit feeding mercury-contaminated fish to their families. In some cases interviewers reported that interviewees seemed reluctant or refused to answer these questions. Future surveys may be more accurate if household demographic questions are asked before health hazard awareness questions.

Include spotted bass. Spotted bass are the subject of multiple consumption advisories in the Gold Country, and should be specifically listed in the survey questionnaire.

Reposition age question. A few interviews of minors were inadvertently completed because the question about age category was at the end of the interview. This question should be among the first asked to avoid this problem.

Make age categories consistent with OEHHA guidelines. OEHHA age categories for fish consumption guidelines consist of different guidelines for women over 45, while survey age categories grouped individuals as over or under 49. Future surveys should determine age categories as above or below age 45, in order to be consistent with fish advisories for women.

APPENDIX B

Angler Survey Protocol 2009

This appendix includes the body of a protocol document developed for The Sierra Fund's Gold Country Angler Survey. This document was produced by Friends of Deer Creek in January 2009.

The survey protocol document was intended for use by watershed groups or other organizations to assist in conducting angler surveys in their areas. Contact The Sierra Fund for a full copy of the protocol, which includes background information about mercury and mining activities, and appendices with fish species data, portion models, and health information.

It should be noted that three minor changes were made to the survey questionnaire for the 2010 field season. These changes had no effect on the protocol for conducting the interview.

- *A series of questions were added (after original question 6) to characterize and quantify commercial fish consumption.*
- *The Health Warnings Section was moved after the Household Demographics Section.*
- *The angler's weight was asked or estimated as the final question of the interview.*

Survey Protocol: How to Plan and Conduct the Angler Survey

The following sections outline the approach to planning and conducting the survey:

1. Identify Survey Area
2. Research Fishing Activities
3. Identify at Risk Fishing Populations
4. Identify Timing of Target Fishing Activities
5. Survey Questions and Approach
6. Recruit and Train Survey Interviewers
7. Conduct Survey

Identify Survey Area

Each participating organization will define their survey area based on their available human and financial resources and the extent of the potential mercury exposure problem in their area. For example if the goal is to understand the fish consumption at a single water body, then the survey need only be conducted at that location. If the goal of the survey is to address fish consumption throughout a watershed or on more than one watershed, then the survey should be conducted wherever fishing activity is known to occur in the watershed. Ideally, the survey area would be based on an area local to the organization which is logistically manageable (within one hour drive of the organization office) and where mercury impacted fishing waters are present.

Within the general survey area specific target waterways should be determined based on existing information such as the presence of mercury impacted waterways, either those defined by regulatory agencies (303d listings) or suspected based on historic activities. This would include historic mining activities which released mercury within or upstream of the target waterway. All waterways which have been 303d listed for mercury impacts by the California Regional Water Quality Control Boards should be considered priority locations for surveys. Using historical books, illustrations and maps, identify all possible sources of mercury including hydraulic mining, hard rock gold mining where stamp mills used mercury or waste water treatment plants which release effluent to waterways

.

Prioritize your identified waterways by magnitude of potential impact, regulatory listings, likely amount of fishing activity and accessibility. Identify a list of specific target waterways likely to have significant mercury impacts and fishing activity. You may want to identify more potential waterways initially and focus on the highest priority locations first depending on resource availability.

Research Fishing Activities in Target Waterways

Once you have identified a list of target waterways for your survey, begin researching fishing activities in these areas. The following list of suggested activities will help you to find popular fishing spots, learn what types of fish are typically caught in these locations and decide where to conduct your survey.

1) Start with an internet search such as “fishing”, “(name of target waterway)”. Many fishing web sites provide useful information for your survey. Google Earth and web based mapping services will help identify access and use patterns. List specific information which will help in conducting the survey such as specific fishing locations, types of fish caught, bait shop locations and guide services (a valuable source of fishing information).

2) Visit the waterways; look for fishermen, note accessible fishing locations, evidence of fishing, boat ramps, bait shops.

3) Talk to local fishermen if you see them or anyone who might know about fishing. Ask people background questions about fishing in that location such as: How is the fishing here? What fish do you catch? How big do they get? When is the best time to fish? Are they good to eat? Do a lot of people fish here? Who fishes here? Do they eat the fish? etc.

4) Research whether any angler surveys have been done for this waterway (mercury or not) such as creel surveys by the Department of Fish and Game.

5) Interviews: Make phone calls to guide services, bait shops and the Department of Fish and Game (DFG). The local DFG game warden is likely the most knowledgeable person regarding all aspects of fishing activities in your area.

Once you have completed the above steps, you should have enough information to determine where and when to conduct your angler survey.

Identify At Risk Fishing Populations

While you conduct your background research, keep in mind the question; which groups are most likely eating the fish caught in local waterways? Develop a general idea of where you can get the most information from these groups. Indentify and contact local Tribes and Tribal Governments to ask for their input and assistance in conducting your survey. Talk with Government Agencies or other groups about fishing and awareness of mercury health issues associated with eating fish such as County Health Departments, California Department of Public Health (CDPH), Department of Fish and Game (DFG) and community service organizations. Record the names and contact information of helpful people in each organization. Tell them about your angler survey project. Ask for their advice and if they are interested, offer to share your survey findings once you have completed the study. In this way you will build a group of technical advisors and community stakeholders who will be helpful to your organization during the survey and in the future.

Based on your background research and general inquiries, identify all populations who may be at risk of eating mercury impacted fish. Anecdotal evidence suggests that individuals who rely on fishing for a part of their diet may not obtain fishing licenses and therefore may not be aware of fish advisories. It may be challenging to get these people to participate in your survey and may require creative strategies. The CDPH Needs Assessment, (conducted mainly in the Central Valley region) identified Southeast Asians, Latin Americans, African Americans and Russians as ethnic groups who eat locally caught fish. Native American Tribes in the Sierra Nevada region also eat locally caught fish as a traditional part of their diet. If you suspect any of these groups area fishing in your area make every effort to include them in your survey.

Previous studies have suggested that shore fishermen and bait fishermen are more likely to be eating the fish they catch and may be less aware of health advisories than fly fishermen and boat fishermen. While all fishermen should be part of the survey, at risk fishing groups should be the main target of your survey, especially if resources are limited. Be aware of the different ethnic groups and potential language barriers. For example Southeast Asians traditionally rely on fish as a major part of their diet. Recent immigrants may speak little English and may have no way of knowing of mercury hazards. Special considerations may be required to survey these fishermen. Your survey will be most effective if you can recruit translators, cooperative bilingual fishermen and ethnic community service groups such as the South East Asian Assistance Organization to assist in bridging the language barriers. In home surveys for different ethnic groups conducted by an interviewer in the native language may be easier to conduct and more comprehensive.

Identify the Best Time to Conduct the Survey

Levels of fishing activity in the Sierra Foothills region vary considerably based on time of year, weather, water level, water temperature, insect hatch, fish planting etc. Research or ask knowledgeable people (guide services, game warden, etc.) when the best time of year, time of day and weather for fishing are. Each waterway may be different depending on elevation, fish species, fish planting and other local conditions. Check local newspapers sports pages for fishing columns or articles about fishing conditions in your area. Review published Department of Fish and Game (DFG) regulations regarding fishing seasons.

Based on initial inquiries, find out when the most common fishing season is (often spring or summer) and what time of day the most fishermen are out. If they fish from boats, when do they typically go out and return? Do shore fishermen fish at different times than boat fishers or fly fishermen? Before you start the survey, figure out when you have the best chance of meeting fishermen who will participate in your survey.

Survey Questions

This protocol document includes a template survey provided as Appendix A. The template is based on a Sacramento River and Delta survey conducted by Healthy Fish Coalition in 2005 and has been modified by Friends of Deer Creek for use in the Bear River, Deer Creek and South Yuba River watersheds. To adopt the survey for your area, modify the place names of target waterways (page 1) and fish species (questions 5a and 5d). The survey is intended to be used along with previous surveys in the Sacramento San Joaquin River Delta and proposed surveys in the Sierra Nevada Region in order to be able to evaluate fish mercury exposure over a broad geographical area. Consistency in data collection is critical to this effort.

The following guidelines and suggestions on how to give the survey effectively are referenced to specific questions on the attached Gold Country Survey template (Appendix A). Use these suggestions to train the people who will be giving the survey.

General: Approach fishermen in a friendly conversational manner. Be prepared to ask the first few questions (at least questions A, 2, 3a) before you pull out paperwork or a clip board. At this point, ask if the person is willing to participate in a survey that will take about 10 minutes. If they say yes, then you can pull out the clipboard, briefly jot down the initial responses and continue with the survey. Be sure to move through the questions relatively quickly. Fishermen will likely be anxious to start fishing or get back to fishing.

Date, Interviewer Name, Time, Location: This information is important in case questions come up during data compilation and evaluation so that the Survey interviewers can be contacted and to refresh his or her memory.

Question A: (Have you ever been interviewed) If the person answers yes and they have been interviewed by a person in your organization for the current survey, thank them and do not continue the survey. This will avoid duplicate data collection. If they say no or that they participated in a different survey, continue with the interview if they are willing.

Q2. (What fish are you catching) Take a brief answer, Question 5 asks more specific details on the species of fish they may be catching and eating.

Q3a. (Are you going to eat the fish) This question may prompt the interviewee to ask "why do you ask?" If they do, defer the question until the end of the interview. This will avoid biasing their responses. Offer to give them a brochure and answer their questions at the end of the survey. Say "I'd be happy to answer all your questions at the end of the interview, but we would like to get your responses before we give you our information." In this way you will reduce the risk of biasing their answers and your data.

Q4. (How often do you fish?) If they are not sure, ask for an estimated number of fishing days in the past month.

Q5a-5d. (Fish species and amounts eaten) These questions will be easier to get accurate answers if you have props including color pictures of fish species and scale models or pictures of fish filet portions.

Q5a. Show the interviewee a printed card showing names and pictures of fish species. People may not know the names of fish or use different names for the fish. Record the name they give you and if different, what you think the species listed on the survey is.

Q5c. (Size of portions) The Healthy Fish Coalition survey used scale models of portion sizes to show survey participants. Models are provided to assist in giving surveys. Use the models to show people for a visual approximation of how much they typically eat. If models are not available for your survey, show the interviewees the scaled fish filet portion. This picture shows the large (12 oz) size portion. Be sure to tell them this is an uncooked filet. Marks on the picture indicate the approximate, medium (8 oz) and small (4 oz) portion sizes. Be sure not to modify the scale when copying this picture.

Q5d. (Where fish caught) Modify your survey question to include your target waterways. Note code numbers for each location which will be used during data evaluation.

Q6a,b. (Amount of commercial fish consumption) This question is important to help identify the total amount of fish people are eating. Commercial fish (particularly ocean fish) also contain varying amounts of mercury depending on species and size.

Q7a.-9. (Health warning awareness) Have a fish mercury health warning pamphlet to give the interviewee but do not give it to them until the interview is complete. Do not push a pamphlet on them if they seem uninterested.

Q9. (Information sources) Ask this question without reading response categories. We are only interested in their clear recollections as opposed to sparking vague recollections.

Q10.-13. (Household and demographic info) Be sensitive when asking personal questions. Although these questions are very important to knowing who is eating the fish, do not push people who seem unwilling to answer personal questions.

Q13a. (Ethnicity) This is also important but it may be a sensitive question. If they don't readily answer this question, go to Q 13c. and record an apparent ethnicity. Determining the ethnicity of people who eat fish will help target communities and languages for health risk warnings.

Q14. 15. 16. (Age zip code, gender) The answers to these questions will be useful to determine demographics of "at risk" groups.

Special Questions. These questions are optional and can be given to willing participants who show interest in mercury contamination in the fish they catch. Give them a brochure when you

ask these questions and be willing to discuss their concerns. For example, be able to quote or show them the OEHHA fish consumption advisories for the particular waterway you are on and the fish they may be catching.

Recruit and Train Survey interviewers

A major factor in the effectiveness of your survey will be to having enough trained and enthusiastic survey interviewers to cover the specific waterways and target populations you determine. You may need to narrow down the number of target waterways and survey locations, so that you have enough Survey questioners to adequately cover each location. A recruitment effort could include emails or flyers to members and volunteers of your organization. If a University or Community College is located in your area, motivated students could be volunteer survey interviewers. Contact a science department faculty member or student advisor to help you recruit volunteers. Some schools may give credit to students who participate in conducting the angler survey.

Organizational meetings:

Once you have a group of interested people, hold a meeting to discuss the project, distribute copies of the survey, protocol document and pamphlet. Request input to encourage "ownership" If you need more people, encourage attendees to recruit their friends.

Training: Once you have a survey team, make sure they are familiar with survey protocol, memorize key survey questions so they can approach fishermen in a casual manner. Discuss time commitments, safety issues, assign teams and coverage areas. Identify language barriers early in the process. If possible, find bilingual survey interviewers to match with fishermen language groups. Strategize on access points, times to give surveys, how to approach people to encourage participation. For example, if attempting to interview fishermen who may not have licenses, survey interviewers could bring a fishing pole and fish themselves to gain trust and ask as many questions as possible from memory.

Have survey interviewers practice on each other before they go out, so that the survey can be done without heavy reliance on the paperwork. The survey will be more effective if the initial questions can be given and the fisherman is comfortable with participating before paperwork is pulled out. Ask if the fisherman is willing to complete the survey before digging in to the more detailed questions.

Conducting the Survey

The angler survey can be conducted over as wide a geographical area as is feasible for the participating organization. All data can potentially be valuable in identifying at risk fishing groups and developing strategies for directing information and advisories which are protective of human health. Especially in the case of smaller surveys, the goal of the survey may not be so much to provide detailed quantitative statistical analysis, as to identify specific at risk fishing groups, where they fish, what they catch and how much fish they eat. This information will be used to better inform policy makers at risk groups and to inform and promote mercury cleanup efforts.

Teams of two people should go out together for safety, support and fun. Have survey interviewers split up to give surveys in a broader area. Have each survey questionnaire stapled or bound together and the props handy so the survey can be given efficiently. Approach fishermen in a calm friendly manner so that you do not disturb their fishing experience. Any adult with a fishing pole is a potential candidate to be interviewed. If you encounter a group of fishermen, try to interview as many fishermen as will cooperate, but try and get them to move away from the group for the interviews so that their answers do not influence later interviewees.

Consider giving thank you gifts such as lures or color fish ID cards to survey participants. The Healthy Fish Coalition offered a choice of lures from a tackle box to fishermen after they had completed a survey. Other surveys have handed out fish carabineers to survey participants. This is a nice gesture of appreciation and leaves everyone with a good feeling about the survey experience.

Identify a target number of questionnaires to complete for your survey. The more survey questionnaires that are completed, the more accurate the statistical analyses will be and the less statistical variability will be inherent in the data. Set a specific time period over which your angler survey will be given (such as 2 months) so data collection and evaluation can be efficient and doesn't drag on. You could have a pilot survey period with later surveys such as at a different seasons or split up the survey by location if you have limited resources or if timing of high fishing activities varies by waterway.

Different populations may fish at different times. Some studies have suggested that the majority of fishing activities happen before 9am and after 6pm. Schedule times of day and days of the week that your surveys are conducted so that all fishing activity is represented in your data.

Set achievable targets for your survey interviewers in advance including, number of surveys per day, number of days in the field and hours per day. Talk with your survey interviewers frequently and ask for feedback and accounts of their experiences. This way survey interviewers feel useful but not overused and you avoid burnout. Schedule survey times in advance and have a responsible staff person from your organization on call during survey periods to provide support and deal with any problems or questions that arise. A staff person should also be designated to collect completed surveys within a reasonable time frame.

APPENDIX C

Gold Country Angler Survey Target Waterbodies

This appendix provides detailed information on several of the waterbodies targeted by the study. A map showing all waterways included in the survey can be found on page 10.

Deer Creek

Deer Creek, a southern tributary of the Yuba River, is approximately 30 miles long and runs from its headwaters at 5,000 feet elevation through Upper Scotts Flat and Lower Scotts Flat Lakes, Nevada City, Lake Wildwood and into the Lower Yuba River below Lake Englebright. During the latter half of the 19th century until the middle of the 20th century, mining activities in the watershed deposited vast quantities of hydraulic mining debris and stamp mill tailings in Deer Creek and its tributary drainage courses. Hydraulic mining debris (gravel, sand, and fine particles) were washed down from hydraulic mines, angular waste rock was deposited on the creek banks from hard rock mining tunnels, and mercury-contaminated mill sands were discharged into the creek from stamp mills. Mining in the Deer Creek watershed produced approximately 25 million cubic meters (33 million cubic yards) of mine waste, which is equivalent to the removal of approximately 13 centimeters (five inches) of material across the entire watershed area (Allan, 2009).

Hydraulic and hard rock mining debris in Deer Creek – Photo of the Champion Mine and Home Mine, upstream of Lake Wildwood, viewed from the east at the Providence Mine, two miles west of Nevada City. (Photo: Friends of Deer Creek)

Posted fish advisories were neither observed, nor anticipated at popular fishing locations on Deer Creek. Deer Creek was 303(d) listed as impaired for mercury in November 2010. Deer Creek had a fish consumption advisory in 2003 for all trout, which recommended no more than two meals per month for women of childbearing age and children age 17 and younger. However, in 2009 OEHHA determined that there was not enough data to support a fish advisory for Deer Creek (OEHHA, 2009). Little Deer Creek, a tributary that converges with Deer Creek in Nevada City, is also 303(d) listed as impaired for mercury due to USGS samples taken in 1999 by May et al. (CVRWQCB, 2006).

Upper and Lower Scotts Flat Lakes

Upper Scotts Flat Lake is a reservoir located in the upper Deer Creek watershed at an elevation of approximately 3,000 feet. Lower Scotts Flat Lake, just downstream, is much smaller. Together they have combined water storage of 5,555 acre-feet (Nevada Irrigation District, 2001). Upper Scotts Flat offers a wide variety of fish, including German brown and rainbow trout,

kokanee salmon, largemouth bass, smallmouth bass, bluegill, bullhead catfish and channel catfish. Lower Scotts Flat has rainbow trout, brown trout and a self-sustaining population of kokanee salmon. Upper Scotts Flat offers a barrier-free fishing pier and launch ramp facilities, a full service marina and abundant camping facilities. Lower Scotts Flat is a quiet, lightly-fished reservoir where "the bank fisherman and float tuber is king." The Department of Fish and Game stocks 5,000 pounds of catchable rainbows in the upper lake and 1,000 pounds in the lower lake each year, according to the American River Fish Hatchery. The DFG also stocks 50,000 kokanee salmon fingerlings annually in the upper lake.

Posted fish advisories were not observed at Upper Scotts Flat Lake or Lower Scotts Flat Lake. Upper Scotts Flat Lake is listed as impaired for mercury by the Clean Water Act section 303(d) (CVRWQCB, 2010). Upper Scotts Flat Lake also had a fish advisory in 2003 recommending no more than one meal per month of bass and no more than two meals per month of catfish for women of childbearing age and children age 17 and younger. However, in the 2009 update due to more stringent data requirements, it was determined that there was insufficient data to issue a fish consumption advisory on Upper Scotts Flat Lake (OEHHA, 2009). The Nevada Irrigation District has expressed interest in posting this reservoir with general fish consumption and mercury advisory information at the boat launch area and at the fish washing area.

Lake Wildwood

Lake Wildwood is a relatively shallow reservoir located in the lower Deer Creek watershed. The reservoir is located downstream of large hydraulic and hard rock gold mine sites and receives sediment and water contaminated with mercury. The lake is privately owned by the Lake Wildwood Association and is surrounded by residential development. The only public access other than homeowners and guests is from the dam area along Pleasant Valley Road. People fish from the dam and from the shore at this location, especially during the spring and early summer. As the lake warms during the summer, fishing activity at the dam decreases significantly. The water level in Lake Wildwood is lowered most years by over ten feet in the fall (around early October) to allow for dredging of accumulated sediment. Lake Wildwood is located within a 30 minutes' drive of Marysville and other low-income Central Valley communities.

Fish advisory signs posted at Lake Wildwood
(Photo: James Worthy)

A posted fishing advisory sign is located on the dam at Lake Wildwood. The sign reads:

> *Warning: The California Office of Environmental Health Hazard Assessment has issued a health advisory urging limited consumption of largemouth bass caught in Scotts Flat Reservoir in the Deer Creek watershed (which is upstream from Lake*

Wildwood). Because of a pattern of mercury contamination in fish sampled throughout the Sierra Lakes Region, which includes Lake Wildwood, women of childbearing age and children under 18 should eat bass no more than once a month. Others should eat bass no more than twice a month. For information on advisories in this area call OEHHA at 916-323-4763.

A "Catch and Release Largemouth Bass" sign was also recently erected at the dam fishing location. Both of these signs are in English. Lake Wildwood was recently listed as impaired for mercury under the Clean Water Act but it does not currently have a fish consumption advisory issued by OEHHA.

Rollins Lake

Rollins Lake is a reservoir in the upper Bear River watershed at an elevation of approximately 2,200 feet with a surface area of 900 acres and 26 miles of shoreline. Rollins has a storage capacity of 65,988 acre-feet. It is located on the border of Nevada County and Placer County. Rollins Lake is 303(d) listed for mercury and is located downstream of Greenhorn Creek, Steephollow Creek, and the upper Bear River, all of which remain choked with mercury-contaminated historic hydraulic mining debris. In addition, the reservoir catchment basin contains both large and small abandoned hydraulic mine pits which discharge mercury-contaminated sediment and water.

Greenhorn Creek, a tributary to Rollins Reservoir – Photo taken in 2010 shows the creek channel still choked with hydraulic mining debris. (Photo: Nevada Irrigation District)

Rollins Lake is accessible from Interstate 80 near the town of Colfax off Rollins Lake Road and from Highway 174 off Orchard Springs Road and Greenhorn Road. Boat ramps are located to the north of the dam and southeast of the dam. Private campgrounds are located on a northern arm of the lake off Greenhorn Road and on the east side of the lake off You Bet Road. According to a fishing web site, brown trout fishing is best in winter and fall, rainbow trout in spring and summer, smallmouth bass in spring, summer and fall, channel catfish in summer and fall, and bluegill and crappie in summer and fall.

Posted fish advisories were not observed at any of the three Rollins Lake boat ramps that were visited.

Rollins was 303(d) listed as impaired for mercury in 2010, and it does have a current fish consumption advisory for catfish, of which no more than one meal per month is recommended for women of childbearing age and children age 17 and younger (OEHHA, 2009). Other fish species such as bluegill, brown trout, crappie and largemouth bass may be impacted by mercury, however OEHHA did not have sufficient sample data from which to develop a fish consumption advisory for these species at Rollins Lake. The Nevada Irrigation District has expressed interest in posting this

reservoir with general fish consumption and mercury advisory information at the boat launch areas.

Camp Far West Reservoir

Camp Far West Reservoir is in the lower Bear River watershed at an elevation of 300 feet. The lake is approximately 2,200 acres in size with 30 miles of shoreline when full. The lake is mostly in Yuba County with the western shore in Nevada County and the southern shore in Placer County. It is a 303(d) listed waterway for mercury contamination resulting from mine waste from upstream in the Bear River. Recent USGS studies have identified some of the highest mercury levels in fish in the Sierra region in this reservoir. It is located within one hour's drive of Sacramento and 15 to 30 minutes of the towns of Lincoln, Wheatland and Marysville, providing easy access to low-income fishermen as well as sport fishermen. Fishing is mainly from boats and occasionally from the shore. Boat ramps are located at the North Recreation Area, accessible from Camp Far West Road and the South Recreation Area accessible from Karchner Road. According to a fishing web site, largemouth (black) bass are the most popular sport fish along with spotted bass and smallmouth bass. Night fishing is reportedly "great in the summer." Other fish include channel catfish, crappie, bluegill and bullheads.

No posted fishing advisories were observed at either of the two entry gates, boat ramps or camping areas at Camp Far West Reservoir. Camp Far West is listed as impaired for mercury by the Clean Water Act section 303(d) and it has a 'Do Not Eat' fish consumption advisory for catfish and largemouth, smallmouth and spotted bass, and recommends one serving per week of bluegill and crappie for women of childbearing age and children age 17 and younger (CVRWQCB, 2010; OEHHA, 2009).

Lake Englebright

Lake Englebright is a long, narrow, and deep reservoir in the lower Yuba River watershed at an elevation of 527 feet. The lake is 850 acres in size and has 24 miles of shoreline. Englebright Dam was constructed as a debris dam to contain hydraulic mining debris from the three forks of the Yuba River. It is a listed by the Clean Water Act section 303(d) as impaired for mercury. It is accessed from Mooney Flat Road off State Highway 20, approximately 30 minutes' drive from Marysville and 20 minutes from Grass Valley. The main fish species include rainbow and brown trout, kokanee salmon, smallmouth and largemouth bass, and catfish. Most fishing was observed to be from boats. Limited shore fishing is accessible from the dam area and the boat ramp area on the south side of the lake or from Rice's Crossing Road near the upper end of the lake.

One posted fishing advisory was observed at the Joe Miller Recreation Area boat ramp at Lake Englebright. The posting was on a letter-sized printed black and white sheet on a bulletin board with several other fliers and could easily be overlooked by many anglers. Lake Englebright has a "Do Not Eat" fish consumption advisory for largemouth, smallmouth and spotted bass, and recommends no more than one meal per week of bluegill and sunfish, and two meals per week of rainbow trout for women of childbearing age and children age 17 and younger (OEHHA, 2009).

APPENDIX D

Gold Country Angler Survey

Date: _____ **Interviewer name:** _____ **Time start:** _____:_____ **am** **pm**
end: _____:_____ **am** **pm**

Location of Interview:

- ☐ Lake Wildwood
- ☐ Upper Scotts Flat Lake
- ☐ Lower Scotts Flat Lake
- ☐ Deer Creek- location:_____
- ☐ Lake Englebright
- ☐ South Yuba River- location:_____
- ☐ Camp Far West Reservoir
- ☐ Lake Combie
- ☐ Rollins Lake
- ☐ Bear River- location:_____
- ☐ Other:_____

A. Have you ever been interviewed before about fishing or eating fish

- ☐ Y (fishing ___eating fish ___) Who?
- ☐ N (proceed)

1b. [IF INDIVIDUAL DOES NOT WANT TO BE SURVEYED] Please note any known reason that they declined:

- ☐ No time
- ☐ Language barrier
- ☐ Appeared threatened/uncooperative
- ☐ Other:_____
- ☐ Unknown

1c. [IF NO] Record observed gender and ethnicity:

- ☐ Male ☐ Female
- ☐ White ☐ Asian/Pacific Islander
- ☐ Black ☐ Native American
- ☐ Hispanic ☐ DON'T KNOW
- ☐ Other _____

2. What are you trying to catch today?_____

3a. Are you going to eat the fish you catch today?

- ☐ Yes
- ☐ No
- ☐ Don't know/Not Sure
- ☐ Refused

[If yes] Are you going to feed it to your family? ☐ Yes ☐ No

3b. [IF NO] What are you going to do with the fish you catch?

- ☐ Give it to others to eat
- ☐ Catch and release it
- ☐ Other: _____
- ☐ Refused

3c. [IF NO] Do you ever eat fish that you or someone you know catches?

- ☐ Yes
- ☐ No [IF NO, SKIP TO **Q6a**]
- ☐ Don't know/Not Sure [SKIP TO **Q6a**]
- ☐ Refused [SKIP TO **Q6a**]

4. About how many times did you go fishing in the last 30 days?

_____**[ENTER NUMBER] per**

- ☐ week
- ☐ month
- ☐ other_____

- ☐ Don't know
- ☐ Refused

5a. Do you eat [*NAME OF FISH]* that you or someone you know catches? *Ask about specific fish listed below, as well as any others that are not named.* *Do this question first down the column, then come back and do fish by fish for b-d.*	**5b. How many times did you eat *[NAME OF FISH]* in the LAST 30 DAYS?** *If zero, skip to next row.*	**5c. How much *[NAME OF FISH]* did you eat in one meal?** *SHOW PICTURE OF FISH PIECES. Circle letter and write number of UNCOOKED models per meal.* *Only ask for types eaten in the **last 30 days.*** **A – Small** **C – Medium** **E – Large**	**5d. Where was the *[NAME OF FISH]* caught?** *Only ask for types eaten in the **last 30 days.*** *WRITE RESPONSE AND ENTER CODE* 1= Lake Wildwood 2= Upper Scotts Flat Lake 3= Lower Scotts Flat Lake 4= Deer Creek 5= Englebright Lake 6= South Yuba River 7= Camp Far West Reservoir 8= Lake Combie 9= Rollins Lake 10= Bear River 11= Other Location of survey(write response below)
☐ Catfish/Bullhead		A C E (Circle) ____ # of portion models/meal	
☐ **Bass (don't know which species)**		A C E (Circle) ____ # of portion models/meal	
☐ Large Mouth Bass		A C E (Circle) ____ # of portion models/ meal	
☐ Small Mouth Bass/ Black Bass		A C E (Circle) ____ # of portion models/ meal	
☐ Stripped Bass		A C E (Circle) ____ # of portion models/ meal	
☐ Sunfish		A C E (Circle) ____ # of portion models/ meal	
☐ Bluegill		A C E (Circle) ____ # of portion models/ meal	
☐ Crappie		A C E (Circle) ____ # of portion models/ meal	
☐ Rainbow Trout		A C E (Circle) ____ # of portion models/ meal	
☐ Brown trout		A C E (Circle) ____ # of portion models/ meal	
☐ Kokanee Salmon		A C E (Circle) ____ # of portion models/ meal	
☐ Other_____		A C E (Circle) ____ # of portion models/ meal	
Do you eat [*NAME OF SHELLFISH]* that you or someone you know catches?			
☐ Clams		____ # of clams/meal	
☐ Crawdads/ crayfish		____ # of crayfish/meal	

6. In the last 30 days, have you eaten fish that came from stores, markets, restaurants, or cafeterias? (examples, tuna, fish sticks)

☐ Yes

☐ No

☐ Don't know/ Not Sure

☐ Refused

7a. Do you eat [*NAME OF FISH]* from stores, markets, restaurants, or cafeterias? *Ask about specific fish listed below, as well as any others that are not named.* *Do this question first down the column, then come back and do fish by fish for b-d.*	**7b. How many times did you eat *[NAME OF FISH]* in the LAST 30 DAYS?** *If zero, skip to next row.*	**7c. How much *[NAME OF FISH]* did you eat in one meal?** *SHOW PICTURE OF FISH PIECES or models. Circle letter and write number of UNCOOKED models per meal.* *Only ask for types eaten in the **last 30 days.*** **A – Small** **C – Medium** **E – Large**	**7d. Where was the *[NAME OF FISH]* bought?** *Only ask for types eaten in the **last 30 days.*** *WRITE RESPONSE AND ENTER CODE* 1= grocery store 2= restaurant 3= cafeteria 4= Other
☐ Shark		A C E (Circle) ____ # of portion models/meal	
☐ Bass		A C E (Circle) ____ # of portion models/ meal	
☐ Swordfish		A C E (Circle) ____ # of portion models/ meal	
☐ Tile fish		A C E (Circle) ____ # of portion models/ meal	
☐ King Mackerel		A C E (Circle) ____ # of portion models/ meal	
☐ Albacore Tuna		A C E (Circle) ____ # of portion models/ meal	
☐ Canned Tuna		A C E (Circle) ____ # of portion models/ meal	
☐ Salmon		A C E (Circle) ____ # of portion models/ meal	
☐ Fish sticks		A C E (Circle) ____ # of portion models/ meal	
☐ Halibut		A C E (Circle) ____ # of portion models/ meal	

☐ Other_____		A C E (Circle) ____ # of portion models/ meal	
Do you eat [*NAME OF SHELLFISH]* that you or someone you know catches?			
☐ Clams		____ # of clams/meal	
☐ Calamari		____ # of calamari/meal	
☐ Shrimp		____ # of shrimp/meal	

HOUSEHOLD & DEMOGRAPHIC INFORMATION

8. In the past year, have any children under 18 in your household eaten fish that you or someone you know catches?

☐ Yes

☐ No

☐ Don't know/ Not Sure

☐ Refused

9. In the past year, have any women between ages 18 and 49 in your household eaten fish that you or someone you know catches?

☐ Yes

☐ No

☐ Don't know/ Not Sure

☐ Refused

10. In the past year, have any women expecting a child or who have a baby in your household eaten fish that you or someone you know catches?

☐ Yes

☐ No

☐ Don't know/ Not Sure

☐ Refused

HEALTH WARNINGS

11a. Have you ever heard or seen any health warnings about eating fish?

☐ Yes →
☐ No
☐ Don't know/Not sure
☐ Refused

[GO TO Q9]

11b. [IF YES] Do you remember what the warning said?

☐ Yes
☐ No
☐ Don't know/Not sure
☐ Refused

[IF YES, RECORD EXACT RESPONSE]

_____

_____

_____

12. Do you remember where you saw or heard this warning?

1 ☐ Television 2 ☐ Radio 3 ☐ Sign at fishing location 4 ☐ Friend 5 ☐ Brochure
6 ☐ Market or store 7 ☐ Clinic 8 ☐ Other: _____
9 ☐ Don't Know/Not Sure 10 ☐ Refused

13. Where do you get information about your health, about what is good or bad for you, that you <u>trust, that you really believe</u>?
[DO NOT READ RESPONSE CATEGORIES. CHECK UP TO 3 THAT APPLY.]

1 ☐ Health care provider, clinic or hospital
2 ☐ Internet
3 ☐ Friend, family member
4 ☐ TV
5 ☐ Radio
6 ☐ Books
7 ☐ Newspaper/Magazine
8 ☐ Fishing Regulation Manual
9 ☐ Posted signs
10 ☐ Community center or organization
11 ☐ Church, mosque, or temple
12 ☐ Other (specify): _____
13 ☐ Don't know/Not sure
14 ☐ Refused

14a. If you don't mind, could you tell me how best to describe your race or ethnicity. [SHOW list. CHECK ALL THAT APPLY]

- ☐ **White**
  - ☐ Russian
  - ☐ Ukrainian
  - ☐ Other _____
- ☐ **Black/African American**
- ☐ **Black/Caribean**
- ☐ **Native American**
- ☐ **Hispanic/Latino**
  - ☐ Mexican
  - ☐ Guatemalan
  - ☐ El Salvadorian
  - ☐ Nicaraguan
  - ☐ Honduran
  - ☐ Caribean (Dominican, Puerto Rican, Cuban, etc.)
  - ☐ Other: _____
- ☐ **Other:** _____
- ☐ **Unknown**
- ☐ **Refused**
- ☐ **Asian**
  - ☐ Cambodian
  - ☐ Chinese
  - ☐ Hmong
  - ☐ Filipino
  - ☐ Japanese
  - ☐ Khmu
  - ☐ Korean
  - ☐ Lao
  - ☐ lu-Mien
  - ☐ Vietnamese
  - ☐ Other:_____
- ☐ **Pacific Islander**
  - ☐ Fijian
  - ☐ Hawaiian
  - ☐ Samoan
  - ☐ Tahitian
  - ☐ Tongan
  - ☐ Other:_____

14b. [IF MORE THAN ONE BOX SELECTED] Which race do you most identify with: _____

14c. [IF REFUSED, RECORD OBSERVED ETHNICITY]: _____

15. If you don't mind me asking, what is your age: [READ CHOICES. CHECK APPROPRIATE BOX.]

1 ☐ Under 18

2 ☐ between 18 and 34

3 ☐ between 35 and 45

4 ☐ over 45

5 ☐ Refused

16. What zip code do you live in? _____

17. [RECORD GENDER]

☐ male

☐ female

18. [RECORD APPROXIMATE WEIGHT]

☐ under 70 pounds

☐ over 150 pounds

☐ estimate_____

Special Questions We are doing this surveying because there is mercury in the fish in the lake/river that people like you are eating. We know where a lot of the mercury is coming from, how it is getting into fish, and that people like to eat the fish.

We would like to know what you think should be done about this?

Do you think the government should clean up the mercury so it does not get into the fish?

Do you think people like you should eat less fish because there is mercury in the fish?

APPENDIX E

Sierra Nevada Sport Fish Species

Black Crappie (*Pomoxis nigromaculatus*)

Bluegill (*Lepomis macrochirus*)

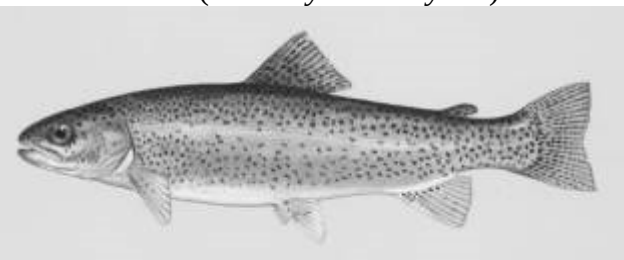
Brown Trout (*Salmo trutta*)

Channel Catfish (*Ictalurus punctalus*)

Green Sunfish (*Lepomis cyanellus*)

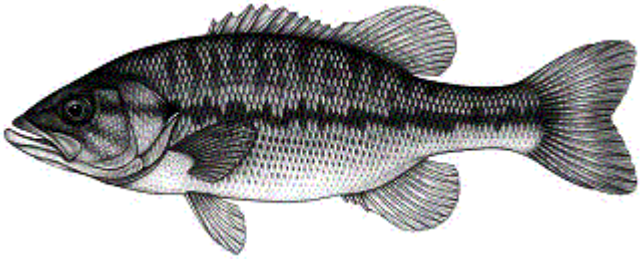
Largemouth Bass (*Micropterus salmoides*)

Rainbow Trout (*Oncorhynchus mykiss*)



Smallmouth Bass (*Micropterus dolomieu*)

Spotted Bass (*Micropterus punctulatus*)



APPENDIX F

Fish Portion Model

APPENDIX G

Health Advisory for Selected Water Bodies in the Northern Sierra Nevada Foothills (Nevada, Placer, and Yuba Counties)

California Office of Environmental Health Hazard Assessment (OEHHA)
December 12, 2003

Based on evaluation of data from this Sierra region OEHHA recommends that females of childbearing age and children aged 17 and younger should eat no bass from Camp Far West Reservoir. Additionally, they should eat no more than two meals per month of channel catfish from that site. At Lake Combie, Lake Englebright, Rollins Reservoir, and Scotts Flat Reservoir, consumption of bass and channel catfish should be restricted for this group to no more than one or two meals per month for these species, respectively. No more than two meals per month of any trout species should be consumed from Deer Creek or no more than four meals per month of any trout species from mining areas of the Bear and South Yuba Rivers. For other fish in reservoirs or streams in this region and throughout California, it is recommended that females of childbearing age and children aged 17 and younger follow the recent U.S. EPA national freshwater sport fish consumption advice for pregnant or nursing women and young children of no more than four meals per month of fresh water fish (U.S. EPA, 2001).

OEHHA also recommends that females of childbearing age and children aged 17 and younger follow the FDA advice for pregnant women, women of childbearing age who may become pregnant, nursing mothers, and young children on commercial fish consumption. FDA advises these individuals not to eat shark, swordfish, king mackerel, or tilefish because of their high levels of mercury. FDA also recommends that these women can safely eat up to an average of 12 ounces per week of other cooked fish from a store or restaurant such as shellfish, canned fish, smaller ocean fish or farm-raised fish. Children should limit consumption to less than 12 ounces of cooked fish per week. Also, if 12 ounces of cooked fish from a store or restaurant are eaten in a given week, then sport fish caught in the Sierra Lakes region should not be eaten in the same week.

For the females beyond their childbearing years and adult males, OEHHA recommends that bass from Camp Far West Reservoir be consumed no more than two times per month. Additionally, consumption of channel catfish from this reservoir should be limited to no more than four meals per month. Consumption of all bass and channel catfish from Lake Combie, Rollins Reservoir, and Scotts Flat Reservoir should be restricted to no more than two or four meals per month for these species, respectively. Consumption of all bass and channel catfish from Lake Englebright should be limited to no more than four meals per month. Additionally, no more than four meals per month of any trout species should be consumed from Deer Creek or no more than twelve meals per month of any trout species from mining areas of the Bear and South Yuba Rivers. Because of the general pattern of mercury contamination in all fish sampled from the Sierra Lakes region, OEHHA advises that consumption of all other fish for which no site specific

advice is given above be restricted to no more than 12 meals per month for females beyond their childbearing years and adult males from any of the above sites. Additionally, OEHHA recommends that females beyond their childbearing years and adult males take into account the commercial fish they eat, especially high-mercury fish such as shark, swordfish, king mackerel, or tilefish. If they consume these species, they should reduce consumption of sport fish caught in this Sierra region accordingly.

Fish Consumption Guidelines for Females of Childbearing Age and Children Aged 17 and Younger	
Location and Fish Species	Do Not Eat More Than*
	Meals per Month
Camp Far West Reservoir	
All Bass	Do Not Eat
Channel Catfish	2
Lake Combie, Lake Englebright, Rollins Reservoir, and Scotts Flat Reservoir	
All Bass	1
Channel Catfish	2
Bear River below Highway 20, South Yuba River	
Below Lake Spalding	
All Trout	4
Deer Creek	
All Trout	2
All of the Above Sites**	
Other sport fish species	4
* Consumption limits for each species assume that no other contaminated fish are being eaten. If you eat multiple fish species or fish at multiple sites, limit your total consumption to the amount recommended for the fish with the fewest recommended meals. If you also eat fish from a store or restaurant, reduce your consumption of sport fish from the Sierra Lakes region accordingly. **All fish species were not evaluated at all sites. If available, use consumption advice for the most similar species at the same site or the same species at a nearby site, whichever recommends the fewest meals. If consumption advice is not available for that species at any site, follow U.S. EPA national guidance for pregnant or nursing women and young children recommending consumption of no more than one meal per week of freshwater sport fish.	

Fish are nutritious and should be part of a healthy, balanced diet. As with many other kinds of food, however, it is prudent to consume fish in moderation. OEHHA provides this consumption advice to the public so that people can continue to eat fish without putting their health at risk.

Fish Consumption Guidelines for Females Beyond Their Childbearing Years and Adult Males	
Location and Fish Species	DO Not Eat More Than*
	Meals Per Month
Camp Far West Reservoir	
All Bass	2
Channel Catfish	4
Lake Combie, Rollins Reservoir, and Scotts Flat Reservoir	
All Bass	2
Channel Catfish	4
Lake Englebright	
All Bass	4
Channel Catfish	4
Bear River below Highway 20, South Yuba River	
Below Lake Spalding	
All Trout	12
Deer Creek	
All Trout	8
All of the Above Sites **	
Other sport fish species	12
* Consumption limits for each species assume that no other contaminated fish are being eaten. If you eat multiple fish species or fish at multiple sites, limit your total consumption to the amount recommended for the fish with the fewest recommended meals. If you also eat fish from a store or restaurant, reduce your consumption of sport fish from the Sierra Lakes region accordingly. **All fish species were not evaluated at all sites. If available, use consumption advice for the most similar species at the same site or the same species at a nearby site, whichever recommends the fewest meals. For fish species caught from the listed water bodies but not included in the guidelines, OEHHA recommends consumption of no more than 12 meals per month of any fresh water sport fish from the Sierra Lakes region.	

If you have questions, please contact :
California Environmental Protection Agency
Office of Environmental Health Hazard Assessment
Pesticide and Environmental Toxicology Section
P.O. Box 4010
Sacramento, California 95812-4010
Phone: (916) 323-4763
Fax: (916) 327-7320

APPENDIX H

Office of Environmental Health Hazard Assessment (OEHHA) 2009 Update of California Sport Fish Advisories March 2009

(Excerpts: Protocols and Sierra Nevada Water Bodies)

Excerpt 1: Protocols

OEHHA's Protocol for Updating Fish Advisories

The purpose of this report is to describe the process the Office of Environmental Health Hazard Assessment (OEHHA) used to update existing sport fish advisories. Two factors prompted the update procedure: 1) the development of advisory tissue levels, or ATLs, and 2) new chemical data for fish from California water bodies with advisories. OEHHA included the updated advisories in the California Department of Fish and Game 2009 Sport Fishing Regulations booklets, published in spring 2009. Not all advisories were updated at this time. Updated advisories are also posted on OEHHA's Web site (http://www.oehha.ca.gov/fish/so_cal/index.html).

Advisory Tissue Levels (ATLs)

OEHHA's fish advisories are also called "safe eating guidelines." They provide information to sport fish consumers in California to assist them in choosing to eat fish low in contaminants and high in beneficial fats. OEHHA developed ATLs for evaluating fish tissue data and developing advisories. ATLs were determined after several steps.

Safe Exposure Thresholds

First, OEHHA established limits for exposure to common chemicals in fish based on a review of the toxicity of these chemicals. OEHHA used these safe exposure thresholds to develop the ATLs. OEHHA applies ATLs to measured levels of chemicals in sport fish to determine how much fish can be safely eaten.

Benefits of Eating Fish

Second, OEHHA reviewed studies that showed regular fish consumption—such as twice a week—provides many types of health benefits. ATLs were thus designed to achieve two outcomes that support public health: 1. Discourage eating sport fish that cannot be eaten often because of chemical contamination 2. Encourage consumption of sport fish that can be safely eaten in amounts likely to confer health benefits

Improving Communication

Third, OEHHA took into account principles of good communication when developing the ATLs. For example, ATLs simplify advice by limiting the number of possible recommendations. The ATLs identify the contaminant threshold for fish that can safely be eaten at least once a week. OEHHA uses the ATLs to organize fish with different chemical levels into high, medium, and low level groups. OEHHA also worked with the California Department of Public Health to simplify advisories and improve their design. For further information on ATLs and the toxicology of common chemicals in fish, see the June 2008 OEHHA report[1] by Klasing and Brodberg at: http://www.oehha.ca.gov/fish/gtlsv/crnr062708.html.

New Data for Fish from California Water Bodies

OEHHA obtained new data on mercury and other chemicals in fish from several sources.

(1) The California Surface Water Ambient Monitoring Program (SWAMP) This program collected mainly largemouth bass, but also several other fish species, from lakes throughout California in 2007. In addition to mercury, SWAMP analyzed some samples for selenium and chlorinated hydrocarbon contaminants.

(2) The Fish Mercury Project (FMP) The California Bay-Delta Authority funded researchers from several organizations to study mercury in the Central Valley. Fish samples were collected for three years, 2005 – 2007. (See http://www.sfei.org/cmr/fishmercury/ for more information on this project.)

(3) The United States Geological Survey (USGS) USGS provided fish data to OEHHA from studies of mercury at several water bodies.

(4) The City of Benicia The City of Benicia sampled fish from a local water body in 1998 and tested them for mercury.

OEHHA combined new data with data staff previously used to develop safe eating guidelines. OEHHA then evaluated the combined dataset—using the ATLs—to update the existing safe eating guidelines.

Internal Guidelines for Consistency

A major goal in updating the advisories was to ensure that current and future advisories are based on consistent guidelines. OEHHA developed and used the following guidelines for that purpose.

Sample Size

OEHHA issues advice for fish or shellfish species only when there are enough samples to evaluate.

- ☐ OEHHA requires at least nine individual fish from a species at a water body to issue advice for that species.
- ☐ An exception can apply to a few fish species commonly known to build up high levels of mercury.
    - Examples include largemouth bass and Sacramento pikeminnow.
    - When at least five individuals, but less than nine, of one of these species have been sampled at a water body, OEHHA will consider giving advice for that species.
    - OEHHA will compare mercury levels in that species and others from the same water body that build up mercury. OEHHA will consider giving the same advice for both species.

Related Species

Closely related species can be hard to tell apart, and often have similar levels of contamination.

OEHHA used these guidelines to simplify advice for related species.

- ☐ Closely related species are evaluated together as a group.
- ☐ Examples of closely related species are:
    - Black bass—largemouth, smallmouth, and spotted bass
    - Sunfish—bluegill, redear, and green sunfish
- ☐ The species group must contain at least nine individual fish of two or more of the related species.
- ☐ An average chemical concentration of all fish in the species group is used for the group. The average is weighted by the number of individual fish per species.
    - For example, the average chemical level measured in a composite of ten fish from one species would count ten times more than the level in one fish sampled from a second species.

Balancing Risks and Benefits

OEHHA recommends eating fish species known to have high levels of beneficial fats—omega-3 fatty acids—that can provide health benefits to consumers. OEHHA will consider the omega-3 content of fish species when its chemical level is close to the border between two consumption recommendations.

- ☐ If the species has high levels of omega-3 fatty acids, OEHHA will consider recommending the greater amount of consumption.
- ☐ When omega-3 levels are low, or unknown, OEHHA will consider giving the more restrictive recommendation.

Keeping Communication Simple

Safe eating guidelines are matched to a familiar color code scheme as follows:

- ☐ Fish with high mercury levels are shown in a red category
- ☐ Fish with medium mercury levels are shown in a yellow category
- ☐ Fish with low mercury levels are shown in a green category

When the advice differs for species within the same category, OEHHA may make minor changes for some species to keep the safe eating guidelines simple and easier to follow. For example, OEHHA may choose the most restrictive advice, the most common, or an average of possible recommendations within the category. In these cases, OEHHA considers specific factors for each situation.

The process OEHHA used to update the safe eating guidelines presented in this report can also serve for developing consistent advisories in the future. By using the ATLs to evaluate all fish data and following the internal guidelines described above, OEHHA can provide more uniform advice for eating fish.

Excerpt 2: Sierra Nevada Water Bodies

9. Northern Sierra Nevada Foothills (Nevada, Placer, and Yuba Counties)

OEHHA previously issued an advisory for a combination of several reservoirs, rivers, and creeks in the Sierra foothills. In the advisory update process, only fish species with sufficient sample sizes were given safe eating guidelines. Because sample sizes were not adequate for any fish species from the following water bodies, safe eating guidelines ***are no longer provided***. It was not possible to determine whether fish from these water bodies are safe to eat based on the limited data.

- ☐ Bear River below Highway 20
- ☐ Deer Creek
- ☐ South Yuba River
- ☐ Scotts Flat Reservoir

Other considerations:

Seven largemouth bass were sampled from Scotts Flat Reservoir, and bass are a known accumulator of mercury. However, the average mercury level in bass from Scotts Flat Reservoir (0.38 ppm) was lower than mercury levels in bass from the other reservoirs in the Sierra foothills region. This lower level also corresponds to safe consumption. Because no other fish species

were analyzed from Scotts Flat Reservoir, OEHHA was not able to evaluate whether consumption of bass (or other fish species) from Scotts Flat Reservoir could be recommended.

The remaining water bodies in the Sierra foothills advisory—Lake Englebright, Rollins Reservoir, Camp Far West Reservoir, and Lake Combie—were updated. Separate safe eating guidelines were issued for each water body, as explained below.

10. Lake Englebright (Yuba and Nevada Counties) The updated safe eating guidelines for Lake Englebright included new data combined with prior data. More information about this updated advisory is given below.

New data:

OEHHA received fish data collected and analyzed for mercury at Lake Englebright by University of California at Davis researchers (in cooperation with the U.S. Geological Survey—USGS) as part of the 2002 Upper Yuba River Studies Program[6]. The dataset included:

- ☐ 29 bluegill
- ☐ 3 largemouth bass
- ☐ 11 smallmouth bass
- ☐ 25 spotted bass
- ☐ 49 rainbow trout

Related species:

OEHHA grouped the following related species:

- ☐ Bass: largemouth, smallmouth, and spotted bass
- ☐ Sunfish: bluegill and green sunfish

Table 6 shows a summary of data used in the updated advisory for Lake Englebright.

Common Name	Number of Fish	Mean Mercury (ppm)	Mean Total Length (mm)
Sunfish	31	0.30	161
Bass	56	0.45	338
Rainbow trout	49	0.08	290

11. Rollins Reservoir (Nevada and Placer Counties)

No new data were available for Rollins Reservoir. The updated safe eating guidelines were based on prior data and the ATLs. Only channel catfish had an adequate sample size for inclusion in the updated advisory. OEHHA omitted the following fish species because sample sizes were too small:

- ☐ Three bluegill
- ☐ Four brown trout
- ☐ One crappie
- ☐ Two largemouth bass

12. Camp Far West Reservoir (Yuba, Nevada, and Placer Counties)

The updated safe eating guidelines for Camp Far West Reservoir included new data. More information about this updated advisory is given below.

New data:

OEHHA combined previous data with new data for Camp Far West Reservoir from two sources to update the safe eating guidelines:

- ☐ SWAMP sampled 13 legal-size spotted bass from Camp Far West Reservoir in 2007 and analyzed them for mercury. They also sampled ten channel catfish and analyzed them for mercury, selenium, and organics.
    - Selenium and organics concentrations were below levels of health concern.
    - OEHHA combined the results for mercury levels with prior data to update the advisory.
- ☐ In addition to sampling in 2000, which provided data for the previous advisory, USGS collected additional samples in 2002 from Camp Far West Reservoir[7]. The samples were analyzed for mercury and included:
    - 16 bluegill
    - 10 spotted bass

Related species:

OEHHA grouped the following related species:

- ☐ Bass: largemouth bass and spotted bass

Beneficial fats:

The mean mercury level for catfish from Camp Far West Reservoir was close to the limit for "no consumption" for the sensitive population, women aged 18 – 45 and children 1 – 17 years. Because catfish are not known to have high omega-3 levels, OEHHA changed the recommendation for the sensitive population from one serving a week to "no consumption." Table 7 shows a summary of average mercury concentrations in the fish samples from Camp Far West Reservoir.

Table 7. Average Mercury and Size in Fish from Camp Far West Reservoir

Common Name	Number of Fish	Mean Mercury (ppm)	Mean Total Length (mm)
Bluegill	19	0.19	140
Channel catfish	13	0.44	443
Largemouth and spotted bass	38	0.85	357

13. Lake Combie (Placer and Nevada Counties)

The updated safe eating guidelines for Lake Combie included new data combined with prior data. More information about this updated advisory is given below. **New data:** In 2007, SWAMP sampled two fish species from Lake Combie. Ten legal-size largemouth bass were analyzed for mercury. One composite sample of five suckers was analyzed for mercury, selenium, and organics. A second composite sample of five suckers was also analyzed for mercury.

- ☐ The concentrations of organics and selenium were below levels of health concern.
- ☐ Average mercury levels in the largemouth bass and two composite samples of sucker were included in the updated advice.

Sample size:

Fish species with insufficient sample sizes (less than a minimum of nine individuals) were not included in the safe eating guidelines:

- ☐ Two bluegill
- ☐ Two rainbow trout

Table 8 shows average mercury concentrations in the combined fish data for the updated safe eating guidelines for Lake Combie.

Common Name	Number of Fish	Mean Mercury (ppm)	Mean Total Length (mm)
Largemouth bass	19	0.90	393
Sucker	10	0.53	444

14. Lower Feather River (Butte, Yuba and Sutter Counties) OEHHA updated the safe eating guidelines for the Lower Feather River using new data combined with prior data and the ATLs.

New data:

Fish from several locations on the Lower Feather River were sampled and analyzed for mercury under the FMP in 2005 and 2006. FMP samples included:

- ☐ 10 American shad

- ☐ 5 bluegill
- ☐ 10 redear sunfish
- ☐ 5 carp
- ☐ 5 crappie
- ☐ 14 largemouth bass
- ☐ 23 pikeminnow
- ☐ 30 sucker

Sample size:

Crappie was the one fish species with insufficient sample size (less than a minimum of nine individuals) to include in the safe eating guidelines. Bluegill data were combined with those for redear sunfish, and carp samples were combined with prior data for carp. In addition, five river-run Chinook salmon and six river-run steelhead trout were collected at the Feather River Hatchery. Although samples sizes were too small for evaluating these fish specifically, OEHHA issued general safe eating guidelines in 2009 for river-run salmon as follows.

River-run salmon from rivers in northern California are generally low in contaminants. Unless otherwise noted, prohibited, or restricted, they can be eaten 2 to 3 servings a week by women ages 18 – 45 and children ages 1 – 17 years; and 7 servings a week by men over 17 years and women over 45 years old.

Known accumulator species:

Striped bass are known to accumulate high levels of mercury. OEHHA provided advice for six striped bass based on the advice for largemouth bass and pikeminnow, species also high in mercury in the Lower Feather River. Table 9 shows a summary of mercury data for fish in the updated safe eating guidelines for the Lower Feather River.

Table 9. Average Mercury and Size in Fish from the Lower Feather River

Common Name	Number of Fish	Mean Mercury (ppm)	Mean Total Length (mm)
American Shad	10	0.05	436
Bluegill and redear sunfish	30	0.18	172
Carp	16	0.24	504
Channel and White Catfish	47	0.43	465
Largemouth Bass	61	0.71	337
Sacramento Pikeminnow	38	0.87	345
Sacramento Sucker	38	0.25	424
Striped Bass	6	1.27	652

Reclaiming the Sierra Initiative

RESOURCES

As a part of the **Reclaiming the Sierra Initiative,** The Sierra Fund is building a toolbox to help Sierra Nevada community members and leaders learn about and address the issue of legacy mining toxins. The following documents are available online at *www.sierrafund.org:*

Mining's Toxic Legacy: An Initiative to Address Legacy Mining Toxins in the Sierra Nevada

This 85-page report is the first-ever comprehensive look at the ongoing environmental, cultural and human health impacts of the Gold Rush. Also available: 8-page Executive Summary.

Protecting Public Health and the Environment from Legacy Mining Toxins: A Primer for Nonprofit Organizations in the Sierra Nevada

This document summarizes the key issues that confront land trusts and land and water conservation organizations working in the Sierra Nevada.

Protecting Public and Environmental Health from Legacy Mining Toxins: A Primer for Local Government Officials in the Sierra Nevada

This document summarizes the key issues that confront local government officials with legacy mining in their jurisdiction.

Building a Mining Toxins Working Group: A Blueprint for California

This working document is meant to guide collaboration among and encourage community involvement in the many efforts to address legacy mining contamination in the Sierra Nevada.

Recreational Trails and Abandoned Mines Assessment

Released in June 2010, the purpose of this study was to learn whether recreationists may be exposed to mine waste or naturally occurring hazardous substances on public lands in the Sierra Nevada.

THE SIERRA FUND

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(530) 265-8454 - info@sierrafund.org
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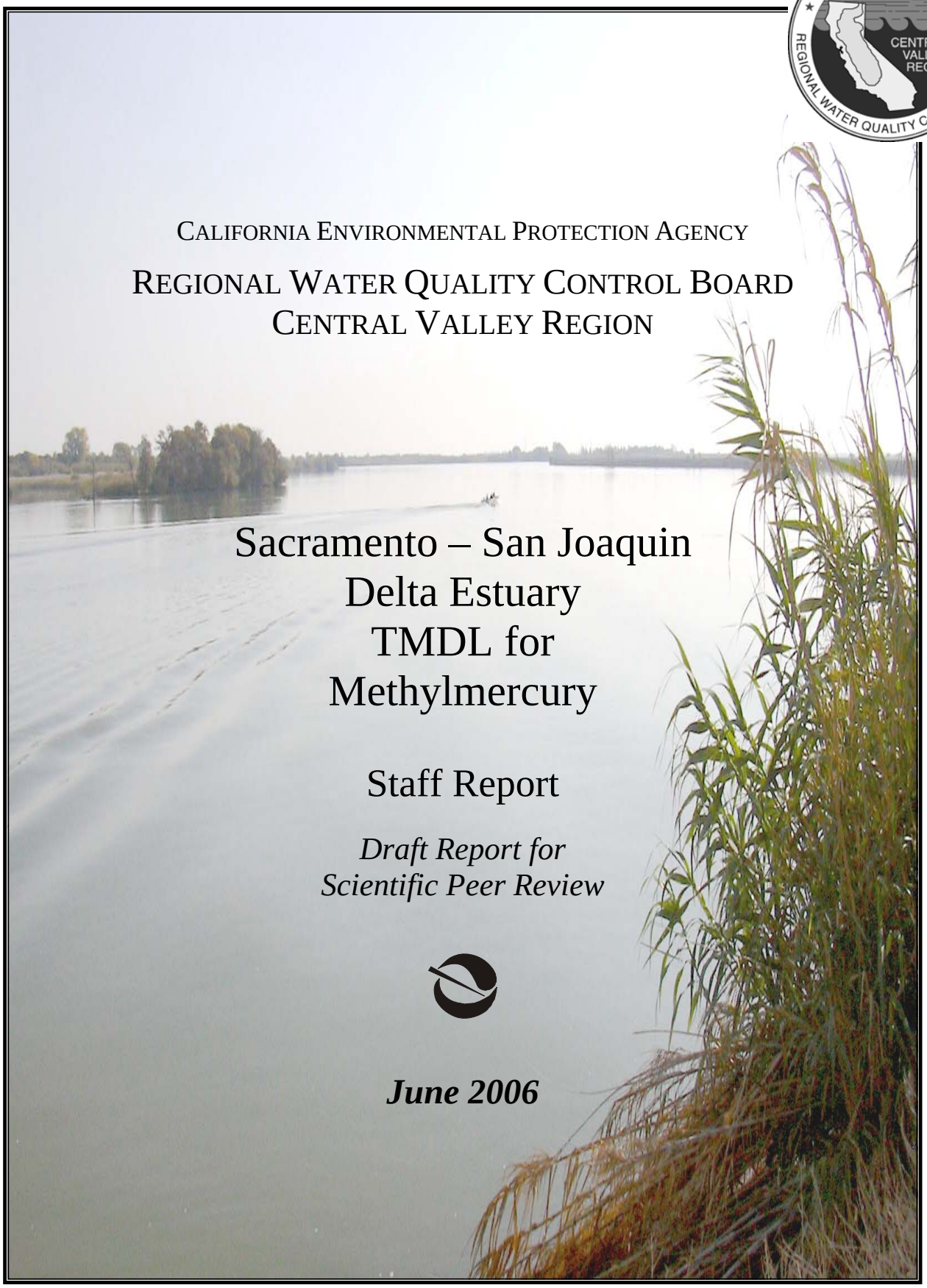

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury

Staff Report

Draft Report for Scientific Peer Review

June 2006

State of California
Arnold Schwarzenegger, Governor

California Environmental Protection Agency
Linda S. Adams, Secretary

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CENTRAL VALLEY REGION

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CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury

Staff Report

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Scientific Peer Review

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SACRAMENTO – SAN JOAQUIN DELTA ESTUARY TMDL FOR MERCURY

EXECUTIVE SUMMARY

This draft report presents Central Valley Regional Water Quality Control Board (Central Valley Water Board) staff recommendations for establishing a Total Maximum Daily Load for methylmercury in the Sacramento-San Joaquin Delta Estuary. The report contains an analysis of the mercury impairment, a review of the primary sources, a linkage between methylmercury sources and impairments, and recommended mercury reductions to eliminate the impairment.

This TMDL report is the first component in the Central Valley Water Board's water quality attainment strategy to resolve the mercury impairment in the Delta. The second component is implementing a control program through amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (the Basin Plan), as described in the main text and Appendix A of the Proposed Basin Plan Amendment draft staff report.

Scope, Numeric Targets & Extent of Impairment

In 1990 the Central Valley Water Board identified the Delta as impaired by mercury because fish had elevated levels of mercury that posed a risk for human and wildlife consumers. As a result, the Delta methylmercury TMDL addresses all waterways within the legal Delta boundary. In addition, the San Francisco Bay Regional Water Quality Control Board (San Francisco Water Board) identified Central Valley outflows *via* the Delta as one of the principal sources of total mercury to San Francisco Bay and, in its 2004 mercury TMDL for San Francisco Bay, assigned the Central Valley a load reduction of 110 kg/yr. Therefore, the final mercury TMDL control plan for the Delta must ensure protection of human and wildlife health in the Delta and meet the San Francisco Bay load allocation to the Central Valley.

This TMDL report addresses both methyl and total mercury sources. Reductions in ambient aqueous methylmercury and methylmercury sources are required to reduce methylmercury concentrations in fish. The methylmercury linkage and source analyses divide the Delta into eight subareas based on the hydrologic characteristics and mixing of the source waters. A separate methylmercury allocation scheme is developed for each subarea because the levels of impairment and the methylmercury sources in the subareas are substantially different. Reductions in total mercury loads are needed to reduce aqueous methylmercury in the Delta, to maintain compliance with the USEPA's criterion of 50 ng/l, and to comply with the San Francisco Bay mercury control program.

The concentration of methylmercury in fish tissue is the type of numeric target selected for the Delta methylmercury TMDL. Acceptable fish tissue levels of methylmercury for the trophic level TL food groups consumed by piscivorous wildlife species were calculated using a method developed by the U.S. Fish and Wildlife Service that addresses daily intake levels, body weights and consumption rates. Numeric targets were developed to protect humans in a manner analogous to targets for wildlife using a method approved by the U.S. Environmental Protection Agency and Delta-specific information.

Three numeric targets are recommended for the protection of humans and piscivorous wildlife: 0.24 mg/kg (wet weight) in muscle tissue of large[1] trophic level four (TL4) fish such as bass and catfish; 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon; and 0.03 mg/kg (wet weight) in whole trophic level 2 and 3 fish less than 50 mm in length. The targets for large TL3 and 4 fish are protective of (a) humans eating 32 g/day (1 meal/week) of commonly consumed, large fish; and (b) all wildlife species that consume large fish. The target for small TL2 and 3 fish is protective of wildlife species that consume small fish.

It was possible to describe these recommended objectives in terms of the mercury concentration in standard 350 mm largemouth bass. A methylmercury concentration of 0.28 mg/kg in 350 mm largemouth bass is equivalent to the water quality objective of 0.24 mg/kg for large TL4 fish. A methylmercury concentration of 0.24 mg/kg in 350 mm largemouth bass is equivalent to the water quality objective of 0.08 mg/kg for TL3 fish. A methylmercury concentration of 0.42 mg/kg in 350 mm largemouth bass is equivalent to the water quality objective of 0.03 mg/kg for small fish. As a result, a methylmercury concentration of 0.24 mg/kg in 350 mm largemouth bass is referred to as the recommended implementation goal for largemouth bass.

Elevated fish methylmercury concentrations occur along the periphery of the Delta while lower body burdens occur in the central Delta. Concentrations are greater than recommended as safe by the USFWS for wildlife in all subareas except in the Central Delta subarea. The Central Delta subarea requires no reduction to meet the proposed large TL3 fish target for human protection and an 8% reduction to meet the proposed large TL4 fish target for human protection. Percent reductions in fish methylmercury levels ranging from 0% to 75% in the peripheral Delta subareas will be needed to meet the numeric targets for wildlife and human health protection.

Linkage

The Delta linkage analysis focuses on the comparison of methylmercury concentrations in water and biota. Statistically significant, positive correlations have been found between aqueous methylmercury and aquatic biota, suggesting that methylmercury levels in water may be one of the primary factors determining methylmercury concentrations in fish.

The mercury concentrations in standard 350-mm largemouth bass for each Delta subarea were regressed against the average unfiltered aqueous methylmercury concentrations. Substitution of the recommended implementation goal for largemouth bass (0.24 mg/kg) into the equation developed by this regression results in a predicted average safe aqueous methylmercury concentration of 0.066 ng/l. Incorporation of an explicit margin of safety of about 10% results in the recommended implementation goal for unfiltered ambient water of 0.06 ng/l methylmercury. This implementation goal would be applied as an annual average methylmercury concentration in ambient waters of the Delta. The recommended implementation goal is currently met in the Central Delta subarea.

[1] Large fish are defined as 150-500 mm total length or legal catch length if designated by CDFG.

Sources – Methylmercury

Average annual methylmercury inputs and exports were estimated for water years 2000 to 2003, a relatively dry period that encompasses the available information. Sources of methylmercury in Delta waters include tributary inputs from upstream watersheds and within-Delta sources such as sediment flux, municipal and industrial wastewater, agricultural drainage, and urban runoff. Losses include water exports to southern California, outflow to San Francisco Bay, removal of dredged sediments, photodegradation, uptake by biota and unknown loss term(s). Figure 1 illustrates the Delta's average daily methylmercury imports and exports. Sediment fluxes in wetland and open water habitats and tributary water bodies account for about 30 and 60%, respectively, of methylmercury inputs to the Delta. The difference between the sum of known inputs and exports is a measure of the uncertainty of the loading estimates and of the importance of other unknown processes at work in the Delta. Preliminary photodegradation study results for the Sacramento River near Rio Vista (Byington *et al.*, 2005) suggest that methylmercury loss from photodegradation may account for about 60% of the unknown loss rate illustrated in Figure 1.

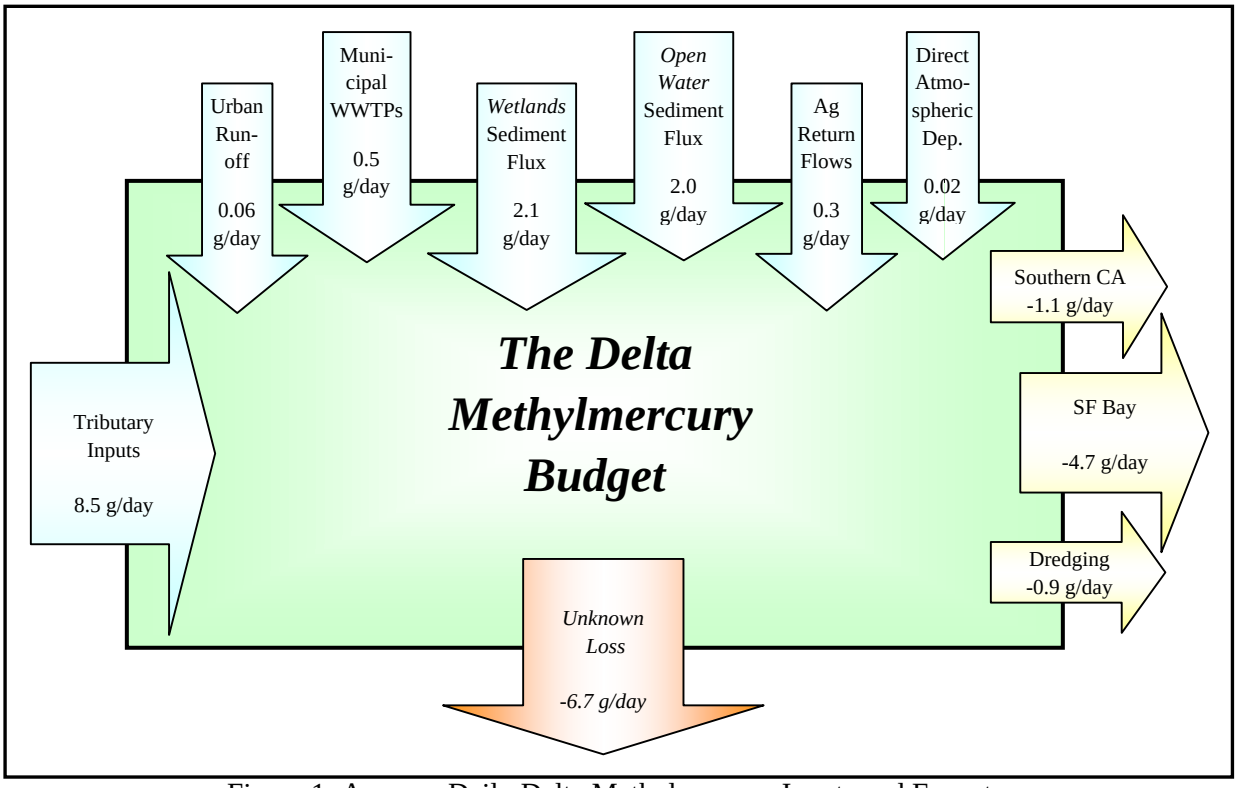

Figure 1: Average Daily Delta Methylmercury Inputs and Exports.

Sources – Total Mercury & Suspended Sediment

Sources of total mercury in the Delta include tributary inflows from upstream watersheds, atmospheric deposition, urban runoff, and municipal and industrial wastewater. More than 96% of identified total mercury loading to the Delta comes from tributary inputs; within-Delta sources are a very small component of overall loading. Losses include outflow to San Francisco Bay, water exports to southern California, removal of dredged sediments and evasion.

The Sacramento Basin (Sacramento River + Yolo Bypass) contributes approximately 80% or more of total mercury fluxing through the Delta. Of the watersheds in the Sacramento Basin, the Cache Creek and upper Sacramento River (above Colusa) watersheds contribute the most mercury. The Cache Creek, Feather River, American River and Putah Creek watersheds in the Sacramento Basin have both relatively large mercury loadings and high mercury concentrations in suspended sediment, which makes these watersheds more likely candidates for load reduction programs.

Methylmercury Allocations & Total Mercury Limits

Methylmercury allocations were made in terms of the existing assimilative capacity of the different Delta subareas. To determine reductions, the existing average aqueous methylmercury levels in the Delta subareas were compared to the proposed methylmercury goal (0.06 ng/l). The amount of reduction needed in each subarea is expressed as a percent of the ambient concentration. Percent reductions required to meet the goal ranged from 0% in the Central Delta subarea to more than 70% in the Yolo Bypass and Mokelumne River subareas.

In order to attain the desired ambient methylmercury levels in each Delta subarea, loads of methylmercury from within-Delta point and nonpoint sources and tributary inputs need to be reduced in proportion to the desired decrease in concentrations needed for ambient waters to meet the proposed goal. The percent allocations and acceptable loads and concentrations were calculated as a percent of existing loads and concentrations. The percent reductions vary by subarea because the percent reductions required for ambient water methylmercury levels in each subarea to meet the proposed methylmercury goal vary. No reductions were required for sources to the Central Delta. Percent reductions were applied to point and nonpoint source loads within other subareas, except those sources with existing average methylmercury concentrations at or below the proposed methylmercury goal of 0.06 ng/l. No individual source would be expected to reduce its discharged methylmercury concentrations to below the proposed implementation goal.

A total mercury load reduction strategy was developed to comply with the San Francisco Bay mercury control program, to maintain compliance with the USEPA's criterion of 50 ng/l, and to help reduce aqueous methylmercury in the Delta. Staff recommends total mercury load reductions from the Cache Creek, Feather River, American River and Putah Creek watersheds in the Sacramento Basin. These watersheds have both relatively large mercury loadings and high mercury concentrations in suspended sediment, which makes those watersheds likely candidates for load reduction programs. Staff also recommends that total mercury loading to the Delta not increase as a result of new or expanded projects, and that any increase in total mercury loading be mitigated or in compliance with an offset program. The TMDL for San Francisco Bay assigned the Central Valley a five-year average total mercury load

reduction if 110 kg/yr. Staff considers a 110 kg reduction as a reasonable goal for the first phase of the Delta mercury control program.

The methylmercury allocations and total mercury limits described in this report reflect the preferred implementation alternative described in Chapter 4 of the Proposed Basin Plan Amendment draft staff report and are designed to address the beneficial use impairment in all subareas of the Delta and San Francisco Bay. However, as described in the Proposed Basin Plan Amendment draft staff report, a number of alternatives are possible. The Central Valley Water Board will consider a variety of mercury reduction strategies and implementation alternatives as part of the Basin Plan amendment process. All Central Valley Water Board regulatory actions will be taken in public hearings.

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ACRONYMS

ARB	California Air Resources Board
AWQC	Ambient water quality criterion
BAF	Bioaccumulation factor
Basin Plan	Central Valley Region Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
bwt	Body weight
CCSB	Cache Creek Settling Basin
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services
CEIDARS	California emission inventory department and reporting system
cfs	Cubic feet per second
CFSII	Continuing survey of food intake by individuals
CMP	Coordinated Monitoring Program
CSS	Combined Sewer system
CTR	California Toxics Rule
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board (a.k.a. Central Valley Water Board)
CWA	Federal Clean Water Act
DMC	Delta Mendota Canal
DTMC	Delta Tributaries Mercury Council
DWR	California Department of Water Resources
EC	Electrical conductivity
FCM	Food chain multipliers
GIS	Geographic Information System
HCI	Hydrologic Classification Index
Hg	Mercury
IEP	Interagency Ecological Program
IRIS	Integrated Risk Information System
LMB	Largemouth bass
LOAEC's	Lowest observed adverse effect concentrations
MCL	California/USEPA drinking water standards maximum contaminant levels
MDN	Mercury Deposition Network
mgd	Million gallons per day
MID	Modesto Irrigation District
MeHg	Monomethyl mercury (also referred to as methylmercury in this report)
MS4	Municipal Separate Storm Sewer System
NADP	National Atmospheric Deposition Program
NAS	National Academy of Sciences

NEMD	Natomas East Main Drain
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NWI	National Wetland Inventory
O	Oxygen
o/oo	Parts per thousand (salinity)
OBS	Optical back scatter
OEHHA	Office of Environmental Health Hazard Assessment
RFD	Reference dose
RSC	Relative source contribution
San Francisco Water Board	San Francisco Bay Regional Water Quality Control Board
SFBADPS	San Francisco Bay Atmospheric Deposition Pilot Study
SFEI	San Francisco Estuary Institute
SRCSD	Sacramento Regional County Sanitation District
SRWP	Sacramento River Watershed Program
State Board	State Water Resources Control Board (also shown as SWRCB in reference citations)
Subwatershed	Portion of watershed that is either upstream or downstream of the most-downstream major dam
SWIM	Surface water information
SWP	State water project
SWRCB	State Water Resources Control Board
TDSL	Total diet safe level
TL	Trophic level
TLR	Trophic level ratios
TMDL	Total Maximum Daily Load
TSS	Total suspended solids
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFDA	U.S. Food and Drug Administration.
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
ww	Wet weight concentration (e.g., for fish tissue mercury concentrations)
WWTP	Wastewater treatment plants
X2	Location in the Estuary with 2-o/oo bottom salinity

UNITS OF MEASURE

μg	microgram
μg/g	microgram per gram
μg/l	microgram per liter
μm	micrometer
cfs	cubic feet per second
cm	centimeter
g	Gram
g/day	gram per day
g/l	gram per liter
in/yr	inches per year
kg	kilogram
l	Liter
m	Meter
mg	milligram
mg/g	milligram per gram
ml	milliliter
mm	millimeter
ng	nanograms
ng/l	nanograms per liter
o/oo	parts per thousand (salinity)
ppb	parts per billion; usually μg/kg
ppm	parts per million; usually mg/kg or μg/g
ppt	parts per trillion; usually ng/kg

CENTRAL VALLEY
REGIONAL WATER QUALITY CONTROL BOARD

AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE SACRAMENTO RIVER AND SAN JOAQUIN RIVER BASINS FOR THE CONTROL OF METHYLMERCURY AND TOTAL MERCURY IN THE SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

DRAFT STAFF REPORT

APRIL 2010

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DISCLAIMER
This publication is a report by staff of the California Regional Water Quality Control Board, Central Valley Region. This report contains the evaluation of alternatives and technical support for the adoption of a Basin Plan Amendment to the Water Quality Control Plan for the Sacramento and San Joaquin River Basins (Resolution No. TBD). Mention of specific products does not represent endorsement of those products by the Central Valley Water Board.

CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL VALLEY REGION

Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary

Draft Staff Report

April 2010

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AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE SACRAMENTO RIVER AND SAN JOAQUIN RIVER BASINS FOR THE CONTROL OF METHYLMERCURY AND TOTAL MERCURY IN THE SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

EXECUTIVE SUMMARY

This Central Valley Regional Water Quality Control Board (Central Valley Water Board) staff report describes a proposal to amend the Water Quality Control Plan (Basin Plan) for the Sacramento River and San Joaquin River Basins to address the regulation of methylmercury and total mercury in the Sacramento-San Joaquin Delta Estuary (the Delta). The Delta is on the Clean Water Act Section 303(d) List of Impaired Water Bodies because of elevated levels of mercury in fish. The goal of the proposed Basin Plan amendments is to lower fish mercury levels in the Delta so that the beneficial uses of fishing and wildlife habitat are attained. Central Valley Water Board staff will circulate this staff report and the enclosed draft Basin Plan amendments for public review and comment prior to Central Valley Water Board consideration. The section following the Table of Contents provides the recommended format for comment submittal.

The proposed Basin Plan amendments define the Delta Mercury Control Program. Major components of the proposed Basin Plan amendments are:

- Addition of a beneficial use designation of commercial and/or sport fishing (COMM) for the Delta;
- Numeric objectives for methylmercury in fish tissue that are specific to the Delta;
- An implementation plan for controlling methylmercury and total mercury sources; and
- A surveillance and monitoring program.

2008-2009 Stakeholder Process

Staff and the Sacramento State University's Center for Collaborative Policy (CCP) have involved stakeholders in development of the Basin Plan amendments using a facilitated stakeholder process. At the April 2008 public hearing for the draft Basin Plan amendments, Central Valley Water Board members directed staff to work with stakeholders to resolve stakeholders' concerns about the proposed program. Between December 2008 and January 2010, CCP and staff held thirteen Stakeholder Group meetings (with between 30 and 60 participants at each meeting) and numerous workgroup meetings. Staff incorporated many of the stakeholders' comments into the draft Basin Plan amendments.

Proposed Modifications to Basin Plan Chapter II (Existing and Potential Beneficial Uses)

Staff proposes the addition of the commercial and sport fishing (COMM) as a designated beneficial use for the Delta and Yolo Bypass. The proposed Basin Plan amendment implementation plan is to protect the COMM beneficial use.

Proposed Modifications to Basin Plan Chapter III (Water Quality Objectives)

Staff proposes numeric objectives for methylmercury in fish tissue (referred to as fish tissue objectives) for the Delta. Methylmercury is the most toxic form of mercury and accumulates in successive levels of the food chain.

Staff evaluated five alternatives for the fish tissue objectives, including no action and a range of fish tissue objectives that are based on varying the amount and the trophic level of fish that can be safely consumed by humans. The recommended alternative would establish Delta-specific methylmercury fish tissue objectives of 0.08 and 0.24 mg/kg, wet weight, in fish tissue for large trophic level 3 and 4 fish (150-500 mm total length) and 0.03 mg/kg, wet weight, for small trophic level 2 and 3 fish (less than 50 mm). The proposed objectives are protective of threatened and endangered wildlife species that consume large and small Delta fish. In addition, the proposed objectives allow people to safely eat 32 g/day (eight ounces, uncooked, per week) of a mixture of Delta fish along with a moderate amount of commercial fish. The long-term goal of the mercury program is enable people to safely eat four to five meals per week of top tropic level fish. The proposed fish tissue objectives will be re-evaluated during the scheduled review of the Delta Mercury Control Program defined by the proposed Basin Plan amendments.

Proposed Modifications to Basin Plan Chapter IV (Implementation)

To achieve the proposed fish tissue objectives, staff proposes an implementation plan for the Delta Mercury Control Program that includes actions and time schedules to reduce methyl and inorganic mercury sources to the Delta through a phased adaptive approach. The proposed implementation plan for the Delta Mercury Control Program consists of two phases. Phase 1 spans from the USEPA approval date of this program until the Central Valley Water Board conducts a formal review of the program. Phase 1 is expected to last about nine years. Phase 1 emphasizes studies and pilot projects to develop and evaluate management practices to control methylmercury. Phase 1 includes provisions for: pollution minimization programs and interim mass limits for inorganic mercury point sources in the Delta and Yolo Bypass, and control of discharges of sediment-bound mercury in the Delta and Yolo Bypass that may become methylated in agriculture, wetland, and open-water habitats, and to reduce total mercury loading to San Francisco Bay. The program also contains requirements for improvements to the Cache Creek Settling Basin trapping efficiency, establishes inorganic mercury load reductions from upstream mercury-contaminated watersheds, establishes a mercury exposure reduction program to protect humans consuming Delta fish, and establishes a schedule and guiding principles for developing a mercury offset program and Phase 1 pilot offset projects.

At the end of Phase 1, the Central Valley Water Board will conduct a formal review of the Delta Mercury Control Program. The review will consider modification of methylmercury reduction goals, fish tissue objectives, methylmercury allocations, and compliance dates. The review also will consider requiring dischargers to implement inorganic mercury and methylmercury management practices developed in Phase 1 and will include consideration of a Mercury Offset Program for dischargers who cannot fully meet methylmercury allocations after implementing all reasonable load reduction strategies and can demonstrate no disproportionate impacts on local

communities as a result. The review also will consider the potential public and environmental benefits and negative impacts of attaining the methylmercury allocations. The Phase 1 review will culminate in a revised Delta Mercury Control Program through another Basin Plan amendment in about 2019.

Phase 2 begins after the Phase 1 Delta Mercury Control Program review and lasts until 2030. During Phase 2, dischargers will implement management practices in accordance with schedules adopted for Phase 2 activities. Full compliance with the methylmercury allocations is required by 2030, unless the Central Valley Water Board modifies the final compliance date during the Phase 1 review process.

The recommended Delta Mercury Control Program has the following major components:

- Methylmercury allocations for methylmercury point and nonpoint sources in the Delta and Yolo Bypass.
- A methylmercury control study period during Phase 1. The Control Studies are required for:
    - Irrigated agricultural lands that discharge to the Yolo Bypass and Delta subareas that require methylmercury source reductions
    - Managed wetlands and wetland restoration projects that discharge to the Yolo Bypass and Delta subareas that require methylmercury source reductions.
    - Existing NPDES permitted facilities in the Delta and the Yolo Bypass.
    - Sacramento, Stockton, Contra Costa County stormwater agencies.
    - State and federal agencies whose projects affect the transport of mercury and the production and transport of methylmercury through the Yolo Bypass and Delta (Department of Water Resources, State Lands Commission, Central Valley Flood Protection Board, U.S. Army Corps of Engineers, and U.S. Bureau of Reclamation).

  The Control Studies can be developed through a stakeholder group approach or other collaborative mechanism, or by individual dischargers. Individual dischargers are not required to do individual studies if the individual dischargers join a collaborative study group(s).
- Requirements for NPDES facilities in the Delta and Yolo Bypass to implement mercury-specific pollutant minimization programs and maintain performance-based Phase 1 (interim) effluent inorganic mercury mass limits.
- Requirements for the Sacramento, Stockton, Contra Costa County stormwater agencies to continue to conduct mercury control studies to monitor and evaluate the effectiveness of existing management practices and to develop and evaluate additional management practices as needed to reduce their inorganic mercury and methylmercury discharges within and upstream of the legal Delta boundary.
- A schedule for establishing mercury TMDL control programs for major tributary inputs to the Delta.
- A schedule and guiding principles for developing a mercury offset program and Phase 1 pilot offset projects in coordination with stakeholders.
- Requirements and a schedule to plan and implement an exposure reduction program to protect humans consuming large quantities of Delta fish.

- A schedule for agencies responsible for Cache Creek Settling Basin operations and maintenance to propose and implement improvements to the Basin to reduce inorganic mercury loading to the Yolo Bypass.
- Requirements for dredging projects in the Delta to evaluate management practices to reduce methylmercury and total mercury loads from dredging activities in Delta waterways or from the disposal of dredged materials.

Proposed Modifications to Basin Plan Chapter V (Surveillance and Monitoring)

Staff proposes a surveillance and monitoring program to ensure compliance with the fish tissue methylmercury objectives and methylmercury and total mercury reduction strategy proposed for addition to Chapters III and IV. The program includes fish tissue and water monitoring.

Environmental Analysis

To satisfy requirements of the California Environmental Quality Act (CEQA), staff performed an environmental analysis of the potential impacts of the proposed Basin Plan amendments. Adoption of the proposed Basin Plan amendments will not by itself have a physical effect on the environment, nor will the Phase 1 studies. However, implementation actions taken by responsible entities to comply with some components of the proposed implementation plan and improvements to the environment by controlling mercury and/or methylmercury may have the potential for adverse environmental effects impacts. The environmental analysis determined that implementation of the proposed Basin Plan amendments could result in potentially significant impacts to biological resources, greenhouse gas emissions, hydrology/water quality, and utilities/service systems, unless mitigation is incorporated. The staff report summarizes reasonable actions to reduce the potential impacts from implementation projects. With few exceptions, potential impacts are expected to be limited and mitigated to less than significant levels, if not completely avoided, through careful project planning, design, and implementation. Mitigation measures lie within the jurisdiction of agencies implementing site-specific projects. The Central Valley Water Board does not have legal authority to specify the manner of compliance with its orders and thus cannot specify particular implementation projects nor dictate that specific mitigation measures be implemented by any particular project.

The environmental analysis found that implementation of methylmercury management practices to achieve safe fish mercury levels in the Yolo Bypass has the potential to result in cumulatively considerable impacts to habitat that supports endemic species with limited geographic ranges, such as Sacramento splittail and Delta smelt. Until the Phase 1 control studies have been completed, it is unknown whether the wetlands that act as substantial methylmercury sources in the Yolo Bypass also provide critical habitat to endemic species and whether it will be possible to avoid all potentially significant impacts. In addition, the potential costs of complying with requirements for studies, monitoring and implementation actions are substantial.

Prudent implementation of the proposed Basin Plan amendments is expected to result in overall improvement in water quality in the waters of the Delta region and to have significant positive impacts to the environment and public health over the long term by enabling humans and wildlife to safely consume Delta fish.

DRAFT BASIN PLAN AMENDMENTS

Provided as Attachment 1 to the Central Valley Water Board Resolution N0. R5-2010-####

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AMENDMENTS TO THE WATER QUALITY CONTROL PLAN FOR THE SACRAMENTO RIVER AND SAN JOAQUIN RIVER BASINS FOR THE CONTROL OF METHYLMERCURY AND TOTAL MERCURY IN THE SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Draft Staff Report

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ACRONYMS

§	Section
303(d) List	Clean Water Act Section 303(d) List of Impaired Water Bodies
ATSDR	U.S. Agency for Toxic Substances and Disease Registry
BAF	Bioaccumulation factor
Basin Plan	Central Valley Region Water Quality Control Plan for the Sacramento River and San Joaquin River Basins
BCF	Bioconcentration factor
BMP	Best management practice
bwt	Body weight
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CCR	California Code of Regulations
CCSB	Cache Creek Settling Basin
CDEC	California Data Exchange Center
CDFG	California Department of Fish and Game
CDHS	California Department of Health Services, re-organized in 2007 and renamed "California Department of Public Health" (CDPH). Reports issued before the 2007 re-organization are cited as "CDHS" reports.
CDOF	California Department of Finance
CDPH	California Department of Public Health
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CFR	Code of Federal Regulations
cf	Cubic feet
cfs	Cubic feet per second
CFSII	Continuing Survey of Food Intake by Individuals
cy	Cubic yard
CTR	California Toxics Rule
CVP	Central Valley Project
CVRWQCB	Central Valley Regional Water Quality Control Board (a.k.a. Central Valley Water Board)
CWA	Federal Clean Water Act
CWC	California Water Code
DMC	Delta Mendota Canal
DPC	Delta Protection Commission
DTMC	Delta Tributaries Mercury Council
DWR	California Department of Water Resources
EC	Electrical Conductivity
FCM	Food chain multipliers
GHG	Greenhouse gas
GIS	Geographic Information Systems
GLWQI	Great Lakes Water Quality Initiative Final Rule
GWP	Global Warming Potential
HCI	Hydrologic Classification Index
HCP	Habitat Conservation Plan
Hg	Mercury
hr	Hour
LMB	Largemouth bass
LOAEC's	Lowest observed adverse effect concentrations
LOAEL	Lowest-observable adverse effect level
MCL	California/USEPA drinking water standards maximum contaminant levels
mgd	Million gallons per day
MES	Mass Emissions Strategy
MeHg	Methylmercury

ACRONYMS, *continued*

MOI	Memorandum of Intent
MS4	Municipal Separate Storm Sewer System
MRC	Mercury Study Report to Congress
MRL	ATSDR Minimal Risk Level
na	Not available
NAS	National Academy of Sciences
NEPA	National Environmental Policy Act
NCCP	Natural Communities Conservation Plan
NOAEL	No-observable adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPS	Non point source
NRC	National Research Council
o/oo	Parts per thousand (salinity)
O&M	Operation and maintenance
OEHHA	Office of Environmental Health Hazard Assessment
OPR	Governor's Office of Planning and Research
RfD	Reference dose
RSC	Relative source contribution
SDIP	South Delta Improvement Project
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board (a.k.a. San Francisco Bay Water Board)
SFEI	San Francisco Estuary Institute
SRWP	Sacramento River Watershed Program
SLC	State Lands Commission
SWMP	Storm Water Management Plan
SWP	State Water Project
SWRCB	State Water Resources Control Board (a.k.a. State Water Board)
TDSL	Total diet safe level
TL3	Trophic level 3
TL4	Trophic level 4
TLR	Trophic level ratios
TMDL	Total Maximum Daily Load
TMDL Report	Sacramento – San Joaquin Delta Estuary TMDL for Methylmercury Staff Report, provided as Appendix A to this report.
TSS	Total suspended solids
UC Davis	University of California, Davis
USACE	US Army Corps of Engineers
USBR	US Bureau of Reclamation
USDA	US Department of Agriculture
USEPA	US Environmental Protection Agency
USFDA	US Food and Drug Administration
USFWS	US Fish and Wildlife Service
WHO	World Health Organization
ww	Wet weight concentration (e.g., for fish tissue mercury concentrations)
WWTP	Wastewater treatment plants
X2	Location in the Bay-Delta Estuary with 2-o/oo bottom salinity
yr	Year

UNITS OF MEASURE

μg	microgram
μg/g	microgram per gram
μg/l	microgram per liter
μm	micrometer
cf	cubic feet
cfs	cubic feet per second
cm	centimeter
cy	cubic yard
g	gram
g/day	gram per day
g/l	gram per liter
in/yr	inches per year
kg	kilogram
l	liter
m	meter
mg	milligram
mg/g	milligram per gram
mgd	million gallons per day
Mkg	million kilograms
ml	milliliter
mm	millimeter
MMT	million metric tons
ng	nanogram
ng/l	nanograms per liter
o/oo	parts per thousand (salinity)
ppb	parts per billion; usually µg/kg
ppm	parts per million; usually mg/kg or μg/g
ppt	parts per trillion; usually ng/kg

RECOMMENDED FORMAT FOR COMMENT LETTERS

Comment letters to the Central Valley Water Board on staff recommendations serve two purposes: 1) to identify areas of agreement; and 2) to suggest revisions to staff recommendations. Clear statements of both areas of agreement and suggested revisions will assist the Central Valley Water Board and staff in determining what action, if any, to take. The following format for comment letters is recommended because it will enable the Central Valley Water Board and staff to clearly identify and respond to the specific concerns of the commenter.

Format for Comments Suggesting Revisions

The recommended format is to number the comment, state the topic in one sentence, provide a supporting argument, and make a specific recommendation. Supporting arguments should include citations, where appropriate. The recommended format is:

Comment #. *One sentence describing the topic.*
Section #, Paragraph # (only for comments regarding the staff report).
Text specifying the argument.
Text describing the suggested revision.

Additionally, for suggested revisions to the proposed Basin Plan amendments, please use underline/strikeout to show changes from the staff proposal. Commenters should support their statements with legal or scientific citations, where appropriate.

Format for Comments Supporting Staff Recommendations

The recommended format is to number the comment, state the topic in one sentence, state the section number and paragraph number (only for comments regarding the staff report), and make a statement of concurrence. An example of the recommended format is:

Comment #. *One sentence describing the topic.*
Section #, Paragraph # (only for comments regarding the staff report).
Statement of concurrence.

Commenters may include reasons for support, especially if the reasons differ from the staff rationale, or if the staff rationale could be further enhanced or clarified. Commenters also may support their statements with additional legal or scientific citations.

PREFACE TO THE APRIL 2010 DRAFT STAFF REPORT

The April 2010 draft Basin Plan Amendment draft staff report and draft TMDL report include numerous changes made since the February 2008 draft staff report. Most of the changes are associated with input from the 2008-2009 Stakeholder Process. In addition, updates were made to reflect new information and regulatory requirements. The following list identifies key changes and their locations in the two draft reports:

- 2008-2009 Stakeholder Process: Staff added new sections in Chapter 1 and 8 to describe the Stakeholder Process facilitated by the Center for Collaborative Policy after the April 2008 Board Hearing meeting. In addition, staff made changes throughout the report to reflect input provided by the:
    - Stakeholder Process after the April 2008 Board Hearing meeting;
    - Board members and stakeholders during the April 2008 meeting; and
    - Stakeholders in written comments on the February 2008 reports prior to the April 2008 meeting.
- Implementation alternatives: Staff created a different suite of options for the implementation alternatives analysis in Chapter 4 to incorporate new input from the 2008-2009 Stakeholder Process.
- Implementation cost estimates: Staff updated the cost estimates in Chapter 4 and Appendix C to reflect:
    - The recent changes to the implementation alternatives analysis;
    - Input from the stakeholders since February 2008; and
    - New cost estimates from a Tetra Tech evaluation completed in August 2008.
- Existing regulations and policies: Staff updated Chapter 6 to include policies and plans associated with NPDES compliance schedules, the Delta Vision Strategic Plan, Bay Delta Conservation Plan, Federal Bay-Delta Leadership Committee, state authorities over federal projects, and other State laws and regulations, including the State Water Board's Nonpoint Source Implementation and Enforcement Policy.
- CEQA environmental review: Staff updated the environmental evaluation in Chapter 7 to include an evaluation of climate change factors and additional information about cultural resources related to Native Americans
- Allocations: Staff made changes to the some of the methylmercury waste load allocation calculations for NPDES facilities based on stakeholder input and new information since February 2008. These changes are described in the TMDL Report, Chapters 6 and 8.

In addition, the Stakeholder Group is developing an organizational, adaptive management approach document (currently called the Memorandum of Intent) and a Control Study Workplan Guidance document, which are intended to memorialize some of the 2008-2009 Stakeholder Process and associated products as well as provide tools to help coordinate implementation activities during Phase 1 of the proposed control program. These documents are not included in the April 2010 Basin Plan amendment draft staff report because they are not part of the regulations being considered by the Central Valley Water Board. These documents and the 2008-2009 Stakeholder Process are described in Chapter 8 of this report.

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1 INTRODUCTION AND BACKGROUND

California Water Code Section 13240 requires each of the State's Regional Water Quality Control Boards (Regional Water Boards) to prepare and adopt Water Quality Control Plans, also known as Basin Plans, to regulate water quality. In addition to complying with California law, Basin Plans also satisfy the requirements of Section 303(c) of the federal Clean Water Act (CWA), which requires states to adopt water quality standards to meet federal regulatory requirements. Basin Plans are adopted and amended by the Regional Water Boards using a structured process that includes opportunities for full public participation and state environmental review. A Basin Plan identifies:

- Beneficial uses to be protected;
- Water quality objectives; and
- Implementation plans for achieving the water quality objectives.

This report addresses proposed amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan). The Basin Plan currently in effect was originally adopted by the Central Valley Regional Water Quality Control Board (Central Valley Water Board or CVRWQCB) in 1975. Updated editions were issued in 1989, 1994, and 1998; the Basin Plan was revised in September 2009 to include approved and effective amendments.

Regional Water Boards adopt and amend basin plans through a structured process involving peer review, public participation, and environmental review. Regional Water Boards must comply with the California Environmental Quality Act (CEQA) (Public Resources Code (PRC) §21000 et seq.) when amending their basin plans. The Secretary of Resources has certified the Basin Planning process as exempt from the CEQA requirement to prepare an environmental impact report or other appropriate environmental document (PRC 21080.5; Title 14 CCR §15251(g)). Instead, State Water Board regulations require the Regional Water Boards to conduct public outreach and prepare a written report and an accompanying Environmental Checklist and Determination with respect to Significant Environmental Impacts (Title 23 CCR §3775 *et seq.*).

The proposed amendments discussed in this Central Valley Water Board staff report address the regulation of methylmercury and total mercury in the Sacramento-San Joaquin Delta Estuary (the Delta). This report provides an evaluation of a variety of alternatives for water quality objectives (herein after referred to as fish tissue objectives) for the Delta and implementation options for achieving the fish tissue objectives. This report also includes an evaluation of the potential environmental impacts of the proposed objectives and implementation plan. This report contains an analysis of implementation alternatives and evaluation of their potential environmental impacts, the Environmental Checklist and conclusions of the environmental analysis.

The proposed Basin Plan amendments for control of methylmercury and total mercury in the Delta will be legally applicable once they are adopted by the Central Valley Water Board and approved by the State Water Board, the California Office of Administrative Law, and the

U.S. Environmental Protection Agency (USEPA). Implementation will begin after the Basin Plan amendments are legally applicable.

The Basin Plan amendments proposed for adoption by the Central Valley Water Board are presented after the Executive Summary at the beginning of this report. Chapter 1 of this report provides an introduction and background for the Basin Plan amendment process. Chapter 2 describes beneficial uses and existing conditions of the Delta. Chapter 3 presents the evaluation of alternative fish tissue objectives. Chapter 4 describes implementation alternatives. Chapter 5 details the recommended monitoring and surveillance plan. Chapter 6 summarizes existing federal and state laws and other policies that are relevant to the proposed fish tissue objectives and implementation plan. Chapter 7 provides the Environmental Checklist. Chapter 8 describes the public participation and agency consultations that took place throughout the TMDL and Basin Plan amendment development process. Appendix A is the methylmercury total maximum daily load (TMDL) technical staff report for the Delta (the TMDL Report), which provides the basis of many sections of the proposed Basin Plan amendments and this staff report. Appendix B provides the calculations for the different fish tissue objective alternatives. Appendix C provides the calculations of the estimated costs that support the economic consideration of the proposed fish tissue objectives and implementation program.

1.1 Terms in this Report

This report uses the term "total mercury" (TotHg) to indicate the sum of all forms of mercury (Hg) in water: physical states (e.g., dissolved, colloidal or particulate bound), chemical states (e.g., elemental, mercurous ion, or mercuric ion), organic compounds (e.g., mono-methylmercury), and inorganic compounds (e.g., cinnabar). Monomethylmercury is the predominant form of organic mercury present in biological systems and will be noted in this report as "methylmercury" (MeHg). Because methylmercury typically composes only a small portion of total mercury in ambient water,[1] the phrases "inorganic mercury" and "total mercury" are sometimes used synonymously.

1.2 Watershed Area to Be Considered

The Sacramento-San Joaquin Delta Estuary combined with the San Francisco Bay (the Bay-Delta Estuary) forms the largest estuary on the western coast of North America. The Delta encompasses a maze of river channels and embanked islands encompassing approximately 738,000 acres in Alameda, Contra Costa, Sacramento, San Joaquin, Solano and Yolo counties (DWR, 1995).

This staff report and the proposed Basin Plan amendments address the impairment of waterways inside of the "legal" Delta boundary defined by California Water Code Section 12220 (Figure 1.1). The list of Delta waterways in Appendix 43 of the proposed Basin Plan

[1] For example, a comparison of average annual methylmercury and total mercury loads from tributary watersheds to the Delta (Tables 6.2 and 7.1) indicates that methylmercury loading comprises only about 2% of all total mercury loading from the tributaries.

amendments at the beginning of this report includes all distinct, readily identifiable water bodies within the boundaries of the legal Delta that are hydrologically connected by surface water flows (not including pumping) to the Sacramento and/or San Joaquin rivers. The waterways include flowing rivers, creeks and other upland tributaries, as well as sloughs, backwaters and constructed channels. Small agricultural drains on Delta islands or uplands were not considered "Delta waterways" and are therefore not included in the list in Appendix 43. Identification of the specific waterways clarifies application of the proposed fish tissue objectives. It is not the intent of the proposed amendments to establish fish tissue objectives in canals or drains that are not hydrologically connected by surface water flows or are not distinct and readily identifiable.

The proposed implementation plan addresses methylmercury and total mercury loads in the legal Delta and sources of both in the tributary watersheds. To better address tributary sources, the Delta was divided into eight sub-regions based on hydrology. These include:

- Sacramento River: This subarea is dominated by Sacramento River flows. It is bound to the east by the legal Delta boundary and to the west by the eastern levee of the Sacramento Deep Water Ship Channel. Although drawn as a defined line, the Sacramento River subarea's boundary with the South Yolo Bypass, Central Delta, and West Delta subareas is defined by a gradient in water quality characteristics that varies depending on the tidal cycle, magnitude of wet weather flows, diversions by within-Delta control structures, and releases from reservoirs in the upstream watersheds. The boundary shown in Figure 1.1 is based on available information.
- Yolo-Bypass (North & South): The Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River (see Figure E.2 in Appendix E of the TMDL Report). The Fremont and Sacramento weirs route floodwaters to the Yolo Bypass from the Sacramento and Feather Rivers and their associated tributary watersheds. Cache and Putah Creeks, Willow Slough and the Knights Landing Ridge Cut from the Colusa Basin Drain all drain directly to the Yolo Bypass. Only the southern two thirds of the Yolo Bypass lie within the legal Delta. This portion is divided into "north" and "south" subareas by Lisbon Weir, which limits the range of tidal fluctuations upstream of the weir. In this document the North and South subareas are sometimes referred to as 2 distinct areas, but the allocations and implementation plan apply to both sections as one subarea.
- Cosumnes/Mokelumne: This subarea includes the lower Cosumnes and Mokelumne Rivers and is defined by the legal Delta boundary to the east and the Delta Cross Channel confluence with the Mokelumne to the west.
- Marsh Creek: This subarea is defined by the portion of the Marsh Creek watershed within the legal Delta boundary that is upstream of tidal effects.
- West Delta: This subarea encompasses the confluence of the Sacramento and San Joaquin Rivers, which transport water from the Central Valley to the San Francisco Bay. The western boundary of the West Delta subarea is defined by the jurisdictional boundary between the Central Valley Water Board and the San Francisco Bay Regional Water Quality Control Board (a.k.a. San Francisco Bay Water Board or Region 2). Water quality characteristics are determined by the tidal cycle, magnitude of wet weather flows, controlled flow diversions by within-Delta structures, and releases from reservoirs in the upstream watersheds.

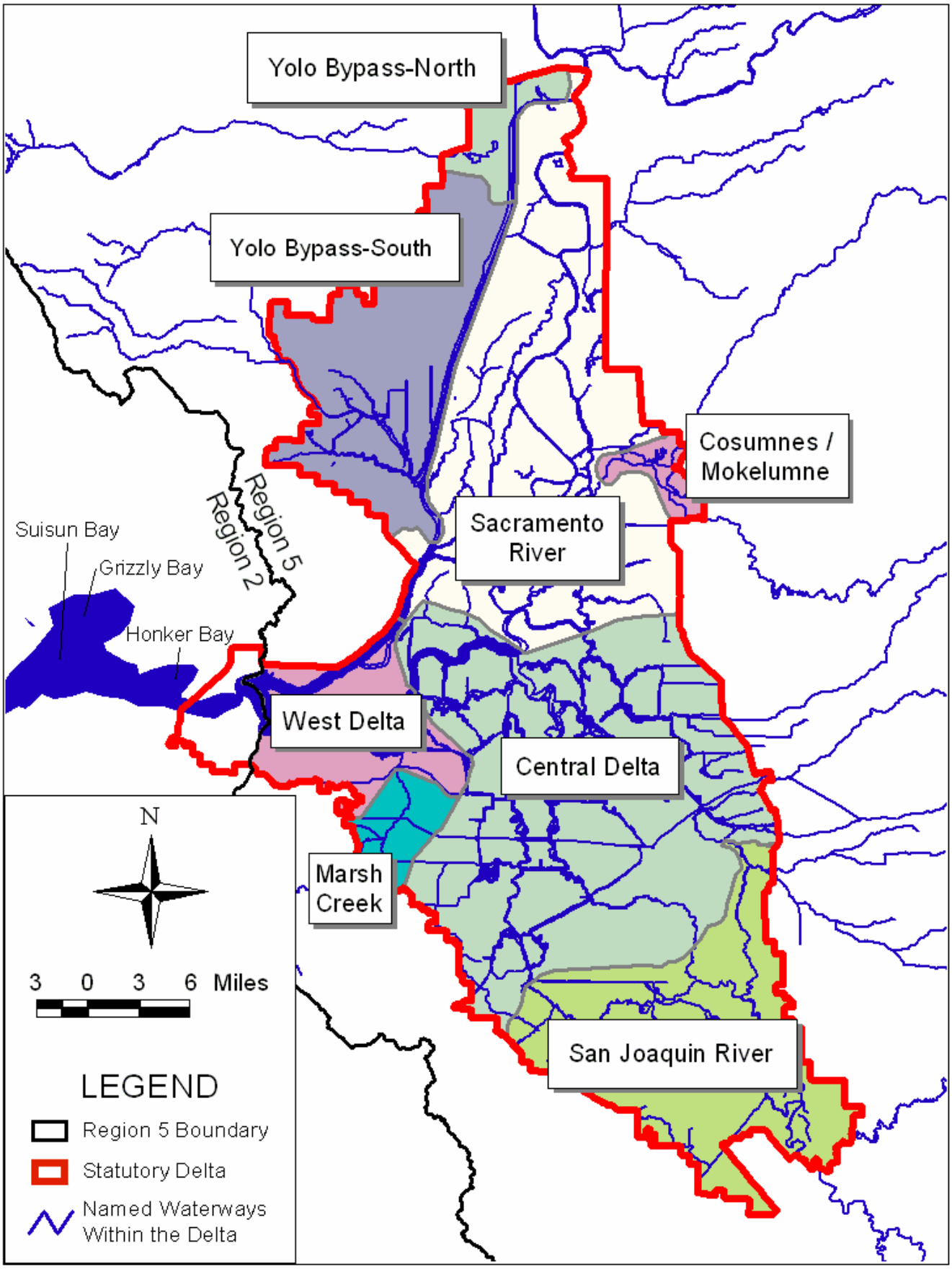

Figure 1.1: The Legal Delta Boundary Including the Eight TMDL Hydrologic Subareas

- Central Delta: This subarea includes a myriad of natural and constructed channels that transport water from the upper watersheds to San Francisco Bay to the west and the state and federal pumps to the southwest. The Central Delta tends to be most influenced by Sacramento River water.
- San Joaquin River: This subarea is defined by the legal Delta boundary to the east and south, and the Grantline Canal coupled with the beginning of the Stockton Deep Water Channel to the north. At present, the San Joaquin River is almost entirely diverted out of the Delta through the Old River and Grantline Canal for export to areas south of the Delta via the state and federal pumping facilities near Tracy.

1.3 Need for an Amendment to the Basin Plan

Section 303(d)(1)(A) of the Clean Water Act requires the Regional Water Boards to:

- Identify the Regions' waters that do not comply with water quality standards;
- Rank the impaired water bodies, taking into account factors including the severity of the pollution and the uses made of such waters; and
- Establish water quality management strategies (TMDLs) for those pollutants causing the impairments to ensure that impaired waters attain their beneficial uses.

In 1990, the State Water Board adopted the Clean Water Act 303(d) list that identified the Delta as impaired due to mercury pollution. The listing was based on a 1971 human health advisory issued for the Delta advising pregnant women and children not to eat striped bass. In 1994, the California Office of Environmental Health Hazard Assessment (OEHHA) issued an interim advisory for San Francisco Bay and the Delta that recommended no consumption of large striped bass and shark because of elevated concentrations of methylmercury and polychlorinated biphenyls (OEHHA, 1994). Additional monitoring indicates that several more species, including largemouth bass and white catfish (two commonly-caught local sport fish), also have elevated concentrations of methylmercury in their tissue (Davis *et al.*, 2003; Melwani et al., 2007; Slotton *et al.*, 2003; LWA, 2003; SWRCB-DWQ, 2002). In 2009, OEHHA released its most recent safe eating guidelines for the North Delta/Sacramento River, Central/South Delta, and the San Joaquin River. These guidelines address a variety of fish and shellfish species and indicate species that are low in mercury.

At this time, the Basin Plan does not include numeric fish tissue objectives for methylmercury in Delta fish or an implementation plan to control methylmercury or total mercury in the Delta. Therefore, Central Valley Water Board staff proposes that the Basin Plan be amended to include fish tissue objectives for methylmercury, as well as reduction strategies for methylmercury and total mercury for the Delta and its tributary watersheds.

The Central Valley Water Board will develop a water quality management strategy for each water body and pollutant in the Central Valley identified on California's 303(d) List. The management strategy for control of mercury in Delta is being conducted in several stages:

- Total Maximum Daily Load Development: Involves the technical analysis of the sources of pollutant, the fate and transport of those pollutants, the numeric target(s), and the amount of pollutant reduction that is necessary to attain the target(s). The TMDL Report for the Delta was first released to the public for comment in August 2005; a revised version was

released in June 2006 for scientific peer review. This report formed the basis of many parts of the proposed Basin Plan amendment staff report. Comments received on the 2005, 2006 and 2008 draft TMDL Reports were considered in the development of this staff report and the updated TMDL Report presented in Appendix A.

- Basin Planning: Focuses on the development of Basin Plan amendments and staff report that includes information and analyses required to comply with CEQA. The Basin Planning process satisfies State Water Board regulations for the implementation of CEQA. The Basin Plan amendments will include those policies and regulations that the Central Valley Water Board believes are necessary to attain the fish tissue objectives. Comments received on the draft 2006 and 2008 Basin Plan Amendments were considered in writing this report.
- Implementation: Establishes a framework that ensures that appropriate management practices or technologies are implemented (§13241 and §13242 of the Porter-Cologne Water Quality Act).

1.4 Guiding Principles for the Delta Mercury Control Program

The Delta Methylmercury TMDL Stakeholder Group agreed upon the following "Guiding Principles" for the Delta Mercury Control Program, Methylmercury TMDL, and Basin Plan amendments on 14 May 2009. The Guiding Principles were developed between January and May 2009 in meetings of the Stakeholder Group and a Principles Workgroup. The Stakeholder Group sought consensus on the wording of the principles. The Stakeholder Group's explanatory text that accompanied some principles is available on the Board's website and is included in the Administrative Record. Details of the 2008-2009 Stakeholder Process are provided in Chapter 8 of this report.

Guiding Principles for the Delta Mercury Control Program

1. Phase 1 studies should address both inorganic mercury (inorganic Hg) and methylmercury (MeHg) from all sources. Reasonable control options should be implemented during Phase 1 for inorganic Hg and/or MeHg.
2. Phase 1 control studies should develop knowledge for effectively controlling MeHg.
3. The Basin Plan amendment (BPA) and staff report should state the current state of knowledge of the ability to control inorganic Hg and MeHg sources to attain their load and waste load allocations and fish tissue objectives. The TMDL source control requirements should be based on that knowledge and the results of the Phase 1 studies, and be reasonable.
4. The mercury control program should incorporate an adaptive management process.
5. The mercury control program should implement reasonable, feasible actions to address MeHg loads/production and human/wildlife exposure in the near-term. The BPA should particularly address public health impacts of mercury in Delta fish, including activities that reduce actual and potential exposure of – and mitigate health impacts to – those people and communities most likely to be affected by mercury in Delta-caught fish, such as subsistence fishers and their families.
6. The mercury control program should incorporate long-term stakeholder involvement in the control studies, Technical Advisory Committee, and upstream TMDLs.

7. The control program should create strategies, including incentives to encourage innovative actions, to address the accumulation of MeHg in fish tissue and to reduce MeHg exposure, including watershed approaches, offsets projects, and short and long-term actions that result in reducing inorganic Hg and MeHg. Innovative and creative solutions such as offsets should not substitute for reasonable actions to address local impacts.
8. The linkage analysis and fish tissue objectives and the attainability of the allocations should be re-evaluated based on the findings of Phase 1 control studies and other information. The linkage analysis, fish tissue objectives and allocations should be adjusted in Phase 2, if appropriate.
9. The implementation plan should include methods to assess the relative magnitudes and other factors of different MeHg and inorganic Hg sources, and prioritize study and control actions, if and when it is not feasible to pursue those actions simultaneously.
10. The Phase 1 studies should be subject to independent peer review by the Technical Advisory Committee.
11. The geographic scope of the Phase 1 mercury control studies should include all sources downstream of major dams. Allocations in the Delta TMDL should be given to all point and non-point methylmercury sources within the legal Delta and Yolo Bypass, including open waters.
12. The mercury control program and other Delta projects should recognize the multiple competing and potentially conflicting interests and projects, such as habitat restoration, flood protection, water supply, and human and wildlife consumption of fish.
    Efforts should be taken to ensure all stakeholder interests are represented in developing mercury control programs.

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2 BENEFICIAL USES AND EXISTING CONDITIONS

2.1 Delta Beneficial Uses Cited in the Basin Plan

The federal Clean Water Act and the state Porter-Cologne Water Quality Act require identification and protection of beneficial uses of water. Beneficial uses are designated by the Central Valley Water Board and are shown in Table II-1 of the Basin Plan (CVRWQCB, 2009b). Table 2.1 lists the existing and potential beneficial uses of the Delta. The Delta provides habitat for warm and cold-water species of fish and their associated aquatic communities. Additionally, the Delta and its riparian areas provide valuable wildlife habitat. There is significant use of the Delta for fishing and collection of aquatic organisms for human consumption. Further, water is diverted from the Delta for municipal (MUN) and agricultural (AGR) use.

Beneficial uses of the Delta that are impaired due to elevated methylmercury levels in fish are wildlife habitat (WILD) and human consumption of aquatic organisms. High methylmercury levels in fish pose risks for people and wildlife that eat Delta fish. A summary of Delta fish methylmercury levels is presented in Section 2.2. Note that in Table 2.1, contact recreation (REC-1) is identified as impaired by mercury. When the Central Valley Water Board first adopted the Basin Plan, the commercial and sportfishing beneficial use (COMM) was only defined for saltwater, not freshwater. Water bodies in the Central Valley were not specifically assessed for consumption of fish and shellfish and REC-1 was assumed to cover consumption where it occurred. Staff proposes adding the COMM beneficial use, which is now available for freshwater, as a designated use for waterways within the legal Delta boundary, including the southern Yolo Bypass and within the Yolo Bypass upstream of the Delta (see Section 2.3).

The municipal and industrial supply (MUN) beneficial use is designated in the Basin Plan for all waterways within the legal Delta boundary except Marsh Creek and waterways within the Yolo Bypass (e.g., Cache Creek Settling Basin outflow, Prospect Slough, and the downstream segment of Putah Creek within the Yolo Bypass). Staff evaluated whether levels of total mercury in water in Delta waterways support the MUN beneficial use. The California Toxics Rule (CTR) criterion for mercury protects humans from exposure to mercury through fish consumption and drinking water and is enforceable for all waters with a municipal and domestic water supply or aquatic beneficial use designation. As described in the TMDL Report Section 2.4.2, the CTR mercury criterion is exceeded in outflow from the Cache Creek Settling Basin and possibly in Prospect Slough, Putah Creek, and Marsh Creek; however, MUN is not designated for these waterways. Mercury reductions may be needed to meet the CTR in the Yolo Bypass downstream of the Cache Creek Settling Basin and in Marsh Creek, but these reductions will be addressed by the existing TMDL for Cache Creek and future TMDLs for the Marsh Creek and Putah Creek watersheds (see TMDL Report Section 7.4.2), in addition to actions designed to reduce fish methylmercury concentrations in the Delta/Yolo Bypass and total mercury exports to San Francisco Bay (see TMDL Report Section 8.2).

The Delta provides habitat for diverse populations of wildlife. Over two hundred and eighty species of birds and fifty species of fish inhabit the freshwater portion of the Delta, making it one of the State's most important wildlife habitats (Herbold *et al.*, 1992). Delta wildlife species that are primarily or exclusively piscivorous (that is, feed on fish) and therefore most likely at risk for

mercury toxicity include: American mink, river otter, bald eagle, kingfisher, osprey, western grebe, common merganser, peregrine falcon, double crested cormorant, California least tern, and western snowy plover[2] (USEPA, 1997; CDFG 2002). Peregrine falcons are not piscivorous, but they eat birds that feed in the aquatic food chain. Bald eagles and California least terns are listed by the State of California or by the U.S. Fish and Wildlife Service (USFWS) as either threatened or endangered species. The Delta is a foraging and possible wintering habitat for bald eagles (USFWS, 2004). California least terns also forage in the Delta. There is at least one nesting colony of these terns within the Delta (USFWS, 2004). Although most of the Delta habitat is not preferred by peregrine falcons for nesting, several pairs have nested on bridges in the area (Linthicum, 2003). Although other wildlife species eat fish in the Delta, consumption patterns of the species listed above span the range of sizes of fish eaten.

Table 2.1: Existing Beneficial Uses of the Delta

Beneficial Use [(a)]	**Status**
Municipal and domestic supply (MUN)	Existing [(b)]
Agriculture – irrigation and stock watering (AGR)	Existing
Industry – process (PROC) and service supply (IND)	Existing
Contact recreation (REC-1) [(c)]	Existing [(b)]
Non-contact recreation (REC-2) [(c)]	Existing
Freshwater habitat (warm and cold water species)	Existing
Spawning, reproduction and/or early development of fish (SPWN) (warm water species)	Existing
Wildlife habitat (WILD)	Existing [(b)]
Migration of aquatic organisms (MIGR) (warm and cold water species)	Existing
Navigation (NAV)	Existing

(a) This table lists the beneficial uses designated for the Delta in Table II-1 of the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins (Basin Plan) (CVRWQCB, 2009b; available at: http://www.waterboards.ca.gov/centralvalley/water_issues/basin_plans/). As noted in Chapter 1, the Yolo Bypass is a 73,300-acre floodplain on the west side of the lower Sacramento River. The lower two thirds of the Yolo Bypass are within the legal Delta, and waterways within the entire Delta are included in Clean Water Act 303(d) List as mercury-impaired. Table II-1 in the Basin Plan includes separate rows for the Yolo Bypass and Delta. Beneficial use designations are different in the two rows, but both include the REC-1 beneficial use. In a footnote, Table II-1 also has a separate beneficial use list for Marsh Creek, which includes Rec-1.

(b) These are beneficial uses impaired by mercury.

(c) REC-1 includes recreational activities involving body contact with water, where ingestion of water is reasonably possible. These uses include, but are not limited to, swimming, wading, water-skiing and fishing. REC-2 includes recreational activities involving proximity to water, but where there is generally no body contact with water, nor any likelihood of ingestion of water. These uses include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, hunting and sightseeing.

[2] The CDFG *California Wildlife Habitat Relationships* database also reports observations of clapper rails in the Delta. Both of these species are federally listed as endangered and depend on the aquatic food web. However, staff of the Biological Contaminants Division of the US Geological Survey (USGS) confirmed that clapper rails prefer salt-water habitats and are only occasional visitors to the Delta regions (personal communication from Dr. S. Schwarzbach, USGS, to J. Cooke, CVRWQCB, April 2003).

2.2 Existing Concentrations of Methylmercury in Delta Fish

High levels of mercury in fish are of concern to people and wildlife that eat Delta fish. Table 2.2 summarizes average methylmercury concentrations in fish tissue for the eight Delta subareas by trophic level (TL).[3] Common small (<50 mm) TL2 and 3 fish species in the Delta include inland silverside, mosquitofish and threadfin shad. Common TL3 fish include bluegill, carp, redear sunfish, Sacramento sucker, and Chinook salmon (a.k.a. king salmon). Common TL4 fish include largemouth and striped bass, channel and white catfish and Sacramento pikeminnow. Most fish data summarized in Table 2.2 were collected between 1998 and 2001. Additional information is provided in the TMDL Report.

Significant regional variations in fish mercury concentrations exist in the Delta. Elevated concentrations occur along the periphery of the Delta while lower body burdens are measured in the central Delta. Concentrations are greater than levels identified as safe by the USEPA and USFWS (see Chapter 3) at all locations except in the central Delta. Reductions in fish methylmercury levels ranging from 0% to more than 70% in the peripheral Delta subareas are needed to achieve fish mercury levels protective of people and wildlife species that eat Delta fish.

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[3] Trophic levels are the hierarchical strata of a food web characterized by organisms that are the same number of steps removed from the primary producers. The USEPA's 1997 Mercury Study Report to Congress used the following criteria to designate trophic levels based on an organism's feeding habits:

Trophic level 1: Phytoplankton.
Trophic level 2: Zooplankton, benthic invertebrates, and plant-eating fish (Delta examples: clams, shrimp).
Trophic level 3: Organisms that eat zooplankton and other TL2 organisms (Delta examples: bluegill, carp, crayfish, Sacramento splittail, salmon, sucker, shad, sturgeon, and yellowfin goby).
Trophic level 4: Organisms that eat trophic level 3 organisms (Delta examples: largemouth, smallmouth, and striped bass; white catfish; and crappie).

Table 2.2: Weighted-Average Methylmercury Concentrations in Delta Fish

Key Species of Concern	Fish Species Trophic Level Food Group	Species-Specific Target (mg/kg)	MeHg Concentration by Delta Subarea (mg/kg) [a]							
			Central Delta	Marsh Creek [b]	Moke-lumne River	Sacra-mento River	San Joaquin River	West Delta	Yolo Bypass North [c]	Yolo Bypass South [c]
Human	TL4 Fish (150-500 mm)	0.24	0.26	na	0.92	0.56	0.50	0.32	0.51	0.53
Human	TL3 Fish (150-500 mm)	0.08	0.08	na	0.28	0.21	0.11	0.11	0.28	0.19
Osprey	TL4 Fish (150-350 mm)	0.26	0.20	na	0.75	0.46	0.42	0.24	0.50	0.47
Grebe	TL3 Fish (150-350 mm)	0.08	0.08	na	0.29	0.17	0.12	0.08	na	na
Kingfisher	TL3 Fish (50-150 mm)	0.05	0.03	0.10	0.09	0.04	0.04	0.03	na	0.07
Least Tern	TL2/3 Fish (<50 mm)	0.03	0.02	na	0.07	0.03	0.04	0.03	na	0.05

(a) Samples were comprised of both individual fish and composites of multiple fish. Weighted average mercury concentration is based on the number of fish in the composite samples analyzed, rather than the number of samples. Fish mercury data were not available for every TL food group in every Delta subarea.

(b) Fish data collected in 1995 and 1996.

(c) Fish mercury data were not available for all trophic level food groups in the Yolo Bypass.

2.3 Proposed Modification to Beneficial Uses Identified in the Basin Plan

As noted in Section 2.1, the Basin Plan lists the existing and potential uses of the Delta and Yolo Bypass. The Basin Plan provides a standard definition for commercial and sport fishing (COMM). The COMM designation is defined as “uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes” (CVRWQCB, 2009b). The Basin Plan does not include the COMM designation for the Delta or Yolo Bypass. However, commercial and sport fishing is a past and present use of the Delta. To clarify the use of the Delta as a fishery, staff proposes to include the COMM beneficial use designation in the Basin Plan. The COMM designation would apply to named waterways in the Delta and Yolo Bypass. Staff listed and mapped these waterways and proposes adding them to the Basin Plan as Appendix 43. The purpose of the recommended fish tissue objectives and the implementation plan is to protect for the consumption of fish, which is more accurately covered under COMM than REC-1. The inclusion of COMM will not change fishing habits or patterns.

The Delta provides habitat for as many as fifty freshwater, saltwater and anadromous fish species (Moyle, 2002), including popular sport species such as bass, salmon, sturgeon and catfish. The California Department of Fish and Game (CDFG) issues commercial fishing licenses in California and reports active commercial fishing in the Delta. CDFG’s Marine Resources website provides summary data for commercial landings and associated costs for fishing years 2001 and 2002. The predominant species targeted include bay shrimp, crayfish

and threadfin shad. Threadfin shad are used mainly as baitfish for catching striped bass. Historical data for other commercial fishing activities are not available.

Noncommercial fishing is common throughout the Delta and takes place year round. On average, sport fishing license sales in the six Delta counties account for 19% of all licenses issued in California for striped bass, salmon and steelhead. It is unknown what portion of those licenses was purchased for fishing within the statutory Delta boundary. However, creel surveys and interviews indicate that sport and subsistence anglers actively fish the Delta waterways year-round by boat and from banks. CDFG's creel surveys indicate that multiple species are caught and kept, including catfish, striped bass, black bass, and Sacramento pike minnow, Chinook salmon (a.k.a. king salmon), American shad, splittail, sunfish, sturgeon, starry flounder, common carp, Sacramento sucker, steelhead trout and rainbow trout. Recent interviews of selected groups in the Delta region found that members of Southeast Asian, Latino, African-American, and Russian communities regularly eat local fish, especially striped bass and catfish (CDHS, 2004 & 2006; Silver *et al*, 2007; see Section 4.6.3 in the TMDL Report). Several fishing derbies for striped bass, black bass and sturgeon take place in the Delta every year. Sacramento blackfish, shimofuri goby and clams may also be collected from the Delta (Moyle, 2002; anecdotal information). However, the CDFG creel surveys (CDFG, 2000-2001), anecdotal information provided by CDFG staff (Schroyer, 2003), and the other recent interviews indicate that many Delta anglers target salmon, sunfish, striped bass, largemouth bass and catfish and are not as likely to take home clams and shrimp species. For specific information on fish licenses and CDFG's creel survey data, refer to Appendix C of the TMDL Report.

Staff proposes to add the COMM designation without describing it as a potential or existing use. Designating a beneficial use in the Basin Plan means that the State is obligated to protect that beneficial use. The State's obligation to protect the use is the same, regardless of whether the use is identified in the Basin Plan as potential or existing. Sport fishing occurs widely in the Delta, but methylmercury concentrations in fish and extent of commercial fishing vary across subareas. Deciding which modifier is appropriate for each Delta subarea could be time and resource consuming and is not necessary for the scope of the current amendment. The aim of the Basin Plan amendments is to protect COMM, regardless of whether it is existing or potential.

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3 FISH TISSUE OBJECTIVES

Water quality objectives are established in Basin Plans by the Regional Water Boards to protect beneficial uses. Water quality objectives provide a specific basis for the measurement and maintenance of water quality. For this Basin Plan amendment, the objective that needs to be established to protect the beneficial use is methylmercury concentrations in fish tissue. Therefore, instead of "water quality objectives", the appropriate term for the objectives used in this report is "fish tissue objectives".

The Basin Plan for the Sacramento River and San Joaquin River Basins does not contain numeric objectives for fish tissue methylmercury within the legal Delta boundary. Not until recently have fish tissue objectives been adopted for any of the Delta's tributary watersheds (e.g., Clear Lake and Cache Creek). Methylmercury concentration in fish tissue is considered an appropriate objective for the Delta because it is the most toxic form of mercury; it is the form by which people and wildlife may be exposed in the Delta at levels to cause adverse effects; it provides the most direct assessment of fishery conditions and improvement; and a safe fishery is the foremost unmet beneficial use of the Delta.[4]

This chapter evaluates five possible alternatives for fish tissue objectives to address methylmercury in Delta fish. In developing the alternative fish tissue objectives below, Central Valley Water Board staff considered (1) existing conditions in the Delta (see Chapter 2), (2) numerical guidelines and recommended criteria available from USEPA, USFWS and other agencies, and (3) that the current listing of Delta waterways as impaired for mercury because of fish consumption advisories (OEHHA, 1994 & 2007).

Fish tissue concentrations in the Delta exceed human and wildlife guidelines of the USEPA, and USFWS. The recommended objectives incorporate current USEPA and USFWS information regarding methylmercury toxicity to people and wildlife (see Section 4.5.1 of the TMDL Report).

3.1 Alternatives Considered

To develop fish tissue objective alternatives, staff used a formula that incorporated the safe daily intake of methylmercury (reference dose), consumer's body weight, and fish consumption rate. See Appendix B for calculations of the alternatives. Chapter 4 (Numeric Targets) in the TMDL Report provides detailed explanations of these calculations and:

- Shows how the safe level of mercury in fish varies between fish trophic level and length;

[4] In the Delta TMDL Report, Central Valley Water Board staff provided safe methylmercury concentrations in piscivorous and omnivorous birds eaten by bald eagles and peregrine falcons. Existing concentrations in such "avian prey" are not known. Because people do not typically eat birds that are preyed upon by bald eagles and peregrine falcons, it would be difficult to determine whether a safe concentration in avian prey is protective of people who eat Delta fish. For these reasons, Central Valley Water Board staff is not proposing tissue objectives for avian prey species. The USFWS concluded that meeting protective levels in fish tissue would adequately reduce methylmercury levels in the avian prey species that eat Delta fish or invertebrates (USFWS, 2004).

- Evaluates the safe level of mercury in fish for human consumption under 15 different scenarios based on different consumption rates and trophic level (TL) distributions (see Table 4.5 in the TMDL Report).
- Determines whether safe levels for human and wildlife consumption of large TL4 fish equate to safe levels for wildlife consumption of small fish.

This alternatives analysis focuses on five of the scenarios described in the TMDL Report. The alternatives vary in the amount and trophic level of fish that can be safely eaten by people and wildlife, as depicted in Table 3.1. Numeric objectives are proposed as average concentrations in fish muscle tissue (for large fish) or in whole fish (for small fish).

Although the fish tissue objectives are based on bodyweights and consumption rates for adults, the objectives also protect children. Children have smaller bodyweights than adults and typically eat less fish than adults. Under the recommended fish tissue objectives, children are only at risk of mercury toxicity if they eat more than the average portion for their body size. OEHHA advises that children 12 and under be served no more than half of an adult portion size (8 ounces uncooked; OEHHA, 2008).

Wildlife species most at risk from methylmercury are primarily or exclusively piscivorous. Species at risk in the Delta include the American mink, bald eagle, California least tern, common merganser, double crested cormorant, kingfisher, osprey, peregrine falcon, river otter, western grebe, and western snowy plover. Evaluation of the alternatives takes into account protection of wildlife. In addition, Alternatives 3 and 4 include an objective for small (less than 50 mm total length) TL2 and TL3 fish to ensure that wildlife species eating these fish are protected.

The following sections describe the alternatives' fish tissue objectives with their corresponding human consumption rates.

Table 3.1: Comparison of Fish Tissue Objective Alternatives

Alternative	**Recommended Objective for MeHg in Large TL4 Fish** (mg/kg)	**Potential Human Consumption Rates & Trophic Level Distributions of Delta Fish Consumed** [(b)]
2	0.58	3.8 g/day of TL2 fish, 8.0 g/day of TL3 fish, and 5.7 g/day of TL4 fish, for a sum of 17.5 g/day
3 [(a)]	0.29	17.5 g/day of large TL4 fish
4 [(a)]	0.24	32 g/day of a 50/50 mix of large TL3 and 4 fish
5	0.05	142.4 g/day of large TL4 fish

(a) Alternatives 3 and 4 also propose an objective for small, whole TL2 and TL3 fish of 0.03 mg/kg to protect wildlife species that eat small fish. In addition, Alternative 4 proposes a methylmercury objective for large TL3 fish of 0.08 mg/kg.

(b) Consumption rates are in terms of uncooked fish.

3.1.1 Alternative 1. No Action

Alternative 1 contains no fish tissue objective for the Delta. The existing toxicity-related narrative objective of the Basin Plan would still apply: "All waters shall be maintained free of toxic substances in concentrations that produce detrimental physiological responses in human, plant, animal or aquatic life." The criterion likely to be used to interpret the narrative objective is the California Toxics Rule criterion of 50 ng/l for total recoverable mercury in water.

This alternative does not sufficiently protect people or sensitive fish-eating wildlife that eat Delta fish. Although water column total mercury concentrations are less than the CTR throughout the Delta (see Chapter 7 in the TMDL Report), fish mercury levels still exceed safe levels for people and wildlife. As explained later in Section 3.2.3 of this chapter, water column total mercury concentrations lower than the CTR criterion would be needed to protect people and wildlife species that consume Delta fish and the safe levels would vary throughout different areas of the Delta. For that reason, Alternatives 2 through 5 propose numerical fish tissue objectives to explain the narrative objective in the current Basin Plan and facilitate implementation of a water quality management strategy to reduce methylmercury levels in Delta fish.

3.1.2 Alternative 2. Fish Tissue Objective of 0.58 mg/kg Methylmercury in Large TL4 Fish

Alternative 2 contains one fish tissue objective (average methylmercury concentration): **0.58 mg methylmercury/kg muscle tissue, wet weight, for large TL4 fish** (legal size if designated by CDFG, otherwise 150-500 mm total length). The large fish tissue objective is based on the following scenario:

- People eat 17.5 grams/day of freshwater/estuarine (local Delta) fish (one fish meal every two weeks) and 12.46 g/day of marine (commercial) fish (0.4 fish meals per week; USEPA, 2000b).[5] A national survey found that 90% of the nation's population eats 17.5 g/day or less of freshwater (local) fish.
- Adult body weight is 70 kg (about 154 pounds).
- Fish or shellfish eaten are from a variety of trophic levels (TL2, TL3, and TL4, with consumption rates of 3.8, 8.0, and 5.7 g/day, respectively).
- The USEPA reference dose (RfD) for people (0.1 micrograms per kilogram body weight per day; USEPA 2001) is an acceptable daily intake level.

As noted in Table 4.5 of the TMDL Report, mercury concentrations in TL2 and TL3 fish that correspond to the TL4 fish objective are 0.04 and 0.20 mg/kg, respectively. By meeting the TL4 fish objective, these concentrations will be met as well.

Alternative 2 uses the same methods and assumptions that the USEPA used in developing its recommended methylmercury criterion to protect human health (USEPA, 2001). The USEPA

[5] One meal of fish for an adult human is assumed to be eight ounces of uncooked fish or shellfish (6 ounces cooked). The consumption rate of 17.5 g/day is equivalent to one eight-ounce meal per 2-week period, or four ounces per week (2.3 meals/month).

recommends an ambient water quality criterion of 0.3 mg/kg methylmercury in fish tissue, on a wet weight basis,[6] which represents the concentration in fish tissue that should not be exceeded based on a total consumption of locally caught fish of 17.5 g/day. The USEPA criterion, like Alternative 2, assumes that people will eat a mixture of locally caught freshwater or estuarine fish from trophic levels 2, 3, and 4 in the proportions described above.

Alternative 2 is not protective of people eating mainly TL4 fish (such as bass and catfish) and also is not protective of several fish-eating wildlife species, including bald eagle, osprey, river otter, grebe, common merganser, and least tern (as shown in Table 4.3 of the TMDL Report). However, this alternative would be protective of mink, double-crested cormorant, belted kingfisher, and western snowy plover.

Therefore, Alternative 2 is protective of (a) people who eat a moderate amount of fish from different trophic levels (TL2, 3, and 4), and (b) some sensitive fish-eating wildlife.

3.1.3 Alternative 3. Fish Tissue Objectives of 0.29 mg/kg Methylmercury in Large TL4 Fish and 0.03 mg/kg in Small TL2/3 Fish

Alternative 3 contains two fish tissue objectives (average methylmercury concentration): **0.29 mg methylmercury/kg muscle tissue, wet weight, for large TL4 fish** (legal size if designated by CDFG, otherwise 150-500 mm total length) and **0.03 mg methylmercury/kg whole fish, wet weight, for small TL2 and TL3 fish** (less than 50 mm total length).

USEPA's 2001 Water Quality Criterion report allows for using site-specific information to set a local methylmercury criterion. The large fish tissue objective is based on the following scenario, which makes use of site-specific information:

- Some of the same conditions as Alternative 2 (USEPA default), that is:
  - People eat 17.5 g/day of freshwater/estuarine (local Delta) fish and 12.5 g/day of marine (commercial) fish.
  - Adult body weight is 70 kg (about 154 pounds).
  - The USEPA RfD for people (0.1 micrograms per kilogram body weight per day; USEPA 2001) is an acceptable daily intake level.
- One change from the conditions in Alternative 2, that is, local Delta anglers prefer to eat primarily TL4 fish (not a mixture of TL 2, 3, and 4 fish), as evidenced by CDFG creel surveys (CDFG, 2000-2001), anecdotal information by CDFG staff (Schroyer, 2003), and other recent local surveys (see Section 4.6.3 in the TMDL Report).
- Delta creel surveys show that anglers may target an almost even mix of TL3 (American shad, salmon, sunfish, and splittail) and TL4 fish (catfish and striped bass) in the Sacramento and Mokelumne Rivers subareas of the Delta, and primarily TL4 species in other areas of the Delta. Local anglers take home fewer TL2 species, such as clams,

[6] USEPA's criterion of 0.3 was rounded to one significant digit from 0.288 mg/kg. The fish tissue objective alternatives calculations were based on a methylmercury in fish tissue concentration of 0.29 mg/kg to incorporate two significant digits. Detailed calculations are included in Appendix B and in Chapter 4 in the TMDL Report.

shrimp, and shimofuri goby, than indicated in the national dietary used in the USEPA methylmercury criterion and Alternative 2.

In several small surveys in the Delta, the California Department of Public Health found that while striped bass (a TL4 species) is frequently sought, people who regularly eat Delta fish do so from both trophic levels 3 and 4 (CDHS, 2004-2006; Silver *et al.*, 2007; Ujihara, 2006); see Section 4.6.3 in the TMDL Report). TL3 species such as bluegill are available year-round. Popular fish such as salmon and shad are available seasonally.

In addition to the large fish objective, Alternative 3 includes a small fish objective for TL2 and TL3 fish to protect wildlife that eat small fish. This objective represents the safe level for prey eaten by the California least tern, a federally endangered species. This small fish objective also protects other wildlife consuming small fish in the Delta, including herons, rails, egrets, western snowy plovers, and other species of concern. Meeting the objective for large TL4 fish is expected to reduce methylmercury in smaller fish sufficient to protect wildlife because methylmercury concentrations in large TL4 fish show statistically significant, positive relationships with concentrations in smaller fish and in fish in different trophic levels. Alternative 3 includes an objective of 0.03 mg/kg methylmercury in whole, TL2 and TL3 fish less than 50 mm in length so that fish monitoring may verify that small fish mercury levels decrease to protective levels as large fish mercury levels decrease.

Therefore, Alternative 3 is protective of (a) people who eat a moderate amount of fish that are primarily large TL4 species, and (b) all sensitive fish-eating wildlife.

3.1.4 Alternative 4. Fish Tissue Objectives of 0.24 mg/kg Methylmercury in Large TL4 Fish, 0.08 mg/kg in Large TL3 Fish and 0.03 mg/kg in Small TL2/3 Fish

Alternative 4 contains three fish tissue objectives (average methylmercury concentration). For large fish, the objectives are **0.08 and 0.24 mg methylmercury/ kg, wet weight, in muscle tissue of large TL3 and 4 fish**, respectively (legal size if designated by CDFG, otherwise 150-500 mm total length). These objectives are protective of (a) people eating 32 g/day (eight ounces, uncooked fish per week) of commonly eaten, legal size fish, and (b) all wildlife species that eat large fish. For small fish, the objective is **0.03 mg methylmercury/ kg, wet weight, in whole TL2 and TL3 fish less than 50 mm** in total length.

These large fish tissue objectives are based on the following scenario:

- Some of the same conditions as Alternative 2 (USEPA default), that is:
  - Adult body weight is 70 kg (about 154 pounds).
  - The USEPA RfD for people (0.1 micrograms per kilogram body weight per day; USEPA 2001) is an acceptable daily intake level.
- Two changes from the conditions in Alternative 2, that is:
  - People eat more local fish, at a rate of 32 g/day (one fish meal per week).
  - People eat a 50/50 combination of TL3 and 4 fish, based on CDFG creel surveys in the Sacramento River and Mokelumne subareas of the Delta and CDPH angler surveys of Delta subpopulations.

The higher consumption rate is based on a detailed angler consumption survey for San Francisco Bay that was conducted in 1998 and 1999 (CDHS & SFEI, 2001). The consumption rates for the 95th percentile of anglers that were "consumers" (ate Bay fish at least once prior to the interview) was 32 g/day (about one eight-ounce meal per week). San Francisco Bay Water Board staff used this consumption rate to develop the water quality objective for mercury in Bay fish, which was approved by the San Francisco Bay and State Water Boards (see Section 6.2.11 in Chapter 6). One meal per week is also used by OEHHA in development of fish consumption advisories (OEHHA, 2004; 2005).

Like Alternative 2, Alternative 3 includes a small fish objective of 0.03 mg/kg methylmercury in whole TL2 and TL3 fish to ensure that wildlife species that eat small fish are protected, even though the objective for large TL4 fish is expected to reduce methylmercury in smaller fish sufficient to protect wildlife. The recommended small fish objective is the level needed by the California least tern and will protect other fish-eating wildlife species.

Therefore, Alternative 4 is protective of (a) people who eat a relatively high amount of fish that are an even mixture of TL3 and TL4 species, and (b) all sensitive fish-eating wildlife.

3.1.5 Alternative 5. Fish Tissue Objective of 0.05 mg/kg Methylmercury in Large TL4 Fish

Alternative 5 contains one fish tissue objective (average methylmercury concentration): **0.05 mg methylmercury/kg muscle tissue, wet weight, for large TL4 fish** (legal size if designated by CDFG, otherwise 150-500 mm total length). This fish tissue objective is based on the following scenario:

- Some of the same conditions as Alternative 2 (USEPA default), that is:
  - Adult body weight is 70 kg (about 154 pounds).
  - The USEPA RfD for people (0.1 micrograms per kilogram body weight per day; USEPA 2001) is an acceptable daily intake level.
- Two changes from the conditions in Alternative 2:
  - Some people are subsistence consumers; because of tradition or need, these people have high consumption rates of locally caught fish, represented by a rate of 142.4 g/day (four to five fish meals per week). This rate is the 99th percentile consumption rate identified in a national food intake survey and recommended by USEPA for subsistence anglers and their families. These subsistence anglers are expected to eat mainly TL4 species like catfish and bass.
  - The calculations assume that methylmercury intake is from only Delta fish and that none is from commercial fish.

Alternative 5 does not include a small fish objective because the large TL4 fish objective (0.05 mg/kg) is so close to the safe level for the smallest fish (0.03 mg/kg). Additionally, the large TL4 fish objective is substantially lower than necessary to protect wildlife consuming large TL3 and TL4 fish (see Table 4.9 in the TMDL Report).

Therefore, Alternative 5 is protective of (a) people who eat a very high amount of TL4 fish species, and (b) all sensitive fish-eating wildlife.

3.2 Evaluation of Alternatives

Section 13241 of the Porter-Cologne Water Quality Act identifies six factors that must be addressed when evaluating a fish tissue objective. Factors to be considered are:

- Past, present, and probable future beneficial uses of water;
- Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;
- Water quality conditions that could reasonably be achieved through the coordinated control of all factors that affect water quality in the area;
- Economic considerations;
- The need for developing housing within the region; and
- The need to develop and use recycled water.

The alternatives for fish tissue objectives are evaluated with respect to these factors in the following six sections. The alternatives are evaluated with respect to applicable state and federal policies in Chapter 6.

3.2.1 Beneficial Uses

Several beneficial uses of Delta waters are impaired by mercury: consumption of fish and shellfish by people (REC-1, COMM), and wildlife habitat (WILD). The recommended fish tissue objectives and implementation plan are intended to restore these beneficial uses.

Under Alternative 1, beneficial uses are protected by the narrative toxicity objective of the Basin Plan. However, evaluating the success of methylmercury reduction efforts (as part of the implementation plan) will be easier using numeric fish tissue objectives such as those in Alternatives 2 through 5.

Alternatives 2 through 5 protect the REC-1 beneficial use already identified in the Basin Plan and the proposed COMM beneficial use. Alternative 2 is not fully protective of the WILD beneficial use because the alternative exceeds the safe methylmercury levels for some wildlife species. Alternatives 3 through 5 fully protect the WILD beneficial use. Alternative 5 provides the greatest protection to people who eat Delta fish.

3.2.2 Environmental Characteristics of the Hydrographic Unit

Delta water is used for drinking water, irrigation, contact recreation, stock watering, commercial/sport fishing, and habitat for warm- and cold-water aquatic species. In addition, the Delta provides a significant fishery and habitat for terrestrial wildlife. Environmental characteristics and existing conditions of the Delta and tributaries are discussed in more detail in Chapters 1 and 2, respectively.

All alternatives would affect environmental characteristics of the hydrologic unit by improving water quality conditions of the Delta and its tributaries to varying degrees. Improvements likely to be achieved by each alternative (through different numeric fish tissue objectives for

methylmercury) are described in the next section. Methylmercury levels in water and fish in the Delta vary as a function of hydrology and patterns of flow of water from the major tributaries into and through the Delta. To ensure that the water quality objectives are attained throughout the Delta, the recommended control program divides the Delta into seven hydrologically-based subareas with specific source reduction requirements for each subarea.

3.2.3 Water Quality Conditions That Could Reasonably Be Achieved

Alternatives and Consumption Rates They Would Allow

Alternative 1 (No Action) contains no fish tissue objective for the Delta, but defaults to the Basin Plan's existing narrative toxicity objective, which is translated into a numerical objective (based on the USEPA CTR criterion) of 50 ng/l total mercury in the water column. However, calculations show that a lower CTR criterion is needed to protect people and sensitive wildlife species that eat Delta fish. The CTR criterion was derived using similar factors as the fish tissue alternatives, with an additional factor to relate fish tissue methylmercury concentrations to water total mercury concentrations. This additional factor, termed the practical bioconcentration factor (BCF), is the ratio of mercury concentrations in fish and water. The BCF used for the CTR criterion is 7,342.6 (USEPA, 2000a). In comparison, the BCFs for large TL4 fish and ambient total mercury in the Delta vary by subarea and range between 18,000 and 170,000, and the BCFs for large TL3 fish and ambient total mercury in the Delta range between 6,300 and 53,000. The presence of higher BCFs in the Delta, compared to the CTR's BCF, indicate that a total mercury concentration lower than the CTR criterion would be needed to protect people and wildlife species that eat Delta fish. The final Great Lakes Water Quality Guidance developed bioaccumulation factors (BAFs) for TL3 and TL4 fish of the Great Lakes Basin by multiplying watershed-specific BCFs by a food-chain multiplier. The BAFs for mercury for TL3 and TL4 fish were 27,900 and 140,000, respectively, which are comparable to the TL3 and TL4 BCFs calculated for the Delta, indicating that the BCFs for the Delta are not anomalous.

Alternative 2 has a fish tissue objective that allows people to safely eat a moderate amount of Delta fish from a variety of trophic levels but does not fully protect all sensitive fish-eating wildlife. Under Alternative 2, people safely may eat up to 17.5 g/day of local fish (one eight-ounce meal every two weeks), if they eat a mixture of TL2 (21.7%), TL3 (45.7%), and TL4 (32.6%) fish. Alternative 2, however, could exceed the safe intake levels identified by the USFWS for bald eagle and least tern.

Alternative 3 has fish tissue objectives that allow people to safely eat a moderate amount of Delta TL4 fish and also fully protects all sensitive fish-eating wildlife. Under Alternative 3, people safely may eat up to 17.5 g/day of local TL4 fish such as bass and catfish. Alternative 3 is more protective of people than Alternative 2 because, by protecting people who eat more of the Delta fish that are highest in methylmercury (TL4 fish), the fish tissue objective is lower in Alternative 3 than in Alternative 2.

Alternative 4 has fish tissue objectives that allow people to safely eat a relatively high amount of Delta TL3 and TL4 fish and also fully protects all sensitive fish-eating wildlife. Under Alternative 4, people may safely eat up to 32 g/day (one eight-ounce meal week) of local fish, if they eat an even mixture of TL3 and TL4 fish. Alternative 4 is more protective of people than

Alternative 3 because, by protecting people who eat more Delta fish, the fish tissue objective is lower in Alternative 4 than in Alternative 3.

Alternative 5 has a fish tissue objective that allows people to safely eat a very high amount of Delta TL4 fish and also fully protects all sensitive fish-eating wildlife. Under Alternative 5, people may safely eat up to 142.4 g/day (four to five meals per week) of local TL4 fish. Alternative 5 is more protective of people than Alternative 4 because, by protecting people who eat the most Delta fish (due to tradition or need), the fish tissue objective is lower than in Alternative 5 than in Alternative 4. Accordingly, Alternative 5 has the lowest fish tissue objective of any alternative.

Alternatives Compared to Current Conditions

Currently, Alternatives 2 through 5 have varying levels of attainment of fish tissue objectives. Alternative 2 currently is attained in seven of eight subareas of the Delta, while Alternative 3 currently is attained in only one subarea (Central Delta subarea). Alternative 4 is close to attainment in the Central Delta subarea, but not in other subareas. Alternative 5 is not attained in any subareas of the Delta.

The level of reduction required by each alternative depends on the subarea. For example, to attain Alternative 2, methylmercury in large TL4 fish must decrease by 43% in the Mokelumne/Cosumnes subarea while no reductions are needed in other subareas. To attain Alternatives 3 and 4, methylmercury in fish must decrease from little to none in the Central Delta subarea, but must decrease by greater than 70% in the Mokelumne/Cosumnes subarea. To attain Alternative 5, methylmercury in large TL4 fish must decrease by 81% to 95% in all subareas of the Delta.

Alternatives Compared to Regional Mercury Levels and Their Potential Attainability

In a recent study, the USEPA and Oregon State University collected and analyzed 2,707 large TL3 and 4 fish from 626 streams and river segments in the western United States, including California, using a probability design (Peterson *et al.*, 2007). The purpose of the study was to assess the distribution of mercury in fish across the region. Central Valley Water Board staff evaluated the study results in terms of the existing fish mercury levels in the Delta and alternative fish tissue objectives (Foe, 2007). Only 1 to 3% of the waterways evaluated by the study had fish mercury concentrations higher than those observed in the Mokelumne/Cosumnes subarea of the Delta. Fish mercury concentrations in the Sacramento, San Joaquin, and Yolo Bypass subareas were in the top 20 to 25% of fish mercury concentrations observed throughout the western United States. These comparisons confirm that Delta fish have elevated concentrations in comparison to regional background levels and suggest that the Delta and its tributary watersheds contain mercury sources in addition to atmospheric deposition, e.g., abandoned mines and sites where the mercury is efficiently converted to methylmercury that bioaccumulates in the aquatic food web (Foe, 2007).

Of the sampled waterways in the western United States, none supported a fish population with mercury concentrations as low as Alternative 5 (0.05 mg/kg in large TL4 fish) (Peterson *et al.*, 2007; Foe, 2007). Therefore, Alternative 5 may not be attainable. In contrast, about 30% to

40% of the sampled waterways supported a fish population with mercury concentrations lower than Alternatives 3 and 4, suggesting that these alternatives may be attainable with implementation of a vigorous control program.

Alternatives and Effectiveness of Their Implementation Programs

As described in the TMDL Report (Chapters 3 and 5), the problem with methylmercury in Delta fish can be defined as biotic exposure to methylmercury. Therefore, decreasing biotic exposure to methylmercury is the ultimate goal of the Delta methylmercury TMDL implementation program, with methyl and total mercury source control actions focused on reducing methylmercury levels in ambient Delta waters. The implementation program for Alternative 2 requires source controls only for the Mokelumne/Cosumnes River subarea, thus would not measurably improve conditions in the rest of the Delta. The implementation programs for Alternatives 3 through 5 also would focus on source controls but vary regarding (a) where source controls are required, (b) the number of individual sources required to characterize and control their source inputs (methyl and total mercury), and/or (c) the percent reductions required for source inputs.

Attainment of Alternative 5 will be difficult to track. This is because Alternative 5 (0.05 mg/kg in large TL4 fish) is substantially below existing conditions, thus making it difficult to accurately extrapolate from methylmercury in fish (fish tissue objective) to corresponding methylmercury in water (aqueous methylmercury concentration). Such extrapolation for Alternative 5 produces a concentration of 0.028 ng/l methylmercury in water, which is below the current minimum reporting level for laboratory analyses for methylmercury. (Minimum reporting levels are equivalent to the lowest calibration standard for methylmercury, which is currently 0.05 ng/l.) Though aqueous methylmercury concentrations below the minimum reporting level can be detected, they cannot be quantified accurately; thus, Alternative 5 progress will be difficult to quantify and track. In contrast, Alterative 4 (0.24 mg/kg in large TL4 fish) corresponds to 0.066 ng/l methylmercury in water, which is above the minimum reporting level of 0.05 ng/l and thus can be quantified accurately.

Time to Reach Attainment

In general, the lower the fish tissue objective, the greater the source reductions needed to attain the objective and the greater the time expected to reach attainment. Alternative 1 (No Action), by definition, does not require adoption of new objectives. Under Alternative 1, staff would likely use the CTR mercury criterion when numeric interpretation of the Basin Plan's narrative toxicity objective is needed. Mercury reductions may be needed to meet the CTR in the Yolo Bypass downstream of the Cache Creek Settling Basin and in Marsh Creek, but these reductions will be addressed in existing (Cache Creek) and future (Marsh Creek) TMDLs (see TMDL Report Section 7.4.2). Because the CTR is less protective than any of the fish tissue objective alternatives, the Delta would continue to be impaired by mercury. Alternative 2 (0.58 mg/kg in large TL4 fish) currently is attained in seven of eight subareas of the Delta and requires an average fish mercury reduction of 43% in the Mokelumne/Cosumnes subarea. In contrast, Alternative 5 (0.05 mg/kg in large TL4 fish) requires fish mercury reductions of 81% to 95% in all subareas of the Delta.

Concentrations of methylmercury in water and fish are expected to decrease as sediment mercury concentrations decline due to total mercury source control actions. Mercury control programs in other states and countries demonstrated significant reductions in fish methylmercury concentrations after source control, but decades later the fish mercury levels were still higher than at uncontaminated, comparison sites.[7] In these mercury control programs, efforts were directed solely at total mercury sources and not at a combination of total mercury and methylmercury sources. A total mercury-focused control program would likely attain Alternative 2 because Alternative 2 requires a comparatively modest reduction in fish mercury levels in only one Delta subarea (Mokelumne/Cosumnes subarea) that is supplied by a relatively small watershed within the Sierra Foothills (compared to the watershed that supplies the Sacramento, Yolo Bypass, San Joaquin subareas; see Figure 6.1 in the TMDL Report).

Targeting methylmercury sources in addition to total mercury sources – by reducing methylmercury discharges or curtailing the methylation process – is expected to more rapidly reduce methylmercury concentrations in fish and enable full compliance with Alternatives 3 and 4. Under an implementation plan to reduce methyl and total mercury sources, measurable decreases in fish methylmercury concentrations are expected to occur within approximately five to ten years (two to three fish life cycles) after control actions are implemented and allocations for Delta/Yolo Bypass sources are achieved. Staff expects additional decreases as upstream mercury control programs are developed and implemented to achieve the tributary allocations. However, those decreases would be followed by a long, gradual decline because natural erosion (a slow process) may be needed to wash out legacy mercury in the Delta's tributary channels (see Chapter 4). Thus, actual attainment of Alternatives 3 and 4 could take more than a hundred years, assuming that legacy and new inputs of mercury are significantly reduced.[8] As noted earlier, Alternative 5 may not be attainable because its fish tissue objective is below regional background fish mercury levels observed in the western United States.

3.2.4 Economic Considerations

Cost of Implementation

Depending on the alternative, anticipated costs of implementation include some or all of the following activities: public education, fish tissue monitoring, construction and maintenance. Alternative 1 involves only public education, while Alternatives 2 through 5 involve all four activities. The costs for education – about $130,000 per year – are relatively small, compared to costs for monitoring, construction and maintenance (see Chapter 4, Tables 4.4 and 4.5, and Appendix C).

Alternative 1 is the least expensive of the alternatives, because Alternative 1 involves only public education. Alternative 2 is the next least expensive because control programs are

[7] See the review of mercury cleanup projects in Chapter 3 of the TMDL Report.

[8] For additional discussion of the estimated time to reduce inorganic mercury inputs and attain fish tissue objectives, see "Staff's Initial Responses to Board and Stakeholder Questions and Comments at the April 2008 Hearing", items 3 and 44, available in the Administrative Record.

needed in only one subarea. However, these alternatives do not sufficiently protect people and sensitive wildlife species.

Alternatives 3 through 5 have essentially the same cost for Phases 1 and 2 of the control program, despite their different fish tissue objectives, because these alternatives require control programs throughout the entire Delta region. (The Alternative 3 objective currently is met in only one subarea of the Delta, and the Alternatives 4 and 5 objectives currently are not met in any subarea.) Costs associated with the Phase 1 methylmercury control studies for existing sources may range from about $4.4 million to $14.7 million. Annual costs associated with monitoring activities may range from $75,000/yr to $276,000/yr. Annual costs associated with new total mercury minimization activities implemented by point sources may range from about $1.8 million to $7.3 million. Annual costs for Phase 2 methylmercury reduction actions may range from about $2.4 million/yr to $26.5 million/yr. Costs will be less if an alternative with higher fish tissue objectives is selected because higher objectives may take less time and effort to be attained, thereby reducing the cost of reduction activities as well as long-term monitoring and public outreach and education costs.

Importance of Delta Fishery

The Central Valley Water Board is not legally required to estimate the value of resources as part of the economic considerations. However, because information is available on the value of the fishery and the potential costs of mercury intake, this information is summarized below.

The Delta fishery is a valuable resource. In 1994, the Delta Protection Commission estimated the value of recreational activities, including fishing, for the local economy. Anglers on average spent an estimated $186 million inside the Delta and $206 million outside of the Delta, for sport-fishing activities in the Delta (Goldman *et al.,* 1998). The worth of Delta fish as a food source, particularly for people who eat local fish because of custom or to supplement their diet, has not been calculated but is likely substantial.

OEHHA issued an interim fish consumption advisory for the Delta in 1994 and released a draft advisory for the south Delta in March 2007 that addresses a variety of fish and shellfish species. Recent publicity about consumption advisories for the Delta may decrease angling in the near term, but the use of Delta fish as a food resource could increase as methylmercury levels decline, which would benefit the Delta economy.

Under existing conditions, consumption of some Delta fish more than one or two times per month may cause adverse health effects. Mercury is a toxicant that can have lasting effects on neurological development and abilities of persons exposed *in utero* and as children. People exposed to methylmercury through consumption of fish showed deficits in memory, attention, language, fine motor control, and visual-spatial perception that can result in lowered intelligence (NRC, 2000; Trasande *et al.*, 2005).

Lower intelligence causes a decrease in income that persists over the lifetimes of affected persons. To estimate the loss in earnings to children born in one year and exposed to mercury in Delta fish, staff used national survey data of methylmercury concentrations in blood of women of childbearing age (Mahaffey *et al.*, 2004), the income loss calculation of Trasande and

colleagues (2005), and United States census data on population and birth rates in six Delta counties in 2000.[9] In year 2000 dollars, the calculated loss in income for all Delta residents entering the workforce in a single year is $156 million,[10] but could range from $41 to 250 million[11] (best-case to worst-case scenario).

3.2.5 Need for Housing

None of the alternatives restricts the development of housing in the Delta. Additionally, the alternatives are consistent with existing requirements for new urban development, including the municipal separate storm sewer system (MS4[12]) permitting program.

The reduced wastewater waste load allocations described in Chapter 4 of this report and in Chapter 8 of the TMDL Report may result in economic costs due to wastewater treatment system improvements. Municipal wastewater treatment capacity is often designed to accommodate a large percentage of possible housing development in the collection area. Wastewater treatment system improvements may be necessary to accommodate new housing development because the waste load allocations are based on current performance, not plant design capacity. In addition, it is conceivable that wastewater treatment plant (WWTP) upgrades and new best management measures (BMPs) to control total mercury and methylmercury implemented by urban stormwater management agencies to comply with the recommended Basin Plan amendments could entail the displacement of available housing or possibly require land that takes the place of new housing development. However, these concerns are not likely to affect more than a few housing units in the Delta, if any, for several reasons:

- It is reasonable to assume that wastewater treatment system improvements will be undertaken over the next one to two decades for a range of reasons including replacing aging infrastructure, TMDLs for other pollutants, and other regulatory actions unrelated to the Clean Water Act. These improvements could simultaneously address requirements for methylmercury reductions.
- The State Water Resources Control Board and the federal government offer funding for wastewater treatment system improvement, which would limit the economic impact of treatment improvements on development of new housing.

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[9] U.S. census information is available at: http://quickfacts.census.gov/qfd/states/.

[10] Assumptions: 10% of mothers have methylmercury levels in blood that result in decreased IQ of their children; the decreases in IQ cause certain percentage decrease in expected income over lifetime.

[11] Trasande and colleagues (2005) varied the modeling of the dose-effect relationship, the ratio of methylmercury in maternal to fetal blood, and the lowest methylmercury concentration at which impairments were observed in children. The low estimate assumes the combination of variables that produce the least severe effect. The high estimate is the "worst case" combination of variables. All estimates provide cost due to anthropogenic sources of mercury, based on understanding that about 70% of mercury worldwide comes from anthropogenic sources.

[12] A municipal separate storm sewer system (MS4) is a conveyance or system of conveyances that include roads with drainage systems, municipal streets, alleys, catch basins, curbs, gutters, ditches, manmade channels, or storm drains, owned by a State, city, county, town or other public body. MS4s are designed and used for collecting or conveying storm water and do not include combined sewer systems or parts of a publicly owned treatment works. MS4s discharge to waters of the United States. The Municipal Storm Water Permitting Program regulates storm water discharges from MS4s.

- More than 500,000 acres of the Delta's 738,000-acre area is within the Primary Zone, an area where the Delta Protection Act of 1992 has the goal to "Protect, maintain, and, where possible, enhance and restore the overall quality of the delta environment, including, but not limited to, agriculture, wildlife habitat, and recreational activities." Substantial urban development has not taken place in the lowland areas encompassed by the Primary Zone. In contrast, the periphery of the Delta (the Secondary Zone) has undergone rapid urbanization associated with substantial population growth. However, with only two exceptions for Rio Vista and Ironhouse Sanitary District, the Delta Protection Act does not allow the location of new WWTPs that support urban development or business in the Secondary Zone to occur within the Primary Zone. As a result, WWTP improvements are unlikely to affect housing throughout at least 500,000 acres of the Delta.
- As described in Section 4.3.10, there are multiple reasonably foreseeable methods of compliance with the recommended Basin Plan amendment requirements to reduce methylmercury loading from wastewater treatment systems and urban runoff. Therefore, it is not reasonably foreseeable that the responsible agencies would implement compliance methods that would require the displacement of available housing when other compliance methods are available.

3.2.6 Need to Develop and Use Recycled Water

None of the alternatives restricts the development or use of recycled water. Currently, there are no restrictions on recycling of water due to mercury. The alternatives, therefore, are consistent with the need to develop and use recycled water. Recycling water may be the most feasible management measure for limiting discharge of methylmercury from some irrigated agricultural fields and managed wetlands.

3.3 Recommended Alternative

Staff recommends the adoption of Alternative 4. Alternative 4 establishes Delta objectives of 0.24 and 0.08 mg/kg methylmercury in wet weight fish muscle tissue, as the average concentration in large fish of trophic levels (TL) 4 and 3, respectively, and 0.03 mg/kg methylmercury, wet weight, in small whole TL2 and 3 fish less than 50 mm total length. The objectives for large fish protect of people and sensitive wildlife (including bald eagle, otter, and osprey) that eat large Delta fish, allowing people to safely eat 32 g/day of an even mixture of large TL3 and TL4 fish from the Delta and 12.5 g/day of commercial fish. The objective for small fish protects the California least tern (a federally endangered species) and other wildlife (including herons and rails) that eat small Delta fish or aquatic invertebrates.

Alternative 4 is recommended for the following reasons:

- It fully protects wildlife species, including threatened and endangered species as required by the Endangered Species Act.
- It protects people who eat Delta fish by safely allowing the consumption of one eight-ounce meal per week of Delta fish with a mixture of TL3 and TL 4 species (i.e., bass, catfish, salmon, and sunfish). This consumption rate is greater than the USEPA default rate used in Alternatives 2 and 3. The Alternative 4 objectives are therefore more protective of people who by custom, need, or enjoyment, more frequently eat Delta fish.

- It incorporates local consumption patterns, which show that Delta anglers commonly target fish like salmon (TL3) and striped bass (TL4). Under the Alternative 4 objectives, consumers that select low-mercury species, such as salmon, shad, Sacramento blackfish, and bluegill, would be able to safely eat more than one meal of Delta fish per week.
- It is consistent with the fish tissue objectives approved by the State Water Board for San Francisco Bay (SFBRWQCB, 2006; SWRCB, 2007)). Like the Alternative 4 large fish objectives, San Francisco Bay's methylmercury objective is based on protecting people who eat 32 g/day of local fish. Alternative 4 takes into consideration that people, fish-eating wildlife and their prey (e.g., anadromous species) travel between the Delta and San Francisco Bay.
- It contains fish tissue mercury concentrations that are lower than concentrations currently in much of the Delta, but that are seen elsewhere in the western United States. Observation of these fish mercury concentrations elsewhere suggests that this alternative can be achieved.

Alternative 1 (No Action; default to the existing narrative toxicity objective) is not recommended because the default numerical criterion (USEPA's CTR criterion of 50 ng/l total mercury in the water column) does not sufficiently protect people and threatened and endangered wildlife species that eat Delta fish.

Alternative 2 is not recommended because it does not reflect local consumption patterns or protect all fish-eating wildlife. The Alternative 2 objective of 0.58 mg/kg methylmercury in large TL4 fish is too high to protect bald eagle, osprey, river otter, western grebe, and other sensitive wildlife, as determined by the USFWS risk assessment (2004).

Alternative 3 is not recommended because it does not reflect local consumption patterns. Interviews and surveys show that many local people, particularly Southeast Asians and African Americans, eat more than 17.5 g/day (one 8-ounce meal every two weeks) of freshwater/estuarine fish (CDHS, 2004; Ujihara, 2006; Silver *et al.*, 2007). Therefore, Alternative 3 may not be sufficiently protective of people who eat Delta fish.

Alternative 5 is not recommended because it may not be achievable or reliably measured (in terms of the fish tissue objective's corresponding aqueous methylmercury concentration).

Staff will reevaluate the Delta fish tissue objectives during Phase 1 of the Delta mercury control program, as more information is learned about local consumption patterns and more technology is developed. An expanded exposure reduction program should be implemented to protect people with the highest consumption rates of Delta fish even before consumption studies are conducted or methylmercury reductions are achieved.

3.4 Recommended Alternative Applied to the Basin Plan

The recommended alternative (Alternative 4), if adopted into the Basin Plan, would establish:

- Delta-specific numerical fish tissue objectives for methylmercury in large TL3 fish, large TL4 fish, and small TL2/3 fish in the Delta; and

- A monitoring program that specifies fish species and sizes within each target trophic level to facilitate evaluating compliance with the fish tissue objectives.

Chapter 5 in this report describes staff recommendations for a monitoring program. The Central Valley Water Board will be the lead agency in developing or reviewing detailed monitoring plans to evaluate compliance with the recommended fish tissue objectives.

Along with the fish tissue objectives, the recommended Basin Plan amendments contain a long-term goal for lower Delta fish tissue objectives and a commitment to review the fish tissue objectives at the end of Phase 1 of implementation. Stakeholders, including representatives of Native American Tribes, Delta community-based organizations, and Environmental Justice organizations, informed staff that the recommended objectives will not protect the many people who regularly eat more than one meal per week of Delta fish. Staff carefully considered these comments. As described in Section 3.2.3, fish data from other streams in the western United States suggest that the recommended fish tissue objectives can be achieved, but that lower levels might not be met. Because the USEPA requires that a TMDL exhibit assurance of being achieved, staff did not change its recommendation for the fish tissue objectives. Staff recognizes that there are people who eat more than one meal per week of Delta fish and agrees that the objectives should be as protective as possible. In response to stakeholders' comments, staff recommends that the Central Valley Water Board commit, in the Basin Plan, to reviewing Delta fish tissue objectives to determine whether more protective fish tissue objectives can be attained. The reviews will occur at the end of Phase 1 of implementation and in later program reviews.

4 PROGRAM OF IMPLEMENTATION

The recommended water quality objectives for methylmercury in Delta fish (fish tissue objectives) are exceeded throughout much of the Delta. Per the Porter-Cologne Water Quality Act Section 13050(j)(3), the recommended Basin Plan amendments must include an implementation program for the TMDL to bring the Delta into compliance with the proposed objectives to protect beneficial uses. Water Code Section 13242 prescribes the contents of an implementation plan, which include: 1) a description of the actions necessary to achieve the water quality objectives; 2) a time schedule; and 3) a monitoring and surveillance program.

This chapter evaluates implementation alternatives and recommended actions and timelines to reduce methyl and total mercury sources. The chapter is divided into five sections:

- Section 4.1 describes methyl and inorganic mercury sources to the Delta, the linkage between methylmercury in water and fish tissue, and the ambient methylmercury reductions needed to achieve the proposed fish tissue objectives.
- Section 4.2 reviews the nine main considerations for the TMDL implementation program, describes options for addressing each consideration, and formulates four implementation alternatives from different combinations of the options.
- Section 4.3 describes potential regulatory actions and reasonably foreseeable methods of compliance for each alternative. The Central Valley Water Board will not specify particular practices or technologies. Reasonably foreseeable methods of compliance are reviewed so that the potential environmental effects, costs, ability to achieve the proposed fish tissue objectives, and overall feasibility of each alternative can be evaluated.
- Section 4.4 evaluates each alternative for potential environmental effects, costs, ability to attain water quality objectives, feasibility, and consistency with federal and state regulations and policies. Detailed reviews of existing federal and state regulations and policies, potential environmental effects, and cost considerations are in Chapters 6 and 7 and Appendix C, respectively.
- Section 4.5 further evaluates the different alternatives and identifies staff's recommended implementation alternative.

The proposed Basin Plan amendments (after the Executive Summary) reflect the recommended implementation alternative and include an implementation plan. The proposed Basin Plan amendments have been developed in conjunction with an extensive formal stakeholder process (described in Chapter 8). The implementation plan (a.k.a. the Delta Mercury Control Program) describes the actions necessary to achieve proposed fish tissue objectives, the actions the Central Valley Water Board will take, a time schedule, and a monitoring and surveillance program. The proposed amendments also include recommendations to the State Water Board and other agencies regarding actions for which the Central Valley Water Board does not have direct authority.

The implementation plan must ensure that all applicable water quality criteria will be attained and maintained. The applicable water quality criteria consist of:

1. The proposed Delta-specific methylmercury fish tissue objectives for the protection of wildlife and human health (Chapter 3).

2. The five-year average total mercury load reduction of 110 kg/yr required within 20 years by the San Francisco Bay mercury TMDL implementation program for Central Valley outflows to the Bay (SFBRWQCB, 2006; SWRCB, 2007).
3. The California Toxics Rule total mercury water column criterion for the protection of human health (50 μg/l total recoverable mercury; USEPA, 2000a).

The implementation plan must include actions necessary to reduce methylmercury inputs to the Delta to achieve the fish tissue objectives. The TMDL methylmercury allocations are in the form of methylmercury loads in unfiltered water discharged by point and nonpoint sources to the Delta and Yolo Bypass. The allocations are specifically correlated with and set to attain and maintain the proposed fish tissue objectives. In addition, the proposed implementation actions are designed to reduce the amount of *total* mercury entering the Delta to ensure attainment and maintenance of both the San Francisco Bay TMDL's allocation for total mercury loading and the CTR total recoverable water column criterion. Reducing total mercury inputs will reduce the amount of mercury available for methylation in the Delta's aquatic environment and therefore further reduce methylmercury in ambient Delta waters.

Tables A through D in the proposed Basin Plan amendments list the recommended methylmercury load and waste load allocations for nonpoint and point sources within and tributary inputs to the Delta and Yolo Bypass, as well as interim (Phase 1) total mercury mass limits for point sources in the Delta and Yolo Bypass. A detailed description of the allocation calculation methods is in Chapter 8 of the TMDL Report (Appendix A of this report). The strategy that directs how the allocations and Phase 1 limits are determined reflects the recommended implementation alternative summarized in Section 4.5 of this chapter.

4.1 Methyl & Total Mercury Sources & Necessary Reductions

This section provides a brief description of methyl and inorganic mercury sources, the linkage between methylmercury in water and fish tissue, and ambient methylmercury reductions needed to meet the proposed water quality objective. The TMDL Report (Appendix A of this report) contains detailed discussions of each of these topics.

4.1.1 Methyl and Inorganic Mercury Sources

Sources of inorganic mercury in the Delta include tributary inflows from upstream watersheds, atmospheric deposition, urban runoff, dredging activities, and municipal and industrial wastewater. Sources of inorganic mercury in the watersheds upstream of the Delta (a.k.a. "the Delta's tributary watersheds") include gold and mercury mine sites, legacy mercury in the stream channel sediments, geothermal springs, atmospheric deposition, urban runoff, and municipal and industrial wastewater. Figure 4.1 illustrates average annual total mercury loading to the Delta during water years[13] (WY) 1984 through 2003, a period that includes a mix of wet

[13] A "water year" (WY) is defined as the period between 1 October and 30 September of the following year; for example, WY2001 is the period between 1 October 2000 and 30 September 2001. Water year types in California

and dry years statistically similar to conditions in the Sacramento Basin over the last 100 years. About 98% of identified total mercury loading to the Delta comes from tributary inputs; within-Delta sources are a very small component of overall loading. The Sacramento Basin (Sacramento River + Yolo Bypass) contributed almost 90% of total mercury fluxing through the Delta. Of the watersheds in the Sacramento Basin, the Cache Creek, Feather River, American River and Putah Creek watersheds had both relatively large mercury loadings and high mercury concentrations in suspended sediment, which makes those watersheds effective candidates for total mercury load reduction programs (see Chapters 7 and 8 in the TMDL Report). Although it is not as large a source of total mercury loading, the Mokelumne/Cosumnes watershed in the San Joaquin Basin also may be an effective candidate because of its high mercury concentrations in suspended sediment.

The San Francisco Bay mercury TMDL implementation program assigned the Central Valley a five-year average mercury load allocation of 330 kg/yr or a decrease of 110 kg/yr. This represents about a 28% decrease in the 20-year average annual loading from Delta tributaries and would enable Delta waters to maintain compliance with the CTR criterion of 50 ng/l (see Section 7.4 in the TMDL Report). Staff has estimated that mercury loading to the Delta will likely need to be reduced by more than 110 kg/yr (see Section 8.2 in the TMDL Report) and coordinated with methylmercury management practices in the tributary watersheds in order to address the mercury impairment in the Delta as well as impairments in the watersheds.

Sources of methylmercury in Delta waters include tributary inputs from upstream watersheds and within-Delta sources such as methylmercury production in wetland and open water habitat sediments, municipal and industrial wastewater, agricultural drainage, and urban runoff. Figure 4.2 illustrates the Delta's average annual methylmercury inputs for WY2000 to 2003, a relatively dry period that encompasses the available methylmercury information. Methylmercury inputs from wetland/open-water sediments and tributary watersheds during this period account for about 30 and 60%, respectively, of methylmercury inputs to the Delta.

As illustrated in Figure 1.1 in Chapter 1 and described in more detail in the TMDL Report, the methylmercury linkage and source analyses divide the Delta into subareas based on the hydrologic characteristics and mixing of the source waters. Figure 4.3 shows the contribution of each source category's estimated methylmercury loading to each subarea. A separate methylmercury allocation system is required for each subarea because of substantially different levels of fish mercury impairment and substantially different types and amounts of methylmercury inputs to each subarea. For example, wetland and open-water habitat within the Yolo Bypass may contribute almost as much methylmercury to the subarea as its tributaries, in contrast to the Sacramento and San Joaquin subareas, which receive substantially more annual methylmercury loading from their tributaries.

As discussed in the attached TMDL Report, CalFed mercury study results that became available after the February 2008 Basin Plan Amendment and TMDL draft staff reports were developed indicate that when wet years are included in the methylmercury source analysis,

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are classified according to the natural water production of the major basins. See Appendix E in the TMDL Report for more information about water year classifications.

tributary inputs provide a much larger relative methylmercury load contribution to the Delta than within-Delta sources. This is not unexpected, given that the tributary watersheds (about 42,500 square miles; see Table 2.1 in the TMDL Report) span an area almost 40 times the area of the Delta (about 1,100 square miles), a difference that becomes even more apparent during wet years. Since tributary watersheds account for a substantial amount of methylmercury loading to the Delta, TMDLs for the upstream watersheds will be developed during Phase 1 of the Delta implementation plan. A TMDL for the Delta is needed for the following reasons:

- In June 1999, the State Water Board adopted the Consolidated Toxic Hot Spots Cleanup Plan (Cleanup Plan), as required by California Water Code Section 13394. The Cleanup Plan identifies the entire Delta as a hot spot for mercury due to elevated mercury levels in fish and contains cleanup requirements for mercury in the Delta. [See Section 6.2.6 for additional discussion.]
- The Delta TMDL's methylmercury allocations for tributary inputs establish the minimum net reductions that must be accomplished for the tributary watersheds. [Note, additional methylmercury and total mercury load reductions may be required within those watersheds to address any mercury impairment within those watersheds.]
- Completing the Delta TMDL and implementing actions to reduce Delta fish methylmercury concentrations is a high priority because of the high number of people who consume Delta fish, especially because of the number of people who consume Delta fish at levels likely harmful to their health. In a survey of 500 anglers and members of community-based organizations, UC Davis researchers found that approximately half of Delta anglers and their families take in methylmercury above the USEPA reference dose and 5% are exposed to methylmercury at 10 times the reference dose (Shilling, 2009). [Methylmercury intake at 10 times the reference dose affects memory, fine motor control, and audiovisual learning in children (NRC, 2000).]

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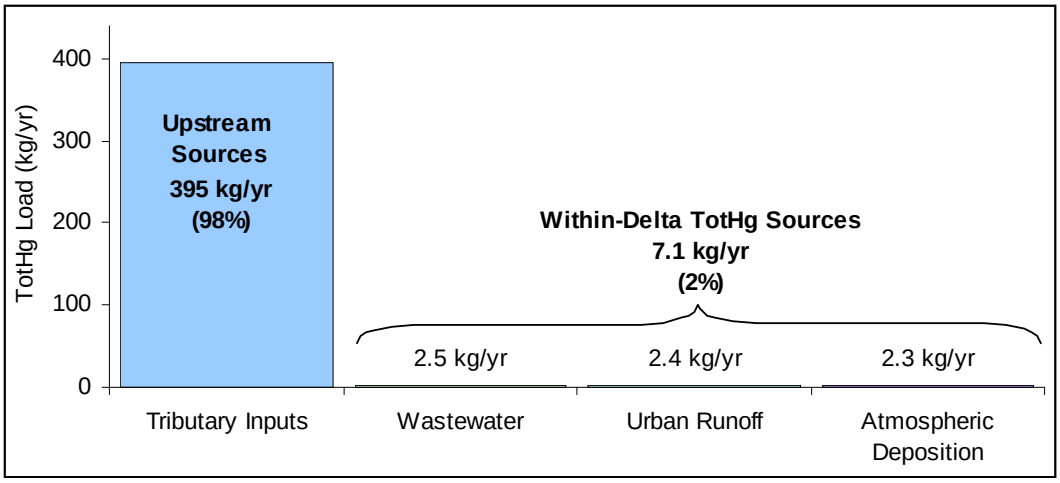

Figure 4.1: Twenty-year Average Annual Total Mercury Inputs to the Delta

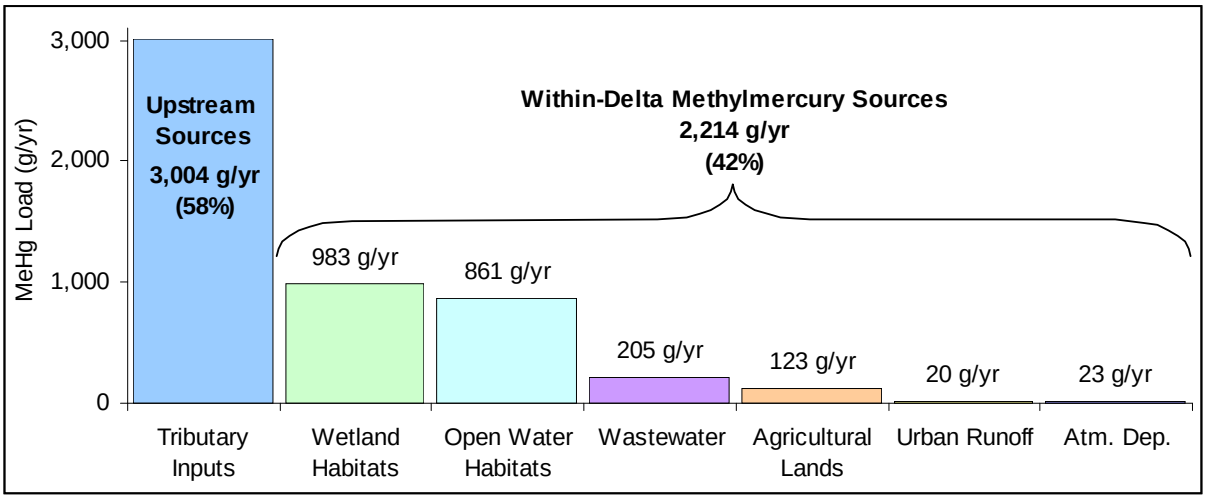

Figure 4.2: Average Annual Methylmercury Inputs to the Delta during WY2000 to 2003

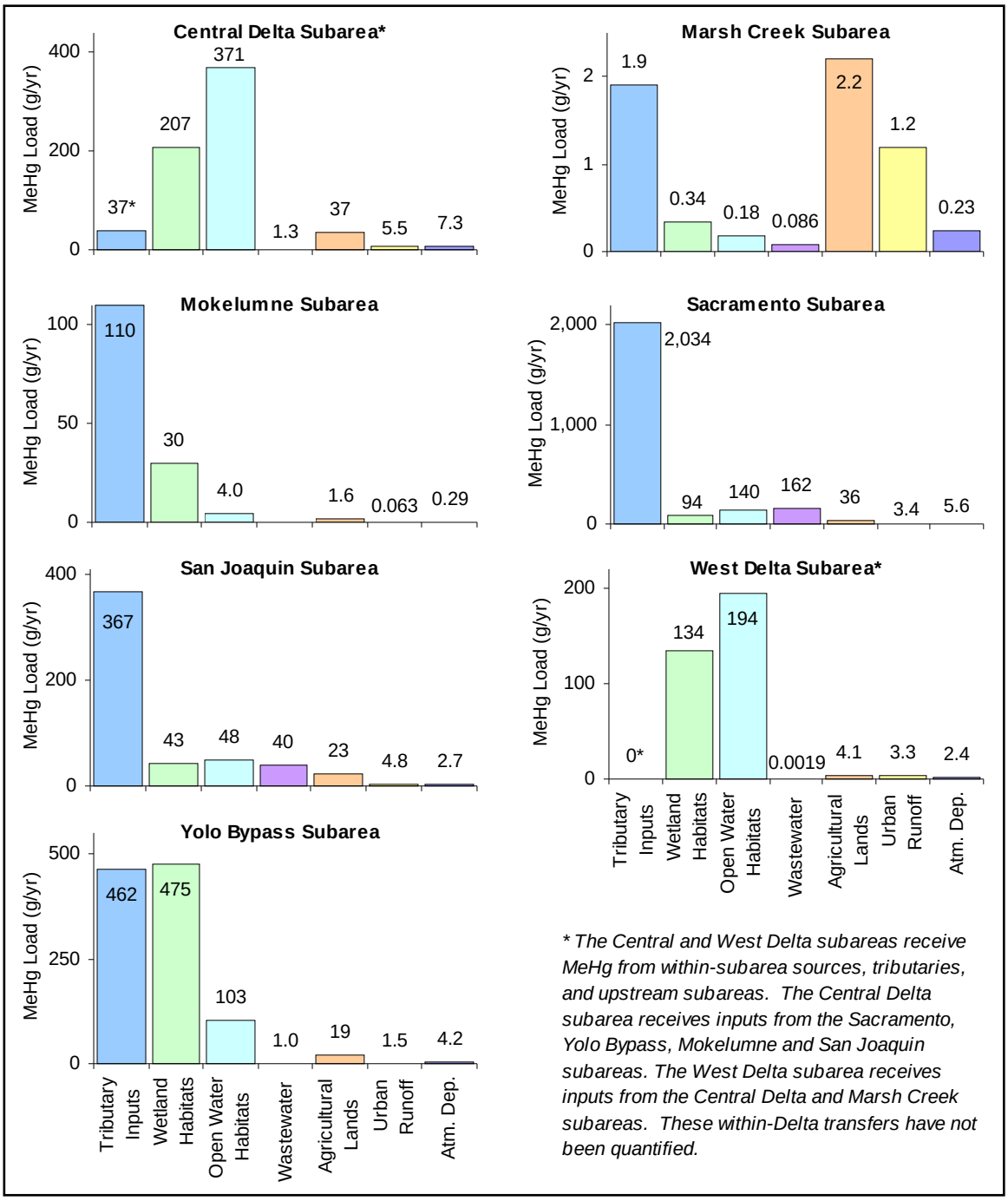

Figure 4.3: Average Annual Methylmercury Inputs to the Delta Subareas during WY2000 to 2003

4.1.2 Linkage between Methylmercury in Water and Fish Tissue

As described in the previous chapter, staff recommends three fish tissue objectives: 0.24 mg/kg (wet weight) in muscle tissue of large[14] TL4 fish such as bass and catfish; 0.08 mg/kg (wet weight) in muscle tissue of large TL3 fish such as carp and salmon; and 0.03 mg/kg (wet weight) in whole TL2 and 3 fish less than 50 mm in length. The TMDL links methylmercury concentrations in fish to methylmercury concentrations in water to determine an acceptable ambient methylmercury concentration that could then be used to determine methylmercury source reductions necessary to achieve the fish tissue objectives.

Chapter 5 (Linkage Analysis) in the TMDL Report describes in detail the relationships between methylmercury in ambient water and largemouth bass in the Delta. Largemouth bass was selected for the linkage analysis for several reasons:

- Largemouth bass was the only species systematically collected near many of the aqueous methylmercury sampling locations used in the TMDL source and linkage analyses.
- Largemouth bass are abundant, are widely distributed throughout the Delta, and stay at one location (Davis *et al.,* 2003), making them useful bioindicators of spatial variation in mercury accumulation in the aquatic food chain.
- Spatial trends in standard 350-mm largemouth bass mercury concentrations across the Delta are representative of spatial trends in mercury levels in other Delta fish species (see Sections 4.7 and 4.8 in the TMDL Report).

As detailed in Section 4.8 of the TMDL Report, it was possible to describe the proposed fish tissue objectives for large TL3 and 4 fish and small TL2/3 fish in terms of the equivalent methylmercury concentration in standard 350-mm largemouth bass. As shown in Figure 4.4:

- A methylmercury concentration of 0.28 mg/kg in 350-mm largemouth bass is equivalent to the fish tissue of 0.24 mg/kg for large TL4 fish.
- A methylmercury concentration of 0.24 mg/kg in 350 mm largemouth bass is equivalent to the fish tissue of 0.08 mg/kg for TL3 fish.
- A methylmercury concentration of 0.42 mg/kg in 350 mm largemouth bass is equivalent to the fish tissue of 0.03 mg/kg for small fish.

Of the three concentrations above, the most protective is the second one: a methylmercury concentration of 0.24 mg/kg in bass predicted to correspond with the TL3 fish tissue objective. This concentration of 0.24 mg/kg in bass protects both human and wildlife consumers of higher and lower trophic level fish in the Delta because the concentration is the lowest of the bass values predicted for the three fish tissue objectives. As a result, a methylmercury concentration of 0.24 mg/kg in 350 mm largemouth bass is proposed as the implementation goal for largemouth bass throughout the rest of this report.

Strong, positive correlations have been found between methylmercury in unfiltered ambient water and methylmercury in largemouth bass. The relationship between methylmercury

[14] Large fish are defined as 150-500 mm total length or legal catch length if designated by CDFG.

concentrations in ambient water and standard 350-mm largemouth bass sampled in the Delta is illustrated in Figure 4.5. Substitution of the implementation goal of 0.24 mg/kg methylmercury for largemouth bass into the equation developed by this regression results in a predicted safe ambient water methylmercury concentration of 0.066 ng/l. Staff incorporated an explicit margin of safety of about 10% to develop the recommended **implementation goal for unfiltered ambient water of 0.06 ng/l methylmercury**. This goal describes the assimilative capacity of Delta waters in terms of concentration and would be applied as an annual average methylmercury concentration. Figures 4.4 and 4.5 show the coefficient of determination (R^2) for each regression. Staff used the R^2 to compare between regression equations, but did not rely solely on the value of R^2 as the foundation for the methylmercury fish/water linkage (see Chapter 5 in the TMDL Staff Report).

It is anticipated that, as the average concentration of methylmercury in ambient water in each Delta subarea decreases to the implementation goal, the fish tissue objectives will be attained. The implementation goal for methylmercury in ambient water is intended to be used to determine the amount of methylmercury source reduction needed to achieve the proposed fish tissue objectives and to track progress in meeting the objectives.

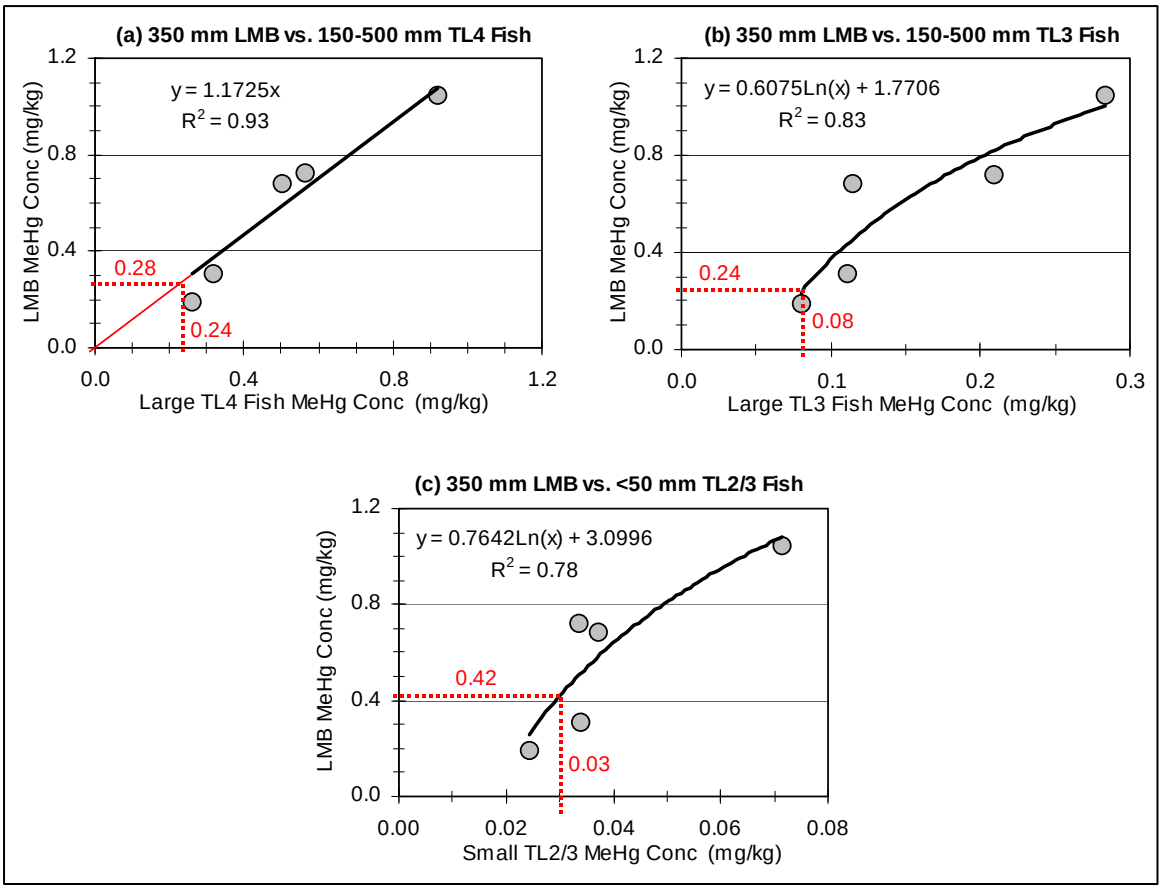

Figure 4.4: Comparison of Methylmercury Concentrations in Standard 350-mm Largemouth Bass (LMB) Caught in September/October 2000 and Composites of Fish Sampled between 1998 and 2001 from (a) 150-500 mm Trophic Level 4 Fish, (b) 150-500 mm Trophic Level 3 Fish, and (c) <50 mm Trophic Level 2/3 Fish