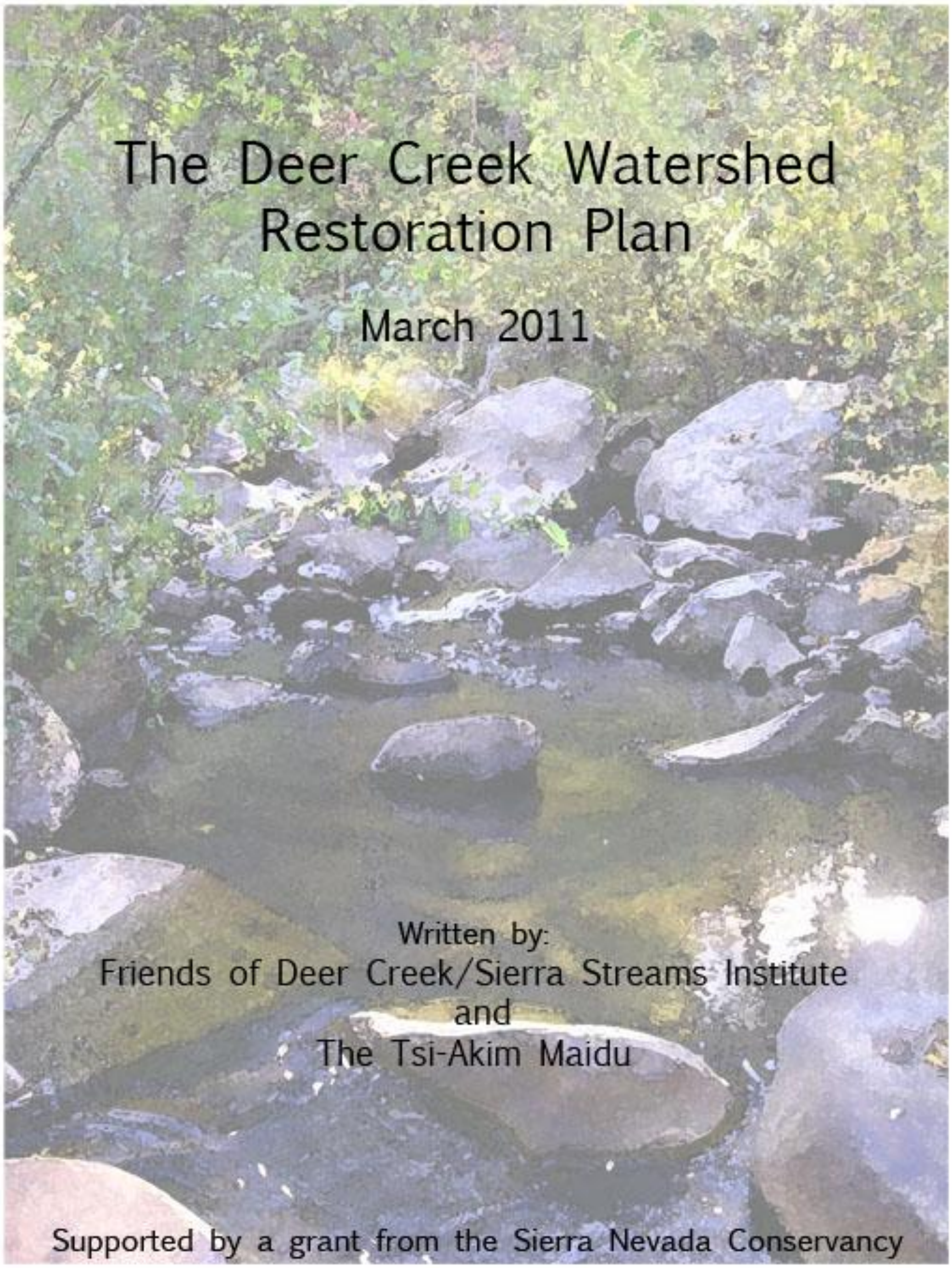

The Deer Creek Watershed Restoration Plan

March 2011

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Friends of Deer Creek/Sierra Streams Institute
and
The Tsi-Akim Maidu

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Special thanks to the faithful volunteers of Friends of Deer Creek, whose tireless efforts ensure a healthy creek for future generations.

Table of Contents

Executive Summary

The Deer Creek Restoration Plan is an assessment of the entire watershed, expanding upon the Upper Deer Creek Assessment and Restoration Plan that was developed by Friends of Deer Creek and the Natural Heritage Institute in 2006, and incorporating the cultural perspective of the Maidu, watershed stewards for thousands of years prior to the discovery of gold in 1848.

Deer Creek's ecology has suffered numerous impacts from a century and a half of mining, development, water diversions, and agriculture. This report identifies the outcome of these impacts, including: altered flows; reduced frequency of substrate mobilization; infrequent inundation of floodplain habitat; residual mining deposits; reduced complexity and cover of riparian vegetation communities; prevalence of non-native riparian vegetation; excessive fine sediment deposits in certain reaches; excessive nutrient loads in certain reaches; non-point source pollution inputs; and sources of mercury and other heavy metal contamination from past mining activities.

Deer Creek is fortunate to be the subject of an extensive longterm citizen monitoring program, in place since 2000. The long term dataset generated by this monitoring program has enabled a comprehensive assessment of the health of the creek, the results of which are described in this report. Many actions are identified to address Deer Creek's problems, such as restoring a more natural flow regime, removing non-native vegetation and replanting with natives, reducing erosion from roads and other sources, reducing pollution from point and non-point sources, restoring sites that have cultural significance to native people, and remediating sites contaminated with heavy metals. In addition, many topics requiring further study are also identified, including the indigenous history of the watershed, further flow monitoring and analysis, status of fishes and other aquatic biota, sources of fine sediment, sources of non-point pollution, sources of heavy metal contamination, process and extent of mercury methylation, and measures to reduce contaminant inputs and transport through the watershed.

Implementing the recommended actions would greatly enhance the health and productivity of Deer Creek. It is expected that with the human and scientific resources available to Friends of Deer Creek/ Sierra Streams Institute, combined with the support of partners such as the Tsi-Akim Maidu, Bureau of Land Management, US Geological Survey, US Forest Service, Lake Wildwood Association, Nevada City, Nevada County, American Rivers, SYRCL, The Sierra Fund, Nevada County Land Trust, Wolf Creek Community Alliance, and residents of the Deer Creek watershed, Deer Creek can thrive and gain recognition as an invaluable community resource.

Friends of Deer Creek/ Sierra Streams Institute
The Tsi-Akim Maidu
Nevada City, CA
March 2011

Chapter I: Introduction

Sol Henson

A. Problem Definition

The Deer Creek Watershed is located in Nevada County on the western slope of the northern Sierra Nevada region, with the last one hundred feet of the lower watershed in Yuba County. The Deer Creek watershed is experiencing rapid growth, particularly in the lower reaches, because of its proximity to the Sacramento metropolitan area, its natural beauty, and its location below the snow line. The Deer Creek of today is significantly different from the Deer Creek that amply supported a significant population of Native American residents for thousands of years, and the Deer Creek that greeted gold prospectors when they first arrived in the late 1840s. Now, three dams and numerous small diversions regulate flows and affect water quality and habitat conditions. In addition, Deer Creek suffers from the legacy of the gold mining era, present day management of the river largely for water supply, and increasing urban encroachment. This report examines Deer Creek in an integrated manner that discusses past and present uses of the creek, encompasses the value of the river as an ecosystem, and incorporates the perspective of the native Maidu people, successful stewards for thousands of years of a thriving ecosystem.

B. Project Goal and Objectives

The goal of the Deer Creek Restoration Plan is to develop a scientifically sound and implementable plan to improve the health and function of Deer Creek (**Figure 1.1**) from the headwaters to the confluence with the Yuba River. This project is funded by the Sierra Nevada Conservancy, The Sierra Fund, The California Department of Conservation, and the California Wellness Foundation, and is jointly implemented by Friends of Deer Creek/Sierra Streams Institute (FODC/SSI) and the Tsi-Akim Maidu Tribe.

More specifically, the six objectives of the Deer Creek Restoration Plan are to:

- Develop a quantitative understanding of river hydrology and geomorphology;
- Integrate the indigenous cultural perspective and traditional ecological knowledge;
- Evaluate creek health through assessment and analysis of data;
- Identify overall opportunities and constraints to restoration in Deer Creek; and
- Make recommendations regarding restoration goals, approaches and additional analysis.

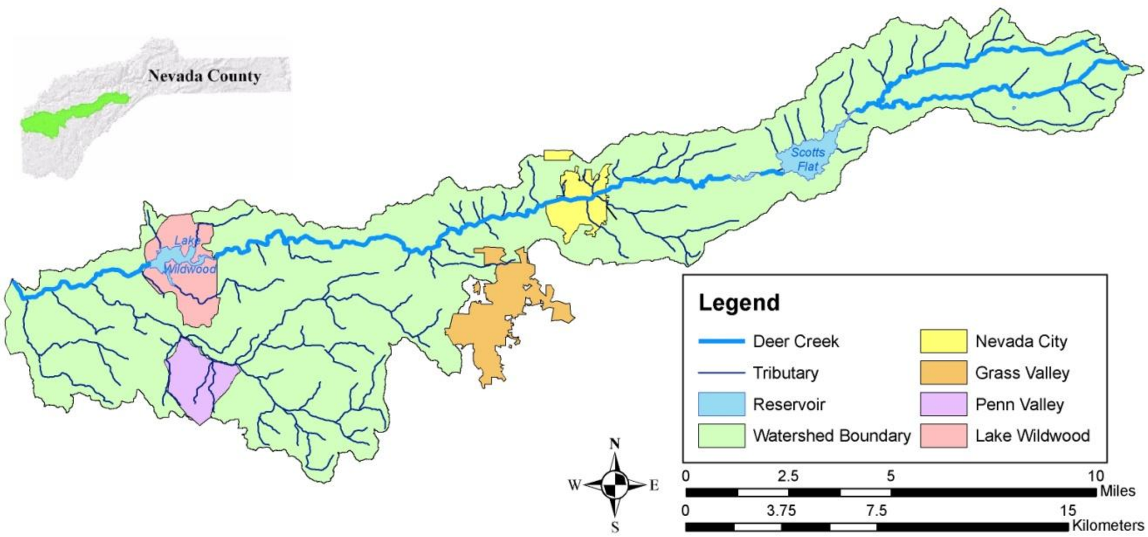

Figure 1.1: Deer Creek Watershed

C. Approach

The approach used for the development of the Restoration Plan involved a combination of desktop study, field observation, and analysis of ten years of monitoring data. The Upper Deer Creek Assessment and Restoration Plan, developed in 2006 by FODC/SSI with Natural Heritage Institute, was used as a starting point. The scope of the present plan has been expanded to incorporate the entire watershed and to include the Maidu cultural perspective.

Before initiating the Plan, a considerable amount of time was spent developing a conceptual framework to guide the assessment, analysis, and planning. The approach taken reflects a general consensus among assessment methodology sources on the importance of geomorphic processes to stream health. Understanding geomorphic processes and how they vary along Deer Creek is critical to any restoration plan because geomorphic processes drive the form of the creek channel and floodplains, which in turn influence in-stream and floodplain habitat, riparian vegetation, water quality, biota and many other important stream qualities (National Research Council 1992). Thus, to restore and maintain healthy aquatic and riparian ecosystems successfully, restoration efforts must recreate the physical conditions necessary to support natural biotic communities (Gore 1985; National Research Council 1992). In addition, the design and implementation of a restoration program should be guided by an understanding of past changes, and should address the historical causes and course of channel degradation while also considering future impacts to the system (Kondolf 1995; Brookes and Sear 1996).

Figure 1.2 illustrates the basic structure of a river system and the foundational role that river hydrology and morphology play. Key inputs, processes, and attributes that contribute to a healthy river (from McBain and Trush, 2004) include:

- channel morphology that is scaled to flow conditions;
- sediment supplies that are balanced with sediment transport capacity;
- frequent scour of bed surface and periodic scour of bed subsurface;
- channel migration (in alluvial sections);
- frequent floodplain inundation;
- self-sustaining diverse river corridor.

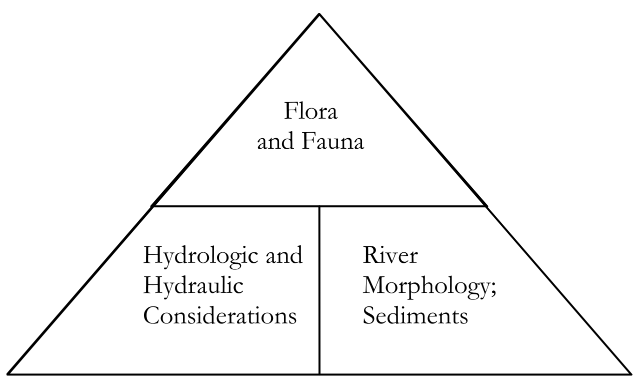

Figure 1.2: Basic Structure of a River System (Brookes and Shields 1996)

Based on this approach, the Restoration Plan included the components described below.

Pre-contact Indigenous Management of the Watershed

The project implementation is a collaborative effort by FODC/SSI and the Tsi-Akim Maidu tribe to integrate the cultural and ecological perspective of the native people of the area with current scientific monitoring and assessment methods. For thousands of years, Deer Creek supported a human population whose management practices of the watershed have much to teach its present stewards. Indigenous people practiced a form of semi-nomadic proto-agriculture, in which plant and animal species were managed through the use of fire ecology and game fencing, to create zones for efficiency of harvesting and hunting. Although the watershed was altered by human use, the ecosystem thus created was balanced and healthy. In addition to a consideration of the Maidu's ecological practices, the Plan includes cultural elements in an effort to restore places and species that were of significance in tribal life.

Geology

The geologic formations and deposits present in the Deer Creek watershed were evaluated, along with changes brought about over time by natural processes, and by the significant impacts of human activities. Placer, hydraulic and hard rock gold mining along with deforestation, road building and construction of dams have greatly altered sediment supply and transport in the watershed since gold rush times.

Hydrology

Flow data from Nevada Irrigation District (NID) and USGS gauges were analyzed to begin to describe flows that could be considered "natural" or unimpaired by NID's water supply system, in addition to describing key hydrological patterns under current conditions. The upper portion of Oregon Creek was used as a reference site for the upper watershed for predicting natural flows, because it is unimpaired by dams and diversions but otherwise similar in elevation, size, geology, climate, and other factors.

Geomorphology

The geomorphic analysis first involved broadly classifying the distinct reaches of Deer Creek and characterizing the morphological channel types found along the majority of the study area. This included determining for several specific study sites the channel dimensions and stability, substrate characteristics, efficiency of sediment transport, amount of sediment supply available for transport, and the potential for channel-floodplain interaction.

River Ecology

Chemical, physical, and biological water quality data collected by FODC/SSI were analyzed to evaluate the ecological integrity of the Deer Creek watershed. Data include monthly water quality monitoring, storm-event sampling, riparian vegetation assessments, and biological data from bacteria, algae, benthic macroinvertebrate, fish, and vertebrate assessments.

Future Development

The outcomes of climate change, projected future population growth and development, and future water resources development in the Deer Creek watershed were assessed to predict their probable impacts. The existing regulatory structure was reviewed to determine its adequacy in controlling or mitigating these impacts.

Recommendations

As a result of this Plan, gaps in critical data, information, and analysis were identified, as well as strategic areas for restoration, management changes, public outreach, education, and regulatory reform.

Friends of Deer Creek/Sierra Streams Institute
Tsi-Akim Maidu

March 2011

Chapter II: Understanding Deer Creek's Indigenous Past

Michael Ben Ortiz

Introduction:

Prior to the Gold Rush of 1849 and the influx of white settlers, the Deer Creek watershed was inhabited for thousands of years by native people who have come to be known as the Maidu. The Maidu, a word that means "people" in their own language, were divided into three basic groups: Nisenan (foothill or Southern Maidu, including the inhabitants of the Deer Creek watershed), Konkow (valley or northwestern Maidu), and mountain or northeastern Maidu (SYRCL, 2011). They subsisted on a variety of vegetable resources, primarily acorns, greens and grass seeds, supplemented with fish and game, and depended on an intimate knowledge of the ecosystem of which they were a part. Settlements were relatively small, with a restricted home range that provided the bulk of the food supply, and a wider hunting and harvesting range (Heizer and Whipple 1951). The vegetation was characterized by isolated stands of a predominant plant species, rather than an even spread of vegetation throughout the region, with animal species likewise unevenly distributed depending on its diet. Fire was a critically important tool in the native people's management of their landscape. Foothill Indians had the highest population densities in California, enjoying the most favorable conditions and occupying relatively permanent settlements that supplied the bulk of their needs.

Today, only a handful of Maidu people remain, having been largely exterminated as a race after the discovery of gold in 1849. Tribal groups are currently engaged in efforts to revive their language and culture, and to restore tribal lands in the Deer Creek watershed. Ecosytem restoration, and the reconnection of people to their environment, are of the utmost importance in the effort to preserve the ancient ways.

Traditional Ecological Knowledge

Michael Ben Ortiz

In tribal life, songs were sung that revealed and celebrated the relationship between humankind, animals, and inanimate objects such as trees and stones. Songs and stories are the foundation of the Maidu worldview and the basis of Maidu traditional ecological knowledge. Collecting and telling traditional stories and songs is an important step in the restoration of balance.

Life in balance was reflected in every creature and every artifact. Everyone and everything was important. Cookware was made from local stone. The vole aerated the soil by tunneling, spread seeds, and was itself a food source for other animals, which in turn were in balance. Bears visited villages and stayed until their bellies were full. Meanwhile villagers congregated in community structures or roundhouses and thrived as a community, united by this adversary. Failure to value any element of the natural world has consequences for the harmony of the whole. When we let the salmon become extinct, there is an imbalance. When a creek becomes a sewer pipeline, there is an imbalance. With the loss of salmon is also the loss of fishing villages, the loss of songs, and the loss of ceremonies and community life.

Maidu traditional ecology consists of ecosystem management techniques that included pruning, burning, digging, fencing, and harvesting. Fire in particular has been lost as an ecosystem management tool, with current practices favoring fire suppression. Low-intensity fire, as practiced by the Maidu, resulted in soil enhancement, stimulation of seed growth, and removal of debris that inhibits plant growth. Low intensity fires were set each fall, without the catastrophic fires that occur now as a result of decades of fuel build-up caused by fire suppression efforts.

Importance Of Deer Creek For The Perpetuation Of Tribal Tradition:

The Maidu believe that Worldmaker gives every creature a place that is their home, where they can be productive and survive, and will want for nothing. Homes will be built here, like those of their grandfathers. In this place they will leave their footprints. In this place are ceremony grounds, provided by Worldmaker, determined by their elders, and continuously used by their ancestors before them. Each ceremony ground is truly one of a kind. Preservation of these places is of the highest importance because no replacement can be conceived. Moreover, preservation of ceremony grounds results in protection of both cultural traditions and of the watershed, since Maidu people use native plants adjacent to ceremony grounds in their ceremony as well as for their livelihood. Continued annual use of these plants created, as a result, the natural landscape of the Deer Creek watershed. Tribal access to traditional ceremony grounds should be included in all restoration plans.

Key to reestablishing the Maidu people's role in the stewardship of the Deer Creek watershed will be identifying and classifying each cultural site boundary. Cultural sites that are now on private land may involve a different and more time consuming planning process than those that are on public land. Although many cultural sites have been confirmed in surveys, more time is needed to locate and assess boundaries, environs, and probable habitats, providing the information required to classify traditional cultural properties into three categories: Primary, Secondary, and Tertiary Traditional Cultural Properties.

- Primary Traditional Cultural Properties are the areas of communal congregation, such as village sites, ceremony grounds, large hunting and gathering encampments, cemeteries, and sacred sites.
- Secondary Traditional Cultural Properties are locations with favorable conditions for specialized hunting and foraging habitat. This will include maintained stands of native plants used for both food and material cultural items, hunting and fishing areas, waterfalls, pools, natural hunting blinds, stone quarries and large game trails.
- Tertiary Traditional Cultural Properties are all other lands. These lands traditionally involved less annual maintenance, since harvesting and burning alone comprised the horticultural practices required to achieve a balanced ecosystem.

Preservation Of Spring Waters:

Michael Ben Ortiz

Cool, clear, non-contaminated drinking water is a resource that was managed by the Maidu people through habitat enhancement, protected tribal boundaries, and individual commitment to long enduring customs. These practices allowed the Maidu to live in a world where one could drink water directly from streams. In terms of ecosystem health, clean water is an important indicator of balanced ecosystem function.

The finest drinking water is found flowing from foothill and mountain springs. At the source of the spring where the water emerges from the earth is the best supply of non-contaminated drinking water. These emergent locations are where the Maidu people preferred to obtain their drinking water. After the water's emergence, downstream in its water course, there is every opportunity for contamination. All other water outside of the spring box needed to be boiled before it was consumed and was always considered secondary in quality. Drinking water was dipped into stone, wood, and textile vessels, from a spring-box that was constructed of stone and covered with a plank roof. Preservation of drinking water springs included the establishment and maintenance of both game fencing to lessen the chance of contamination at the spring box, and deep shade to lessen the diversity of vegetation adjacent to the spring. Preservation of drinking water locations was the highest communal priority, and application of the ancient rules and customs associated with the stewardship of the spring is a high restoration priority.

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Assessment of the drinking water springs located within the Deer creek watershed revealed evidence of the long enduring cultural practices associated with these locations. However, at each location visited we also encountered the outcome of the transformation of the surroundings to suit the purpose of ranchers, miners, and loggers, including past and present spring water retention and conveyance systems. Of all the springs we were able to identify adjacent to Maidu village and encampment sites in the Deer creek drainage, the spring and village at Pam Pakan near Mooney Flat is the best preserved. This is due in part to the lack of mechanized land alterations, and the longevity of cattle ranching in this area. This spring is also the second to the last spring on lower Deer Creek prior to entering the Yuba river. At the Pam Pakan village site, cows were observed fenced into, not out of, the spring. Identification and correction of pollutants entering Deer Creek should be among the first projects undertaken.

Restoration of the springs in the watershed will require the cooperation and long term involvement of the land owner, working with Maidu people and other land managers in their preservation and restoration projects. Key to establishing this working relationship is identifying the long term goal and understanding the process required to achieve the goal, and maintaining regular communication among all interested parties.

Restoration options might include the installation of fencing to keep cows out of the spring and riparian areas; the cleanup of human-caused debris from the water course; and the re-introduction of native plant species, including white alder, big leaf maple, spice bush, willow species, Valley oak and many others, to provide shade in and around the spring and riparian areas.

Habitat Enhancement:

An enduring plant and animal community was the only chance of survival for the Maidu. Establishment, enhancement, and preservation of game habitat were tasks undertaken on a daily basis by the Maidu people. A clear understanding of the nature of plants and animals, and their relationships with all others, comes from daily observation coupled with storytelling. A hunting and harvesting plan that provides a benefit to every plant, animal and human can only be conceived through a higher understanding of the nature of each plant and animal. This is the Maidu concept.

Fencing was used within large pastures to enhance bio-diversity and habitat through the introduction of missing and poorly represented native plant species. Key to the success of a fenced-in habitat is identifying the proper location for its establishment. Slope, exposure, and soil type determine plant choices. Fenced-in habitat could be designed to invite, protect, and nourish specific plant and animal species. The installation of dead hard wood timber into the fenced-in habitat would invite animals such as voles, fox, raccoon, coyote, bob cat, ringtail cat, pack rat, snakes, and many others. If an area is designed that allows full sun without the encroachment from other trees in the fenced-in habitat, the effective establishment of native bulbs and grasses can begin.

After determining the type of habitat a site could supply, a maintenance plan is developed. A steep inaccessible shaded canyon may involve less extensive annual maintenance than the wide descending ridge tops and rolling oak woodlands. There is a season for each of the many tasks required to establish and maintain a balanced eco-system. The proper timing of each maintenance practice is very important. Poor timing could lead to crop failure and the decline of favorable plant and animal species.

Although the Maidu were not farmers, they practiced a kind of proto-agriculture that consisted of aggregating specific beneficial species in a particular area in order to create a harvest ground, using fire as a tool for establishing the ideal conditions for growth. For example, in order to maintain a stand of hazelnut, the tribe would identify companion plants, and would reintroduce preferred species in the area. They would identify adjacent animal habitat and preserve it through selective use of fire, back burning from the habitat boundary into the hazel nut grove. These habitat areas could be as small as one hundred square feet, or as large as an entire canyon slope. Typical preserved habitat adjacent to the hazelnut grove might be packrat nesting sites, fox dens under fallen and rotten logs, vole nesting sites, bear dens, marten and fisher dens. Back burning is also used to preserve installed game fencing. Animals respond to slope and exposure in predictable ways: fences built from forest debris direct animals into the hunting areas that use topography opportunistically. Maidu people maintained game fences continuously in the same location for generations. Back burning from established game fencing was most important, and was included in their annual stewardship plan.

After preservation of the identified habitat areas, the tribe would begin burning some big leaf maple trees to allow the sunlight on to the hazel nut grove. This was done by back burning a ring around the tree, approximately ten feet in diameter, smearing pitch above the trunk all around, and finally building a fire around the tree and scraping its bark and wood repeatedly during the slow burning process until the tree falls. After the trees hit the ground, the bark will be removed and the inner bark separated. This will be stored and used later for skirts and ceremony flagging. After the bark is removed the tree will be burned into sections, or left on the forest floor for habitat enhancement. Burning may occur in the following season, once the tree is dry.

The tribe would selectively burn hazelnut bushes, causing them to grow new straight shoots for baskets and other items next year. Bushes selected for burning would be those located on the south-east side of the hazelnut grove, allowing sunlight to reach the other fruiting stand of hazel nuts that would provide the following summer's harvest. Next the hazelnut branches would be pruned to about ten inches above the ground. An amount of forest litter sufficient to cover the basal portion of the pruned shrub (about one foot thick) would be installed and then quickly burned in the late fall. This fire should not last longer than five minutes.

This type of environmental management was repeated throughout Maidu country, in the grasslands, the oak woodlands, the pine forest, and the high Sierra Nevada summits.

Forest Floor Bio-Diversity:

The maintenance practices of the Maidu people were driven by the need for community preservation, through establishment and stewardship of a bio-diverse habitat. Again, observation and tradition allowed the Maidu people a storehouse of resources that were sufficient for their needs, without adversely impacting their plant and animal neighbors.

Imagine entering a supermarket and there is only one aisle stocked, and all the others empty. This is how you would feel as a Maidu looking into the Deer Creek watershed today. Clearly, families have not been sustained by this land for over a hundred years. There are no more maintained native stands of anything other than timber, with the maintenance practices of the timber industry being the greatest deterrent to the establishment of any bio-diverse community. Heavy equipment simply runs through the forest floor understory, and no attempt is made to replace the damaged understory.

Restoration and establishment of a bio-diverse forest floor should begin by addressing logging practices and the timber industry's restoration and preservation policies.

Orientation To Trade And Traveling Trails:

Maidu villages and encampments were often situated adjacent to the major trails. Once the storehouses were full, the trade season would begin. Tribespeople would walk to Lincoln on the Auburn Ravine with bow wood from Deer Creek yew trees and trade for salt from the salt marsh.

Trails radiate in all directions from Maidu village sites. Destinations could include fishing and hunting grounds, oak groves, plots of grasses, bulbs and other plant resources, neighboring villages, and drinking water. Often these trails converge at intersections in remote areas. One such site is five miles north of Nevada City, on State Highway 20, where the lowest point of Washington Ridge meets with Harmony Ridge. From this intersection the trail follows the ridge and goes west, skirting the drainage of Rock Creek and into the lower drainage of Deer Creek at Anthony House (Lake Wildwood). Trail spurs enter the drainage of Rock Creek to the north, South Yuba River in the north east, or Deer Creek to the south. Heading east up Washington Ridge to the headwaters of Deer Creek, a trail enters the northern watershed of the Bear River, including the headwaters of Greenhorn Creek, and Steep Hollow. This area contains a concentration of seasonal Maidu encampments.

Identification of Maidu trails within the Deer Creek watershed is difficult because they have been successively overlain by sheep herding trails, the overland immigrant trail, logging and mining roads, and paved roads such as State Highway 20. The best preserved Maidu trails are located in the lower reaches of Deer Creek in areas inaccessible to heavy equipment, and are now mostly game and cattle trails. Efforts to preserve these trails might include an educational map depicting historic trails and destinations.

Mixed Conifer And Deciduous Forest Canopy:

The importance of a mixed conifer and deciduous forest canopy can be directly related to an abundant and diverse understory and forest floor. When the leaves from broad leaf deciduous trees and shrubs become mixed with pine and fir needles on the forest floor, they decompose at a rate that is in balance with the accumulation rate. This balance provides suitable conditions for the creation of forest humus and a viable seed bed that can be exposed from the slightest disturbance, such as a fox chasing a mouse. When logging activities remove the major broadleaf deciduous trees, optimum decomposition rates cannot occur. The establishment of a viable seed bed is necessary for the perpetuation of a diverse plant community which attracts a diverse animal population. Conversely, plants require animals to eat the seed and disburse them on a viable seed bed. This is a necessary and complex inter-relationship, in which birds play a major role. As a consequence of logging activity outside the riparian area, birds are unable to find suitable perches in the upslope reaches, and hence seed dispersal fails to occur in the denuded reaches most suitable for the establishment of vegetation. Seeds that are dispersed from birds perching in riparian areas often land on ground not suitable for establishment.

Through habitat identification, plant species re-introduction, and dedicated forest management programs that take into account the complex relationships between plant and animal species, a balance can be achieved. The importance of identifying the most likely habitat areas prior to plant species re-introduction is of the greatest concern. Planting in stands rather than in isolation creates better opportunities for pollination, seed consumption, and dispersal.

The wide range of ecosystem types that exists in the watershed is evidence that a much greater plant and animal bio-diversity was once present. The animal community is directly affected by the absence of the full range of understory plants, making their reintroduction a high priority. As noted above, the lack of broadleaf deciduous trees among the conifers in the upper or mid stories has led to an imbalance that prevents the likelihood of a viable seed bed. However, a field survey of the upper watershed of Deer Creek revealed a healthy representation of the plant and animal species required to begin a reestablishment program.

The lower Deer Creek watershed has been negatively affected in different ways from the upper watershed. In the lower reaches, there has been ranching activity for the last 150 years, including removal of trees to create pasture, water diversions for irrigation purposes, and the extermination of predators. Agricultural practices have directly led to the lack of biodiversity in the lower watershed, which was once a very productive oak woodland.

The following list of poorly represented or missing plants from the upper watershed is taken from the *Tahoe National Forest Sensitive Plant Program Standard And Guidelines* (1999) prepared by Kathy Van Zuuk, forest botanist. More study is needed to correctly identify all under-represented species.

MISSING PLANTS

Mountain Alder, *Alnus tenuifolia*
Tan-Bark Oak, *Lithocarpus densiflora*
Madrone, *Arbutus menziesii*
Sierra Plum, *Prunus subcordata*
Western Choke Cherry, *Prunus demissa*
Pacific Yew, *Taxus brevifolia*
Sugar Pine, *Pinus lambertiana*
California Nutmeg, *Torreya californic*a
Western Service Berry, *Amelanchier alnifolia*
Sierra Coffeeberry, *Rhamnus rubra*
Hollyleaf Redberry, *Rhamnus ilicifolia*
Fremontia, (Flannel Bush) *Fremontia californica*
Silk Tassel *Garrya fremonti*
Labrador Tea *Ledum glandulosum*
Western Azalea, *Rhododendron occidentale*
Blue Elderberry, *Sambucus caerulea*
Snowberry, *Symphoricarpus albus*
Mountain Snowberry, *Symphoricarpus*
Arrowleaf Balsamroot, *Balsamorrhiza sagittata*
Bear Grass, *Xerophyllum tenax*
Bunchberry, *Cornus canadensis*
Coptis, *Coptis occidentalis*
Wax Currant, *Ribes cereum*
Squawbush, *Rhus trilobata*
Twinberry, *Lonicera involucrata*
California Hazelnut, *Corylus cornuta californica*
Creeping Oregon Grape, *Berberis repens*
Fireweed, *Epilobium angustifolium*
Pipsissewa, *Chimaphila umbellata*
Pyrola, *Pyrola asarifolia*
Spring Beauty, *Claytonia lanceolata*
Wild Ginger, *Asarum caudatum*
Yampa, *Perideridia gairdnera*
Angelica, *Angelica species*
Arnica, *Arnica cornifolia*
Columbine, *Aquilegia formosa*
Lewis's Syringa, *Philadelphus lewisii*

Proposed Future Projects:

The field study conducted by Maidu tribal members resulted in the following list of priority projects:

1. Collect oral and written history of the area including all available resources.
2. Collect a list of historical documents for research database, including Maidu placename history in the Deer Creek watershed.
3. Identify historic trails in the watershed.
4. Create a pre-contact map and model of the Nevada City area. This would include roundhouse sites, trails, settlement areas, cemeteries and springs.
5. Implement a program to build understanding of Maidu ecosystem stewardship as a baseline for restoration planning
6. Prepare and present a wake-up program for instructors to build community understanding, capacity and support for restoration efforts.
7. Ensure the preservation of Maidu artifacts such as millstones and arrowheads by creating and disseminating protocols for handling found items.
8. Erect a monument at Lake Wildwood for the Anthony House.
9. Identify threatened artifacts and if necessary remove them to safer locations for protection.
10. Erect large statues of bears in Gateway Park in Penn Valley, where bears were abundant.
11. Erect signage denoting the significance of public-use areas.
12. Provide funding and supervision for a major public and private plant restoration, including trees and seedbeds.
13. Indentify historic creek channels and potential for restoration actions.
14. Clean up contaminated mine tailings and other pollutants.
15. Replace native animal and plant species missing from the habitat.
16. Create bear and other wildlife corridors with access to water.
17. Protect the headwaters springs.
18. Complete a study of historic salmon ranges on Deer Creek.
19. Recreate conditions to allow salmon spawning in Deer Creek.
20. Post warning signs in multiple languages for fish consumption, and water toxicity levels in swimming areas.
21. Prioritize restoration efforts, using techniques derived from traditional ecological knowledge, with a focus on primary traditional cultural properties, including the village sites at Mooney Flat and the Deer Creek headwaters.

Chapter III: Geology, Soil, Mining and Dams

A. Setting

The Deer Creek watershed is located in the western foothills of the northern Sierra Nevada mountain range. The watershed is approximately 34 miles long and 2 to 4 miles wide with a total area of 83 square miles. The headwaters of Deer Creeks are located approximately 10 miles east of Nevada City at an elevation of 5,000 ft mean sea level (msl), as compared with local Sierra crest elevations near 10,000 ft msl. Deer Creek is impounded by three moderately sized dams and several water conveyance diversions and ultimately flows into the Lower Yuba River at an elevation of 300 ft msl, approximately one mile downstream of Englebright Dam and 20 miles east of Marysville. Much of the watershed is undeveloped or rural with occasional populated areas including Nevada City, Penn Valley and the Lake Wildwood community. The Deer Creek watershed rises in conifer forests at its upper elevations passes through mixed conifer-oak forests at its middle elevations and terminates in oak woodlands and grasslands near the Sacramento Valley floor.

B. Sierra Nevada Geology

Deer Creek flows over many of the major geologic features of the northern Sierra Nevada mountain range and is morphologically influenced by these rocks and sediments, as well as by exploitation of both placer and hard rock or lode gold deposits during the California

Gold Rush. The following paragraphs summarize northern Sierra Nevada geologic stratigraphy, structural formation, gold deposition and quaternary glaciation. Later paragraphs describe the major stratigraphic units within the Deer Creek watershed.

The stratigraphy of the Sierra Nevada Mountains can be divided into two major groups, the subjacent (older) series and the superjacent (younger) series rocks (Lindgren 1896, James 2007). The subjacent or basement series is composed mainly of severely deformed and slightly metamorphosed Paleozoic (542-256 million years before present (Ma B.P.) and Mesozoic (256-65 Ma B.P.) marine sedimentary and volcanic rocks intruded by granitic batholiths. These rocks were accreted onto the North American continent and then deformed by later tectonic events. Subjacent rocks have been exposed by erosion in the canyon bottoms and lower slopes of the Deer Creek watershed.

Superjacent series rocks lie uncomformably on top of the Subjacent series and dip gently to the west with relatively little deformation or regional metamorphosis. Early superjacent rocks include the Tertiary auriferous (gold bearing) river gravels. Later superjacent rocks are largely volcanic or volcanoclastic and were deposited during two major volcanic episodes, a period or ryolytic volcanism followed by extensive andesitic volcanism which was largely lahars (volcanic mud and hot ash flows) in the foothills region. Superjacent rocks are generally exposed on ridge tops and slopes that bound the Deer Creek watershed.

The Sierra Nevada Mountain Range was formed during several periods of uplift separated by periods of tectonic stability and erosion. An early period of rapid uplift in the late Mesozoic or early Tertiary (65-2.5 Ma B.P.) which formed the proto Sierra was followed by a long period of tectonic stability with deep erosion exposing the tops of the granitic batholith by the early Tertiary. Renewed Sierra uplift and erosion in the late Cenozoic (65 Ma B.P. to present) created the modern valleys. Two periods of uplift and tilting are thought to have occurred at the end of the Miocene (23 to 7 Ma B.P.) and at the beginning of the Quaternary (2.5 Ma B.P. to present). Continued uplift and balancing erosional forces maintain the mountain range in its present form.

Lode Gold Deposits

Lode gold deposits in the Sierra Nevada Range formed after the subjacent series rocks, during the 150 – 120 Ma B.P. deformation of the Sierra Nevada Foothills Metamorphic Belt (Bierlein et al. 2008). Although the ultimate source of the gold and the origin of ore-bearing fluids in the Sierra Nevada Foothills Metamorphic Belt have not been determined, the general hypothesis is that the deposits were formed by a hydrothermal process, in which gold ore is dissolved from rocks deep within the earth and brought to the surface in solution. As the water cooled, the ore precipitated into a solid, forming veins of ore within the fractures. These are known as hydrothermal deposits. The gold deposits follow structural instabilities such as faults and fracture zones present in nearly all types of subjacent series rocks. Individual gold deposits within the Mother Lode include gold-bearing quartz veins from a few inches or less to up to 50 ft thick and a few thousand feet long. Lode gold is also present outside of quartz veins, disseminated in sulfide deposits. There is also a close spatial relationship between gold and serpentinized ultramafic rock. Along with the gold, other metals including arsenic, lead and cadmium enriched the ore veins and sulfide deposits as well as country rocks surrounding the gold deposits. Lode gold deposits are discontinuous and are scattered though most of the Deer Creek watershed but are most concentrated in the areas surrounding and downstream of Nevada City.

Placer Gold Deposits

Native gold is also found in the form of free flakes, grains or larger nuggets that have been eroded from rocks and end up in alluvial deposits called placer deposits. Locally, the placer gold primarily comes from Ancestral Yuba River deposits which formed during the Tertiary during a time characterized by a warmer, wetter climate and were derived from erosion of a proto Sierra Range to the east of the present range.

Waldemar Lindgren succinctly and poetically described the depositional history of these deposits and the overlying volcanics in the following excerpt from his seminal document *The Tertiary Gravels of the Sierra Nevada* (Lindgren 1911):

> The Paleozoic and early Mesozoic seas once extended over the site where the Sierra now lifts its broad back. Toward the close of the Mesozoic era the sediments were compressed in heavy folds, and the intrusion of granitic magmas forced them upward to lofty summits. After the intrusion, the fissures and joints of granitic rocks and altered sediments became filled with veins and seams of gold-bearing quartz. A long period of erosion in the early Cretaceous planed down the newborn mountains. The concentration of the gold from the veins began in countless streams. Pauses in the erosion, when the topography had been reduced to gentle outlines, permitted deep rock decay and promoted the liberation of gold from its matrix. Renewed uplift quickened erosion and facilitated the further concentration of gold. Throughout Cretaceous and Tertiary time these conditions continued.
>
> Long-quiescent volcanic forces asserted themselves toward the end of Tertiary time, contemporaneously with the greatest volcanic activity in the Great Basin. Rhyolite flows filled the valleys, covered the auriferous gravels, and outlined new stream courses in the old valleys. Eruptions of andesitic tuffs began in enormous volume and effectually buried a large number of the streams, filling their valleys to the rims. At the close of the Tertiary period a steaming, desolate expanse of volcanic mud covered almost the whole of the northern Sierra, in startling contrast to the peaceable verdure-clad hills of the Miocene.

The volcanic cap rocks are more resistant to erosion than the surrounding weathered basement rocks. Tertiary gravel and volcanic cap rocks are generally located on the ridges and slopes along the margins of the Deer Creek watershed. This phenomenon is known as "inverted terrain" since the younger volcanic rocks which were originally deposited in low lying drainages now form the ridges which bound much of the watershed.

Placer gold deposits are present on slopes and beneath ridges in the Deer Creek watershed particularly in areas surrounding Upper Scotts Flat reservoir, to the north and west of Nevada City, in the Rough and Ready and Mooney Flat areas. The accessible portions of the gold-bearing gravel deposits have largely been washed down slope by placer and hydraulic mining operations into the Deer Creek drainage where the sediments have been transported downstream or impounded behind dams.

Glacial and Quaternary Deposits

During the Pleistocene Ice Age, which lasted between approximately 2.5 million years ago to 11,000 years ago, mountain glaciers advanced and retreated from the Sierra Nevada range, creating the sculpted high country we see today. The prominent glacial features evident in the Northern Sierra were mainly formed during four well-documented stages: McGee, Sherwin (both prior to 730,000 B.P.), Tahoe and Tioga (James 2008). Glacial moraines deposited during the Tahoe and Tioga ice advances and interglacial outwash deposits are likely the main source of glacial sediment remaining in western Sierra watersheds.

The maximum glacial advancement on the western slopes of the Sierra during the most recent (Tahoe and Tioga) glacial periods extended down to about 4,800 ft msl elevation. Due to the geographic location of the Deer Creek watershed with a maximum elevation near 5,000 ft msl, and the proximity of the far deeper canyon of the South Yuba River to the north and the Bear River watershed to the south, little glacial debris was apparently deposited in the Deer Creek watershed during the late Pleistocene glacial advancements and Holocene outwash was minimal. As a result, no significant deposits of glacial sediment have been identified in the Deer Creek watershed.

C. Geologic Outcrops in the Deer Creek Watershed

Geologic formations exposed within the Deer Creek streambed and the slopes of the watershed span a wide range of ages and rock types including Paleozoic and Mesozoic sedimentary and volcanic rocks, Mesozoic intrusive rocks, early tertiary gold bearing stream channel deposits, mid to late tertiary volcanic cap rocks, and quaternary to recent alluvial deposits including mine waste. The following paragraphs summarize the approximate locations of geologic formations and major structures mapped in the Deer Creek watershed based on the Geologic Map of the Chico Quadrangle (California Geological Survey 1992) and are presented from the headwaters to the confluence.

Subjacent Paleozoic and Mesozoic Basement Rocks

The Paleozoic and Mesozoic Era range in age from 542 – 251 Ma. B.P., and 251 – 65 Ma. B.P., respectively. These rocks are commonly exposed in the streambed, banks and steeper slopes of the Deer Creek watershed. From the headwaters to the confluence these rocks include:

- Areas east of Scotts Flat Reservoir: Paleozoic Calaveras Complex consisting of chert and argillite and occasional metavolcanic rocks.
- The Scotts Flat Dam area and areas surrounding the western portion of the lake: Underlain by undifferentiated metasedimentary rocks.
- Immediately west of the Scotts Flat Dam: A thrust fault is mapped which has laterally pushed metavolcanic rocks eastward over metasedimentary rocks.
- Areas of the watershed from approximately 2 ½ miles upstream of Nevada City to one mile downstream: Underlain by the Jurassic (early Mesozoic) aged Yuba River Pluton which consists of massive granite and granodiorite rocks.
- From approximately one to four miles downstream of Nevada City: Several units of the Mesozoic-aged Smartsville Complex, consisting of gabbroic rocks, diabase, ultramafic, metavolcanic and metasedimentary rocks.
- Three miles west of Nevada City: The Grass Valley Fault cuts through the drainage and several traces of the Wolf Creek Fault Zone are located one to two miles downstream. These faults are thought to be inactive and have not shown movement in the Quaternary Period (2.5 Ma B.P. to present) or significant recent seismicity.
- Areas from just west of Bitney Springs Road to ½ mile downstream of Lake Wildwood: Underlain by the Mesozoic-aged Pleasant Valley Pluton. This formation consists of a core of gabbroic rocks in the Lake Wildwood area and upstream areas, with quartz diorite, tonalite and other granitic rocks exposed in the eastern and western portions of the pluton.
- Areas from ½ mile downstream of Lake Wildwood to the confluence with the Yuba River: Underlain by the Mesozoic aged Smartsville Complex. An unnamed fault crosses the drainage near the bridge on Mooney Flat Road. Rocks exposed upstream of the bridge are a diabase dike complex and rocks downstream of the bridge are massive diabase.

Tertiary River Gravels and Volcanic Cap Rocks

The Tertiary Period ranged in age from 65 to 1.8 Ma. B.P. The Tertiary aged rocks are commonly exposed on ridge tops and steep slopes above Deer Creek. From the headwaters to the confluence these rocks are exposed in the following areas:

- Washington Ridge and Burlington Ridge in the headwaters area, Harmony Ridge, Banner Mountain and Alta Hill in the middle watershed and the Ridge between

Mooney Flat and Smartsville in the lower watershed: Early tertiary volcanic rocks consisting of andesitic and ryolitic flows, flow breccias and pyroclastic rocks overlie most exposures of the tertiary gravels and form the volcanic capping rock which protected the gravels from erosion.

- Headwaters area: Late tertiary volcanic rocks are exposed in the headwaters area on the surrounding ridges and within the streambed up to 1 ½ mile downstream.
- The Scotts Flat area: Early tertiary auriferous gravels, the placer gold bearing gravels of the ancestral Yuba River which have been extensively mined by placer and hydraulic processes, are exposed along a small area of the creek bed approximately 3 miles upstream of Scotts Flat Reservoir and in several places upslope of the creek upstream of Scotts Flat Reservoir and along the north and south shores of the reservoir. Larger deposits are exposed along the southeast and south shores of the reservoir. Tertiary gravels are also exposed along the ridges north of the lake downstream to the Nevada City area (Coyote Diggings and Manzanita Diggings) extending 1 ½ mile downstream of Nevada City (Hirschmans and American Hill Diggings).
- Rough and Ready area: Tertiary gravels are also exposed in smaller areas upslope to the south of Deer Creek in the Rough and Ready area and near Mooney Flat in the westernmost portion of the watershed.

D. Soil

Most soils in the Deer Creek watershed have formed since the end of the last glacial ice advance approximately 12,000 years ago. Maintenance of healthy soil regimes has a significant impact on healthy intact vegetation, limiting erosion and cycling nutrients.

Soils in the Deer Creek watershed vary considerably based on underlying geology, vegetation, altitude, relief, past mining and other human disturbance (James 2008). Soils in the lowest portions of the drainage were formed under thermic temperature and xeric moisture regimes (typical moisture regime in areas of Mediterranean climates) and support grasses and oak woodlands. Soils in the middle and upper portions of the watershed were formed under mesic and urdic soil moisture regimes (common to the soils of humid climates that have well distributed rainfall) and support coniferous forests. Paleosols (older soils preserved beneath buried surfaces) including Ultisols and Alfisols with red argelic (clay) horizons are common on stable interfluvial surfaces within the Tertiary auriferous gravels and along the rims of hydraulic mines.

The Soil Survey of Western Nevada County, California (USDA Soil Conservation Service 1975) presents a general map of soil associations and detailed maps of individual soil types in Western Nevada County along with descriptions, type sections and other information regarding each soil type.

The following soil associations are depicted on the Soil Survey General Map within the Deer Creek watershed from Scotts Flat Lake to the confluence with the Yuba River:

- Areas north of Scotts Flat Lake are mapped as Aikens Cohasset Association. These soils are described as gently sloping to steep, well-drained loams and cobbly loams formed over andesitic conglomerate and metabasic rock. Depth to weathered rock ranges from 42 to 60 inches. Aikens Cohasset Association soils are used for timber production, grazing irrigated pasture and orchards (although the later two activities are minimal in the higher elevations of the Deer Creek watershed).
- Areas south of Scotts Flat Lake to east of Nevada City are mapped as Josephine Sites Association. These soils are described as undulating to very steep, well-drained loams formed over metasedimentary and metabasic rock. Depth to weathered rock ranges from 15 to 60 inches with some rock outcrops. Josephine Sites Association soils are used for timber production, irrigated pasture, improved dry pasture and orchards.
- Areas surrounding Nevada City to 2 miles west of Nevada City are mapped as Hoda Chaix Musix Association. These soils are described as gently sloping to very steep, well-drained sandy loams formed over metasedimetary and metabasic rock. Depth to weathered rock ranges from 20 to 60 inches. These soils are used for grazing irrigated pasture and improved dry pasture and for timber production.
- Areas west of Nevada City to Bitney Springs Road are mapped as Secca Boomer Association. These soils are described as undulating to very steep, well-drained and moderately well drained gravelly silt loams and loams formed over metabasic rock. Depth to weathered rock ranges from 40 to 60 inches. These soils are used for annual range, irrigated pasture and improved dry pasture and watershed.
- Areas between Bitney Springs Road to east of Lake Wildwood are mapped as Boomer Sites Sobrante Association. These soils are described as undulating to very steep, well-drained loams formed over metabasic rock. Depth to weathered rock ranges from 40 to 60 inches or more. These soils are used mostly for annual range, irrigated pasture and improved dry pasture with gentler slopes used for timber and orchards.
- Areas surrounding Lake Wildwood are mapped as Trabuco Sierra Association. These soils are described as gently rolling to steep, well drained loams and sandy loams formed over granitic rock. Depth to weathered rock ranges from 42 to 60 inches. These soils are used for annual range, irrigated pasture and hay.
- Limited areas to the west of Lake Wildwood are mapped as Ahwahnee Sierra Association. These soils are described as gently rolling to steep, well-drained sandy loams formed over granitic rock. Depth to weathered rock ranges from 30 to 60 inches. These soils are used for annual range, irrigated pasture and hay.
- Much of lower Deer Creek west of Lake Wildwood to confluence are mapped as Auburn Sobrante Association. These soils are described as undulating to steep, well

drained loams formed over metabasic rock. Depth to weathered rock ranges from 14 to 36 inches. These soils are used for annual range, dry pasture and irrigated pasture.

- A small portion of the lower watershed near Mooney Flat is mapped as Placer Diggings. These soils are described as placer mining debris, river wash, waste rock, and rolling to hilly, well drained loams formed over gravelly terrace remnants. Depths to rock are variable. These soils are unsuitable for agriculture and are used for recreation, watershed and wildlife habitat.

E. Anthropogenic Influences to the Geomorphology of the Deer Creek Watershed

The current geomorphic condition of Deer Creek has been strongly influenced by human activities during historic time. Human impacts, including hydraulic and hard rock mining, dam building, logging and other land use practices, have extensively affected sediment supply and transport mechanisms. Historical activities in the Deer Creek watershed have resulted in six time periods with distinctly different geomorphic and hydraulic conditions, namely prehistoric, hydraulic and hard rock mining era, post hydraulic/ hard rock mining era, post mining pre-dam time period, post Scotts Flat dam, and post Lake Wildwood dam times. A discussion of each of these time periods and resulting geomorphic conditions is provided below.

Pre-Contact

Prior to gold rush era mining, the ecosystem was enhanced by the native people through the use of fire. Prescribed burns were regularly set to thin underbrush, promote natural diversity and protect animal habitat and stands of useful plants. Native people used fire to manage the natural environment so that a diverse set of resources could be used, creating a state of "pyrodiversity" in which the local Nisenan and other California Indians thrived. The pre-mining landscape was relatively stable with park-like old growth forests with an open understory and maintained stands of useful plants. Well-developed soils and well graded streams sediments were in a balanced state of erosion and downstream transport. Abundant large woody debris in the stream channels slowed the stream flow and increased sinuosity by creating meanders and evenly graded stream channels beneficial to fish and wildlife.

The Gold Rush

The western invasion of these traditionally managed native lands brought on early changes including livestock grazing, timber harvest and some clearing for agriculture. However, these changes were minimal in the Deer Creek area until the discovery of gold on the South Fork American River in 1848. The first significant changes came shortly after gold discovery as multitudes of fortune seekers swarmed into the Sierra Foothills, particularly in gold-rich watersheds such as Deer Creek. During the gold rush, native people were killed or driven off the land. Indigenous land use practices, which had been in effect for millennia, were halted. Old growth forests were cut down for fuel, shelter and mine uses. Annual burning practices were stopped, eventually allowing fuel loading and catastrophic fires. Water was diverted to supply the mines, changing summer flow regimes.

Within a few years, stream sediments throughout the drainage were literally turned over by placer mining activities to sift out the gold nuggets and flakes. Diversions and sluice channels completely altered the streambed. Stream morphology was destabilized, plant and animal communities were destroyed, and fine-grained sediments and woody debris were washed out, leaving irregular piles of gravel and cobbles. Meandering channels straightened, increasing erosional forces during high water and causing additional stripping of bank sediments. Because the rich placer gold deposits were distributed up and down Deer Creek, this process occurred throughout the watershed.

By the mid 1850s most of the easy-to-recover gold had been found, and more and more ingenious mining methods were needed to exploit the rich placer gravel deposits in the uplands of the Deer Creek watershed.

Hydraulic Mining

circa 1855

Hydraulic mining was first invented at American Hill just outside Nevada City in 1853 using canvas hoses and long tapered metal nozzles to direct high velocity jets of water at the gravel banks. Over the next three decades huge volumes of gravel were washed down the drainage. During the 31 year period from 1853 to 1884 an estimated 29 million cubic meters of hydraulic mine waste was eroded from the Deer Creek watershed (James 2004). This corresponds to a basin wide denudation rate of approximately 4.1 millimeter per year (mm/yr) for a total average of 126 mm (5 inches) of erosion over the entire basin during the hydraulic mining era. Only four other watersheds in the northern Sierra had higher denudation amounts during the hydraulic mining era: the Bear River at 237 mm, Middle Yuba at 204 mm, North Fork American River at 181 mm and South Yuba at 167 mm. All these watersheds have higher flows and more transport capability than Deer Creek. Thus the Deer Creek watershed was subject to some of the most extreme hydraulic debris impacts in the Sierras.

The massive amounts of hydraulic debris choked the creek bed beneath 20 feet (ft) or more of gravel from the mining areas to the confluence with the Yuba River and beyond.

The major areas of hydraulic mining in the Deer Creek watershed included hill slopes surrounding what is now Scotts Flat Lake and the hillsides and ridges above Nevada City (Coyote Diggings, American Hill and Hirschmans Pond). Other hydraulic mining sites were located near Rough and Ready, and in the lower watershed near Mooney Flat (Black Swan Diggings).

Although the Sawyer Decision, which banned releases of sediment into waterways, effectively ended hydraulic mining in 1884 hydraulic mining debris continued to wash down the stream channel for decades. In some areas large gravel bars and stream terraces remain to this day, particularly in the area downstream of Nevada City known as Stocking Flat. Sediment transport in Deer Creek during post hydraulic mining times has been transport-limited with relatively little sediment moving during normal stream flows. Record floods in 1862, 1909 and 1986 as well as other large floods in 1906, 1955, 1964 and 1997 transported much of the sediment.

The legacy of hydraulic mining also left large volumes of elemental mercury in the stream channel. In the mining process, mercury was added to the sluice boxes to help recover the gold. Of the approximately 26 million pounds of mercury used in the gold mines of California, it is estimated that 3-8 million pounds was lost to the environment (Alpers et al. 2005). Considering the extent of local mining activities, a large amount of mercury was certainly lost in Deer Creek, much of which remains today. Elemental mercury remains in stream sediments as droplets, pools and amalgam (bound to gold). Elemental and fine particles of mercury, often adhered to clay and silt is also present in sediment trapped in reservoirs (Alpers et al. 2005, 2010). Methyl mercury, the biologically available form of mercury, is formed in reducing environments including reservoir sediments and can move up the food chain and biomagnify to hazardous levels in fish and the predators who eat them (including humans). Recreational suction dredging, currently not permitted, removes elemental mercury but also remobilizes mercury in a smaller "reactive mercury" form which is prone to methylization and bioaccumulation. Additional discussion of the water quality and biological impacts of mercury is included in Chapter VI: River Ecology.

Hard Rock Mining

Hard rock mining in the Deer Creek watershed also began in the 1850s and continued into the 1940s, long after hydraulic mining stopped. Hard rock mining brought mineral-rich ores and waste rock from depth to the surface where ore was crushed and processed. Waste rock, often with high metal content, was dumped near the mine entrance. Fine-grained crushed ore was dumped directly into the creek for disposal or slurried into tailings ponds that eventually erode into the creek.

Although the volume of hard rock mine waste dumped in the watershed was less than hydraulic debris, hard rock mine waste, is also impacted by mercury lost at stamp mills, as well as relatively high concentrations of naturally occurring metals and metalloids such as arsenic, lead, chromium and cadmium, at levels often significantly higher than background surface concentrations.

Mill tailings from hard rock gold processing facilities were often dumped or later eroded into the creek. Large mill sites along Deer Creek were present at the Stiles Mill, Providence and Champion Mines in the Nevada City area. Tailings from historic sulphuret works, a secondary process used in the late 1800s which produces waste extremely high in arsenic and lead, is also present in several areas of the watershed including two abandoned facilities in the Gold Run tributary drainage. Sulphuret tailings have a distinct purplish or maroon color, the infamous "purple dirt" which has negatively impacted some local real estate developments.

Although hard rock mines and mine prospects are located throughout the watershed, the greatest concentration and largest mines were generally in the areas within a few miles upstream or downstream of Nevada City and in tributary drainages such as Little Deer Creek, Gold Run and Woods Ravine.

Dams and Diversions

Three regulated dams and several small water diversion dams now create barriers to downstream sediment transport in Deer Creek. Scotts Flat Dam, Deer Creek Diversion Dam (Lower Scotts Flat Lake) and Anthony House Dam (Lake Wildwood) were constructed after or near the end of the mining era (**Table 3.1**).

Dam	Location	Owner	Year Built	Height (ft)
Deer Creek Dam (Lower Scotts Flat)	River Mile 21.5	NID	1928	92
Scotts Flat Dam	River Mile 23	NID	1948 Raised 1964	175
Anthony House Dam (Lake Wildwood)	River Mile 4.25	Lake Wildwood Association	1970	75

Table 3.1: Large Dams on Deer Creek

Deer Creek Diversion Dam located at river mile 21.5 impounds Lower Scotts Flat Reservoir. Construction of the dam was completed in 1928. The reservoir has a normal surface area of 56 acres. It is owned by NID and is used for irrigation purposes. The dam is a concrete arch, with a height of 92 ft and length of 334 ft. The spillway elevation is 2904 ft msl. Normal storage is 1,400 acre ft. From its completion in 1928 until the construction of Scotts Flat Dam in 1948, Deer Creek Diversion Dam trapped sediment from upstream hydraulic mining debris and natural sediment transport. Much of the storage capacity of the reservoir is filled with sediment from upstream sources.

Scotts Flat Dam is a rock fill dam located 1.5 miles upstream of Deer Creek Diversion Dam at river mile 23. The dam was completed in 1948 and was raised to a height of 175 ft high in 1964. It now has a normal surface area of 725 acres (1.1 square miles). Since its construction approximately 64 years after hydraulic mining ended, Scotts Flat Dam has trapped upstream hydraulic mining debris and continues to prevent downstream migration of sediment. The size of Scotts Flat Lake ensures the lake will continue to capture sediment for many decades or even centuries.

Anthony House Dam, which impounds Lake Wildwood, is a rock fill dam 75 ft in height, which was completed in 1970. It is located 17.6 miles below Deer Creek Diversion Dam and 4.25 miles upstream of Deer Creek's confluence with the Lower Yuba River. Since its construction approximately 86 years after hydraulic mining ended, Anthony House Dam has captured hydraulic mining debris from areas below Deer Creek Diversion Dam and currently stops downstream migration of sediment. Lake Wildwood has a relatively small sediment storage capacity and the lake is periodically dredged to prevent it from filling. The average volume excavated each year between 1986 and 2002 is 12,300 cubic yards (yd^3). The dredged sediment has been removed from downstream migration and used outside the drainage as fill. Dredging has stopped in recent years, in part due to environmental concerns.

Several minor diversion dams in the drainage have trapped minor quantities of sediment but are for the most part filled, with sediment now passing downstream.

Deforestation, Road Building and Urbanization

Deforestation, Road Building and Urbanization have also drastically changed the landscape of the Deer Creek watershed. Hard rock mining operations required huge volumes of cord wood to fire steam generators and stamp mills. Additional wood was used to shore the extensive network of mine shafts running tens of miles in length and extending thousands of ft underground. Although much of the watershed is now forested with tall late growth pines and oaks, historic photographs of the Grass Valley/Nevada City area in the late 1800s show bare hillsides with very few trees. The miners cut down all of the old growth trees. Regrowth has changed the forest composition favoring conifers such as Ponderosa Pines in the upper portion of the watershed. Pre-mining times had more forest diversity, with more oaks and other favored food-bearing trees such as hazelnuts. Stands of favored trees were enhanced by the use of fire by the native Nisenan.

Road building was an integral element of mining, especially around the larger-scale hard rock mines in the Nevada City area. Mine waste was often used as fill and aggregate during road building, unknowingly spreading mining toxins far beyond the mined areas and into Deer Creek tributary creeks. Huge volumes of mine waste were used during construction of the Golden Center Freeway through Nevada City and Grass Valley in the late 1960s and early 1970s. Although this mine waste fill is capped by asphalt paving, soluble metals could potentially be leaching into groundwater and ultimately the creeks. Urbanization, parking lots and paved roads increase runoff rates and decrease the proportion of rainwater infiltrating to groundwater, reducing groundwater flows to the creek during the summer months.

F. Sediment Transport in the Deer Creek Watershed

circa 1908

From a sediment transport standpoint, the Deer Creek watershed can now be separated into four large-scale geomorphic stream segments:

1. Headwaters to Scotts Flat Lake
2. Scotts Flat Lake to Deer Creek Diversion Dam
3. Deer Creek Diversion Dam to Lake Wildwood
4. Lake Wildwood to Lower Yuba Confluence

Stream Segment 1: Headwaters to Scotts Flat Lake

The headwaters area of the north and south forks of Deer Creek has been logged several times and much of the area is currently vegetated by relatively dense underbrush in need of clearing. Although this has little immediate effect on erosion, the threat of catastrophic fire could result in periods of bare soil susceptible to extreme erosion, which would send topsoil into the drainages. Catastrophic fires burn everything in their path, whereas controlled burns burn only underbrush, sparing the older trees. Logging roads, if not properly constructed, also increase erosion of fine-grained sediments.

The south fork of Deer Creek is affected by a major NID diversion, which sends significantly greater flow of cold Yuba River water down Deer Creek to be diverted at various ditches further downstream during the summer and fall months when normal flows are lower. This would tend to increase sediment transport rates and bank erosion in these areas by lengthening the period of moderate flow through the summer and fall months when natural flows are typically low.

The remaining impacts of hydraulic mining in areas upstream of Scotts Flat Lake are primarily erosional. Most of the sediment has been washed down into the lake where it is now trapped behind Scotts Flat or Deer Creek Diversion Dam.

Stream segment 1 has significant potential for effective restoration because conditions are closest to pre-mining times. Restoration activities could include manual thinning of underbrush or even small-scale use of fire to clear underbrush and promote biodiversity in the forest understory. Problem trails in the headwater area should be rerouted out of the creek vicinity and headwater springs should be protected.

Stream segment 2: Scotts Flat Lake to Deer Creek Diversion Dam

Little sediment now reaches Lower Scotts Flat Lake due to the proximity to the upstream Scotts Flat Dam. Due to the large volume of Scotts Flat Lake and the relatively small upstream drainage area where most of the loose mine waste has already eroded, sediment accumulation in Scotts Flat Lake is not likely to fill the lake or necessitate dredging for many decades. Thus restoration opportunities in Stream Segment 2 are limited. Scotts Flat Lake and Lower Scotts Flat Lake are integral parts of the NID water distribution system and thus, for political reasons, the dams are unlikely to be removed regardless of the potential ecological benefits.

Stream Segment 3: Deer Creek Diversion Dam to Lake Wildwood

This is the longest geomorphic segment in the watershed with the most variability in sediment distribution and transport conditions. Stream Segment 3 also includes the most accessible areas of the watershed, particularly in the vicinity of Nevada City, and has been the subject of the most assessment.

The sediment in the Deer Creek drainage downstream of the Deer Creek Diversion Dam is depleted in finer grained sediment and consists mostly of gravel, cobbles and boulders with areas scoured to bedrock. Moving downstream, the creek enters the hydraulically mines areas upstream and downstream of Nevada City. The upper portions of this section are mainly scoured to bedrock and large boulders, visible from the Pine Street Bridge in Nevada City. The granitic bedrock and boulders have been sculpted and polished by the scouring action of huge volumes of gravel.

The first significant downstream accumulation of hydraulic mining debris remaining in the streambed begins one to two miles downstream of Nevada City where the gradient becomes less steep. Gravel terraces line both stream banks and are perched above the high water line. These terraces are remnants from the late 1800s and early 1900s when the entire stream channel was buried beneath 20 ft or more of hydraulic mine waste. Hard rock mine waste has entered the stream here from large-scale mines including the Providence and Champion Mines. Visual inspection of the sediment reveals angular hard rock mine waste mixed with the more rounded hydraulic gravels and cobbles. At Stocking Flat, two miles downstream of Nevada City, the stream gradient flattens further and widens to a broad gravel bar. Remnant gravel terraces stand 15 ft above the downstream end of Stocking Flat, indicating the sediment supply in this area remains large, with continuing downstream impacts.

Downstream of Stocking Flat, sediment is accumulated or depleted depending on the steepness of the stream gradient. Areas with very steep gradients, such as the vicinity of Deer Creek Falls, are generally bedrock reaches polished to a slippery sheen with very little sediment accumulation.

Intermittent gravel bars and occasional terraces extend downstream to Lake Wildwood. However, most of the sediment entering Lake Wildwood is in the sand and silt size range with a relatively small volume of gravel and cobbles. Sediment composition may be influenced by flow, with the larger gravel and cobbles only transported during floods and extremely high storm water flow events.

Stream Segment 3 presents many restoration opportunities due to the accessibility and visibility of this segment, particularly around Nevada City where several active watershed groups are headquartered.

Future restoration projects under consideration in this segment include mapping, characterization and stabilization of mine waste to reduce erosion into the stream channel, and restoration of channel morphology.

Stream Segment 4: Lake Wildwood to Yuba Confluence

This stream segment includes Lake Wildwood, the most recently dammed and smallest volume reservoir in the watershed. Lake Wildwood has a relatively small sediment storage capacity and would fill with sediment in several decades if not regularly dredged.

The lowest four miles of Deer Creek below Anthony House Dam and the confluence with the Lower Yuba River is the most impacted segment of the watershed. It is also the least visited, being mostly surrounded by private land and crossed by only one road, Mooney Flat Road. This segment is extremely scoured and sediment starved due to sediment trapping in Lake Wildwood. Due to the relatively steep gradient, most of this segment has been scoured to bedrock during periods of high flow over the dam. Many of the smaller gravels and fines in the lowermost portion of the stream segment, within a quarter mile upstream of the confluence, have been eroded in recent years, leaving cobbles and boulders which armor the underlying gravel.

Fall run Chinook salmon are known to have spawned in the lower portion of this segment in recent years. However, gravel depletion is seriously impacting spawning habitat. The very steep gradient below Mooney Flat Road, including several waterfalls of 10 to 20 ft or more, now prevent salmon passage beyond these falls. However, according to native oral history, old growth log dams or "races" may have allowed salmon passage beyond the currently impassible falls before mining sediments completely altered the stream morphology. The remaining gravel beds in the downstream-most section of Deer Creek currently represent the largest possible extent of salmon spawning grounds in the Yuba River system, along with the adjacent one-mile section of the Yuba River main stem downstream of Englebright Dam.

Summer flows in Deer Creek below Lake Wildwood are very low since most of the water is diverted above the lake by NID for irrigation purposes. Treated effluent from the Lake Wildwood Waste Water Treatment Plant provides a significant percentage of the baseline summer flow.

Stream Segment 4 has the highest need for restoration activities. Restoration projects currently in progress or under consideration include gravel augmentation to improve riparian habitat and create more potential salmon spawning beds, and summer flow enhancement, possibly through an agreement between Lake Wildwood Association and NID. This could be facilitated by a settlement agreement through the ongoing FERC relicensing process. Although Anthony House Dam is not a federally licensed dam (and thus is not specifically part of the FERC process), a settlement agreement could be reached to offset impacts in other areas.

G. Recommendations

Recommended restoration actions are focused on remediation of impacts from Deer Creek's mining history.

- **Create inventory of historic mine sites**
  The existing inventory of mine sites should be expanded using additional map research to include all historic mine sites within 500 ft of Deer Creek and its tributaries, with a particular focus on sites in the vicinity of recreational trails. The resulting base map will be used for fieldwork.

- **Conduct field mapping**
  The base map should be used to assess each mine site in the vicinity of the creek, identifying which sites have mine waste in contact with or in close proximity to Deer Creek drainage course or trail alignment. The mine site data should be characterized in a manner consistent with existing inventories in use by agencies such as USFS.

SYRCL's Yuba Stewards Mine Assessment Worksheet could be used as a template for this purpose.

- **Conduct sampling and analysis**
  Samples of mine waste should be collected where it is found to be in contact with or in close proximity to streams or recreational trails, along with any mine drainage. Initial samples should be analyzed for total mercury, arsenic and lead, based on findings of prior sampling efforts focused on mine waste in the Deer Creek watershed.

- **Conduct data evaluation and site prioritization**
  Field data should be reviewed to prioritize sites by amount of mine waste in contact with the creek or trail, levels of mine toxins, potential impacts to stream channel morphology, environmental impacts to stream, and potential human health impacts from mine toxins. Additional sampling and analysis (such as Cam 17 Metals, Acid Generating Potential, metal solubility) may be required to improve the characterization of potentially high impact sites.

- **Implement mine waste removal and stabilization projects**
  High impact mine waste sites should be remediated at the point of contact with the stream or trail. Methods to minimize contact between mine waste and the stream or trail may include bank stabilization, phytoremediation, excavation and removal or other appropriate remediation techniques. Providence Mine and Stiles Mill Brownfields sites, on city-owned land in Nevada City, are already characterized, with cleanup implementation beginning in the spring of 2011. These sites were identified as high priority for remediation based on planned recreational reuse. The US EPA Brownfields program funds implementation. Because US EPA Brownfields projects prioritize human health, other partnering projects can focus on bank stabilization and reduction of environmental impacts.

Chapter IV: Understanding the Hydrology of the Deer Creek Watershed

FODC/SSI

A. Introduction

The climate, geography and geology largely determine the natural hydrology of the Deer Creek watershed. The Deer Creek watershed is located in northern California, northeast of Sacramento in the foothills of the Sierra Nevada Mountains. The watershed ranges from 5,000 ft at the highest elevations to approximately 300 ft at Deer Creek's confluence with the Yuba River. The watershed is subject to a Mediterranean climate, with a distinct cool wet season (November-May) and warm dry season (June-October). Precipitation is greatest from November through May (**Figure 4.1**), with an annual average precipitation of 58 inches in Nevada City from 1967 – 2004 (**Figure 4.2**). The higher elevations (>3,000 ft) of the watershed receive an average of 60 inches of precipitation annually, with 45 – 50 inches in the middle elevations (1,500 – 3,000 ft), and 40 – 45 inches in the lower elevations (<1,500 ft) of the watershed. Each year a portion of the precipitation falls as snow, typically above 2500 ft. The hydrograph is dominated by rainfall and occasional rain on snow or snowmelt events (see **Figure 4.3**).

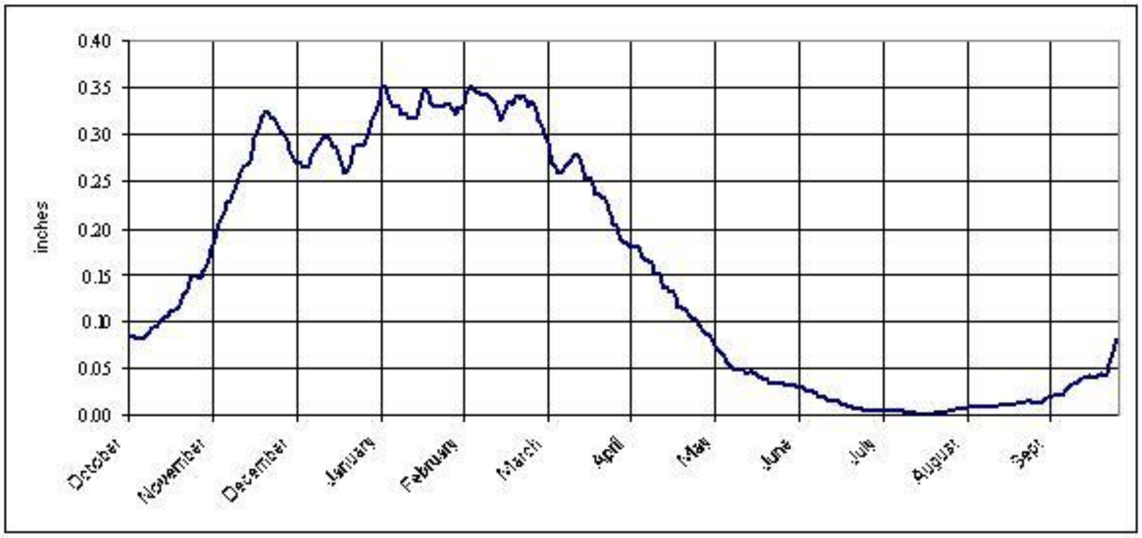

Figure 4.1: Nevada City Average Daily Precipitation, 1967 to 2004.

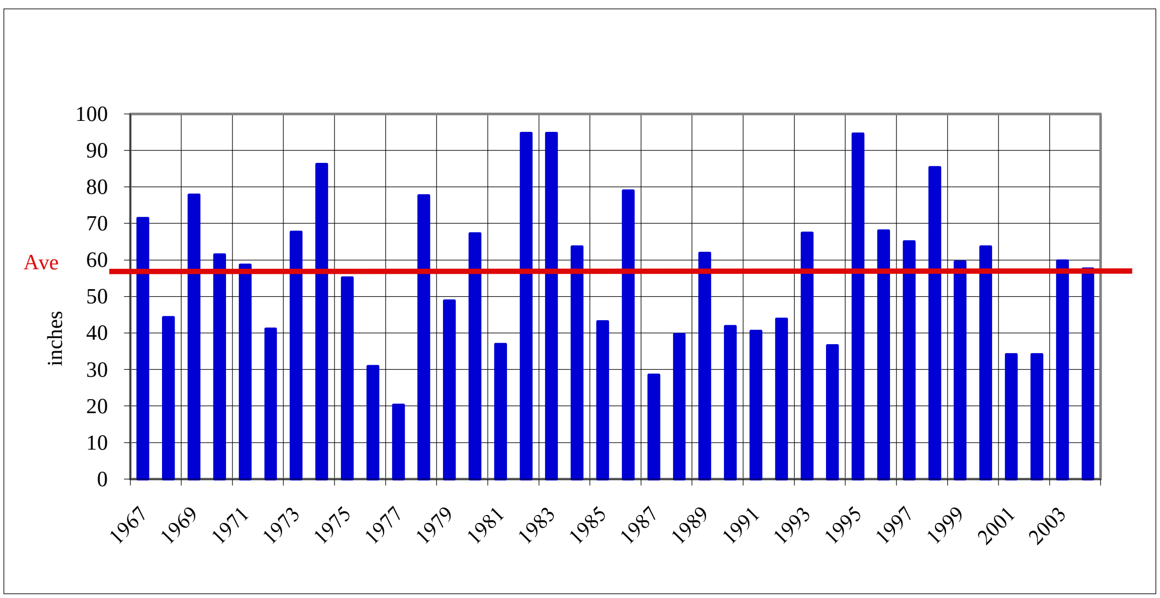

Figure 4.2: Annual Nevada City precipitation, calendar years 1967 – 2004. Red line is the average for the period of record.

Storms that cause rain to fall on snow typically generate the highest flows each year. **Figure 4.3** shows the highest daily mean flow in the Deer Creek watershed for water year 2002, of 1,050 cfs on February 20, 2002, when 2.3 inches of rain fell on several inches of snow that had accumulated in the upper watershed above 3500 ft elevation. In addition to rain on snow precipitation events, the highest flows often occur after Scotts Flat reservoir fills and begins to spill into Deer Creek. Once the reservoir begins to spill, surface water is allowed to flow through the watershed in a manner that more closely resembles the natural flow regime.

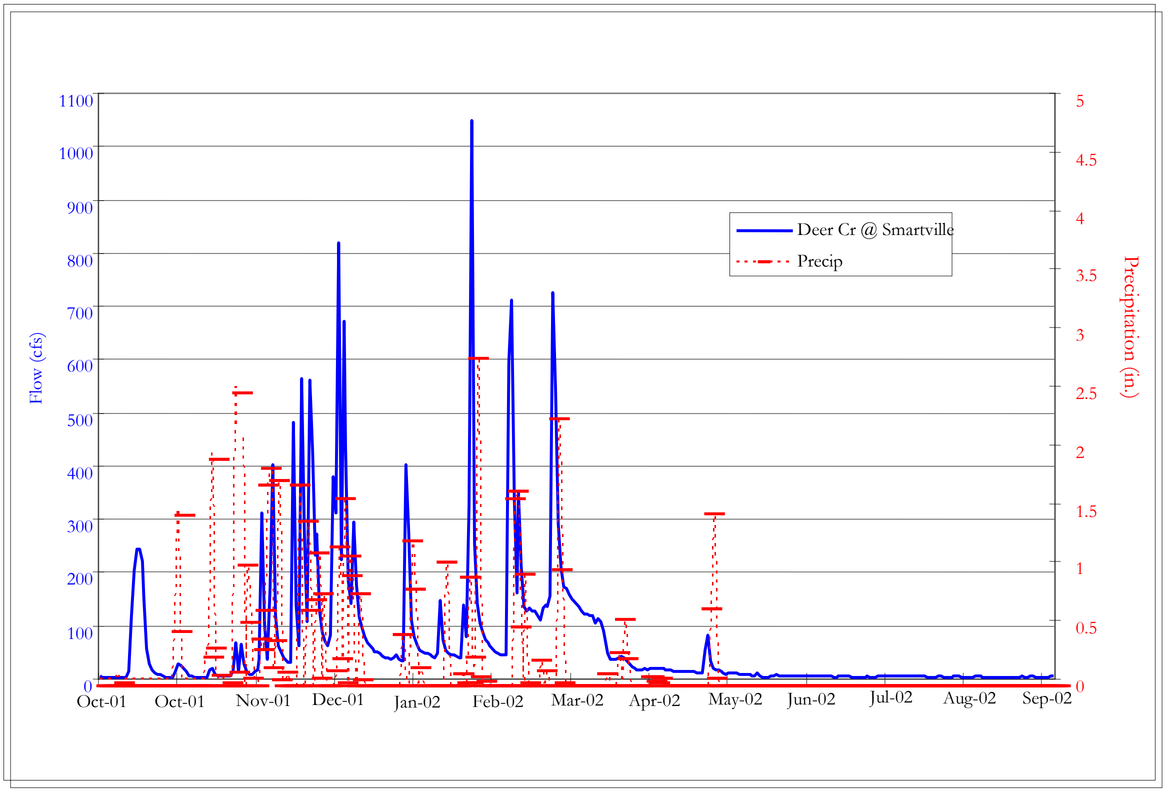

Figure 4.3: Water Year 2002 precipitation at Nevada City (right axis) and Deer Creek stream flow at Smartsville (left axis; USGS #11418500, daily mean discharge).

B. Stream Flow Gauges

Justin Wood

Flow gauging capacity in the watershed derives from NID, USGS, and Sierra Water Trust equipment, as follows:

NID Stream Flow Gauges

Nevada Irrigation District estimates natural flow into Scotts Flat reservoir by monitoring reservoir storage levels, volume of imported water from the South Yuba River, and water deliveries from Scotts Flat reservoir. Estimates are made on a daily basis, with monthly average flow estimates shown in **Figure 4.4**. Inflows to Scotts Flat reservoir (**Figure 4.4**) follow a similar trend to the Nevada City average daily precipitation plot (**Figure 4.1**), with the one exception being that snowmelt drives inflow during the low precipitation months of May, June, and July.

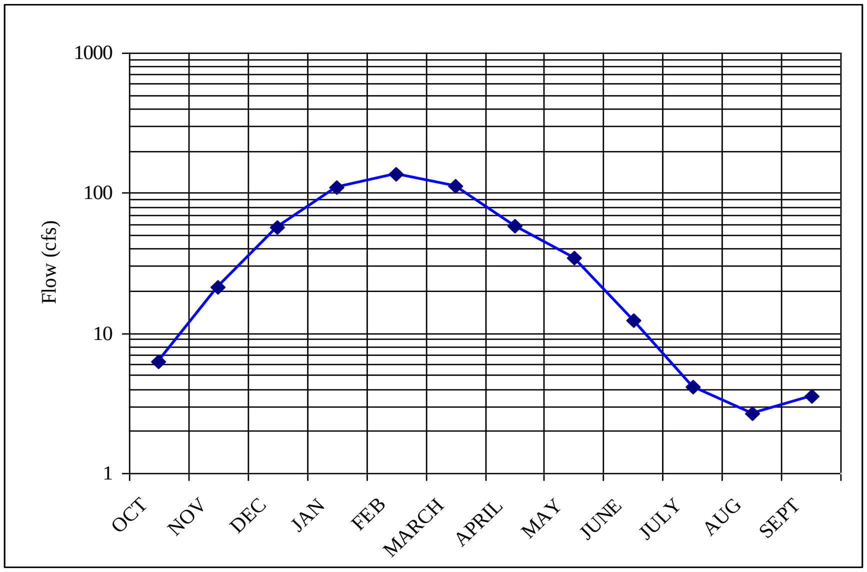

Figure 4.4: Average monthly natural stream flow into Scotts Flat reservoir (NID data, 1984-2004).

USGS Stream Flow Gauges

The United States Geological Survey (USGS) operates a long-term stream flow gauging station in the Deer Creek watershed, located on the main stem of Deer Creek at river mile 0.9, downstream of all three dams (see **Figure 4.5**). The period of record for the Deer Creek and other USGS gauge data used in this report is shown in **Table 4.1**.

Gauge Number	Gauge Location (River Mile)	Period of Record
USGS 11418500	Deer Creek near Smartsville (RM 0.9)	10/1/1935* – present
USGS 11409300	Oregon Creek near Camptonville (RM 5.5)	10/1/1967 – 4/21/2001

Table 4.1: Stream flow gauges and periods of record

****This chapter includes an estimated peak flow discharge outside of the period of record, for March 1928, based on high water marks.***

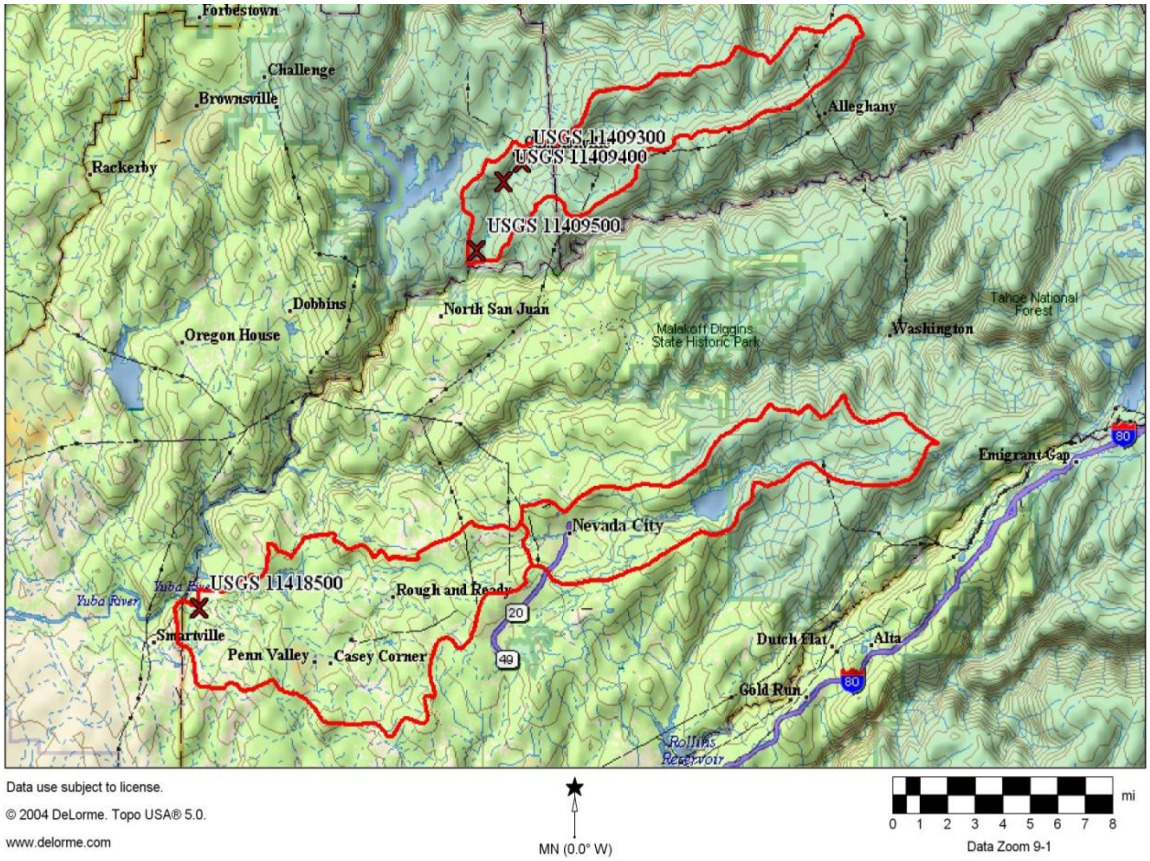

Figure 4.5: Locations of USGS stream flow gauges (marked with red Xs) on Deer Creek and Oregon Creek. There are three gauges on Oregon Creek and one on Deer Creek.

Sierra Water Trust Gauging Stations

In November 2010 as part of the Sierra Water Trust project, FODC and American Rivers worked to install seven additional stream flow gauging stations in the Deer Creek watershed (**Figure 4.6**). Gauging stations target major tributaries in the watershed and several locations on the main stem of Deer Creek that are in close proximity to NID diversion points. Major tributaries where gauging stations were installed were, from upstream to downstream in the watershed, Willow Valley Creek at Willow Valley Road, Little Deer Creek at Nimrod Street, Gold Run Creek at Flume's End, and Squirrel Creek at Pleasant Valley Road. Gauging stations on the main stem of Deer Creek are located in Nevada City at Nevada Street, at the Bitney Springs Road bridge over Deer Creek, and the Lake Wildwood reservoir spillway.

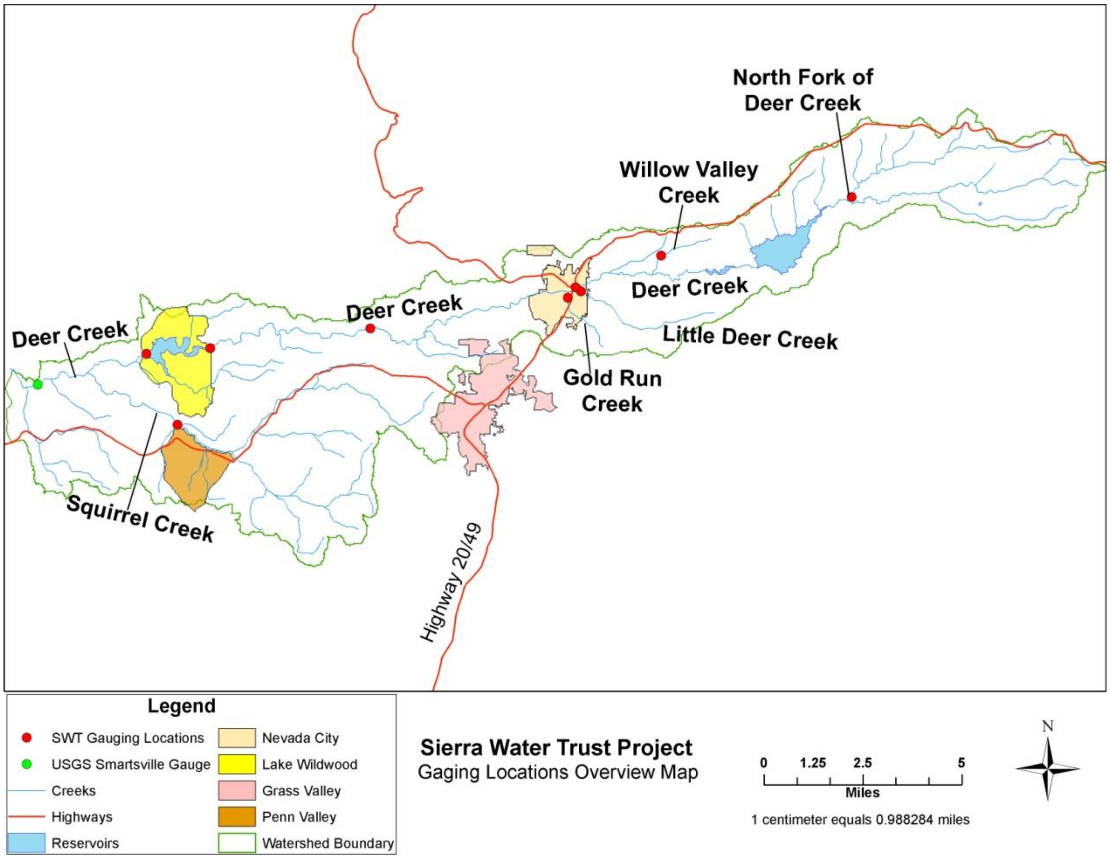

Figure 4.6: Sierra Water Trust gauging station locations.

Additional gauging infrastructure was purchased in 2010 and will be installed in 2011, after the winter storm season ends, snow in the upper watershed melts, and stream flows are lower. These additional gauges will be located on the North Fork of Deer Creek upstream of Scotts Flat reservoir and at the Lake Wildwood Reservoir inlet. Gauging the North Fork of Deer Creek will allow for comparison of stream flows with the regulated South Fork of Deer Creek, and provide data for natural flows in the upper watershed. The increase in stream flow gauging capacity will provide an important set of data for monitoring and assessments, investigating climate change impacts, and formulating restoration and management plans.

C. Methods and Results

Matt Freitas

Hydrologic regimes play a significant role in determining the biotic composition, structure and function of aquatic and riparian ecosystems (Richter et al. 1996). Intra-annual variation in flows is essential to lifecycle success of many aquatic and riparian organisms because it influences reproductive success, natural disturbance and biotic competition (Poff and Ward 1990). Modification of hydrologic regimes can indirectly alter the composition, structure and function of aquatic and riparian ecosystems by changing the physical habitat characteristics such as water temperature, oxygen content, water chemistry and substrate particle size (National Research Council 1992; Sparks 1992). To better understand the hydrologic dynamics of Deer Creek, field assessments and desktop analysis were performed. Understanding the hydrology of Deer Creek is important because hydrologic regimes have a significant influence on the biotic structure, composition, and function of aquatic and riparian ecosystems (Richter et al. 1996). Knowledge of the variations in Deer Creek's flow regime and how the natural hydrologic regime has been altered is critical to the formulation of successful restoration and management recommendations.

Natural flows, prior to reservoir development and water management, were estimated for specific locations in the watershed using a variety of methods. USGS stream flow data for Deer and Oregon Creeks were analyzed to investigate modifications to Deer Creek's hydrologic regime. There are no diversions or dams on Oregon Creek upstream of USGS gauge #11409300, where a natural flow regime is present. In addition, Oregon Creek has a similar watershed size, orientation, climate, elevation, vegetation, and topography as the upper Deer Creek watershed, which allows Oregon Creek to serve as a proxy for estimating flows in the upper Deer Creek watershed. The focus of the analyses was primarily on the five fundamental characteristics exhibited by hydrologic regimes. The following are some examples of how these five characteristics can influence the environment:

Magnitude of flows – can determine the availability and suitability of habitat;
Timing of flows – can determine the life-cycle success or degree of stress or mortality on aquatic and riparian organisms;
Frequency of flow events – can affect population dynamics by influencing reproduction or mortality events;
Duration of flow conditions – may determine whether a certain life-cycle can be completed or the degree to which stressful effects such as inundation or desiccation accumulate;
Rate of change of flows – can affect the stranding of certain organisms or the ability of plant roots to maintain contact with water in soils.

Chinook salmon runs provide a perfect example of how these characteristics influence the Deer Creek watershed. Chinook salmon runs are influenced by the timing and magnitude of flows. The magnitude, duration, and rate of change of flows are important for potential stranding of Chinook salmon and redds, with stranding of salmon redds observed on Deer Creek in association with the Lake Wildwood reservoir drawdown release. The frequency, timing, and magnitude of peak flows can influence success of spawning as large floods can initiate considerable bedload sediment transport, potentially causing mortality to salmon redds and altering population dynamics.

Deer Creek Predicted Natural Flows Methods

The goal of this analysis was to use a variety of methods, combining fieldwork and desktop analysis, to predict or estimate natural stream flows in the Deer Creek watershed for comparison with current flows. The analysis focused on the magnitude and frequency of peak stream flows under current conditions, and under hypothetical conditions unaffected by dams, diversions, and reservoirs. Fieldwork consisted of conducting longitudinal and cross section surveys, measuring stream flows, and documenting channel and water conditions on six tributaries to Deer Creek. Each of the tributaries except Woods Ravine flows into Deer Creek in the Nevada City area between Scotts Flat Reservoir and the wastewater treatment plant (WWTP). Wood Ravine flows into Deer Creek just downstream of the WWTP. **Figure 4.7** shows the location of five of these tributaries. The water surface slope was obtained from the longitudinal profile surveys, and was used to calculate discharge. During each longitudinal profile survey the channel was walked, and channel characteristics were observed and recorded. For each tributary, cross sections were surveyed, and at each cross section the water depth and velocity were measured with a flow meter and recorded. Additional fieldwork included measurements of active channel width at multiple locations on main stem Deer Creek and one location on Squirrel Creek.

In addition to fieldwork, stream flow data from NID and the USGS were analyzed for Deer and Oregon Creeks, to estimate natural and current flows on the main stem of Deer Creek. A flood frequency analysis was performed on NID data related to occurrences of uncontrolled spill and controlled discharges from the Scotts Flat reservoir complex (NID 2005) to determine the magnitude and frequency of annual peak flows released from Scotts Flat reservoir. To determine the degree to which reservoirs and water management operations have altered flood flows, several methods were used to estimate the magnitude and frequency of flows that would be expected without dams on Deer Creek. Below is a summary of the methods used in the flood frequency analysis, with a map of the locations in the Deer Creek watershed provided in **Figure 4.7**.

Method 1: Analysis of NID estimates of Deer Creek flows into Scotts Flat reservoir and data on uncontrolled spill and controlled releases from Scotts Flat.

Method 2: Flow estimates based on equations of Waananen and Crippen (1977) that predict flows based on watershed area, elevation, and average annual rainfall.

Method 3: Equations of Hedman and W.R. Osterkamp (1982) that predict flows based on the size of a stream's active channel.

Method 4: Estimates of runoff per watershed area based on surveys of the key tributaries and application of equations that relate channel geometry and area to estimated flood flows, e.g. the "Mannings equation" (Limerinos 1970; Hedman and Osterkamp 1982).

Method 5: Analysis of USGS gauge records for Oregon Creek, a watershed with similar characteristics to upper Deer Creek, used as a proxy for unimpaired Deer Creek flows.

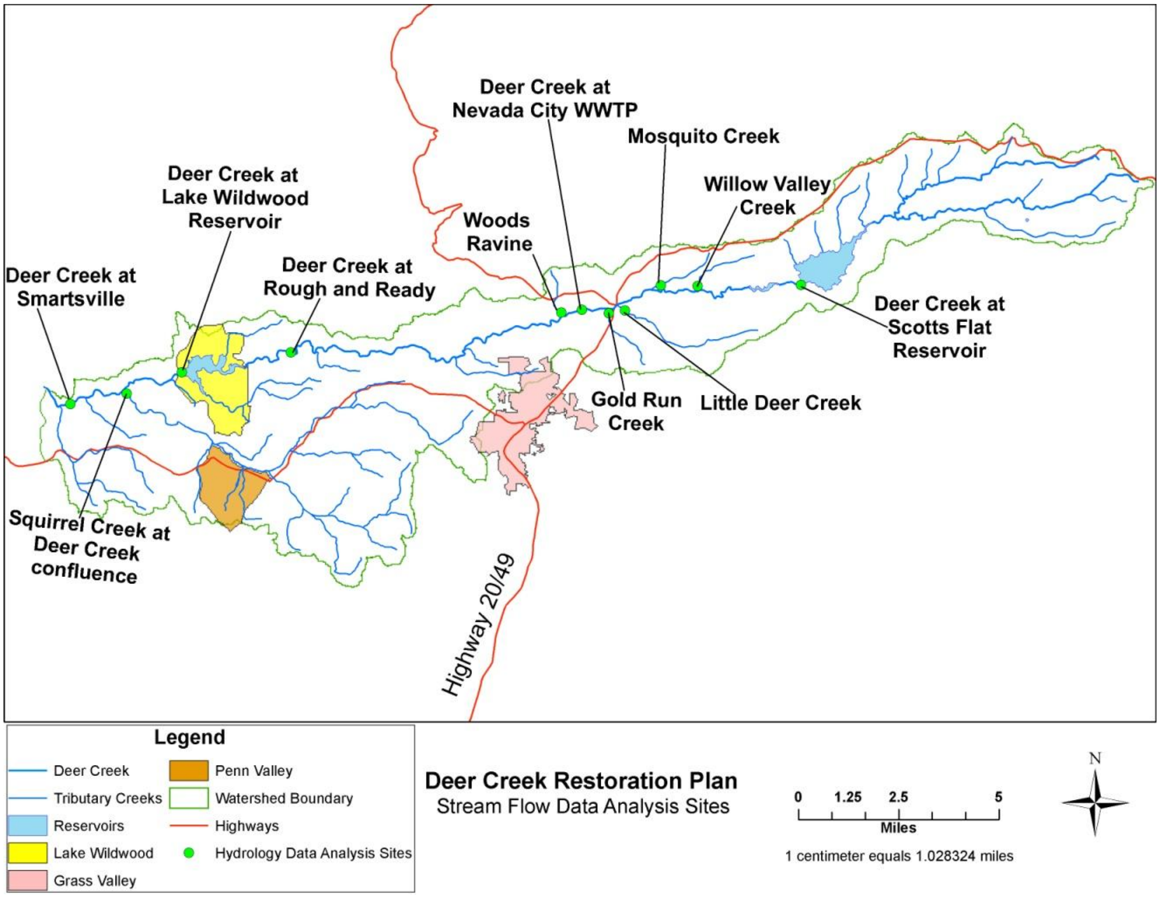

Figure 4.7: Map showing the locations at which natural high flows were predicted in the Deer Creek watershed. Note: Eagle Ravine tributary is not shown.

Deer Creek Predicted Natural High Flows Results and Discussion

Results of methods 2-5 are shown in **Tables 4.2** and **4.3** and detail the predicted natural peak flows for common hydrologic return intervals. A 2-yr flow (Q2) event is a flow of a magnitude that is statistically expected to occur once every two years, and a 5-yr flow (Q5) would be expected to occur once every five years, on average, and so on up to the 100-yr (Q100) event.

Location	Method/Source	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
Predicted peak flow at Scotts Flat (area = 20.8 mi^2)	Average of Methods 2, 3, and 5	930	1,802	2,391	3,367	4,076	5,033
Predicted peak flows at Nevada City WWTP (area = 32 mi^2)	Average of Methods 2, 3, 4, and 5	1,241	2,433	3,239	4,633	5,621	6,999
Predicted peak flows at Rough and Ready (area = 47.3 mi^2)	Average of Methods 2, 3	2,465	4,463	5,703	7,759	8,988	10,618
Predicted peak flows at Lake Wildwood Reservoir (area = 54.5 mi^2)	Average of Methods 2, 3	2,867	5,150	6,548	8,862	10,217	12,015
Predicted peak flows for Squirrel Creek at Deer Creek confluence (area = 24.8 mi^2).	Average of Methods 2, 3	1,405	2,589	3,359	4,653	5,464	6,515
Predicted peak flows for Deer Creek at Smartsville (area = 84.6 mi^2)	Average of Methods 2, 3	4,584	8,021	10,047	13,432	15,313	17,791

Table 4.2: Comparison of peak flows at locations on Deer and Squirrel Creeks.

Estimates are provided for one location on Squirrel Creek at the Deer Creek confluence and five specific locations on Deer Creek: Scotts Flat reservoir, the Nevada City wastewater treatment plant (WWTP), Rough and Ready, Lake Wildwood reservoir, and the USGS Smartsville gauge. The estimates for each method produce results that are within an order of magnitude of each other at each site. As you move downstream, peak flow magnitudes increase as expected.

The sum of discharge for Scotts Flat reservoir and the tributary flows (excluding Woods Ravine) results in greater flow values than for the Nevada City WWTP. Doing a basic mass balance calculation the sum of the Scotts Flat reservoir and tributary flow data accounts for 116.8% of the Nevada City WWTP flow at the Q2, 122.3% at the Q5, 125.6% at the Q10, 127.0% at the Q25, 129.7% at the Q50, and 131.7% at the Q100. These results indicate that further analysis is needed to accurately quantify peak flows at these locations, and that the methods used to calculate flows at these locations should be re-evaluated. Deer Creek discharge at the USGS Smartsville gauge is approximately equal to the sum of flows from Deer Creek at the Lake Wildwood reservoir and Squirrel Creek at the Deer Creek confluence. Doing a basic mass balance calculation, the sum of the Lake Wildwood reservoir and Squirrel Creek at the Deer Creek confluence data accounts for 93.2% of the USGS Smartsville gauge flow at the Q2, 96.5% at the Q5, 98.6% at the Q10, 100.6% at the Q25, 101.9% at the Q50, and 104.2% at the Q100.

Tributary estimates in **Table 4.3** do not exceed the estimates for main stem Deer Creek at the Nevada City WWTP, and estimates for tributaries using two different methods are within an order of magnitude of each other for each tributary (Skrtic 2005). The unimpaired tributaries contribute a significant volume of water to main stem Deer Creek downstream of Scotts Flat reservoir, which helps to mitigate potential impacts associated with water storage in the reservoir. The significance of reduced flood peaks is explored further in the Geomorphology and River Ecology Chapters.

Tributaries	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
Little Deer Creek (area = 3.71 mi²)	153	333	463	694	874	1,132
Gold Run Creek (area = 1.99 mi²)	114	247	345	512	641	822
Willow Valley Creek (area = 1.2 mi²)	59	134	192	291	372	489
Mosquito Creek (area = 1.0 mi²)	85	180	252	371	462	587
Woods Ravine (area = 0.75 mi²)	38	90	129	197	254	337
Eagle Ravine (area = 0.5 mi²)	32	74	107	163	209	275
Total Tributaries (area = 9.15 mi²)	480	1,057	1,486	2,227	2,811	3,641

Table 4.3: Flow estimates for tributaries in the upper Deer Creek watershed (data from Skrtic 2005).

Deer Creek Current High Flows Methods

A frequent application of stream flow records is to predict the magnitude and frequency of annual peak flow and flood events. The magnitude and frequency of annual peak flows were analyzed under current conditions and under hypothetical conditions unaffected by NID reservoirs. To determine the magnitude and frequency of current peak flows in the upper Deer Creek watershed at Scotts Flat reservoir, a flood frequency analysis was performed using NID data related to occurrences of uncontrolled spill and controlled discharges from the Scotts Flat complex (**Table 4.4**) (NID 2005). Flood frequency analysis was conducted using the US Army Corps of Engineers Hydrologic Engineering Center Statistical Software Package (HEC-SSP), following guidelines outlined in Bulletin 17B, "Guidelines for Determining Flood Flow Frequency" (IACWD 1982; USACE 2008). This analysis provides data on current peak flows in upper Deer Creek in reaches near Scotts Flat reservoir, which can be evaluated against the predicted natural flows at Scotts Flat reservoir to determine if reservoir management has impacted the peak flow regime at this location.

To determine the magnitude and frequency of peak flows at the watershed outlet, flood frequency analysis was performed using data from the USGS Smartsville stream gauge on Deer Creek. Data from this gauge describe peak flows leaving the watershed, as this gauge is located at river mile 0.9 on Deer Creek and captures the majority of water flowing out of the watershed. **Table 4.5** provides results of the one period flood frequency analysis using the USGS Smartsville gauge on Deer Creek downstream of Lake Wildwood reservoir, which can be evaluated against the predicted natural flows at the USGS Smartsville gauging station to determine if reservoir management has impacted the peak flow regime at this location. The following is a summary of methods used in the flood frequency analysis of the USGS Smartsville gauge:

- Analysis of USGS gauge records for Deer Creek near the confluence with the Yuba River, using the Weibull plotting method (Dalrymple 1960);
- Analysis of USGS gauge records for Deer Creek near the confluence with the Yuba River, using a modified Weibull plotting method (Cunnane 1978);
- Analysis of USGS gauge records for Deer Creek near the confluence with the Yuba River, using multiple methods available within the HEC-SSP based on Bulletin 17B (IACWD 1982; USACE 2008).

Deer Creek Current High Flows Results and Discussion

The results of the Scotts Flat reservoir flood frequency analysis, using NID data related to occurrences of uncontrolled spill and controlled discharges, are provided in **Table 4.4**. The computed and expected results are in good agreement at the Q2, Q5, Q10, and Q25 peak flows. The results begin to diverge at the Q50 and Q100 flows, with the expected results an order of magnitude or greater than the computed results. This can be attributed to the expected curve analysis attempting to correct for bias in the short period of record. The data used in this analysis were from 1973 – 2007, a thirty-four year period of record. As a longer period of record becomes available it is probable that the computed and expected results will come into better agreement. This analysis is useful for determining what the annual peak flows discharged from Scotts Flat reservoir are, so that these values can be compared against predicted results for the Scotts Flat location, to evaluate whether peak flows are being achieved with the current water management system in place.

Location	Method/Source	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
Releases from Scotts Flat	HEC-SSP-Computed (NID Data)	245	695	1,309	2,758	4,643	7,619
Releases from Scotts Flat	HEC-SSP-Expected (NID Data)	245	718	1,400	3,145	5,658	10,049

Table 4.4: Comparison of annual peak flows at Scotts Flat reservoir, using NID data from 1973-2007.

The results of the Deer Creek USGS gauge flood-frequency analysis are provided in **Table 4.5**. The calculated flow values for each return interval are in good agreement through the 100-year flood flow (Q100) for each method. Above the Q100 the weighted skew option (HEC-SSP 2) diverges from the other methods, resulting in greater Q200 and Q500 flows than from the other analyses. This could be due to the use of the weighted skew in the HEC-SSP 2 analysis, which uses a generalized regional skew to determine flows (USACE 2008). In the seventy-four year period of record, the greatest peak flow was 16,000 cfs on December 31, 2005. This observed peak flow is comparable to the Q100 values derived by each method.

Method	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)	Q200 (cfs)	Q500 (cfs)
Weibull	5,410	7,650	11,030	12,150	14,750	16,300	X	X
Cunnane	5,410	7,640	11,000	11,800	14,100	15,600	X	X
HEC-SSP 1 Computed	5,160	8,072	9,939	12,179	13,750	15,238	16,653	18,426
HEC-SSP 1 Expected	5,160	8,114	10,030	12,363	14,023	15,618	17,151	19,112
HEC-SSP 2 Computed	5,062	8,055	10,107	12,725	14,674	16,612	18,545	21,101
HEC-SSP 2 Expected	5,062	8,100	10,211	12,951	15,027	17,126	19,256	22,138

Table 4.5: Comparison of peak flows at USGS gauge #11418500 on Deer Creek in Smartsville.

The analysis is important because it determines what the magnitude and frequency of annual peak flows on Deer Creek are for the overall period of record. These values can be compared against the predicted natural flows for the Scotts Flat reservoir and USGS Smartsville gauging station location, to determine whether current high flows are within the estimated natural range, or whether water management and reservoir development and other impacts have altered the natural flood regime.

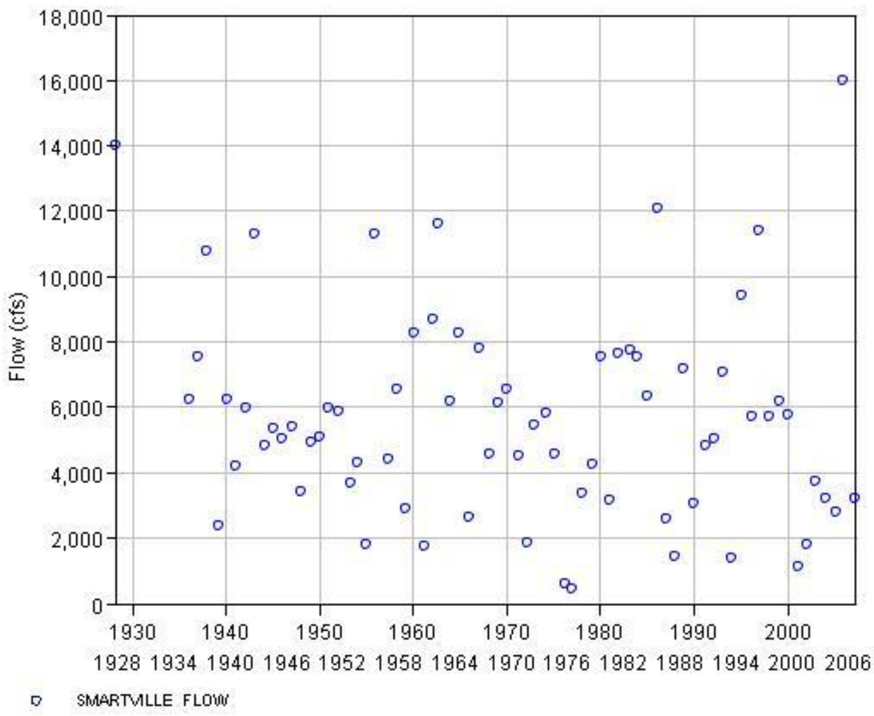

Figure 4.8: Annual peak stream flow data, USGS gauge #11418500 on Deer Creek in Smartsville.

The peak stream flow record at this gauge can be evaluated to determine whether reservoir development has affected the magnitude and frequency of flows on Deer Creek. **Figure 4.8** plots the peak annual stream flow from the beginning of the gauge record and does not provide much insight into whether the magnitude and frequency of Deer Creek flood flows have been impacted by reservoir development. To investigate alterations to the annual peak flow regime further, two analyses were employed:

- Current and predicted annual peak flows were compared for two locations on main stem Deer Creek using the results from the previous sections.
- Two-period flood frequency analysis was conducted from water years 1935-1964 and 1965-2009. These date ranges coincide with the period before and after the change to Deer Creek's base flow, as indicated by the USGS Smartsville gauging station record. In addition, July 1964 was when the major upgrade to Scotts Flat reservoir was completed. The two-period flood frequency analysis is provided in the two-period flood frequency analysis section.

Deer Creek Natural and Current High Flows Discussion

Natural annual peak discharges were predicted for several locations on the main stem of Deer Creek, for comparison with current peak discharges at two locations on Deer Creek.

Comparisons of current and predicted natural peak flows are available for Scotts Flat reservoir and the USGS gauge at Smartsville. **Table 4.6** shows that Scotts Flat reservoir reduces annual peak flows in upper Deer Creek for the 2-yr (Q2), 5-yr (Q5) and 10-yr (Q10) flood events. Current Scotts Flat reservoir releases for the 25-yr (Q25) flow fall within the range of estimates for unaltered natural stream flows at the reservoir's location. The data indicate that the Q50 and Q100 flows are being achieved at the Scotts Flat reservoir location, as is evidenced by the releases from Scotts Flat reservoir for the Q50 and Q100 producing greater peak flows than the predicted natural flows method. This indicates that Q50 and Q100 flows are potentially greater than would be expected in a natural system. It is important to compare the confidence intervals for current annual peak flows against the predicted peak flows at Scotts Flat reservoir, to look for overlap between the confidence intervals and predicted data.

Location	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
Current releases from Scotts Flat reservoir	245	706	1,355	2,952	5,150	8,834
Predicted peak flow at Scotts Flat reservoir	930	1,802	2,391	3,367	4,076	5,033

Table 4.6: Comparison of current and predicted natural annual peak flows for Scotts Flat reservoir.

The confidence intervals (**Table 4.7**) for the current Q2, Q5, and Q10 peak flows at Scotts Flat reservoir do not overlap with the predicted peak flows at the reservoirs location, further indicating that Scotts Flat reservoir has reduced the magnitude and frequency of small flood flows and that releases are outside of the predicted natural range for Q2 – Q10 events. The confidence intervals for current releases from Scotts Flat reservoir overlap with the predicted peak flows for the reservoir's location at the Q25, Q50, and Q100, indicating that current releases are within the predicted natural range for the larger flood events (Q25 – Q100). A larger period of record is needed for analyzing current releases from Scotts Flat reservoir, to increase the accuracy of results for the Q50 and Q100 flows.

Q2 (cfs)		Q5 (cfs)		Q10 (cfs)	
.95 Confidence Limit	.05 Confidence Limit	.95 Confidence Limit	.05 Confidence Limit	.95 Confidence Limit	.05 Confidence Limit
177	336	498	1,042	890	2,177

Q25 (cfs)		Q50 (cfs)		Q100 (cfs)	
.95 Confidence Limit	.05 Confidence Limit	.95 Confidence Limit	.05 Confidence Limit	.95 Confidence Limit	.05 Confidence Limit
1,719	5,313	2,699	9,999	4,129	18,318

Table 4.7: Confidence intervals for releases from Scotts Flat reservoir, for comparison with predicted natural peak flows at Scotts Flat reservoir.

NID generally captures all inflow to Scotts Flat reservoir from approximately mid-October until the reservoir fills completely, which can be as late as March or April in some years (S. Sindt, pers. comm.). Therefore, unless a flow event of significant magnitude occurs after Scotts Flat reservoir has filled, the contribution of flow from the watershed upstream of Scotts Flat (~25% of total watershed area) into Deer Creek is eliminated. The resulting reduction in peak flows would be most pronounced immediately downstream of Scotts Flat reservoir, and would diminish progressively moving downstream as tributaries contribute unimpaired peak flows. To determine that impacts are evident near the watershed outlet, current and predicted natural flows were compared for the USGS gauge at Smartsville, with results provided in **Figure 4.16**.

The data in **Table 4.8** provide a comparison of current and predicted annual peak flows near the Deer Creek watershed outlet, with peak flow magnitudes for return intervals up to Q100. The Q2, Q5, and Q10 natural estimates are in good agreement with the current peak flows using each analysis method, with results within an order of magnitude of each other. This suggests that in this portion of the watershed small floods (Q2 – Q10) are currently occurring as frequently as they would under natural circumstances. At the Q25, Q50, and Q100, natural peak flow estimates are slightly greater than the methods based on the period of record, with the HEC-SSP confidence intervals overlapping with the predicted natural flow estimates. Confidence intervals (not shown) for the Q25, Q50, and Q100 using each HEC-SSP method overlap with the current annual peak flows, indicating that although the current results are slightly less than the predicted values, current flows are potentially within the predicted natural range. This suggests that the current magnitude and frequency of annual peak flow events is potentially less than would have been expected under natural stream flow conditions, but more data and further analysis are needed.

Method	Q2 (cfs)	Q5 (cfs)	Q10 (cfs)	Q25 (cfs)	Q50 (cfs)	Q100 (cfs)
Weibull	5,410	7,650	11,030	12,150	14,750	16,300
Cunnane	5,410	7,640	11,000	11,800	14,100	15,600
HEC-SSP 1 Computed	5,160	8,072	9,939	12,179	13,750	15,238
HEC-SSP 1 Expected	5,160	8,114	10,030	12,363	14,023	15,618
HEC-SSP 2 Computed	5,062	8,055	10,107	12,725	14,674	16,612
HEC-SSP 2 Expected	5,062	8,100	10,211	12,951	15,027	17,126
Deer Creek at Smartsville (area=84.6 mi^2)	4,584	8,021	10,047	13,432	15,313	17,791

Table 4.8: Flood frequency analysis results comparing current and natural discharges at the USGS gauge on Deer Creek.

Overall the predicted natural and current peak flow analysis indicates that alterations to the annual peak flood regime have occurred. On upper Deer Creek (**Table 4.6**) Scotts Flat reservoir reduces peak flows at the Q2, Q5, and Q10, while in lower Deer Creek (**Table 4.8**)

Q2, Q5, and Q10 peak flows are being achieved, due to the contribution of unimpaired flow from numerous perennial tributaries around Nevada City and from Squirrel Creek downstream of Lake Wildwood reservoir. Potential impacts to the Q25, Q50, and Q100 flows at Scotts Flat reservoir and the USGS Smartsville gauge should be investigated further. The results indicate that efforts should be undertaken to restore the magnitude and frequency of peak flood flows in the Deer Creek watershed, focusing on small flood flows (Q2 – Q10) in the upper watershed. Additionally, more data and further analysis is needed, including a longer period of record for both Scotts Flat reservoir and the USGS Smartsville gauge.

Low Flow Analysis Introduction

Low stream flows are the dominant flow condition in most creeks and rivers (Richter et al. 1996). After a rainfall event or snowmelt period has passed and the associated surface runoff has flowed through the catchment, the creek returns to base or low flow level (Richter et al. 1996; TNC 2009). Low flows are sustained by groundwater discharge into the river and by perennial tributaries in a natural system, and potentially by water management activities in a managed system. Seasonal variations in low flow levels impose constraints on a river's aquatic communities as these variations determine the amount of available aquatic habitat for the majority of the year (TNC 2009). The availability of aquatic habitat strongly influences the diversity and number of organisms that can inhabit a reach of creek.

Three methods were used to estimate low flows along sections of main stem Deer Creek. Two methods were used to estimate low flows in upper Deer Creek, and Deer Creek between Scotts Flat and Lake Wildwood reservoirs. The first method employs NID's estimates of natural flows, while the second method uses Oregon Creek flow data as a proxy. The third method, low flow frequency analysis of the USGS Smartsville gauge data, was used to investigate low flows in Deer Creek downstream of Lake Wildwood, at the outlet of the watershed.

Low Flow Analysis Methods and Results

Method 1: Low Flow Analysis of NID Natural Flow Data

Since 1972, NID has estimated the amount of runoff into Scotts Flat reservoir by determining the increase in Scotts Flat reservoir storage that cannot be attributed to imports from the South Yuba River. These estimates are made approximately every day by monitoring the change in storage for Scotts Flat reservoir, the measured volume of transfers into the reservoir from the South Yuba River through the South Yuba Canal, and the releases from the Scotts Flat complex into the D-S Canal and Deer Creek. It is unlikely that this method produces accurate estimates of low flows considering NID data indicate inflows can remain at zero for many days during the summer, then jump up to 5 or 10 cfs for one or two days, before dropping back to zero. These rapid pulses of flow do not correspond to rainfall events and thus these low flow estimates may be prone to substantial error or do not provide a high enough resolution to capture the actual daily flows.

The 30-plus years of data NID has collected suggest that under natural conditions Deer Creek summer low flows at Scotts Flat reservoir would have dropped to under 5 cfs in most years (**Figure 4.9**). Natural summer low flows downstream of Scotts Flat would have been higher than this because of groundwater inputs and stream flow contributions from numerous perennial tributaries including Willow Valley, Mosquito, Little Deer, Gold Run, Woods Ravine, and Slate Creeks. Under current circumstances NID water management influences summer flows downstream of Scotts Flat reservoir, with Deer Creek used as a "canal" to convey water for irrigation.

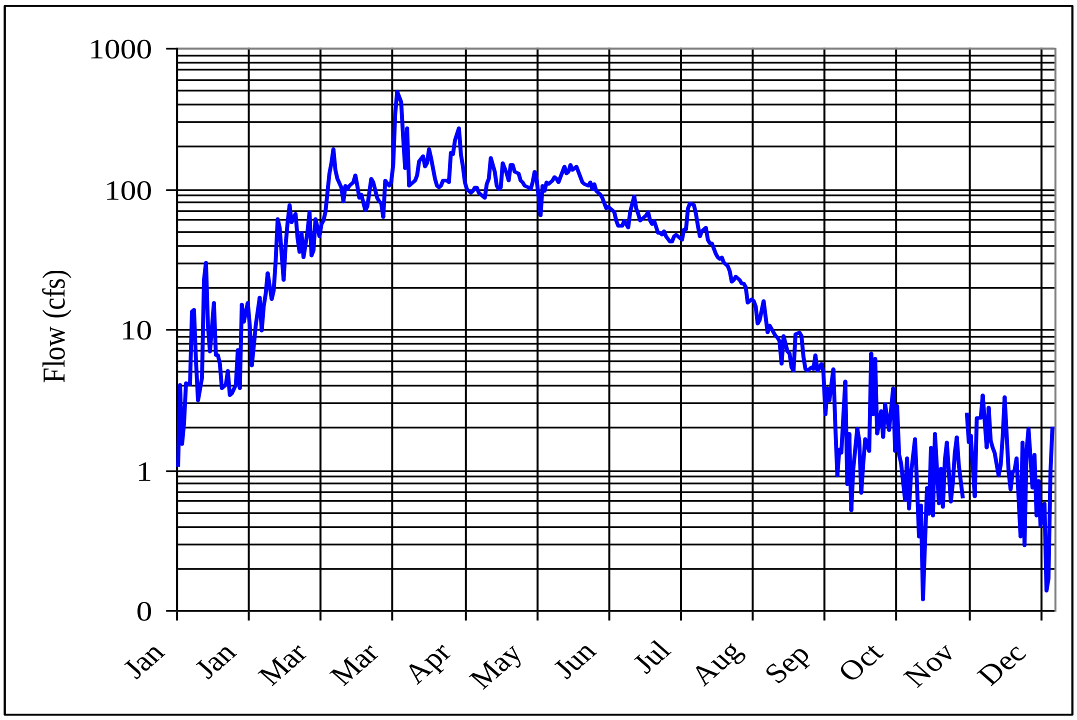

Figure 4.9: 30-year average of NID estimates of natural inflow to Scotts Flat reservoir.

Summer low flows in upper Deer Creek between Scotts Flat and Lake Wildwood reservoirs are artificially high because NID uses the creek to deliver water from Scotts Flat to the Newtown and Tunnel canals, and to Lake Wildwood reservoir to maintain water levels. During the irrigation season (April 15^{th} – October 15^{th}) flows between Scotts Flat reservoir and the Newtown Canal diversion dam (4.5 mi.) are approximately 20 – 30 cfs. Flows from the Newtown Canal diversion to Tunnel Canal diversion dam (~8 mi.) typically do not drop much below 10.0 cfs. At this point NID diverts much of the flow into the Tunnel Canal. Summer flows in the four miles from the Tunnel canal to Lake Wildwood reservoir are approximately 4.0 cfs (S. Sindt, pers. comm.). At Lake Wildwood reservoir irrigation water is diverted into the Keystone Canal, with Lake Wildwood reservoir contracted by NID to pass 1.0 cfs through the reservoir into lower Deer Creek (Lake Wildwood Lake Committee, pers. comm.). There is a water rights requirement for the Lake Wildwood Association of 5.0 cfs or the natural flow, whichever is less, downstream of Lake Wildwood reservoir, but it is unclear whether this requirement is being met or what the natural flow is.

Method 2. Low Flow Analysis of Oregon Creek Flows As A Proxy

Oregon Creek, a tributary to the Middle Yuba River, is similar to the upper, higher elevation portions of the Deer Creek watershed in many respects (e.g. size, shape, orientation, elevation and vegetation). USGS gauge #11409300 captures 23 mi^2 of the Oregon Creek watershed, similar to the 22 mi^2 area upstream of Scotts Flat Reservoir. With many characteristics similar to the upper portions of Deer Creek, Oregon Creek serves as a useful proxy for estimating low flows in the upper quarter of the Deer Creek watershed under natural conditions. One can see that the flows are fairly similar in magnitude and timing, with Oregon Creek exhibiting slightly higher flows from February through September (**Figure 4.10**). Deer Creek appears to experience lower and more variable summer low flows, but NID's method of estimating Deer Creek inflows is less accurate at lower flow levels, and there are more rise and fall changes due to NID water management, which leads to a less smooth hydrograph than Oregon Creek.

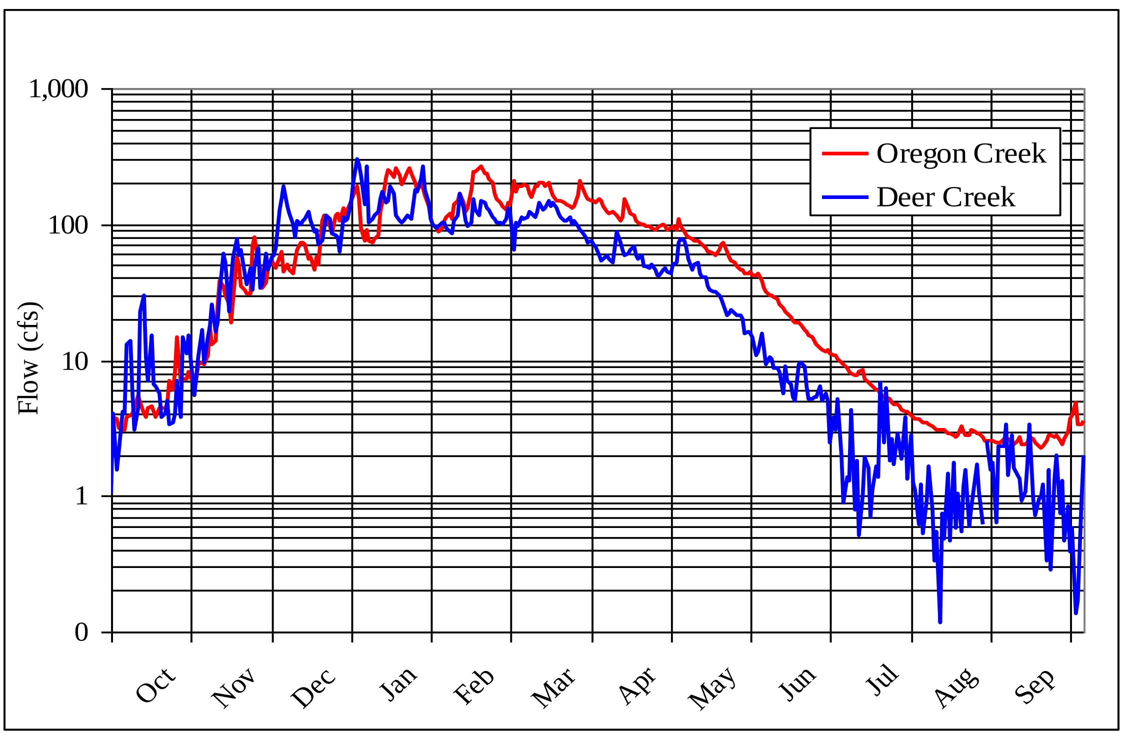

Figure 4.10: Average Daily Flows in Deer Creek (into Scotts Flat) and in Oregon Creek at Camptonville (USGS gauge #11409300, 1967-2001)

Figure 4.11 shows average daily flow levels for Oregon Creek at USGS gauge #11409300 over a 35-year period from 1967 – 2002. The 5th percentile curve represents the lowest 5% of daily flows for each date over the 35-year record, i.e. 95% of flows for each day were greater than those in the 5th percentile curve. The 50th percentile curve is the median flow value for that date over the 35-year period. The 5th percentile and 25th percentile curves can be used as an index of extreme low flow and low flow conditions respectively. The 50th percentile (median) can be used as an index of base flow conditions, the 75th percentile can be used as an index of high flow pulses, and the 95th percentile can be used to investigate high flow peaks.

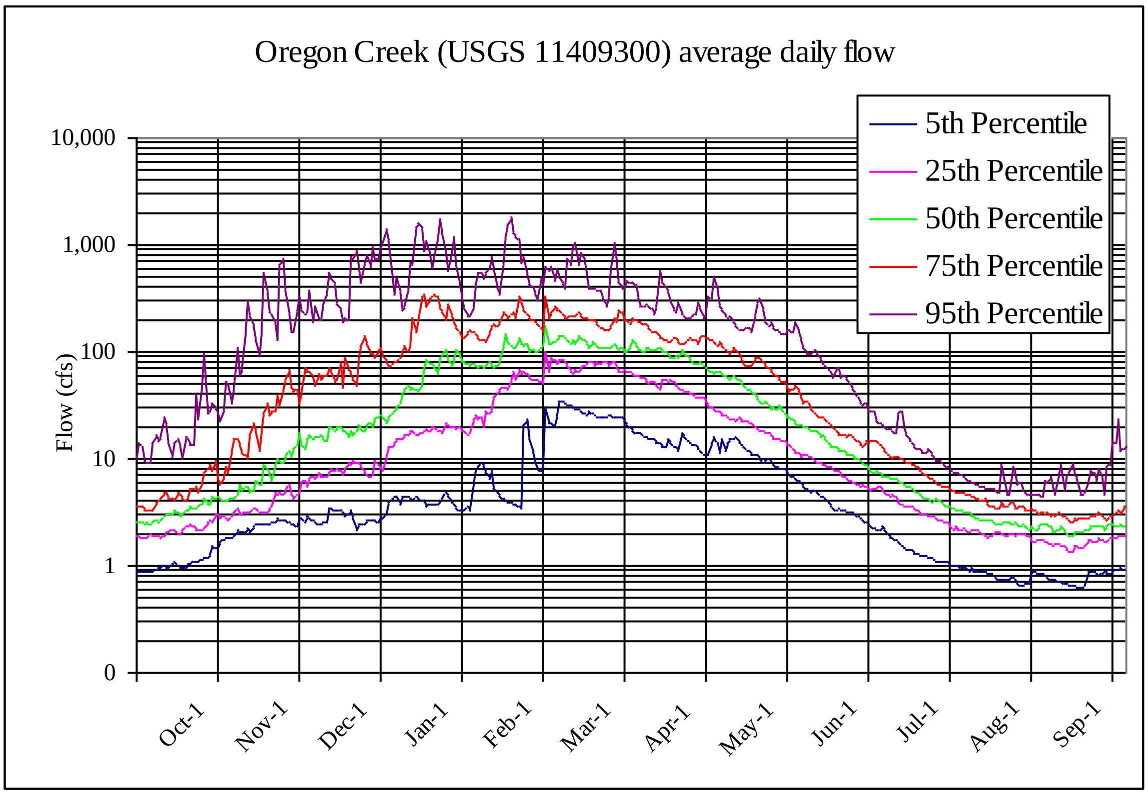

Figure 4.11: Oregon Creek average daily flows at USGS gauge #11409300.

In dry (5th percentile) and below normal (25th percentile) water years, flows in Oregon Creek from August through October fluctuated between 0.5-2 cfs. In average (50th percentile) water years, flows in Oregon Creek from August-October ranged from 2-4 cfs. In above normal (75th percentile) and wet (95th percentile) water years, flows ranged from 3-9 cfs. It seems possible therefore that from August to October, Deer Creek upstream of Scotts Flat would experience flows in the 3-9 cfs range in above normal to wet years, 2-4 cfs range in average years, less than 2 cfs in below normal and dry years, and less than 1 cfs in critically dry years. Considering these data represent percentiles over a 35-year flow record it seems likely that surface flows occasionally reduced to a trickle in Oregon Creek during dry and critical water years. However, it is probable Oregon Creek or Deer Creek would not dry up even in the driest years, unless there were numerous consecutive critically dry years. As you move downstream through the watershed from Scotts Flat reservoir, summer low flows increase due to the contribution of numerous downstream perennial tributaries as well as possible groundwater contributions. No other gauges exist to enable the assessment of low flows on Deer Creek until USGS gauge #11418500, 0.9 miles upstream from the Yuba River, downstream of Lake Wildwood and of the last major tributary Squirrel Creek.

Method 3. Low Flow Frequency Analysis using the Deer Creek USGS Gauge at Smartsville

Low flow frequency analysis was performed using mean daily flow data from the USGS Smartsville gauge on Deer Creek downstream of Lake Wildwood reservoir. Data used in this analysis were from water years 1935 – 2009. For this analysis water year 2005 is defined as 4/1/2004 – 3/31/2005, a period of high flow to high flow, instead of 10/1/2004 – 9/30/2005, a period of low flow to low flow.

The goal of low flow frequency analysis was to estimate the frequency or probability with which a given magnitude of daily stream flow would be less than a certain volume in a given reach (Dingman 2002). This analysis was most applicable to reaches of Deer Creek downstream of Lake Wildwood reservoir. For the low flow frequency analysis the annual minimum flows were averaged over consecutive periods of varied length, referred to as *d*-days or *d*-day averages. One of the most common averaging periods is *d*=7, with analysis often carried out for *d*=1, 3, 7, 15, 30, 60, 90, and 180 days (Dingman 2002; Pyrce 2004). The *d*= 1, 3, 7 day analyses are important for assessing the frequency of low flows over the short term, while the *d*= 15, 30, 60, 90, and 180 day analyses are important for assessing the frequency of low flows over the long term. Short-term flows are important for assessing acute stressors to the aquatic ecosystem, while long term flows are important for evaluating drought conditions and sustained periods of low flow. The 1-day average flow with a return interval of once in every ten years is the 1Q10 flow, the 1-day average flow with a return interval of once in every fifty years is the 1Q50, the 7-day average flow that has a return interval of once in every ten years is the 7Q10, and so on. The 1Q10 and 7Q10 are often used as low-flow design values for protection or regulation of water quality, water supply decisions, chronic criteria for aquatic life, and habitat protection during drought conditions (Dingman 2002; Pyrce 2004).

The low flow analysis employed *d*=1, 3, 7, 15, 30, and 90 day averaging periods, with figures provided for the *d*=1 and *d*=15 analysis, to demonstrate how different *d*-day averages influence the results. Results of the additional *d*-day analyses are provided in the Hydrology Chapter Appendix. The analysis was first conducted on the entire data record, then comparing two periods before and after a change to base flow, to investigate alteration of the hydrologic regime. The analysis using the entire period of record is presented in this section, with the two period low flow frequency analysis presented in the Two Period Stream

Flow Data Analysis section of the Hydrology Chapter. Low flow frequency analysis employs a non-parametric approach similar to the flood frequency analysis, but in the case of low-flow analysis one is interested in the non-exceedance probability (Dingman 2002; Pyrce 2004). Both the Weibull and Cunnane plotting methods are used in this analysis.

The low flow analysis on the entire period of record is useful for determining the probability of low flows in Deer Creek. The Cunnane method plots slightly greater flows at the low flow end of the non-exceedance probability, with the two methods overlapping in the middle, and the Weibull method plotting slightly greater flows at the high flow end of the non-exceedance probability. Flows are lowest in the 1-day analysis and increase through the 90-day analysis, which makes sense considering the use of moving averages, with flows averaged for one day in the *d*=1 analysis, and flows averaged over 90 days in the *d*=90 analysis. As the averaging period increases, so do low flow values, as a larger date range is used. The averaging of a larger date range also leads to a smoother low flow frequency curve, as low or high flow peaks are averaged with many other values, leading to a curve that is smoother and with fewer peaks. **Figure 4.12** and **Table 4.9** provide examples of 1-day and 15-day plots, with return intervals provided in **Figure 4.13** and **Table 4.10**, and additional results provided in the Hydrology Chapter Appendix.

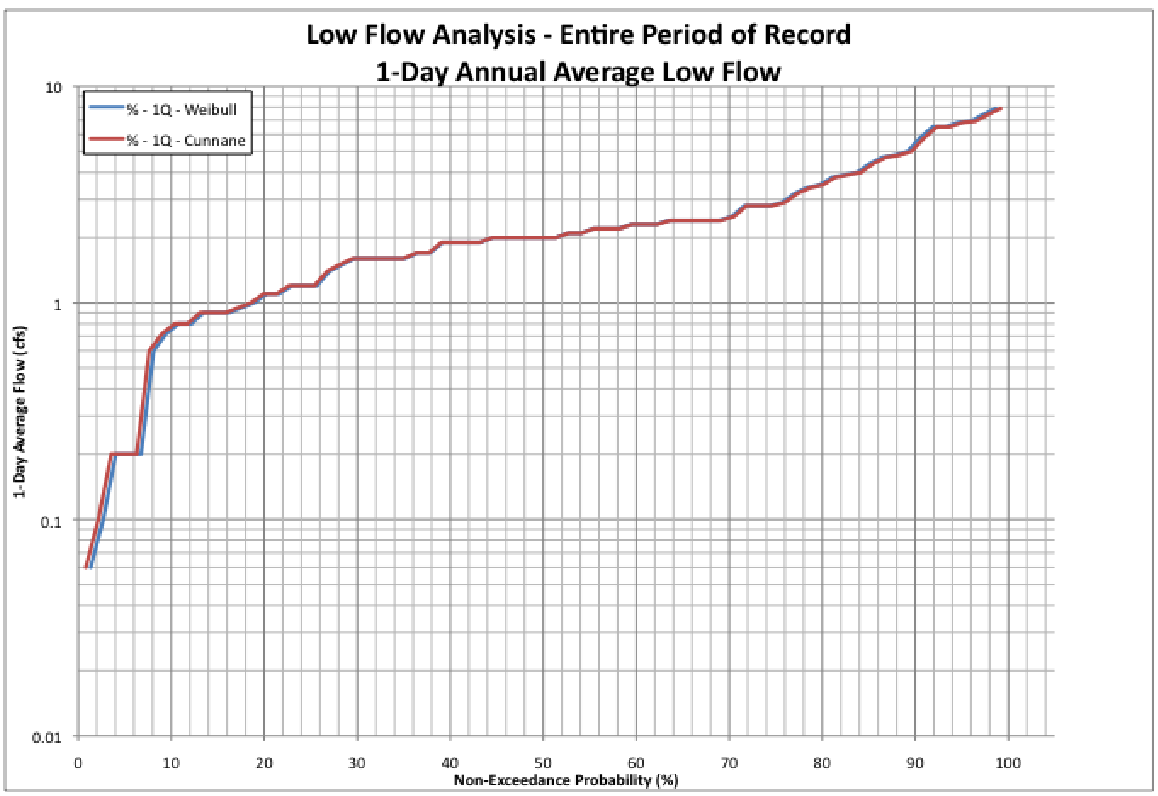

Figure 4.12: Low flow frequency analysis for USGS gauge #11418500 on Deer Creek, d=1, using the Weibull (blue) and Cunnane (red) plotting methods.

Non-Exceedance Probability (%)	Return Interval (years)	Discharge (cfs)
1	100	0.06
2	50	0.1
5	20	0.2
10	10	0.8
20	5	1.1
50	2	2.0
99	1.01	7.9

Table 4.9: Results of the low flow frequency analysis, d=1, non-exceedance probability estimates.

Figure 4.12 and **Table 4.9** provide results of the 1-day low flow frequency analysis. The data indicate that Deer Creek has not exhibited any intermittent flow in the period of record, with stream flows of less than 0.06 cfs expected to occur approximately once every one hundred years. The lowest flow in the period of record, 0.06 cfs, coincides with a two-year drought period during the late 1970's, with no other daily stream flows below 0.1 cfs. In any given year it is probable that stream flows would fall below 7.9 cfs, with stream flows expected to fall below 2.0 cfs once every two years. The steep nature of the low discharge end of the curve, below the 10% non-exceedance probability and approximately 0.8 cfs, indicates that extreme low flows (< 1.0 cfs) occur infrequently, on the order of once every ten to one hundred years. These data are useful for planning purposes as they provide information regarding the frequency of extreme low flows associated with droughts and subsequent water availability for aquatic habitat. Extreme low flows can result in stressful conditions for aquatic and riparian organisms. In addition, these data reflect low flow conditions in a managed system, downstream of all reservoirs and diversion points. It is therefore important to compare the *d*=1 Deer Creek low flow frequency results with the results from the natural flow analysis in the previous sections, which incorporated NID and Oregon Creek data to estimate low flows in upper Deer Creek. This will allow investigation into whether managed flows are less than would be expected in a natural system.

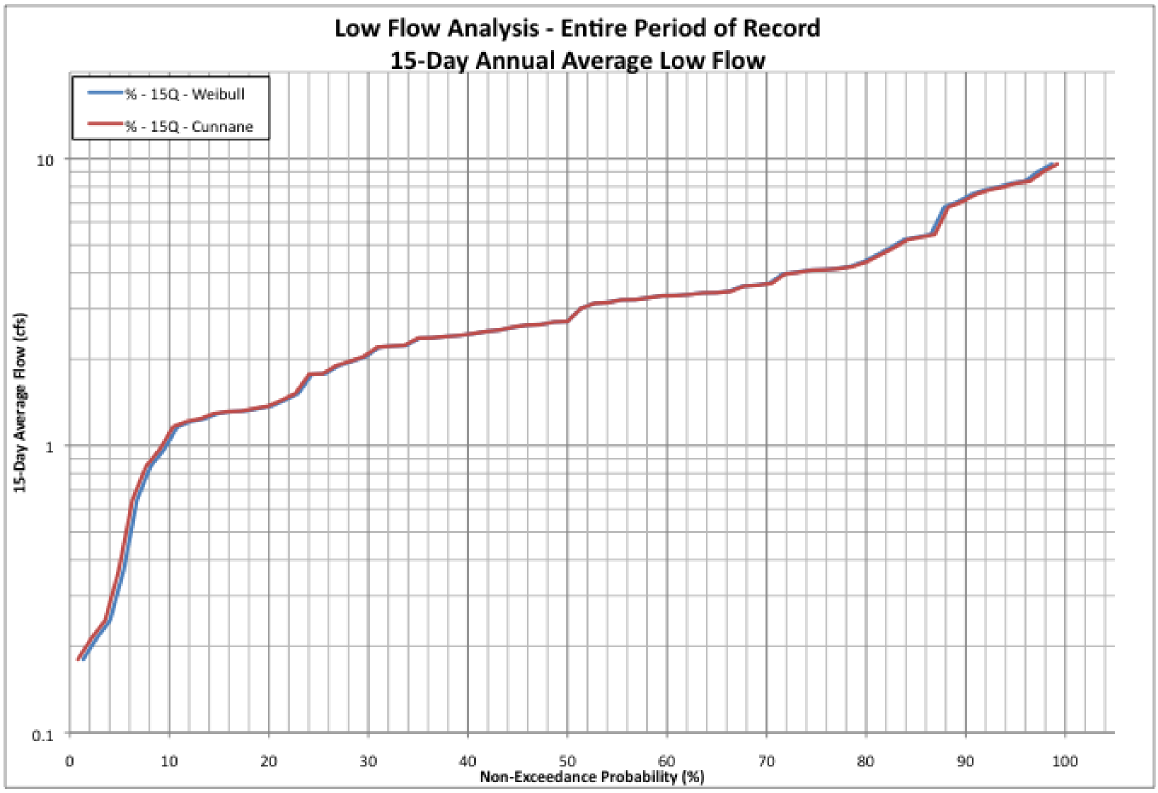

Figure 4.13: Low flow frequency analysis for USGS gauge #11418500 on Deer Creek, d=15, using the Weibull (blue) and Cunnane (red) plotting methods.

Figure 4.13 and **Table 4.10** provide results of the 15-day low flow frequency analysis. As expected, the shape of the curve in **Figure 4.13** is quite similar to that of **Figure 4.12**, although the curve in **Figure 4.13** is smoother and shifted up on the graph, due to 15-day moving averages being used in the analysis. The data indicate that 15-day average stream flows of less than 0.18 cfs are expected to occur once every one hundred years, 0.21 cfs every fifty years, 0.37 cfs every twenty years, and 1.16 cfs every ten years (15Q10). In any given year it is probable that the 15-day average stream flow will fall below 9.56 cfs, with stream flows falling below 2.71 cfs once every two years, and below 1.37 cfs once every five years. As with the 1-day plot, the steep nature of the low discharge end of the 15-day curve, below the 10% non-exceedance probability and approximately 1.0 cfs, indicates that extreme low flows of extended duration occur infrequently, from once every ten to one hundred years. While analysis of the entire period of record provides details regarding the observed flow record in this section of Deer Creek, comparing these results with the estimated natural flows in the upper Deer Creek watershed is important for investigating whether historical low-flow conditions are present in lower Deer Creek at the gauging station and watershed outlet. In addition, conducting low flow frequency analysis on two periods of record (pre- and post-Scotts Flat reservoir) is important for investigating whether reservoir development and water management have caused alterations to the low flow regime and the aquatic ecosystem.

Non-Exceedence Probability (%)	Return Interval (years)	Discharge (cfs)
1	100	0.18
2	50	0.21
5	20	0.37
10	10	1.16
20	5	1.37
50	2	2.71
99	1.01	9.56

Table 4.10 Results of the low flow frequency analysis, d=15, non-exceedance probability estimates.

Low Flow Analysis Discussion

Three separate methods were used to investigate the frequency of low flows in sections of the Deer Creek watershed, focusing on the upper watershed around Scotts Flat reservoir, and the lower watershed near the watershed outlet at the USGS Smartsville gauge. The first method used NID data to investigate natural flows in the upper watershed and indicated that under natural conditions summer low flows at Scotts Flat reservoir would typically drop below 5 cfs in most years. This analysis also determined that summer flows are artificially high in upper Deer Creek, with water transferred from the South Yuba River into Scotts Flat reservoir, and subsequently into Deer Creek to convey water to downstream diversion points. This results in a lack of natural low-flow conditions in these sections of Deer Creek. Periodic low flow conditions can be important for inducing stress on aquatic and riparian organisms.

The second method compared NID data with USGS data from Oregon Creek, as the Oregon Creek USGS gauge exhibits a hydrograph similar to that of Deer Creek upstream of Scotts Flat (**Figure 4.10**). The similar hydrograph and other features, such as topography, vegetation, watershed size, and climate, allow Oregon Creek to serve as a useful reference for estimating natural flows on Deer Creek at Scotts Flat reservoir. The results (**Figure 4.11**) indicated that during summer months Deer Creek would experience year round flow at Scotts Flat reservoir, with flows of 3-9 cfs expected in above normal to wet years, 2-4 cfs during normal or below normal years, and 1-3 cfs in dry and critically dry years. The results from method 2 are in line with those from method 1, with both methods concluding that at Scotts Flat reservoir in above normal and wet years stream flows of greater than 5 cfs would be expected, normal years would produce flows near 5 cfs, with drier years potentially producing stream flows of less than 1-2 cfs. These results are important because both methods indicate that there would be stream flow at Scotts Flat, even in critical or dry water years. Additionally, the fact that summer low flow conditions could be greater than 5 cfs, and are greater than 1 or 2 cfs except for dry or critical water years in this portion of the watershed, indicates that downstream at the USGS gauge, near the watershed outlet, stream flows of at least this magnitude would be expected during low-flow periods. This is based on the amount of natural flow estimated at Scotts Flat, plus contributions from numerous perennial tributaries between Scotts Flat and the Deer Creek watershed outlet. Comparing the results from method 1 and 2 with the results from method 3 allows for further investigation into low-flow patterns in the watershed.

The results of the low flow frequency analysis in Method 3 (**Figures 4.12, 4.13, Tables 4.9, 4.10**) indicate that stream flows of less than 1.0 cfs are uncommon and occur on the order of once every ten to one hundred years at the USGS Smartsville gauge near the Deer Creek watershed outlet. Annually stream flows are expected to fall below 7.9 cfs, with stream flows of less than 2.0 cfs expected once every two years based on the period of record. When compared with the results from method 1 and 2 it is apparent that flow in the lower watershed is less than naturally would be present. Method 3 indicates that flows of less than 7.9 cfs are expected to occur each year at the watershed outlet (a=84.6 mi^2), with Method 2 indicating that flows of between 3-9 cfs would be present at Scotts Flat (a=20.8 mi^2) during above normal and wet years with flows of 2-4 cfs in normal years. These estimates, combined with the contributions of numerous perennial tributaries and surface and groundwater storage flows from an increasing watershed size, suggest that flows in lower Deer Creek are not meeting natural values. In addition, this suggests that stream flows are potentially not meeting the required 5 cfs or natural flow volume downstream of Lake Wildwood reservoir. Opportunities to ensure that 5 cfs, or the natural flow volume, is delivered to lower Deer Creek should be explored through working with Lake Wildwood Association, NID, and the California Division of Water Rights.

Flow Duration Curves – Methods

Hydrographs allow for the examination of watershed characteristics that influence conditions such as runoff and storage (Morisawa 1968). Hydrographs are also useful for investigating the timing, duration, and management of flows (Searcy 1959). Flow regime and duration analysis was performed using mean daily discharge data from USGS gauge #11418500. Flow duration curves (FDCs) provide a conceptually simple yet highly informative way to summarize the variability of a time series (Dingman 2002). Duration curves are cumulative frequency curves that show the fraction or percent of the time that the magnitude of a given variable exceeds a value, over a period of extended observation that includes a wide range of seasonal and inter-annual variability (Dingman 2002). For hydrology purposes, duration curves are typically used to depict the temporal variability of daily stream flow. FDCs are a plot of the daily average flow magnitude against exceedance probability. FDCs can be used to gain insight into the temporal variability of stream flow for a given watershed or catchment, with the shape of the curve representing watershed characteristics. Searcy (1959) and Vogel and Fennessey (1994) provided comprehensive reviews of FDCs (Dingman 2002). FDCs were constructed for the entire period of record using Microsoft Excel, to investigate how different methods for constructing FDCs produce unique results for Deer Creek.

There are two approaches to construction of FDCs, including period of record FDCs and median-annual (or mean-annual) FDCs. Period of record FDCs are the conventional method but the median-annual FDCs represent the preferred method (Dingman 2002). Median-annual FDCs are the preferred method because period-of-record FDCs depict the historical variability of stream flows without providing information regarding the inter-annual variability of flows or the uncertainty of the estimated exceedance frequencies due to a finite record length (Vogel and Fennessey 1994; Dingman 2002). This often leads to the low flow end of the period-of-record FDC being significantly influenced by the water years in which flow was measured (Vogel and Fennessey 1994; Dingman 2002). Median-annual FDCs are less influenced by the particular period of record and are useful for estimating the inter-annual variability and uncertainty of FDCs (Vogel and Fennessey 1994). For this analysis FDCs were computed using the period-of-record method, median-annual, and mean-annual methods.

Daily flows were ranked 365*N from lowest (rank I = 1) to highest (rank *I* = 365*N) and the *i*th-ranked flow was designated as q(i). The non-exceedance frequency of each flow was calculated using equations 2 and 3, for the period-of-record and median-annual FDCs respectively. Each method used equation 1 to determine the exceedance probability, with the period-of-record curve constructed by plotting the q(i) values against the EPQ(q(i)) values. The median-annual FDC curve was constructed by applying equation 3 to each water year of record and equation 1 to compute the corresponding EPQ(q(i)) values for the flows of each year. Then the median (or mean) of the N values of q(i) that are associated with each exceedance probability was computed and plotted as the FDC. For this analysis both the median and the mean of the N values were computed.

EPQ(q) = 1 – FQ(q), where EPQ(q) is the exceedance probability; q is the daily average flow magnitude; and FQ(q) is the cumulative distribution function (non-exceedance probability) of q.

FQ(q(i)) = I / 365 * N + 1, for the period-of-record FDCs.

FQ(q(i)) = I / 365 + 1, applied to each water year of record, for the median-annual and mean-annual FDCs

Flow Duration Curves – Results and Discussion

Detailed results of the FDC analysis, including all graphs and Excel data files, are provided in the Hydrology Chapter Appendix. **Figure 4.14** provides an example of the FDCs generated from this analysis. **Figure 4.14** shows that the three methods for constructing FDCs each produce different results. In addition, **Figure 4.14** shows the general shape of the FDC for Deer Creek. The analysis method and data record significantly influence the low flow end ($q_{.85}$ – $q_{.99}$) of the period-of-record FDC, with the median and mean annual

FDC resulting in higher low flows. Fennessey and Vogel (1990) found that the median FDC plots greater flows than the period-of-record FDC in the low range and reflects more typical behavior of the stream. Between $q_{.70} - q_{.85}$ the period-of-record and mean/median-annual FDC coincide quite well, with the mean-annual and period-of-record coinciding better than with the median-annual from $q_{.01} - q_{.25}$.

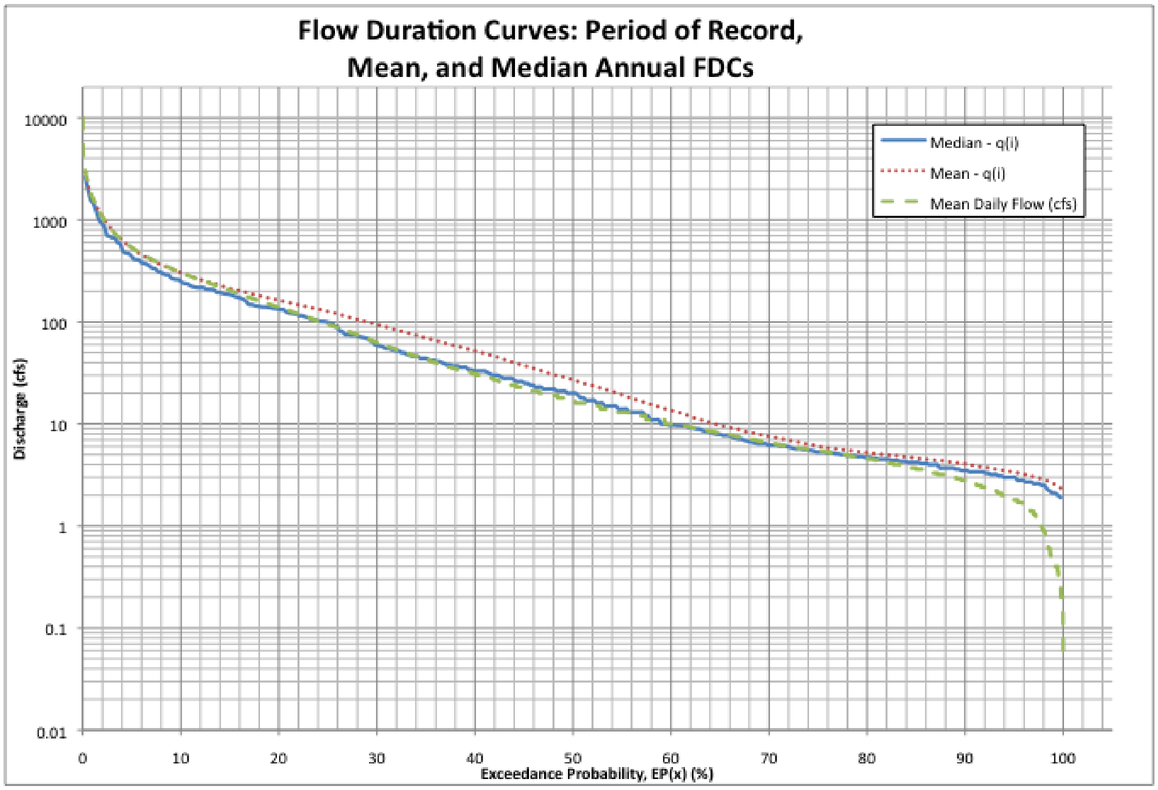

Figure 4.14: Flow Duration Curves: Period-of-record (green-Mean Daily Flow (cfs)), median-annual (blue-Median – q(i)), and mean-annual (red-Mean – q(i)).

The FDCs in **Figure 4.14** show that for the period of record FDC (green curve-Mean Daily Flow) there is a steep slope at both ends of the curve, with this FDC exhibiting the highest and lowest values and the steepest curve due to the FDC being influenced by the period of record. The steep nature of the low discharge end (>90%) of the period of record FDC indicates minor base flows, potentially due to minimal amounts of ground water storage or impacts associated with water management, with the Deer Creek gauge located downstream of multiple reservoirs and water diversion points. The blue median and red mean annual FDC's are also steep at the high discharge end of the curves (0-10%), indicating that daily flow values greater than 1000 cfs (0 – 2%) do not occur most of the time and that floods are caused by direct runoff from rainfall. In addition, a steep curve at the high discharge end of the FDC indicates Deer Creek is a relatively small watershed with little natural surface storage in swamps, wetlands, floodplains, and natural depressions. The blue median and red mean annual FDCs exhibit a relatively flat curve at the low discharge end when compared to the period of record FDC, indicating the median and mean annual FDCs are less influenced by the period of record, that flows generally are greater than 2.0 cfs at the gauging station, and that groundwater or water management helps sustain perennial flows.

The USGS gauge has been recording data since 1935, and thus data exist before the development and expansion of many of the major impoundments on Deer Creek, including Scotts Flat reservoir (1948 & 1964) and Lake Wildwood reservoir (1969). Although the natural flow of Deer Creek was affected prior to the installation of the USGS gauge on Deer Creek by development of Lower Scotts Flat (Deer Creek Diversion Dam, 1928) and mining activities, the gauging data provide an opportunity to investigate flows before and after the major reservoirs were constructed.

Two-Period Stream Flow Data Analysis

Methods

USGS records for gauge #11418500 on Deer Creek indicate a change to base flow occurred in water year 1965, coinciding with the 1964 upgrade of Scotts Flat reservoir from 27,000 to 48,547 acre-feet (S. Sindt, pers. comm.). Such a change provides an appropriate point to separate the stream flow record into two periods, one before the base flow change and one after the base flow change, to determine to what extent the overall hydrograph has been altered. A detailed analysis was undertaken for water years before (1935-1964-PreSF period) and after (1965-2009-PostSF period) the base flow change, using multiple methods to analyze annual peak flow and mean daily flow data. This included a flood frequency analysis, low flow frequency analysis, and construction of FDCs. Flood and low flow frequency analysis was conducted to investigate whether the base flow change associated with the construction of Scotts Flat reservoir has led to an alteration in the frequency and magnitude of the annual flow maxima and minima. FDCs were constructed using the mean-annual, median-annual, and period of record FDCs methods, to investigate changes to the flow regime.

In addition to the two period analysis provided in this section, analysis of Deer Creek's stream flow gauging record was conducted using the Indicators of Hydrologic Alteration software package. The Indicators of Hydrologic Alteration (IHA) software (Version 7.1) was used to calculate sixty-seven statistical parameters, including thirty-three IHA parameters and thirty-four Environmental Flow Component (EFC) parameters (TNC 2009). Non-parametric data analysis was conducted for two periods of record (1935-1964, 1965-2009) to analyze alterations to the hydrologic regime, with results and discussion provided in the IHA section of the Hydrology Chapter.

Deer Creek High Flows – Two-Period Flood Frequency Results and Discussion

Table 4.11 provides results from the HEC-SSP tabular output for the period before (PreSF) and after (PostSF) the Scotts Flat reservoir upgrade and base flow change and allows for quick comparison of flow values for each exceedance probability and return interval. **Figures 4.15** and **4.16** provide HEC-SSP plots of the flood frequency analysis results for each period. Each graph shows the observed events (Weibull method), the computed and expected probability curves, and the $5^{th}/95^{th}$ confidence limits. The results of the two-period flood frequency analysis indicate that reservoir development and water management have potentially impacted the flood regime.

Table 4.11 and **Figures 4.15,** and **4.16** show that the flood regime has potentially been altered through reservoir development and water management, with computed and expected peak flows greater in the PreSF period than in the PostSF period for each return interval, despite the highest flow on record and more wet water years occurring in the PostSF period. The confidence intervals for the PreSF and PostSF periods overlap for each peak flow return interval, indicating that alterations have not been significant from the PreSF to PostSF period and that further analysis is needed to make definitive conclusions about the extent of alterations.

There are five flow events Q>10,000 cfs in the PreSF period and only three PostSF, with the shorter period of record (PreSF) having more frequent Q>10,000 cfs annual peak flow events than the longer period of record (PostSF). There are no annual peak flow events less than 1,000 cfs in the PreSF period, with two annual peak flows of less than 1,000 cfs in the PostSF period, which influences the analysis. The combination of shorter record length, Q>10,000 cfs flows, and the lack of Q<1,000 cfs flows in the PreSF period results in greater peak flow estimates when compared with the PostSF period, indicating that record length and water year types should be considered in this analysis. The HEC-SSP program attempts to correct the bias introduced by analyzing a shorter period of record, which could partially explain the greater magnitudes calculated for the PreSF period expected curve.

% Chance Exceedance	Return Interval (years)	PreSF-Computed Curve Flow (cfs)	PostSF-Computed Curve Flow (cfs)	PreSF-Expected Curve Flow (cfs)	PostSF-Expected Curve Flow (cfs)
0.2	500	19,086	16,029	21,031	16,683
0.5	200	17,213	14,969	18,595	15,498
1	100	15,744	14,028	16,769	14,473
2	50	14,221	12,946	14,940	13,295
5	20	12,105	11,251	12,514	11,486
10	10	10,399	9,719	10,625	9,859

20	5	8,554	7,904	8,656	7,973
50	2	5,682	4,823	5,682	4,823
90	1.11	2,773	1,724	2,686	1,665
99	1.01	1,415	568	1,252	490

Table 4.11: HEC-SSP flood frequency results.

The period of record length and the quantity of specific water years in the observed period of record can influence the flood frequency analysis. The length of record influences the flood frequency statistical analysis, as a large sample size is necessary for an accurate analysis. The PreSF period has an n=30 with the PostSF n=42. The period of record lengths should accurately capture most large-scale variations in climate, such as the Pacific Decadal Oscillation and the El Niño/Southern Oscillation, with thirty years a typical time period used for analyzing climate data. Although the thirty-year time period potentially reflects large-scale climate variations this is likely not an adequate record length for the flood frequency analysis, particularly for values that must be extrapolated from the small data record, such as the Q50, Q100, Q200, and Q500-year floods. The shorter period of record often introduces bias in the expected results, as the analysis attempts to compensate for the short period of record. Although the PreSF period of record length is fixed, the PostSF period of record length will increase through the future allowing for more accurate predictions of peak stream flows. In addition to the period of record influences on the analysis there is a lack of critical water years during the PreSF period, with the PostSF period having several water years classified as critical.

Critical water years, such as 1976 and 1977, often result in low annual peak flows (peak < 2,000 cfs). The PreSF period had no critical water years, eight dry water years, and eight below normal water years, with the PostSF period having seven critical water years, eight dry water years, and six below normal water years. The PreSF period had no annual peak flows below 1,000 cfs whereas the PostSF period had two years below this threshold; the PreSF period had two annual peak flows below 2,000 cfs with the PostSF period having seven; and the PreSF period had four annual peak flows below 3,000 cfs with the PostSF period having ten. There appears to be a relationship between water year type and annual peak flow magnitude, with critical water years in 1976 and 1977 resulting in flows of less than 1,000 cfs and critical water years in 1988 and 1994 resulting in flows less than 2,000 cfs. This relationship is further evidenced by the fact that every annual peak flow of greater than 10,000 cfs occurred in wet water years. The relationship is less clear when comparing annual peak flows in dry, below normal, and above normal water years.

Overall the data suggest that alterations to the peak flow regime have occurred from the PreSF to PostSF period, but more investigation into the extent of these alterations is necessary.

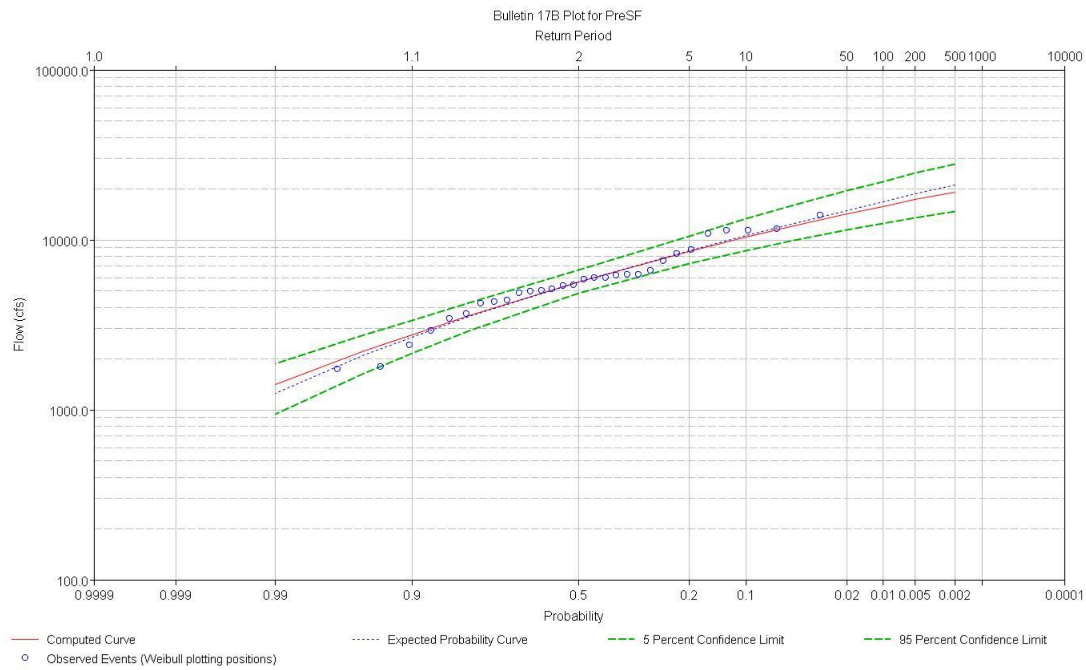

Figure 4.15: Results of the PreSF period (1935-1964) flood frequency analysis, n=30.

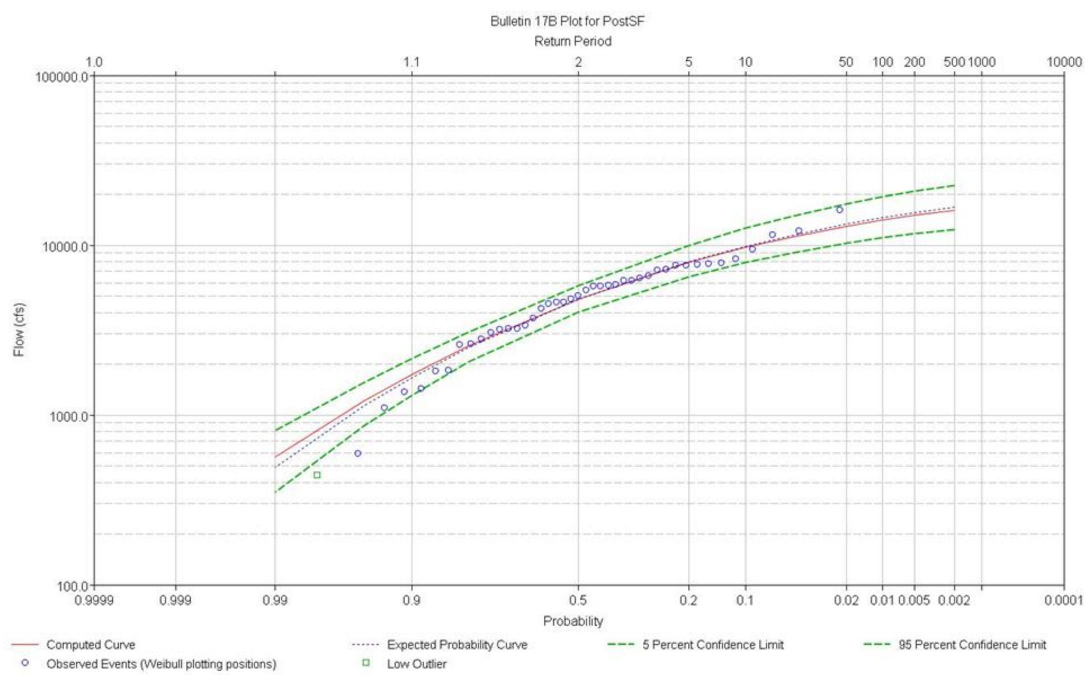

Figure 4.16: Results of the PostSF period (1965-2009) flood frequency analysis, n=42.

Deer Creek Low Flows – Two Period Low Flow Frequency Results and Discussion

As mentioned previously the two-period low flow frequency analysis is important for assessing impacts and alterations to the hydrologic regime, which are associated with the upgrade of Scotts Flat Reservoir and subsequent base flow change in water year 1965. Additionally the low-flow analysis is based upon stream flow records from the USGS gauge at Smartsville, in the downstream-most reaches of Deer Creek. This allows for analysis of how water management and reservoir development have impacted critical low-flows in this section of creek. This section of Deer Creek downstream of Lake Wildwood reservoir is subject to the most adverse impacts of water management and development and is home to threatened and endangered species of Chinook salmon and steelhead trout. Assessing the impacts to stress-inducing low flows is therefore critical to planning aquatic ecosystem and flow regime restoration efforts.

Results of the two-period low flow frequency analysis indicate that reservoir development and water management have impacted low flows in Deer Creek. This is evident when plotting the 1, 3, 7, 15, and 30-day annual average low flows for the PreSF and PostSF periods. **Figures 4.17** and **4.18** provide results of the 1-day and 15-day analysis, with results of both the 1 and 15-day analysis provided in **Figure 4.19**, using the Weibull plotting method.

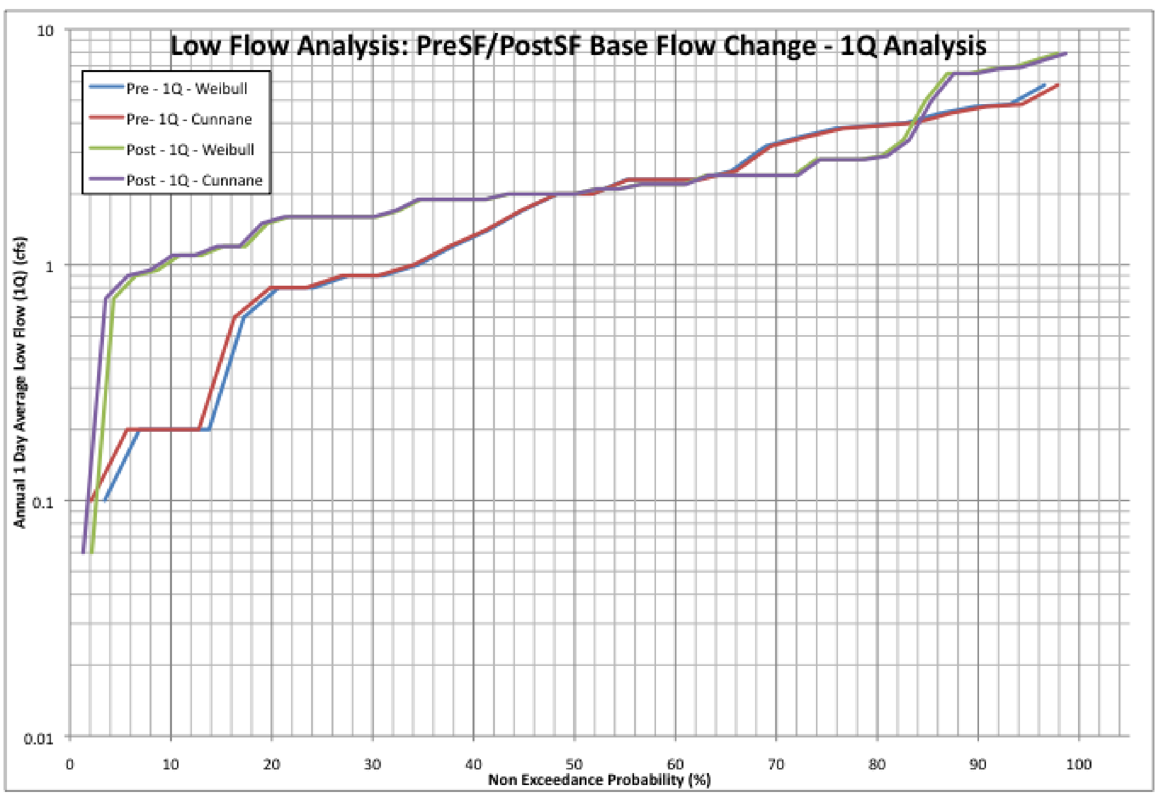

Figure 4.17: Results of the two-period low flow frequency analysis, d=1, annual 1-day average low flow.

Certain trends are apparent and persist in each *d*-day analysis with the PostSF period annual *d*-day low flows generally greater from about the 0-50th non-exceedance probability, similar from the 50-60th, lower from 60-84th, and greater from 84-100th when compared against the PreSF period. With the 15-day (**Figure 4.18**) and 30-day averages the PostSF period low flows are generally greater from about the 0-55th non-exceedance probability, similar through the 80th, and greater from the 80-100th. The differences between the PreSF and PostSF period low flow frequency results are quite small, typically on the order of less than 1.0 cfs. This indicates that minor alterations to the magnitude and frequency of low flows has occurred in this section of Deer Creek, with the slight flow increase possibly attributed to the development of the Lake Wildwood reservoir WWTP in the PostSF, which continually discharges effluent into lower Deer Creek immediately downstream of Lake Wildwood reservoir. In summer months the Lake Wildwood WWTP often discharges at a rate of 0.62 cfs, potentially accounting for a substantial portion of the 1.0 cfs or less flow increase.

While the volume of low stream flows is slightly higher in the PostSF period, the increase potentially results from effluent discharged by the Lake Wildwood WWTP, and thus an increase in flow quantity does not necessarily equate to an improvement in water quality or habitat conditions. These alterations to the low flow regime have important consequences for Deer Creek, as the magnitude and duration of annual minimum flows can influence the ecosystem in the following ways (TNC 2009):

· Balance of competitive, ruderal, and stress- tolerant organisms
· Structuring of aquatic ecosystems by abiotic vs. biotic factors
· Soil moisture stress in plants
· Dehydration in animals
· Anaerobic stress in plants
· Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments
· Distribution of plant communities in lakes, ponds, floodplains

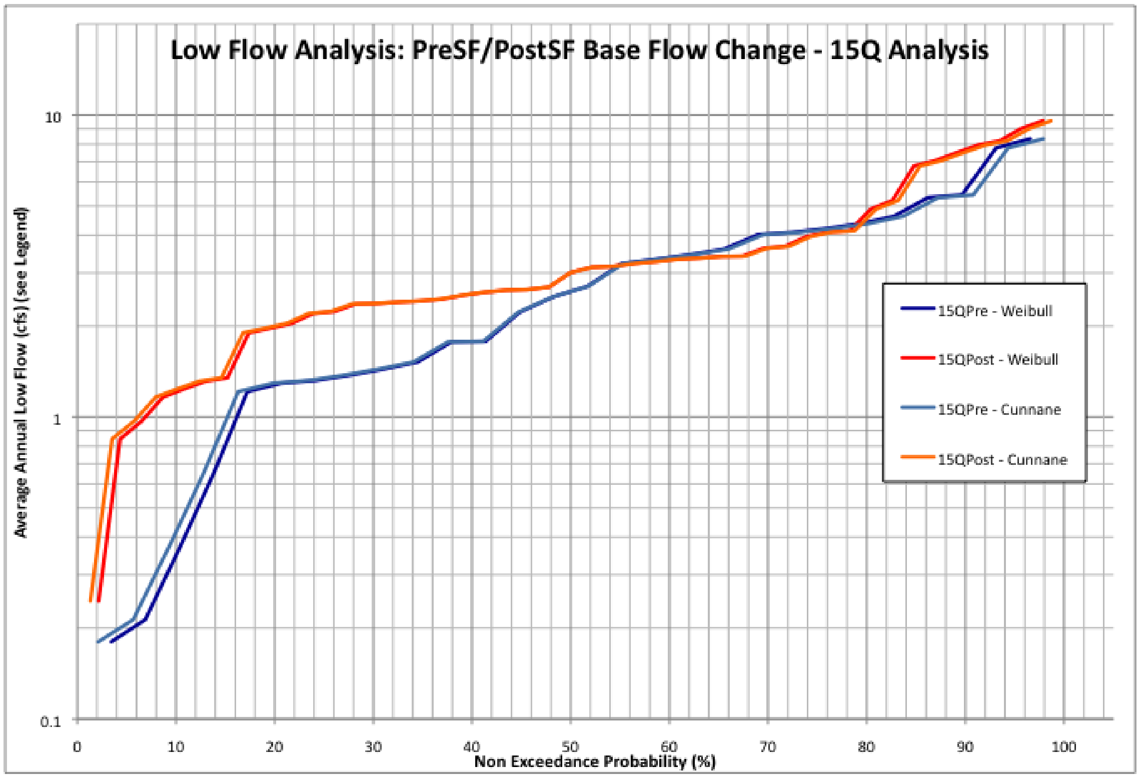

Figure 4.18: Results of the two period low flow frequency analysis, d=15, annual 15-day average low flow.

Low flow conditions can create stressors or even barriers for certain aquatic organisms, with high temperatures, low oxygen levels, and high nutrient concentrations often associated with low flow conditions. Elevated levels of nutrients in the water, resulting from wastewater treatment effluent discharges and agricultural and urban runoff, can promote excessive algal growth at low flows. This is a common problem in Deer Creek downstream of Lake Wildwood reservoir during the summer months, as the majority of the water is removed for management activities such as irrigation and maintaining reservoir levels. Algal blooms can lead to dramatic fluctuations in dissolved oxygen levels, with the possibility of periods with little to no oxygen in the water column. Such anaerobic conditions can kill fish and macroinvertebrates. Under less disturbed conditions, it is likely that aquatic organisms could have endured low flow periods more easily. These and other stressors resulting from management of the hydrologic regime are discussed further in the River Ecology Chapter.

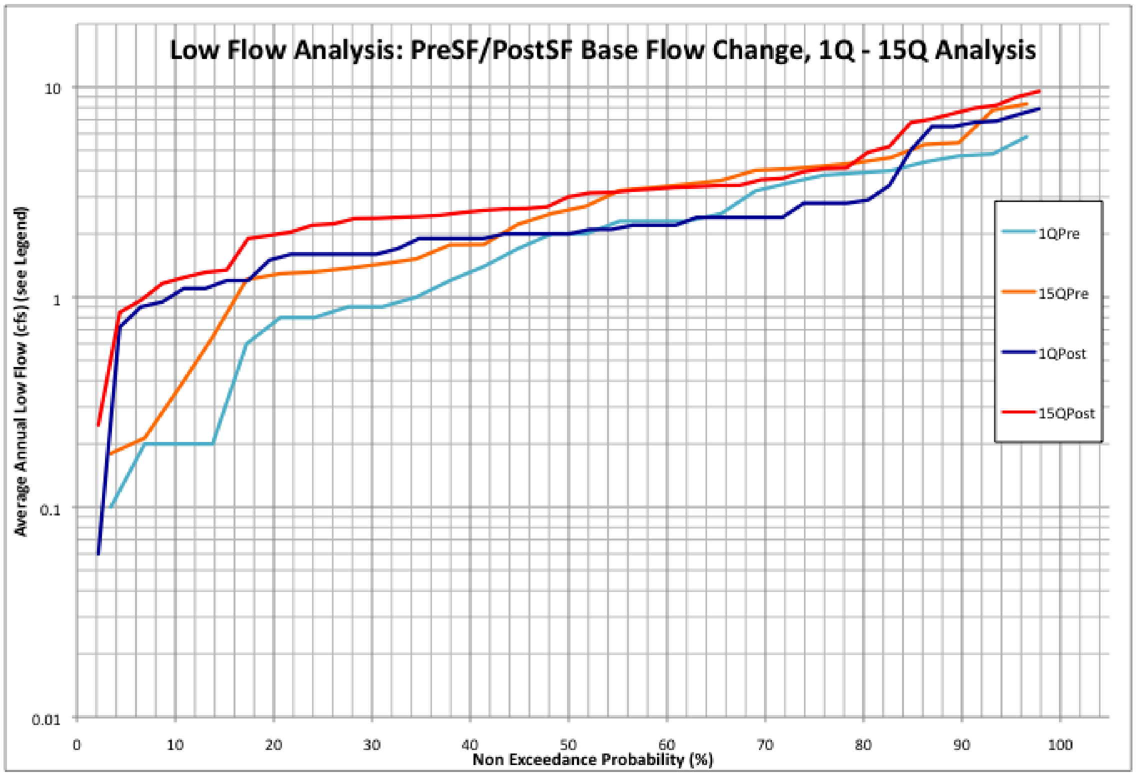

Figure 4.19: Results of the two-period low flow frequency analysis, d=1 and d=15, using the Weibull plotting method.

Two-Period Flow Duration Curves Analysis Results and Discussion

FDCs were constructed for two time periods, from water years 1935-1964 and 1965-2009, to investigate impacts to the flow regime associated with the upgrade of Scotts Flat reservoir from 27,000 to over 48,000 acre-feet in 1964 and base flow change in water year 1965. The period-of-record, median-annual, and mean-annual methods were used in this analysis. Detailed results of the FDC analysis, including all graphs and data files, are provided in the Hydrology Chapter Appendix. **Figures 4.20** and **4.21** provide examples of the FDCs generated from this analysis.

Figure 4.20 provides median and mean-annual FDCs for the periods before (PreSF) and after (PostSF) the base flow change in water year 1965. Upon assessing **Figure 4.20** it is evident that the hydrologic regime is different now than prior to the 1964 Scotts Flat reservoir upgrade. The median and mean-annual FDCs in **Figure 4.20** generally coincide with each other and follow similar patterns at the high and low flow ends of the plots, but there are distinct differences between the PreSF and PostSF periods. In the PostSF period at the low flow end the mean-annual results in greater low flows ($q_{.75} - q_{.99}$) with the median-annual PostSF also resulting in greater low flows ($q_{.88} - q_{.99}$). This indicates that there was a greater probability of lower discharge flows PreSF and the base flow change. This slight increase in low or base flow conditions (< 1.0 cfs) could potentially be attributed to the Lake

Wildwood reservoir WWTP, which began discharging effluent into lower Deer Creek during the PostSF period. On a typical day during the summer months the WWTP discharges approximately 400,000 million gallons per day of effluent into Deer Creek, which equates to 0.62 cfs (Scott Joslyn, pers. comm.). In winter months on days with high precipitation and usage the WWTP discharges up to 800,000 million gallons per day of effluent into Deer Creek, equating to 1.24 cfs (Scott Joslyn, pers. comm.).

In **Figure 4.20**, for the mean-annual FDC above $q_{.75}$ there was a greater probability of higher discharge flows in the PreSF period than PostSF, with the median-annual FDC following the same pattern of a greater probability of higher discharge flows in the PreSF period from $q_{.15}$ – $q_{.88}$. Above $q_{.15}$ the mean and median annual FDCs generally coincide, with no significant differences between the mean PreSF and PostSF or median PreSF and PostSF. The greater probability of high flows and base flows, above $q_{.75}$ for the mean-annual and above $q_{.88}$ for the median-annual FDC, indicates that there is less water flowing through the watershed outlet in the PostSF period. This suggests that reservoir development and water management have altered the flow regime in the Deer Creek watershed by removing water from the system.

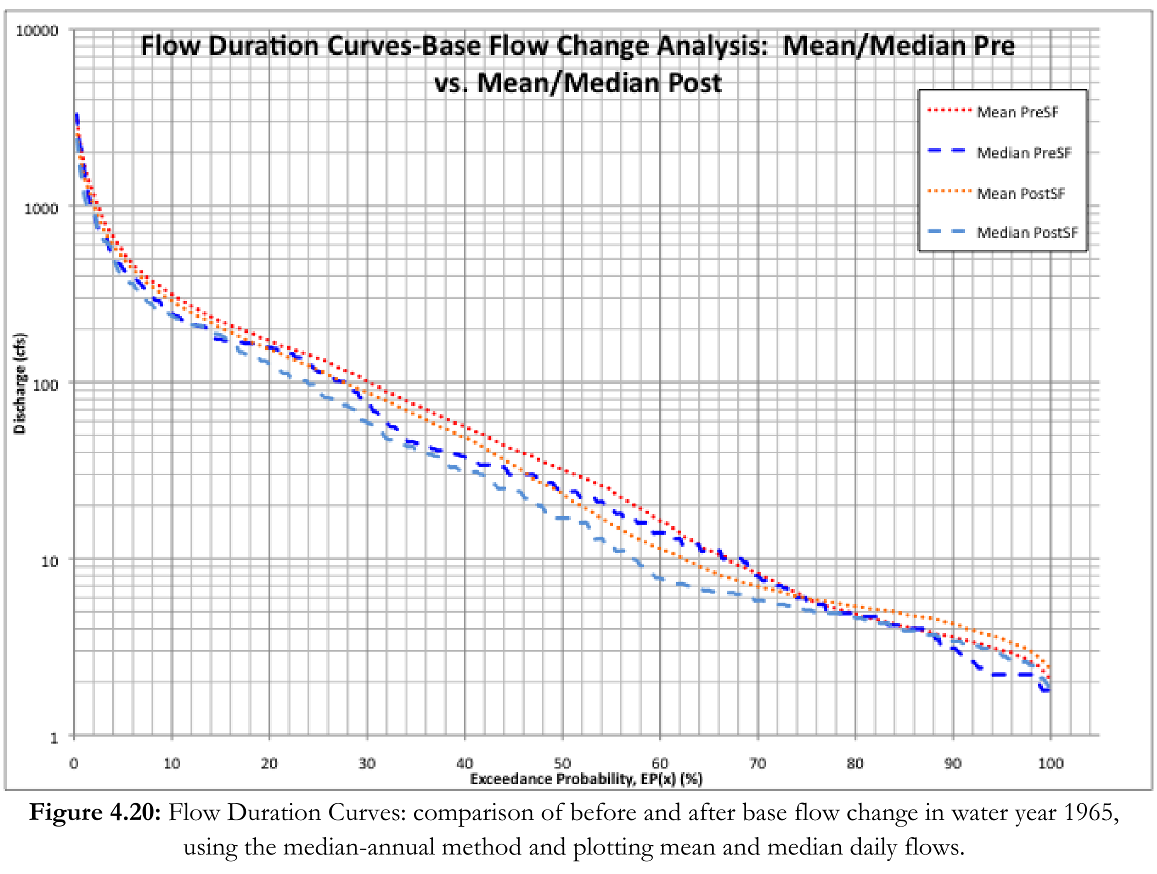

Figure 4.20: Flow Duration Curves: comparison of before and after base flow change in water year 1965, using the median-annual method and plotting mean and median daily flows.

The period-of-record FDCs in **Figure 4.21** follow a similar trend to the median and mean-annual FDCs (**Figure 4.20**) with a greater probability of lower discharge flows PreSF ($q_{.90}$ –

$q_{.99}$), a greater probability of higher base and high pulse discharge flows ($q_{.15}$ – $q_{.90}$) in the PreSF period, with the curves coinciding above $q_{.15}$. The lowest flows on record occurred in the PostSF period, which is evident from the period-of-record FDC (**Figure 4.32**). For comparison, **Figure 4.21** was evaluated against the two-period annual FDC generated by the IHA software analysis (**Figure 4.31**). The IHA software also uses the period-of-record method to calculate FDCs and therefore can be used to independently assess the success of the analysis. The curves in **Figure 4.21** and **Figure 4.31** are essentially identical and confirm the success of the FDC analysis through independent methods, as well as the fact that the hydrologic regime has been altered through reservoir development and water management.

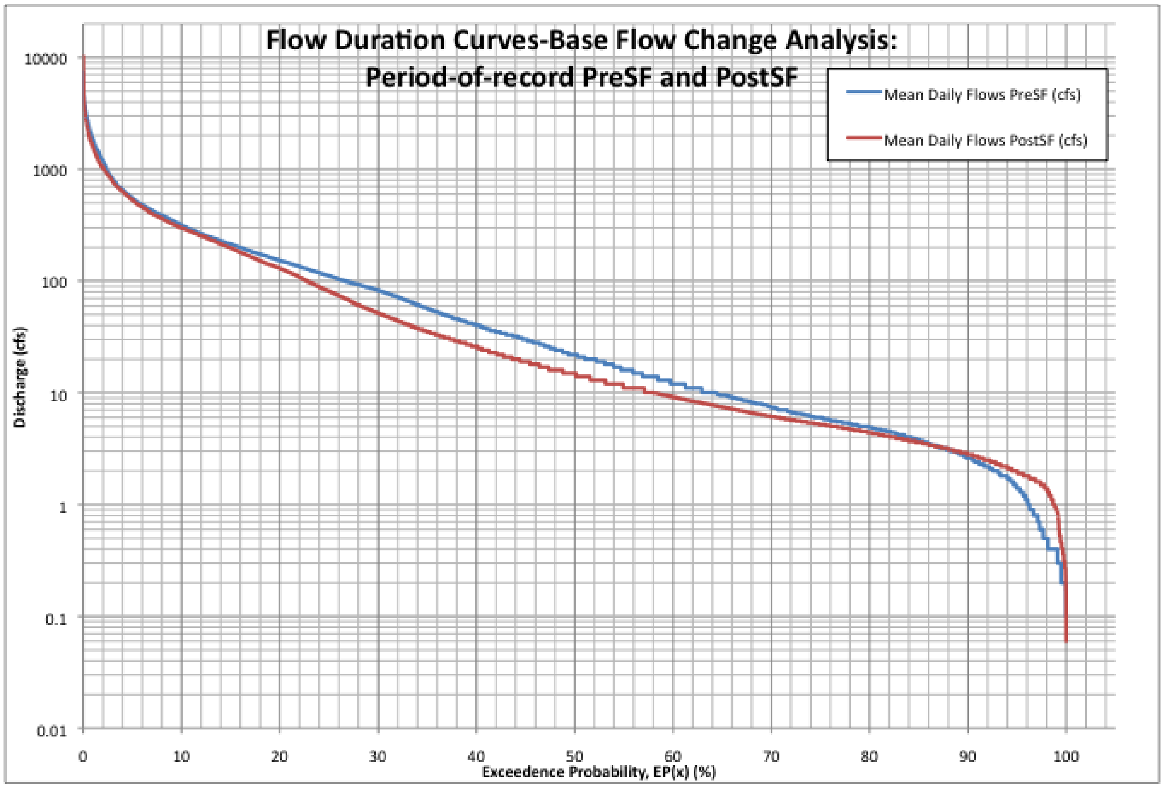

Figure 4.21: Flow duration curves to compare the period before (PreSF) and after (PostSF) water year 1965, using the period-of-record method and plotting mean daily flows.

Indicators of Hydrologic Alteration (IHA) Flow Data Analysis

Indicators of Hydrologic Alteration – High Flows

The IHA software calculates a variety of parameters that are applicable to the high flow analysis. This includes analysis of the annual flow maxima, frequency and duration of high flow pulses, timing of annual maximum flows, high flow pulses, small floods, and large floods. Two period analysis was conducted for each of these parameters, from 1935-1964 and 1965-2009, to investigate alterations to the hydrologic regime through reservoir development and water management. Annual maximum flows, frequency and duration of high flow pulses, and the Julian date of annual minimum flows use the Range of Variability Approach (RVA), to assess the degree of hydrologic alteration to each parameter (Richter et al. 1997; TNC 2009). The high flow pulse, small flood, and large flood are part of the Environmental Flow Components (EFC) analysis, which does not allow for the RVA to assessing hydrologic alteration. For these methods hydrologic alteration was assessed through changes to the 25th, 50th (median), and 75th percentiles from the PreSF to PostSF period.

The following is taken from the IHA Tutorial and describes the RVA methodology used in this analysis (Richter et al. 1997; TNC 2009):

The RVA uses the pre-development (PreSF) natural variation of IHA parameter values as a reference for defining the extent to which natural flow regimes have been altered. The pre-development (PreSF) variation can also be used as a basis for defining initial environmental flow goals. Richter et al., (1997) suggests that water managers should strive to keep the distribution of annual values of the IHA parameters as close to the pre-impact distributions as possible. RVA analysis also generates a series of Hydrologic Alteration factors, which quantify the degree of alteration to the thirty-three IHA flow parameters.

In the RVA analysis, the full range of pre-impact data (PreSF) for each parameter was divided into three different categories. The boundaries between categories are based on percentile values, which are specified by the user. The default non-parametric RVA analysis places the category boundaries 17 percentiles from the median, which yields an automatic delineation of three categories of equal size: the lowest category contains all values less than or equal to the 33rd percentile; the middle category contains all values falling in the range of the 34th to 67th percentiles; and the highest category contains all values greater than the 67th percentile. The program then computes the expected frequency with which the post-impact (PostSF) values of the IHA parameters should fall within each category (in the non-parametric default, this would be 33% for each of the three categories). The program then computes the frequency with which the post-impact (PostSF) annual values of IHA parameters actually fell within each of the three categories. This expected frequency is equal to the number of values in the category during the pre-impact (PreSF) period multiplied by the ratio of post-impact (PostSF) years to pre-impact years (PreSF). Finally, a Hydrologic Alteration factor is calculated for each of the three categories as:

(observed frequency – expected frequency) / expected frequency

A positive Hydrologic Alteration value means that the frequency of values in the category has increased from the pre-impact (PreSF) to the post-impact (PostSF) period, with a maximum value of infinity, while a negative value means that the frequency of values has decreased, with a minimum value of -1.

While it is possible to use parametric statistics for RVA analysis and to adjust the RVA boundaries, the recommended way to run an RVA analysis is to use the non-parametric defaults, because of the skewed or non-normal nature of many hydrological datasets and to ensure an equal number of data points are distributed outside of the RVA boundaries for assessing alterations in the two period analysis (TNC 2009). Using the 33rd and 67th percentiles ensures that in most situations an equal number of pre-impact values will fall into each category, which makes the results easier to understand and interpret.

Method 1. Annual Maximum Flow Analysis

The IHA software calculates the magnitude and duration of annual extreme water conditions using 1, 3, 7, 30, and 90-day means. Comparing these hydrologic parameters for two time periods allows for analysis of how the Scotts Flat reservoir upgrade and subsequent base flow change has altered the magnitude and duration of the annual maximum *d*-day flows. The magnitude and duration of annual maximum flows can have the following ecosystem influences (TNC 2009):

· Balance of competitive, ruderal, and stress- tolerant organisms
· Creation of sites for plant colonization
· Structuring of aquatic ecosystems by abiotic vs. biotic factors
· Structuring of river channel morphology and physical habitat conditions
· Volume of nutrient exchanges between rivers and floodplains
· Distribution of plant communities in lakes, ponds, floodplains
· Duration of high flows for waste disposal, aeration of spawning beds in channel sediments

Figure 4.33 summarizes the degree of Hydrologic Alteration (HA) for the annual flow maximum, based on the RVA analysis, with Figure 4.34 providing an example plot of the 1-day *d*-day analysis. Results of the IHA annual *d*-day maxima analysis indicate that the magnitude of annual maximum flows has been altered from PreSF to PostSF. For each of the 1, 3, 7, 30, and 90 day averages, the PreSF *d*-day median flow is greater than in the PostSF period.

Table 4.12 indicates that there have been changes to the annual flow maxima for each of the *d*-days analyzed, with **Table 4.12** detailing how the 1-day maximum has been altered. In each *d*-day analysis there is an increase in the low RVA category and in four of the five analyses (excluding the 30-day analysis) a decrease in high RVA category flows in the PostSF period, as well as a median shift downward on the plot, indicating that annual *d*-day maximum flows have decreased from the PreSF to PostSF period. The negative values for the high RVA category indicate a decrease in annual maximum flow magnitudes and the positive values for low RVA category indicate a trend of lower magnitudes for maximum flow events in the PostSF period. There is an insignificant increase to the 30-day high RVA category. The middle RVA category exhibits decreases in four of the five analyses, excluding the 3-day analysis, in which there is an insignificant increase in middle RVA category flows. This further indicates a decrease in the magnitude of annual maximum flows from the PreSF to PostSF period. The median *d*-day annual flow maximum decreases for each *d*-day analyzed, with the magnitude of change indicated in **Table 4.12**. **Figure 4.22** shows that the annual maximum flow experiences greater variability PostSF, with both the highest and lowest annual flow maxima occurring in the PostSF period. This could possibly be influenced by the types of water years observed in the period of record.

Annual Maxima	Low RVA (HA)	Middle RVA (HA)	High RVA (HA)	Median Change (cfs)
1 day	0.5037	-0.1798	-0.284	-810
3 day	0.5753	0.05455	-0.642	-720
7 day	0.4321	-0.1212	-0.284	-260.1
30 day	0.4321	-0.4141	0.07407	-158.7
90 day	0.5753	-0.297	-0.2123	-65.9

Table 4.12: IHA software high flow analysis, annual d-day maxima, RVA and Hydrologic Alterations summary.

The alterations to the hydrologic regime in the PostSF period have important implications for aquatic and riparian organisms and the Deer Creek watershed as a whole. Annual *d*-day maximum flows in the PostSF period tend to be lower, with fewer flows in the middle and high RVA category and more in the low RVA category. A lower annual flow maximum has implications for the Deer Creek ecosystem, influencing the volume of nutrient exchanges between the creek and floodplain, the distribution of plant communities in floodplains, lakes, and ponds, and the duration of high flows for waste disposal and aeration of spawning beds (Richter et al. 1997; TNC 2009). The cause of this is probably Scotts Flat reservoir, which captures flows from one quarter of the watershed until the reservoir fills. In wet years Scotts Flat reservoir can fill as early as November, while in dry years Scotts Flat will not fill until as late as March, and sometimes only then with significant imports from the South Yuba (S. Sindt, pers. comm.). This can result in a reduction in the annual flow maxima downstream of the reservoir and shows the need for working with NID to manage flood flows for the benefit of the Deer Creek watershed.

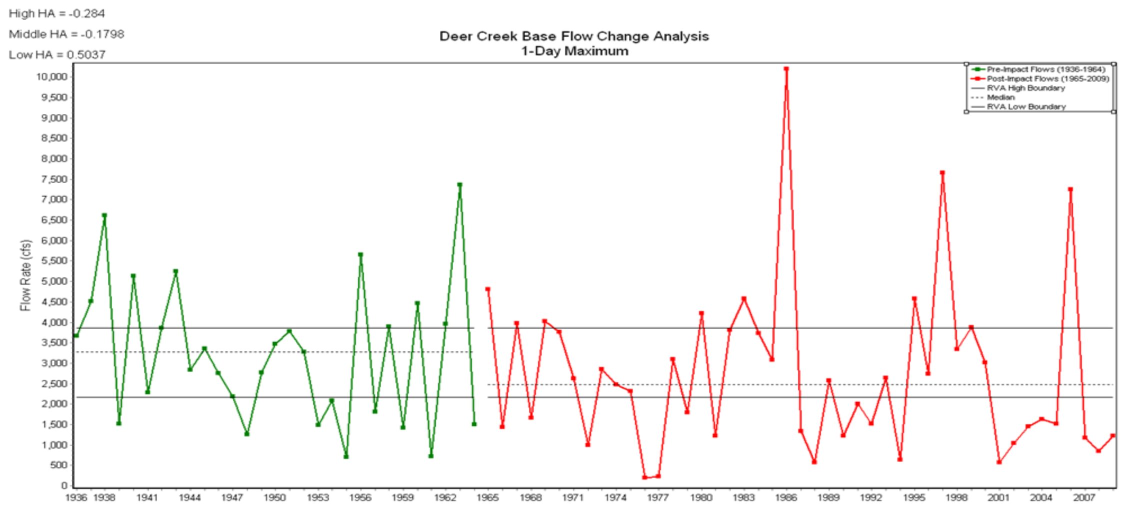

Figure 4.22: IHA software maximum flow analysis, annual 1-day maximum plot.

Method 2. High Flow Pulses: Frequency and Duration

The IHA software calculates the frequency and duration of high flow pulses during each water year. High flow pulses are classified as flows above the 75th percentile of flows for the entire period of record, with the frequency being the number (count) of high flow pulses in each water year, and high flow pulse duration the median length of high flow pulses in days (TNC 2009). The two-period high flow pulse analysis allows for investigation into the Scotts Flat reservoir upgrade and base flow change, and whether these have impacted the frequency and duration of high flow pulses at the USGS Smartsville gauge near the Deer Creek watershed outlet. The duration and frequency of flow pulses can influence many factors that are important to aquatic ecosystem function and health, including (TNC 2009):

· Frequency and magnitude of soil moisture stress for plants
· Frequency and duration of anaerobic stress for plants
· Availability of floodplain habitats for aquatic organisms
· Nutrient and organic matter exchanges between river and floodplain
· Soil mineral availability
· Access for water birds to feeding, resting, reproduction sites
· Bedload transport, channel sediment textures, and duration of substrate disturbance

Figure 4.23 provides results of the high pulse frequency (count) analysis, with results from the high pulse duration analysis provided in **Figure 4.24**. The results of the high flow pulse analysis indicate that both the frequency and duration of high flow pulses have been altered from the PreSF to PostSF period. The high flow pulse analysis suggests a slight increase in the frequency of high flow pulse events from the PreSF to PostSF period, and a decrease in the duration of high flow pulses in the PostSF period. There is considerable variability in both high pulse count datasets (**Figure 4.23**), which in part can be attributed to year-to-year variability in weather and climate. The frequency of high flow pulses increases slightly from the PreSF to PostSF period, with the PostSF median increasing from seven to eight high pulses annually. This increase is also evidenced by the RVA analysis with an increase in the High Hydrologic Alteration category (0.2889) and decreases in the Middle (-0.06263) and Low (-0.2132) categories. This indicates that the frequency of high pulses in Deer Creek has increased slightly since 1964 and could have implications for the watershed including an increased frequency of bedload transport, substrate and plant disturbance, and anaerobic stress for plants (TNC 2009).

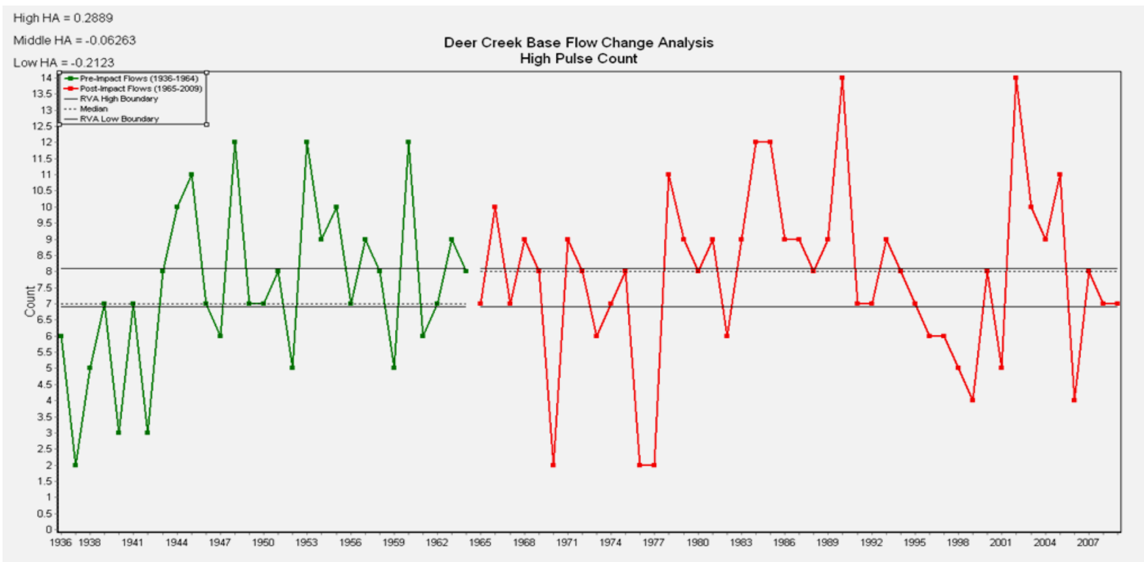

Figure 4.23: IHA software high flow pulse analysis, high pulse count (frequency) plot.

The results of the high flow pulse duration analysis in **Figure 4.24** indicate differences between the PreSF and PostSF periods. The PostSF median shifts lower by approximately 1 day, to near the PreSF low RVA boundary. In the PreSF period there are two years with high pulses of extended duration (> 50 days), which is not the case in the PostSF period with the greatest high pulse duration being forty-five days. The decreased high pulse duration in the PostSF period is further evidenced by a decrease in the High (-0.4988) and Middle (-0.1254) Hydrologic Alteration categories and a large increase in the low (1.041) category. The decrease in extended duration high flow pulses can have numerous implications for aquatic ecosystems including a reduced duration of plant and substrate inundation, a reduction in the extent of nutrient and organic matter exchange between the creek and floodplain, and a reduction in the availability of floodplain habitats (TNC 2009).

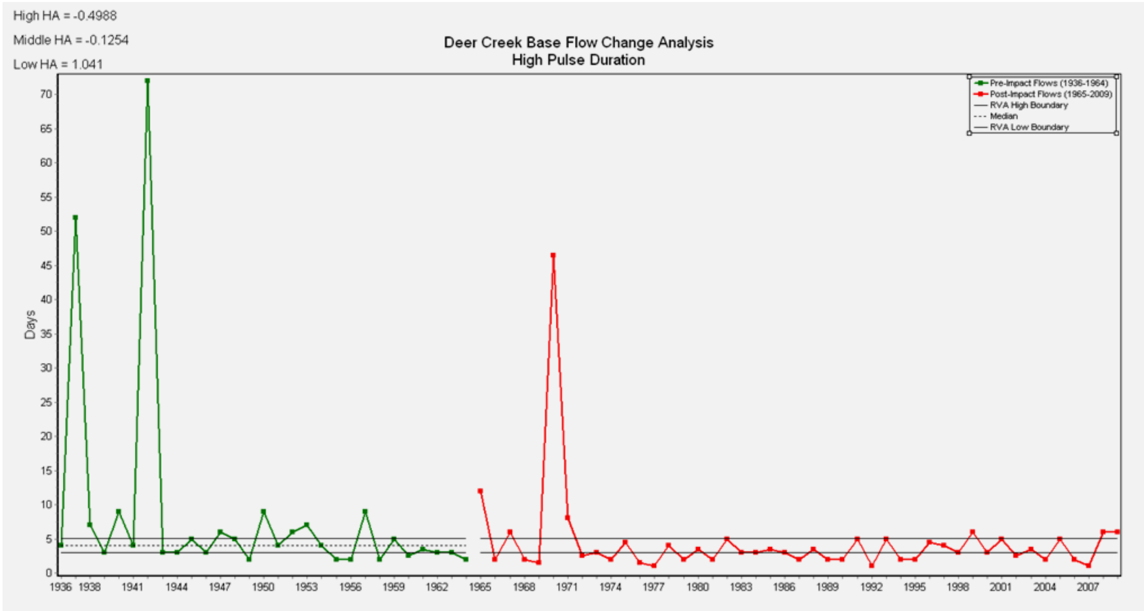

Figure 4.24: IHA software high flow pulse analysis, high pulse duration plot.

Method 3: Julian Date of Annual Maximum Flow

The IHA software analyzes the mean daily flow record to determine the Julian day of the annual maximum flow. The Julian day is used because this method simplifies calculating statistics for timing variables. Julian dates represent calendar dates by integer values, with 1 corresponding to January 1 and 366 to December 31. There are always 366 Julian days in a year, regardless of whether it is a leap year or not, with February 29 corresponding to Julian day 60 in leap years (TNC 2009). This ensures that each calendar date is represented by the same Julian date in each year. The Julian date analysis is important because the timing of annual extreme water conditions can influence many factors important to aquatic organisms, including (TNC 2009):

· Compatibility with life cycles of organisms
· Predictability/avoidability of stress for organisms
· Access to special habitats during reproduction or to avoid predation
· Spawning cues for migratory fish
· Evolution of life history strategies, behavioral mechanisms

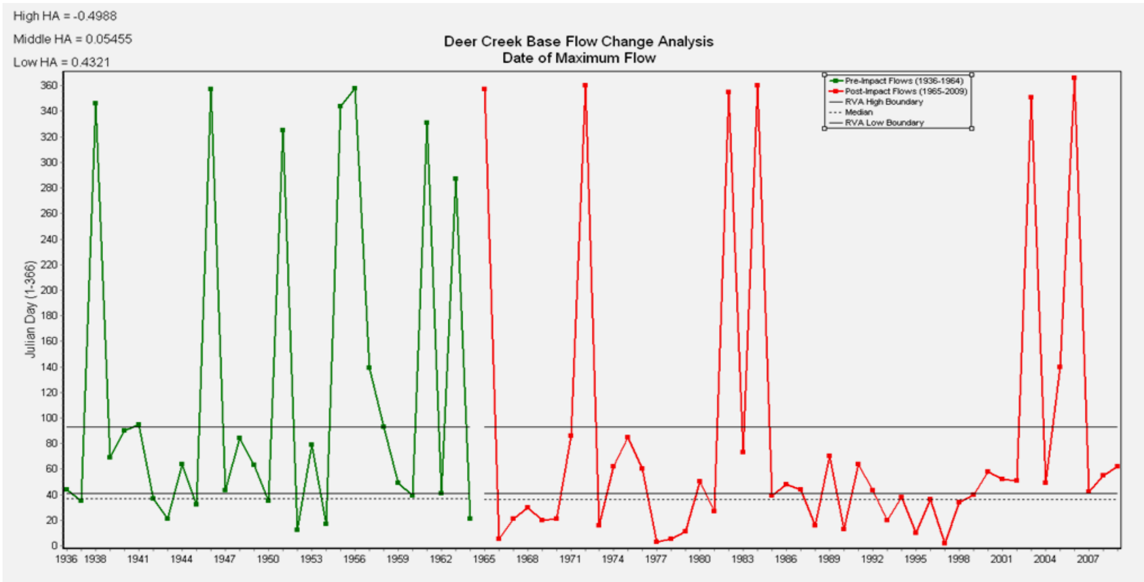

Figure 4.25: IHA software Julian date analysis, plot of the date of annual maximum flow.

The results of the IHA software Julian data analysis are displayed in **Figure 4.25** and indicate that there have not been significant alterations to the timing of the annual maximum daily flow from the PreSF to PostSF period. The PreSF and PostSF medians are very similar, with the PostSF median shifted earlier in the water year by one day. There is an increase in the low RVA category and decrease in the high RVA category, indicating a shift in the annual flow maximum towards earlier in the water year. Further investigation should be conducted into alterations to the date of the annual flow maximum using additional methods, and as more data becomes available.

Methods 4a – 4c: Indicators of Hydrologic Alteration Environmental Flow Components Analysis

The IHA software allows for analysis of five different types of Environmental Flow Components (EFC) including extreme low flows, low flows, high flow pulses, small floods, and large floods. Three of the EFC are relevant for the IHA High Flows analysis and include high flow pulses, small floods, and large floods. EFC are based upon the fact that hydrographs can be separated into a set of hydrographic patterns, patterns that repeat themselves and are ecologically relevant. The spectrum of flow conditions, represented by the five types of flow events, should be maintained in order to sustain the health and function of the aquatic ecosystem. Hydrologic parameters calculated in the EFC analysis include the magnitude of annual peak flow, duration of the flow, frequency of EFC type, timing (Julian day) of the event, and rise and fall rates associated with the EFC type.

EFC analysis utilizes mean daily stream flow data from the USGS gauge on Deer Creek. The user calibrates the software to determine the thresholds for high flow pulses, small floods, and large floods. High flows are defined as flows that exceed 75% of daily flows for the period, with flows below 25% of daily flows for the period defined as low or base flows. Between these two flow levels a high flow begins when flow increases by more than 75% per day and will end when flow decreases by less than 20% per day. Small flood events are defined as an initial high flow with a peak flow greater than the 2-year return interval, with large floods greater than the 10-year return interval. These return intervals are based on mean daily flow data and not instantaneous peak flows, as was the case with the flood frequency analysis. The EFC parameters do not permit using the RVA analysis method, but PreSF and PostSF medians and interquartile ranges (25^{th} and 75^{th} percentiles) can be compared in order to assess alteration to the hydrologic regime.

4a. High Flow Pulse

During rainstorms or periods of snowmelt Deer Creek will often rise above its low-flow or base flow level. For the EFC analysis, high flow pulses include any water rises that do not overtop the channel banks ($Q <$ bankfull), up to the 2-yr return interval. Pulses of this nature provide an important and necessary disruption in low flow periods, with brief pulses of fresh water providing much-needed relief from stressors such as high water temperatures, high specific conductivity, high nutrient concentrations, and low dissolved oxygen conditions, which are common in low flow periods. Additionally high flow pulses deliver organic material and food resources to support the aquatic food web, provide fish and other aquatic organisms increased access to habitat, and help to flush the system of fine sediments and algae that can reduce the quality of available habitat (TNC 2009). High pulses can have the following influences on the aquatic ecosystem (TNC 2009):

· Shape physical character of river channel, including pools, riffles
· Determine size of streambed substrates (sand, gravel, cobble)
· Prevent riparian vegetation from encroaching into channel
· Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants
· Aerate eggs in spawning gravels, prevent siltation
· Maintain suitable salinity conditions in estuaries

The results of the High Flow Pulse analysis indicate that there have been slight alterations to the high flow pulse regime from the PreSF to PostSF period, through changes to the high flow pulse peak, duration, frequency, timing, and rise and fall rates. **Table 4.13** summarizes changes to the high flow pulse EFC.

Parameter	PostSF Median	PostSF Interquartile Range
Peak	Median decrease (~40 cfs)	Slightly larger interquartile range, shifted down on plot.
Duration	Same median (5 days)	Slightly smaller interquartile range, with 75th percentile shifted down on plot.
Frequency	Median increases, from 9 to 11 times annually.	Similar interquartile range, shifted up on plot with median.
Rise Rate	Median decrease (~10 cfs)	Similar interquartile range, shifted down on plot with median.
Fall Rate	Slight median decrease on plot (slight fall rate increase (~2 cfs)	Larger interquartile range.
Timing	Median shifts earlier in water year by 35 days.	Smaller interquartile range, 25th and 75th percentiles shifted earlier in water year.

Table 4.13: Summary of the EFC High Flow Pulse analysis, with hydrologic parameters, changes to the PostSF Median, and changes to the PostSF interquartile range.

Table 4.13 depicts changes from the PreSF to PostSF period, with a brief discussion of how the PostSF median and interquartile range has been altered for each hydrologic parameter. The annual high flow peak magnitude has been altered, with a median decrease of 40.0 cfs in the PostSF period and an interquartile range shifted lower on the plot. This indicates that high flow pulses were greater during the PreSF period with a similar range of variability in the PostSF period. The duration with which high flow pulses persist has been minimally altered, with no change to the PostSF median and a slight decrease in the size of the interquartile range. The frequency with which high flow pulses occur has changed, with a slight median increase in the PostSF period and a similar interquartile size shifted up on the plot with the median. This indicates that there is a greater frequency of high flow pulses in the PostSF period. The high flow pulse rise rate has been altered, with a median decrease of 10 cfs in the PostSF period and a similar interquartile range shifted down on the plot with the median. This indicates a slight decrease in the rise rate for high flow pulses. The high flow pulse fall rate has been minimally altered, with a slight median decrease of 2 cfs in the PostSF period but a larger interquartile range. This indicates a slight increase in the fall rate for high flow pulses, with much more variability in fall rates in the PostSF period. The timing plot indicates a 35-day shift in the median Julian date for peak high flow pulse to earlier in the water year, and a smaller interquartile range that is shifted earlier in the water year. The 35-day shift is a significant alteration from the PreSF to PostSF period. The median high flow pulse peak occurred in late January or early February in the PreSF period, and in late December in the PostSF period. This smaller interquartile range indicates that there is less variability in the timing of the high flow pulse peak.

The analysis indicates that the peak, frequency, timing, and rise rate of high flow pulses are the most impacted parameters of the high pulse regime. The peak high flow pulse has decreased in the PostSF period, possibly due to dams attenuating stream flows by capturing runoff for storage. The frequency analysis indicates that while the magnitude of high flow pulses has decreased, the pulses are occurring more frequently. This could be attributed to many factors, including the presence of more wet and above normal water years in the PostSF period analysis, leading to more frequent high flow pulses in Deer Creek. It is difficult to tell whether the timing shift of over a month earlier in the water year, with less variability in the high flow pulse timing, is as a result of Scotts Flat reservoir and NID water management. It is possible that drawdown releases in the PostSF period by Lake Wildwood reservoir during October has influenced the shift to the timing of high flow pulses, with high flow pulses occurring earlier in the water year in the PostSF period. The slight decrease in the high pulse rise rate in the PostSF period could potentially be attributed to dams attenuating stream flows, with increased surface storage in the watershed leading to a less flashy hydrologic regime, but further investigation is needed to determine whether these impacts are significant.

4b. Small Floods

During floods, fish and other mobile aquatic organisms are able to access increased habitat, including floodplains, flooded wetlands, secondary channels, backwaters, sloughs, and shallow flooded areas (TNC 2009). These often-inaccessible areas provide substantial food resources, with shallow flooded areas often being warmer than the main channel and full of nutrients and insects to fuel rapid aquatic organism growth (TNC 2009). For this analysis small floods include river rises that overtop the bankfull channel, with an approximate return interval of two years, but do not include the largest, most extreme and infrequent flood events. As with the high flow pulse analysis, mean daily flow data are used in this analysis, and therefore the analysis does not represent peak small flood flows in the watershed. The IHA Tutorial lists the following influences that small and large floods can have on aquatic ecosystems (TNC 2009):

· Provide migration and spawning cues for fish
· Trigger new phase in life cycle (i.e. insects)
· Enable fish to spawn in floodplain, provide nursery area for juvenile fish
· Provide new feeding opportunities for fish, waterfowl
· Recharge floodplain water table
· Maintain diversity in floodplain forest types through prolonged inundation (i.e. different plant species have different tolerances)
· Control distribution and abundance of plants on floodplain

· Deposit nutrients on floodplain
· Maintain balance of species in aquatic and riparian communities
· Create sites for recruitment of colonizing plants
· Shape physical habitats of floodplain
· Deposit gravel and cobbles in spawning areas
· Flush organic materials (food) and woody debris (habitat structures) into channel
· Purge invasive, introduced species from aquatic and riparian communities
· Disburse seeds and fruits of riparian plants
· Drive lateral movement of river channel, forming new habitats (secondary channels, oxbow lakes)
· Provide plant seedlings with prolonged access to soil moisture

The results of the small floods analysis (**Table 4.14**) indicate that the hydrologic regime has potentially been altered from the PreSF to PostSF period, through changes to the small flood peak, timing, and rise and fall rates. Each of these plots is somewhat difficult to draw strong conclusions from, as there are not many data points, some plots are skewed (frequency plot), and some of the data do not make sense (duration plot). The duration and frequency analysis results are questionable because of the extended duration of small flood events calculated in the analysis, and because the years in which small floods do not occur skew the frequency analysis. **Table 4.14** summarizes alterations to the small floods regime, as indicated by the EFC analysis results.

Parameter	PostSF Median	PostSF Interquartile Range
Peak	Median increase (~750 cfs).	Similar interquartile range, shifted up on plot with median.
Duration	Unable to interpret.	Unable to interpret.
Frequency	Unable to interpret, data skewed by zero years.	Unable to interpret, data skewed by zero years.
Rise Rate	Median decrease (~100 cfs)	Smaller interquartile range, shifted down on plot with median.
Fall Rate	Fall rate median decrease (~80 cfs)	Significantly smaller interquartile range, shifted up on plot with median.
Timing	Median shifts earlier in water year by 15 days.	Larger interquartile range, shifted earlier in water year.

Table 4.14: Summary of the IHA EFC Small Flood analysis, with the hydrologic parameters, changes to the PostSF median, and changes to the PostSF interquartile range.

Table 4.14 summarizes changes from the PreSF to PostSF period, with a brief discussion of how the PostSF median and interquartile range has been altered for each hydrologic parameter. The annual small flood peak flow has been altered, with a median increase of 750 cfs in the PostSF period and a smaller interquartile range shifted up on the plot with the median. This indicates that during the PostSF period the magnitude of small flood peaks is potentially greater and there is less variability in small flood flows. The duration plot is difficult to interpret and therefore no assessment of hydrologic alteration was made using this parameter.

The frequency plot is also difficult to interpret, due to the dataset being skewed by zero years. Despite the data being skewed by zero years, it is evident that small floods were more frequent in the PreSF period based upon the number of occurrences in each period of record. Additionally there is only one year in which small floods occurred twice, which is in the PreSF period.

The small flood rise rate has been altered with a median decrease of 100 cfs in the PostSF period and a smaller interquartile range that is shifted down on the plot with the median. This indicates that the rise rate for small floods was greater in the PreSF period and that there is less variability in small flood rise rates in the PostSF period. This could potentially be attributed to reservoirs attenuating small flood flows, leading to a less flashy hydrologic regime and slower rise rates in the PostSF period. The small flood fall rate has been altered, with a median increase of 80 cfs on the plot in the PostSF period and a significantly smaller interquartile range. This indicates that the small flood fall rate was greater in the PreSF period and that there is much less variation in small flood fall rates in the PostSF period. As with the rise rate, this could be attributed to reservoirs adding additional surface water storage capacity in the watershed, with fall rates reduced due to flow contributions stored behind reservoirs. The timing results indicate that small floods have been shifted earlier in the water year by approximately fifteen days, with more variability in the timing of small flood flows in the PostSF period.

4c. Large Floods

During large floods the biological and physical structure of a river and its floodplain are typically reorganized. Large floods can flush away many aquatic and riparian organisms, potentially depleting some populations while creating new competitive advantages for other organisms. Large floods are also important in forming key habitats including floodplains and wetlands. The IHA tutorial lists influences that small and large floods can have on aquatic ecosystems. These are provided above in the Small Floods section.

The results of the IHA EFC large floods analysis indicate that the hydrologic regime has potentially been altered, but definitive conclusions are difficult to make due to the small population of large flood events in both the PreSF and PostSF periods.

Indicators of Hydrologic Alteration – Low Flows

The IHA software was used to conduct a variety of analyses aimed at characterizing alterations to the low flow regime. Annual minima flow analysis was used to analyze changes to the magnitude and duration of annual extreme water conditions. Low pulse analysis was employed to determine the frequency and duration of low pulse events and how these have been altered by reservoir development. The Julian date of the annual minimum flow was calculated to determine the timing of annual extreme water conditions and how water management has shifted the timing. Monthly low flow analysis was used to investigate changes to the magnitude of monthly water conditions. Extreme low flow analysis was used to investigate how most critical low flows have been altered.

The IHA software calculated a variety of parameters that are applicable to the low flow analysis. This included analysis of annual minimum flows, low flow pulses, Julian date of annual minimum flows, monthly low flows, and extreme low flow conditions. Two-period analysis was conducted for each of these parameters, for 1935-1964 and 1965-2009, to investigate alterations to the hydrologic regime through reservoir development and water management. Annual minimum flows, low flow pulses, and the Julian date of annual minimum flows were evaluated using the Range of Variability Approach (RVA), to assess the degree of hydrologic alteration to each parameter. The monthly low flows and extreme low flows are part of the Environmental Flow Components (EFC) analysis and therefore do not allow for the RVA to assessing hydrologic alteration. For these methods hydrologic alteration was assessed through changes to the 25th, 50th (median), and 75th percentiles from the PreSF to PostSF period.

Method 1. Annual Minima Flow Analysis

The IHA software calculates the magnitude and duration of annual extreme water conditions using the 1, 3, 7, 30, and 90-day means. Comparing these hydrologic parameters for two time periods allows for analysis of how the Scotts Flat upgrade has altered the magnitude and duration of the annual minima *d*-day flows. The magnitude and duration of annual minimum flows can have the following ecosystem influences:
· Balance of competitive, ruderal, and stress- tolerant organisms
· Structuring of aquatic ecosystems by abiotic vs. biotic factors
· Soil moisture stress in plants
· Dehydration in animals
· Anaerobic stress in plants
· Duration of stressful conditions such as low oxygen and concentrated chemicals in aquatic environments
· Distribution of plant communities in lakes, ponds, floodplains

Results of the IHA annual *d*-day minima analysis indicate that the magnitude and duration of annual minimum flows have been altered from PreSF to PostSF. For each of the 1, 3, 7, 30, and 90 day averages the PostSF *d*-day minimum median flow is greater than in the PreSF period. **Table 4.15** summarizes the degree of Hydrologic Alteration (HA), with a plot of the 1-day annual minimum provided in **Figure 4.26**. An in depth description of the RVA analysis and methods for calculating the degree of Hydrologic Alteration can be found at the beginning of the IHA section, as well as in TNC (2009).

Annual Minima	Low HA	Middle HA	High HA
1 day	-0.5704	0.8162	-0.4272
3 day	-0.5704	0.7576	-0.3556
7 day	-0.4988	0.5818	-0.2123
30 day	-0.3556	0.2889	0.002469
90 day	-0.1407	0.05455	0.07407

Table 4.15: Annual d-day minima, Hydrologic Alterations (HA) summary.

Table 4.15 indicates that there have been changes to the annual flow minima, for each of the *d*-days analyzed. For each *d*-day analysis in the PostSF period there is a decrease in low RVA category flows, indicating that in the PostSF period there is a lower probability of experiencing flows in the PreSF low range. For each *d*-day analysis in the PostSF period there is an increase in the Middle RVA category, indicating that in the PostSF period there is a greater chance of experiencing flows in the PreSF middle range than historically was observed. For the 1 (**Figure 4.26**), 3, and 7 day average annual flow minima in the PostSF period there is a decrease in the High RVA category, indicating that in the PostSF period there is less chance of experiencing flows in the High RVA category than historically was observed. For the 30 and 90-day analysis hydrologic alteration is not significant in the High RVA category.

The changes observed to the hydrologic regime in the PostSF period have important implications for aquatic and riparian organisms. Annual *d*-day minimum flows in the PostSF period tend to fall within the PreSF RVA boundaries, with fewer points falling above and below the high and low RVA. The decrease in low and high RVA category *d*-day flows combined with the increase in middle RVA category flows in the PostSF period points to less variability in each annual *d*-day minimum. In addition to experiencing less variability annual minimum flows have a tendency to be higher in the PostSF period, which confirms the results of the previous two-period low flow frequency analysis. This slight increase could be attributed to discharges from the Lake Wildwood reservoir WWTP in the PostSF period, contributing constant flow to lower Deer Creek and influencing the low flow record. In addition, it is possible that NID system losses are greater in the PostSF period than the PreSF period. System losses could be attributed to leaking infrastructure (canals, diversion points) or over-estimating system demand and subsequent water deliveries. A third potential source of water could be return flows from agricultural and ranching properties that are downstream of NID canals and diversion points, as NID has no ability to reclaim the water.

In general the alterations to the annual flow minima are minor, with the median annual flow in the PostSF period less than 0.5 cfs greater than in the PreSF period for each *d*-day analysis. This is a much different result from the annual flow maximum analysis, where the peak flow regime has been drastically altered. Although the alterations to the annual flow minimum have been minor, this analysis suggests that the 5.0 cfs or natural in-stream flow water rights requirement is not being achieved at the USGS gauge, with only the 90-d minimum resulting in flows near the 5.0 cfs level. This results in low flow conditions, often concentrated with wastewater effluent, leading to unnatural high temperatures, excessive algae blooms, and pH swings, all of which impact aquatic organisms that inhabit lower Deer Creek including macroinvertebrates and threatened and endangered fish species such as Chinook salmon and steelhead trout. Efforts should be undertaken to work with NID, Lake Wildwood Association, and the State Division of Water Rights to ensure the 5.0 cfs or natural flow allotment achieved downstream of Lake Wildwood reservoir.

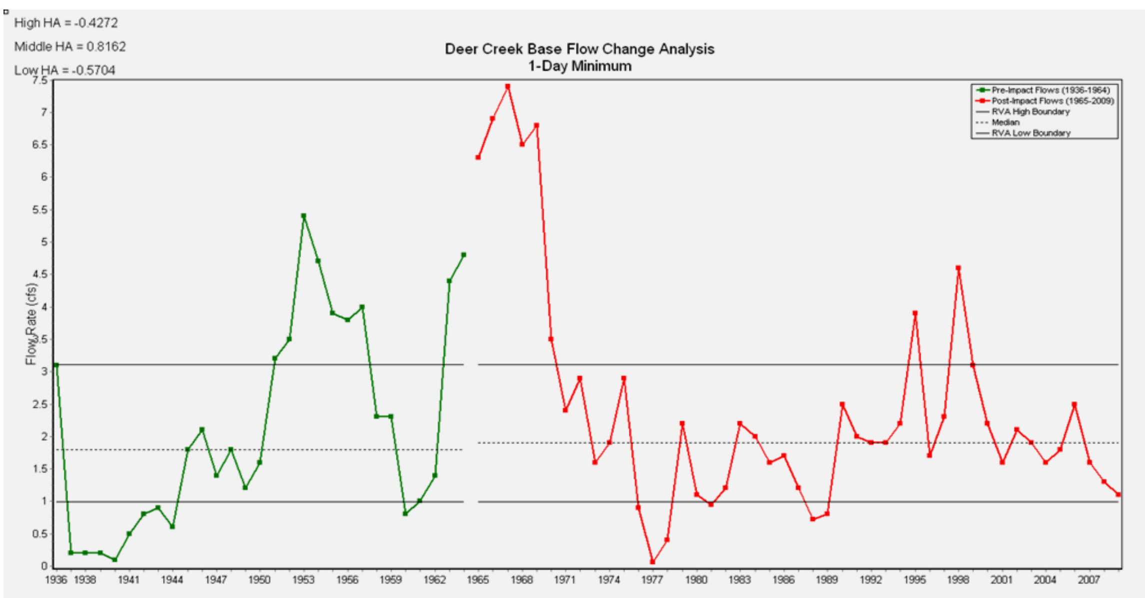

Figure 4.26: IHA software minimum flow analysis, annual 1-day minima plot.

<u>Method 2. Low Pulses: Frequency and Duration</u>

The IHA software calculates the frequency and duration of low pulses during each water year. Low pulses are classified as flows below the 25th percentile of flows for the entire period of record, with the frequency being the number (count) of low flow pulses in each water year, and low flow pulse duration the median length of low flow pulses in days. The low pulse analysis allows investigation into the changes in base flow and whether this has impacted the frequency and duration of low flow pulses in Deer Creek. The duration and frequency can influence many factors that are important to aquatic ecosystem function and health, including (TNC 2009):

· Frequency and magnitude of soil moisture stress for plants

· Frequency and duration of anaerobic stress for plants
· Soil mineral availability
· Access for water birds to feeding, resting, reproduction sites

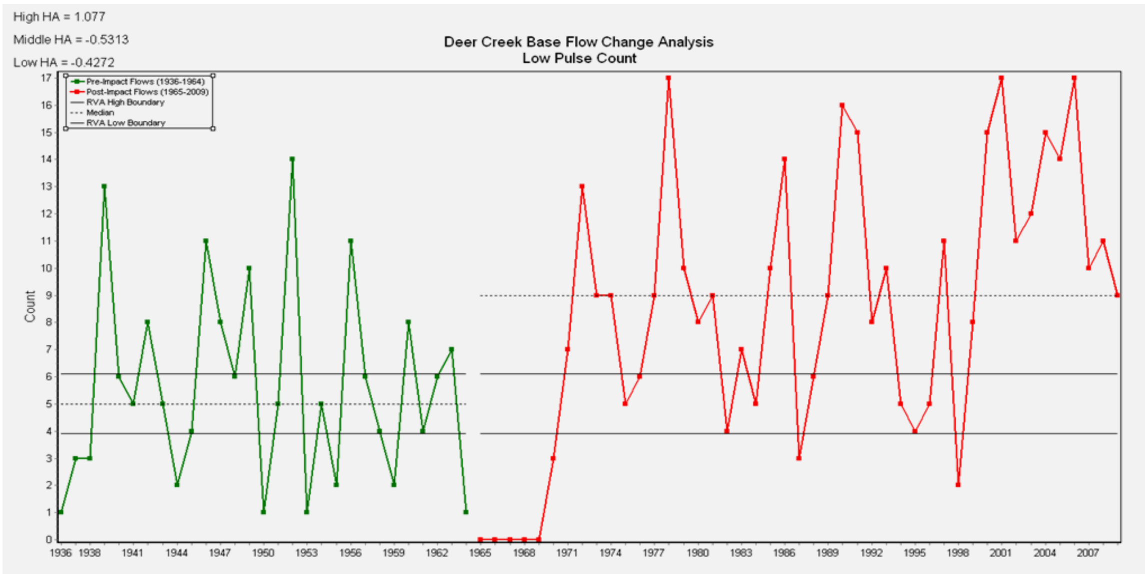

Figure 4.27: IHA software low flow pulse analysis, low pulse count (frequency) plot.

The results of low pulse analysis (**Figure 4.27**) indicate that the change in base flow associated with the upgrade of Scotts Flat reservoir has altered the frequency and duration of low flow pulses in Deer Creek downstream of Lake Wildwood reservoir. There is considerable variability in both low pulse count datasets, likely influenced by changes in weather and climate. The frequency of low pulses increases from the PreSF to PostSF period, with the PostSF median falling above and outside the PreSF RVA boundaries. There were five years of no low flow pulses after upgrading Scotts Flat reservoir, from 1965 to 1969, with low flow pulses increasing in frequency after the completion of Lake Wildwood reservoir in 1970. The median in the PreSF period is five with RVA boundaries at four and six, with the median in the PostSF period at nine. There is an increase in the High Hydrologic Alteration category (+1.077) and decreases in the Middle and Low categories. This indicates that the frequency with which low pulses have occurred in Deer Creek has increased since the upgrade of Scotts Flat, with low pulses being more frequent after 1964 and particularly 1970. This has important implications for aquatic organisms as an increase in low flow pulses could lead to a decrease in the frequency that aquatic habitat is available, reduce surface water availability for aquatic and terrestrial organisms, and cause increased stress on aquatic organisms through increased frequency of low flows that concentrate pollutants and increase water temperature.

The low pulse duration analysis (**Figure 4.28**) also indicates differences between the PreSF and PostSF periods. The PreSF and PostSF medians are the same, with the PostSF median falling within the PreSF RVA boundaries. In the PreSF period there were many years with low flow pulses of extended duration (>20 days) and no years without a low flow pulse, which was not the case in the PostSF period. In the PostSF period the longest duration low flow pulse was seventeen days and there were five years with no low flow pulses, which is further evidenced by the decrease in the High Hydrologic Alteration category (-.7852) and slight increase in the Middle and Low categories. The duration of low flow pulses in the PostSF period was highly clustered around the median, generally within the RVA boundaries, or just above the high or below the low RVA boundaries. The decrease in extended duration low flow pulses can have numerous implications for aquatic organisms and ecosystems as there is a reduced duration of stressful aquatic conditions. However, this could be partially mitigated by the increased frequency of low flow pulses in the PostSF period.

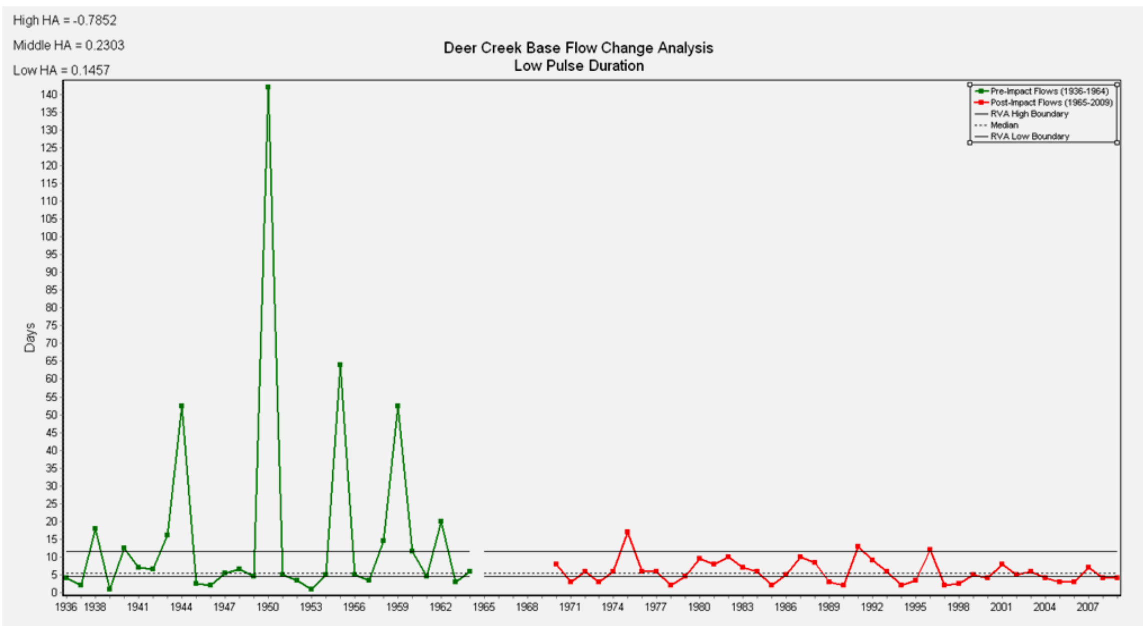

Figure 4.28: IHA software low flow pulse analysis, low pulse duration plot.

<u>Method 3. Julian Date of Annual Minimum Flow</u>

The IHA software analyzes the mean daily flow record to determine the Julian day of the annual minimum flow. The Julian day is used because this method simplifies calculating statistics for timing variables. Julian dates represent calendar dates by integer values, with 1 corresponding to January 1 and 366 to December 31. There are always 366 Julian days in a year, regardless of whether it is a leap year or not, with February 29 corresponding to Julian day 60 in leap years. This ensures that each calendar date is represented by the same Julian date in each year. The timing of annual extreme water conditions can influence many factors important to aquatic organisms. The IHA tutorial lists the following ecosystem influences that can be influenced by the timing of annual extreme water conditions, with results of the date of minimum flow analysis provided in **Figure 4.29**:

· Compatibility with life cycles of organisms
· Predictability/avoidability of stress for organisms
· Access to special habitats during reproduction or to avoid predation
· Evolution of life history strategies, behavioral mechanisms

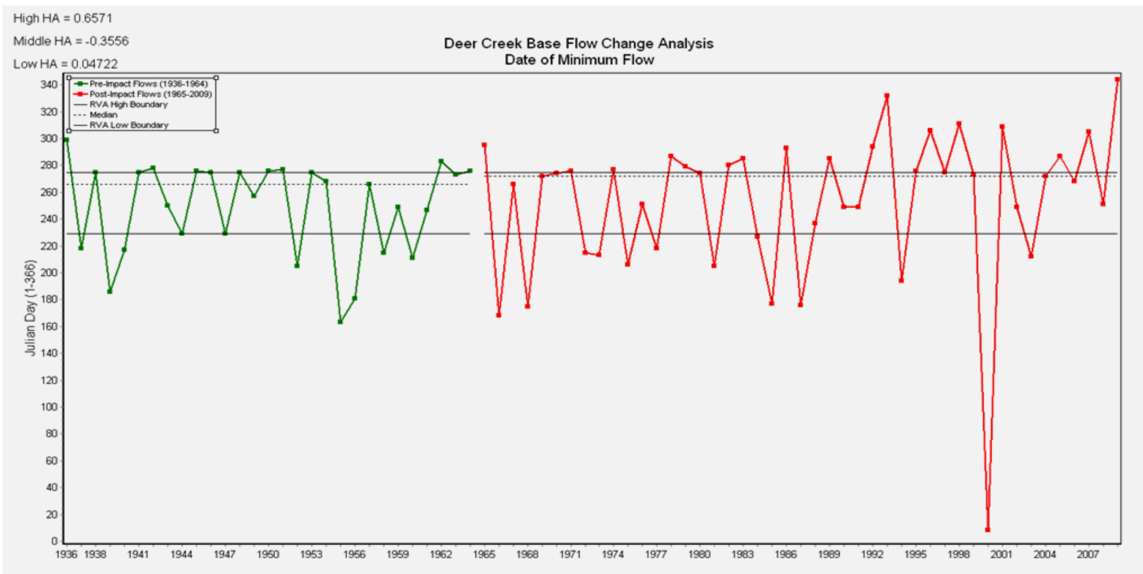

Figure 4.29: IHA software Julian date analysis, plot of the date of annual minimum flow.

The results of the Julian date analysis in **Figure 4.29** indicate that the timing of the annual minimum flow has been altered since the upgrade of Scotts Flat Reservoir and subsequent base flow change. In the PreSF period the Julian date of annual minimum flow falls between day 160-300 (June 8-October 26), with a median of 265 (September 21) and low and high RVA boundaries of 230 (August 17) and 275 (October 1) respectively. In the PostSF period the median (day 273, September 29) is shifted later in the year by twelve days. There is greater variability in the PostSF period with an increase in the High RVA category (0.6571) compared to historical observations. In the PostSF period there is a slight increase in the low RVA category (0.04722), with a decrease in the middle RVA category (-0.3556). In the PostSF period there is one instance (water year 2000) in which the annual minimum flow occurs prior to Julian date 160 (day 5), which does not occur elsewhere in the entire period of record.

The results indicate that there is a greater chance of the annual minimum flow occurring later in the calendar year and on a date that is outside of the PreSF range of variability. The median shift in the timing of the annual flow minimum to twelve days later in the year is potentially significant, although both the PreSF and PostSF period annual minimum flows occur near the beginning of the water year (October 1, day 275), which is to be expected for the Deer Creek watershed. It is possible that the occurrence of the low flow minimum later in the year in the PostSF period is related to the end of the irrigation season, with NID serving more users in the PostSF period and thus delivering more water using Deer Creek. In addition irrigation flows are often not reduced until after October 15, which could potentially shift the annual minimum flow later in the water year. When the irrigation flows are reduced, NID begins capturing water, and system losses from delivery and runoff from properties decrease, potentially leading to less water in the creek after October 15.

Method 4. Environmental Flow Components – Monthly Low Flows Analysis

The IHA software EFC analysis determines the magnitude of monthly water conditions by calculating the median low flow value for each month during the calendar year for each period of record. The user determines how low flows are classified with the default for low flows beginning at the 25th percentile of the median daily flow value for the period of record. After calibrating the software it was determined that flows less than the 25th percentile should be classified as low flows, as is the IHA software default. The magnitude of monthly water conditions can have the following influences on the ecosystem (TNC 2009):

· Provide adequate habitat for aquatic organisms
· Maintain suitable water temperatures, dissolved oxygen, and water chemistry
· Maintain water table levels in floodplain, soil moisture for plants
· Provide drinking water for terrestrial animals
· Keep fish and amphibian eggs suspended
· Enable fish to move to feeding and spawning areas
· Support hyporheic organisms (living in saturated sediments)

Month	PostSF Median	PostSF Interquartile Range
October	Lower median low flow.	Smaller interquartile range, shifted down on plot.
November	Lower median, shifted below 25th percentile.	Smaller interquartile range, PostSF 75th percentile at PreSF median.
December	Lower median-near PreSF 25th percentile.	Similar interquartile range, shifted down on plot.
January	Lower median.	Smaller interquartile range, shifted down on plot.
February	Lower median.	Larger interquartile range.
March	Lower median – near PreSF 25th percentile.	Smaller interquartile range, shifted down on plot.
April	Lower median – near PreSF 25th percentile.	Similar interquartile range, shifted down on plot. PostSF 75th percentile near PreSF median.
May	Lower median – near PreSF 25th percentile.	Similar interquartile range size, shifted down on plot.
June	Lower median – near the 25th percentile.	Smaller interquartile range, PostSF 75th percentile below PreSF median.
July	Slightly lower median.	Smaller interquartile range.
August	Slightly lower median.	Similar interquartile range, slight shift up on plot.
September	Slightly higher median.	Similar interquartile range, shifted up on plot.

Table 4.16: Summary of the IHA software EFC monthly low flows analysis, using the non-parametric method.

Table 4.16 summarizes the results of the IHA EFC monthly low flow analysis, with an example plot provided in **Figure 4.30**. The results of the monthly low flow analysis indicate that the Scotts Flat reservoir upgrade and base flow change have potentially resulted in alterations to the monthly low flow regime. In the PostSF period, every month except for September results in a lower median monthly low flow than the PreSF period. This indicates that the hydrologic regime has been altered and lower monthly median flows are the result, which means less water available in the creek during peak flow months in the winter and spring as well as during summer low flow months. The median monthly flow decreases are larger for the wet season months than during the dry season. This can be attributed to Scotts Flat reservoir capturing large volumes of stream flow during winter and spring months, and water management of flows during irrigation season months. In general the PostSF period interquartile ranges tend to be similar or smaller, except for February, than the PreSF period interquartile ranges. The trend in the smaller interquartile ranges suggests less variability in monthly low flows in the PostSF period when compared to PreSF, which is often the case in a managed watershed.

The EFC monthly low flow analysis indicated that for the majority of months, low flows were greater in the PreSF period compared to the PostSF period, which highlights the impacts of reservoirs and water management on the flow regime. The reduction in monthly low flows in Deer Creek results in reduced habitat availability for aquatic organisms, water availability for terrestrial animals, water table levels in the floodplain, and soil moisture for plants. In addition, particularly during the natural low-flow months of summer and early fall, a decrease in the magnitude of monthly low flows could result in increased water temperatures, decreased water quality, increased concentrations of wastewater effluent, and stranding of fish or amphibian eggs. These attributes are important to consider because there are threatened and endangered species of fish that inhabit lower Deer Creek, with flow alterations potentially decreasing the overall habitat suitability for these organisms.

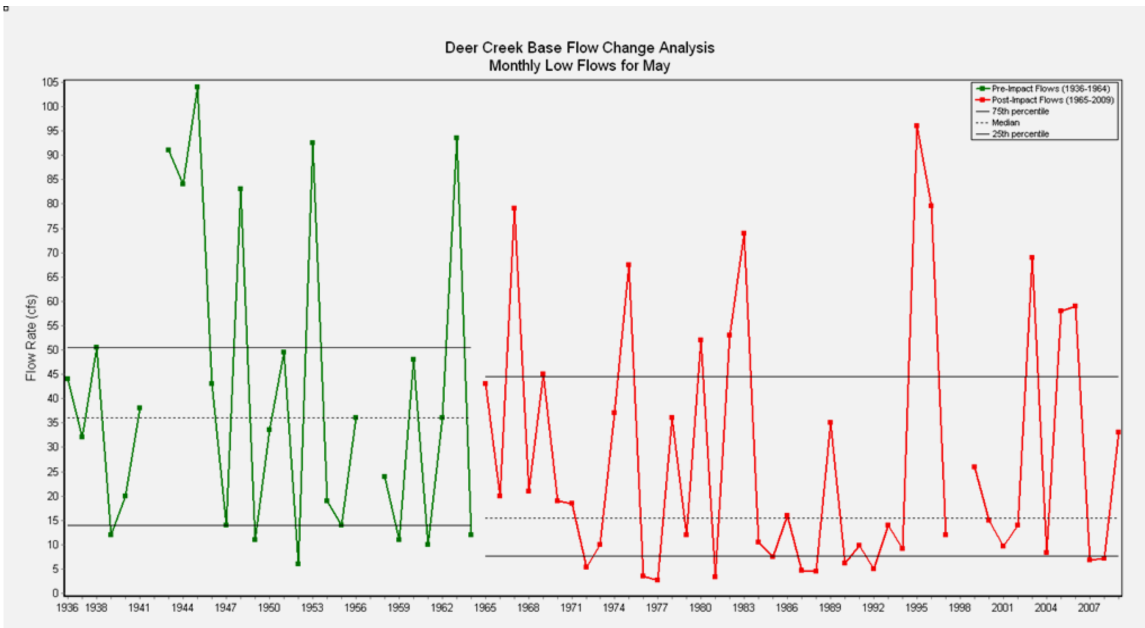

Figure 4.30: Summary plot of the IHA software EFC monthly low flows analysis, using the non-parametric method, and plotting alterations to low flows in the month of May.

<u>Method 5: Environmental Flow Components – Extreme Low Flows Analysis</u>

During droughts or certain times of the year (summer, early fall) flows drop to very low levels, which can be stressful for many aquatic organisms while providing necessary conditions for others (Richter et al. 1996; TNC 2009). Water chemistry, water temperature, and dissolved oxygen levels can become highly stressful to many organisms during extreme low flow conditions, often to the point that these conditions cause considerable mortality. Extreme low flows can also concentrate aquatic prey for some species and may be necessary to dry out low-lying floodplain areas, enabling certain species of plants to regenerate (TNC 2009). The IHA Tutorial lists the following influences that extreme low flows can have on aquatic ecosystems (TNC 2009):

· Enable recruitment of certain floodplain plant species
· Purge invasive, introduced species from aquatic and riparian communities
· Concentrate prey into limited areas to benefit predators

The IHA software EFC analysis classifies flows into multiple categories including extreme low flows, low flows, high flow pulses, small floods, and large floods. The user determines how each is classified with the default for extreme low flows set to the 10^{th} percentile of daily flows for the entire period. After calibrating the software for Deer Creek the 5^{th} percentile was determined to better represent extreme low flow conditions, with 1.4 cfs as the threshold for extreme low flows. This percentile is commonly used to represent low flow conditions (Hauer and Lamberti 1996; Richter et al. 1996; Pyrce 2004; TNC 2009). The analysis computes the median of extreme low flows for each water year. Using this setting 13 extreme low flows occurred in the PreSF period and 11 in the PostSF period. Four outputs are available for extreme low flow analysis including peak, duration, frequency, and timing of extreme low flows.

Results indicate that the base flow change in water year 1965 had a minimal impact on extreme low flows. The median for peak extreme low flows has not changed significantly from the PreSF to PostSF period, although the interquartile range is smaller in the PostSF period and shifted up on the plot, indicating less variability within the extreme low flow classification and higher extreme low flows. The lack of variability could be due to increased water management in the Deer Creek watershed, with more surface storage and water deliveries reducing the magnitude of extreme low flow fluctuations, and water deliveries and system losses leading to increased stream flows during conditions that would naturally promote extreme low flows. The median duration of extreme low flows decreased in the PostSF period, but the variability increases with more 1-day extreme low flows as well as extended duration extreme low flows ($d \geq 7$ days). This is evidenced by the increase in the interquartile range, with the 75^{th} percentile up from 4 to 11 cfs in the PostSF period. The frequency results should be interpreted with caution, as the majority of years do not have extreme low flows. This largely skews the frequency data results. The results indicate that in the PostSF period there is less variability in the frequency of annual extreme low flows, as evidenced by the 75^{th} percentile shift down on the graph from 3 to 0.5. This is largely attributed to the years with no extreme low flows, as the frequency plot clearly exhibits similar variability in the PreSF and PostSF periods. The timing of annual extreme low flows has been impacted by the base flow change, with a slight shift in the PostSF median and interquartile range to later in the year, coupled with a larger interquartile range. This matches the annual minimum flow analysis, with similar medians PreSF and PostSF, and a twelve-day shift in the annual flow minimum to later in the year during the PostSF period annual minimum flow analysis. Overall, the analysis indicates minor impacts to extreme low flows from the PreSF to PostSF period, with the frequency, duration, and timing of extreme low flows altered most in the PostSF period.

Indicators of Hydrologic Alteration – Flow Duration Curves

<u>Method 1. Annual Flow Duration Curves</u>

The IHA software uses daily mean flow data to calculate period of record FDCs for multiple time scales, including annually and monthly. Annual FDCs were generated for two periods, PreSF and PostSF, to investigate the impacts to the hydrologic regime associated with the upgrade of Scotts Flat. **Figure 4.31** plots the annual FDCs for the PreSF and PostSF periods.

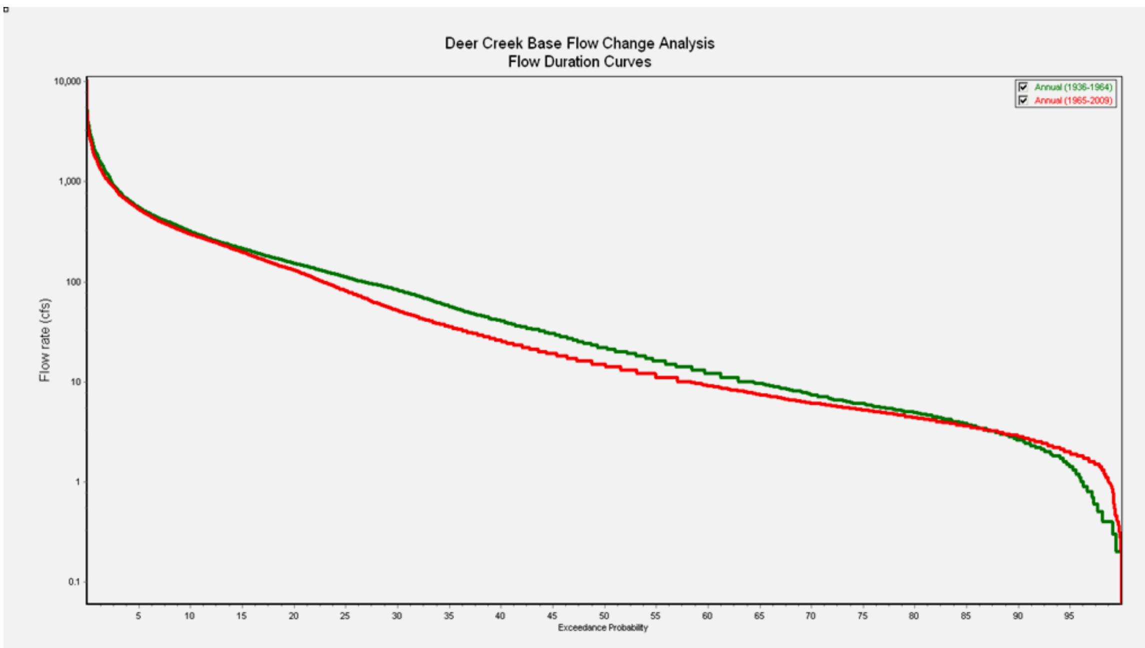

Figure 4.31: IHA software Annual Flow Duration Curves for PreSF and PostSF, with the PreSF period plotted green and the PostSF period red.

The plot in **Figure 4.31** indicates that the annual FDC has changed since water year 1965, coinciding with the upgrade of Scotts Flat. The PreSF period has a greater probability of lower discharge flows ($q_{.90} – q_{.98}$), with the exception $q_{.99} – q_{.100}$, due to critical water years and the lowest mean daily flow on record occurring PostSF. There is a greater probability of higher base and high pulse discharge flows ($q_{.15} – q_{.90}$) PreSF, with the annual curves coinciding above $q_{.15}$. These results are the same as the results of the previous FDC analysis (**Figure 4.21**), and confirm that the hydrologic regime has been altered from the PreSF to PostSF period. The results suggest a greater probability of high and base flows, above $q_{.75}$, which indicates that there is less water flowing in Deer Creek during the PostSF period than the PreSF period, at the USGS gauge near the watershed outlet. In addition, there is a greater probability of low discharge flows PreSF, with the slight increase in flow (< 1.0 cfs) potentially attributed to the Lake Wildwood reservoir WWTP, NID system losses, and runoff from ranches and farms. The WWTP began discharging into Deer Creek during the PostSF period, with NID system losses and runoff from farms and ranches increasing as more water is delivered and applied to the landscape.

Method 2. Monthly Flow Duration Curves

The IHA software generates FDCs for each month of the year, using the same algorithm as in the annual FDC analysis. Monthly FDCs are important for determining the magnitude and frequency of monthly flows, with the two period analysis providing an opportunity to investigate alterations to the hydrologic regime. Results of the monthly FDC analysis are provided in **Table 4.17**, with an example monthly FDC plot provided in **Figure 4.32**.

Month	Flow Duration Curve-Low Flows	Flow Duration Curve-Base/High Pulse Flows	Flow Duration Curve-Flood Flows
October	Similar extreme/low flows (83-99 EP).	Slightly greater PreSF base flows (57-83 EP), similar base/high pulse flows (35-57 EP).	High pulse/flood flows lower in PreSF (1-35 EP), PreSF highest flow on record (0-1 EP, Oct 1962: 11,600 cfs).
November	PreSF lower extreme low flows (96-99 EP); greater PreSF low flows (10-96 EP).	PreSF greater base/high pulse/flood flows (10-96 EP).	PreSF slightly lower large flood flows (2-10 EP), similar monthly peaks (0-2 EP).
December	PreSF lowest point overall, greater extreme/low flows (23-99 EP).	PreSF greater base/high pulse flows (23-99 EP).	PreSF/PostSF similar high pulse/small flood flows (10-23 EP), PreSF greater large flood flows (2-10 EP), PreSF/PostSF similar monthly peaks (0-2 EP).
January	PreSF greater extreme/low flows (35-99 EP).	PreSF greater base/high pulse flows (35-99 EP).	PreSF/PostSF similar small/large flood flows (7-35 EP), PreSF slightly lower (4-7 EP) flows, PreSF/PostSF similar monthly peaks (0-4 EP).
February	PreSF greater extreme/low flows (1-99 EP).	PreSF greater base/high pulse flows (1-99 EP).	PreSF greater high pulse/small flood/large flood flows (1-99 EP), PostSF greatest monthly peak.
March	PreSF greater extreme/low flows (41-99 EP).	PreSF greater base/high pulse flows (41-99 EP).	PreSF/PostSF similar small/large flood flows (5-41 EP), PreSF slightly greater monthly peaks (0-5 EP).
April	PreSF greater extreme/low flows (7-99 EP).	PreSF greater base/high pulse flows (7-99 EP).	PreSF greater small/large flood flows (7-99 EP), similar monthly peaks (0-7 EP).
May	PreSF greater extreme/low flows (12-99 EP).	PreSF greater base/high pulse flows (12-99 EP).	PreSF greater small flood flows (12-99 EP), PreSF slightly lower large flood flows (2-12 EP), PreSF/PostSF similar monthly

			peaks (0-2 EP).
June	PreSF slightly greater extreme low flows (97-99 EP), PreSF slightly lower low flows (95-97 EP), PreSF greater low flows (2-95 EP).	PreSF greater base/high pulse flows (2-95 EP).	PreSF greater small/large flood flows (2-95 EP), PreSF/PostSF similar monthly peaks (0-2 EP).
July	PreSF lower extreme/low flows (80-99 EP).	PreSF slightly lower base/high pulse flows (47-80 EP), PreSF/PostSF similar high pulse flows (0-47 EP).	PreSF/PostSF similar small flood/large flood/monthly peaks (0-47 EP).
August	PreSF lower extreme/low flows (40-99 EP).	PreSF lower base/high pulse flows (40-99 EP), PreSF/PostSF similar high pulse flows (27-40 EP).	PreSF lower flood flows, monthly peaks (0-27 EP).
September	PreSF lower extreme/low flows (0-99 EP).	PreSF lower base/high pulse flows (0-99 EP).	PreSF lower flood flows, monthly peaks (0-99 EP).

Table 4.17: Summary of IHA monthly flow duration curve analysis, comparing extreme and low flows, base and high pulse flows, and small and large flood flows.

The results of the IHA monthly FDC analysis indicate that there have been significant alterations to the majority of the monthly FDCs. Starting with the beginning of the water year in October, there is not much alteration to the FDC up to the 35th exceedance probability ($EP_{.35}$). From $EP_{.35}$ (~10 cfs) to $EP_{.01}$ (~500 cfs) the PostSF period exhibits greater flows than the PreSF period, with the highest flows above $EP_{.01}$ greater in the PreSF period. Flows are higher in the PostSF period from $EP_{.35}$ – $EP_{.01}$ due to the Lake Wildwood reservoir drawdown release in the PostSF period, which has altered the October flow duration curve by increasing the frequency, magnitude, and duration of stream flows in October. Lake Wildwood reservoir drawdown releases have ranged from 100 – 500 cfs in the past. The highest flow on record occurs in the PreSF period, in October 1962, which results in greater flows for the PreSF period. The most significant alteration to the October FDC is the increased frequency of high pulse and small flood flows as a result of the Lake Wildwood reservoir drawdown release.

For the November monthly FDC, flows were generally greater in the PreSF period than the PostSF period, except for the tail ends of the curve. The lowest stream flows occur in the PreSF period, indicating low and extreme low flows were more common during November in the PreSF period. From $EP_{.96}$ – $EP_{.10}$ the PreSF period experiences a greater probability of higher stream flows than the PostSF period, possibly because Scotts Flat reservoir captures runoff from early season stream flows, and Lake Wildwood reservoir re-fills the reservoir that has been drawn down approximately 10ft. Both of these would lead to a reduction in low flow, base, and high pulse stream flows downstream of the reservoirs at the gauging station. Above $EP_{.10}$ PreSF and PostSF flows are generally similar, with slightly lower flows observed in the PreSF period from $EP_{.10}$ – $EP_{.02}$, and overlapping curves through the peak end of the FDC. This indicates that minimal alterations have occurred to the peak flows that occur in November.

The December monthly FDC indicates that flows were greater in the PreSF period from $EP_{.99}$ – $EP_{.23}$, which suggests that December low, base, and high flow pulses were greater in the PreSF period. Above $EP_{.23}$ the PreSF and PostSF FDCs are relatively similar, with a slightly greater PreSF FDC from $EP_{.23}$ – $EP_{.02}$, and a greater peak flow in the PostSF period. The higher peak flow in the PostSF period of record is a result of the highest stream flow in the period of record occurring December 31, 2005. In general, small and large flood flows are quite similar in December, but alterations have occurred to low, base, and high pulse flows with a reduction in stream flows in the PostSF period. This can be attributed to Scotts Flat reservoir capturing early wet season runoff for storage.

The January monthly FDC indicates that low and base flows were greater in the PreSF period, with the PreSF curve plotting greater flows from $EP_{.99}$ – $EP_{.35}$. Above $EP_{.35}$ flows are similar in the PreSF and PostSF periods, indicating minimal alterations to the January high flow pulses, small floods, and large floods. The most significant alteration evident in the January FDC is that flows with exceedance probabilities between $EP_{.99}$ – $EP_{.35}$ were greater in the PreSF period. This indicates that there is less water moving through the Deer Creek system in the PostSF period, which could be attributed to Scotts Flat reservoir capturing runoff for storage.

The February monthly FDCs indicate that there was more water moving through Deer Creek in the PreSF period. The PreSF FDC remains above the PostSF FDC, except above $EP_{.01}$ as a result of the peak February flow occurring in the PostSF period of record. This indicates that there have been significant alterations to the flow regime during this month, with less water flowing through the watershed and available for aquatic and riparian organisms. As with previous months, this could be attributed to Scotts Flat reservoir storing runoff until the reservoir spills.

The March monthly FDC shows that in the PreSF period there was a greater probability of higher stream flows from $EP_{.99}$ – $EP_{.41}$ when compared to the PostSF period. This suggests there is less water in the creek during March in the PostSF period, with a reduction in monthly low and base flow magnitudes. From $EP_{.41}$ – $EP_{.05}$ the PreSF and PostSF FDCs are similar, with overlapping curves, indicating that there has been minimal alteration to the March high flow pulses and small floods. Above $EP_{.05}$ the PreSF period exhibits greater magnitude large flood and peak flows than the PostSF period, but these differences are minor. This indicates that there has been minimal alteration to the high flow regime, with the primary alterations to the March FDC occurring from $EP_{.99}$ – $EP_{.41}$.

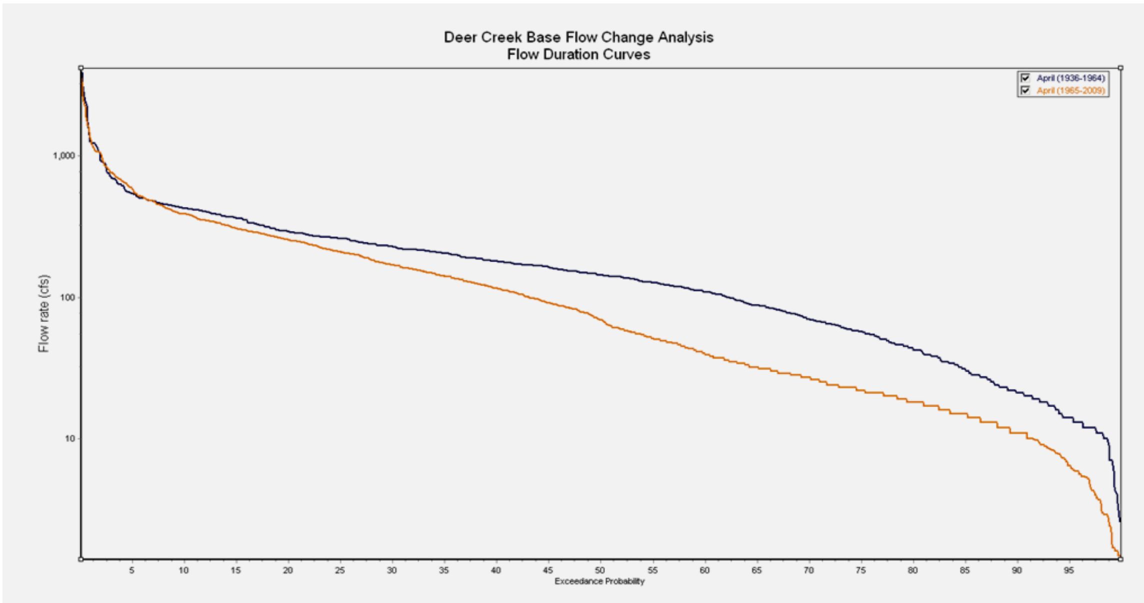

Figure 4.32*:* IHA software monthly flow duration curves for the month of April, with the PreSF period plotted dark blue and the PostSF period orange.

The April monthly FDCs (**Figure 4.32**) indicate that there was a greater probability of stream flows being higher in the PreSF period than the PostSF for the majority of exceedance probabilities during the month of April. PreSF stream flows were greater from $EP_{.99}$ – $EP_{.07}$, indicating that the magnitude of flow associated with these exceedance probabilities has been reduced in the PostSF period. This reduction could be associated with water management, with April 15th the start of the primary irrigation season for NID, but those relationships are difficult to establish using this analysis. Above $EP_{.07}$ the PreSF and PostSF FDCs are similar, overlapping through the peak of the curve. This indicates that the probability of the highest stream flows has not been altered for the month of April, with large flood flows occurring with a similar magnitude, frequency, and duration.

The May monthly FDCs are similar to the April plots in **Figure 4.32**, with a greater probability of higher stream flows in the PreSF period than the PostSF period for the majority of exceedance probabilities. PreSF stream flows were greater from $EP_{.99}$ – $EP_{.12}$, indicating the magnitude of stream flows associated with these exceedance probabilities has decreased from the PreSF to PostSF period. The timing of the reduction in May suggests that NID water management could be responsible for the altered FDC in the PostSF period, as NID captures late spring rainfall and early summer runoff that would typically flow through the watershed and diverts it for urban and agricultural water users, leaving less water flowing through the watershed outlet than would have historically occurred. Above $EP_{.12}$ the PreSF and PostSF FDCs are very similar, with the PostSF curve plotting slightly greater magnitudes for $EP_{.12}$ – $EP_{.02}$, and overlapping curves from $EP_{.02}$ to the peak of the curve, indicating there has been minor alterations to the high flow end of the May FDC.

The June monthly FDCs are similar to those for April and May, with a greater probability of higher stream flows in the PreSF period than the PostSF period, except from $EP_{.99}$ – $EP_{.97}$. Above $EP_{.97}$ the PreSF FDC remains above the PostSF FDC until $EP_{.02}$, upon which the two FDCs are similar through the peak of the curve. The magnitude shift of the FDC down on the plot indicates there is less water moving through the Deer Creek watershed outlet during the month of June in the PostSF period, which can probably be attributed to water management reducing the volume of stream flows at the watershed outlet because these are considered system losses. In the Deer Creek watershed the hydrograph during the months of May and June would be influenced by snowmelt, to keep stream flows high through early summer. Scotts Flat reservoir now allows for management of the snowmelt flows, which ultimately leads to a reduction in stream flows at the watershed outlet, as stream flows are diverted out of Deer Creek into canals, diversions, and other reservoirs.

The July monthly FDCs show the least alteration out of all of the monthly FDCs, with a greater probability of higher stream flows in the PostSF period than the PreSF period from $EP_{.99}$ – $EP_{.80}$, but this difference is minor, on the order of 1.0 cfs or less. Above $EP_{.80}$ the FDCs coincide through the top of the plot, indicating there has been minimal alteration to the July FDC from the PreSF to PostSF period.

The August monthly FDCs indicate that there is a greater probability of higher stream flows in the PostSF period than the PreSF period, for every exceedance probability. This is the first month in the water year where this is the case. Although PreSF and PostSF period FDCs are close from $EP_{.40}$ – $EP_{.27}$, there is still a greater probability of higher flows in the PostSF period for this exceedance probability range. As with the July monthly FDCs, the order of magnitude of alteration is approximately 1.0 cfs or less across the entire range of exceedance probabilities, indicating that while the alterations persists throughout the FDC they constitute minor flow volumes.

The September monthly FDCs, like the August monthly FDCs, indicate that there is a greater probability of higher stream flows in the PostSF period than the PreSF period, for every exceedance probability. This is the second straight month where this is the case, with both months located near the low flow end of the water year. The order of magnitude of alteration is approximately between 1.0 and 5.0 cfs and varies with exceedance probability. This indicates there is a greater probability of more water in the creek at this time of year near the watershed outlet in the PostSF period, which could be a result of the Lake Wildwood reservoir WWTP effluent discharges, NID system losses, and runoff associated with agricultural and grazing properties. The increase in water quantity at this time of year does not necessarily equate to better habitat conditions in lower Deer Creek, due to the altered constitution of the water (see River Ecology Chapter).

During the wet season (November – June) in general there is a greater probability of less water flowing through the watershed outlet in the PostSF period compared to the PreSF period, indicating that reservoir development and water management have altered the magnitude, duration, timing, and frequency of stream flows in the watershed. In dry months (July – September) alterations are less severe, with a greater probability of more water flowing through the watershed outlet in the PostSF period compared to the PreSF period. This could indicate that reservoir development and water management, including increased water deliveries and system losses in the watershed, runoff from working landscapes, and effluent discharges from the Lake Wildwood reservoir WWTP, have slightly increased summer flows at the watershed outlet in August and September.

Other Indicators of Hydrologic Alteration Analysis

Method 1. IHA Monthly Flows

The IHA software allows for analysis of the magnitude of monthly water conditions through mean or median daily flow analysis. This produces an average flow value for each month based on the period of record. A two period non-parametric analysis was employed to determine median monthly flow values for the periods before (PreSF) and after (PostSF) the upgrade of Scotts Flat Reservoir in 1964, the year base flow changed in Deer Creek. The magnitude of monthly water conditions is important to analyze because they can have the following influences on the aquatic ecosystem:
· Habitat availability for aquatic organisms
· Soil moisture availability for plants
· Availability of water for terrestrial animals
· Availability of food/cover for furbearing mammals
· Reliability of water supplies for terrestrial animals
· Access by predators to nesting sites
· Water temperature, oxygen levels, photosynthesis in water column

Table 4.18 provides a summary of the results of the median monthly flow analysis, with a description of how the PostSF median flow has been impacted, and hydrologic alteration values from the RVA analysis. Graphs for each month are provided in the Hydrology Chapter Appendix, with an example plot shown in **Figure 4.33**.

Month	PostSF Median	Low HA	Middle HA	High HA
October	Similar median.	-0.1407	0.2352	-0.1944
November	Median falls below Low RVA boundary (~10 cfs decrease).	0.8617	-0.297	-0.4988
December	Median falls below Low RVA boundary (~10 cfs decrease).	0.6469	-0.2384	-0.3556
January	Median decrease to near Low RVA boundary (~20 cfs decrease).	0.4321	-0.3556	0.002469
February	Slight median decrease (~15 cfs decrease).	0.3605	-0.06263	-0.284
March	Slight median decrease (~20 cfs decrease).	0.3605	-0.4727	0.2173
April	Median falls below Low RVA boundary (~70 cfs decrease)	0.7901	-0.5313	-0.1407
May	Median falls below Low RVA boundary (~30 cfs decrease).	1.077	-0.5313	-0.4272
June	Median decrease to near Low RVA boundary (~10 cfs decrease).	0.1457	0.3475	-0.5704
July	Slight median increase (~1 cfs increase).	-0.1407	0.1717	-0.06914
August	Similar median.	-0.3556	0.07407	0.2889
September	Median increase (~1.5 cfs increase).	-0.642	0.2303	0.3605

Table 4.18: Summary of the IHA monthly flow magnitude analysis.

The results of the IHA software median monthly flow analysis indicate that changes to the magnitude of monthly water conditions have occurred since the upgrade of Scotts Flat reservoir in 1964. Certain trends appear when analyzing the results. The median monthly flow value decreases in 8/12 months, exhibits no change in 2/12 months, and increases slightly in 2/12 months. The median monthly flow decreases are all during the wet season, November – June, indicating that reservoir development has impacted the magnitude of monthly flows during these months, possibly impacting high flow pulses, small and large floods. This could have important implications for aquatic and terrestrial organisms.

The months with no median change (August, October) and months with a slight median increase (July, September) occur during the summer and NID's primary irrigation season. This indicates that reservoir development and management has had a minimal impact on the magnitude of monthly flows during the base and low flow periods of the water year, with approximately 1.5 cfs or less of additional water available during July and September. Some of the impacts during these months could be partially offset by effluent discharges flows from the Lake Wildwood reservoir WWTP, as the plant has operated in the PostSF period since the early 1970's, discharging effluent into Deer Creek downstream of Lake Wildwood reservoir. The WWTP signal is difficult to detect during the wet season but in the summer months, when flows are often less than 10.0 cfs, these effluent flows become significant and could be offsetting flow decreases associated with reservoir development and management. This is purely from a physical quantity perspective, not water quality, as the water consists of wastewater effluent.

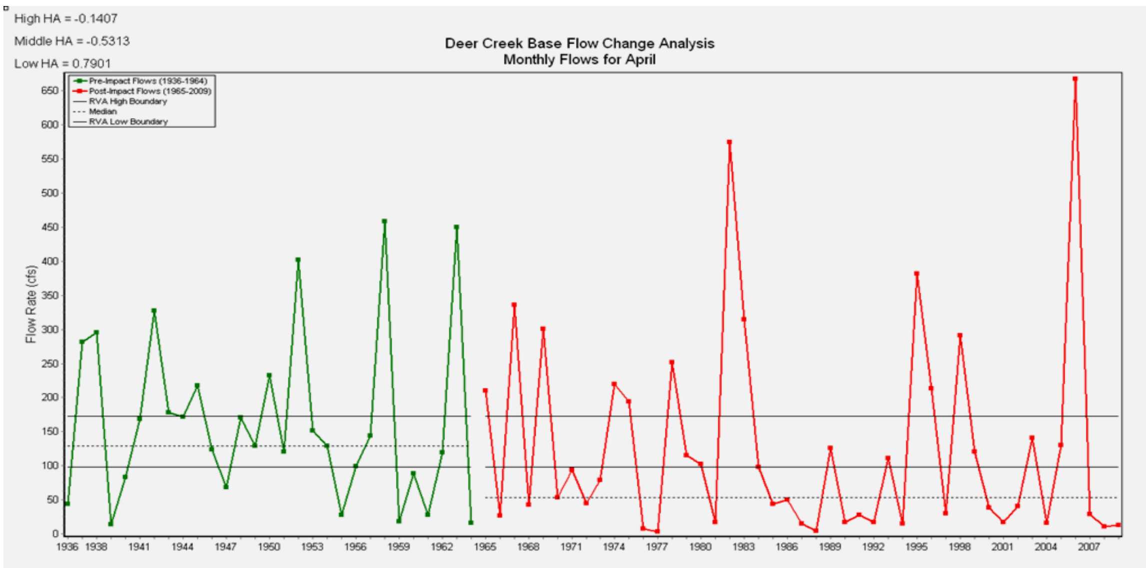

Figure 4.33: Results of the IHA median monthly flow analysis for the month of April.

Hydrologic Alteration values were greatest for November, December, April, and May, with a significant increase in Low RVA category flows in the PostSF period compared to PreSF. This corresponds to decreases in the Middle and High RVA category flows and a median flow decrease. This indicates the hydrologic regime has been altered, in that for 8/12 months of the year the median monthly flow value is now less than before reservoir development. Hydrologic Alteration is also evident during September, with a significant decrease in Low RVA category flows in the PostSF period compared to PreSF. This corresponds to an increase in Middle and High RVA category flows as well as a median flow increase. Much of this can be confirmed through assessing a summary graph of monthly flow alteration values, provided in **Figure 4.34**.

Figure 4.34 is a graphical summary of the results from the monthly flow alteration analysis and confirms the results already presented. Visualizing the results illustrates the magnitude of monthly flow alteration. Months with the greatest hydrologic alteration are evident by the lack of overlap between the PreSF RVA boundaries and the PostSF median monthly flow values. As previously discussed this includes November, December, April, and May.

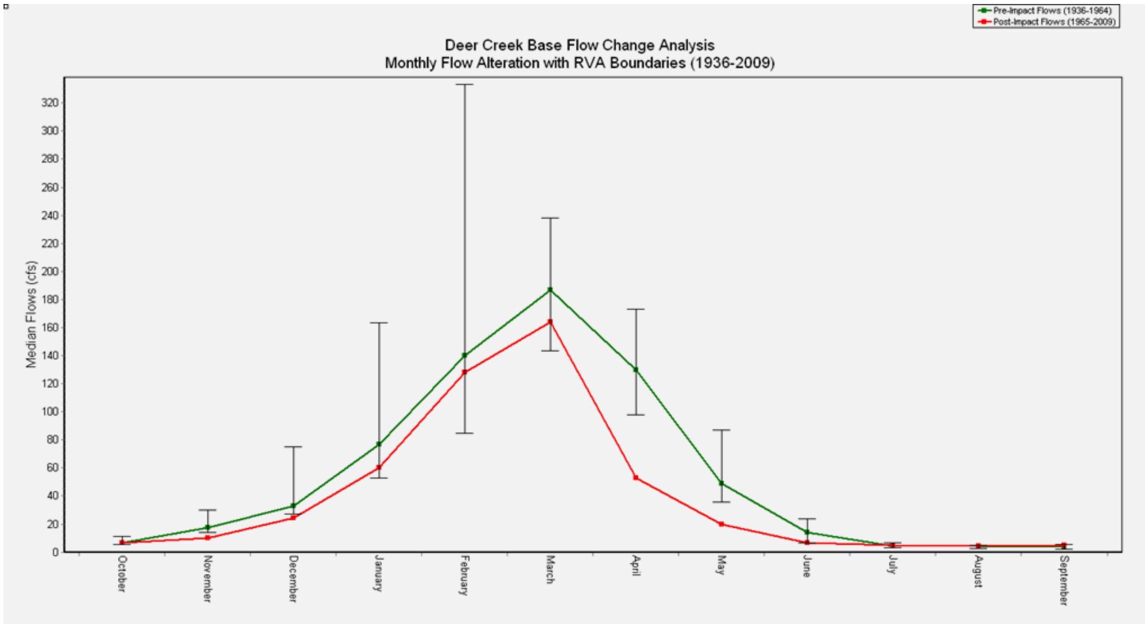

Figure 4.34: IHA monthly flow alteration with RVA boundaries.

Reductions in the magnitude of median monthly flow values can have important implications for the ecosystem. The decrease in median monthly flows during April and May is of particular concern, due to the magnitude of the alteration. Fortunately there have not been significant alterations to median monthly flow values during the driest months of the year. For 8/12 months there is a reduction in the median monthly flow value and thus less water available for aquatic and riparian organisms. This means fewer habitats available for aquatic organisms, less water for terrestrial animals, and less water for riparian plants (TNC 2009).

Method 2. Rate and Frequency of Changes in Stream flow

The IHA software calculates the frequency of stream flow reversals by dividing the hydrologic record into rising and falling periods, corresponding to daily changes in flows that are positive or negative. The number of reversals corresponds to the number of times that flow switches from one type of period to another (Richter et al. 1996). Rates of change were calculated for each rise and fall period with the median of all positive or negative differences between consecutive daily values representing the average annual rate of change (Richter et al. 1996). RVA analysis was used in the rate and frequency analysis and allows for assessment of the degree of hydrologic alteration from the PreSF to PostSF period. Rates of change are important to assess because they influence the ability of aquatic and riparian organisms to take refuge or otherwise respond to changing flows, the amount of habitat availability, and the potential for stranding of organisms (Cassin et al. 2005). Flow reversals can constitute a disturbance for organisms sensitive to changes in water depths, velocities or amount of habitat available (Cassin et al. 2005). Frequent flow reversals could require greater energy expenditure, interfere with feeding behavior or efficiency, and reduce the availability of refugia (Cassin et al. 2005). The frequency of reversals and the rates of flow change parameters characterize the degree of flashiness exhibited by a given river system. The IHA Tutorial provides the following ecosystem influences that can be impacted by the rate and frequency of annual water condition changes (TNC 2009):

- Drought stress on plants (falling levels)
- Entrapment of organisms on islands, floodplains (rising levels)
- Desiccation stress on low-mobility stream edge (varial zone) organisms

Parameter	Low HA	Middle HA	High HA	Median Change
Rise Rate	0.09333	-0.5569	0.1278	-1.2 cfs
Fall Rate	-0.1944	-0.1573	0.45	1 cfs
Reversals	0.04722	0.1278	-0.2123	1

Table 4.19: Summary of the IHA software rate and frequency of change analysis, with each parameter, the hydrologic alteration factors, and change to the median value. A decrease in median rise rate corresponds to a slower rise rate while the increase in fall rate median corresponds to a slower fall rate.

Method 2a. Rise Rate

Table 4.19 summarizes the results of the rise rate of change analysis, with the degree of hydrologic alteration to each RVA category and median change from the PreSF to PostSF period. The results indicate that the rise rate of change has been altered. There is a negligible increase in low RVA category flows (0.09333), appreciable decrease in middle RVA category flows (-0.5569), and slight increase in high RVA category flows (0.1278). The median rate of change decreases 1.2 cfs day^{-1} and falls below the PreSF low RVA boundary, with the highest and lowest annual rise rates occurring in the PostSF period. The decrease in middle RVA category flows combined with an increase in low and high RVA category flows, indicate that there is an increase in values outside of the historic range of variability. This is confirmed by the rates of change in the PostSF period, with values greater than and less than any value observed in the PreSF record. This points to greater dispersion of flows and an increase in extreme rise rates that are outside the historic range of variation. The changes observed to the rise rates could have implications for aquatic and riparian organisms, although more investigation is needed.

Method 2b. Fall Rate

Table 4.19 summarizes the results of the fall rate of change analysis, with the degree of hydrologic alteration to each RVA category and median change from the PreSF to PostSF period. The results indicate that the change in fall rate has been altered from the PreSF to PostSF period. There is a decrease in low (-0.1944) and middle (-0.1573) RVA category flows, and an increase in high RVA category flows (0.45). The median increases by 1.0 cfs from the PreSF to PostSF period and plots at the high RVA boundary, which represents a decrease in the flow fall rate. As with the rise rate analysis, the slowest and greatest rates of change occur in the PostSF period. This combined with the decrease in low and middle RVA flows and increase in high RVA flows indicates that there is an increase in values outside of the historic range of variability. This is confirmed by the rates of change in the PostSF period, with values greater than and less than any value observed in the PreSF period. This points to greater dispersion of flows and an increase in extreme fall rates that are outside the historic range of variation, with the changes observed to the fall rates potentially having implications for aquatic and riparian organisms.

Method 2c. Flow Reversals

Table 4.19 summarizes the results of the fall rate of change analysis, with the degree of hydrologic alteration to each RVA category and median change from the PreSF to PostSF period. The results indicate that the frequency with which hydrologic reversals occur has been altered from the PreSF to PostSF period. There is an insignificant increase in low RVA category flows (0.04722), increase in middle RVA category flows (0.1278), and a decrease in high RVA category flows (-0.2123). The median increases by one reversal from the PreSF to PostSF period and plots within the PreSF RVA boundaries. As with the rise and fall rate analysis the most extreme values occur in the PostSF period, with the greatest and least number of annual reversals occurring in the PostSF period. In general this points to a decrease in the annual number of flow reversals in the PostSF period, with the potential for a greater variability in annual flow reversals.

Indicators of Hydrologic Alteration Summary

The IHA software allows for creation of a plot that summarizes the extent of alteration to each IHA parameter, identifying the greatest alterations to each parameter. **Figure 4.35** provides a plot of the IHA parameters and the greatest hydrologic alterations. The larger the hydrologic alteration value is (the larger the bar), the greater the alteration from the PreSF to PostSF period. Details for each parameter are provided in the previous sections, with this plot only providing a visual summary of the results for every IHA parameter analyzed.

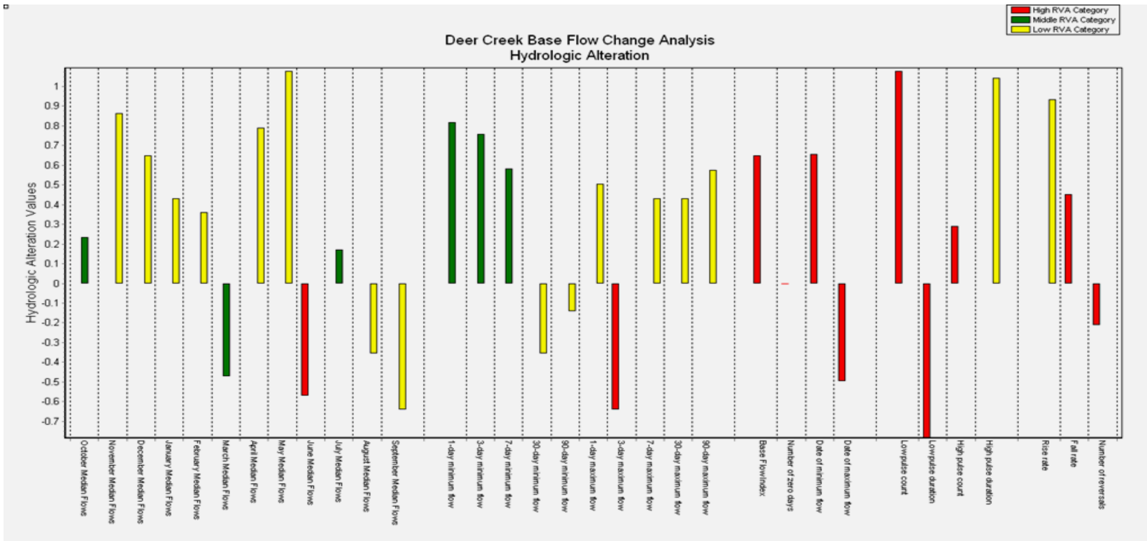

Figure 4.35: Graph showing results of the IHA analysis, displaying the areas of greatest hydrologic alteration for each IHA parameter analyzed.

Lake Wildwood Drawdown Release Flood Frequency Analysis

Methods

The flood flow frequency analysis methodology that was used is based on USGS and U.S. Army Corps of Engineers (USACE) methods outlined in Bulletin 17b, and is based on the same methods as the other flood frequency analyses in this chapter (IACWD 1982). Log Pearson type III method was used to conduct the flood flow frequency analysis (IACWD 1982). To perform flood flow frequency analysis the USACE HEC-Statistical Software Package was used. Mean daily flow (cfs) values were used for this analysis, as instantaneous peak flow data for the month of October were not available. The data record was separated into two periods, before (1936-1969) and after (1970-2007) Lake Wildwood reservoir was constructed.

Results and Discussion

The flow regime of lower Deer Creek for the month of October has been fundamentally changed by the Lake Wildwood reservoir annual drawdown events since they began in 1978 (**Table 4.20, Figure 4.36**). Lower Deer Creek experiences consistently higher flow magnitudes and durations in the month of October since Lake Wildwood reservoir was built. The return interval for a 302 cfs flow event before the Lake Wildwood Reservoir was built was every 18 years with a yearly occurrence probability of 5.6%. Since the dam was built the return interval for a 302 cfs flow event is only 3.3 years with a yearly occurrence probability of 30.8%. A list of the recurrence intervals for the 2, 5, 10, 20, 50, and 100 year flow events for pre and post dam construction can be found in Figure 4.55.

October Flow Analysis

Return Interval (yrs)	Pre-LWW	Post-LWW
2	34	166
5	88	425
10	146	587
25	249	749
50	351	837
100	479	902

Table 4.20: Return intervals for the month of October, for the 2, 5, 10, 25, 50, and 100-year flows before Lake Wildwood reservoir was built (1936 – 1969) and after (1970 – 2007).

It is extremely difficult to quantify the impact that these flows have had on aquatic and terrestrial wildlife. It is known that fish, macroinvertebrates, and vegetation rely on life cycle triggers that include flow magnitude, duration, timing, as well as water temperature (Poff et al. 1997). Large releases of water in October can potentially have negative impacts on stream biota because flows of these magnitudes and durations would not occur naturally. A study by Novotney (1985) on a flood control dam in Kentucky compares macroinvertebrate populations upstream and downstream of a reservoir. The study attributes major decreases in sensitive Ephemeroptera, Trichoptera, and Plecoptera organisms downstream of the dam to changes in the natural flow patterns (Novotney 1985). Because the drawdown has occurred periodically for the past 30 years, communities of fish and macroinvertebrates have most likely shifted to accommodate the highly unseasonal October flows. By reducing the discharge of the release it may be possible to restore hydrologic function to the October hydrograph and improve the conditions and habitat for macroinvertebrates and fish, such as Chinook salmon and steelhead trout, in lower Deer Creek. Further investigation is needed into the impacts associated with the drawdown release, as well as methods for remediating impacts to the flow regime and aquatic ecosystem.

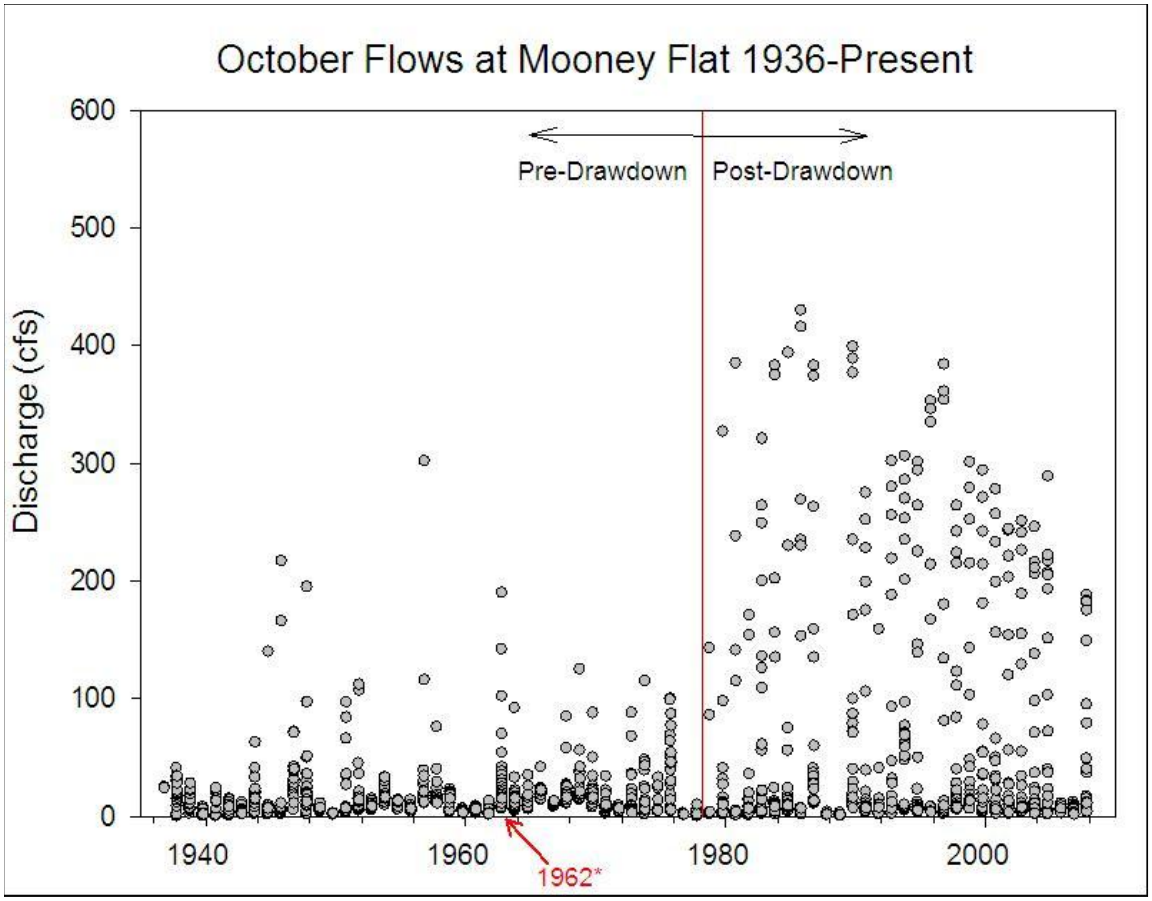

Figure 4.36: Historic flows for the month of October from 1936 to present. Each column represents average daily flows for the month of October. Lake Wildwood Dam was built in 1969 and drawdown management began in 1978. 1962* was the largest storm on record for October and the third highest average daily flow recorded overall at 7370 cfs (data point not shown on the figure).

D. Recommendations

Justin Wood

- **Compare the timing, both seasonally and between years, of peak flows occurring in Oregon Creek and Deer Creek to better understand the impact of Scotts Flat reservoir on peak flows in Deer Creek.**
  Investigations into Oregon Creek low flows should be conducted by water year type, to determine natural flow volumes in each type of water year for potential application to Deer Creek. In addition, better methods for estimating unimpaired, natural stream flows in the Deer Creek watershed should be explored, possibly through GIS-based modeling and desktop analysis.

- **Install rain gauges at locations near gauging stations, to better understand rainfall-runoff relationships, and to understand the full range of natural flow variability within Deer Creek.**
  Two rain gauges are being installed in the watershed in 2011; one in Nevada City and one in Rough and Ready, to supplement the existing USGS, NID, and Sierra Water Trust stream flow gauging infrastructure. Additional rain gauges and precipitation loggers should be installed in areas upstream of Scotts Flat reservoir, and in the Squirrel Creek watershed.

- **Restore the natural peak flood flow regime in the Deer Creek watershed and further investigate peak flows in the watershed.**
  Current peak flood flow magnitudes and return intervals near Scotts Flat reservoir and downstream of Lake Wildwood reservoir are potentially outside the predicted natural range due to reservoir development and water management. In addition, the Scotts Flat reservoir upgrade and base flow change in 1964 has resulted in alterations to the flood regime, with potential reductions in the magnitude and frequency of peak flood flows in the period after the reservoir upgrade, which further indicates there have been alterations to the annual peak flow regime. When compared to the predicted natural flows, current peak flows at Scotts Flat reservoir in the upper Deer Creek watershed have been reduced from the Q2 – Q10 range, possibly due to the dam capturing runoff from one-quarter of the watershed. Peak flows downstream of Lake Wildwood reservoir in the lower Deer Creek watershed have potentially been reduced from the Q25 – Q100 range, due to reservoirs capturing runoff and reducing the magnitude and frequency of large flood flows. Restoration would involve experimenting with the flood regime, through releases from Scotts Flat reservoir during storm events, to ensure that natural peak flows are achieved throughout the watershed. In addition, restoring the flood regime would also lead to more natural annual and monthly FDCs, increased duration of high flow pulses, increased monthly median flows, and an increase in monthly low flows. The FDCs indicated there is much less water in the creek annually and during the wet season months (November – June), with high flow pulse durations, monthly median, and monthly low flows reduced during wet months after Scotts Flat reservoir upgraded in 1964. Efforts to allow more natural runoff patterns, such as snowmelt and upper tributary flow through Scotts Flat reservoir, should be explored during April, May, and June, with reductions to the median monthly flow volumes in these months, due to water management and diversions of water away from the main stem of Deer Creek.

- **Restore a more natural hydrograph to the October flow regime downstream of Lake Wildwood reservoir and investigate changes to the aquatic ecosystem as a result of the drawdown releases.**
  The periodic Lake Wildwood reservoir drawdown release alters the flood regime during the month of October, increasing peak stream flow magnitudes for each return interval from Q2 – Q100. Large releases of water in October can potentially have negative impacts on stream biota because flows of these magnitudes and durations would not occur naturally. By experimenting with drawdown release magnitudes and durations it may be possible to restore hydrologic function to the October hydrograph and improve the conditions and habitat for macroinvertebrates and fish, such as Chinook salmon and steelhead trout, in lower Deer Creek. Analysis should be conducted on historic October flows that are not associated with the

drawdown release, to investigate the magnitude, duration, frequency, and rise and fall rates for rainfall events that trigger rises in stream flow during the month of October. By investigating historic, pre-Lake Wildwood reservoir October rise and fall rates, and flow magnitudes and durations, drawdown releases could potentially be designed to be more in line with natural flow conditions. Experiments should be conducted into whether a shorter duration, higher magnitude release or a longer duration, lower magnitude release impacts the ecosystem more. This could be investigated through collecting water quality and macroinvertebrate data, sediment and mercury transport and deposition rates, and monitoring the impacts of the release on Chinook salmon and steelhead trout. Anadromous fish enter Deer Creek during the months of September or October and could potentially be affected by the drawdown release. Therefore investigations should be made into impacts to these threatened and endangered fish species.

- **Work with Lake Wildwood Association, Nevada Irrigation District, and the State Division of Water Rights to ensure that in-stream flow requirements outlined in water rights documents are achieved downstream of Lake Wildwood reservoir.**

  Currently water rights state that 5 cfs or the natural flow volume must be passed through Lake Wildwood reservoir. Efforts to quantify natural flows indicate that in a natural system during summer and early fall low flow months there would be 5.0 cfs in Deer Creek downstream of Lake Wildwood reservoir during most water years, except for potentially dry and critical water years. Low flow frequency analysis indicates that at present, mean daily low flows drop below 7.9 cfs every year, with flows dropping below 2.0 cfs every other year, which suggests the in-stream flow requirements are not being achieved. Overall the results indicate that the 5.0 cfs or the natural flow volume requirement is not being achieved downstream of Lake Wildwood reservoir all the time, and efforts should be undertaken to ensure the required in-stream flow allotment is received. It is important to ensure these flow volumes are achieved because they improve water quality by reducing the impact of Lake Wildwood reservoir WWTP effluent discharges on lower Deer Creek through reduced nutrient concentrations and water temperatures, and increased dissolved oxygen levels. It is of particular importance that the 5.0 cfs or natural flow requirement is achieved during September, October, and November, as these are the months in which Chinook salmon begin to enter Deer Creek to spawn. This could possibly be achieved through effective management of the Lake Wildwood reservoir drawdown release.

Chapter V: Understanding Deer Creek Geomorphology

FODC/SSI

A. Introduction to the Geomorphology of Deer Creek

Understanding geomorphic processes and how they vary along Deer Creek is a critical element of the Deer Creek Assessment and Restoration Plan because geomorphic processes drive the form of the creek channel and floodplains, which in turn influence in-stream and floodplain habitat, riparian vegetation, water quality, biota and many other important stream qualities (National Research Council 1992). To restore and maintain healthy aquatic and riparian ecosystems successfully, restoration efforts must recreate the physical conditions necessary to support natural biotic communities (Gore 1985).

It is important to recognize that Deer Creek exhibits reaches typical of a classic Sierra Nevada bedrock river, (McBain and Trush 2004) and reaches characteristic of an alluvial river (Trush et. Al. 2000). Steep, bedrock reaches are often followed by more gradually sloped reaches where significant alluvial features can be found for great distances (see Geomorphology Appendix C for maps of morphological types). A common misperception of bedrock rivers is that the channel morphology is static, and thus unaffected by changes to flow and sediment supply. However, bedrock rivers are often dynamic depositional environments too. Deposition occurs within a confining, rigid bedrock framework that exhibits a bedrock template of pools and riffles.

This bedrock framework provides complex hydraulic controls that create diverse nested depositional features ranging from formations of large boulders to fine sand deposits. These depositional areas are important because the richness of biological communities in Sierra Nevada river ecosystems depends in part on the complexity created by these depositional features and processes. Sierra bedrock rivers have the following attributes of properly functioning bedrock river reaches (McBain and Trush 2004):

1. Bedrock rivers exhibit nested depositional features;
2. Bedrock river ecosystems require variable annual hydrographs;
3. Episodic sediment delivery enhances spatial complexity;
4. Bedrock channel maintenance requires multiple flow thresholds;
5. Maintenance of depositional features is partially independent of bedload transport capacity;
6. Biological hotspots occur at highly depositional reaches;
7. Hydraulic pathways in the river corridor fluctuate seasonally and annually.

Several attributes of properly functioning alluvial river reaches have been identified that can help identify desired processes and develop management actions to restore or maintain healthy functions for Deer Creek. Trush et al. (2000) identified 10 such attributes, the following seven of which are most relevant to Deer Creek:

1. Each annual hydrograph component accomplishes specific geomorphic and ecological functions.
2. The channel bed surface is frequently mobilized.
3. Alternate bars must be periodically scoured deeper than their coarse surface layers.
4. Alluvial channels are free to migrate.
5. Floodplains are frequently inundated.
6. Large floods create and sustain a complex main stem and floodplain morphology.
7. Diverse riparian plant communities are sustained by the natural occurrence of annual hydrograph components.

Each of these attributes is a function of the relationship between the hydrologic and geomorphic conditions of the river. The hydrologic patterns necessary to understand this relationship in Deer Creek have been described above. The geomorphic assessment approach and results are described below.

B. Approach

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The general approach taken to begin to understand the geomorphic aspects of Deer Creek involves the following steps:

- Reach classification: using aerial video footage and analysis of topographic data, the distinct reaches of Deer Creek were identified and mapped based on longitudinal slope and valley width parameters.
- Channel Morphology typing: within each reach, the channel morphology and major habitat types were identified and mapped.
- Detailed surveys: within key reaches, locations that can serve as indicators of hydro-geomorphologic function and health were identified and surveyed in detail.
- Analysis of data collected in the previous three steps.

C. Reach Classification

The purpose of classifying Deer Creek into distinct geomorphic reaches is to "permit rapid inventory of large regions, provide a stratified geomorphological framework within which more detailed observations can be organized, and provide an initial basis for selecting restoration strategies" (Kondolf 1995).

By analyzing aerial photos, topographic maps, and aerial video footage of the entire length of Deer Creek, eleven distinct reaches were identified. **Figure 5.1** shows the reach divisions in upper Deer Creek (see the Geomorphology Appendix for a detailed description of the reach classification analysis). Reach divisions correspond with significant slope breaks, adjusted slightly to allow easy identification in the field. For this chapter Scotts Flat reservoir refers to both upper and lower Scotts Flat (Scotts Flat dam and Deer Creek Diversion Dam).

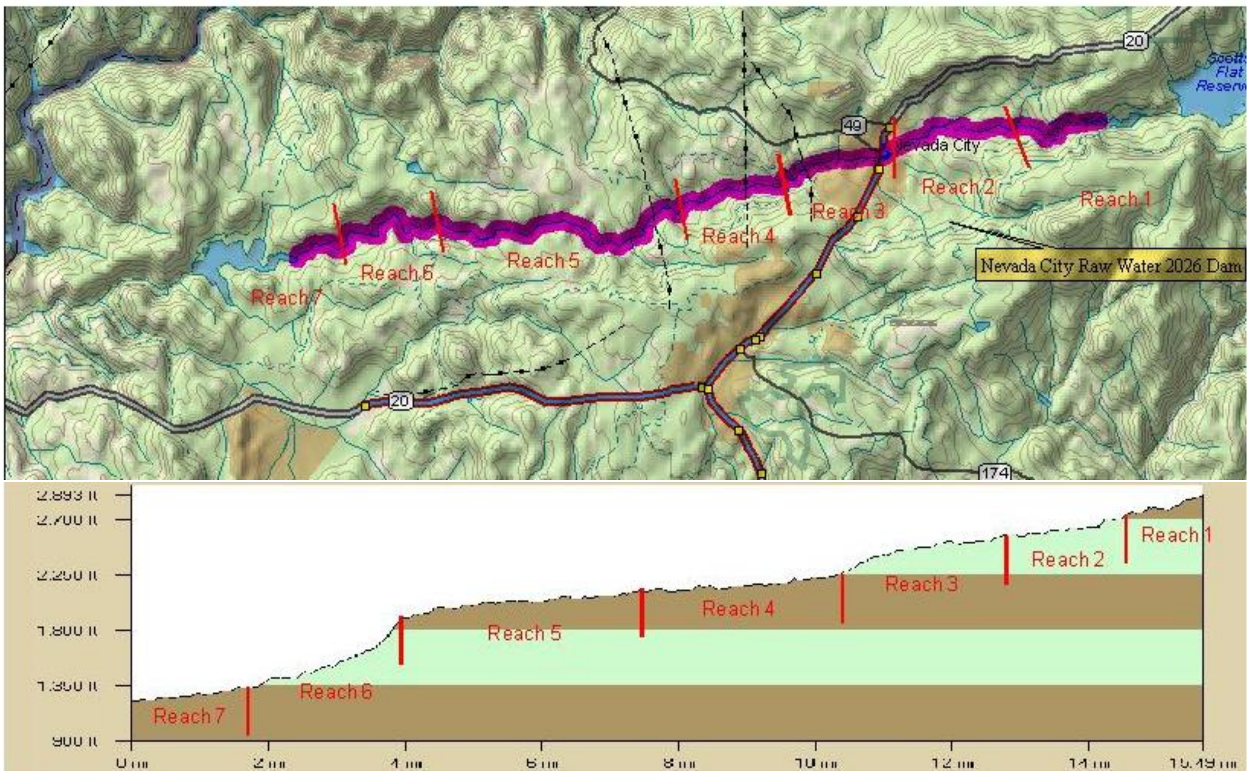

Figure 5.1: Plan View of Reach Divisions along the Main stem of Deer Creek, from lower Scotts Flat Reservoir downstream to Lake Wildwood Reservoir

Seven reaches were identified in upper Deer Creek (Scotts Flat to Lake Wildwood):

Reach 1: Lower Scotts Flat Reservoir to Willow Valley Creek

- Upstream Elevation: 2884 ft
- Downstream Elevation: 2624 ft
- Change in Elevation: 260 ft
- Linear Distance: 9030 ft
- Average Slope: 0.028

Reach 2: Willow Valley Creek to Little Deer Creek

- Upstream Elevation: 2624 ft
- Downstream Elevation: 2475 ft
- Change in Elevation: 149 ft

- Linear Distance: 11460 ft
- Average Slope: 0.013

Reach 3: Little Deer Creek to Providence Mine Road
- Upstream Elevation: 2475 ft
- Downstream Elevation: 2182 ft
- Change in Elevation: 293 ft
- Linear Distance: 11040 ft
- Average Slope: 0.027

Reach 4: Providence Mine Road to Little Deer Creek Lane
- Upstream Elevation: 2182 ft
- Downstream Elevation: 2108 ft
- Change in Elevation: 74 ft
- Linear Distance: 10670 ft
- Average Slope: 0.0069

Reach 5: Little Deer Creek Lane to Tunnel Ditch
- Upstream Elevation: 2108 ft
- Downstream Elevation: 1940 ft
- Change in Elevation: 168 ft
- Linear Distance: 16740 ft
- Average Slope: 0.010

Reach 6: Tunnel Ditch to Paddy Flats
- Upstream Elevation: 1940 ft
- Downstream Elevation: 1330 ft
- Change in Elevation: 610 ft
- Linear Distance: 14100 ft
- Average Slope: 0.043

Reach 7: Paddy Flats to Wildwood Reservoir
- Upstream Elevation: 1330 ft
- Downstream Elevation: 1216 ft
- Change in Elevation: 114 ft
- Linear Distance: 8450 ft
- Average Slope: 0.013

Four reaches were identified in lower Deer Creek (Lake Wildwood to the Yuba River):

Reach 8: Lake Wildwood Reservoir Spillway to one mile downstream of Lake Wildwood Wastewater Treatment Plant (WWTP)

- Upstream Elevation: 1130 ft
- Downstream Elevation: 945 ft
- Change in Elevation: 185 ft
- Linear Distance: 2,799 ft
- Average Slope: 0.066

Reach 9: Downstream of Lake Wildwood WWTP to Squirrel Creek

- Upstream Elevation: 945 ft
- Downstream Elevation: 802 ft
- Change in Elevation: 143 ft
- Linear Distance: 6,515 ft
- Average Slope: 0.0219

Reach 10: Squirrel Creek to Mooney Flat Rd bridge

- Upstream Elevation: 802 ft
- Downstream Elevation: 625 ft
- Change in Elevation: 177 ft
- Linear Distance: 8,905 ft
- Average Slope: 0.0199

Reach 11: Mooney Flat Rd bridge to Yuba River

- Upstream Elevation: 625 ft
- Downstream Elevation: 280 ft
- Change in Elevation: 345 ft
- Linear Distance: 4,774 ft
- Average Slope: 0.0723

D. Channel Morphology Typing

Justin Wood

Within each of the reaches described above, the channel morphology type was determined as part of the field assessment. The most appropriate classification system for channel type morphology for Deer Creek is the Montgomery-Buffington classification of channel-reach geomorphology in mountain drainage basins (Montgomery and Buffington 1997), which offers a "process-based framework within which to assess channel condition and response potential." Mountain drainages exhibit seven channel morphologies: colluvial, bedrock, cascade, step pool, plane bed, pool riffle, and dune riffle. Five classifications are represented in **Figure 5.2**.

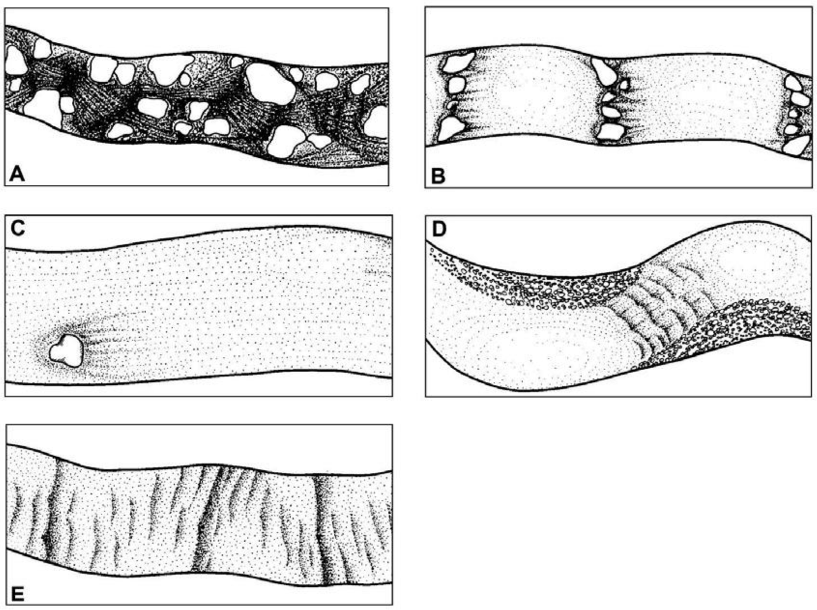

Figure 5.2: Schematic Plan Form of Mountain Stream Channel Classifications: **A)** Cascade; **B)** Step Pool; **C)** Plane Bed; **D)** Pool Riffle; **E)** Dune Riffle (Reprinted from Montgomery and Buffington 1997).

Examples of these channel types on Deer Creek are shown in **Figures 6.3, 6.4, 6.5, 6.6,** and **6.7**. Note that Deer Creek does not feature Dune Riffle habitat, Type E.

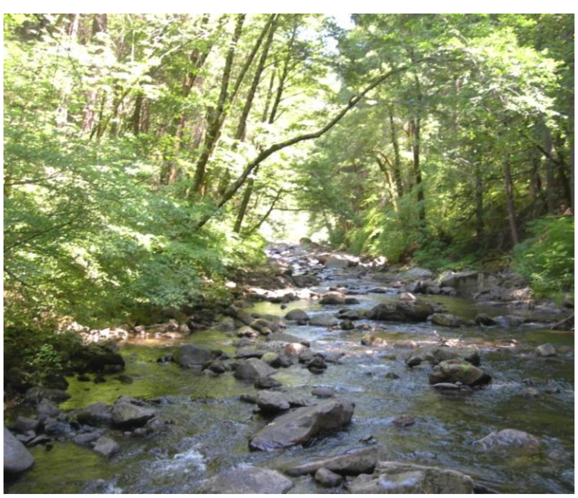

Figure 5.3: Example of a cascade reach **(Type A)**, one mile downstream of Scotts Flat

Figure 5.5: Example of a step pool reach **(Type B)**, ¼ mile downstream of Scotts Flat

Figure 5.4: Example of plane bed reach, **(Type C)**, ¼ mile upstream of Bitney Springs Road

Figure 5.6: Example of a riffle pool reach **(Type D)**, ½ mile upstream of Bitney Springs Road

Figure 5.7: Bedrock reach, ¾ mile downstream of Scotts Flat

E. Sediment Supply

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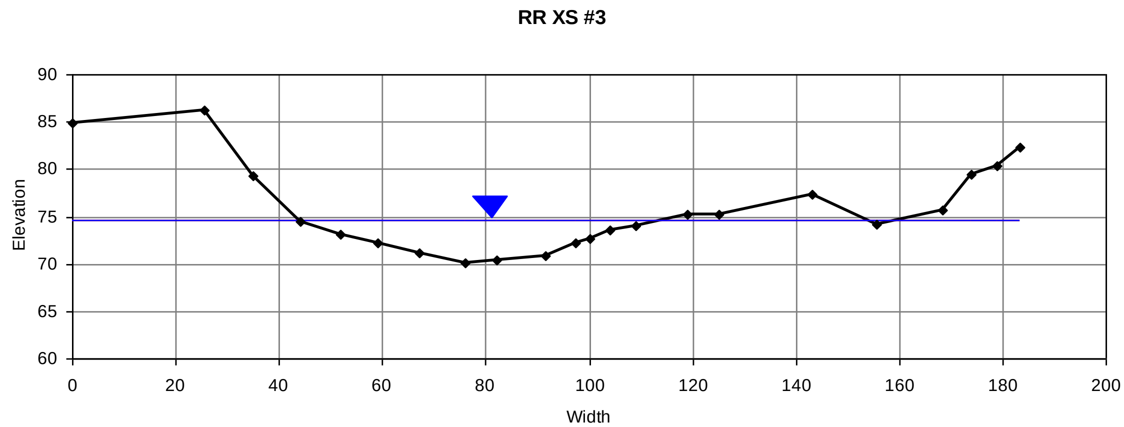
The design and implementation of a restoration program should be guided by an understanding of past changes, and should address the historical causes and course of channel degradation (Kondolf 1995; Brookes and Sear 1996). It is important to clarify that in the discussion of geomorphology here, the term "sediment" means alluvium in general, including cobbles, gravels and fines. While excessive fine sediment loading to creeks from soil disturbance is a common water quality problem and a concern for Deer Creek, a healthy variety of sediment/alluvium, as discussed below, is an important characteristic of a healthy watershed.

Before the mining era in larger mountain channels such as Deer Creek, alluvium collected in low gradient reaches while large cobbles, boulders, and bedrock armored steep reaches. These channels stored relatively little fine sediment and the rate of material coming from the hill slopes controlled pre-mining sediment volumes available for transport or deposition in Deer Creek (James 2004). Sediment yields and the distribution of alluvium in such basins depend on the balance between hill slope sediment production and channel transport capacity (Montgomery et al. 1996).

Prior to disturbances, the power of Deer Creek in the headwater reaches would have been sufficient to carry most of the sediment supplied to the creek by hill slope process, so



channel-beds were dominated by coarse channel lags, boulder sized colluvium, and bedrock. From 1849 through the 1930s the Deer Creek watershed was the focus of significant mining activities that produced approximately 25 million cubic meters of sediment. Over a relatively short period of time during hydraulic mining (1852-1885), channels in and below the mines were converted from colluvial supply systems to alluvial streams with abundant stores of relatively fine alluvium (James 2004). Through time, Deer Creek shifted from a supply-limited to a transport-limited system in response to the introduction of massive volumes of mining sediment.

Based on studies of the Bear River and other Sierra rivers, much of the sediment from the mining era has been transported out of the main stem portions of Deer Creek and other systems by now (James 1999). This is not true of all significant rivers or tributaries, such as Greenhorn Creek on the Bear River. In addition, there are still significant deposits of sediment produced by mining along Deer Creek, which continue to supply sediment to the system. One such deposit is a terrace that is immediately downstream of the former Champion and Providence mines where the high-gradient reach (5% slope) that flows through Nevada City becomes more gradual. The terrace sits 12-25 ft above the current channel elevation (**Figure 5.8**). During the mining era sediment supply surpassed sediment transport capacity and the channel aggraded in this reach by at least 15 ft, as was the case in many locations on Deer Creek (**Figure 5.9**). After the end of the mining era and the associated reduction in sediment supply, Deer Creek cut down through the mining deposits to bedrock in many locations. Although much of the mining sediment has been transported out of this and similar reaches, a portion remains in the terraces and will only be transported during flood flows and as Deer Creek migrates laterally into the banks of the deposits. Significant channel incision, another way to transport sediment, will be limited due to the location of exposed bedrock.

Figure 5.8: Channel Cross-Section Showing Elevated Terrace of Mining Debris, River Left.

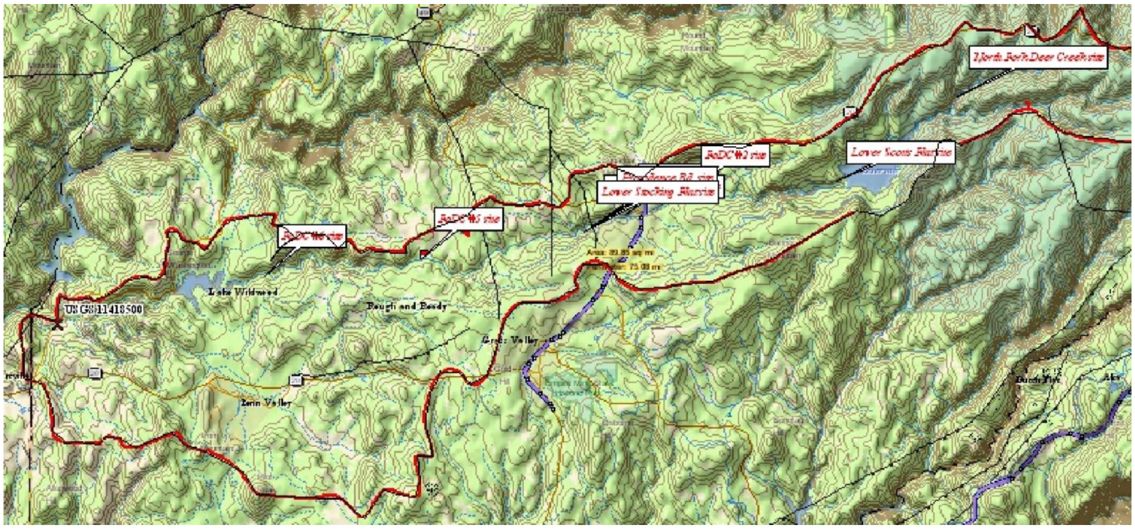


Figure 5.9: Location of Survey Sites

Influence of Scotts Flat Reservoir on Sediment Supply and Downstream Habitat

Primary changes caused by dams include a reduction in the river's sediment load as well as an alteration of the flow regime. A few examples of alterations to the flow regime include a reduction in the magnitude and frequency of peak flows, an increase in the magnitude of summer low flows, and changes to the timing of flows. Such artificially introduced changes may trigger an adjustment by the river as it attempts to re-establish an approximate equilibrium between the channel and the discharge and sediment load being transported (Kondolf 1997; Juracek 1999).

Figure 5.10: Bedrock Outcropping Below Scotts Flat

In general, rivers downstream from dams initially adjust by channel degradation. Typically, a river will scour, and thus lower its channel bed elevation as the sediment-depleted water emerging from the dam attempts to replenish its sediment load. Channel degradation often begins near the dam and may migrate a considerable distance downstream (Williams and Wolman 1984). Deer Creek is an exception to this rule in the case of Scotts Flat reservoir, because a series of bedrock outcroppings occurs approximately 500 ft below Lower Scotts Flat (**Figure 5.10**), thus limiting its ability to degrade. A different scenario exists immediately downstream of Lake Wildwood Reservoir, where the channel is being scoured out and exhibiting signs of degradation due to the lack of bedrock close to the water surface and lack of an upstream coarse sediment supply.

Downstream of Scotts Flat reservoir, current sources of sediment are limited to bed and bank erosion, hill slope processes, and input from tributaries. Stream surveys, including pebble counts, were conducted that were similar to other studies of rivers downstream of dams. Surveys indicated that Scotts Flat has caused the channel substrate in the first 1.5 miles downstream of the dam (until the confluence with Willow Valley Creek) to become larger than sediments found in similar reaches further downstream and upstream of the dam. The average diameter, D_{50}, of channel substrate below the dam is 100mm, whereas at a location of similar channel slope three miles downstream of the confluences of three significant tributaries, the D_{50} is 47mm. Upstream of the dam the D_{50} is 55mm. In addition, the substrate immediately downstream of the dam is largely angular, suggesting the sediment comes from the nearby hill slopes and the creek has had little chance to abrade the sharp edges. At the survey site three miles downstream, sediment is more rounded and less angular. This indicates that the substrate has been worked by the creek to a greater degree than that upstream (**Figure 5.11**). This is a common effect of dams (Grant et. Al. 2003).

Figure 5.11: Substrate Immediately Below Scotts Flat **(L)**, and 3 miles Downstream **I**

Influence of Lake Wildwood on Sediment Supply and Downstream Habitat

Surveys were also conducted upstream and downstream of Lake Wildwood Reservoir, with results similar to the Scotts Flat survey data. Geomorphology surveys, including pebble counts, were performed in riffles and gravel bars on sections of Deer Creek both upstream and downstream of Lake Wildwood Reservoir (Wolman 1954). Pebble counts were also conducted on Squirrel Creek, the only perennial tributary to lower Deer Creek and currently the primary source of spawning gravels and cobbles to the sections of Deer Creek near the Yuba River confluence. Pebble counts were conducted immediately upstream of the reservoir (site 6), immediately downstream of the reservoir (weir), upstream of Squirrel Creek (site 8), on Squirrel Creek (site 16), downstream of Squirrel Creek (site 9, site 10), and in the confluence reach. A summary of the pebble count survey results is provided in **Table 5.1**. Gravel size D_{50} (median particle size) in millimeters indicates that 50% of gravels in the sample were smaller and 50% were larger. D_{84} indicates the size of gravel larger than 84% and smaller than 16% of the sample.

Site	Mean	D50	D84	Site Mean	Site D50	Site D84
Site 6 (1)	44.9	74	210	55.1	70	223.3
Site 6 (2)	42.4	47	250			
Site 6 (3)	78	89	210			
Site 6 (4-gravel bar)	48.8	67	140			
Weir (1)	65.5	64	110	66.5	70	120.0
Weir (2)	67.5	76	130			
Site 8 (1)	152	160	330	110.8	108	273.3
Site 8 (2)	109.5	120	250			
Site 8 (3)	71	44	240			
Site 8 (4-gravel bar)	32.6	36	59			
Site 16 (1)	49	40	120	37.7	35	102.3
Site 16 (2)	26.2	30	57			
Site 16 (3)	37.8	35	130			
Site 16 (4-gravel bar)	21.7	21	43			
Site 9 (1)	102.5	130	300	71.0	71.00	273.3
Site 9 (2)	45.7	24	220			
Site 9 (3)	64.8	100	300			
Site 9 (4-gravel bar)	18.8	19	43			
Site 10 (1)	54.2	98	210	49.1	67	152.7
Site 10 (2)	60.7	75	160			
Site 10 (3)	32.5	28	88			
Confluence (1)	176.6	70	2400	176.6	70	2400.0

Table 5.1: Summary of pebble count survey data results. Pebble count data is in mm.

Table 5.1 provides a summary of the pebble count survey data, including the mean, D_{50}, and D_{84} for each riffle or gravel bar, and the mean, D_{50}, and D_{84} for each site excluding the gravel bar sample. Studies have shown Chinook salmon use gravels with a D_{50} between 7 and 100 mm (Platts, et al. 1979; Reiser and Bjorn 1979; Kondolf 1988; Fairman 2007). A study by Vyverberg et al. (1997) using bulk samples indicates that a suitable D_{50} range is from 16 to 71 mm, and D_{84} range from 32 to 133 mm. This work was based on Chinook salmon spawning on the lower American River.

Upstream of Lake Wildwood reservoir at site 6, the D_{50} for each riffle and gravel bar is within the appropriate range for Chinook salmon spawning, but suggests the D_{84} particle size is larger than spawning material used by Chinook on the American River and therefore might be too large for successful spawning (Vyverberg et al. 1997).

Immediately downstream of Lake Wildwood reservoir at the weir site the D_{50} for each riffle is within the appropriate range for Chinook salmon spawning and suggests the D_{84} particle size is also appropriate for spawning salmon. Many of the gravels and cobbles in the weir reach consist of angular and very coarse sediments that have been washed into the creek from local hillsides, or entered the creek as shot rock during the construction of the Lake Wildwood dam. Therefore, although the gravel and cobbles are appropriately sized, the quality of these gravels is low, which could prevent successful spawning. This is the most impacted reach because it is located directly downstream of the dam and only has access to a limited local supply of gravel. With each passing year the streambed in this reach becomes more armored, as the smaller gravels are transported downstream and out of the reach, with no upstream source or supply of gravels to replenish them. This reach should be targeted for gravel augmentation based on the proximity to the dam.

Approximately 1.5 miles downstream of Lake Wildwood Reservoir in the site 8 reach, the D_{50} and D_{84} for two of the three in-stream pebble counts was larger than the appropriate size for Chinook salmon, with the third in-stream site having an appropriate D_{50} but too large D_{84} particle size. The site 8 gravel bar consists of appropriately sized gravels for Chinook salmon spawning and suggests some of the material available for transport in the site 8 reach is suitable for spawning, but the majority of material available for transport is too large for Chinook salmon to use for creating spawning beds. This suggests the need for gravel augmentation in this reach.

Squirrel Creek, the major tributary to lower Deer Creek, flows into Deer Creek between site 8 and site 9 and contributes year-round flow and sediment to Deer Creek. The D_{50} and D_{84} data suggest that Squirrel Creek is a source of smaller sized gravels and is contributing spawning sized gravels downstream.

Downstream of Squirrel Creek there is a drastic difference between the site 9 reach and the nearby site 8 reach, primarily due to the gravels being transported into the site 9 reach by Squirrel Creek. The D_{50} in the site 9 reach is smaller than in the site 8 reach, but is still larger than the D_{50} used by spawning Chinook salmon. There is also a slight decrease in D_{84}

particle size from site 8 to site 9, but the D_{84} is still too large for Chinook salmon to utilize for spawning. This points to the need for gravel augmentation in Deer Creek upstream of the Squirrel Creek confluence, as Squirrel Creek is the primary source of spawning sized material for the spawning reach of Deer Creek. The Squirrel Creek contribution does not result in sufficient streambed material that is appropriate for spawning in Deer Creek, further pointing to the need for gravel augmentation in upstream reaches as far as the Lake Wildwood Reservoir dam.

The site 10 reach is approximately 1.5 miles downstream of Squirrel Creek and one mile upstream of the Chinook salmon spawning reach in Deer Creek. The D_{50} in the site 10 reach is smaller than at site 8 and site 9 and is generally within the appropriate range for Chinook salmon spawning, with a D_{50} of 75 mm and 98 mm at two riffles, which is just outside the range observed on the lower American River and just within the appropriate range suggested in other studies (Platts, et al. 1979; Reiser and Bjorn 1979; Kondolf 1988; Vyverberg et al. 1997; Fairman 2007). This suggests that the D_{50} in the site 10 reach could be appropriate for Chinook salmon spawning. The D_{84} in the site 10 reach is appropriate in one section of creek, however two of the three pebble count areas resulted in a D_{84} that is larger than Chinook salmon typically select for spawning (Vyverberg et al. 1997). Overall this suggests that there are appropriately sized gravels in the site 10 reach, however there is also a substantial amount of bed material that is too large for successful spawning. With the D_{50} skewed to the high end for appropriately sized spawning material, and the D_{84} too large for spawning salmon, there is a need for gravel augmentation in this reach, particularly because of the proximity to the spawning location in the confluence reach.

One pebble count was conducted in the confluence reach, at a pool-riffle transition. The data for the confluence reach indicate the D_{50} is appropriate for Chinook salmon spawning, but the D_{84} is significantly greater than the range specified by Vyverberg et al. (1997). This is due to the quantity of large cobbles and boulders, some of which are larger than a car. Overall the confluence reach is heavily armored by these larger substrates, which limits Chinook salmon spawning habitat in this reach. The quantity of large substrates within this reach indicates the need for spawning bed enhancement and strategic removal or placement of boulders, to create ideal conditions for salmonid spawning.

It is important to note that volumetric analysis of sediment supply and transport in lower Deer Creek was not conducted, but estimates of sediment transport into Lake Wildwood Reservoir exist. Based on excavation data from Lake Wildwood Reservoir an annual sediment deficit of approximately 12,300 yd^3 exists downstream of the dam (**Table 5.1**).

F. Bank Stability

Upper Deer Creek Bank Stability

Introduction and Methods

Stable banks are characterized by the presence of boulders, rocks, or rooted vegetation that reduces the bank's susceptibility to erosion, while unstable banks are characterized by the presence of exposed raw dirt, lack of rooted vegetation, steep sloped banks, undercuts, and often slumping banks (See Geomorphology Appendix for a full description of the methodology used). **Figures 5.12** and **5.13** show both stable and unstable banks on Deer Creek.

Figure 5.12: Example of unstable bank.

Figure 5.13: Example of stable bank

The stability of the banks on upper Deer Creek was evaluated using three methods. In 2005 aerial photographs were evaluated to determine the history of large-scale channel movements, and local channel stability was evaluated using the methodology described by Johnson et al (1998). In addition the bank stability of upper Deer Creek was evaluated in 2010 using state protocols that incorporate a physical habitat assessment. The CSBP method was also used to evaluate bank stability in lower Deer Creek, Little Deer Creek, and Squirrel Creek.

The CSBP bank stability analysis includes seven long-term monitoring sites in the upper Deer Creek watershed: sites 1, 2, 4, and 6 on the main stem of Deer Creek and sites 13, 12, and 11 on Little Deer Creek. The physical habitat data were collected as part of FODC's regular monitoring program and follow protocols developed by the Department of Fish and Game Aquatic Bioassessment Laboratory (CABL). There are 10 parameters assessed as part of the California Stream Bioassessment Procedure (CSBP), as discussed in the River Ecology Chapter, with the three most applicable parameters for this discussion being bank stability, vegetative protection, and riparian zone width. Each parameter is scored out of twenty points (10 points for each bank) with the data from 2000 – 2008 averaged to get the score for each site. Data are collected twice a year in June and October, with the assessment covering a 100 m reach. Optimal habitat scores are from 16 – 20, suboptimal from 11 – 15, marginal from 6 – 10, and poor from 0 – 5. Overall a score of 48 (80%) or greater is optimal, 33 (55%) to 47.9 is suboptimal, 18 (30%) to 32.9 is marginal (Figure BNKSTB).

Results

Aerial photographs show that in the alluvial reaches, Deer Creek has experienced significant adjustments as a result of large flow events. For example, flooding in 1997 caused the reach downstream of Providence Mine Road to shift more than 150 ft in several locations.

The survey of local-scale bank conditions indicates that much of the creek has moderate to good bank stability, while certain locations suffer from poor bank stability conditions (**Table 5.2**). Bank stability ratings start downstream of Scotts Flat Reservoir and continue downstream to Lake Wildwood Reservoir. Reach 3 rated the highest for bank stability with a score of 3.5, which is described as slightly unstable to stable (see **Appendix E** for details). This reach primarily had well rooted vegetation, such as large trees and shrubs down to the stream's edge and only some areas showed signs of minor erosion. Reach 4 was rated as a 2.76 and can be described as moderately unstable to slightly unstable. This reach had bank undercutting and less vegetation down to the stream edge. Reach 5 was the least stable reach, classified as a 2.15 and can be described as moderately unstable. This reach had extensive undercutting and erosion. Reach 6 and 7 do not conform to the general trend of progressively less stable banks as one moves downstream. Reach 6 rated 2.37 and reach 7 rated 2.83, slightly unstable to stable. One explanation for this sudden change in trend is that the banks were less steep and more in contact with the floodplain in these lower reaches, and therefore destabilization processes were more difficult to detect during summer low flows, when this study was conducted. See **Appendix E** for a map of areas along upper Deer Creek with unstable bank conditions.

The CSBP data indicate that site 1, site 4, and site 6 are optimal overall, with site 2, site 13, and site 11 suboptimal, and site 12 providing marginal bank stability and riparian habitat. All three parameters are classified as optimal at site 1, site 4, and site 6. Sites 1 and 4 have the highest scores, primarily because both sites have many large boulder or bedrock sections of creek that help to support and stabilize the bank. Additionally these sites have adequate riparian vegetative cover including large trees and aquatic vegetation that help secure the banks, and have little activity or development encroaching on the majority of the reach around these sites. Site 6 is also optimal primarily due to the presence of a wide, well vegetated riparian corridor, with large boulders and bedrock being less of a factor contributing to bank stability. There is much less bedrock and large boulder material in the site 6 reach, compared to sites 1 and 4. Development is beginning to cause banks to become unstable in some sections of the site 6 reach, as evidenced by recent field observations.

Sites 2, 13, and 11 are classified as suboptimal, primarily due to development encroaching on the creeks. At site 2, Deer Creek is located within ten ft of Willow Valley Road, a major county roadway. Here, portions of the roadway are breaking off and into the creek at the historic low water crossing, where vehicles with high clearance often drive across the creek from Willow Valley Rd to Boulder St, further contributing to bank erosion. Additionally, runoff from the roadway and inputs from Mosquito Creek, a tributary that flows into Deer Creek through a set of channelized conduits on river right within the site 2 reach, further contribute to erosion during periods of increased runoff. These two factors inhibit bank stability and reduce the density and width of the riparian corridor, which further contribute to unstable banks that are susceptible to erosion. Despite the presence of Willow Valley Road and the historic low-water crossing the data indicate that the banks are stable in most of the reach, with bank stability in the low end of optimal. This could be attributed to the wide floodplain on river left, and lack of channel incision, which allows the creek to disperse its energy during high flows. The riparian conditions are at the low end of suboptimal, indicating lack of native vegetative cover as well as limited riparian zone width, with the latter primarily attributable to the roadway on river right and the historic low water crossing.

Sites 13 and 11 are on Little Deer Creek upstream and downstream of Pioneer Park in Nevada City. Both sites are located in close proximity to residential developments, as well as the park and its recreational features such as trails, Little Deer Creek, and baseball fields. The downstream most portions of the site 13 reach are impacted by activity directly related to the park, with the right bank much more degraded than the left bank, due to the public access on the right bank. Farther upstream in the reach the public access to the park transitions into private residential developments, which have encroached on the creek and its riparian corridor. This is evidenced by old barbed wire fencing in the creek and riparian corridor, with additional new fencing constructed on the river left banks. Trails run along the right side of the creek, connecting the park to the residential properties at the upstream end of the reach. This has led to considerable erosion in sections of this reach, with denuded banks and a very narrow or complete lack of riparian corridor. The situation at site 12, within Pioneer Park, is less optimal than the two locations surrounding the park, primarily due to impacts associated with park development and recreation.

The site 12 reach of Little Deer Creek is located within Pioneer Park and is one of the park's attractions. The site 12 reach has been severely impacted, due to the creek channel being re-routed. Evidence of this channelization and re-routing is still present, with concrete channel walls and gabion lining small sections of the creek. The channelization has led to a lack of bank stability, as the creek does considerable work on the channel during higher flows. Bank stability is generally low, due to impacts associated with recreational users at the park, who often walk in or along the creek and on its banks. The riparian corridor is fairly limited in the site 12 reach, which further leads to bank erosion and a lack of overall bank stability. One restoration project occurred in this section of creek in 2003 and the data indicate that the banks are becoming more stable and the riparian zone more vegetated as time goes by. Sections of creek are lined with willow and alder but the riparian corridor is still very narrow and is denuded in many portions, likely due to users of the park. The success of willow and alder growth in the site 12 reach points to the need for additional projects in this and other sections of creek.

Site #	Bank Stability (20 pts)	Vegetative Protection (20 pts)	Riparian Zone Width (20 pts)	Total Score (60 pts)	% Score
Site 1	17.5	18.5	17.0	53.1	88.5
Site 2	16.7	12.9	11.9	41.5	69.2
Site 13	15.8	15.9	13.9	45.6	76.1
Site 12	13.9	9.8	4.6	28.4	47.3
Site 11	15.7	12.5	11.9	40.1	66.8
Site 4	18.4	18.2	19.1	55.7	92.8
Site 6	16.8	16.1	16.5	49.3	82.2
Site 8	17.1	15.0	14.5	46.5	77.6
Site 15	13.4	12.4	10.9	36.7	61.2
Site 16	17.3	16.0	16.0	49.3	82.1
Site 9	19.1	15.2	14.7	48.9	81.5
Site 10	17.1	16.9	16.2	50.2	83.6

Table 5.2: Bank stability data collected from 2000 – 2008 as part of the FODC CSBP monitoring program. Sites are organized from upstream (Site 1) to downstream (Site 10). Sites 13, 12, and 11 are on Little Deer Creek; sites 15 and 16 are on Squirrel Creek.

Lower Deer Creek Bank Stability

Methods

The bank stability of lower Deer Creek was evaluated using several methods. Annual CSBP physical habitat data collected at three sites on lower Deer Creek and two sites on Squirrel Creek, in June and October of each year, were analyzed to evaluate local bank and channel stability and vegetative protection on the bank, an indicator of bank stability. A stream walk and visual assessment of the entire portion of lower Deer Creek was conducted in the summer of 2008, to evaluate local bank stability at locations not annually surveyed as part of the FODC's regular monitoring program. Aerial photographs were evaluated to determine the history of large-scale channel movements.

Results

Lower Deer Creek CSBP Data

The CSBP data indicate that site 16 on Squirrel Creek and sites 9 and 10 on Deer Creek have optimal bank stability and vegetative protection overall, with site 15 and site 8 in the suboptimal range. Site 16 on Squirrel Creek and site 10 on Deer Creek are the only sites with optimal scores for each parameter. Site 15 is the only site with a marginal score, for riparian zone width.

Site 16 and site 10 had the highest scores for bank stability, due to a variety of factors. At both sites the presence of bedrock makes the banks stable in portions of the reaches, although the bedrock limits vegetative cover. Site 16 is on a property that is part of a conservation easement and is only accessible by foot. The property has no development on it, which helps to preserve the quality of the habitat. Grazing has occurred in the past at site 16, and grazing of a single horse actively occurs at site 10. There is evidence of the presence of grazing impacts in some locations, but this does not appear to significantly impact bank stability or vegetative cover in the riparian zone overall. Site 9 also scored in the optimal category, primarily due to the high score for bank stability, but had suboptimal scores for riparian vegetation. The site 9 reach is dominated by bedrock step-pools with stable bedrock banks in many sections. This leads to a lack of riparian vegetation in sections of the site 9 reach, as vegetation is unable to grow due to the rocky ground. The site 9 reach is isolated and shows no recent signs of development or grazing that are causing bank instability or excessive erosion.

Site 8 scored at the high end of the suboptimal category with an optimal score for bank stability and suboptimal score for riparian vegetation. Sections of the site 8 reach include bedrock step-pools with stable banks, but the majority of the banks in the reach are not bedrock in nature. Evidence of historic low-water crossings are present at two locations within the site 8 reach, one located where the monthly monitors cross Deer Creek to access the adjacent site 16 property and the second farther downstream near the Clear Creek confluence. Cattle have also been observed crossing the creek at this location. Both of these locations are cleared of vegetation to the creek. This has led to areas where the bank is unstable and bare of riparian vegetation, and thus prone to erosion. Most of the banks are stable, due to thick riparian vegetation, but there are gaps in the vegetative cover from the old crossings, grazing, and other activities. Additionally the riparian zone is narrower than it should be, possibly due to grazing operations, and hosts a variety of non-native species including Himalayan blackberry, yellow star-thistle, and black locust.

Site 15 on Squirrel Creek in Penn Valley is much different in nature from the other lower Deer Creek and Squirrel Creek sites, as most of the lower Deer Creek sites are quite rural while site 15 is located in the town of Penn Valley. This makes site 15 subject to development impacts that are similar to those experienced at sites 2 and 12 in the Nevada City area. Site 15 is located inside a mobile home park in Penn Valley and is frequented by residents of the park. The river right bank of the site 15 reach is characterized by steep slopes, many of which are bare and show obvious signs of erosion. Large portions of both banks are covered by invasive blackberry, with the left bank much less steep than the right bank and thus less prone to erosion. However, the left bank is more accessible by residents of the park than the right bank, and there are signs of erosion at several locations throughout the reach, apparently associated with residents of the park accessing the creek for recreation. At the downstream end of the reach a paved bridge crosses the creek, with an inappropriately sized conduit system, which causes backwater conditions that promote bank scouring and associated signs of erosion. Additionally the bridge seems to be losing its integrity and is possibly making erosion problems worse during high stream flows.

Lower Deer Creek Stream Walk and Visual Assessment

The stream walk and visual assessment on lower Deer Creek indicated that the majority of lower Deer Creek consists of stable or moderately stable banks, with minimal areas of excessive erosion and fine sediment entering the creek. Aerial images focusing on specific areas of erosion are found in the Geomorphology Chapter Appendix. From Lake Wildwood reservoir downstream to the site 8 reach no CSBP data are available on bank stability, primarily because the habitat consists of steep bedrock canyons in which the CSBP assessment is difficult to complete. This includes reach 8 and 9 from the Reach Classification, with reach 8 predominantly steep bedrock and reach 9 alternating between bedrock step-pools and pool-riffle alluvial sections. A small approximately 175 m long section of Deer Creek in reach 8, from the Lake Wildwood spillway to the Lake Wildwood WWTP, is more alluvial in nature with banks that are capable of being eroded in some locations. There is evidence of bank undercutting and erosion in this reach, with a dirt and gravel road encroaching on the creek on river left, which appears to have caused bank instability. The road is present so that Lake Wildwood can maintain their reservoir, and is planned for use by FODC during their gravel augmentation project, but is a major source of fine sediment to the creek. Other than this location near the spillway the banks are predominantly stable from Lake Wildwood reservoir downstream to near the site 8 reach.

Around site 8, within the downstream most portions of reach 9 before Squirrel Creek enters Deer Creek, there is evidence of unstable banks that are bare of vegetation, either due to clearing or grazing activities. Cattle have been observed grazing on both sides of Deer Creek in this area, and vehicles historically crossed Deer Creek at multiple locations around site 8. This has led to bank and riparian conditions that are less than optimal, but conditions are not severely degraded and excess erosion is not evident.

Downstream of Squirrel Creek to Mooney Flat Road, within reach 10, there are few signs of unstable banks or excessive erosion. Reach 10 alternates between bedrock, large boulder and bedrock dominated step-pools, and alluvial pool-riffle sequences, many of which promote stable channel conditions. At the downstream end of reach 10, residential development begins to encroach on the creek, with grazing on river right just upstream of Mooney Flat Bridge over Deer Creek.

In Reach 11, downstream of Mooney Flat Road Bridge to the confluence with the Yuba River, the banks of Deer Creek are very stable, due to bedrock dominating the reach. The hill slopes are very steep in reach 11 and could be susceptible to erosion, but this was hard to evaluate during summer low flow conditions. There is a lack of riparian vegetation in the majority of this reach, primarily due to the predominance of bedrock and large boulders in the riparian zone. Upland growth is sparse and areas of upland erosion are present, possibly associated with animal trails, but none appears to be causing severe erosion to enter Deer Creek.

Bank Stability Discussion

Bank stability of tributary creeks and reaches of Deer Creek were evaluated through multiple methods. The survey of local-scale bank conditions indicated that much of the creek has moderate to good bank stability, while certain locations suffer from poor bank stability conditions. Bank stability ratings started downstream of Scotts Flat Reservoir and continue downstream to Lake Wildwood Reservoir. Reach 3, from Little Deer Creek to Providence Mine Rd, received the highest overall score of 3.5, indicating the presence of slightly unstable to stable banks in this reach. FODC site 4 is within this reach, with the CSBP method confirming that primarily stable, well-vegetated banks characterize this reach. Reach 4 scored a 2.76, indicating moderately to slightly unstable banks. There is no FODC monitoring site within this reach for comparison, but FODC and American Rivers at

Stocking Flat established a long-term monitoring site in 2008 as part of the ongoing floodplain restoration project located at Stocking Flat. Reach 5 scored the lowest on bank stability, with a 2.15, with reach 6 scoring a 2.37. Although FODC monitoring site 5 is located within reach 5, CSBP habitat assessment data collection at this site began in 2010 and thus there is not an appropriate dataset for comparison. Reach 7 shows improvement from reach 6, with a score of 2.83 indicating banks in this reach are slightly unstable to stable. Reach 7 includes FODC monitoring site 6, with the CSBP dataset indicating that site 6 is at the low end of optimal for bank stability. This indicates that both methods come to a similar conclusion regarding bank stability in this reach.

Using the CSBP method, bank stability and vegetative protection were analyzed for twelve sites in the Deer Creek watershed, including sites on Little Deer Creek and Squirrel Creek. The CSBP data indicate that multiple sections of Little Deer Creek, Deer Creek, and Squirrel Creek have unstable banks with inadequate vegetative cover, and are actively eroding or susceptible to future erosion. Many of these areas are impacted due to development for transportation, recreation, or residential dwellings. The most impacted sites are sites 12 in Pioneer Park, site 15 in Penn Valley, and site 2 upstream of Nevada City. All of these sites have development impacts that have led to unstable banks and a lack of vegetative protection of the banks. Using the CSBP method 50% (6/12) of the sites in the watershed were classified as having optimal bank stability and vegetative cover, 41.7% (5/12) classified as suboptimal, with 8.3% (1/12) classified as marginal. The CSBP method points to Little Deer Creek as having several sections of creek with unstable banks, around the Pioneer Park area. Additionally Squirrel Creek in Penn Valley is actively eroding and contributing fine sediment to the creek for downstream transport.

G. Sediment Transport

Kyle Leach

Introduction

As mentioned above, several attributes of healthy rivers are a function of sediment transport and deposition dynamics, including in bedrock reaches. These attributes are as follows:

- Bedrock rivers exhibit nested depositional features.
- Episodic sediment delivery enhances spatial complexity.
- Biological hotspots occur in reaches with significant deposits, gravel bars and floodplain habitat.

And in depositional reaches:

- The channel bed surface is frequently mobilized.
- Alternate bars must be periodically scoured deeper than their coarse surface layers.
- Alluvial channels are free to migrate.
- Diverse riparian plant communities are sustained by the geomorphic effect of natural annual hydrograph components.

It is important therefore to understand the sediment transport and deposition dynamics of Deer Creek to determine whether the attributes of a healthy creek are being sustained. Low flows, which occur most of the time, transport relatively minor amounts of bedload sediment because the bedload transport rate is near zero. Very large flood flows, although having the highest transport rates, account for relatively minor amounts of bedload sediment because high flows occur infrequently and are generally of short duration. Consequently, the largest proportion of the total bedload is transported by flows around the peak of the total bedload transport curve (i.e., the effective discharge). In many rivers, bankfull discharge approximates effective discharge.

Conceptually, the required maintenance flow regime begins at a discharge at which gravels making up the bed of the channel begin to move and includes all flows up to and including the 100-year flow. This range of flows should sustain the attributes of healthy functions listed above, including: mobilize the channel bed sediment, scour alternate bars deeper than their coarse surface layers, scour vegetation from the channel, partially inundate the floodplain, and provide high flow functions needed to sustain streamside vegetation (Schmidt and Potyondy 2004).

Methods

For the purpose of evaluating whether current flows are of sufficient magnitude to sustain healthy river attributes, it was assumed that mobilization of the median sized sediment (D_{50}) would represent mobilization of some portion of the bed. It was assumed that the mobilization of the D_{84} sized sediment would represent mobilization of the channel bed as a whole.

Sediment supply thresholds were evaluated using a combination of field observation and calculations. Field data were collected at six sites on the main stem of upper Deer Creek, at four sites on lower Deer Creek, and one site on Squirrel Creek. Data were collected at each site generally according to the methods described in Harrelson *et al.* (1994) and included channel cross sections, longitudinal profile, channel substrate size, high-water marks and water surface elevations. Channel substrate size was determined by pebble counts (Wolman 1954). The sediment transport estimates are based on the investigations of Sagan and Bagnold (1975) and Leopold, Wolman and Miller (1964). The approach is based on observations of the mobilization of channel substrate as a function of water depth and channel slope. The results of the estimates are provided in the Geomorphology Chapter Appendix, in addition to particle size distribution curves, cross-sections, and longitudinal profiles for each of the sites.

In addition to the field data and observations, dredged material data from Lake Wildwood reservoir were analyzed to investigate the annual amount of sediment transported into Lake Wildwood reservoir. Examining records of sediment excavated from Lake Wildwood during reservoir maintenance and dredging operations can provide estimates of the amount of sediment currently transported by Deer Creek.

Results

Upper Deer Creek

Table 5.3 indicates that at the majority of sites, three of the key attributes of good geomorphic function (*i.e.,* D_{50} is mobilized every 1-2 yrs, D_{84} is mobilized every 5-10 years and the floodplain is inundated every 1-2 years) are accomplished much less often than is considered necessary for a properly functioning river. With the exception of the Nevada City Wastewater Treatment Plant, where D_{50} and D_{84} material would be expected to be mobilized at the ideal frequency, and the Upper Stocking Flat location, where D_{50} sediments would be mobilized at a good frequency, none of the other sites achieve the desired frequency for any of the three attributes. Only at FODC/SSI site 5 does the floodplain get inundated at relatively close to the ideal frequency. This indicates that overall, upper Deer Creek is not healthy and functioning from a geomorphic perspective.

Site No.	Site name	Frequency D_{50} mobilized (yrs) (1 – 2 yrs is ideal)	Frequency D_{84} mobilized (yrs) (5 – 10 yrs is ideal)	Frequency floodplain is inundated (yrs) (1 – 2 years ideal)
1	Scotts Flat	2 – 5	25 – 50	no floodplain
2	FDC #2	10	50 – 100	10
3	NC WWTP	1	5 – 10	no floodplain
4	Providence	2 – 5	100	10 – 25
5	Upper Stocking	1 – 2	50 – 100	10 – 25
6	Lower Stocking	5 – 25	50 – 100	5 – 10
7	FDC #5	2 – 5	10 – 25	2 – 5
8	FDC #6	10 – 25	50 – 100	no floodplain

Table 5.3: Summary of substrate mobilization and floodplain inundation frequencies in upper Deer Creek.

Lower Deer Creek and Squirrel Creek

Three cross sections were surveyed at site 8, site 16, site 9, and site 10, with two cross sections surveyed at the LWW Weir. The data in **Table 5.4** summarize the results from all cross sections at each site, which explains why there is a large frequency range for some of the attributes. Table 5 indicates that at the majority of sites surveyed in lower Deer Creek and Squirrel Creek, key attributes of good geomorphic function are accomplished within the necessary frequency for a properly functioning river.

Site (Reach)	Frequency D_{50} mobilized (1 – 2 years ideal)	Frequency D_{84} mobilized (5 – 10 yrs is ideal)	Frequency floodplain is inundated (1 – 2 yrs is ideal)
LWW Weir (Reach 8)	1 – 2	5 – 10	5 – 10
Site 8 (Reach 9)	2 – 5	5 – 25	2 – 10
Site 16	1 – 2	5 – 10	2 – 5
Site 9 (Reach 10)	1 – 5	10 – 25	2 – 5
Site 10 (Reach 10)	1 – 2	2 – 10	2 – 5

Table 5.4: Summary of substrate mobilization and floodplain inundation frequencies in lower Deer Creek and Squirrel Creek.

The data indicate that the Lake Wildwood Weir site, immediately downstream of Lake Wildwood Reservoir, is accomplishing two of the three geomorphic functions: The D_{50} and D_{84} are mobilized at an ideal frequency. However, the floodplain is inundated every five to ten years, instead of at the ideal frequency of one to two years, indicating that floodplain connectivity in this reach could be improved. This may be in part due to the road and developments that exist downstream of the spillway, with the road having been built up over time and armored with large rocks, which prevents access to the floodplain in some locations.

At site 8 the frequency at which the D_{50} and D_{84} are mobilized is within the ideal range at some cross sections, as indicated by the overlap between the expected and ideal years, but not at every cross section. This indicates that the D_{50} and D_{84} are potentially being mobilized at the ideal frequency. The same situation occurs with regards to floodplain inundation, as there is an overlap between the ideal and expected frequencies. This suggests that the floodplain at site 8 could potentially be inundated at the ideal frequency in some locations.

The data for site 16 on Squirrel Creek suggest that all three geomorphic attributes are being accomplished at the ideal frequency. Mobilization of the D_{50} and D_{84} is expected within the ideal frequency at each of the cross sections. Inundation of the floodplain is predicted at a frequency of two to five years, which suggests that the floodplain may or may not be inundated at the ideal frequency. Overall the data point to good geomorphic health and function in this section of Squirrel Creek.

The data for site 9 indicate that all three geomorphic attributes are potentially being accomplished at the ideal frequency, with expected frequencies that overlap the ideal frequency for each attribute. Mobilization of the D_{50} is predicted to occur every one to five years, which suggests that the D_{50} could be mobilized at the ideal frequency. Mobilization of the D_{84} is expected to occur every ten to twenty five years, which is just outside the ideal frequency and suggests that the D_{84} is not mobilized at an ideal frequency. The floodplain at site 9 could be inundated at the ideal frequency in some locations, indicating there is potentially adequate floodplain connectivity in this section of Deer Creek.

At site 10 the data suggest that all three geomorphic attributes are potentially accomplished within the ideal frequency, with the D_{50} and D_{84} mobilized at the ideal frequency. Inundation of the floodplain at site 10 is expected every two to ten years, which indicates there is potential for the floodplain to be inundated within the ideal frequency, but it is likely that floodplain connectivity is less than ideal based on the expected range.

Lake Wildwood Reservoir Sediment Transport Estimates

Figure 5.14 shows the volume of annual sediment excavated from Lake Wildwood reservoir since 1986. The average volume excavated per year is 12,300 yd^3, and consists of a combination of suspended and bedload sediment. It is important to note that the Lake Wildwood managers do not completely remove all of the sediment that is transported into the reservoir, with the area of excavation typically focused on the upstream end of the reservoir, and the finest material transported beyond this zone of excavation, particularly during the extreme flood events. 2008 was the first year that other portions of the reservoir were dredged for sediment, all of which consisted of very fine material. Thus, the excavation data likely underestimate the amount of sediment transported by Deer Creek into Lake Wildwood.

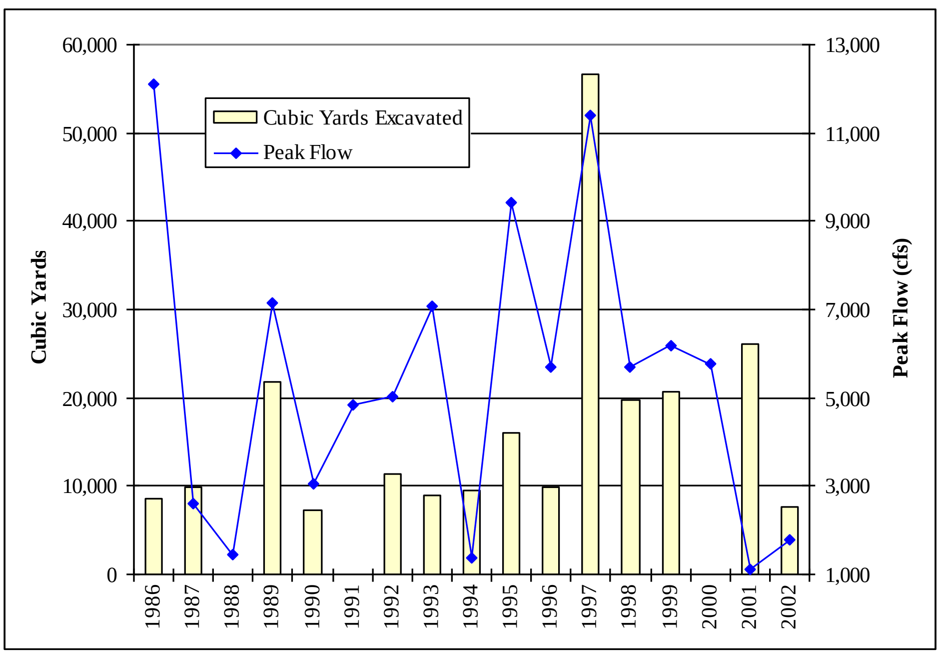


Figure 5.14: Amount of sediment excavated from Lake Wildwood compared to annual peak flows on Deer Creek at the Smartsville Gage (USGS #11418500)

Lake Wildwood is approximately 15.5 miles downstream of the Scotts Flat reservoir complex, and the watershed area between the two dams is approximately 36 mi^2. Based on the Lake Wildwood excavation data the average sediment yield therefore is 342yd^3/mi^2 each year, or approximately 764 tons/mi^2/yr. The maximum amount of sediment transported in one year occurred in 1997 when Deer Creek transported 56,000 yd^3, or 1555 tons/mi^2, enough sediment to cover the 36 mi^2 portion of the watershed to a depth of 0.6 in. By contrast, during the 19^{th} century hydraulic mining era, the Deer Creek drainage produced enough sediment to cover the entire watershed in 4.7 inches of sediment (Heur 1891; Gilbert 1917 in Allan 1999). The average sediment yield rate of 764 tons/mi^2 is less than the average yield rate estimated for California of 1,300 tons/mi^2 (Dunne and Leopold 1978). The USGS estimated that the Yuba River sediment yield is approximately 970 tons/mi^2/yr (Snyder et. Al. 2004). Residual stores of sediment generated during the mining era also affect transport in the Yuba River drainage. The climate, unstable bedrock, rate of geologic uplift, and land use within California's watersheds produce the highest yields of sediment in the country and some of the highest in the world (Mount 1995).

Discussion

The sediment transport estimates indicate that most of the sites on upper Deer Creek are not exhibiting the geomorphic attributes of a healthy and functioning creek, while sites on lower Deer Creek and Squirrel Creek generally are functioning and healthy from a geomorphic perspective. This is evident by the number of sites on upper Deer Creek that do not meet the ideal frequency for D_{50} or D_{84} mobilization and floodplain inundation, with only two sites mobilizing the D_{50} at the ideal frequency, one site mobilizing the D_{84} at the ideal frequency, and no sites that inundate the floodplain at the ideal frequency. Only the Nevada City WWTP site accomplishes the mobilization attributes, and there is no floodplain present at this location to evaluate floodplain inundation. The low frequency with which substrates are mobilized and floodplains are inundated in upper Deer Creek reduces the health and productivity of the Deer Creek watershed overall. The low frequency of these events is primarily caused by three factors:

1. Scotts Flat reservoir reduces the magnitude of flows for floods in the 2 – 25 year frequencies.
2. Scotts Flat eliminates the supply of sediment from the watershed upstream of the reservoir, resulting in the coarsening of sediment downstream of the dam. This results in higher flows being required to mobilize the dominant substrate in the channel.
3. Residual debris from the mining era remains at many locations in terraces above the stream channel, from Scotts Flat downstream to Lake Wildwood reservoir, which limits the capacity for floodplain inundation.

The sites on lower Deer Creek do not appear to be as impacted by Scotts Flat as sites on upper Deer Creek, likely due to increasing watershed area and contributions of sediment and stream flow from numerous perennial tributaries. In lower Deer Creek several sites accomplish the mobilization attributes and inundate the floodplain at an ideal frequency, with three sites mobilizing the D_{50} at the ideal frequency, three sites mobilizing the D_{84} at the ideal frequency, and two sites inundating the floodplain at within the ideal frequency. Squirrel Creek is unaffected by Scotts Flat reservoir, with minimal impacts to sediment transport capacity in Squirrel Creek near the Deer Creek confluence.

The data indicate there is a fundamental difference in geomorphic attributes when comparing upper Deer Creek with lower Deer Creek and Squirrel Creek. Squirrel Creek is an undammed tributary and thus is able to flow freely from its headwaters to the confluence with Deer Creek, which allows for natural sediment transport and deposition processes to occur. On Deer Creek downstream of Lake Wildwood reservoir there is a sufficient volume of flow to mobilize the creek bed and inundate the floodplain at an ideal frequency, likely due to increased distance from Scotts Flat reservoir. The farther downstream from Scotts Flat reservoir, the larger the watershed area that is contributing flow to Deer Creek, with numerous additional tributaries contributing flow that helps mobilize sediments and inundate the floodplain. The bed downstream of Lake Wildwood has not coarsened to the same extent as the reach downstream of Scotts Flat and is still capable of being mobilized at desired frequencies. This could possibly be attributed to the type or purpose of each dam and the duration each dam has been in existence. Scotts Flat reservoir was constructed before Lake Wildwood reservoir and serves to capture water, which reduces flows directly downstream of Scotts Flat when the reservoir is not at full capacity, and leads to bed coarsening. The tall, steep spillway at Scotts Flat promotes scour of Deer Creek, whereas the spillway at Lake Wildwood is not as tall or steep and has a large pool at its base, which leads to less bed scour than downstream of Scotts Flat. Lower Deer Creek and Squirrel Creek do not have as much evidence of remnant mining debris as does upper Deer Creek in the form of tailings and debris piles, and therefore have the capacity for floodplains to be inundated at an ideal frequency. This could be due to the steep, bedrock nature of much of lower Deer Creek, leading to transport reaches that have blasted the mining sediment downstream and into the Yuba, without leaving any terraces in the more gradual depositional stretches of creek.

H. Floodplain Connectivity

Introduction

As described above in the sediment transport section, one of the attributes of a healthy river is that the floodplains are frequently inundated (Trush et al. 2000). Floodplains are the engines of biological activity in river systems. Flooding of riparian areas delivers much needed sediment and nutrients to the floodplain, scours and prepares the floodplain surface for pioneer species, provides rearing habitat for key fish species, and delivers nutrients back into the main channel. The frequency, timing, and magnitude of flooding have profound impacts on the type of vegetation and habitat that exist in the riparian areas. Ideally, alluvial rivers in California would experience overbank flooding every 1-2 years. Whether or not this occurs is a function of the shape, size, and roughness of the channel, and the stream hydrograph, all of which have been altered in Deer Creek. Hydraulic mining contributed massive amounts of sediment to Deer Creek, some of which is still stored in its channel and floodplains in locations such as Providence Mine and Stocking Flat (**Figure 5.15**).

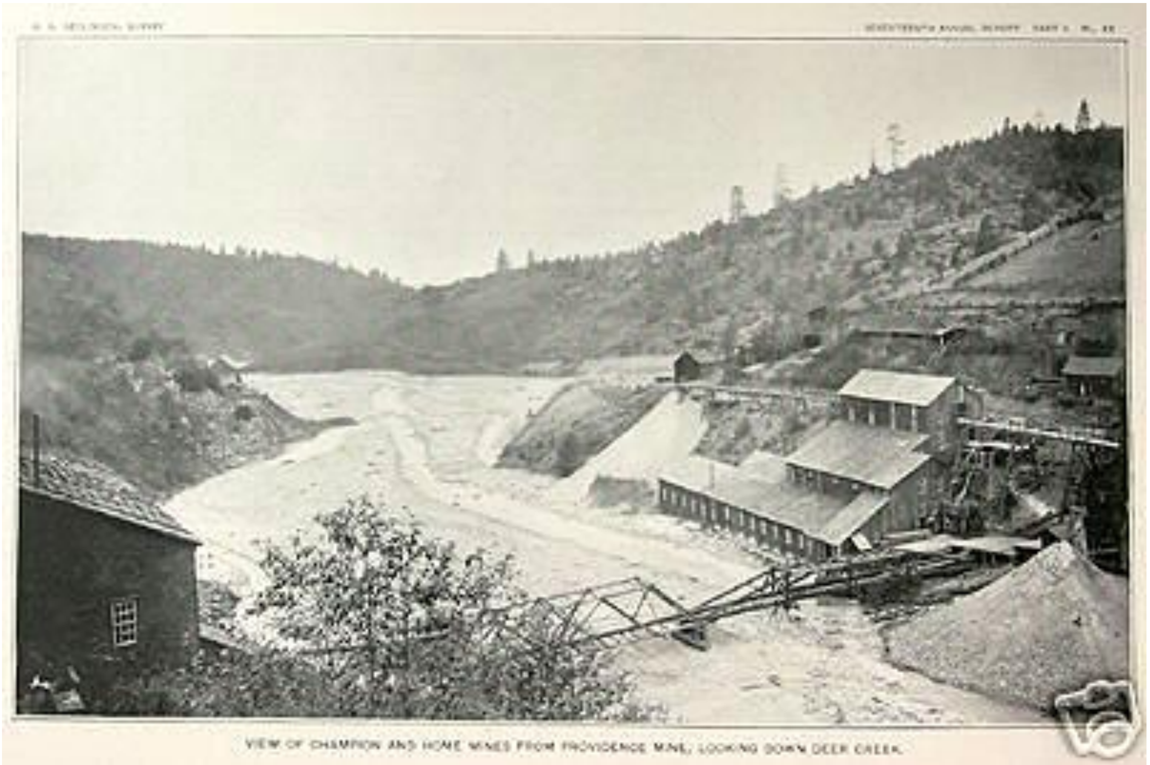


Figure 5.15: Massive amounts of sediment in the Deer Creek channel at the height of the mining era. This photo is of Deer Creek at Champion Mine, 1.5 miles West of Nevada City, circa 1880.

Methods and Results

Analysis was conducted on the frequency of floodplain inundation in the Deer Creek watershed. This was accomplished by surveying several cross sections along Deer Creek and Squirrel Creek and comparing that with the high flow events of varying return intervals. By examining aerial photographs and surveying the creek from the over flight, most of the likely floodplains in the study area were identified. Cross sections were selected to provide a reasonable representation of the floodplain types in the Deer Creek watershed. The results of this analysis are provided in **Table 5.5**, with survey data and calculations provided in the **Geomorphology Chapter Appendix**.

The results indicate that in many sections of upper Deer Creek between Scotts Flat and Lake Wildwood reservoirs, the floodplain is not inundated as frequently as it should be. The data indicate that the floodplains are inundated more frequently on lower Deer Creek downstream of Lake Wildwood and on the undammed Squirrel Creek. On upper Deer Creek the impacts of water management and mining are quite apparent, with abandoned floodplain terraces that are not appropriately scoured, seeded, and inundated by frequent small floods. This is evident at the Providence Mine and Stocking Flat locations. Only two of the nine survey locations on upper Deer Creek have a floodplain that is inundated at the ideal frequency. Terraces of mining rock and debris have been abandoned due to channel incision and post-mining degradation, with NID flow management compounding the problem by reducing small floods with a return interval of 2 – 25 years. The cross-section in **Figure 5.16** details an abandoned floodplain terrace at Stocking Flat and shows that the river left floodplain is more than ten ft above the bankfull stage. In lower Deer Creek and Squirrel Creek impacts are not as severe, with four of five surveyed floodplains inundated within the ideal frequency.

Floodplains in lower Deer Creek are inundated more frequently than those in upper Deer Creek. There is minimal evidence of mining rock and debris in lower Deer Creek and Squirrel Creek, with no large areas of hydraulic mining deposits or tailing piles that have led to abandoned floodplain terraces. Additionally Squirrel Creek is an undammed tributary and lower Deer Creek benefits from a large watershed area downstream of Scotts Flat reservoir, thus allowing small floods to occur in these reaches of creek more frequently than in upper Deer Creek. The LWW Weir site is the only location on lower Deer Creek at which floodplain inundation does not occur at the ideal frequency. This could be attributed to road and other infrastructure developments in the floodplain at the LWW Weir site, with the road built up above the floodplain and thus preventing access to the historic floodplain. Additionally the creek has been forced to adjust to the construction of the Lake Wildwood dam and spillway, which likely altered floodplain connectivity in this reach of Deer Creek.

Location	Flow to Inundate Floodplain (cfs)	Return Interval (yrs)	Adequate Return Interval?
Site 2	2100	50	No
Providence XS #1	3600	50	No
Providence XS #2	5800	100	No
Upper Stocking XS#1	1976	2	Yes
Upper Stocking XS#2	3250	50	No
Lower Stocking #1	4026	50	No
Lower Stocking #2	2525	20	No
Lower Stocking #3	3250	35	No
Site 5	1200	2	Yes
Lake Wildwood Weir	2808	5 – 10	No
Site 8	2048	2 – 10	Maybe
Site 16	1012	2 – 5	Yes
Site 9	2086	2 – 5	Yes
Site 10	3070	2 – 5	Yes

Table 5.15: Frequency of floodplain inundation on Deer and Squirrel creeks.

Discussion

Impacts from mining and water management have altered floodplain connectivity in the Deer Creek watershed, with numerous floodplains no longer inundated at the ideal frequency for maintaining the health and function of the creek. Floodplains are most impacted in and around Nevada City for multiple reasons including mining and water management. At site 2 a major road prevents Deer Creek from accessing its historic floodplain on river right. At Providence Mine and Stocking Flat, excess mining debris has choked the channel and caused floodplain terraces to become abandoned, with NID flow management preventing small floods that would help maintain floodplain connectivity. Flow management has promoted creek incision into the mining deposits, which has resulted in abandoned floodplain terraces high above the creek channel. Stocking Flat is the largest depositional floodplain in the Deer Creek watershed. In mountain streams, where so much of the biotic activity occurs in depositional reaches and occasional large floodplains, it is critical that the floodplains function properly, which is clearly not the case in the majority of upper Deer Creek.

In lower Deer Creek there is no evidence of hydraulic mine tailing piles, as are found in upper Deer Creek, to limit access to the floodplain. There are also no large depositional areas such as Stocking Flat located on lower Deer Creek, with much of the habitat consisting of bedrock dominated transport reaches. Lower Deer Creek is also farther downstream from Scotts Flat, and in some sections has the flow contribution from the undammed Squirrel Creek, thus alleviating impacts associated with flow management to some degree, as small floods occur closer to the historic frequency. The Lake Wildwood Weir is the only site where the floodplain is not inundated at the ideal frequency, as development of a road on river left has limited floodplain connectivity.

I. Vegetation Encroachment

In the winter of water year 1997, flows in Deer Creek likely exceeded the Q100 flood. As a result many of the floodplain surfaces were inundated and cleared of vegetation, and in some cases, the stream avulsed into a new channel. Figure 42 shows “Rich’s Reach” in an August 1998 aerial, and an October 2004 oblique aerial. The August 1998 photo includes a GIS overlay of the stream course based on pre-flood conditions.

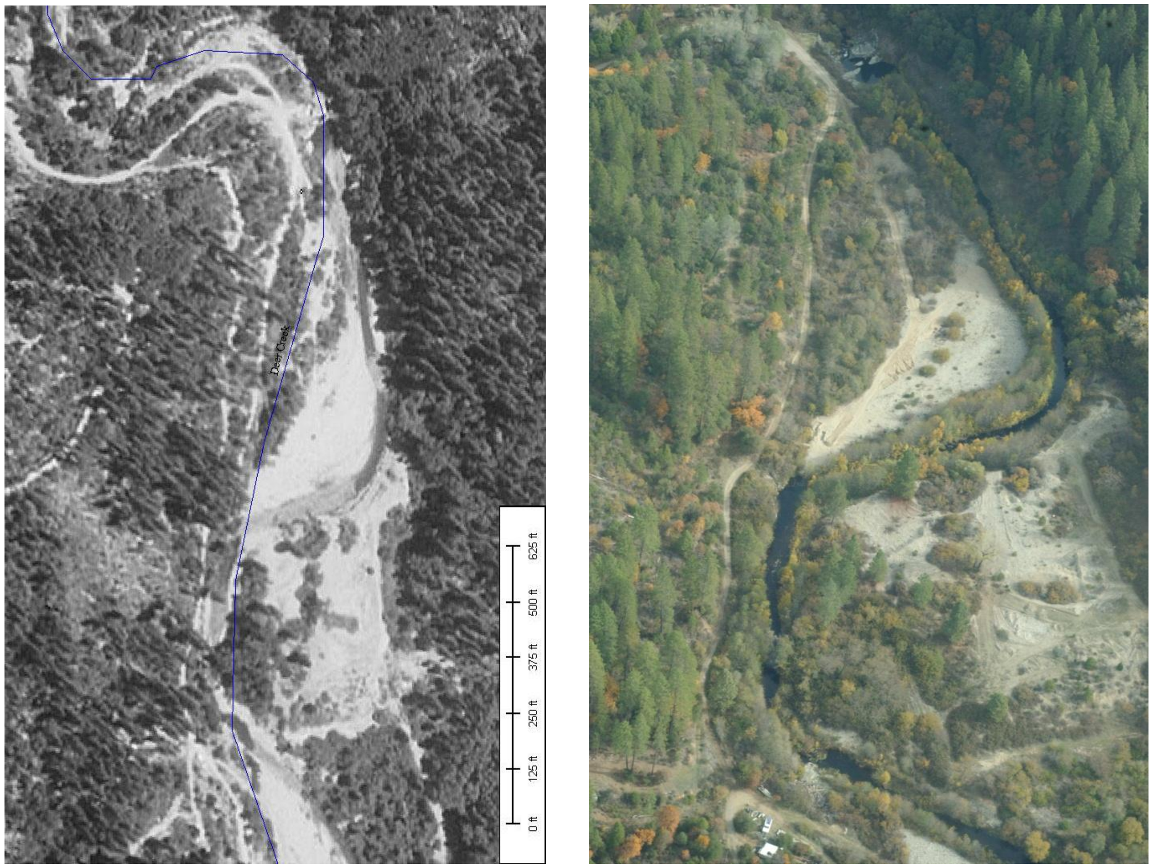


Figure 5.16: Aerial of Lower Stocking Flat in August 1998 (left) and Oblique Aerial of Lower Stocking Flat in October 2004 (right)

The blue line in the photo on the top indicates the previous stream course before the 1997 flood redirected the channel. Note in the photo on the bottom the development of a narrow band of willows and white alders along the margin of the stream and the dearth of vegetation in the interior section of the floodplain.

The 1997 flood moved the stream in Stocking Flat southward and cleared the floodplain surface of all woody vegetation. In the six years between photos the major change is the growth of willows and white alders along the margins of the stream. In a properly functioning system one would expect to find a wider swath of riparian vegetation covering the entire floodplain. There are two reasons the floodplain is not functioning properly. First, this reach experienced deep deposits of mining debris, and significant amounts of mining sediments remain. The river left side of the channel (right side in photos) has abandoned terraces between ten and fifteen feet above the channel. This elevated floodplain surface prevents riparian vegetation from establishing because groundwater is too deep. On the right side of the creek (left side of photos), although the floodplain elevation is relatively close to the channel, the attenuation of flood flows prevents the floodplains from being inundated frequently. With a natural hydrograph, flows would likely have covered the floodplain in three of the past six years, preparing the surface, depositing silt, and distributing seed sources. The absence of vegetation across the entire floodplain implies that high flows are not inundating the surface, or if they are, it is not for a suitable duration.

As described in the Hydrology Chapter, summer flows in Deer Creek are likely higher than they would have been under the natural hydrograph. These higher summer flows could be promoting a narrow band of extremely hearty riparian vegetation. This overly dense band of vegetation may be encroaching on the stream channel, preventing small floods from accessing the flood plain and focusing more of the stream's energy in the channel, causing incision rather than lateral erosion. This pattern is repeated several times in reaches 5 though 7 and thus its implications could affect floodplain health and function in much of Deer Creek.

J. Recommendations

Michael O'Connor

- **Expand hydrological and geomorphological monitoring in the Deer Creek watershed.**
  In order to better understand the geomorphic function of Deer Creek, it is essential to collect additional hydrologic and geomorphic data. Recording stream gauges should be installed throughout the watershed, with attempts to gauge major tributaries and sections of creek near reservoirs, cities, and NID diversion points. Geomorphological monitoring should focus on expanding to major tributaries and

sections of Deer Creek that were not surveyed as part of this project. This includes the north and south forks of Deer Creek upstream of Scotts Flat reservoir, Squirrel Creek, Clear Creek, Grub Creek, Gold Run Creek, and Slate Creek.

- **Monitor Stocking Flat for overbank flooding (timing, frequency, extent, duration), and changes in geomorphology and vegetation.**
  The reach is easily accessible and has multiple documented cross-sections that can be used to monitor changes to geomorphology over time. In addition to monitoring the floodplain at Stocking Flat, an automatic stream gauge should be installed to collect hydrological data in this reach.

- **Further investigate the extent of floodplain problems, such as connectivity and disturbance, in the Deer Creek watershed; address the problem associated with the infrequency of floodplain inundation.**
  To advance geomorphic restoration goals, more investigation is needed into the extent that floodplain problems are caused by historic mining practices or other factors, and the opportunities and constraints on removing hydraulic debris terraces to restore floodplain connectivity. To address the problem associated with the lack of frequent floodplain inundation, two approaches could be employed. First, during storm events releases from Scotts Flat could be increased enough to inundate floodplains on an average frequency of once in two years. The level of flow increase required would range from 500 – 4,000 cfs depending on location. At locations requiring increases of more than 1,000 cfs, floodplains are likely artificially elevated as a result of residual mining debris. At these locations floodplains have essentially become terraces, abandoned as the river cut down through mining deposits. In these locations the second approach could be employed: reshaping the river channel using heavy equipment to create a channel that reflects the altered hydrology and sediment supply of today. This approach has been used on the Trinity River, which has a mining and dam building history not unlike Deer Creek. On the Trinity, managers re-graded significant areas of abandoned floodplain terraces down to elevations that are now flooded on a regular basis. Initial attempts to re-grade the floodplain at Stocking Flat began in 2009, but the project is currently on hold because the property owners, the Bureau of Land Management, found that there was mercury stored in the floodplain, which could potentially methylate with restored floodplain inundation. In addition to the floodplain at Stocking Flat a large floodplain exists on a downstream property, where the landowners are open to restoration of their property and the creek. Opportunities to restore the health and function of Deer Creek at this location should be pursued, since the landowners have been very supportive of the work of FODC/SSI.

- **Implement gravel augmentation projects downstream of reservoirs in the watershed.**
  Downstream of both Scotts Flat and Lake Wildwood reservoirs a sediment supply deficit exists, due to the dams capturing the majority of sediment, which would have historically been transported to downstream reaches. While gravel supplies have been depleted in the bedrock section just downstream of lower Scotts Flat dam, the lack of channel downcutting and difficulty of access make gravel augmentation a low priority at this location. Reaches downstream of Lake Wildwood Reservoir, including at the spillway (Lake Wildwood Weir), site 8, and site 10, are a high priority for gravel augmentation and habitat restoration, based upon ease of access and permission from landowners, lack of adequate in-stream habitat, and importance of aquatic habitat to critical species such as Chinook salmon and steelhead. A pilot gravel augmentation project is scheduled for implementation during summer 2011 at site 10, and the results from this project will inform larger scale gravel augmentation work in the lower Deer Creek watershed.

- **Monitor fine sediment levels over time; incorporate erosion control Best Management Practices into development guidelines, such as the Nevada County General Plan.**
  With the likelihood of continued rapid growth leading to more soil disturbance in the watershed, fine sediment levels should be monitored over time and erosion control Best Management Practices incorporated into development guidelines, including the county General Plan, to insure that fine sediments levels do not become serious water quality concerns. Friends of Deer Creek has been monitoring turbidity and total suspended solids since 2000 in the Deer Creek watershed, providing a baseline dataset to evaluate future changes. In addition, benthic macroinvertebrates make ideal bio-indicators for assessing the impacts of fine sediment associated with developments that impact Deer Creek and its tributaries. Benthic macroinvertebrates were recently added to the monitoring requirements for General Construction Permits under the Storm Water Program of the California State Water Resources Control Board, to help evaluate impacts associated with development, such as fine sediment loading to creeks. With a long-term macroinvertebrate dataset dating back to 2000, Friends of Deer Creek is well positioned to monitor the impacts of development on the watershed. When possible, Friends of Deer Creek should collaborate with developers to monitor major construction activities that are undertaken in the watershed, using macroinvertebrates as indicators of stream health.

- **Monitor ephemeral stream channels that flow into perennial streams.**
  In addition, ephemeral streams should be considered in development guidelines, such as the General Plan, as these drainage networks convey significant amounts of fine sediment and nutrient inputs to perennial water bodies. Currently, these

drainages are not taken into account in development guidelines. Friends of Deer Creek developed a preliminary ephemeral drainage assessment in 2009, with two ephemeral drainages assessed in the Nevada City area. This assessment could be further used to investigate the health and function of ephemeral drainages throughout the watershed.

❖ **Implement stream bank stabilization restoration projects at sites with degraded stream banks.**

Site 2 adjacent to Willow Valley Road upstream of Nevada City, site 12 in Pioneer Park in Nevada City, and site 15 in Creek Side Mobile Home Village in Penn Valley exhibited the most unstable banks in this assessment.

- At site 2, restoration work would involve the County Transportation Department, as much of the erosion is associated with Willow Valley Road on river right, and the existing low-water crossing of Deer Creek at this location. To restore bank stability the low-water crossing should be closed and access to the creek for vehicles should be blocked. This would reduce bank erosion on both banks and allow vegetation to re-establish. Native vegetation should be planted at this site, particularly on river left, where a large bare stretch of riparian zone exists due to clearing for vehicle and recreational access. Contact with the property owners on river left needs to be established before any restoration efforts begin.
- At site 12 in Pioneer Park, the banks of Little Deer Creek are quite unstable and suffer from a lack of adequate riparian vegetation. Historically Little Deer Creek flowed through a wide wetland at this location. The creek was channelized and wetland filled in to create a park. The unstable banks are due to the stress on the stream channel during high flows, caused by channelization of the creek. Evidence of channelization still exists, with concrete walls and gabion in the creek. A previous restoration project at site 12 focused on removal of non-natives and planting of native species in the riparian zone, and also strategic placement of a number of large boulders to increase bank stability. Further restoration projects at this site should expand upon this initial effort to increase bank stability and riparian vegetation. Planting of native species and removal of non-natives should occur, in an attempt to expand the width of the riparian zone and increase ground and tree cover. Concrete, gabion, and angular pieces of rock should be removed from the creek channel using heavy equipment, and the bank should be stabilized using natural materials, including large boulders, willow wattles, and native plantings. Opportunities to “de-channelize” Little Deer Creek should be explored with the city of Nevada City, owners of Pioneer Park.
- At site 15, both banks are actively eroding into Squirrel Creek, with impacts associated with human development and recreation impacting the banks on

river left. On river right there are large sections of steep, bare bank in the riparian zone that are actively eroding. Restoration of this section of the creek would include multiple aspects, including outreach to residents of the mobile home park, removal of non-native plant species, planting of native species, and bank stabilization through large boulders or other methods. Outreach to the residents is necessary, as their activities are impacting the riparian zone with residents creating access routes to the creek, disturbing new vegetative growth, and contributing to the spread of non-native species. Non-native Himalayan blackberry is present in many locations along this section of Squirrel Creek, and attempts to remove it should be undertaken. In some circumstances, blackberry may be important for stabilizing the bank, and restoration efforts should consider the impacts associated with its removal. Planting of native species, including willows and alders, as well as larger trees such as cottonwoods, should be implemented. There is a lack of native vegetation to secure the banks at this site. Re-vegetation efforts should include methods for keeping humans and animals out of the riparian zone, as there is considerable human activity at this site, especially on river left. Property owners on both river right and left should be identified and contacted prior to undertaking any restoration projects at this site. The mobile home park owns the majority of river left, but the river right property owners have not been identified.

- **Restore sediment transport capacity to the Deer Creek watershed.**
  To address the problem associated with mobilizing substrates in upper Deer Creek and at the Lake Wildwood weir site, two methods could be used. First, releases from Scotts Flat reservoirs could be increased during certain storm events to reach mobilization thresholds. During 2-year events, flows would need to be increased by at least 400 cfs, and for 10-year events flows should be increased by at least 1000cfs. Second, certain reaches with significant riffle habitat could be "mechanically mobilized," a strategy used in restoration efforts downstream of dams on streams that support anadromous fish such as salmon and steelhead. Mechanical mobilization involves using tractors pulling implements that rip up the top layer of gravel bars to facilitate mobilization when significant flow events occur. This, combined with supplementation of gravels through gravel augmentation, would reduce the dominant size of channel substrates, and would reduce the flows at which substrates would be mobilized.

- **Restore a natural hydrograph to main stem Deer Creek.**
  The absence of a natural hydrograph results in reduced winter flood flows, reduced spring flows, and increased summer low-flows. The reduction in winter flood flows and spring flows leads to a decrease in the frequency of floodplain inundation. This,

combined with increased summer low-flows, results in a narrow band of riparian vegetation in many portions of upper Deer Creek. Restoring the natural hydrograph would promote floodplain inundation, disturbance of the floodplain surface, deposition of silt and sands, and deposition of seed sources, all of which would increase the health and function of the riparian zone.

Chapter VI: River Ecology

FODC/SSI

A. Introduction

The beneficial uses of the Deer Creek watershed are numerous, including irrigation, stock watering, hydropower generation, recreation, warm and cold freshwater habitat, wildlife habitat, groundwater recharge, freshwater replenishment, and the supply of municipal and domestic drinking water (FODC 2004). The Deer Creek watershed plays a critical role for the communities and agencies that depend on its resources for domestic, agricultural, recreational and economical uses. These needs must be balanced with those of the countless biological communities that rely on a healthy watershed to reproduce, develop, and thrive in the reaches they inhabit.

Historically, many studies have focused on the chemical and physical characteristics of rivers and streams to determine ecological health. However, as these attributes have been assessed and addressed, it has become more apparent that the primary ecological concern is the actual biological communities that inhabit the streams (Stoddard et al. 2005). The chemical and physical features of the river system should not be disregarded, but more recent research is shifting its focus to biological assemblages as significant indicators of stream health (Karr and Dudley 1981, Stoddard et al. 2005; SRWP 2010). The State Water Board is currently in the process of developing biological objectives for freshwater streams and rivers in

California. Biological objectives will provide the narrative and numeric biological benchmarks that describe conditions necessary to protect aquatic life beneficial uses.

An integrated approach and understanding of how chemical, physical, and biological conditions interact and influence one another is essential for a thorough assessment of the ecological condition of the Deer Creek watershed. The purpose of this chapter is to review and integrate chemical, physical, and biological data collected by FODC/SSI starting in 2000 along with research from external sources to assess the health of the Deer Creek watershed.

B. Methods and Results

Chemical Parameters

Justin Wood

Evaluation of the chemical characteristics of a river system is a fundamental objective when assessing the ecological condition of a watershed. The chemical attributes of a river will not only affect designated uses established for the water resource (e.g. domestic, recreational, agricultural), but they will also influence what biotic assemblages inhabit stream reaches. Additionally, monitoring chemical characteristics along a stream can help identify impaired reaches and possible stressors, as well as monitor the effectiveness of restoration efforts.

Friends of Deer Creek/Sierra Streams Institute (FODC/SSI) has been collecting and analyzing chemical water quality data since 2000 at 16 sites[1,2] in the Deer Creek watershed (**Figure 6.1**). A majority of the chemical data is collected in association with the citizen-based monthly water quality monitoring program. Chemical parameters measured monthly include water temperature, pH, dissolved oxygen, specific conductivity, turbidity, and nutrient concentrations (total phosphate and total nitrate). Sampling occurs throughout the watershed on the main stem of Deer Creek and in three tributaries: Little Deer Creek, Gold Run Creek, and Squirrel Creek. In addition to monthly chemical analyses, FODC/SSI also conducts heavy metal assessments, predominantly mercury contamination; and monitors several sites during storm events to evaluate how elevated flows affect mercury and sediment loads, and chemical parameters such as water temperature, pH, and specific conductivity. Examining high flow periods is a critical component in determining the condition of the Deer Creek watershed as transport of sediment, nutrients, algae, bacteria, and heavy metals often increase during these flow pulses.

[1] Site 14 is located at Deer Creek's confluence with the South Fork of the Yuba River but has limited sampling due to landowner permission issues. Recent landowner changes at this site may make sampling possible in the future. Data from site 14 is not included in this report due to its limited dataset.

[2] Monthly monitoring at sites 11-13 on Little Deer Creek began in 2001. Monthly monitoring on Squirrel Creek began at site 15 in 2001 and site 16 in 2004. Monthly monitoring on Gold Run Creek at site 17 began in 2010. Data from site 17 is not included in this report due to its limited dataset.

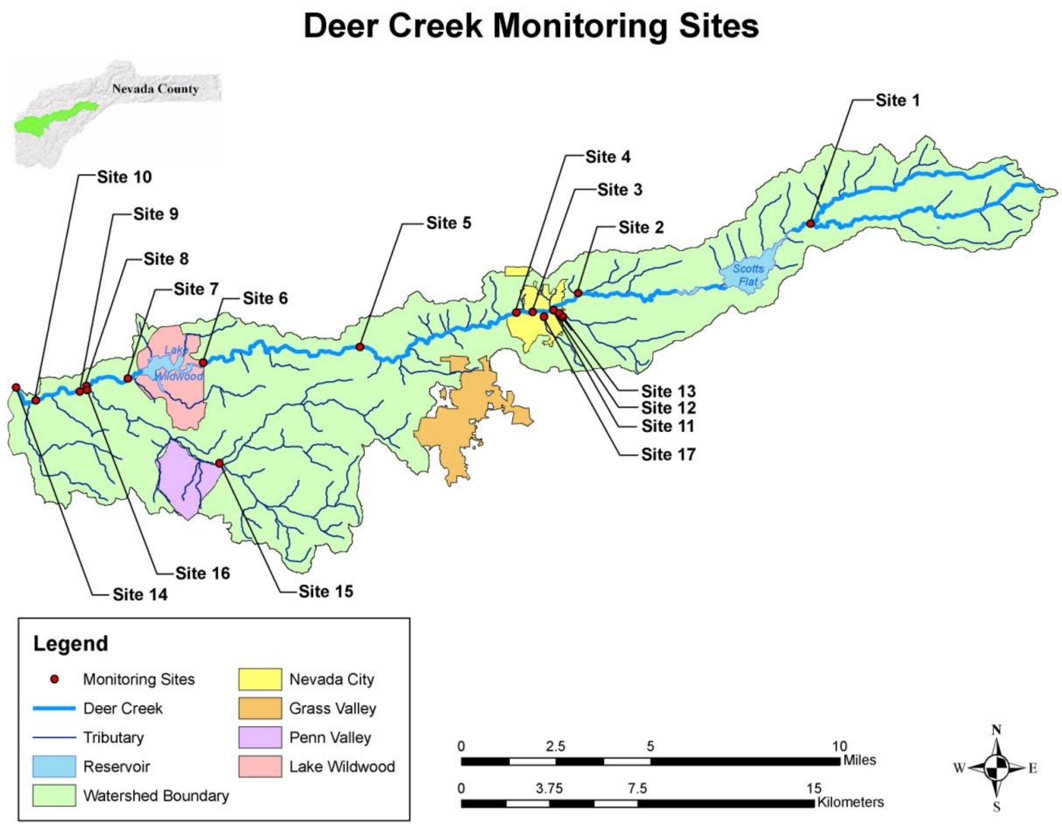


Figure 6.1: FODC/SSI monthly monitoring sites in the Deer Creek watershed. In addition to monitoring the main stem of Deer Creek, three tributaries are also monitored monthly: Little Deer Creek (Sites 11-13), Squirrel Creek (Sites 15-16) and Gold Run Creek (Site 17). Site 17 was added in 2010. Site 14 is currently not an active monitoring site.

Staff and volunteers have been trained in water quality procedures detailed in the Deer Creek Water Monitoring Quality Assurance Project Plan (QAPP; FODC 2008a). FODC/SSI staff calibrate water quality instruments prior to sampling. Samples and measurements are taken at approximately the same location in the river at each monitoring site during the second full week of each month. Supplementary data collected at monthly monitoring sites include ambient air temperature, elevation, GPS coordinates, approximate stream width, depth, and flow, as well as past and current weather conditions. Nutrient samples are collected in 125 mL bottles that are transported back following standard chain-of-custody procedures to the FODC/SSI laboratory where they are processed and analyzed the same day following La Motte colorimetric analysis protocols. . Data are reviewed for quality control (QC) by FODC/SSI staff and Technical Advisory Committee (TAC) and then entered into the FODC/SSI database. A summary table of monthly chemical data is included in the appendix (**Figure 6A.1**)

Water Temperature

Water temperature is one of the most important water quality parameters. It influences other water chemistry parameters such as dissolved oxygen levels, pH, rates of nutrient cycling, and contaminant transformation rates (USEPA 2010). Water temperature also regulates many aquatic organism functions including growth, reproduction development, habitat preference, and competition (USEPA 2010). Water temperature can also affect physical attributes such as water density and thermal stratification (USEPA 2010). Thus, monitoring water temperature is a significant water quality parameter as it will affect many different attributes in an aquatic ecosystem.

Water temperature is affected by numerous natural and anthropogenic factors. Water temperature will vary naturally in response to amount of sunlight, canopy cover, air temperature, flow, water depth, inflow of groundwater and surface water, and turbidity. Human factors that can alter these natural influences include removal of riparian vegetation, soil erosion, storm-water runoff, and alterations to stream morphology and hydrology (e.g. channelization, diversions, and dams) (USEPA 2010). The SRWP (2010) reported that one of the main factors influencing elevated water temperatures in the region is modified flow rate.

Water temperatures in Deer Creek increase heading downstream from site 1 located near the headwaters above Scotts Flat to site 10 above the confluence with the South Fork of the Yuba River (**Figure 6.2**). Water temperatures are clearly elevated below the Lake Wildwood reservoir and wastewater treatment plant (WWTP) with the highest mean water temperatures occurring at sites 7 and 8 (15.9°C). Mean summer water temperatures in the lower watershed exceed 20°C, the Bay-Delta basin plan objective, with temperatures often exceeding 25°C (**Figure 6.3**). Coupled with higher nutrient levels, elevated water temperatures promote algae growth that results in higher pH and has been associated with fish kills in the lower watershed. The main stem of Deer Creek below Lake Wildwood reservoir is listed as impaired for pH in the Clean Water Act (CWA) Section 303(d)/305(b) Integrated Report for the Central Valley Region (2009a).

In the Sacramento River Basin Report Card (SRBRC), the Deer Creek watershed received the highest possible score for water temperature (100/100 – mean water temperatures <18°C); however, the reported noted a limitation to FODC/SSI water temperature data is that it is not consistently monitored over time or space (SRWP 2010). FODC/SSI performed some continuous water temperature monitoring in the watershed in 2001 and 2010. 2001 data indicated a strong diurnal effect at site 10 in the lower watershed with water temperatures fluctuating by approximately 5°C in the summer with the peak in the early evening. Data collected in 2010 has not been reviewed yet. Additionally, seasonal analysis indicates that mean water temperatures exceed 18°C at sites 6-10 on the main stem of Deer Creek and site 16 on Squirrel Creek.

Water temperature is a very important parameter for ecological integrity and FODC/SSI results indicate areas of concern in the Deer Creek watershed, particularly the main stem below the Lake Wildwood reservoir where water temperatures are notably high in the summer months. Future continual water temperature monitoring should prioritize focus on lower Deer Creek sites. Continued monthly water quality monitoring may identify additional sites of concern that warrant further investigation.

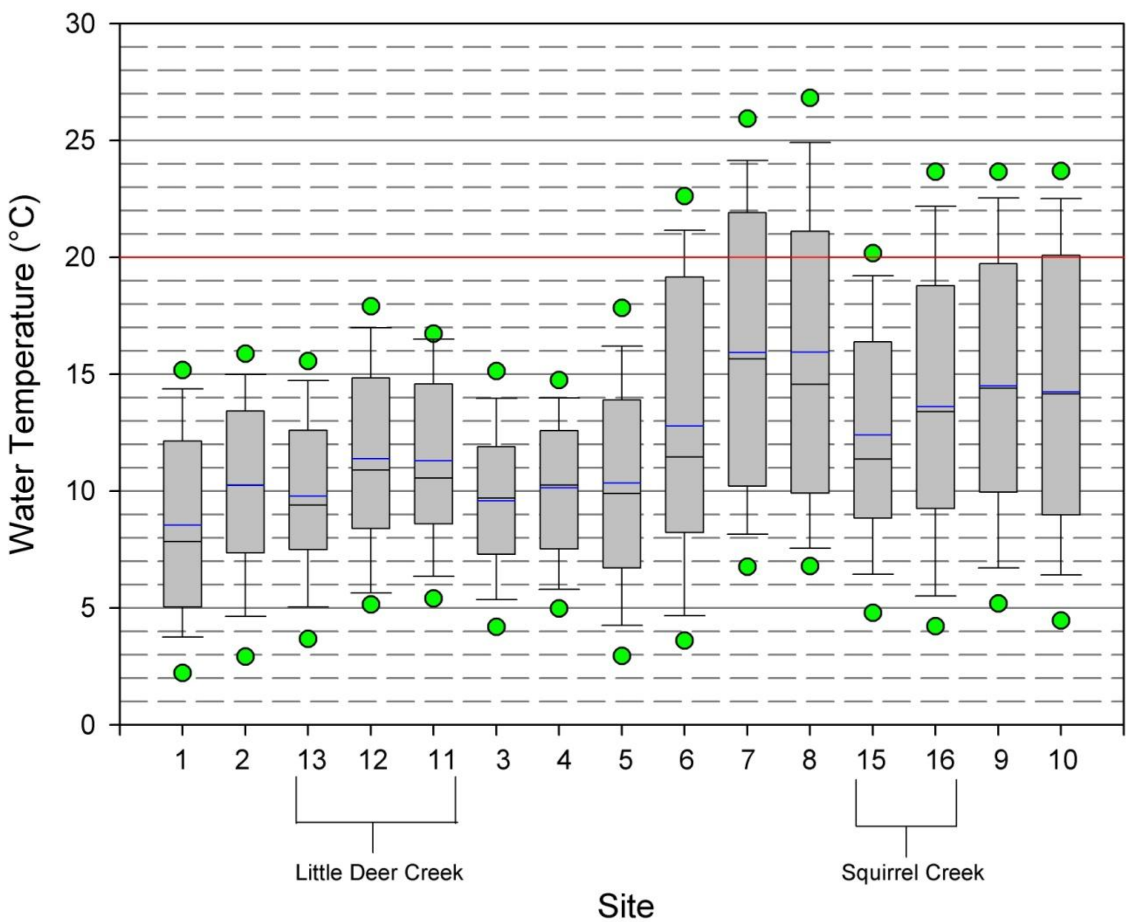


Figure 6.2: 2000-2010 Water temperature results at FODC/SSI monthly monitoring sites in the Deer Creek watershed. The Basin Plan objective for the Bay-Delta is 20°C (red line). The black and blue lines within the box represent the median and mean values respectively. The lower and upper edges of the box represent the 25th and 75th percentiles. Whiskers represent the 10th and 90th percentiles and the green dots represent the 5th and 95th percentiles. Each box plot presented in this chapter is similarly constructed. The absence of 5th/95th percentiles signifies that the dataset was not sufficient enough to compute these values.

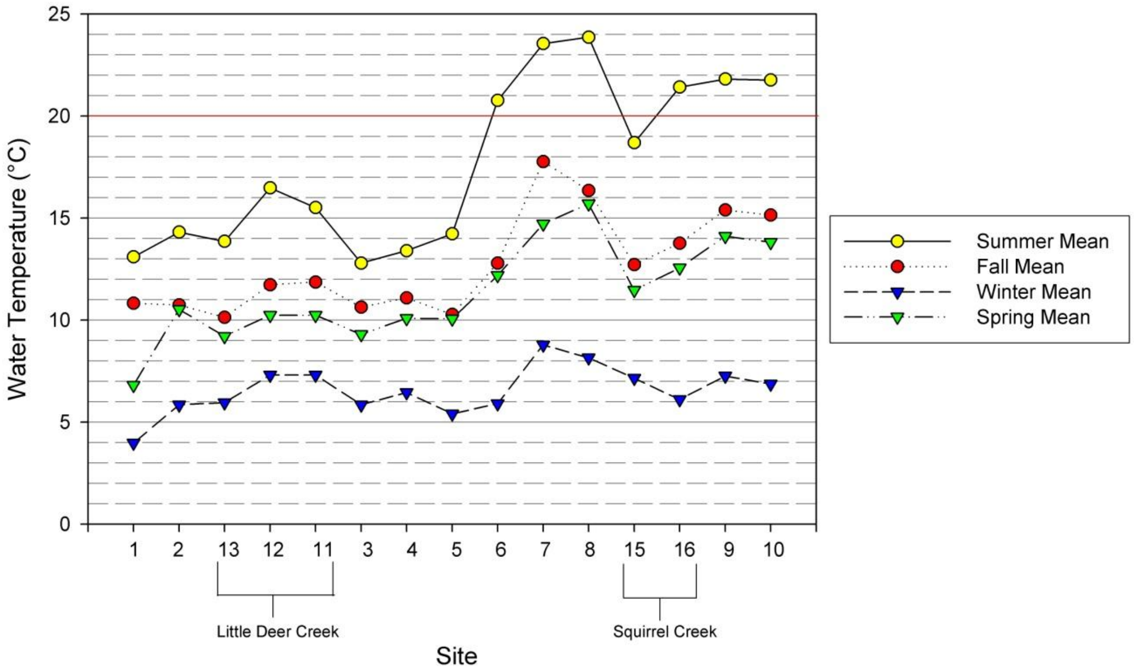


Figure 6.3: 2000-2010 Mean seasonal water temperatures for FODC/SSI monthly monitoring sites in the Deer Creek watershed. Note that summer mean water temperatures in lower Deer Creek below the Lake Wildwood reservoir and at site 16 on Squirrel Creek exceed the Basin Plan objective for the Bay-Delta (red line).

pH

pH is an important parameter in water that affects many chemical and biological processes. It is one of the most important factors limiting the distribution of species in aquatic habitats (USEPA 2010). The Central Valley Regional Water Quality Control Board (CVRWQCB) Basin Plan objective range for pH is ≥6.5 and ≤8.5 (2009b). Sustained or fluctuating pH outside of this range reduces biological diversity in streams and can impose stress on aquatic organisms including decreased reproduction, decreased growth, disease, or death (USEPA 2010). Additionally, pH can alter the chemical state of many pollutants, such as mercury and nutrients, which can change their solubility, transport, or bioavailability in the stream (USEPA 2010).

Along the main stem of Deer Creek, pH tends to increase moving downstream (**Figure 6.4**). Lowest pH ranges are found on Little Deer Creek with mean pH values falling below the CVRWQCB's Basin Plan objective for pH (2009b). Highest pH values are found in lower Deer Creek at sites 8 and 9 where algal blooms are common and likely influence pH. The main stem of Deer Creek below Lake Wildwood reservoir is listed as impaired for pH under the CWA Section 303(d)/305(b) Integrated Report for the Central Valley Region (CVRWQCB 2009a).

It is important to note that pH has a diurnal component and an extreme range has been observed in the Deer Creek watershed. A 2001 pH study conducted by FODC/SSI found that pH peaked in the early evening with lower pH being measured in the early morning. pH values in June 2001 at site 10 in lower Deer Creek fluctuated between 7.5 in the morning to 9.5 in the early evening and were found to correlate with diurnal water temperature fluctuations (**Figures 6A.2** and **6A.3**). Seasonal analysis (**Figure 6.5**) indicates mean pH peaks in the summer months with pH notably high below the Lake Wildwood reservoir.

Although pH means at monthly monitoring sites do not exceed the CVRWQCB Basin Plan objective of 8.5, pH has been measured above 8.5 on numerous sampling events in the lower watershed. Furthermore, monthly monitoring generally occurs in the morning hours; therefore, pH data do not take into account its diurnal component. The increasing pH in lower Deer Creek is in part due to the consumption of carbon dioxide by algae that reduces the carbonic acid in solution. The rate of this process increases with elevated water temperatures that are evident in lower Deer Creek. The causes for low pH ranges measured in Little Deer Creek have not been thoroughly investigated. Areas of concern identified by monthly monitoring should be further evaluated for diurnal fluctuation patterns to better determine its effects on the river ecosystem.

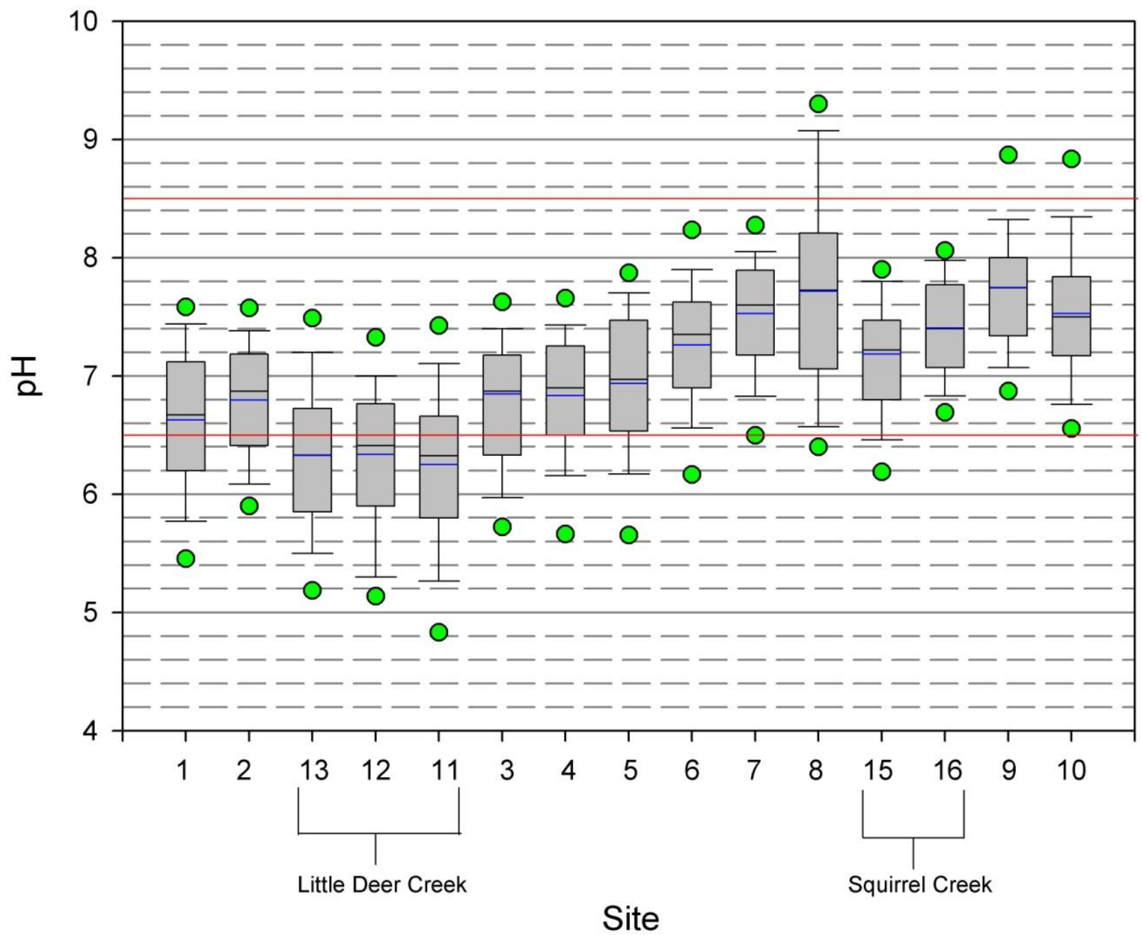


Figure 6.4: 2000-2010 pH results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. The CVRWQCB Basin Plan objective for pH is 6.5≤pH≤8.5 (2009b).

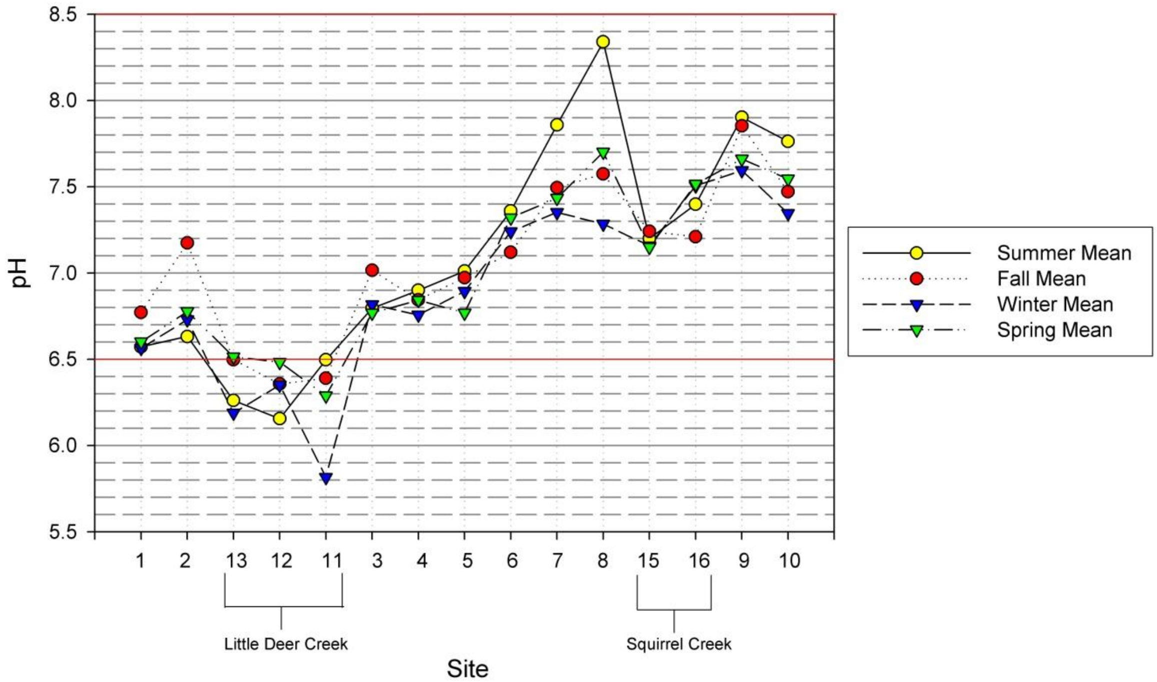


Figure 6.5: 2000-2010 Mean seasonal pH for FODC/SSI monthly monitoring sites in the Deer Creek watershed. The red lines represent the CVRWQCB Basin Plan objective range for pH (6.5<pH<8.5; 2009b). Although summer means may fall within the objective, pH typically peaks in the early evening and exceeds 8.5 at sites in lower Deer Creek. Mean pH in Little Deer Creek sites are equal or less than the lower pH limit of 6.5.

Dissolved Oxygen

Dissolved oxygen (DO) in streams is needed by aquatic organisms for respiration with adequate concentrations of DO crucial for growth and survival of aerobic aquatic life (USEPA 2010). Decreasing DO levels can result in death of adults and juveniles, reduction in growth, and failure of eggs or larvae to survive. Additionally, the concentration of DO will influence the aquatic species that inhabit river reaches. For example, species such as trout and stoneflies require high DO concentrations while species such as catfish, worms, and dragonflies can inhabit reaches with lower DO concentrations.

The CVRWQCB's Basin Plan water quality objective for DO is >7.0 mg/L for streams that support coldwater and spawning fish habitat (2009b). Dissolved oxygen concentrations at monthly monitoring sites appear to be satisfying this objective (**Figure 6.6**). Lowest DO concentrations are seen in the summer months due to warmer water temperatures and additional factors such as algae blooms in lower Deer Creek that can affect DO levels (**Figure 6.7**). Nonetheless, DO concentrations have rarely measured below 7.0 mg/L at monthly monitoring sites. Finer-scale temporal assessments, such as diurnal analysis, have not been conducted for DO in the Deer Creek watershed.

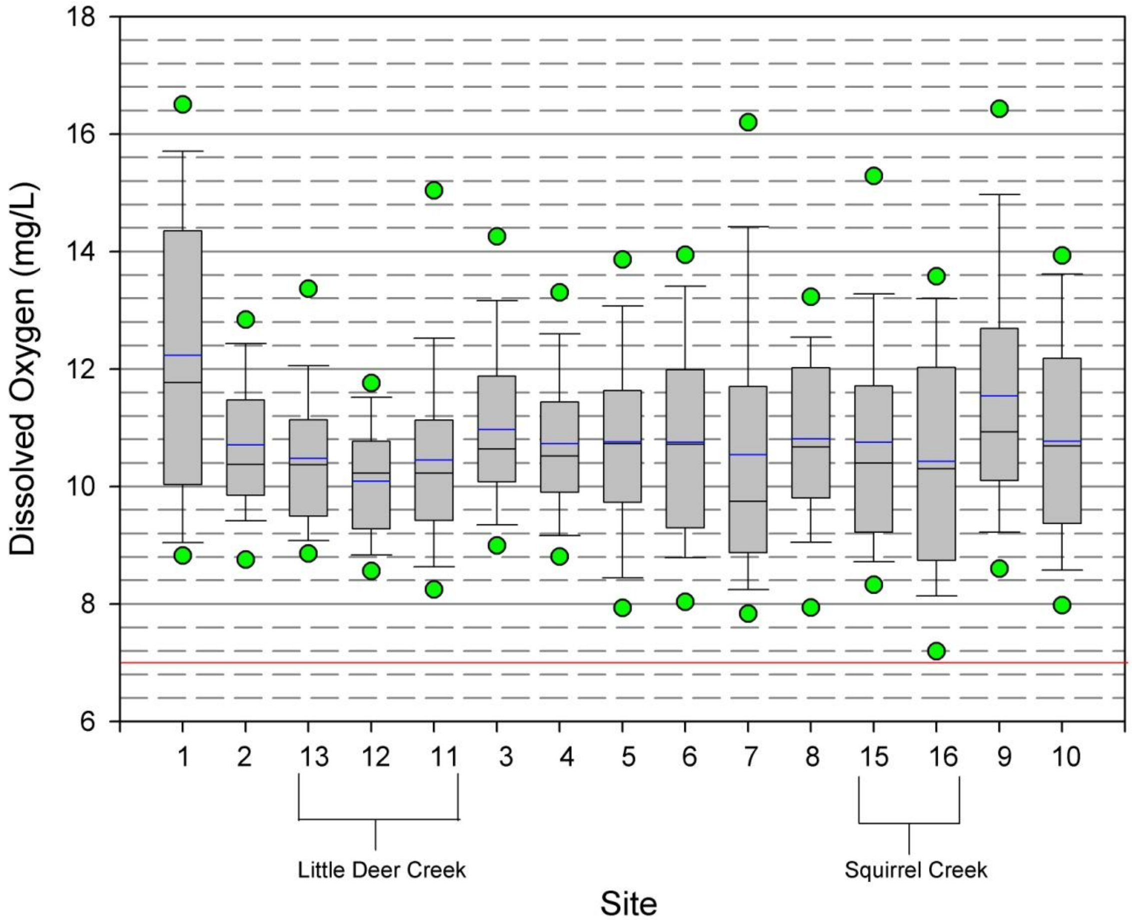


Figure 6.6: 2000-2010 Dissolved oxygen results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. The CVRWQCB Basin Plan objective for DO is >7.0 mg/L (2009b).

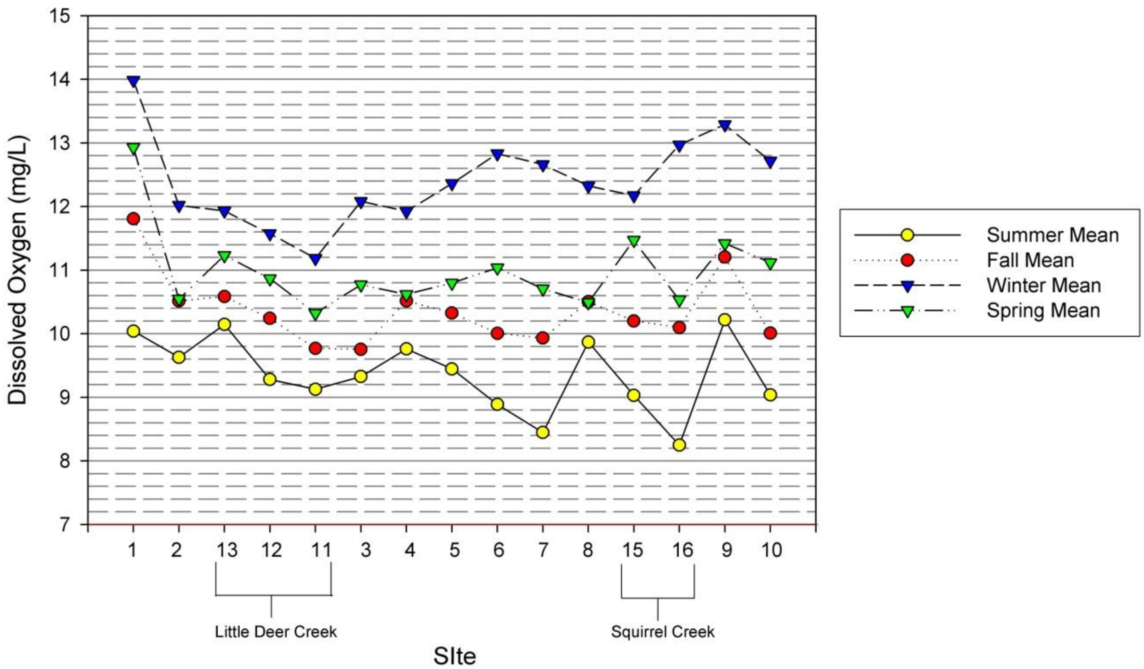


Figure 6.7: 2000-2010 Mean seasonal DO concentrations for FODC/SSI monthly monitoring sites in the Deer Creek watershed. The red line represents the CVRWQCB Basin Plan objective range for DO (>7.0 mg/L; 2009b).

Specific Conductivity

Specific conductivity is the ability of water to conduct an electrical current at a normalized temperature of 25°C. Dissolved ions in the water including sodium, calcium, potassium, magnesium, chloride, sulfate, carbonate, and bicarbonate are major conductors. Different species will tolerate different conductivity ranges; therefore increasing conductivity and changes in ionic composition can lead to shifts in community composition and function in a stream (USEPA 2010).

Conductivity will vary based on the water source (e.g. groundwater, agricultural runoff, wastewater, rainfall); therefore, conductivity can be used to detect novel flow inputs such as groundwater seepage or a sewage leak. Additionally, local geology will influence the amount and type of ions that will be dissolved in the water.

FODC/SSI monthly monitoring results indicate that specific conductivity generally increases in the downstream direction in the watershed (**Figure 6.8**). Noticeable jumps in conductivity are found below waste treatment plants in Nevada City and Lake Wildwood. Elevated nitrate and phosphate ions have also been measured at these locations. Specific conductivity remains elevated in the lower watershed in comparison to the upper watershed. Conductivity typically peaks in the summer months in Deer Creek below the Lake Wildwood reservoir suggesting a considerable input from the Lake Wildwood WWTP (**Figure 6.9**). Analysis of what ions are dissolved in the water would provide better insight into ecological implications from novel water inputs such as wastewater treatment plants.

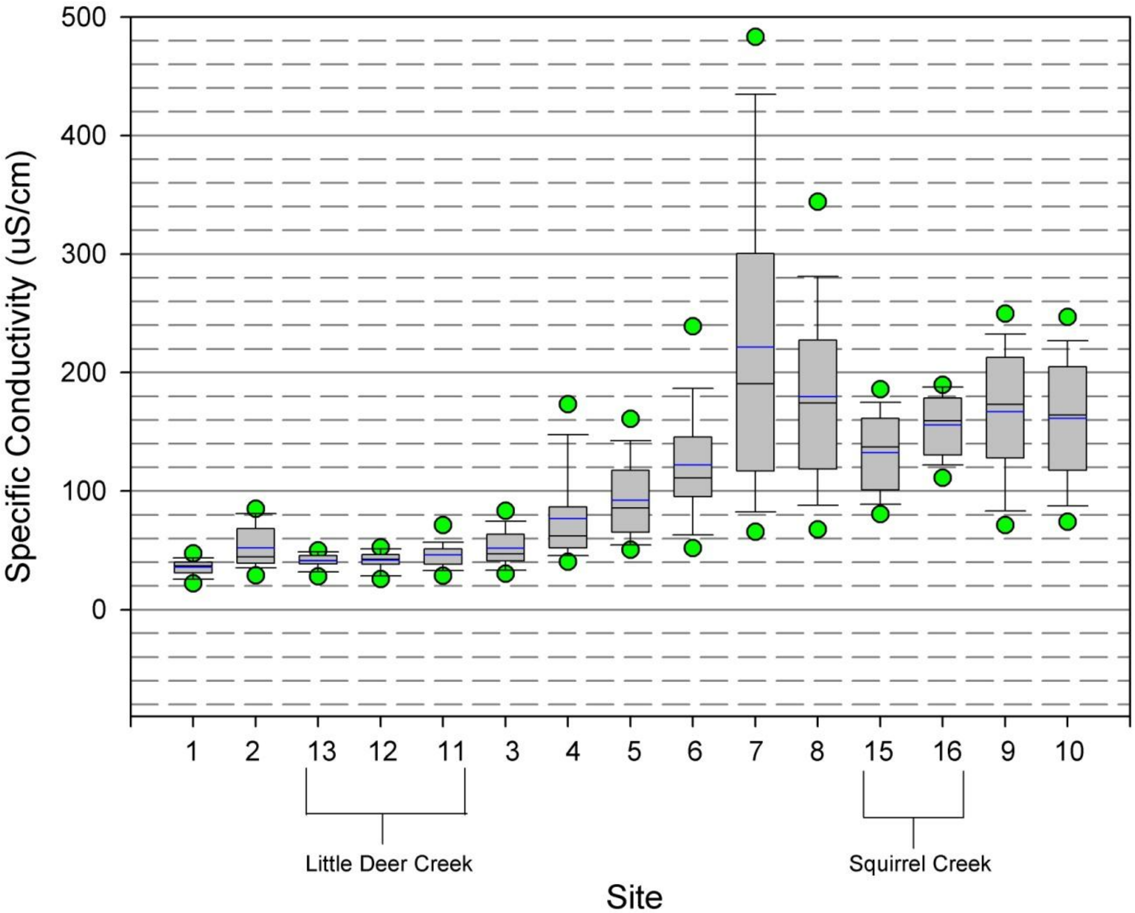


Figure 6.8: 2000-2010 Specific conductivity results for FODC/SSI monthly monitoring sites in the Deer Creek watershed.

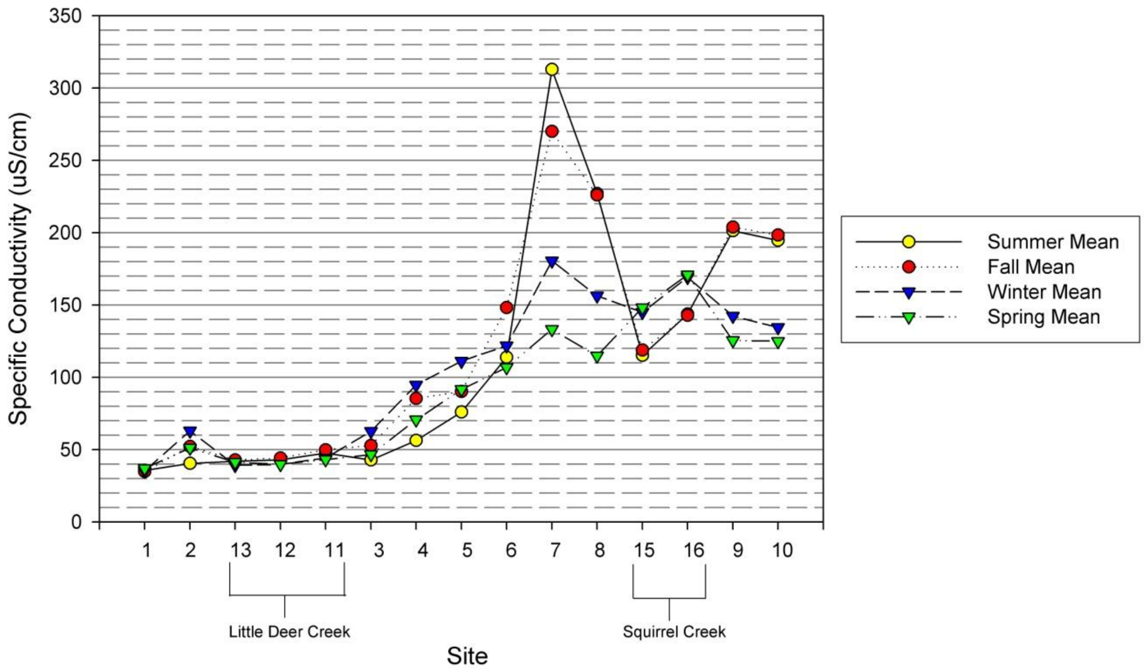


Figure 6.9: 2000-2010 Mean seasonal specific conductivity results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. Elevated specific conductivity below the Lake Wildwood WWTP suggests an effluent-dominated flow in the summer and fall months in lower Deer Creek.

Turbidity

Turbidity is the measure of suspended particles including algae, suspended sediment, organic matter, and pollutants that can cloud the water. Suspended particles in a river diffuse sunlight and absorb heat that can increase water temperatures while reducing light availability for photosynthesis.

During the storm season, turbidity increases in Deer Creek that can be attributed to elevated flows that increase material transport through the stream system (**Figure 6.10**). In the summer and fall, turbidity greater than 1 NTU can be an indicator of constituents such as wastewater effluent, bacteria, and suspended algae that can cloud the water. Mean turbidity in the summer and fall greater than 1 NTU is evident at sites 12 and 11 (Little Deer Creek in and below Pioneer Park), site 3, site 7 below the Lake Wildwood WWTP, and sites 15 and 16 (Squirrel Creek) where elevated bacteria levels are notable (see Bacteria section below). Elevated turbidity during low flow periods can be attributed to recreational activities in Little Deer Creek and Squirrel Creek. Elevated turbidity during low flow periods at site 7 can be attributed to Lake Wildwood WWTP effluent. The Lake Wildwood treatment plant has been fined in the past for exceeding turbidity limits among other parameters (CVRWQCB 2009c).

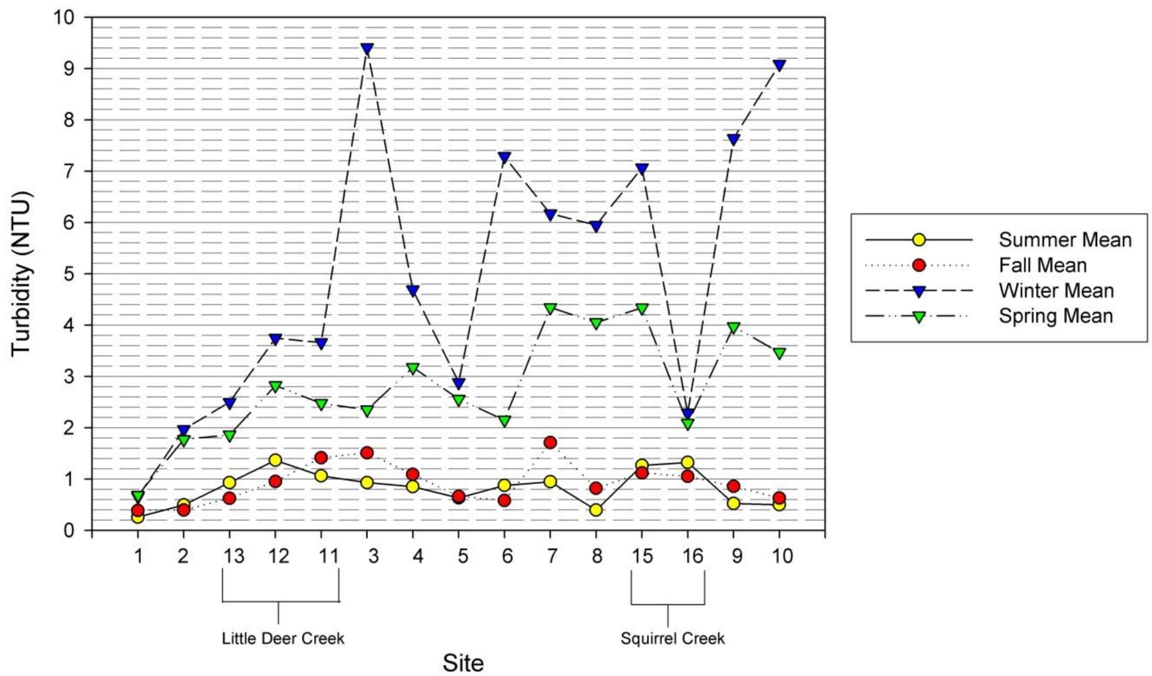


Figure 6.10: 2000-2010 Mean seasonal turbidity results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. Turbidity >1 NTU during low-flow conditions in the summer and fall may indicate novel inputs of suspended material such as wastewater effluent, bacteria, and algae.

Nutrients: Nitrate and Phosphate

Nutrients are essential for plant growth with nitrogen and phosphorous being the major limiting nutrients in most aquatic environments (USEPA 2010); however, excessive nutrient concentrations can lead to adverse ecological effects. Excessive concentrations of nutrients can effect primary production as well as the growth and species composition of algae, which can impose stress on biological communities (i.e. BMI and fish). Furthermore, algal blooms caused by elevated nutrients can result in DO depletion and increase pH impacts in the ecosystem.

FODC/SSI has been monitoring nutrient concentrations in the Deer Creek watershed as part of its citizen-based monthly water monitoring program since 2000. Grab samples are collected from the subsurface in three 125mL sample bottles. Samples are securely transported back to the lab where they are processed the same day. FODC/SSI analyzes for total nitrate (NO_3) and total phosphate (PO_4) using La Motte colorimetric methods.

Mean nutrient concentrations in upper Deer Creek (**Figures 6.11** and **6.12**) mostly fall within natural background levels suggested by Dubrovsky and Hamilton (2010; 0.58 and 0.034 mg/L for NO_3 and PO_4 respectively) with a slight increase in NO_3 and PO_4 evident at site 4 immediately downstream of the Nevada City WWTP. Elevated nutrient concentrations become more apparent in Deer Creek below the Lake Wildwood reservoir with a spike in

NO_3 and PO_4 immediately downstream of the Lake Wildwood WWTP. Sites 7 and 8, located below the Lake Wildwood reservoir and Lake Wildwood WWTP display the highest nutrient concentrations in the watershed (**Figures 6.11** and **6.12**).

Seasonal analysis of NO_3 and PO_4 (**Figures 6.13** and **6.14**) indicate highest concentrations in the summer and fall months, especially in lower Deer Creek. This is likely a result of a more effluent dominated flow from Lake Wildwood WWTP due to lower flow rates below the Lake Wildwood reservoir. In the summer, Lake Wildwood WWTP effluent is the dominant flow input in Deer Creek until the confluence of Squirrel Creek at site 9. The Lake Wildwood WWTP implemented facility upgrades in late 2006 to reduce nitrate and ammonia concentrations in its effluent (Scott Joslyn pers. comm.). Data before and after the upgrade suggest a decrease in nitrate concentrations at sites 7 and 8 downstream of the Lake Wildwood WWTP (**Figure 6.15**).

In the SRBRC, Deer Creek received a score of 0/100 in nitrogen loading due to NO_3 samples exceeding 10 mg/L; however, the SWRP (2010) noted that nitrate is not a reliable indicator of nitrogen cycling disruption and is a limitation to FODC/SSI data. In addition to continued NO_3 and PO_4 monthly monitoring, future FODC/SSI monitoring should incorporate ammonia (NH_4) and nitrite (NO_2) analysis that would provide more insight into nitrogen cycling effects in the watershed. Continued monitoring and expanding analyses to include ammonia, nitrite, and other ions present in the effluent (e.g. chlorine) will be important to monitor the effectiveness of wastewater treatment plant upgrades and to identify additional constituent influxes and sources in the Deer Creek watershed.

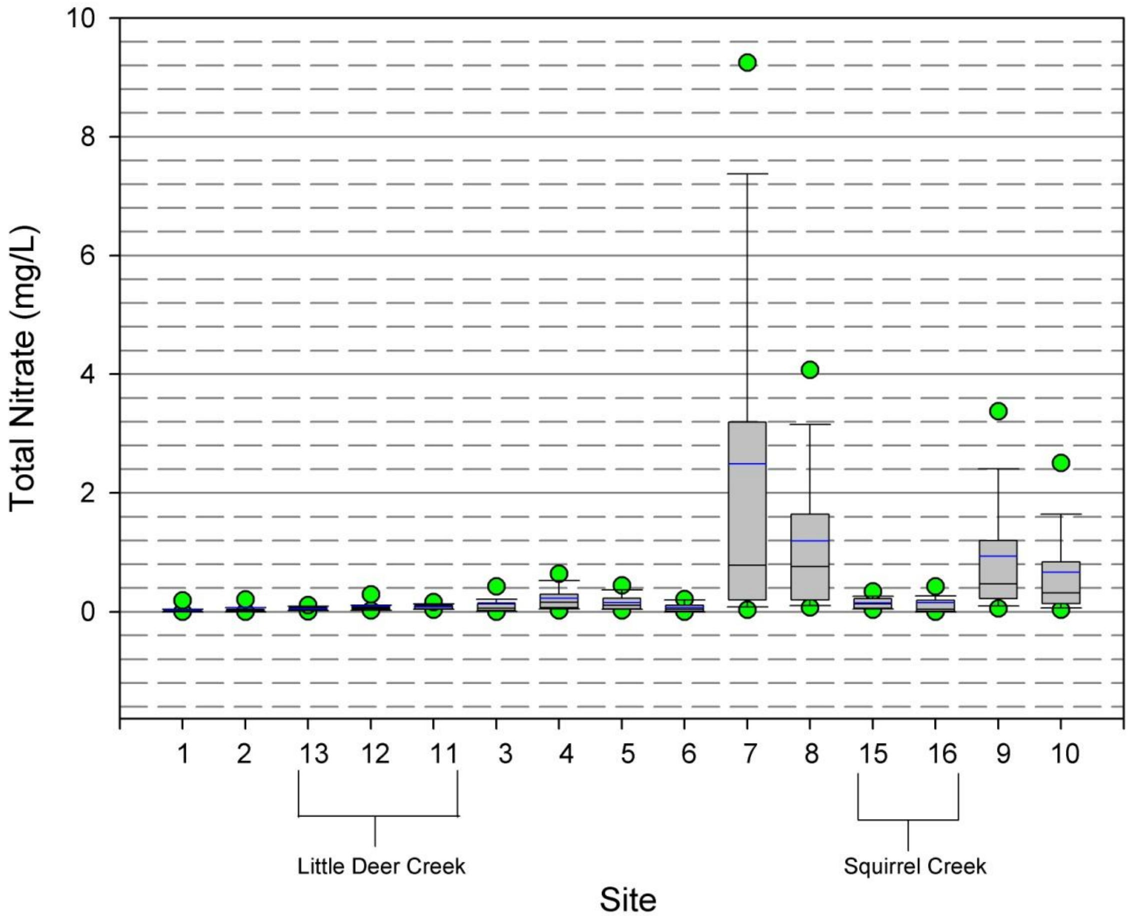


Figure 6.11: 2000-2010 Nitrate concentration results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. A spike in NO_3 is apparent below the Lake Wildwood WWTP and remains elevated in downstream sites compared to upper Deer Creek.

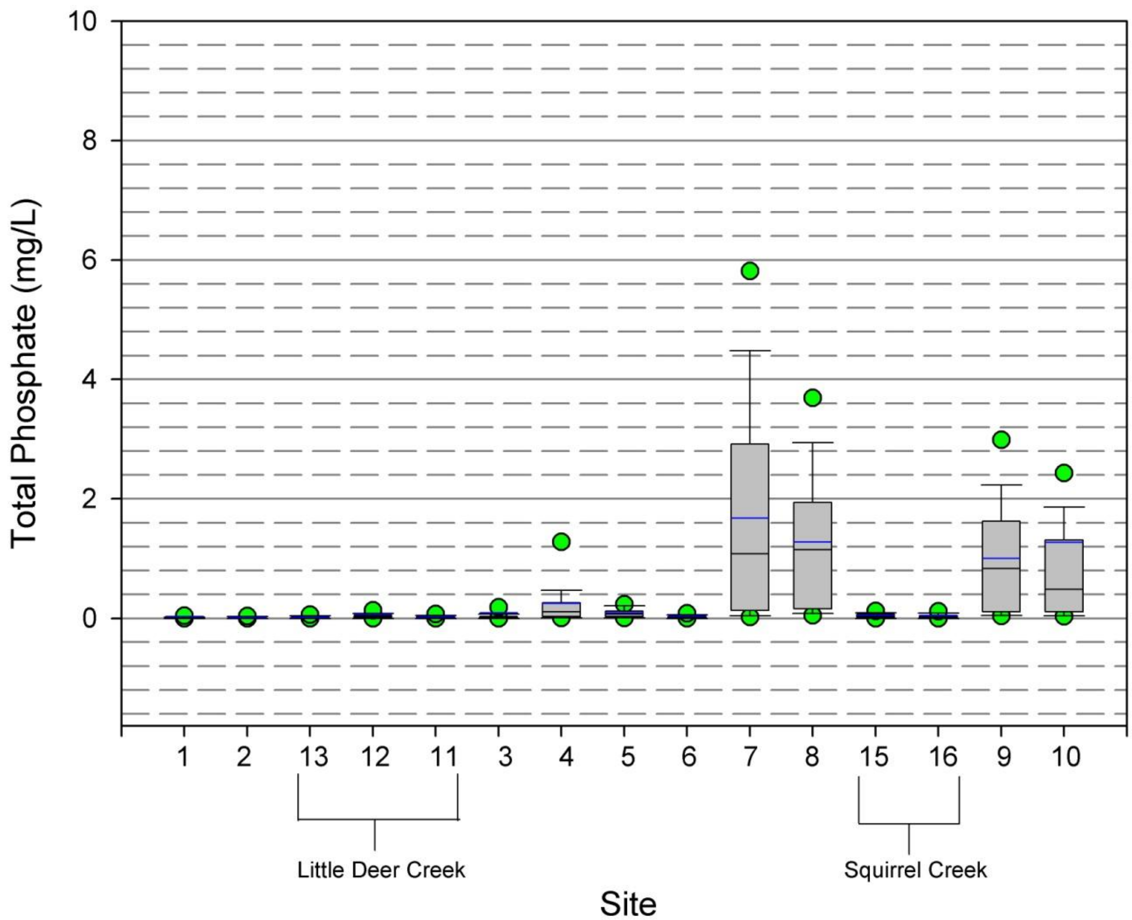


Figure 6.12: 2000-2010 Phosphate concentration results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. A spike in PO_4 is apparent below the Lake Wildwood WWTP and remains elevated in downstream sites compared to upper Deer Creek.

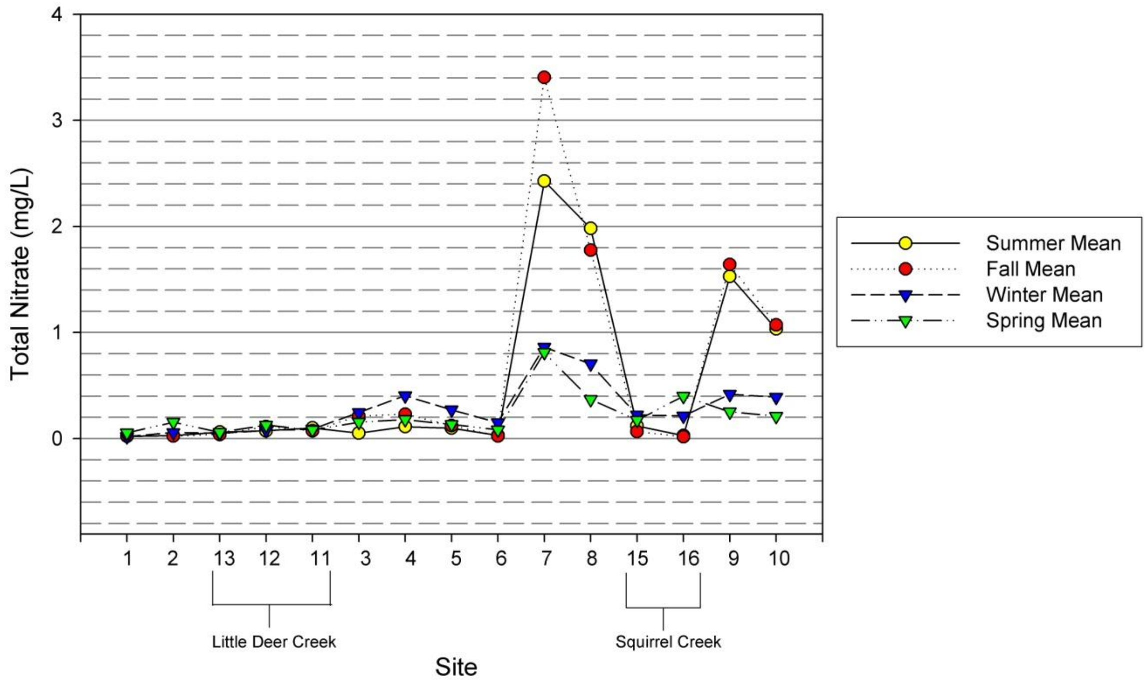


Figure 6.13: 2000-2010 Mean seasonal nitrate results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. High means in lower Deer Creek suggest an effluent-dominated flow in the fall and summer.

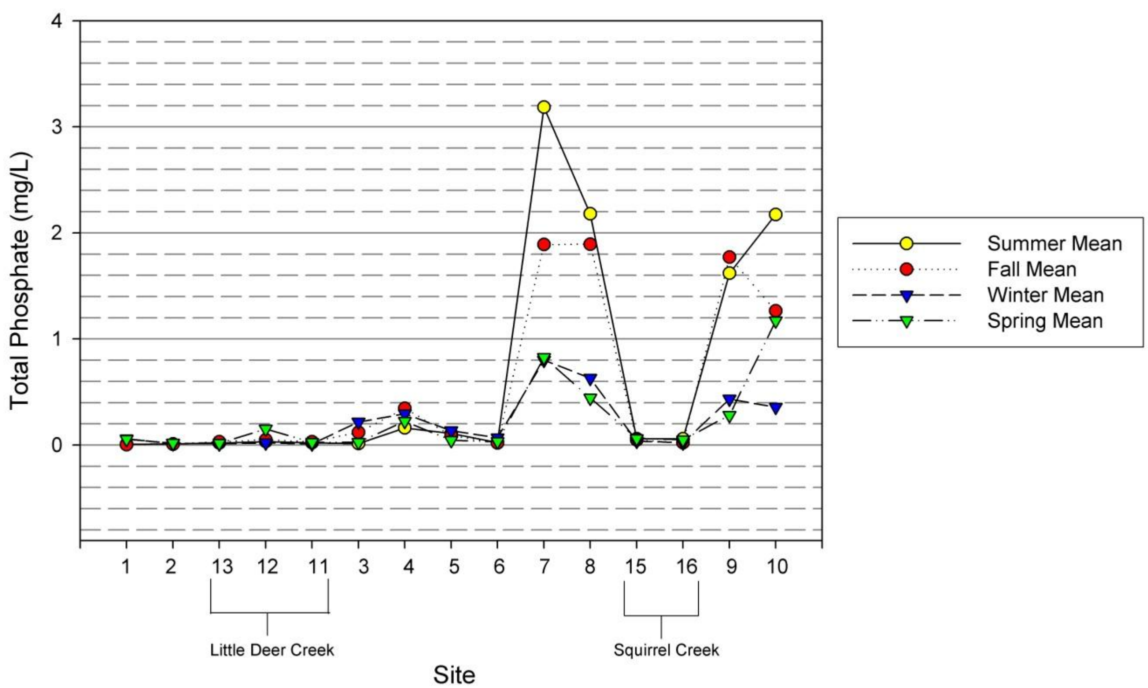


Figure 6.14: 2000-2010 Mean seasonal phosphate results for FODC/SSI monthly monitoring sites in the Deer Creek watershed. High means in lower Deer Creek suggest an effluent-dominated flow in the fall and summer.

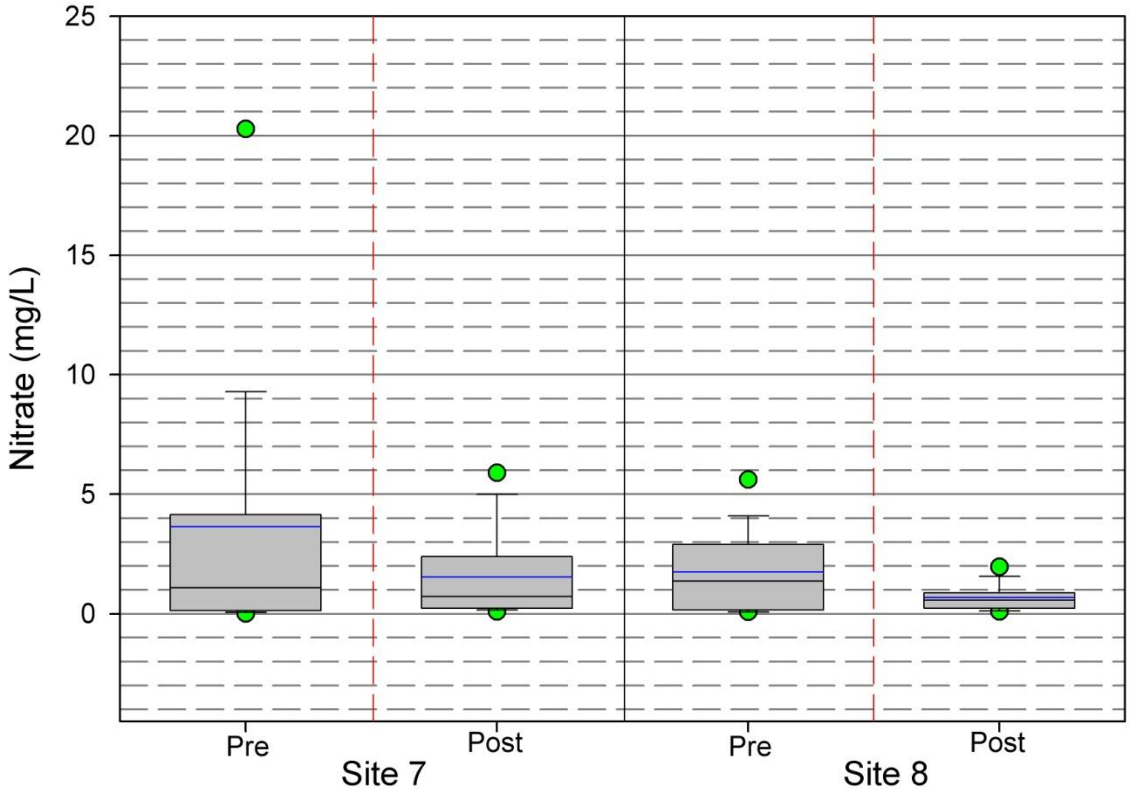


Figure 6.15: Nitrate concentrations before and after major upgrades in late 2006 at the Lake Wildwood WWTP at sites 7 and 8. Data indicate a decrease in nitrate concentrations since the upgrades.

Mercury

The Deer Creek, Yuba River, and Bear River watersheds were the location of some of the most extensive gold mining in the Sierra Nevada from the mid 1800s through the early 1900s. Numerous hydraulic and hard-rock gold mines were located in the Deer Creek watershed that greatly affected the surrounding environment. Large amounts of gravel and soil were washed off hillsides altering river geomorphology while millions of pounds of mercury were released into the environment (estimated 11-12 million pounds in the Sierra Nevada) (Alpers et al. 2005). Therefore, on a watershed scale mercury (Hg) is one of the primary water quality concerns in Deer Creek, as it is in many streams and rivers in the Sierra Gold Country.

Although atmospheric deposition does account for a small amount of mercury in the watershed, nearly all the mercury in Deer Creek was released during the gold rush times. A large amount of this mercury remains in the ecosystem, distributed from the hydraulic and hard rock mines and mill sites downstream to the Yuba and Sacramento River Delta and eventually into the San Francisco Bay (Alpers et al. 2005).

Mercury, both organic and inorganic, remains in the Deer Creek watershed including river and reservoir sediments as well as in the biota. Elemental mercury can be found as free mercury (quicksilver) or as amalgam bound to gold and silver along the stream bed, primarily in cracks and depressions in bedrock and beneath sedimentary deposits. Floured mercury, often in an oxygenated state or "reactive mercury" is disseminated in stream and reservoir sediments often adhered to clay and silt particles (Alpers 2010). This reactive mercury is prone to entering the food chain and is mobilized during large storm events. Elemental mercury and mercury adhered to fine particles can be disseminated and made more reactive hydroelectric turbines and by suction dredge mining (Humphreys 2005). This is of particular concern since reactive mercury is susceptible to methylization and entering the food chain (Alpers 2010).

Methylmercury (MeHg), the biologically available form of mercury, forms in oxygen-depleted environments that support high biological activity (e.g. acid mine wastes). It is theorized that sulfur and iron reducing bacteria utilize reactive mercury as an energy source, producing MeHg, a highly toxic form of mercury as a byproduct. Methylmercury is incorporated into plankton and algae that then moves up the food chain through BMI, amphibians, small fish, and eventually large fish including game fish and predators. As MeHg moves up the food chain it biomagnifies to higher and higher concentrations resulting in hazardous levels in fish tissue and the predators who consume them.

FODC/SSI conducted a mercury survey in the Deer Creek watershed from 2005-2007 to try and identify the quantity, location, and time of mercury transportation and its effects on biota (FODC 2008b). Sediment and water samples were collected and analyzed for mercury during variable flows from low-flow irrigation conditions to large storm events. Bio-sampling included BMI and fish communities. Samples were collected from the main stem of Deer Creek including the Scotts Flat and Lake Wildwood reservoirs and several major tributaries including Little Deer Creek, Gold Run Creek, and Squirrel Creek.

Total mercury (THg) in sediment samples collected in the Deer Creek watershed ranged from below method detection limits (MDL = 0.1 mg/kg) to 51 mg/kg (ppm) wet weight. Tributary sediment samples possessed some of the highest THg concentrations in the watershed (FODC 2008b). A Gold Run Creek bank sediment sample measured 51 ppm wet weight THg, more than 2.5 times greater than the Resource Conservation and Recovery Act (RCRA) hazardous waste limit. The sample was taken from an eroding bank very close to the site of a historic ore processing facility. An elevated THg concentration in sediment (5.9 ppm) was also measured in Little Deer Creek.

Sediment samples collected in the Deer Creek watershed exceeded global background levels (0.08 ppm) 94% of the time. In addition, 91% of the samples exceeded the San Francisco Bay remediation goal (0.2 ppm) and 10% of the samples exceeded the EPA preliminary remediation goal for THg in soil (2.3 ppm) indicating that mercury concentrations are elevated throughout the Deer Creek watershed and a methylation source for biological communities leading to human advisories for eating wastewater fish.

Total mercury in storm water was evaluated by analyzing grab and auto samples collected during 10 sampling events in varied flow conditions including low-flow irrigation season (<10 cfs), intermediate-flow (100-1000 cfs) and high-flow storm events (>1000 cfs). In addition to THg, total suspended solids (TSS) and discharge were also measured for each sampling event. Total mercury concentrations in water ranged from 0.34 ng/L to 1,003 ng/L (ppt) suggesting that soluble mercury in water is not of major concern. FODC/SSI also investigated total suspended solids (TSS) during storm events and its relationship to mercury contamination. Results indicated a strong relationship between the two parameters (FODC 2008b) indicating that the primary mode of mercury transport in Deer Creek is suspended material such as sediment and algae.

Total mercury concentrations in BMI and fish communities were measured as a proxy for MeHg levels in the Deer Creek watershed. Total mercury was used as a proxy for MeHg concentrations because it has been estimated that MeHg accounts for approximately 95% of the total mercury in several species of fish (Bloom 1992) and has recommended by the USEPA (2000) to be used as a proxy for MeHg.

BMI samples were collected in D-frame kick nets with a total of seven families collected: Aeshnidae, Cordulegastridae, and Gomphidae (Odonata); Corydalidae (Megaloptera); Gerridae (Hempitera); Hydropsychidae (Trichoptera); and Perlidae (Plecoptera) (FODC 2008b). The highest THg concentration measured was upstream of the Lake Wildwood inlet (site 6) in a Hydrophyschidae (0.23 ppm). The lowest THg concentration was measured in a Corydalidaie (0.017 ppm) at St. Louis Mine (upstream of site 2). The Gomphidae family consistently exhibited some of the highest THg concentrations among large predators. Tributaries measured comparable THg concentrations with the Cordulegastridae family in Little Deer Creek and Gold Run Creek exhibiting elevated MeHg concentrations (FODC 2008b).

Total mercury concentrations in fish tissue were measured in Largemouth Bass, Sacramento Pikeminnow, Rainbow Trout, and Brown Trout. Sampling sites included the main stem of Deer Creek, Lake Wildwood reservoir, and Little Deer Creek. Forty-seven percent of the fish sampled exceeded the Office of Environmental Health Hazard Assessment (OEHHA) screening level of 0.3 ppm wet weight (FODC 2008b). Lake Wildwood reservoir had the highest THg concentrations in the watershed with the minimum recorded concentration (0.538 ppm wet weight) surpassing the maximum concentrations measured at all other sites (0.512 ppm wet weight). The highest THg concentration was from a Largemouth Bass tissue sample (1.167 ppm wet weight) that exceeds the EPA action level for MeHg in fish (1.0 ppm wet weight). A large decrease in THg concentrations in fish was observed below the Lake Wildwood reservoir at monitoring site 10 although samples at this site consisted of Sacramento Pikeminnow and not Largemouth Bass (FODC 2008b).

A mercury storm-event assessment was conducted by FODC/SSI from 2008-2010. Sampling locations included FODC/SSI monitoring sites 2, 3, 6, and 10 along the main stem of Deer Creek and two tributaries – Little Deer Creek and Gold Run Creek. Sampling was also conducted immediately upstream of the Nevada Street bridge (NSB) on the main stem of Deer Creek in Nevada City (downstream of site 2), Lake Wildwood, Lake Wildwood drawdown release point, and the Lake Wildwood weir immediately downstream of the reservoir.

Samples were collected via grab samples in 1000 mL sample containers or by an ISCO autosampler at standard intervals in 1000 mL sample containers. Each grab sample generally included a 1000 mL duplicate sample. pH, turbidity, and specific conductivity were measured either in the stream during the storm event or in the samples at the FODC/SSI laboratory if the stream was not wadeable. Total suspended solids and THg concentrations were analyzed in the FODC/SSI laboratory following methods SM 2540 D and EPA 7473 respectively. Data include samples collected from October 2008 through April 2010. Subsequent samples are in the process of being analyzed and therefore are not included in this report.

Total mercury concentrations for the 2008-2010 survey ranged from 11.7 ng/g (ppb) (site 10) to 6426.0 ppb (NSB) (Figure 6.16 and 6.17). The highest THg concentrations measured along the main stem of Deer Creek were located at site 3 and at the Nevada Street Bridge in Nevada City. The tributaries exhibited elevated THg concentrations with Gold Run Creek measuring some of the highest THg concentrations in the watershed with a mean concentration of 2,338.7 ppb, which slightly exceeds the USEPA preliminary remediation goal (2,300 ppb). Little Deer Creek also measured elevated THg concentrations. Note that 2009-2010 Data are limited for all four of these sites. The 2005-2007 survey also measured elevated THg concentrations in similar locations in the main stem of Deer Creek and in the tributaries Gold Run Creek and Little Deer Creek.

2008 Lake Wildwood Release Mercury Concentrations (ng/g)			
Site	**Mean**	**Std. Dev.**	**N**
LWWR	387.9	65.5	15
LWWW	601.7	237.1	190
Site 10	610.4	288.7	91
2009-2010 Storm Sampling Mercury Concentrations (ng/g)			
Site	**Mean**	**Std. Dev.**	**N**
Site 2	564.9	322.3	11
NSB	1383.4	1018.6	66
LDC	1242.1	829.6	11
GRC	2338.7	909.3	11
Site 3	1580.1	686.8	11
Site 6	884.7	256.8	18
LWWW	576.3	182.7	45
Site 10	565.9	417.8	828
2009-2010 Lake Wildwood Sampling Mercury Concentrations (ng/g)			
Depth	**Mean**	**Std. Dev.**	**N**
Surface	540.1	252.4	22
Thermocline	726.4	301.5	29
Depth	824.7	294.1	28
All Depths	709.4	304.5	79

Table 6.1: Table of 2008-2010 total mercury concentration results in the Deer Creek watershed. Abbreviations are Lake Wildwood release point (LWWR), Lake Wildwood weir (LWWW), Nevada Street bridge (NSB), Little Deer Creek (LDC), and Gold Run Creek (GRC).

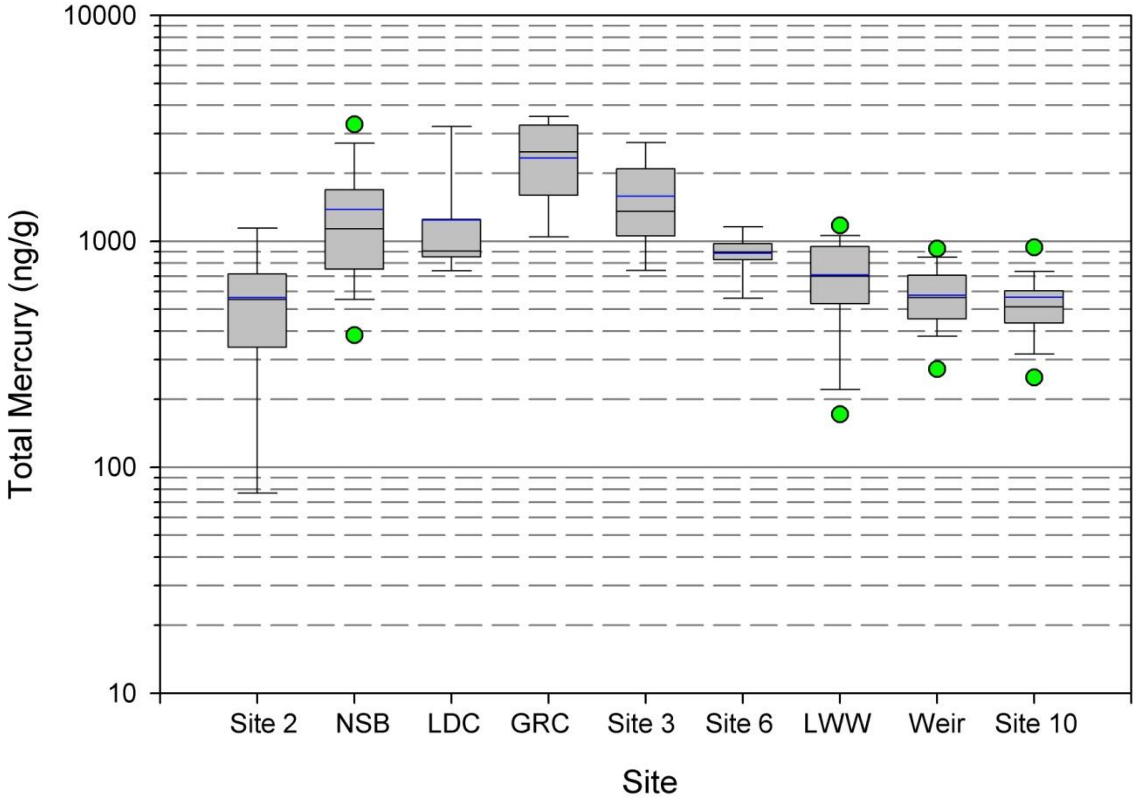


Figure 6.16. 2009-2010 total mercury concentration results for FODC/SSI storm sampling sites in the Deer Creek watershed. Abbreviations are Nevada St. bridge (NSB), Little Deer Creek (LDC), Gold Run Creek (GRC) and Lake Wildwood weir (LWWW). Sampling was limited (n < 20) at site 2, LDC, GRC, 3, and site 6.

A decrease in THg concentrations is evident from site 6 upstream of the Lake Wildwood reservoir downstream to lower Deer Creek sites below the dam (Lake Wildwood weir and Site 10). This agrees with the previous conclusion that the Lake Wildwood dam does prevent some transport of mercury-laden material to downstream sites to some extent; however, THg concentrations measured in Lake Wildwood and downstream at the Lake Wildwood weir are comparable suggesting that during storm events, appreciable amounts of mercury are being transported over the dam (**Table 6.1** and **Figure 6.16**). Furthermore, site 10, located several miles downstream of the Lake Wildwood reservoir measured similar THg concentrations to the Lake Wildwood weir suggesting that storm events transport mercury through lower Deer Creek and likely to the confluence with the South Fork of the Yuba River where salmon spawning occurs. Similar concentrations at the Lake Wildwood weir and site 10 were measured during the 2008 Lake Wildwood release (Figure 6.16). Mercury concentrations in Squirrel Creek were not measured in the 2009-2010 survey; however, data from the 2005-2007 survey indicated low THg concentrations in the lower Deer Creek tributary (FODC 2008b).

Evaluation of the relationship between TSS and THg concentrations in the 2008-2010 Deer Creek study indicates that the overall regression correlation is low for the total dataset at each sampling site; however, individual storm event regression correlation shows a strong relationship between the two parameters further indicating that suspended materials such as sediment and algae are the primary mode of Hg transport. The fact that overall regression correlation is low but individual storm event regression correlation is high may be attributed to storm intensity and needs further investigation.

Bio-sampling for the 2008-2010 Hg survey has not been conducted but sampling is scheduled for 2011; therefore, data is not available to compare to the 2005-2007 study. Unlike the 2005-2007 survey, bio-sampling will attempt to sample similar BMI, fish, and plant communities at all three sites to effectively compare fluctuations in THg above, in, and below the Lake Wildwood reservoir.

A study conducted by the USGS found that Little Deer Creek and Scotts Flat Reservoir on Deer Creek had fish with mercury levels above the CA OEHHA screening levels (May et al. 2000). Little Deer Creek, Gold Run Creek and Deer Creek from Scotts Flat reservoir to Lake Wildwood reservoir are listed on the CWA Section 303(d)/305(b) Integrated Report for the Central Valley Region as having impaired beneficial uses due to mercury contamination (CVRWQCB 2009a)

Additional Heavy Metals

Naturally occurring metals associated with ore and waste rock include arsenic, lead nickel, cadmium, chromium and others. Elevated concentrations of these metals were geologically deposited along with the gold and quartz and are brought to the surface by mining. Oxidation of waste rock releases metals that can leach into soil, groundwater and surface water (DTSC 1998). Soluble arsenic released from mine waste can impact drinking water wells and presents a significant health threat at relatively low levels (10 ppm). Naturally occurring arsenic in soil and mine waste is considered a carcinogen, however the biological availability of arsenic and other metals in soil is not well understood (Mitchell et al. 2010).

FODC/SSI has conducted soil sampling for heavy metals at several abandoned mine sites located adjacent to Deer Creek. An EPA Brownfields Community Wide Assessment of Nevada City owned properties conducted by FODC/SSI was completed in 2009. Results of the assessment of two sites located along Deer Creek indicated significantly elevated heavy metals that warrant cleanup to protect human health and the environment. At the Stiles Mill site located across Deer Creek from downtown Nevada City, soil samples from a mine waste stockpile along the creek indicated elevated arsenic and lead in most samples. Arsenic levels generally ranging from 60 to 200 mg/kg (ppm) and lead from 140 to 250 ppm compared with typical regulatory cleanup goals of 22 ppm and 80 ppm respectively.

At the Providence Mine site located approximately one mile downstream of downtown Nevada City, a steep slope of mine waste eroding into Deer Creek is also impacted by elevated arsenic and lead concentrations. Arsenic levels generally measured from 40 to 75 ppm and lead from 100 to 500 ppm. Much higher lead levels were detected in soil adjacent to part of a popular trail above the creek. Based on the results of the Brownfields Assessment, EPA has recently awarded three Brownfields Cleanup Grants to the City of Nevada City for the Stiles Mill and Providence Mine sites. Cleanup work coordinated by FODC/SSI is scheduled to start in early 2011.

FODC/SSI also preformed soil sampling of mine waste during the summer of 2009 as part of a Sierra Fund sponsored Recreational Exposure Assessment and User Survey in the Northern Sierra Region. Although most of the sampling and assessment work was performed outside of the Deer Creek watershed or in areas not immediately adjacent to the creek, the highest arsenic levels detected during the survey (up to 4,050 mg/kg) were obtained from samples of mine waste located adjacent to the headwaters of Little Deer Creek. These results indicate significant impacts of heavy metals from mine waste warrant additional investigation in the Deer Creek watershed.

Acid Mine Drainage (AMD) discharged from mine shafts or leached from waste rock often contains high levels of arsenic and other hazardous metals. Acid mine drainage is harmful to fish and aquatic life. Although no specific discharges of acid mine drainage have been documented in Deer Creek, uncharacterized mine sites may pose a threat to water quality in some locations, particularly in Squirrel Creek and lower Deer Creek watershed where copper and zinc sulfide deposits have been mined on a small scale. An assessment of AMD in the Deer Creek watershed has not been conducted and should be further investigated.

Physical Parameters

The physical components of a river system can significantly influence the ecological condition of a watershed (Vannote et al. 1980; Poff et al. 1997; Stoddard et al. 2005). The gradient of physical factors formed by the watershed will heavily influence the biological strategies and dynamics of a river system (Vannote et al. 1980) while hydrologic and geomorphic processes regulate the input, transport, storage, and use of organic matter by aquatic communities and influence the habitat complexity of a reach (Poff et al. 1997; Stoddard et al. 2005).

There are numerous alterations and modifications to the physical characteristics of the stream that can adversely affect aquatic organisms. Excess of fine sediments, which is exacerbated by human activities including agriculture, road building, construction, and grazing, can decrease bed stability with impacts on aquatic communities (Stoddard et al. 2005). Additionally, when high sediment inputs cannot be transported downstream, ecologically stressful conditions can develop due to filling of interstitial spaces between cobbles and boulders, which are valuable habitat areas (Stoddard et al. 2005).

Data, discussion, and recommendations for hydrology and stream geomorphology characteristics are covered in the Hydrology and Geomorphology Chapters (Chapter 4 and

5). The focus of this section will be riparian vegetation conditions in the Deer Creek watershed.

Riparian Vegetation

Riparian zones are some of the most productive and structurally diverse habitats in the Sierra Nevada. The health and condition of the riparian zone is a function of underlying geology, soils, the stream hydrograph, and terrestrial activities such as human management and grazing. Healthy riparian zones exhibit the attributes described in **Table 6.2** (reproduced from Kondolf et al. 1996).

Habitat complexity is critical to support diverse biotic assemblages. An adequate mix of large woody debris, boulders, undercut banks, and tree roots will support richer and more diverse aquatic communities (Stoddard et al. 2005). Degradation and simplification of aquatic habitat from anthropogenic activities such as channelization, riparian vegetation degradation, and flow alteration will affect both chemical parameters and biological communities in the stream (Poff et al. 1997; Stoddard et al. 2005).

In the SRBRC, the Deer Creek watershed scored a 63/100 for hydrologic alteration with unnaturally high summer flows reported as the most highly altered aspect of Deer Creek hydrology (SRWP 2010). Additionally, the Deer Creek watershed received some of the lowest scores in terms of aquatic barriers (67) and habitat fragmentation (5) in the SRBRC (SRWP 2010) suggesting impaired conditions that warrant future assessment and restoration efforts.

General Attribute	Specific Attributes	References
Structural complexity	Vegetation provides cover for wildlife, birds Multiple plant canopies create multiple niches	Krzysik 1990
	Seasonal changes in deciduous vegetation	Reynolds et al. 1993
Periodic disturbance	Floods disrupt existing organisms, providing opportunities for pioneer species	Resh et al. 1988 ; Sparks et al. 1990 ; Junk et al.1989
Linear nature	Edge effect: terrestrial-aquatic ecotone	Schimer and Zalewski 1992
	Riparian zones serve as wildlife migration corridors	Thomas et al. 1979
Food resources	Diverse vegetation yields diverse foods	Cross 1988

	Diverse habitat harbors diverse prey Open water available for wildlife	Raedeke et al. 1988
Microclimate	Shaded, cool, moist in summer Protected in winter: over-wintering habitat	Raedeke et al. 1988
Influences on aquatic habitat	Shading moderates water temperatures Shading moderates algal growth	Brown 1969
	Plant materials and insects fall into stream, adding chemical energy and nitrogen	Cummins et al. 1989; Knight and Bottorff 1984
	Riparian zone "buffers" stream from upland	Erman and Mahoney 1983; Mahoney and Erman 1984
	Riparian vegetation stabilizes stream banks	Kondolf and Curry 1986

Table 6.2: Ecological attributes of riparian areas (reproduced from Kondolf et al. 1996).

To assess riparian vegetation conditions in the Deer Creek watershed, a riparian condition rapid assessment methodology (referred to as the NHI[3] Riparian Method) was developed and implemented during a stream-walk from the Little Deer Creek confluence to the Lake Wildwood reservoir along the main stem of Deer Creek (Reaches 3-7[4]) during July and August 2005. The NHI Riparian Method was developed based on modified versions of existing riparian zone surveys (USEPA 1997; Fateman and Yin 2002; SFEI 1996). For each riparian sample location, attributes were measured as described in **Table 6.3**.

General Attribute	Measured Attribute
Structural complexity	Dominant species of upper canopy (trees), lower canopy (shrubs), and percent cover of groundcover (grasses and forbs). Average height of canopies and ground cover
Periodic disturbance	Floodplain terrace height as an indicator of floodplain accessibility and disturbance
Linear nature	Average width of riparian zone
Food resources	Percent non-native
Microclimate	Percent canopy cover over riparian zone
Influences on aquatic habitat	Percent canopy cover over stream

Table 6.3: Measured ecological attributes of Deer Creek watershed riparian areas

[3] NHI = National Heritage Institute
[4] See Geomorphology Chapter (Chapter 5) for Reach descriptions used in this section

For the NHI Method, the active riparian area for each transect was identified as the zone adjacent to the stream that either had typical riparian vegetation or appeared to be within the likely floodplain during an overbank flood event. In some rare cases, abandoned floodplains in the riparian zone were included if new floodplains had not fully developed. The goal was to have at least two transects per geomorphic sub-reach, with transects located in three ways:

1) At existing cross-sections;
2) In areas that appeared to be representative of the sub-reach;
3) Randomly at locations out of sight (e.g., around the next bend)

At each transect, the location (latitude/longitude) was recorded and the approximate distance from the top of bank to the end of the riparian zone was estimated. A total of 62 transects were documented in the study area. Each transect included separate observations for the right and left banks.

Additionally, annual physical and biological habitat assessment data using the California Stream Bioassessment Protocol (CSBP 1999) from 2000-2008 and the Surface Water Ambient Monitoring Program protocol (SWAMP; Ode 2007) from 2007-2010 were analyzed for thirteen FODC/SSI monitoring sites in the Deer Creek watershed to investigate the condition of the riparian corridor in these stream sections. The CSBP and SWAMP methods include sites in upper and lower Deer Creek, Little Deer Creek, and Squirrel Creek. Stream section lengths are 100 meters for the CSBP method and 150 meters with 11 transects in the SWAMP method. These methods investigate many of the same attributes as the NHI Riparian Method including structural complexity, linear nature, microclimate, and influences on aquatic habitat.

It should be noted that the methods used to assess riparian vegetation conditions include qualitative measurements based on visual and therefore inevitably subjective observations by FODC/SSI staff and volunteers. These observations can serve as rough indicators of impaired riparian zone conditions and are useful for prioritizing sites that warrant further investigation for future restoration efforts. Additionally, the physical habitat criteria being used in the Deer Creek watershed is not specific to mountainous streams and is an additional limitation to the data. Assessment of the current protocol and development of a method more specific to the Deer Creek watershed would be valuable for future physical habitat assessments in the watershed.

Structural Complexity

Structural complexity was evaluated by identifying the dominant species in the upper (trees) and lower (shrubs) canopies, estimating the average height of each canopy, noting the presence of groundcover (grasses and forbs), and estimating the percent cover of upper canopy, lower canopy, and groundcover (<20%; 20-40%, 40-60%, 60-80%, >80%).

White alders and willows are prevalent in the upper and lower canopies of the riparian zone throughout the upper Deer Creek study area (**Figure 6.17**). A shift from white alder, dogwood, and white alder/willow mixes upstream of Nevada City (Reaches 3 and 4) to primarily white alder, willow, and occasional cottonwood downstream of Nevada City (Reaches 4-7) is evident. Non-native black locust dominates the riparian zone in several transects, especially around Nevada City.

Interestingly, data indicate ponderosa pine as a dominant riparian species in some transects (**Figure 6.17**). Ponderosa are not typical riparian trees and usually thrive in drier substrate. The presence of ponderosa pine in the lower reaches may indicate abandoned and inaccessible floodplain terraces and warrant further assessment for potential floodplain restoration projects. In the upper reaches, their presence may be a result of a limited riparian zone due to the narrow stream valley.

During a stream walk visual assessment downstream of Lake Wildwood reservoir by FODC/SSI staff in 2008, willow and white alder were noted as common riparian species, with non-native Black Locust (*Robina spp.*) established in many locations. Cottonwoods were also noted as prevalent riparian species along some sections of lower Deer Creek in the visual assessment.

Changes in structural complexity in the watershed appear to be partially a function of elevation and geomorphic changes which favor certain species. Data and visual assessments indicate Black Locust as the most common invasive tree species in the riparian zone of the Deer Creek watershed warranting further investigation into their effects on riparian zone conditions and potential restoration projects.

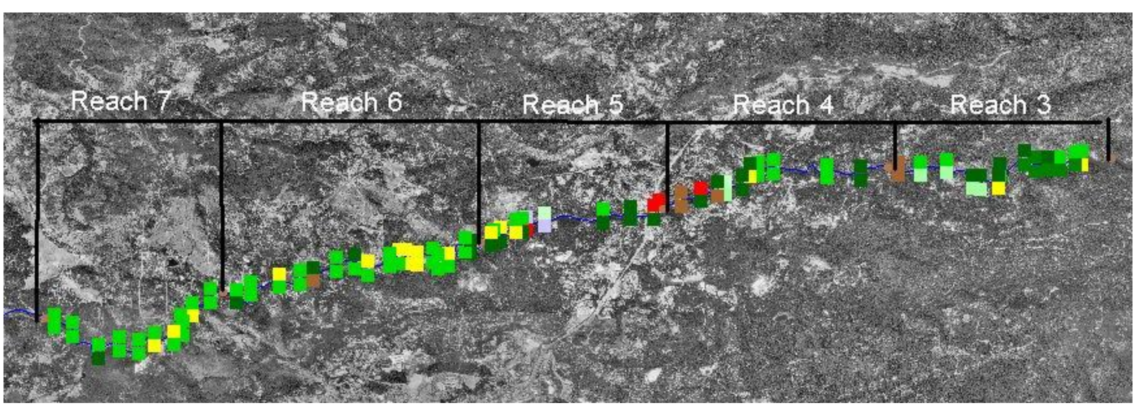


Figure 6.17: Dominant riparian species along upper Deer Creek from the NHI Riparian Method assessment. See Geomorphology Chapter (Chapter 5) for descriptions of Reaches used in this section.

Periodic Disturbance

Periodic disturbance was assessed using data from the floodplain connectivity section of the Geomorphology Chapter in this report (Chapter 5). Terrace height above bankfull elevation served as an approximate indicator for frequency of periodic disturbance. Additionally, terrace height was used as an estimate for inundation frequency using hydrologic and geomorphic data at the established cross sections. If terrace height varied, a range of elevations above bankfull was reported.

Floodplain height above bankfull discharge was estimated at each transect. Floodplains situated 5 ft or greater above bankfull discharge are most likely not regularly disturbed (every 1-2 years; **Figure 6.18**). The prevalence of abandoned floodplains that was observed suggests that the loss of floodplain function may be widespread along the upper Deer Creek study area (especially along Reach 6), and potentially elsewhere in watershed in areas that were not assessed. The absence of regular inundation and periodic disturbance could hinder the function of riparian areas at these locations, leading to watershed-wide impacts.

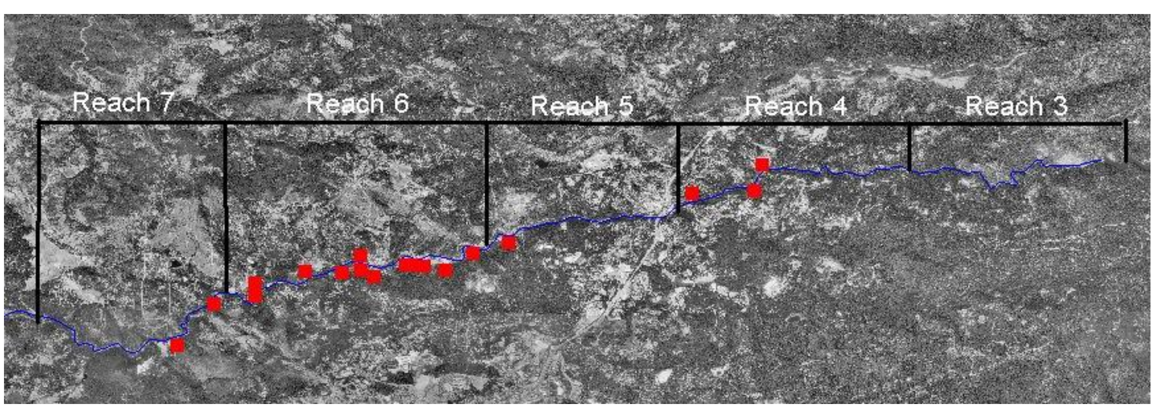


Figure 6.18: Floodplain terraces ≥5 ft above estimated bankfull discharge along upper Deer Creek from the NHI Riparian Method assessment.

Data from 2008 stream walk for lower Deer Creek and Squirrel Creek indicate that the majority of the sites have a floodplain that is accessible and disturbed periodically (**Table 6.4**). Sites 8, 16, 9, and 10 have a potential 2-year return interval for floodplain inundation, which is within the ideal range for floodplain disturbance. The only site that is potentially not accessible or disturbed by bankfull flows is the Lake Wildwood weir, located immediately downstream of the Lake Wildwood reservoir, where development of a road and effects of the spillway prevent floodplain inundation and disturbance.

A visual assessment of lower Deer Creek and Squirrel Creek did not locate any floodplain terraces that were caused by mining impacts, with no unnatural abandoned terraces apparent. Large portions of Reaches 9 and 11 consist of steep, bedrock-dominated canyons and have no true floodplain.

Site (Reach)	Frequency of Floodplain Inundation (1 – 2 yrs is ideal)
LWW Weir (Reach 8)	5 – 10
Site 8 (Reach 9)	2 – 10
Site 16	2 – 5
Site 9 (Reach 10)	2 – 5
Site 10 (Reach 11)	2 – 5

Table 6.4: Summary of floodplain inundation frequency, an indicator of periodic floodplain disturbance, for lower Deer Creek and Squirrel Creek.

It is important to note that only a 250 m section of Squirrel Creek located near its confluence with Deer Creek was surveyed; therefore, a large portion of the Squirrel Creek sub-watershed as well as other sub-watersheds (e.g. Little Deer Creek) have not been thoroughly assessed for floodplain disturbance.

<u>Linear Nature</u>

The width of the riparian zone was estimated by measuring the distance from bankfull to the boundary of the riparian zone using the NHI Riparian Method. Distances of greater than 100ft were recorded as 100+. The greatest riparian zone widths are located in the lower, less steep, and more depositional reaches of the upper Deer Creek study area (Reaches 6 and 7) with narrower riparian zones located in the steeper, upstream reaches (Reaches 3, 4, and 5; **Figure 6.19**) around and upstream of Nevada City.

Limited riparian zone widths around Nevada City indicate impairment due to land development and management impacts. Degradation of riparian zones increases a stream's susceptibility to upland contaminants and further degradation.

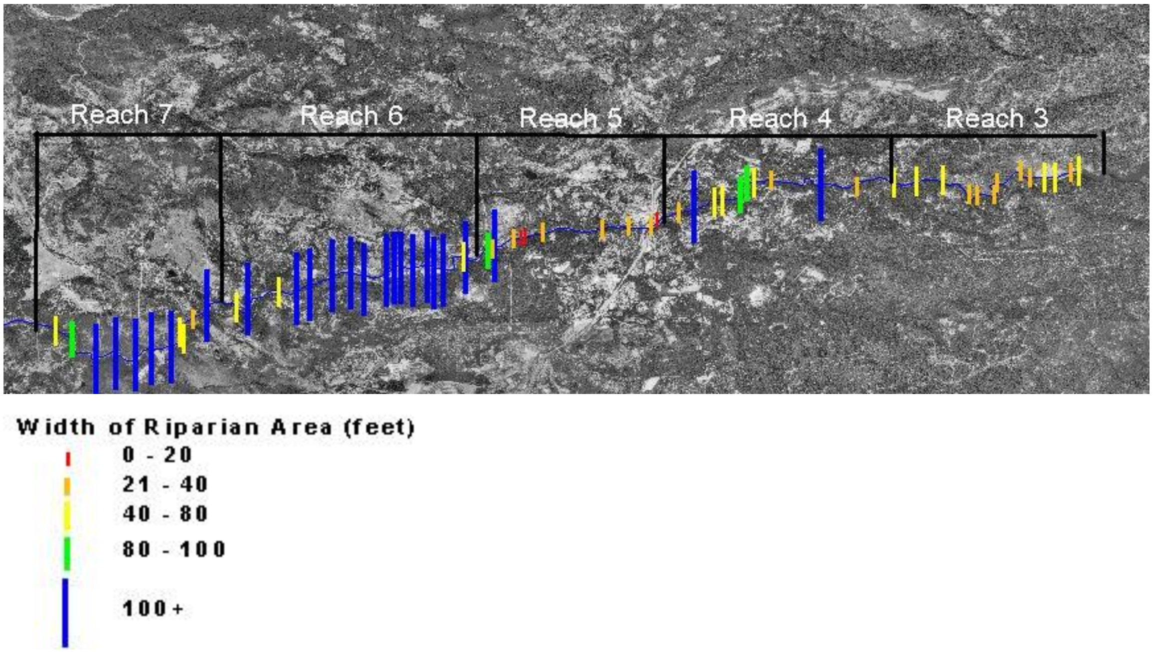


Figure 6.19: Riparian zone width results along upper Deer Creek from the NHI Riparian Method assessment.

In addition, the CSBP method was used to investigate disturbances that have encroached upon or limited riparian zone width. Riparian zone width was estimated and classified as optimal (>18 m), suboptimal (12 – 18 m), marginal (6 – 12 m), or poor (< 6 m) at each site. Both banks were assessed to produce a score out of twenty possible points. CSBP data from 2000 – 2008 was used in this analysis.

The CSBP method for assessing riparian zone width primarily focuses on activities or disturbances, such as development or grazing, which have encroached upon and limited riparian zone width. This is important to investigate as riparian zone width serves as an indicator of its buffering capacity for the stream from upland disturbances. Disturbances and detrimental activities that limit riparian zone width decrease the benefits it provides for the stream.

Data for the CSBP method include sites on upper and lower Deer Creek, Little Deer Creek, and Squirrel Creek (**Table 6.5**). A score >90% indicated optimal riparian zone width, 60% to 90% suboptimal, 30% to 60% marginal, and <30% poor. Only site 4 on Deer Creek was classified as having optimal riparian zone width. Sites 1, 6, 8, 9, and 10 on Deer Creek, 13 on Little Deer Creek, and site 16 on Squirrel Creek, were classified as having suboptimal riparian zone width. Three sites, site 2 on Deer Creek, site 11 on Little Deer Creek, and site 15 on Squirrel Creek, were classified as having marginal riparian zone width while site 12 within Pioneer Park in Nevada City was classified as having poor riparian zone width.

Human activities appear to be one of the major impacts on riparian zone width. Some prominent anthropogenic impacts on riparian width in the Deer Creek watershed are road construction (site 2), residential development (sites 11 and 15), and recreational development (e.g. public parks; site 12). Future assessments and restoration efforts should focus on impaired, thin riparian zones that leave stream reaches most vulnerable to upland runoff. An example of a restoration action was the removal of grazing animals at sites 8 and 9 in lower Deer Creek, which has improved riparian vegetation conditions.

Site #	Riparian Zone Width (20 pts)	% Score	Condition Category
Site 1	17	85	Suboptimal
Site 2	11.9	59.5	Marginal
Site 13	13.9	69.5	Suboptimal
Site 12	4.6	23	Poor
Site 11	11.9	59.5	Marginal
Site 4	19.1	95.5	Optimal
Site 6	16.5	82.5	Suboptimal
Site 8	14.5	72.5	Suboptimal
Site 15	10.9	54.5	Marginal
Site 16	16	80	Suboptimal
Site 9	14.7	73.5	Suboptimal
Site 10	16.2	81	Suboptimal

Table 6.5: Summary of CSBP riparian width data at FODC/SSI monitoring sites.

Food Resources/Non-Native Vegetation

The percent of non-native vegetation species in the upper and lower riparian zone canopies was estimated as a rough indicator of potential food resources for native aquatic species, with non-native ground cover also being noted. **Figure 6.20** exhibits transects with >20% of the upper and/or lower canopy consisting of non-native species. A pronounced increase in the presence of non-natives is evident around and downstream of Nevada City suggesting the anthropogenic influence of spreading non-natives. A majority of the non-natives observed in the upper and lower canopies were Black Locust (*Robina spp.*) trees. Although groundcover vegetation was not quantified, invasive Himalayan blackberry (*Rubus discolor*) dominates much of the groundcover at Reach 4 and downstream. Interestingly, native blackberry appear to out compete Himalayan blackberry upstream of Reach 4, warranting investigation into native and non-native species competition. The percent of non-native species was not quantified for lower Deer Creek, Squirrel Creek, or Little Deer Creek. Future assessments should include these regions in the watershed.

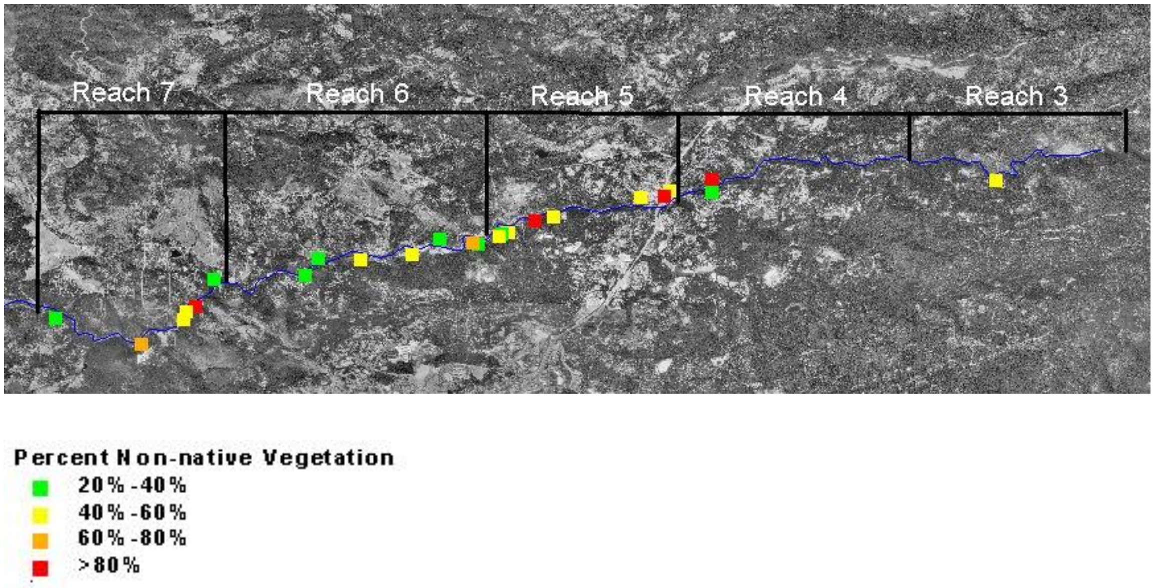


Figure 6.20: Percent non-native vegetation along upper Deer Creek from the NHI Riparian Method assessment

In addition to Black Locust and Himalayan blackberry, problematic and invasive, non-native plant species observed along Deer Creek and its tributaries include Scotch Broom (*Cytisus scoparius*), English Ivy (*Hedera helix*), Vincus (*Vinca spp.*), and Yellow Star-thistle (*Centaurea solstitialis*).

Data and visual assessments indicated that invasive species are prevalent around major communities in the Deer Creek watershed, specifically Nevada City, Penn Valley, and Lake Wildwood. Unchecked invasive species inflict stress on native species through competition and can spread quickly in the riparian zone, replacing native species that provide important habitat and food sources and could result in lower productivity and local extirpation of native biota. Future assessment, outreach, and restoration efforts should focus on these major communities to decrease impacts of invasive, non-native species.

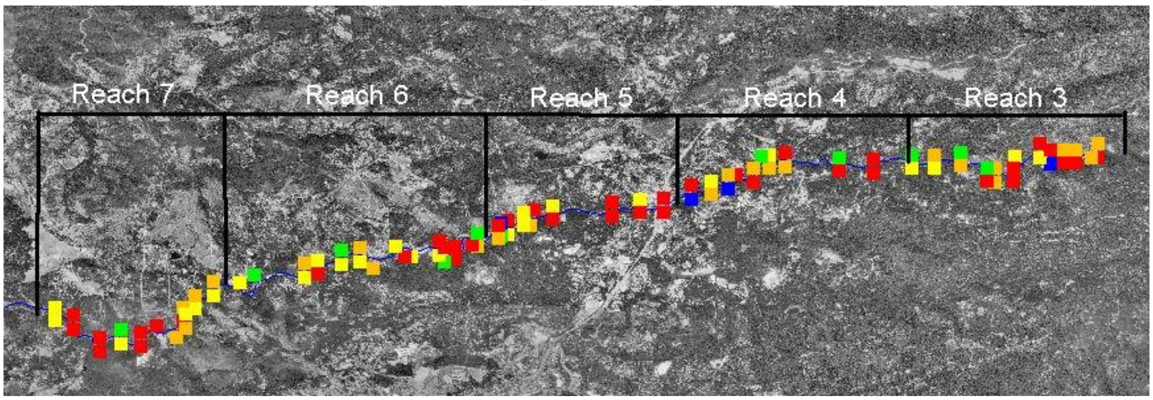
Microclimate

Using the NHI Riparian Method, percent canopy cover of the riparian area was estimated and used as an indicator of microclimate and the ability of the riparian vegetation to cool and shade the riparian zone. Percent cover was classified into five categories (<20%, 20-40%, 40-60%, 60-80%, >80%) for the upper canopy, lower canopy, and groundcover.

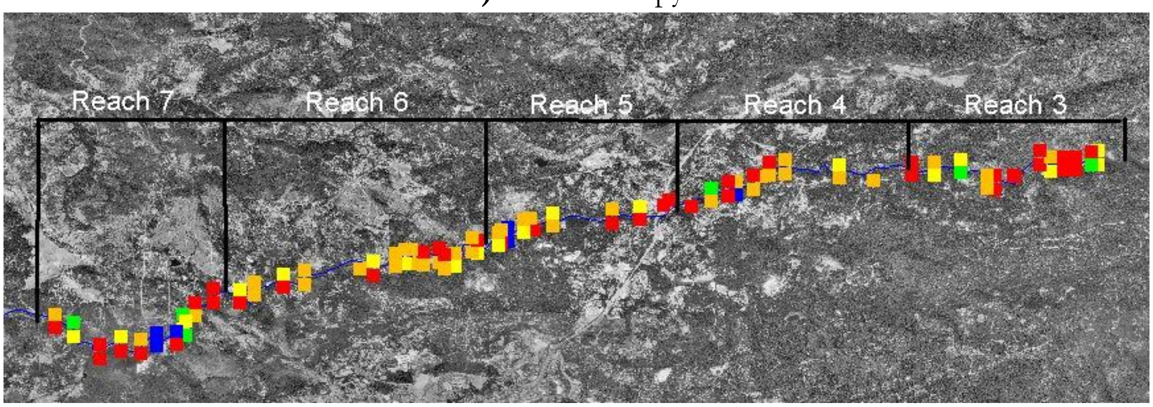
Upper Deer Creek exhibits a diversity of canopy cover amounts with no strong spatial trend evident (**Figures 6.21a and b**). Investigation of transects with less than 20% canopy cover (**Figure 6.26c**) indicates canopy gaps throughout the upper Deer Creek study area with a cluster of gaps apparent in proximity to Nevada City (boundary of Reaches 4 and 5).

Deficiencies in canopy cover limits structural complexity and can increase exposure of ground cover to sunlight, heat, and subsequent evapotranspiration. Twenty percent of transects observed in the NHI Riparian Method study exhibited canopy gaps (<20% upper and lower canopy cover), indicating potential areas for future assessments and restoration efforts.

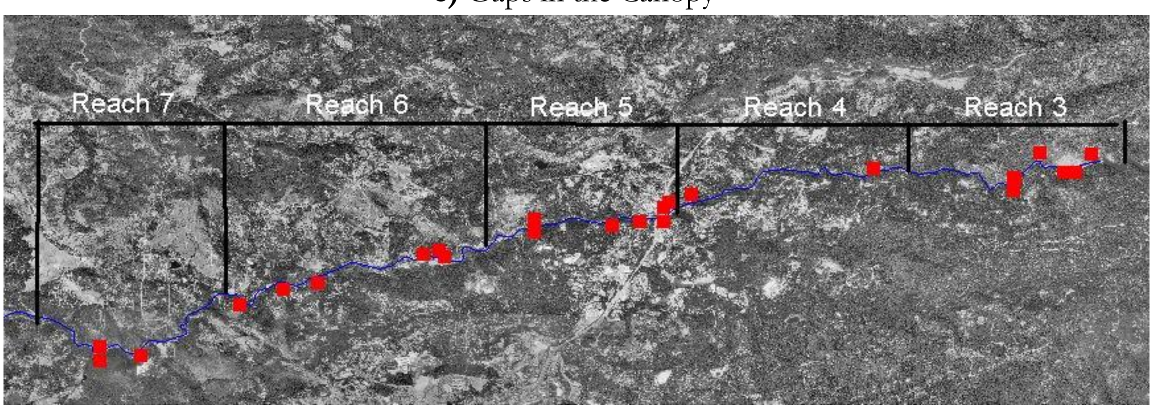
a) Upper Canopy

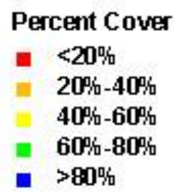


b) Lower Canopy



c) Gaps in the Canopy





Figures 6.21a-c: Percent canopy cover in riparian zones along upper Deer Creek from the NHI Riparian Method assessment.

Additionally, percent canopy cover of the riparian zone was estimated for FODC/SSI monitoring sites 1, 2, 4, 5, 6, 8, 9 and 10 on Deer Creek, sites 11-13 on Little Deer Creek and 15-16 on Squirrel Creek following the SWAMP physical and biological habitat assessment method. Percent canopy cover was estimated for the upper canopy (trees and saplings > 5m), lower canopy (woody shrubs and saplings 0.5 – 5m), and three categories of ground cover (woody shrubs and saplings < 0.5m; herbs and grasses; barren, bare soil, and duff). Scores range from 0 – 4, with a 4 indicating "very heavy" cover (greater than 75%), 3 indicating "heavy" cover (40 – 75%), 2 indicating "moderate" cover (10 – 40%), 1 indicating "sparse" cover (<10%), and 0 indicating that cover is absent (0%). Data used in this analysis were collected in June from 2007 – 2010 with summary tables included in the appendix.

Results for 2007-2010 upper canopy cover data indicate that FODC/SSI monitoring sites 1, 2, 4, 5, 6, and 10 on Deer Creek, sites 13 and 11 on Little Deer Creek, and site 15 on Squirrel Creek exhibit "heavy" upper canopy cover (**Figure 6A.4**). Four sites, including sites 8 and 9 on Deer Creek, site 12 on Little Deer Creek, and site 16 on Squirrel Creek exhibited "moderate" upper canopy cover.

Results for lower canopy cover data indicate that a majority of FODC/SSI monitoring sites exhibit "heavy" (**Figure 6A.5**). Two sites, site 12 on Little Deer Creek, and site 16 on Squirrel Creek, were classified as having "moderate" lower canopy cover.

To supplement canopy cover estimates, densiometer readings were taken from both banks to measure the percent canopy cover at each site. Scores > 80% were classified as optimal canopy cover, 55 – 80% as suboptimal, 30 – 55% as marginal, and < 30% as poor. Data used in this analysis were collected in June 2010.

Right and left bank densiometer data indicate that FODC/SSI monitoring sites 1, 2, 4, 5, and 6 on Deer Creek, sites 13 and 11 on Little Deer Creek, and site 15 on Squirrel Creek exhibit optimal canopy cover (**Table 6.6**). Five sites are classified as suboptimal including sites 8, 9, and 10 on lower Deer Creek, site 12 on Little Deer Creek, and site 16 on Squirrel Creek. The right bank at sites 8 and 10 on Deer Creek was classified as marginal, with values appreciably different than the left bank, which was classified as optimal at site 8 and just outside of the optimal range at site 10. A similar situation occurs at site 12 on Little Deer

Creek, with the left bank classified as suboptimal but the right bank scoring as optimal. No sites exhibited marginal or poor canopy cover overall.

Site #	Left Bank	Right Bank	Site Mean
Site 1	95.72	97.33	96.52
Site 2	89.30	85.56	87.43
Site 13	97.86	99.47	98.66
Site 12	65.24	92.51	78.88
Site 11	91.98	89.84	90.91
Site 4	95.19	91.98	93.58
Site 5	95.72	97.33	96.52
Site 6	97.86	86.63	92.25
Site 8	82.35	52.41	67.38
Site 15	87.70	97.33	92.51
Site 16	68.45	70.59	69.52
Site 9	72.73	69.52	71.12
Site 10	78.07	49.73	63.90

Table 6.6: Canopy cover results measured from both right and left banks at FODC/SSI monitoring sites.

Results for woody shrubs and saplings riparian groundcover data indicate "heavy" cover for FODC/SSI monitoring sites 4, 5, 6, on Deer Creek, sites 13 and 11 on Little Deer Creek, and sites 15 and 16 on Squirrel Creek (**Figure 6A.6**). Five sites were classified as having "moderate" woody shrubs and sapling ground cover including sites 1, 2, 8 and 10 on Deer Creek, and site 12 on Little Deer Creek. Sites 2, 8, and 10 scored very close to the "heavy" classification with each site having one bank that scored "heavy" and overall scores in the upper range of the "moderate" classification.

Results for herbs and grasses riparian groundcover data indicate that FODC/SSI monitoring sites 5, 6, 8, 9, and 10 on Deer Creek, site 12 on Little Deer Creek, and site 16 on Squirrel Creek exhibit "heavy" cover (**Figure 6A.7**). Six sites were classified as having "moderate" ground cover consisting of herbs and grasses including sites 1, 2, and 4 on Deer Creek, sites 13 and 11 on Little Deer Creek, and site 15 on Squirrel Creek.

Analysis of bare, barren soil, and duff riparian groundcover data is performed to pinpoint area with potential for erosion; therefore, higher scores in this category indicate less stable riparian habitat with greater erosion potential. Results indicate "heavy" groundcover exposure at FODC/SSI monitoring sites 1, 6, 9, and 10 on Deer Creek, sites 13 and 11 on Little Deer Creek, and site 15 on Squirrel Creek (**Figure 6A.8**). Six sites were classified as having "moderate" groundcover exposure including sites 2, 4, 5, and 8 on Deer Creek, site 12 on Little Deer Creek, and site 16 on Squirrel Creek.

Results from the NHI Riparian Method and SWAMP method indicate that each stratum of the canopy has been impacted in the Deer Creek watershed. This results in less structural complexity in the riparian zone and limits its ability to buffer the stream from upland runoff. Additionally, areas exhibiting excess bare, barren soil, and duff riparian groundcover are more susceptible to erosion that can impact water quality and aquatic communities. Future assessments should prioritize sites based on the NHI Riparian Method and SWAMP method and determine the most effective restoration actions to restore canopies.

Influences on Aquatic Habitat

Densiometer readings to estimate percent canopy cover over the stream served as an indicator of the riparian zones' ability to shade and to provide nutrient inputs into the stream channel. For the NHI Riparian Method, densiometer readings were taken from the middle of the stream at several locations on upper Deer Creek. Densiometer results for upper Deer Creek indicate a slight downstream trend toward decreasing canopy cover over the middle of the stream (**Figure 6.22**). This trend can at least be partially attributed to an increase in stream width as drainage area and runoff increase downstream (Vannote et al. 1980).

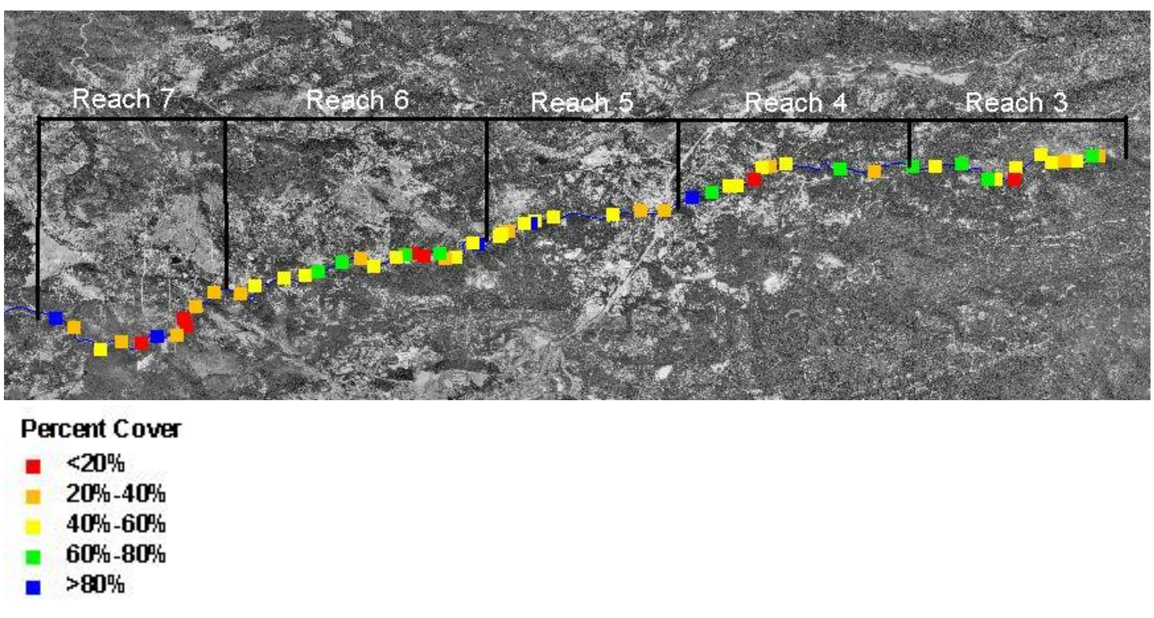


Figure 6.22: Midstream percent canopy cover along upper Deer Creek from the NHI Riparian Method assessment.

Additionally, densiometer readings were taken at FODC/SSI monthly monitoring sites during annual SWAMP physical and biological habitat assessments. For the SWAMP method, densiometer readings were taken from the middle of the creek at 11 transects over a 150-meter section of creek. Measurements were taken facing both right and left banks, as well as upstream and downstream. Scores of > 80% were classified as optimal conditions, 55 – 80% as suboptimal, 30 – 55% as marginal, and < 30% as poor.

Densiometer results following the SWAMP method indicate optimal midstream canopy cover at site 1 on Deer Creek and sites 11 and 13 on Little Deer Creek (**Figure 6A.9**). Four sites in the watershed are classified as having suboptimal midstream canopy cover including sites 4 and 5 on Deer Creek, site 12 on Little Deer Creek, and site 15 on Squirrel Creek. Marginal midstream canopy cover conditions were recorded at sites 2, 6, and 10 on Deer Creek and site 16 on Squirrel Creek. Sites 8 and 9 on Deer Creek scored poor with midstream canopy cover less than 30%.

Some sites with low midstream canopy cover scores, such as site 9 on Deer Creek and site 16 on Squirrel Creek exhibit a large amount of bedrock near the surface within the riparian zone. This may limit the amount of vegetation that can grow in the riparian zone; therefore, lower scores do not necessarily equate to disturbed riparian zones in need of restoration. Further investigations should be implemented at these sites. Sites 8 and 10 on lower Deer Creek exhibited lower densiometer scores and indicate areas of potential restoration efforts to increase midstream canopy cover.

The riparian zone is an important physical and biological factor that greatly affects the ecological integrity of a stream. The presence of diverse, multi-layered riparian vegetation along a stream provides numerous benefits to stream and biological health including canopy cover, energy and habitat input, and buffering capacity from upland runoff. It is important to note again the qualitative and subjective components that are associated with the physical habitat and visual assessments used in this report and that the protocols used in the Deer Creek watershed are not specifically for mountainous streams; therefore, data in this section can only serve as a rough indicator of impaired conditions. FODC/SSI data suggest that riparian zone conditions are less than optimal in areas throughout the Deer Creek watershed warranting further investigations and restoration efforts to improve this vital zone. The development of a physical habitat assessment specifically for the Deer Creek watershed and other Sierra foothill streams would provide better insight into restoration priorities and is recommended.

Biological Parameters

Susan McCormick

Historically, water quality assessments have focused on the chemical and physical attributes of streams to determine the condition of a watershed (Stoddard et al. 2005; Karr and Dudley 1981). However, it has become more apparent over the past several decades that the best way to determine the ecological condition of a river is to examine the status of the aquatic communities that actually inhabit the stream. While chemical monitoring only provides a snapshot of the river conditions at that particular time and place, bio-monitoring can provide information on past pollution and show the cumulative effects of multiple stressors in the watershed (SRWP 2010). Chemical and physical water quality parameters including light, temperature, dissolved oxygen, suspended solids, dissolved ions, and habitat structure will be reflected by the aquatic assemblages found in the stream (Karr and Dudley 1981).

FODC/SSI has been collecting an array of biological over the last decade including bacteria, algae, benthic macroinvertebrate (BMI), and fish data. Coupled with chemical and physical water quality data, impaired reaches and stressors can be more accurately identified and addressed. Additionally, continued bio-monitoring can determine the effectiveness of restoration projects on the biological communities that are targeted for protection or reestablishment.

Bacteria

FODC/SSI has been monitoring bacteria in the Deer Creek watershed since May 2005 at each of the monthly water quality monitoring sites and additional sites that are used for recreation. Samples are collected from flowing water using Whirl-Pak sampling bags or sample bottles, immediately put into a portable cooler with an ice pack, brought back to the FODC/SSI laboratory, and stored in the laboratory refrigerator until analysis. Samples are processed within one to six hours of collection and are analyzed using the IDEXX Colilert® 18 or 24 hour Quanti-Tray® method (IDEXX 2008). Samples are analyzed for Total Coliform and *E. coli*, with results conveyed in Most Probable Number/100 ml (MPN/100 ml). MPN values are statistical estimates of the bacteria concentrations in each sample. The IDEXX Colilert® method is approved by the USEPA and is included in the *Standard Methods for the Examination of Water and Wastewater*, a publication by the American Public Health Association, Water Environment Federation, and American Water Works Association (IDEXX 2008). The concentrations of these indicator organisms can be used to assess the level of bacteria contamination in local waterways and the potential risk to humans recreating in these waterways.

E. coli concentrations in waterways are important for analysis because they are the indicator organism used by the USEPA and Central Valley Regional Water Quality Control Board (CVRWQCB) to evaluate whether a freshwater body is safe for recreation.

Results indicate highest *E. coli* concentrations at Site 15 located on Squirrel Creek at the confluence with Clear Creek (**Figure 6.23**). *E. coli* concentrations at this site exceed the USEPA, and CVRWQCB single sample maximum standard of 235 MPN/100 ml 25-50% of the time. In addition, samples taken at site 15 likely exceed the geometric mean standard for *E. coli*, with 58% of the samples resulting in *E. coli* concentrations greater than the geometric mean standard value (126 MPN/100 ml). However, the geometric mean standard cannot be applied to the above dataset as the standard requires a minimum of five equally spaced samples over a 30-day period. FODC/SSI monthly water monitoring samples are collected at equally spaced time intervals, but the temporal scale is larger than the 30 days required by the standard. Nonetheless, the fact that *E. coli* concentrations regularly exceed this standard raises concern for public health.

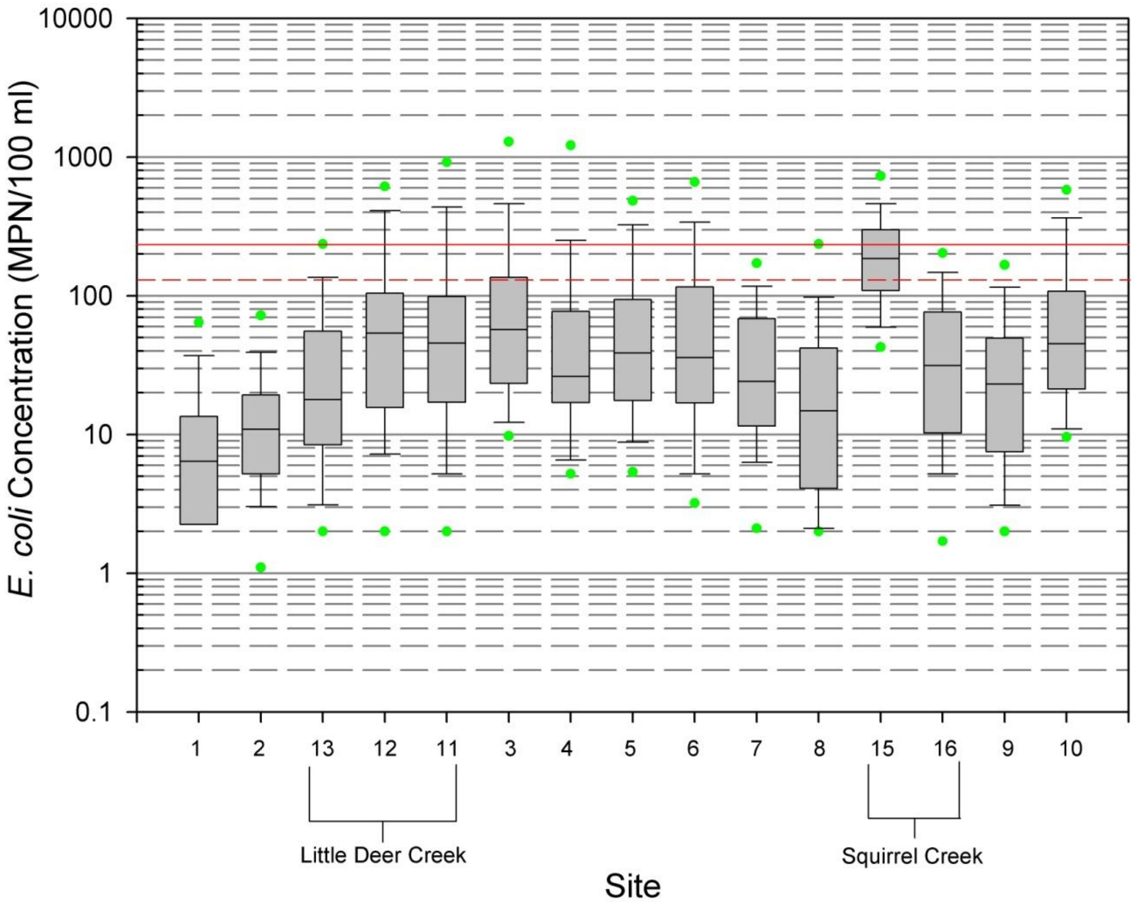


Figure 6.23: *E. coli* sampling results at FODC/SSI monthly monitoring sites. The red lines represent the USEPA and CVRWQCB recreational standards for freshwater, with the dashed line representing the 30 day geometric mean standard (126 MPN/100 ml) and the solid red line the single sample maximum (235 MPN/100 ml).

E. coli contamination at site 15 becomes more apparent when assessing the dispersion of the dataset. In comparison to other sites, Site 15 consistently measures high *E. coli* concentrations that are illustrated in Figure 6.23 by the relatively narrow box plot.

It is important to note that the data in **Figure 6.23** consist of samples collected during all 12 months of the year, and are thus not representative of *E. coli* concentrations during the peak recreation season. Upon analyzing the *E. coli* data for peak recreation months, the percentage of samples exceeding the USEPA and CVRWQCB standards for *E. coli* increases appreciably

(**Figure 6.24**). The geometric mean and single sample maximum bacteria standards are designed to protect people from fecal contamination. Since peak recreation occurs during the summer months, there is a legitimate concern of human exposure to fecal pathogens.

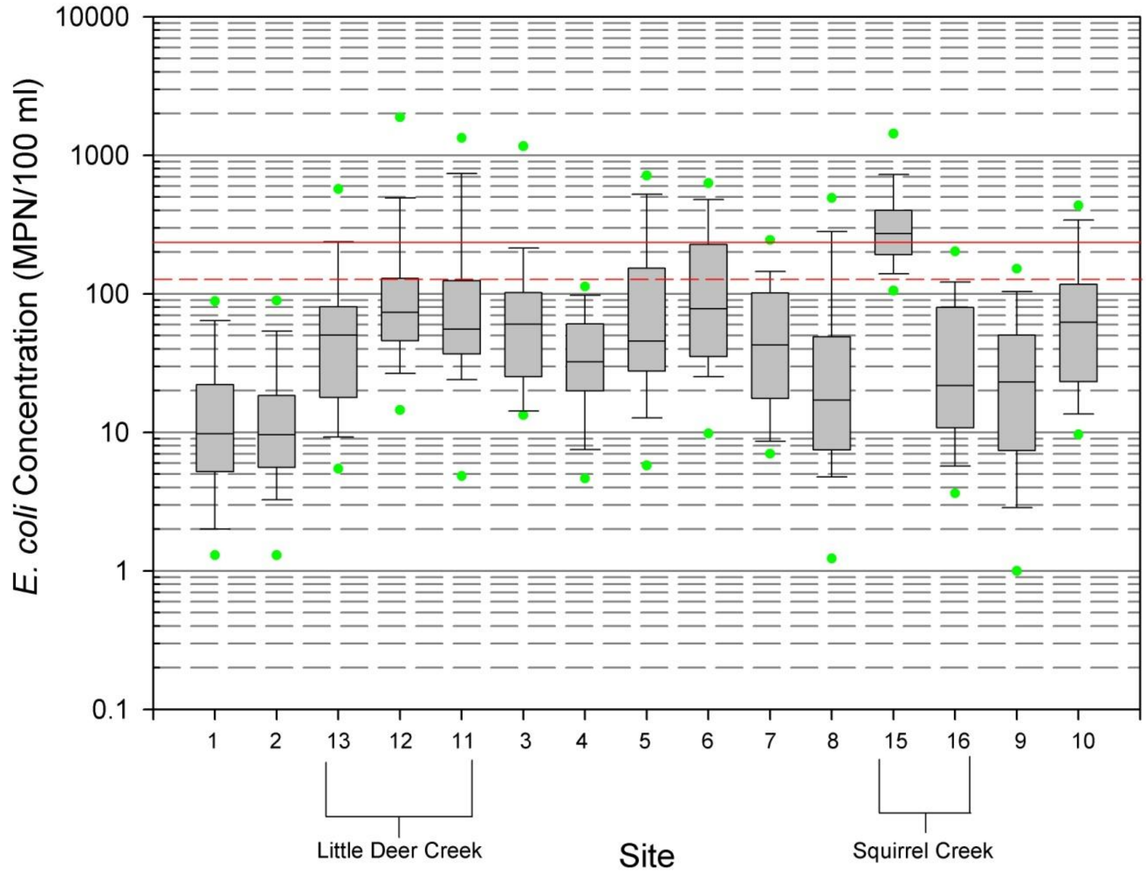


Figure 6.24: *E. coli* concentrations at FODC/SSI monthly monitoring sites during peak recreation season months (May-September) from 2005 – 2009. The red lines represent the USEPA and CVRWQCB recreational standards for freshwater, with the dashed line representing the geometric mean standard (126 MPN/100 ml) and the solid red line the single sample maximum (235 MPN/100 ml).

Figure 6.25 further illustrates the potential health risk associated with recreational activity in Squirrel Creek as site 15 *E. coli* concentrations in the summer exceed the single sample maximum standard in over 60% of the samples collected. The high frequency of exceeding the single sample standard suggests that with more frequent sampling, the geometric mean standard would also be exceeded. At site 15, residents of a local mobile home park make up the majority of recreational users; however a popular public swimming hole located in Western Gateway Park, Penn Valley (**Figure 6.26**) is only 0.85 miles downstream of this site.

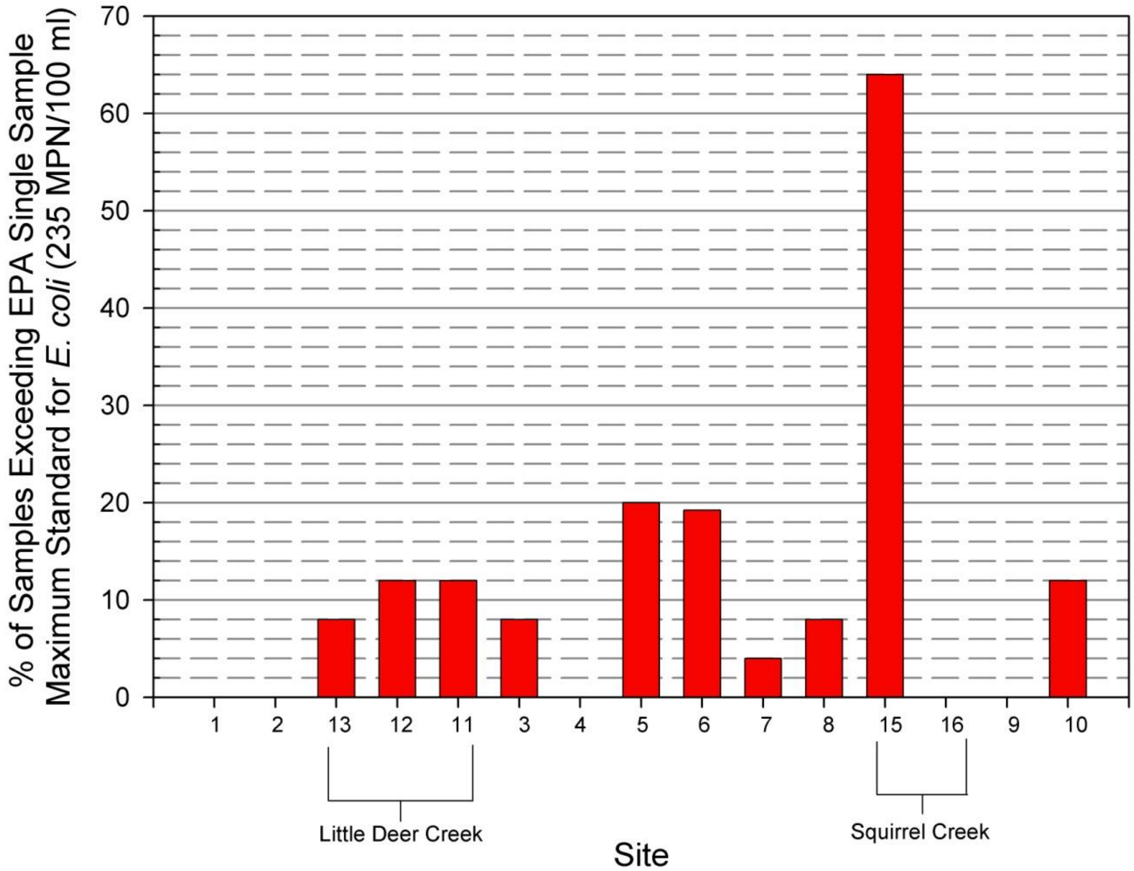


Figure 6.25: Percentage of *E. coli* samples that exceeded the single sample maximum standard at FODC/SSI monitoring sites from May to September 2005-2009. Site 15 on Squirrel Creek exceeds this standard 64% of the time during peak recreation.

Figure 6.26: The swimming hole downstream of the bridge on Squirrel Creek in Western Gateway Park, Penn Valley (8/31/08).

In order to determine if elevated *E. coli* concentrations are also present at Western Gateway Park, extensive sampling was conducted at the swimming hole during the 2008 and 2009 recreation seasons. This included collaborative sampling with the Central Valley Regional Water Quality Control Board (CVRWQCB) and the Nevada County Environmental Health Department (NCEHD). In 2009 FODC/SSI conducted bacteria sampling to capture the geometric mean, which is required to determine if the USEPA and CVRWQCB geometric mean standard is being exceeded. Results for the 2009 geometric mean sampling at Western Gateway Park are included in the appendix (**Figure 6A.10**).

E. coli concentration results at the outlet of the Western Gateway Park swimming hole during 2008 indicate that high *E. coli* concentrations found at site 15 (0.85 miles upstream of Western Gateway Park) persist downstream at the swimming hole in the park (**Figure 6.27**). The results indicate that 33% of the samples from Western Gateway Park exceeded the single sample maximum standard for *E. coli*, compared to approximately 66% at site 15, with over 85% of the sample concentrations exceeding the geometric mean standard. Samples collected at the end of August and early September were a part of a CVRWQCB "Safe-to-Swim" study.

The purpose of the 2008 "Safe-to-Swim" study was to determine if the beneficial use of full contact recreation was being achieved in local swimming holes within the Central Valley during a period of anticipated high use (CVRWQCB 2009d). FODC/SSI staff scientists collaborated with the CVRWQCB to collect duplicate samples on three days surrounding Labor Day weekend. The results of this analysis revealed bacteria contamination problems that plague Squirrel Creek and prompted the CVRWQCB to request FODC/SSI's participation in an additional "Safe-to-Swim" study in June 2009 including capturing the geometric mean.

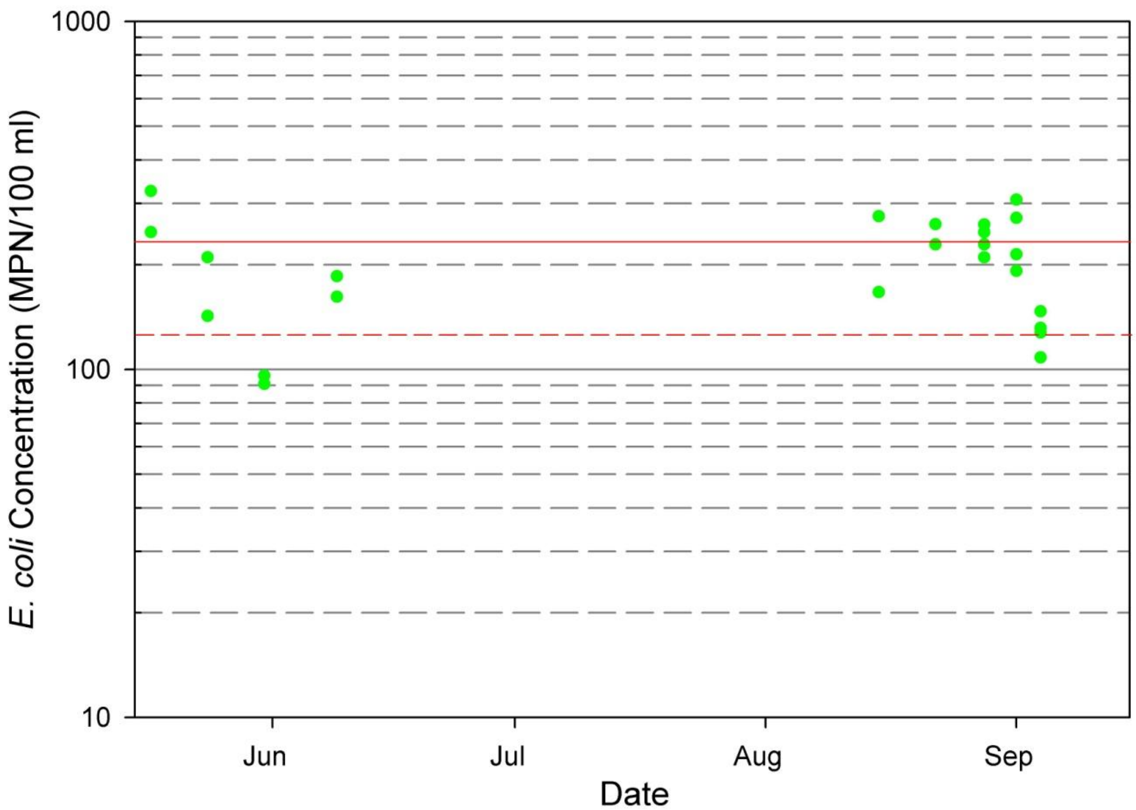


Figure 6.27: *E. coli* concentrations during peak recreation season at the swimming hole in Western Gateway Park in 2008. The red lines represent the USEPA, and CVRWQCB recreational standards for freshwater, with the dashed line representing the geometric mean standard (126 MPN/100 ml) and the solid red line the single sample maximum (235 MPN/100 ml).

The results of the geometric mean sampling indicated that both the single sample maximum and geometric mean standards were being exceeded (**Figure 6.28**). Sampling was conducted immediately upstream and downstream of the swimming hole to see if the swimming hole influenced bacteria concentrations. Both whirlpak and bottle collection methods were used, to see if there was any difference between the two collection methods. The single sample maximum standard was exceeded on four out of five sampling dates (**Figure 6A.10**). The geometric mean standard was exceeded for each sampling method and location, indicating that this swimming hole is not meeting the beneficial use requirements of the CVRWQCB Basin Plan.

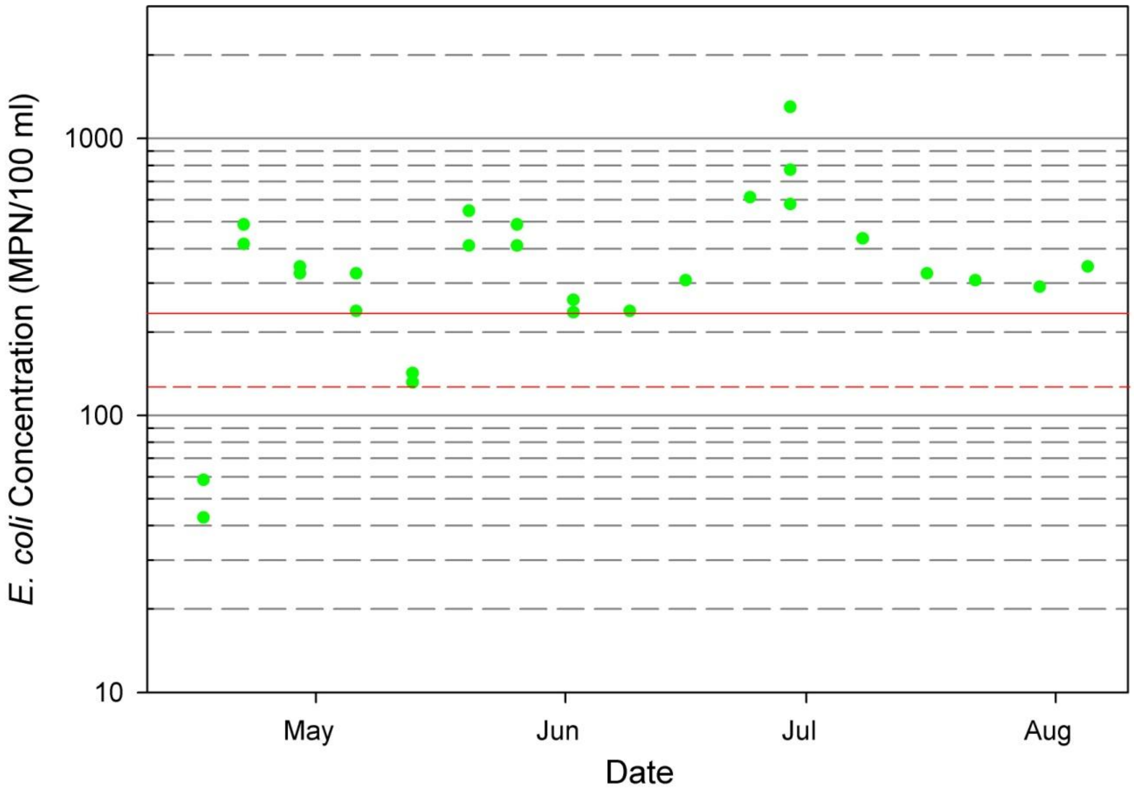


Figure 6.28: *E. coli* concentrations during peak recreation season immediately downstream of the swimming hole in Western Gateway Park in 2009. The red lines represent the USEPA and CVRWQCB recreational standards for freshwater, with the dashed line representing the geometric mean standard (126 MPN/100 ml) and the solid red line the single sample maximum (235 MPN/100 ml).

The purpose of the 2009 "Safe-to-Swim" study was to monitor and evaluate the ambient water quality of four Sacramento River Basin watersheds reporting elevated levels of *E. coli* during the Labor Day 2008 study (CVRWQCB 2010). As part of the June 2009 study, the CVRWQCB collected samples for *E. coli*, *E. coli* O157:H7, *Cryptosporidium*, *Giardia*, *Salmonella*, and numerous other water quality parameters to further investigate the contamination at and upstream of the swimming hole. Since *E. coli* is only an indicator of potential pathogens and does not necessarily identify an immediate health concern, the design of this follow-up study was focused on collecting additional data on pathogen indicators (bacteria) and specific water-borne pathogen concentrations to better assess their impact on the beneficial use of recreation and to identify potential contributors (CVRWQCB 2010). Samples were collected at the swimming hole in Western Gateway Park, Squirrel Creek upstream of the confluence with Clear Creek, and Clear Creek upstream of the confluence with Squirrel Creek.

The results of the 2009 "Safe-to-Swim" study indicated that water quality guidelines were exceeded for *E. coli* and water temperature (**Table 6.7**) (CVRWQCB 2010). There are no water quality guidelines in the Basin Plan for pathogenic *E. coli* O157:H7, *Cryptosporidium*, *Giardia* or *Salmonella* (CVRWQCB 2010). Squirrel Creek upstream of the Clear Creek confluence exhibited the highest *E. coli* concentrations at 1046.2 MPN/100 ml, with Clear

Creek upstream of the Squirrel Creek confluence at 365.4 MPN/100 ml, and Western Gateway Park at 579.4 MPN/100 ml. Squirrel Creek upstream of Clear Creek exhibited the highest *E. coli* concentrations in the entire study, with concentrations over four times greater than the single sample maximum standard. The highest value was measured upstream of the swimming hole, with the swimming hole value close to an average of the two values upstream in Squirrel and Clear Creeks. This suggests that heavy human recreation at the swimming hole is not a major contributor to the elevated *E. coli* concentrations. None of the sites tested positive for pathogenic *E. coli* O157:H7 and there were no measurable amounts of *Giardia* and *Salmonella* at the swimming hole. There was a positive value for *Cryptosporidium* at the swimming hole.

Constituent	Water Quality Guideline	Deer Creek Watershed Sample Sites		
		Squirrel Creek in Western Gateway Park, Penn Valley	Clear Creek above confluence with Squirrel Creek	Squirrel Creek above confluence with Clear Creek
Total Coliform (MPN/100mL)	NA	>2419.6	>2419.6	>2419.6
E. coli (MPN/100 mL)	<235 MPN/100mL (EPA Contact Recreation Guideline)	579.4	365.4	1046.2
E. coli O157:H7 (positive/negative)	NA	negative	negative	negative
Cryptosporidium (oocyst/L)	NA	0.091	No sample taken	No sample taken
Giardia (cyst/L)	NA	0	No sample taken	No sample taken
Salmonella (MPN/100mL)	NA	<2.2	No sample taken	No sample taken
Nitrogen, Total Nitrate-N (mg/L)	≤10 mg/L (Primary Maximum Contaminant Level)[1]	0.19	0.32	0.13
Nitrogen, Total Kjeldahl (mg/L)	NA	<0.50	<0.50	<0.50
Nitrogen, Ammonia-N (mg/L)	NA	<0.20	<0.20	<0.20
Phosphate, Total-P (mg/L)	NA	0.027	<0.020	0.038
Phosphate, Ortho-P (mg/L)	NA	0.0233	0.0148	0.0325
Dissolved Oxygen (mg/L)	≥7 mg/L (Basin Plan Objective)[2]	9.35	9.61	8.7
pH	6.5-8.5 (Basin Plan Objective)[2]	7.95	8.03	7.81
Specific Conductivity (umhos/cm)	≤900 umhos/cm (Secondary Maximum Contaminant Level)[1]	132	201	101
Temperature (° Celsius)	≤20 °C (Basin Plan Objective for Bay-Delta)[2]	21.62	21.16	20.66
Turbidity (ntu)	NA	6.46	2.03	3.92

Shaded cell = Does not meet Water Quality Guideline   1 - Drinking Water   2- Aquatic Life

Table 6.7: Results for the Deer Creek watershed, from the CVRWQCB June 2009 Safe to Swim Study. Values highlighted yellow exceeded the CVRWQCB Basin Plan water quality guidelines.

Bacteria results for the Deer Creek watershed indicated notably high *E. coli* levels in the Squirrel Creek sub-watershed. This is particularly a concern during summer months when recreation in local swimming holes, such as the one at Western Gateway Park, is heavily used. The Nevada County Health department posted signs warning swimmers of the health risk associated with the swimming hole in 2009 and further outreach should be conducted to the public. Upstream sources, such as grazing animals along the creek may be a dominant source of the bacteria influx measured in Squirrel Creek. Identifying types and major sources will be critical in mitigating bacteria contamination in the Deer Creek watershed.

Algae/Periphyton

Benthic algae (periphyton) are a major component in a river system's food web acting as autotrophs that convert the sun's energy into organic molecules through photosynthesis. Because benthic algae are attached to the substrate and are at the beginning of the aquatic food chain, the assemblages present in a particular reach are good indicators of physical, chemical, and biological disturbances that have occurred during the time the algae developed (Barbour et al. 1999). Excessive algae growth can be an indicator of pollution in a river system and is a concern in the managed waterways of California and the Sierra Nevada (SRWP 2010; Fetscher et al. 2009). Algal blooms can negatively affect aquatic communities by disrupting DO levels, fixed carbon production, nutrient cycling, pH, food web structures, and health of fish (SRWP 2010).

Measuring algae density and identifying community structures can help pinpoint ecological stressors such as nutrient loading, elevated water temperatures, land disturbances, and more (SRWP 2010). Disturbances, modifications, and development, such as riparian zone degradation, altered or diverted flows, land uses (e.g. agricultural and urban), and presence of a wastewater treatment plant can result in nutrient loading and elevated water temperatures which in turn promote algal growth in streams. On the opposite end of the spectrum, an uncommonly low abundance of algal biomass may indicate toxic conditions in a river system although this could also be due to other factors such as a storm event or heavy grazing (Barbour et al. 1999).

FODC/SSI has been sampling algae during the summer (primarily June through September) in the Deer Creek watershed since 2003 following the targeted riffle approach outlined in the stream periphyton monitoring manual (Biggs and Kilroy 2000) at 5 sites (2, 4, 8, 9, 16). FODC/SSI transitioned to the SWAMP reach-wide benthos (RWB) method described by Fetscher et al. (2009) and expanded its sampling in 2010. This new protocol couples algae and BMI sampling to provide a more robust and comparable dataset for determining ecological conditions at FODC/SSI monitoring sites. Monthly summer algae sampling expanded from 5 to 11 sites (2, 4, 6, 8, 9, 10, 11, 13, 15, 16, 17). Data included in this report include algae samples collected from 2003 through 2009 at sites 2, 4, 8, 9, and 16 (Squirrel Creek) following the Biggs and Kilroy (2000) protocol. FODC/SSI analyzes ash free dry mass (AFDM) for algae samples.

Algae data collected from 2003 through 2009 indicate algae growth is significant at sites 8 and 9 below the Lake Wildwood reservoir (**Figure 6.29**). The highest AFDM values are located at site 8, located downstream of the Lake Wildwood reservoir and wastewater treatment plant. Site 9, located downstream of site 8 and the confluence of Squirrel Creek has similar AFDM results. Visual inspections during sampling confirm these results, with the monitoring sites on lower Deer Creek, especially sites 8 and 9, having a higher density of algae cover on substrate than sites situated above the Lake Wildwood reservoir.

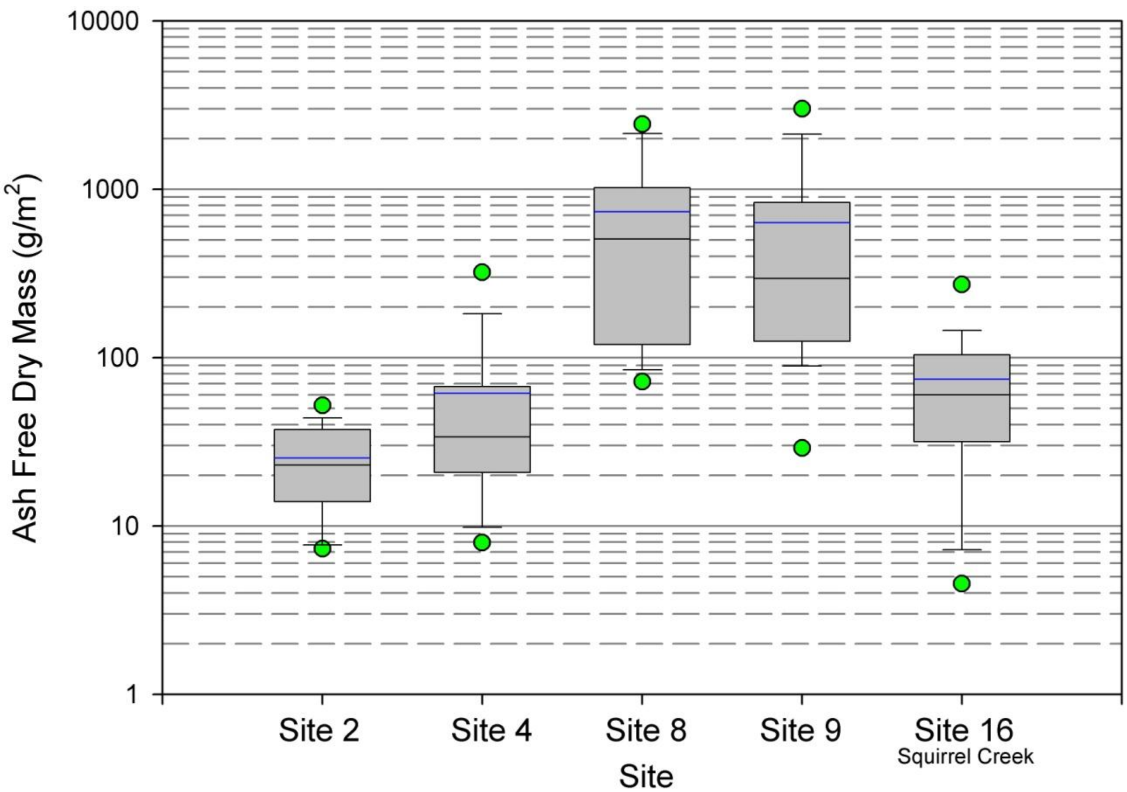


Figure 6.29: 2003-2009 Ash free dry mass (AFDM) results of FODC/SSI monitoring sites in the Deer Creek watershed. Elevated algal growth is evident in lower Deer Creek at sites 8 and 9.

Monthly algae AFDM data indicate that algal growth peaks mid to late summer (July-September) and further illustrate elevated algae growth at sites 8 and 9 below the Lake Wildwood reservoir in comparison to upstream sites (**Figure 6.30**). In the SRBRC, Deer Creek received a periphyton score of 5/100, the lowest score in the study (SRWP 2010). Based on the AFDM ranges set by the SRBRC (>100g/m^2 = 0), sites 8 and 9 on lower Deer Creek would receive a score of zero while sites 2 and 4 scores approach scores of 100 (20gm^2) as AFDM results are closer to naturally occurring levels at these upper watershed sites.

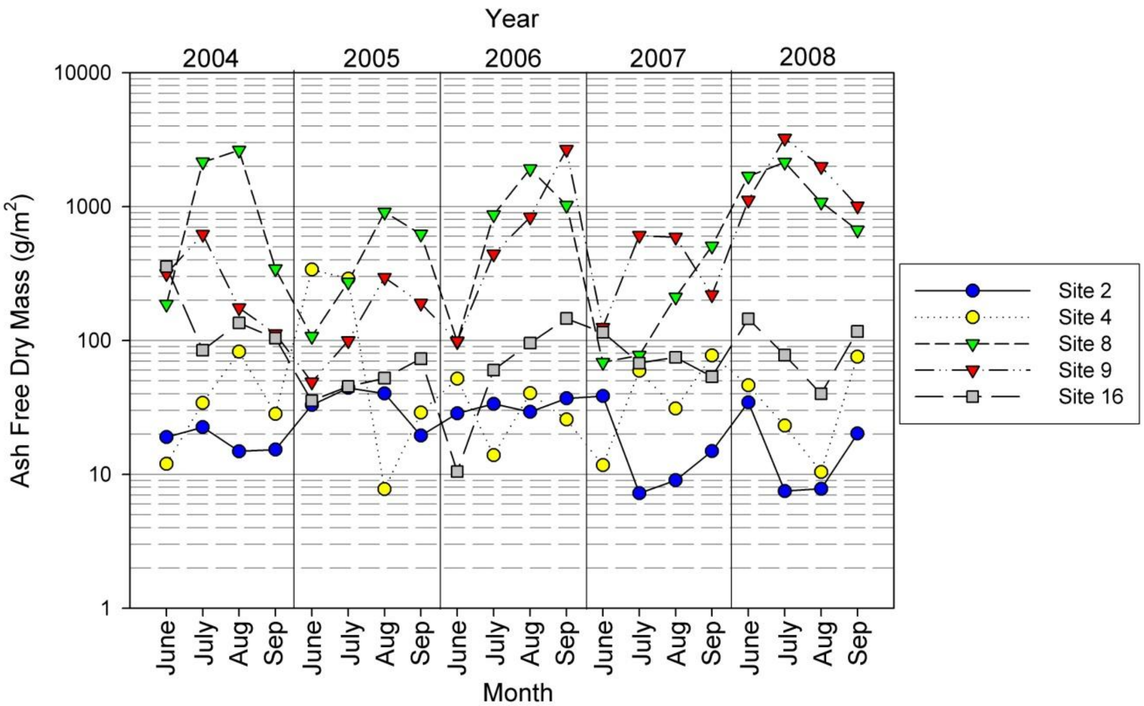


Figure 6.30: 2004-2008 monthly summer AFDM results for FODC/SSI monitoring sites in the Deer Creek watershed. Excessive algae growth at sites 8 and 9 in the mid to late summer is evident. 2003 and 2009 data were not incorporated because they did not include the entire summer.

FODC/SSI AFDM data indicate excessive algae growth is most significant at sites 8 and 9 in lower Deer Creek which is likely influenced by elevated water temperatures and nutrient loading below the Lake Wildwood reservoir and wastewater treatment plant. In addition to AFDM analysis, development of an identification program for algae species present at these sites and throughout the Deer Creek watershed would provide better insight into environmental stressors, native and non-native algae species, impaired sites, best restoration actions, and aid in monitoring the effectiveness of restoration efforts.

Benthic Macroinvertebrates (BMI)

Benthic macroinvertebrates (BMI) are excellent biological indicators of ecological condition and function. They are widespread in river systems, they are long-lived, relatively sedentary, low on the food chain, and some are highly sensitive to pollution. These characteristics make BMI ideal 'bio-sentinels' for assessing stream health as they can reflect long- and short-term effects of activities within the watershed and specific reaches. Besides being useful biological indicators of chemical, physical, and biological water quality conditions, BMI are an integral part of the food web for fish, amphibians, reptiles, and birds.

According to the River Continuum Concept, BMI assemblages found in a river system will vary naturally from the headwaters to its downstream extent based on factors such as water temperature, stream gradient, and the physical characteristics of the stream such as stream substrate (Vannote et al. 1980; Karr and Dudley 1981). For example, a steep, narrow gradient channel characterizes headwaters with few scrapers due to limited algal growth (Vannote et al. 1980). Additionally, a richer riparian zone coupled with a narrow channel results in a more steady supply of coarse particulate organic matter (CPOM) resulting in prominent shredder populations with collector assemblages also present (Vannote et al. 1980; Karr and Dudley 1981). Further downstream, stream-size typically increases, stream gradient becomes more moderate, and canopy cover becomes more open which promotes increased algal growth and shifts energy input to fine particulate organic matter (FPOM). Consequently, BMI assemblages will shift from shredders to more collector and grazer communities to almost exclusively collectors in the lower reaches (Vannote et al. 1980; Karr and Dudley 1981). Anthropogenic disturbances, such as channel modification, flow alteration, riparian vegetation degradation, and pollution will affect this natural variability of BMI assemblages.

Ideally, a watershed will have a rich and diverse BMI framework that reflects natural physical and chemical conditions and maintains ecological stability. To determine the condition of BMI communities, an array of metrics (e.g. taxa richness, EPT index, functional feeding group indices, tolerant/intolerant indices, etc.) can be examined. The best metrics are those that are responsive to anthropogenic stressor gradients and/or those that discriminate between natural ("reference") and disturbed sites (Ode and Rehn 2005). These metrics can then be integrated to develop an index of biotic integrity (IBI) for a region to further characterize its ecological condition and areas of improvement. An IBI for BMI in the Deer Creek watershed or for the Western Sierra has not been developed. An IBI for BMI has been developed for the Eastern Sierra (Herbst and Silldorff 2009) and in streams below hydropower dams on the west slope of the Sierra Nevada (Rehn 2008). An IBI has also been developed for fish and frogs in the Sierra (Moyle et al. 1986). Additionally, the SWRCB is currently in the process of developing quantitative biological objectives for California streams. The development of an IBI for BMI is a high priority in the Deer Creek watershed and regional Sierra foothill watersheds.

FODC/SSI has been collecting BMI samples at 7 sites (1, 2, 4, 6, 8, 9, 10) in the Deer Creek watershed since November of 2000 with most sampling conducted biannually in June and October. Sites 11-13 on Little Deer Creek were added in June 2001. Site 15 on Squirrel Creek was added in October 2001 and site 16 was added in October 2004. Data included in this report spans from 2000-2009 and followed the targeted riffle composite (TRC) sampling following CSBP and SWAMP protocols (CSBP 1999; Ode 2007). To integrate algae sampling with BMI sampling for a more robust bio-assessment, FODC/SSI began employing the reach-wide benthos (RWB) in 2010 (Ode 2007). October 2009 and 2010 data are in the review process and therefore are not included in this report. Benthic macroinvertebrate samples are identified to the family level by trained staff and volunteers in the FODC/SSI BMI laboratory.

A variety of BMI metrics indicate that ecological conditions decline from the headwaters to the lower reaches of Deer Creek (**Figures 6.31, 6.32, 6.35**). Taxa richness (**Figure 6.31**) represents the BMI diversity within a reach and is a key metric in BMI data analysis (Ode and Rehn 2005). It is an index of the general health of the BMI community and is expected to be high in reaches with adequate stream conditions (e.g. habitat diversity and water quality) (SWRP 2010). Taxa richness is greatest at sites 1 and 2, Little Deer Creek, and Squirrel Creek. Taxa richness is lowest at site 8 below the Lake Wildwood reservoir and Lake Wildwood WWTP. Lower index values are also seen at Site 4 below the Nevada City WWTP and at Site 10, the most downstream monitoring site on Deer Creek (0.5 miles above the confluence with the South Yuba). Although taxa richness is a useful metric in BMI data analysis to determine overall reach health, evaluating more specific assemblages is a better method of determining stressors that limit BMI diversity.

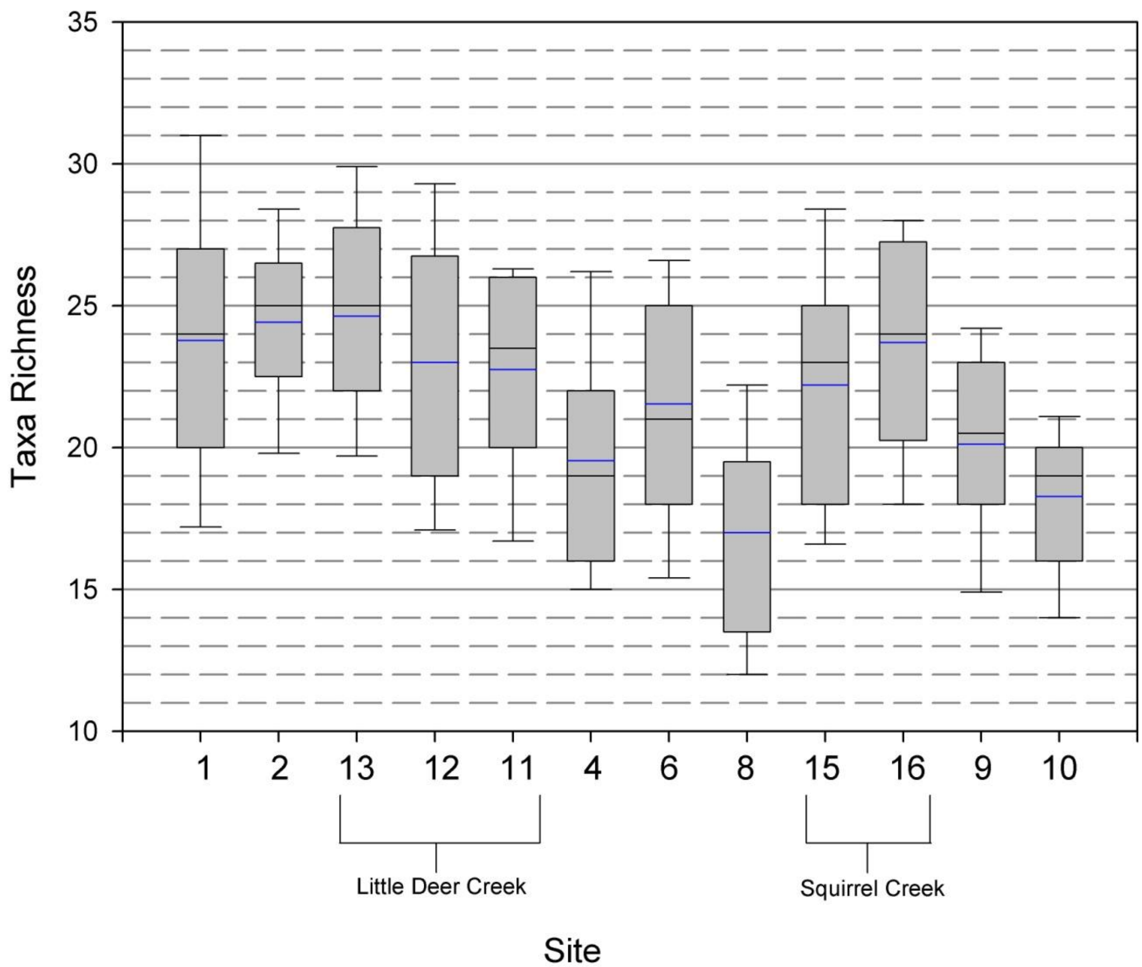


Figure 6.31: 2000-2009 Taxa richness metric results for FODC/SSI BMI data in the Deer Creek watershed.

Examination of functional feeding groups can help identify impaired reaches in a river because an imbalance in these groups may indicate unstable food dynamics caused by stressed conditions (Barbour et al. 1999). Specialized feeders (e.g. shredders) are the more sensitive organisms and their presence typically represents a healthy river system. Generalist feeders (e.g. collectors) have a broader range of acceptable food materials and therefore are considered more tolerant to stressful conditions that may alter the availability of certain food (Barbour et al. 1999). Evaluation of functional feeding groups in the Deer Creek watershed, specifically shredders and collectors (**Figures 6.32** and **6.33**), reveals an inverse correlation, with the abundance of shredders decreasing and collectors increasing downstream.

This trend has been noted in other studies (Vannote et al. 1980; Karr and Dudley 1981) and is a function of numerous factors including stream-size, type and abundance of riparian vegetation, food materials available (e.g. CPOM versus FPOM), and stressors. In the upper reaches of Deer Creek (e.g. site 1), a lush riparian zone readily supplies the river with CPOM, shading, and complex habitat. Downstream, as the river increases in size so does human influence on the landscape, resulting in narrower riparian zones. This results in a shift to collector BMI communities that utilize FPOM from upstream as their primary energy source. In the main stem of Deer Creek below the Lake Wildwood reservoir, there are virtually no shredder BMI communities, and collectors dominate reaches. Although this is a common trend moving downstream in a river (Vannote et al. 1980), the almost complete lack of shredders in the main stem of lower Deer Creek likely signifies impairment.

The highest shredder index is seen at site 13 in the upper reach of Little Deer Creek where there is a copious supply of CPOM for BMI communities. Shredders drastically decrease as Little Deer Creek flows through Pioneer Park (channelized, very thin riparian zone, and heavy human use), and downstream where it drains into Deer Creek.

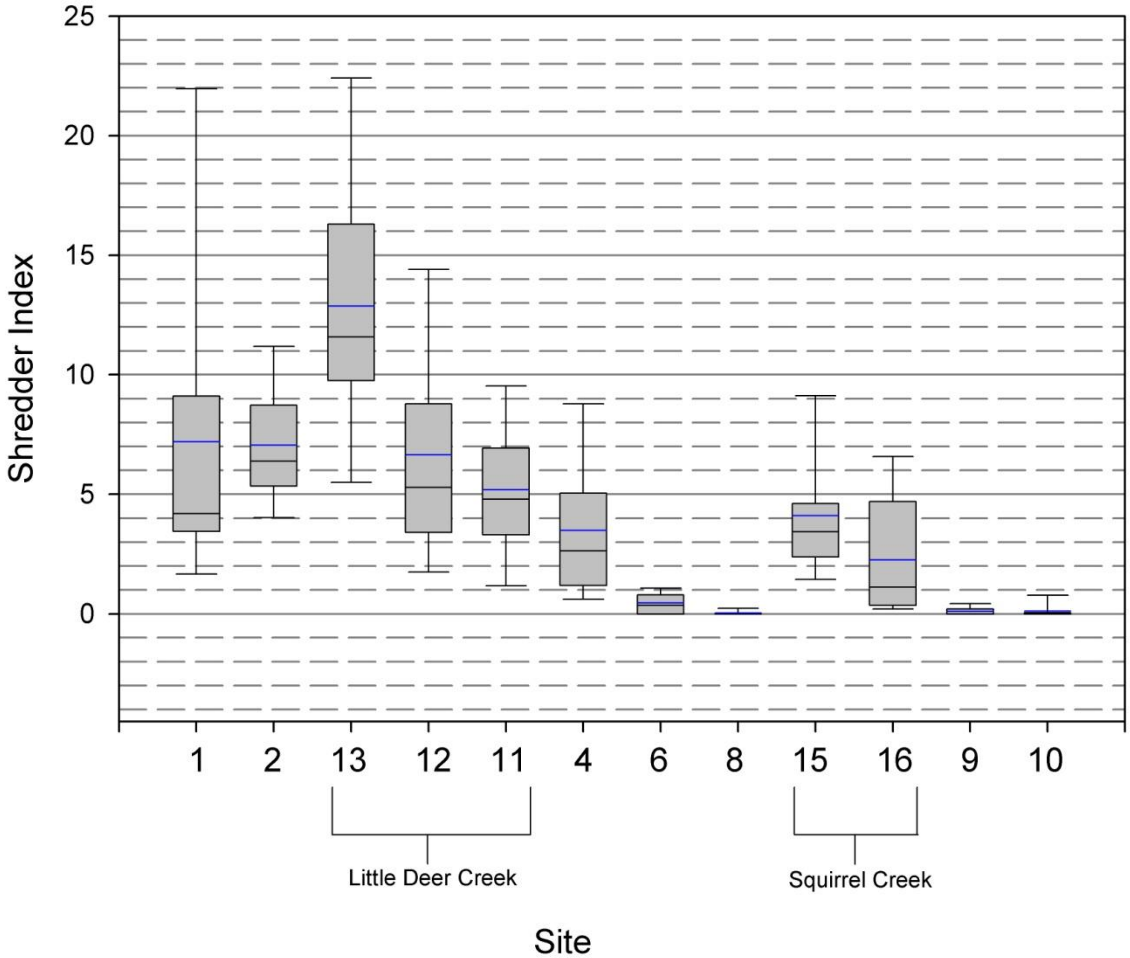


Figure 6.32: 2000-2009 Shredder index metric results for FODC/SSI BMI data in the Deer Creek watershed.

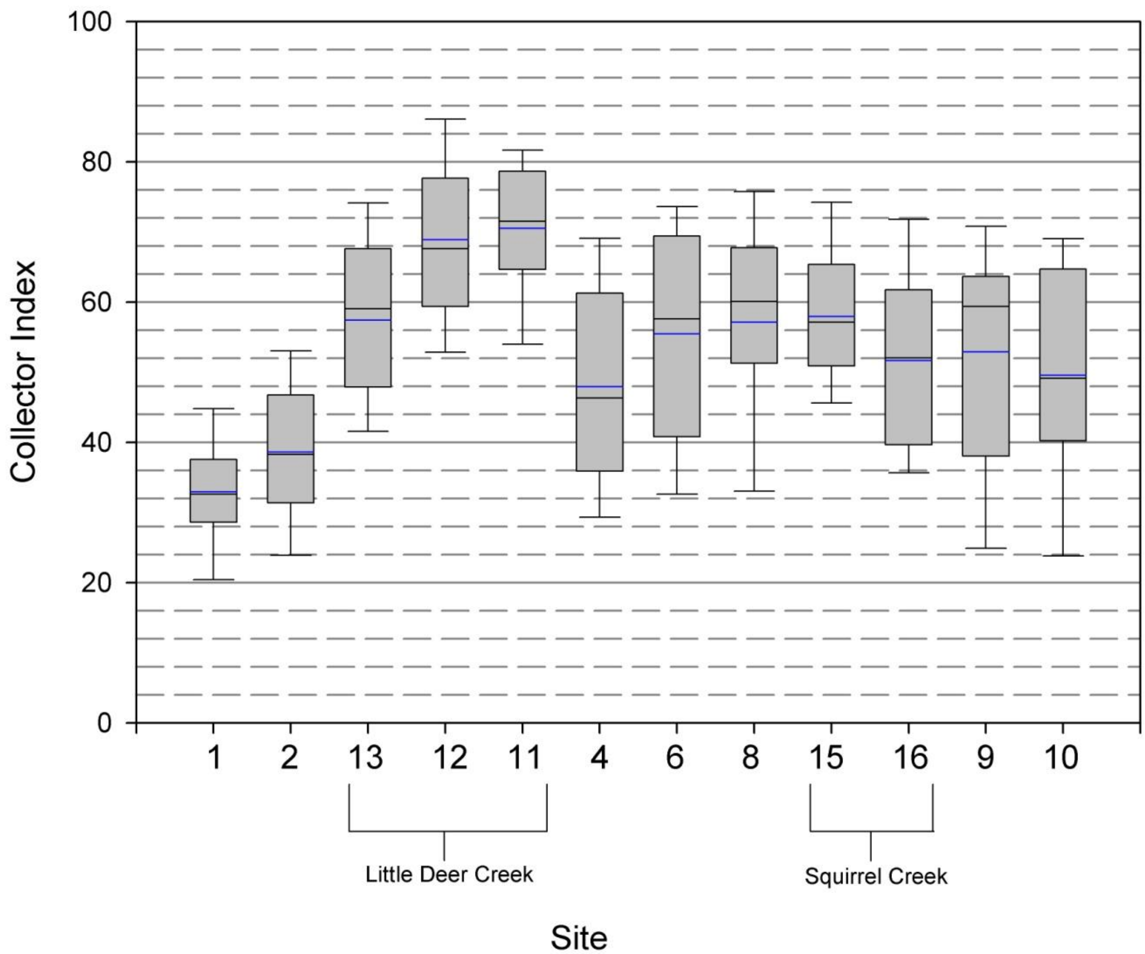


Figure 6.33: 2000-2009 Collector index metric results for FODC/SSI BMI data in the Deer Creek watershed.

Analysis of tolerant and intolerant measures can further characterize the ecological condition of Deer Creek as the metric is representative of the relative sensitivity to perturbation of the BMI communities present in a reach. Results for the tolerant index (**Figure 6.34**) suggest that water quality decreases downstream, indicated by the increase in more tolerant BMI assemblages. Accordingly, an inverse trend is seen with sensitive EPT communities that decrease downstream (**Figure 6.35**). The highest tolerant index values are located in the two lower reaches of Little Deer Creek and in lower Deer Creek. Not surprisingly, these sites also have lowest sensitive EPT index values.

The SRWP (2010) evaluated BMI assemblages based on total taxa richness and EPT taxa richness. Scores were based on the most taxa-rich site (reference site) in the database. The Deer Creek watershed scored low in both categories with a 36/100 in total taxa richness and 0/100 for EPT richness suggesting that restoration efforts are needed to improve biotic conditions in the watershed.

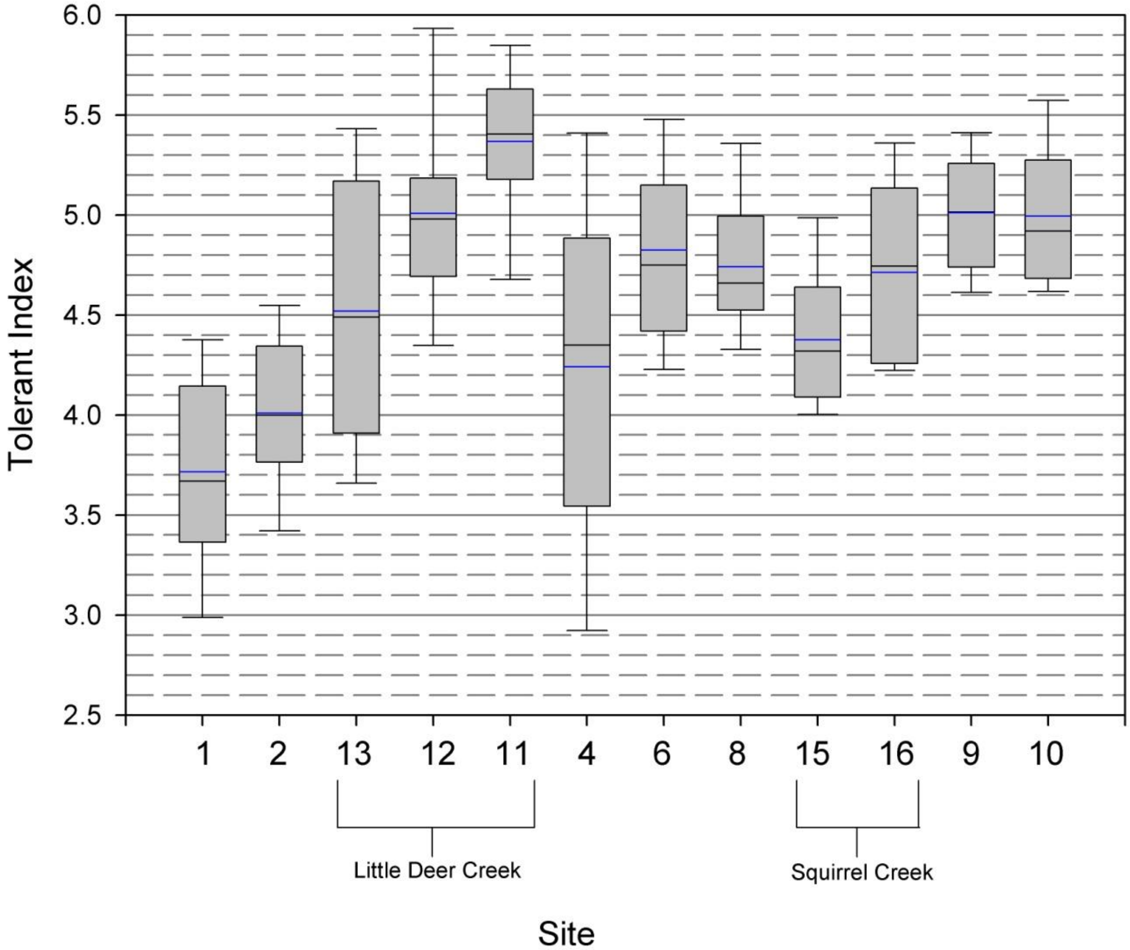


Figure 6.34: 2000-2009 Tolerant index metric results for FODC/SSI BMI data in the Deer Creek watershed.

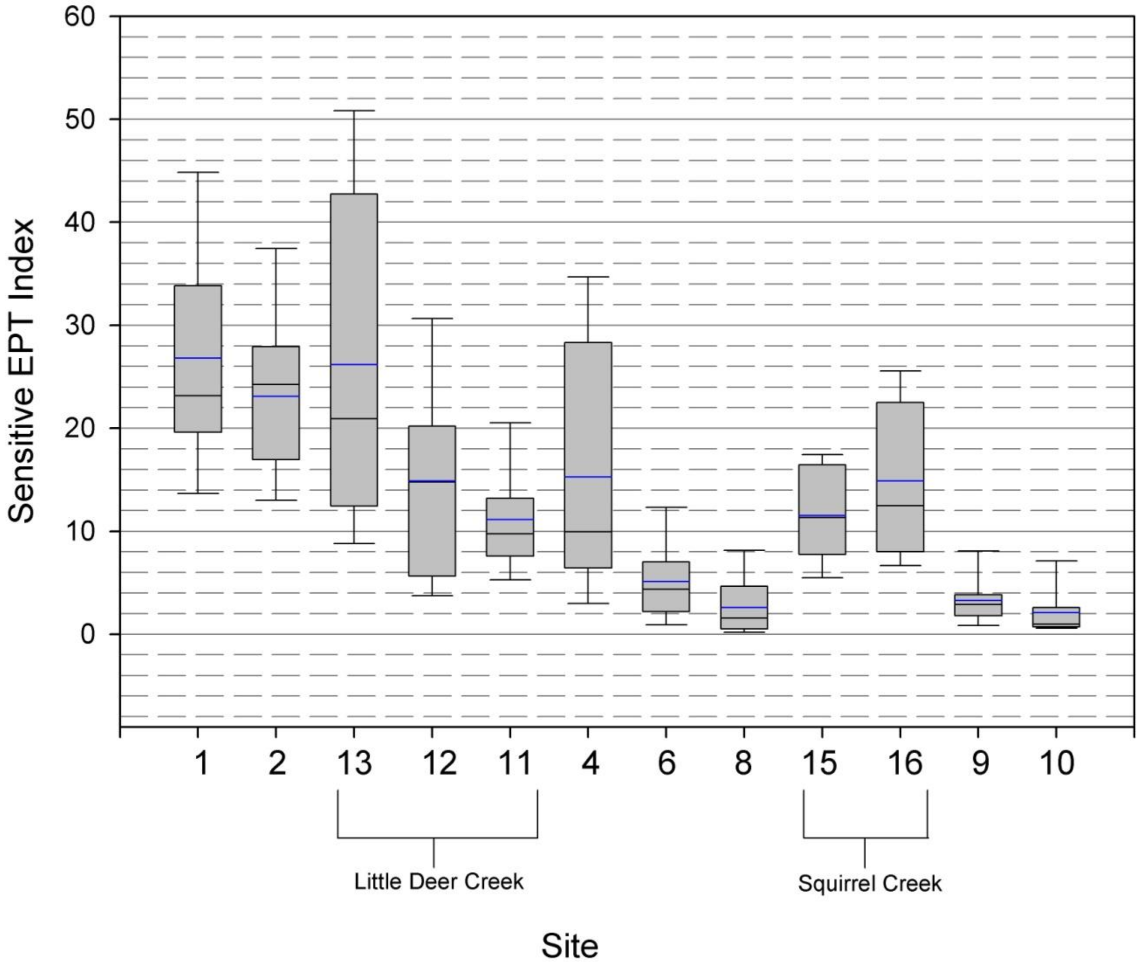


Figure 6.35: 2000-2009 Sensitive EPT index metric results for FODC/SSI BMI data in the Deer Creek watershed.

FODC/SSI data indicate that BMI communities are stressed in reaches through the watershed. The analysis of stream reach data included in this section would be improved by looking at data from reference sites that are relatively undisturbed. The reference sites are currently being chosen by studies done by collaborating state scientists (Andy Rehn, personal communication) and will be a useful tool in future analyses in the Deer Creek watershed. Many of these metrics will be integrated into a single scoring criterion, an Index of Biotic Integrity (IBI) that is a composite score that combines the normalized values of separate measures of community composition, tolerance, and function. This creates a simplified system for assessing biological integrity by comparison to the range of IBI values that are found in reference streams (Stoddard et al. 2006).

Fish

Historically, the Deer Creek watershed provided habitat to numerous fish species including anadromous fish (Yoshiyama et al. 1996). Chinook salmon and steelhead runs in a quarter mile stretch of Deer Creek upstream of its confluence with the Yuba River during the fall and winter months were an important resource that helped sustain life for the native peoples of this region. Thompson and West (1880) reported that salmon, brook trout, lake trout, perch, white fish, sucker, chub, and eels were present in Nevada County at the time of the influx of gold miners. Freshwater species native to Deer Creek include the Sacramento sucker, Sacramento pike-minnow, and rainbow trout. The Department of Fish and Game periodically stocks Deer Creek with fish, and fish stocking has occurred in Scotts Flat reservoir as recently as 2010. At present there are numerous non-native fish species in Deer Creek. FODC/SSI, in collaboration with UC Davis scientists, conducted electro-shocking fish surveys in the Deer Creek watershed during the summer of 2007 and 2008. Data included fish species counts, length, volume, electro-shocking time, water temperature, and stream flow. These data have provided FODC/SSI with insight into what types of fish currently inhabit Deer Creek and its major tributaries.

Currently, fish species downstream of Lake Wildwood Reservoir in Deer Creek during the summer months are characterized by native and non-native warm water species, including Sacramento sucker, redear sunfish, white catfish, Sacramento pike-minnow, spotted bass, and smallmouth bass. Sacramento sucker and Sacramento pike-minnow are native to the Sierra Nevada while redear sunfish, white catfish, smallmouth bass, largemouth bass, and spotted bass are non-native and were introduced to the region. These generally warm water species are also common, along with largemouth bass, in and upstream of Lake Wildwood as far as Deer Creek Falls. Fish shocking data suggest that Deer Creek Falls, a set of steep waterfalls, could serve as a boundary between warm and cold-water fish species. Warm water species were not observed upstream of this location in Deer Creek or its tributaries during the 2007 and 2008 surveys. Although the warm water fish species have not been observed on the main stem of Deer Creek or its tributaries upstream of Deer Creek Falls, warm water species including smallmouth bass, largemouth bass, bluegill, channel and brown bullhead catfish can be caught in Scotts Flat reservoir as a result of fish stocking.

Upstream of Deer Creek Falls, fish shocking data indicate that rainbow and brown trout are the two dominant species in Deer Creek and its tributaries, with redear sunfish present in some locations. Rainbow trout are native to the Sierra Nevada and brown trout are non-native, introduced to California from Europe in the 1890s. During summer months the main stem of Deer Creek is used by NID as a canal, and flow consists of cold snowmelt water from Scotts Flat reservoir, which makes water temperatures in sections of Deer Creek conducive for rainbow and brown trout. More and more of the cold irrigation water is removed from Deer Creek moving downstream from Scotts Flat reservoir, with the majority of the cold water removed at or upstream of Lake Wildwood. This leads to warmer temperatures in lower Deer Creek that are not conducive to trout.

In 2007, FODC/SSI staff observed three native fish taxa and six non-native taxa, and three native fish taxa and four non-native taxa in 2008 (Data included in Appendix). Further electro-shocking efforts should target the same reaches as in 2007 and 2008, while trying to incorporate stretches of major tributary creeks, including Squirrel and Clear Creek in Penn Valley, Gold Run Creek, Little Deer Creek, Mosquito Creek, and Willow Valley Creek in and around Nevada City, and upstream Scotts Flat Reservoir on the main stem, north, and south forks of Deer Creek. It is important to note that electro-shocking data is collected upstream of the spawning grounds for Chinook salmon and steelhead, which is one reason they are not represented in the data. A quarter mile stretch of Deer Creek from the confluence with the Yuba River, upstream to a point below a steep waterfall known as "Salmon Circle," is utilized by these fish from late fall through spring.

The mouth of Deer Creek was once an exceptionally rich salmon and steelhead habitat for the Yuba River (Yoshiyama et al. 1996). Salmon and steelhead were present on Deer Creek and Squirrel Creek, a tributary of Deer Creek, in large numbers in the early part of the 20th century (Yoshiyama et al. 1996) . Steelhead were observed in the 1960's in the first quarter mile of Deer Creek, until the impassible falls, and salmon were observed in large numbers in the 1920's (Yoshiyama et al. 1996). Lake Wildwood reservoir dam on Deer Creek, constructed in 1970, blocks the downstream movement of gravel that is essential for fish spawning habitat, and causes severe impacts to all elements of Deer Creek's riverine function.

In 2004, The Fishery Foundation of California (FFC) monitored Chinook salmon in Deer Creek to evaluate the impacts of the periodic Lake Wildwood reservoir dewatering (**Table 6.8**) (FFC 2004).

Period	Date	Flow (cfs)	Live	Dead	Redds Observed
Pre drawdown	10/6/03	6	28	3	6
	10/10/03	4	3	7	7
Drawdown	10/17/03	220	8	0	7
	10/22/03	37	43	3	7
Post drawdown	10/24/03	19	36	11	8
	10/28/03	10	37	10	
	11/6/03	5	22	4	9

Table 6.8: Number of salmon and redds observed in surveys of lower Deer Creek, conducted by the Fishery Foundation of California.

The data indicate that fall-run Chinook salmon and up to 9 redds were observed in lower Deer Creek in 2003 (**Table 6.8**) (FFC 2004). In this survey the dewatering release attracted greater numbers of salmon into lower Deer Creek, and the subsequent decrease in stream flow did not result in fish stranding, with pools remaining sufficiently watered after the drawdown ended (FFC 2004); however, stranded fish and redds have been observed by FODC/SSI staff during dewatering events as well. In 2010, a year with no dewatering release, FODC/SSI staff observed between 50-60 Chinook salmon in Deer Creek after a large October rainfall event; however, no formal redd survey or salmon count was performed.

Very few locations in the quarter mile spawning reach appeared to exhibit conditions conducive for successful spawning, with much of the reach lacking an appropriate substrate size distribution for spawning and a general lack of in-stream habitat due to large boulders or exposed bedrock. One female salmon was observed actively spawning in one of the few locations that appeared to provide appropriate conditions. This indicates that Chinook salmon are still present and spawning in Deer Creek and would potentially benefit from in-stream work, such as gravel augmentation or spawning bed enhancement. The last tributary on the Yuba River before the impassible Englebright Dam, Deer Creek is likely a critical spawning area.

Additional Vertebrates: Birds, Mammals, Reptiles, and Amphibians

Due to its elevation, gradient, and diversity of vegetation types, Nevada County hosts over 400 vertebrate species including 336 native vertebrates, 45 introduced species, and 52 extremely rare species (Beedy and Brussard 2002).

<u>Birds</u>

Birds are the most diverse vertebrate group with 55 families represented in Nevada County. This includes 212 regular occurring species and 43 extremely rare and/or irregularly occurring species (Beedy and Brussard 2002). Introduced species include ring-necked pheasant, wild turkey, rock dove (domestic pigeon), European starling, and house sparrow.

FODC/SSI conducted bird surveys in the upper Deer Creek watershed in 2008 and 2010 with bird surveyors including members of the Audubon Society who used the Point Reyes Bird Observatory point count protocols. Results from the upper Deer Creek restoration one year bird study revealed approximately 26 species in a woodland area above the creek, 10 species in a remote riparian area, and 12 species in an urban riparian area. More studies need to be conducted in subsequent years for baseline data and to assess the health of restored areas.

Birds are an important indicator of biodiversity as changes in species richness or dominance may reflect shifts and disturbances in the terrestrial ecosystem of a watershed (SRWP 2010). Habitat disturbances such as deforestation, agriculture, and development can adversely affect species richness and diversity as well as increase stress on already threatened species. Ideal conditions are a stable or increasing trend in species richness (SRWP 2010). Bird data for the Deer Creek watershed were not sufficient to score in the SRBRC (SRWP 2010) indicating a need for more bird data in the Deer Creek watershed, particularly population and community indices that can be used to understand bird/habitat relationships and to identify species suitable for monitoring.

In Nevada County, Bald Eagle, Swainson's Hawk, American Peregrine Falcon, California Black Rail, Sandhill Crane, Great Gray Owl, Bank Swallow, and Willow Flycatcher are listed as either threatened, endangered, or candidates under the federal or state Endangered Species Acts (Beedy and Brussard 2002). Of these bird species, Swainson's Hawk, Great Gray Owl, and Bank Swallow have only been recorded occasionally and no nests reported in Nevada County (Beedy and Brussard 2002). A pair of Yellow Breasted Chats- a California Species of Special Concern (CDFG 1998)- were observed in the 2008 bird counts in the Deer Creek watershed.

The Sierra Nevada Ecosystem Project (UC 1996) reports that of the 15 well established, non-native terrestrial vertebrate species in the Sierra Nevada, the brown-headed cowbird, which is found in Nevada County, has had the most serious effects on native species. Cowbirds are social parasites that lay eggs in the nests of other birds, abandoning their young to be raised by foster parents usually at the expense of some of the host's own chicks. Cowbirds are associated with the decline of several songbirds in the Sierra Nevada including the Willow Flycatcher, Bell's Vireo, Yellow Warbler, Chipping Sparrow, and Song Sparrow, as well as others (UC 1996). Additionally, European starlings and house sparrows, which are also non-native, are abundant in the Sierra foothills and compete with native birds for nesting sites.

Mammals

The second most diverse vertebrate group in Nevada County is mammals, represented by 23 families including 74 native species, 4 extremely rare species, and 6 non-native species (Beedy and Brussard 2002). Non-native mammals include Virginia opossum, muskrat, black rat, Norway rat, house mouse, and wild pig (Beedy and Brussard 2002). The Sierra Nevada Ecosystem Project (SNEP; UC 1996) reports that wild pigs are increasing in the Sierra Foothills, where they compete with native species for food, destroy herbaceous vegetation, and root extensively. In the Sierra Nevada, smaller mammal species are more dominant in abundance including 7 shrews, 17 bats, 7 rabbits, and 56 rodents (UC 1996). Larger mammals in the Sierra Nevada include red fox, fisher, marten, and wolverine. Of these species, marten continue to occupy their historic range (UC 1996). Sierra Nevada red fox and California wolverine are reported to occur in Nevada County, although sightings are extremely rare, and the species are listed as threatened, endangered, or candidates under the federal or state Endangered Species Acts (Beedy and Brussard 2002). FODC/SSI has not conducted any major mammal assessments in the Deer Creek watershed.

<u>Reptiles</u>

Reptiles in Nevada County include 8 families with 21 native species and currently no introduced species (Beedy and Brussard 2002). Reptile species are found in all of the aquatic and terrestrial large-patch ecosystems in Nevada County (Beedy and Brussard 2002). In the Sierra Nevada region, 4 of the 32 native reptile species are at risk, namely the western pond turtle, blunt-nosed leopard lizard, California horned lizard, and California legless lizard (UC 1996). These species are only marginally found in the western Sierra foothills except for the western pond turtle that is more common. Habitat alteration is the largest cause for species decline (UC 1996). Unfortunately, little information and data are available regarding truly montane reptile species such as the western rattlesnake and western terrestrial garter snake; therefore, their status is largely anecdotal (UC 1996). FODC/SSI has not performed any extensive reptile surveys in the watershed.

<u>Amphibians</u>

There are seven families of amphibians in Nevada County including nine native species and one non-native, introduced species (bullfrog) (Beedy and Brussard 2002). Amphibians have suffered sharp declines throughout the Sierra Nevada in terms of abundance, distribution, and diversity. Half of the native species found in the Sierra Nevada are at risk of extinction including 8 species of salamanders and 7 species of frogs and toads (UC 1996). Frog populations have declined substantially in all habitats across the Sierra Nevada from alpine lakes to foothill streams. Presently many populations are limited to small foothill streams that have dense canopy cover, few introduced species, and scarce human influence, and to high elevation fishless lakes and streams in remote areas (UC 1996).

In contrast, bullfrog populations have increased prolifically and have completely replaced native red-legged frog and foothill yellow-legged frog populations in many areas of the Sierra Nevada. Bullfrogs not only out-compete native frog species for available resources, but they also prey on western pond turtles and other aquatic and riparian wildlife species (UC 1996). Countless bullfrog tadpoles are seen every year at Sites 8 and 9 in lower Deer Creek. Once widespread in connected corridors, amphibians (especially frogs) are now found in isolated groups that are highly vulnerable. Habitat fragmentation and deterioration as well as predation and competition from introduced species are some of the major stressors imposed on these species. FODC/SSI has not performed any major amphibian assessments in the Deer Creek watershed.

C. River Ecology Discussion

Independent analysis of the chemical, physical, and biological conditions in the Deer Creek watershed is an important component in an ecological assessment; however, these parameters are not independent. Evaluating the health of a watershed requires an integrated approach incorporating these essential watershed attributes as they constantly interact with one another. Moreover, assessing the severity and locations of impacts on biotic communities caused by impaired chemical, physical, and biological conditions in a river is of highest importance. Stoddard et al. (2005) points out that "…it has become obvious that the primary ecological concern is the actual condition of plant and animal communities that inhabit the streams and rivers." Supplementary measurements of stream characteristics, such as physical, chemical, and other biological factors that influence or affect stream conditions, assist in determining ecological conditions by prioritizing impaired sites and identifying possible stressors.

Reviewing FODC/SSI data in the Deer Creek watershed provides clarification to some of the major stressors that are affecting the ecological integrity of the watershed and assist in identifying heavily impacted stream reaches that have future assessment and restoration priorities. Major stressors investigated in this chapter affecting the Deer Creek watershed include nutrient loading, heavy metal contamination, riparian vegetation disturbances, and bacterial contamination. Impaired conditions are evident throughout the watershed indicating numerous future assessment and restoration opportunities.

Nutrient Loading

Human activities have adversely affected the nitrogen cycle by adding as much fixed nitrogen to the terrestrial ecosystem as all the natural sources combined (SRWP 2010). Intuitively, nutrient yields tend to be higher in watersheds dominated by urban and agricultural uses than watersheds consisting of more natural vegetation cover (Wickham et al. 2008; Ahearn et al. 2005; Dubrovsky and Hamilton 2010). Specifically, areas dominated by agriculture typically display the highest nutrient concentrations due to fertilizer, pesticide, and animal waste that subsequently wash into nearby rivers (Dubrovsky and Hamilton 2010, SRBRC 2010). In urban areas, wastewater treatment plants can be a major source of nutrients into the watershed. A study by Ahearn et al. (2005) noted that nitrate loading in the urban study area was relatively low until the construction of a wastewater treatment plant. Excess nitrogen and phosphorous pose a high relative risk for biological communities (Stoddard et al. 2007) and therefore are very important chemical parameters. In the SRBRC, the Deer Creek watershed received a score of 0/100 in nitrogen loading indicating nutrient loading as a prevalent stressor (SRWP 2010).

A spike in nutrient concentrations is evident in lower Deer Creek indicating that Lake Wildwood WWTP effluent discharged into Deer Creek is a point source of nutrient loading. The severity of excessive nutrient concentrations increases in the summer months when flows decrease due to water diversion, damming, and less precipitation, resulting in an effluent-dominated flow in lower Deer Creek. Coupled with warmer water temperatures influenced by sub-optimal midstream canopy cover from impaired riparian zones and lower in-stream flows due to the Lake Wildwood reservoir, nutrient loading promotes excessive algal growth in lower Deer Creek, especially at sites 8 and 9 which are reflected in algae AFDM results and FODC/SSI field observations.

Furthermore, algal blooms affect pH levels in lower Deer Creek. During the day, algae photosynthesis will absorb carbon dioxide thus lowering the amount of carbonic acid and increasing pH, while at night carbon dioxide is reabsorbed by the water thus increasing the amount of carbonic acid and decreasing the pH to its more neutral level (FODC 2004). Mean pH is highest at Sites 8 and 9 with highest values being measured in the summer months when algae communities dominate the substrate. Additionally, the FODC/SSI 2001 pH study indicated strong diurnal fluctuations in the summer with pH commonly measuring a peak pH of 9.5 in the early evening. Lower Deer Creek is currently 303(d) listed as an impaired water body due to pH and is priority for remediation as high pH has been connected with fish kills recorded by FODC/SSI scientists.

Amplified algal growth can also promotes mercury methylation in a water body. Decomposing algae can create an anaerobic environment that provides ideal conditions for bacteria to methylate mercury left from mining activities in the Deer Creek watershed, which in turn can bio-accumulate in aquatic organisms (FODC 2004). Therefore, alleviating nutrient loading in the Deer Creek watershed could indirectly decrease methylation potential by reducing algal blooms. FODC/SSI research indicated that the algae-sediment complex aid in the transport of mercury over the Lake Wildwood dam in route to the Bay.

It is likely that the numerous effects associated with nutrient loading in the Deer Creek watershed are affecting biotic communities, such as the decline of sensitive EPT taxa and increase in more tolerant species, which is apparent in lower Deer Creek. Furthermore, effects of nutrient loading can become more pronounced with riparian zone degradation that can decrease midstream canopy cover and weaken its buffering capacity, leaving the stream more vulnerable to stressors.

Future assessments on the relationship between nutrient loading, water temperatures, algal blooms, and pH will be important to determine and prioritize most effective restoration efforts in impaired stream reaches. Working with the SWRCB in developing a TMDL for pH provides a great opportunity for research and restoration. The Lake Wildwood WWTP updated its facilities in late 2006 to reduce the impacts of effluent discharged into Deer

Creek. 2007-2010 data indicate the upgrades have reduced nitrate concentrations in lower Deer Creek. It will be important for FODC/SSI to continue assessing nitrate and phosphate concentrations in Deer Creek to continue monitoring the effectiveness of past and future upgrades. Collaboration with the Lake Wildwood and Nevada City WWTPs to share data, concerns, and restoration opportunities will be pivotal in future restoration efforts. Additionally, expansion of nutrient analyses to include ammonia and nitrite will provide further insight into nutrient cycling effects from point and non-point nutrient sources. Finally, improving riparian zone conditions along impaired stream reaches will be crucial for canopy cover and runoff buffering which will in turn help alleviate stressors such as nutrient loading and algal blooms in the watershed.

Mercury Contamination

The extensive mining legacy in the Sierra Nevada has resulted in mercury contamination throughout the Deer Creek watershed with bioaccumulation of methylmercury in biotic communities a major concern. Mercury data from FODC/SSI surveys consistently reported elevated THg concentrations in sediment and storm-water samples in the major tributaries Gold Run Creek and Little Deer Creek. Elevated THg concentrations were also prevalent in the main stem of Deer Creek. Little Deer Creek and the main stem of Deer Creek from Scotts Flat reservoir downstream to Lake Wildwood reservoir are 303(d) listed as impaired water bodies for mercury contamination (CVRWQCB 2009a). Continuing and expanding investigation in mercury inputs into the watershed, including fine-scale sampling to accurately pinpoint sources and developing restoration projects for mercury remediation are a priority in the Deer Creek watershed and surrounding Sierra foothill watersheds.

The relationship between THg and TSS in the 2005-2007 and 2008-2010 FODC/SSI mercury surveys showed a strong relationship in individual storm events throughout the watershed indicating mercury is bound to sediment and transported during high flow events when sediment is mobilized. Although dams such as the Lake Wildwood reservoir restrict downstream transport of sediment, data indicate appreciable amounts of mercury are being transported downstream. This is probably partially related to the nature and frequency of storm events that are likely a determining factor of mercury transport. Additionally, mercury associated with algae may also assist in downstream transport of mercury over dams. Further investigation of this notable relationship between TSS and THg will be pivotal in characterizing mercury transport throughout the watershed and determining restoration opportunities.

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The concentration of mercury in biota provides a more direct measure of how mercury contamination in the Deer Creek watershed is affecting ecosystem health and potentially human health. Because BMI are an important food source for fish, they have been used in mercury studies as indicators of bioaccumulation in aquatic food chains (Slotten et al. 1997).

BMI sampling from the 2005-2007 Hg survey measured consistently elevated THg levels in larger predator species while smaller predators and drift feeders measured variable THg concentrations. Preliminary data suggested that THg concentrations in BMI increased downstream to the Lake Wildwood impoundment where levels decreased below this barrier.

Furthermore, FODC/SSI THg data in fish tissue indicated elevated concentrations in trout from Little Deer Creek and Largemouth Bass from Scotts Flat and Lake Wildwood reservoirs. Little Deer Creek and Deer Creek from Scotts Flat reservoir downstream to the Lake Wildwood reservoir are 303(d) listed as impaired from mercury contamination (CVRWQCB 2009a).

The Lake Wildwood reservoir measured the highest THg levels in fish tissue from Largemouth Bass with the minimum concentration measured (0.538 ppm) exceeding the maximum concentrations measured at all other sites (0.512 ppm wet weight). Additional samples collected by the SWRCB Toxic Substances Monitoring program (1978-2000) also found elevated THg concentrations in fish tissue. Conducting further THg assessments in biota as well as investigating methylating process throughout the Deer Creek watershed will be crucial for future education/outreach and restoration opportunities. Coordinating with the SWRCB to develop TMDLs for mercury contamination in the streams 303(d) listed in the Deer Creek watershed provides a great opportunity for mercury research and restoration

Bio-sampling has not been conducted for the 2009-2010 survey but is scheduled to occur in early 2011. One of the limitations to the 2005-2007 study was that BMI and fish communities sampled varied between sites, making it difficult to compare THg concentration levels. Upcoming and future bio-sampling should attempt to focus on sampling common species between sites to make comparisons more valid. Additionally, despite having some of the highest THg concentrations in sediment and storm-water samples, only limited THg in BMI and fish sampling occurred in Gold Run Creek. Future mercury assessments should expand bio-sampling in the Deer Creek watershed to better characterize methylmercury contamination.

Finally, increased sediment input from mine tailings that are situated in proximity to streams in the Deer Creek watershed likely increases stress on biological communities. Increased sediment input can affect aquatic biota in numerous ways including impairment of habitat structure and decrease in oxygen availability for BMI larvae as well as amphibian, reptile, and fish eggs that are blanketed by sediment influxes. Further investigation is needed to determine sediment influxes caused by mining in the Deer Creek watershed.

The mining legacy in the Sierra Nevada has clearly left its imprint on the Deer Creek watershed. FODC/SSI sediment, storm-water, and biotic sampling data indicate elevated THg concentrations in the watershed. Mercury contamination is a concern for both the aquatic communities that inhabit streams in the watershed, but also to humans who may consume fish from the watershed on a regular basis. Future assessments and restoration efforts are needed to address mercury contamination and additional mining impacts in the Deer Creek watershed and surrounding regions.

Riparian Vegetation

The condition of the riparian zone in a watershed is crucial in supporting stream ecological integrity by providing energy input to the stream system, buffering the stream from upland erosion and contaminants, providing habitat and shade cover, and more.

As previously stated, deficient midstream canopy cover likely contributes to elevated water temperatures in lower Deer Creek that promote algal blooms when coupled with excess nutrients. Elevated water temperatures are also a concern in lower Deer Creek as the last quarter mile stretch upstream of the confluence with the Yuba River provides important salmon and steelhead spawning habitat.

Riparian zones with heavy barren soil and duff were prevalent throughout the watershed, which likely promotes erosion. Increased erosion can have adverse impacts on biological communities such as mortality from filling in gills and habitat degradation. Additionally, the correlation between sediment and mercury is an additional water quality implication with increased erosion. Furthermore, the degradation of riparian zone width that was noted around major communities where development is prominent can decrease the riparian zone's buffering capacity making the stream more susceptible to upland runoff and contaminants.

The abundance of non-native, invasive species in the riparian zone also raises concern. Native vegetation provides structural complexity, food sources, and important habitat for native fauna. Increased competition and dominance of invasive species compromises these benefits for biotic communities. Several restoration projects have been completed in the Deer Creek watershed removing invasive species and planting natives in their place. Future assessments should investigate riparian zone reference sites in similar regions to conduct more informed native vegetation restoration projects. Education and outreach should be conducted to major communities where invasive species are most prominent and best management practices (BMPs) for landowners and county agencies should be developed to help restore the riparian zone throughout the watershed.

Bacteria

FODC/SSI 2005-2008 bacteria data indicated high levels of *E. coli* bacteria in the Squirrel Creek watershed, which prompted more thorough sampling with additional monitoring sites in 2008 and 2009. In June 2009, concentrations more than four times greater than the health standards established by the USEPA were observed (USEPA 1986), with concentrations during recreation season consistently above the single sample maximum standard that is designed to protect human health. Data clearly indicate that people who use Squirrel and Clear creeks and the popular swimming hole in Western Gateway Park for recreation are being exposed to fecal contamination in concentrations that have been deemed unsafe by the USEPA (USEPA 1986).

Continued monitoring, outreach, and restoration efforts are needed to address the bacteria issue present in Squirrel Creek and throughout the Deer Creek watershed. For example, further assessments should focus on identifying bacteria sources and perform outreach and restoration efforts accordingly, such as developing BMPs for upstream landowners who may be contributing to bacteria contamination. Furthermore, additional assessments should identify the types of bacteria to determine public health implications from recreational activities coordinated with public health outreach in contaminated areas.

Assessing the chemical, physical, and biological characteristics of Deer Creek and its tributaries indicate many assessment and restoration opportunities throughout the watershed. Nutrient loading, mercury contamination, and riparian vegetation degradation appear to be some of the significant stressors impacting biological communities in the watershed with methylmercury and bacteria contamination also a public health concern. Additionally, stream parameters that were discussed in the Hydrology and Geomorphology chapters in this report (Chapters 4 and 5) also play a significant role in the ecological condition of the watershed as well as future development in the watershed and climate change (Chapter 7). Continued research, restoration, and outreach/education will be crucial in improving and protecting the ecological integrity of the Deer Creek watershed.

D. Recommendations

Stoddard et al. (2005) reported that nutrient loading, mercury in fish tissue, and riparian disturbances were some of the most prolific stressors in the western United States. The Deer Creek watershed is no exception as these same stressors along with flow alterations, sediment loading, heavy metal contamination, and non-native species are affecting the ecological condition of the watershed. Continued monitoring of chemical, physical, and biological parameters and implementation of restoration projects to address impaired areas will be critical in restoring and protecting the ecological integrity of the Deer Creek watershed.

- **Continue nutrient assessments in the Deer Creek watershed and expand analyses to include ammonia and nitrite**
  Nitrate and phosphate data indicated the Lake Wildwood WWTP as a major point source for nutrient loading in lower Deer Creek that promotes excessive algal growth

at downstream sites. Upgrades to the Lake Wildwood WWTP facilities in late 2006 resulted in a reduction in nitrate levels in downstream sites; nonetheless, continued monitoring will be important to monitor the effectiveness of past and future upgrades and will help identify additional point and non-point sources of nutrients as well as provide insight into appropriate restoration actions. Analyzing ammonia and nitrite would provide more insight into nutrient loading and its effects on nutrient cycling and aquatic biota.

- **Plant native riparian vegetation to increase uptake of nutrients**
  Riparian vegetation helps buffer a stream from upland runoff and can uptake nutrients to help reduce their impacts on stream conditions. Lower Deer Creek could benefit from such vegetation restoration to decrease the impacts of nutrient loading that is evident in this section of stream.

- **Conduct N/P ratio studies upstream of, within, and downstream of Lake Wildwood reservoir, and upstream and downstream of Nevada City WWTP**
  An N/P ratio assessment has not been conducted in the Deer Creek watershed and would provide better insight into nutrient loading.

- **Expand mercury contamination assessments in the Deer Creek watershed to locate major sources to the stream system**
  FODC/SSI data indicated elevated THg concentrations in sediment and storm-water samples throughout the watershed. Conducting more comprehensive sampling along the main stem of Deer Creek and major tributaries to increase spatial resolution will help determine major mercury sources and prioritize restoration sites. Assessments should also investigate similarities Deer Creek has with other watersheds in the Sierra foothills.

- **Continue storm-water sampling to better characterize mercury transport in the Deer Creek watershed**
  As previously mentioned, mercury data indicated a strong relationship between THg and TSS during storm events and mercury-laden algae may be an additional transport mechanism. A better understanding of mercury transport in Deer Creek watershed will be important for determining effective restoration actions.

- **Assess the methylating capacity in the Deer Creek watershed and how methylating conditions differ between sites**
  BMI and fish tissue data indicated appreciable THg concentrations in aquatic biota in the Deer Creek watershed; however, little is known about the methylating capacity in the watershed. Assessing methylating capacities would provide better insight into MeHg "hot-spots" and help prioritize restoration sites.

- **Investigate restoration efforts to lower mercury and methylmercury in the Deer Creek watershed**
  As previously stated, elevated THg concentrations in BMI and fish tissue indicate MeHg concerns in the Deer Creek watershed. Restoration possibilities need to be researched to determine the most effective actions. Investigating the use of UV to kill bacteria to lower MeHg and the use of plants for heavy metal bioremediation are examples of potential restoration actions.

- **Investigate the mechanism/pathway for mercury bioaccumulation in aquatic communities.**

- **Conduct outreach and education to the community on mercury and potential hazards from regular consumption of fish from the Deer Creek watershed**

  Data indicated THg concentrations in fish tissue that could have public health implications if consumed on a regular basis. Outreach and education should be conducted to ensure the public is aware of potential mercury contamination in fish caught in the Deer Creek watershed.

- **Conduct tissue analysis on organisms to better understand the accumulation and processes of heavy metal contamination, such as arsenic, in the ecosystem**

- **Investigate acid mine drainage (AMD) in the Deer Creek watershed**

  Although no specific discharges of acid mine drainage have been documented in the Deer Creek watershed, uncharacterized mine sites may pose a threat to water quality in some locations, particularly in Squirrel Creek and lower Deer Creek where copper and zinc sulfide deposits have been mined on a small scale.

- **Investigate utility of the current physical habitat (Phab) assessment protocol being used and develop a Phab assessment protocol specifically for Sierra foothill streams**
  The physical characteristics of a mountainous stream, such as Deer Creek and its tributaries, differ greatly from streams flowing through the Central Valley. The protocol that has been used in the Deer Creek watershed is a general physical habitat assessment that does not specifically apply to mountainous streams. Development or utilization of a protocol that addresses physical parameters present in a mountainous stream is necessary to better characterize physical habitat conditions in the Deer Creek watershed and provide more insight into impaired riparian zones.

- **Continue and expand riparian zone assessments and analyses to include additional stream reaches and conduct a more thorough investigation of ecological impacts of degraded riparian zones**
  Riparian vegetation data indicated numerous concerns in the condition of the riparian zone including structural complexity, floodplain connectivity, periodic floodplain disturbance, canopy cover, riparian width, exposed groundcover, and dominance of invasive, non-native species. Once a Phab protocol for Deer Creek has been developed, an extensive survey in the entire watershed should be implemented to validate (or invalidate) previous assessment results and expand into sub-watersheds. Further investigation of water quality and biological implications from impaired riparian zones in the watershed will be crucial in prioritizing areas of concern and determining the most effective restoration actions in the riparian zone.

- **Investigate riparian zone reference sites in the similar regions to conduct more informed riparian restoration projects in the Deer Creek watershed**
  Evaluating reference sites for riparian vegetation zones in the Deer Creek watershed or similar regions would result in more effective restoration efforts by providing insight into types and densities of native species that should be planted, structural complexity, and more.

- **Conduct outreach to landowners in major communities in the watershed to educate citizens about the importance of the riparian zone**
  Data indicated invasive species were most prominent around major communities such as Nevada City, Lake Wildwood, and Penn Valley. Additionally, deficient lower canopy cover and exposed groundcover were apparent in these communities. Outreach and education efforts to these communities will be crucial for the effectiveness of future restoration projects and decreasing riparian zone impacts from anthropogenic activities.

- **Expand invasive, non-native riparian vegetation assessments in the Deer Creek watershed**
  An extensive survey should be performed throughout the watershed to determine "hot-spots" where invasive species are dominant in the riparian zone and areas where invasive species are beginning to propagate. The assessment should include identification of non-natives at all riparian levels including upper canopy, lower canopy, shrubs, saplings, herbs, and grasses. Additionally, evaluation of competition attributes between native and non-native species should be performed to determine more insightful restoration projects.

- **Remove invasive, non-native species from the riparian and upland zones of the Deer Creek watershed and replace with native species**
  Black locust was identified as the most prevalent non-native species in the upper and lower canopy of the riparian zone in the Deer Creek watershed. Himalayan Blackberry is a dominant shrub throughout the watershed and other non-native species such as Scotch Broom and English Ivy are also prominent. Assessments recommended above would provide insight into invasive, non-native riparian vegetation areas of concern, invasive, non-native herbs and grasses, and most effective restoration opportunities in the watershed. Future restoration projects should continue to collaborate with public and private landowners and coordinate with ongoing projects, such as the Scotch Broom Challenge, to target additional sites within the Deer Creek watershed. Restoring native species in the riparian zone would provide important food sources and habitat benefits for aquatic and terrestrial biota.

- **Conduct a land-use/land-cover (LULC) assessment in the Deer Creek watershed**
  Analyzing LULC data will aid in identifying stressors that are adversely affecting the Deer Creek watershed. The assessment should include aerial imagery analysis that can provide visual data on sites before detrimental activities (e.g. grazing, logging, development, construction) to make more informed restoration projects. A GIS-based analysis should be conducted that correlates land cover and land use impacts to water quality data in the watershed.

- **Collaborate with indigenous people for restoration projects**
  Collaboration with indigenous communities will help ensure representation of plants that were important for cultural and ecological purposes to local tribes.

- **Investigate bacteria types and contamination sources**
  Types of bacteria and contamination sources need to be more thoroughly assessed to better determine health implications and restoration projects. FODC/SSI should collaborate with the Fish and Wildlife Commission, Nevada County Agricultural Commissioner's Office, Natural Resources Conservation Service, and Nevada County Resource Conservation District to conduct a survey of land owners in the vicinity, determine their current practices and willingness to collaborate in an effort to reduce bacteria contamination, and study the feasibility of implementing remediation on land owned by willing land owners and the extent to which such implementation would benefit overall watershed health.

- **Continue to collaborate with regional agencies to conduct bacterial sampling in Western Gateway Park and at upstream sites on Squirrel and Clear creeks during the recreational swimming season**

Monitoring will include continued bacteria and water quality monitoring and speciation of bacteria samples to determine the source. The primary parameter will be *E. coli* testing, working systematically upstream on Squirrel and Clear creeks and using cost-effective in-house testing. Any spikes in *E. coli* would lead to further testing for *E. coli 0157H7* and speciation at an outside lab. Microbial source tracking allows for identification of the source organism of fecal contamination by running markers for cattle, deer and non-ruminants, humans, and for hogs. Further testing to quantify the amount from each type of animal will follow identification of contamination sources.

- ❖ **Collaborate with local, state, and federal agencies to develop a remediation plan for Western Gateway Park**
  The remediation plan should include recommendations and implementation strategies that can be used by specific willing private landowners, and general recommendations for landowners and other stakeholders in the project vicinity.

- ❖ **Conduct outreach and education to communities on bacteria contamination**
  This would include dissemination of project findings through the FODC/SSI website, local news outlets, and the community center at Western Gateway Park; posting data on the State's Safe to Swim Water Quality Portal http://www.swrcb.ca.gov/mywaterquality/safe_to_swim/; and conducting public outreach aimed at providing information and making connections with area ranchers and farmers through Fish and Wildlife Commission public meetings. Additionally, FODC/SSI could develop trainings for bacterial remediation to be offered regionally which would aid other watershed organization and stakeholder groups in determining public health implications of water bodies used for recreation. Trainings could cover sampling, assessments, data analysis, selection, and implementation of remediation options, securing of funding, and public outreach.

- ❖ **Investigate diurnal components of chemical parameters, such as water temperature and pH**
  FODC/SSI data indicated a strong diurnal effect in water temperature and pH at site 10 in lower Deer Creek in the summer. Expanding assessments on the diurnal component of chemical parameters would better characterize stream conditions in the Deer Creek watershed, especially in critical areas such as the quarter mile stretch of lower Deer Creek above the confluence of the Yuba which is important salmon spawning habitat. FODC/SSI used temperature loggers to collect additional data at site 10 in late 2010. In addition to investigating diurnal components, sensors or continuous monitoring could be utilized to evaluate water quality changes in response to other factors such as dam releases and wastewater treatment plant effluent, as was done in 2007 and 2008 during the Lake Wildwood drawdown.

- **Continue and increase algae monitoring efforts in the Deer Creek watershed including more frequent monitoring during summer months**
  Because algae samples are only currently collected once a month during the summer at each site, it is likely that FODC/SSI is missing peak-algae growth at sites. Sampling should be increased to every 14 days on a regular basis in the summer.

- **Continue BMI monitoring in the Deer Creek watershed to identify most impaired sites and effectiveness of restoration efforts**
  BMI monitoring should be expanded to include all reaches in the watershed that are possibly impaired and in proximity to development/construction sites that may affect the watershed.

- **Develop an algae identification program and metric system as a bio-indicator of stream health in the Deer Creek watershed**
  Similar to BMI communities, specific algae species will grow in reaches based on water quality conditions. Identification of algae communities and development of a corresponding metric system in association with BMI bio-assessments will provide better insight into the major stressors impacting biotic communities and most-impaired reaches. Additionally, identifying algae would allow evaluation of native and non-native species to aid in the prevention of spreading non-natives.

- **Develop a family-level Index of Biotic Integrity (IBI) for BMI to be used as a numerical health scale in the Deer Creek and Sierra foothill watersheds**

- **Continue and expand fish surveys in the Deer Creek watershed**

  Further electro-shocking efforts should target the same reaches as in 2007 and 2008, while trying to incorporate stretches of major tributary creeks, including Squirrel and Clear Creek in Penn Valley, Gold Run Creek, Little Deer Creek, Mosquito Creek, and Willow Valley Creek in and around Nevada City, and upstream Scotts Flat Reservoir on the main stem, north, and south forks of Deer Creek. This will provide better insight into the diversity, abundance, and quality of fish species in the watershed. Surveys should include study and comparison to other Sierra foothill watersheds.

- **Conduct surveys of lower Deer Creek at the confluence with the Yuba River for Chinook salmon and steelhead**
  Surveys should focus on surveying physical habitat parameters (velocity, depth, gravel attributes, water quality), the number of adult fish present in Deer Creek during spawning season, the number of redds created by salmon, and the success of fry and juvenile emergence from redds. In addition, surveys should attempt to

identify other fish species present in Deer Creek, for comparison with sites that have been surveyed through fish shocking previously.

- **Implement gravel augmentation and spawning bed enhancement projects on Deer Creek**
  A cobble deficit exists downstream of Lake Wildwood reservoir, which has led to degraded in-stream habitat conditions in Deer Creek. As discussed in the Geomorphology Chapter, gravels and cobbles are not of a suitable size in lower Deer Creek, indicating the need for gravel augmentation. Gravel augmentation will decrease the average size of substrate in lower Deer Creek, to a range that is more suitable for spawning. In addition, conditions within the spawning reach are degraded, with large boulders and cobbles armoring the streambed, reducing the quantity and quality of available spawning habitat. Spawning bed enhancement should be implemented and would involve strategic placement and removal of large boulders and cobbles, to create conditions that are more conducive to spawning. Gravel augmentation efforts are on-going in Deer Creek, with a Feasibility Study and Gravel Augmentation Plan developed in January and March 2010, the necessary permits acquired, and a pilot project scheduled for implementation during the summer of 2011 with two years of funded post-project monitoring. Efforts to restore conditions in the spawning reach have begun, with a partnership established with the private landowner along the spawning reach, preliminary surveys conducted during spawning season, and efforts ongoing to acquire funding to begin the permitting process and to implement the project.

- **Ensure in-stream flows are achieved, as outlined in Lake Wildwood Association water rights documents, downstream of Lake Wildwood reservoir**
  This will ensure that there is adequate stream flow to provide habitat and water quality benefits, so that aquatic organisms such as BMI and anadromous fish may thrive in Deer Creek.

- **Expand assessments on vertebrate communities in the Deer Creek watershed**
  Assessments should be conducted in the watershed on birds, reptiles, amphibians, and mammals in the Deer Creek watershed to determine the diversity and abundance of native and non-native species and impacts associated with non-native species. FODC/SSI currently has limited data collected on these vertebrate communities in the Deer Creek watershed. Collecting baseline data on birds, fish, mammals, reptiles and amphibians will aid in determining which species work best as indicators for overall ecosystem health over time and effects on communities after impairments and improvements.

- **Conduct data analysis of current restoration sites and perform new pilot studies to assess the diversity, abundance and health of biotic communities before and after restoration and development projects to evaluate improvements and impacts**

  Restoration projects in the Deer Creek watershed should include pre and post bio-sampling of biotic communities that are trying to be restored or may be affected by restoration efforts. Additionally, FODC/SSI should collaborate with development/construction projects and conduct pre and post bio-sampling to investigate impacts on biotic communities. Results from such studies could be used to assist in becoming a leader in determining bio-assessments for stream reaches impacted by projects.

- **Re-establish FODC/SSI monitoring site 14 immediately upstream of the Deer Creek confluence with the Yuba River**

  This area of Deer Creek is critical salmon and steelhead spawning habitat. Regular monitoring of the site should be conducted to evaluate water quality in this important section of the watershed. Recent landowner change and correspondence may lead to re-establishing this site.

- **Collaborate with the SWRCB in the development of total maximum daily loads (TMDL) in the Deer Creek watershed**

  Several areas in the Deer Creek watershed are 303(d) listed as impaired water bodies including Deer Creek from Scotts Flat reservoir to Lake Wildwood and Little Deer Creek for mercury; and Deer Creek downstream of the Lake Wildwood reservoir for pH. Total maximum daily loads have not been established and assisting in the development in these TMDLs is a great assessment and restoration opportunity in the Deer Creek watershed.

Chapter VII: Future Development and Its Impact

FODC/SSI

A. Population Growth in the Deer Creek Watershed

Between 1965 and 2001, Nevada County's population increased 3.75 times, from 25,100 to 94,361 (Walker et al. 2003). This significant population increase was primarily driven by in-migration to the County (Berliner 1970; Walker et al. 2003). Population growth estimates project Nevada County's population will increase to 185,000 by 2050, and to roughly 250,000 by 2100 (Landis and Reilly 2003). Under Nevada County's General Plan and current planning rules the build-out capacity of Nevada County is estimated at 233,522, more than 2.5 times the county's 2001 population and less than the estimated population for Nevada County in 2100 (Landis and Reilly 2003; Walker and Hurley 2004).

The Deer Creek watershed will undoubtedly receive a portion of that population growth, as new urban development in Nevada County will favor Nevada City, Grass Valley, and Lake Wildwood, while rural, suburban development will favor the low-gradient slopes found in the Penn Valley area (Landis and Reilly 2003). Currently, more than one fourth of the Nevada County population lives in the Deer Creek watershed, with approximately 25,000 residents living mainly in Nevada City, Lake Wildwood, Rough and Ready, and Penn Valley (Census Bureau 2000). As discussed more fully below, population growth leads to increased development, which can cause significant changes to all aspects of the watershed.

B. Development in the Deer Creek Watershed

Michael Ben Ortiz

With the population of Nevada County projected to more than double by the end of the 21st century, a large amount of new development is likely to occur to accommodate the increase in population. This includes development in both urban and rural locations throughout Nevada County, for residential, commercial, agricultural, transportation, and industrial uses. This will put further pressure to develop on lands that currently exist as open space, as well as on sensitive landscapes or habitats such as steep hill-slopes, wildlife corridors, vernal pools, wetlands, and ephemeral stream drainages. Walker and Hurley (2004) surveyed 358 rural Nevada County landowners, with 71% agreeing that the county "needs strong environmental protection", while 59% disagreed that the county "needs strong government control of land use on private property." This indicates that the majority of private landowners want to protect environmental resources, but without government regulation, which opens the door for collaboration with community and watershed groups with similar interests that have no regulatory authority (Walker and Hurley 2004).

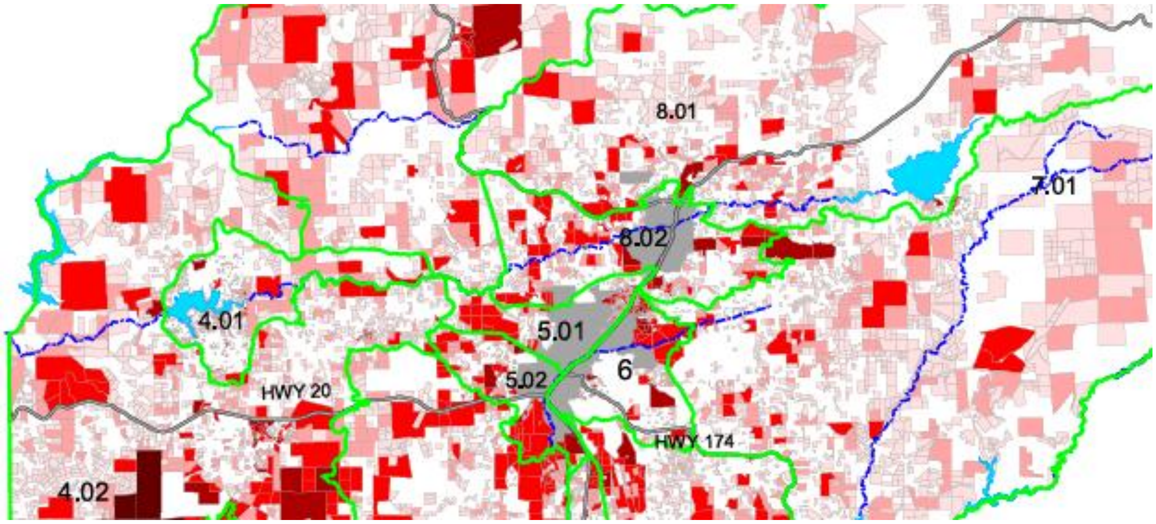
Past Development

Coupled with the significant population growth in Nevada County from 1960 – 2000 was significant development and changes in land use patterns. Walker and Fortmann (2003) reported a dramatic shift in land use, with 30% of private lands in 1957 under residential use, compared with 70% in 2001. This increase in residential land use was coupled with an almost equal decrease in agricultural land use (Walker and Fortmann 2003). Companies such as Boise Cascade Corporation created large residential developments on former ranch and forestland during the 1960s (Berliner 1970). The population growth and development of residential parcels led to landscape fragmentation, reducing the availability of wildlife corridors and open space, and increasing development in sensitive habitats (Walker et al. 2003; Walker and Hurley 2004). The median size of private parcels decreased from 550 acres in 1957 to nine acres in 2001, leading to the highly fragmented landscape that exists today (Walker and Hurley 2004).

Future Development and Urbanization

The data indicate that much of Nevada County's current open space has already been zoned and is intended for future residential development (Walker et al. 2003). In Nevada County approximately 76,145 acres of private land are currently developed (current improvement value > $20,000), with additional development permitted on 281,689 acres (Walker et al. 2003). The Nevada County Planning Department estimated the number of parcels and dwellings that could be created based on the rules and zoning laws adopted in the 1996 Nevada County General Plan. The county identified dozens of parcels in the Deer Creek Watershed that could be developed further, either by building on an existing parcel or splitting a parcel and building dwellings on the newly created parcels (**Figure 7.1**). Some parcels could be split into two, while others could be split into 5 or more separate parcels. In addition, some parcels are permitted to have up to 15 dwellings.

Although it is not possible to tell exactly how many of these parcels are within the watershed, a conservative estimate would be that at least 1500 new dwellings could be constructed on new or existing parcels. There is a concentration of parcels with development potential in the Penn Valley area, but parcels are scattered throughout the Deer Creek watershed. If an average number of people, using the average number of persons per dwelling unit (for Nevada County, 2.47 per unit), were to inhabit these dwellings, the population in the Deer Creek Watershed would increase to 30,000 or more (Walker et al. 2003). This dramatic increase in development and population would have implications for the watershed and ecosystem. This also indicates the need for FODC to work with the county to amend or update the General Plan to include development rules that protect the health of the environment, and to work with willing property owners, community groups, and land trusts to place conservation easements on parcels.



Dwelling Unit Potential

This table summarizes the existing developed residential parcels and the potential undeveloped residential housing units broken down by tract.

Census 2000 Tracts	Existing Improved Parcels (Units)	Future Additional Units
1.02	2709	599
1.03	3098	695
1.04	1121	376
1.05	957	471
2	879	791
3	836	512
4.01	2869	796
4.02	2249	1334
5.01*	2017	274
5.02*	1536	228
6*	1538	205
7.01	3076	1468
7.02	1501	670
8.01	1978	953
8.02*	2648	410
9	1722	3067
12.01*	3667	101
12.02*	6703	16
Total	41104	12966

*Future units numbers do not reflect growth potential within city boundaries.

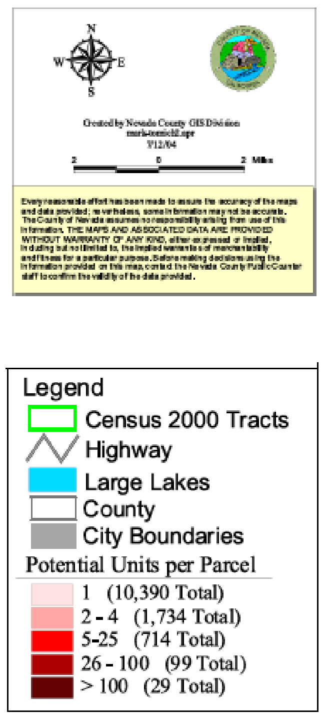


Figure 7.1: Potential for developing additional parcels and dwelling units.

Urbanization and development modifies both the amount and timing of runoff into the creek and the quality of water entering the creek. In both cases, the main driver of change is an increase in impervious surfaces such as paved roads, parking lots, buildings, and storm drains. An increase in impervious surfaces decreases infiltration and increases runoff. **Figure 7.2** illustrates the relationship between percent impervious surface and the fate of rainfall, providing a description of infiltration versus runoff across a continuum of development, while the graph displays the resulting impact on the magnitude of flood peaks and the duration of the lag-time.

The exponential change in infiltration rates that occurs as lands are converted from natural cover to impervious surface has profound effects on local hydrology. In essence, as the Deer Creek watershed continues to develop, rainfall will be transported more rapidly into the stream channels, resulting in shorter lag-times and higher peaks. Since less water infiltrates into the ground, less is stored as groundwater and less released as base flow during low flow times of the year, such as summer.

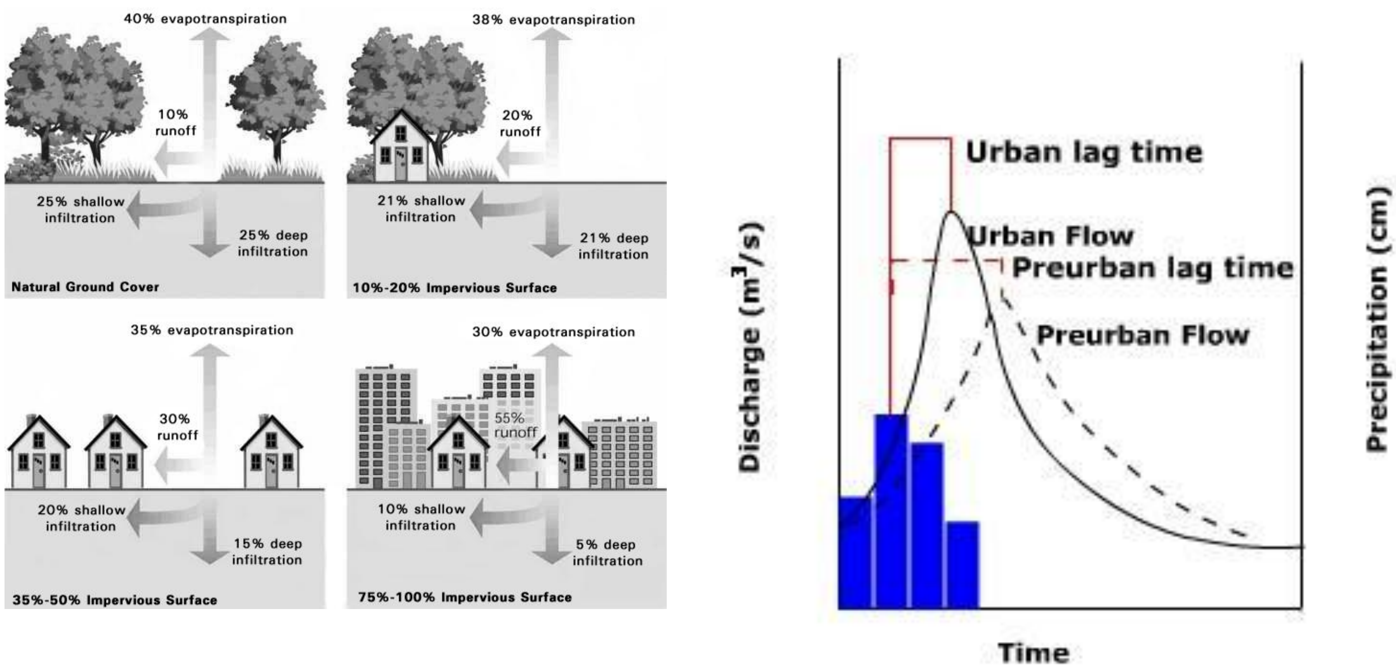


Figure 7.2: Effect of Urbanization on Hydrologic Processes. In the graph on the right, blue bars represent precipitation and solid black bars represent urban discharge, while dotted lines represent pre-urban discharge.

Infiltration into the ground also serves to cleanse the water before it enters the stream channel as depicted in **Figure 7.3**. Under natural conditions, riparian and wetland vegetation along Deer Creek also filter out many potential pollutants. Research demonstrates that higher levels of surface water toxicity are generally associated with watersheds containing more developed land surface and less open space (Skinner et al. 1999).

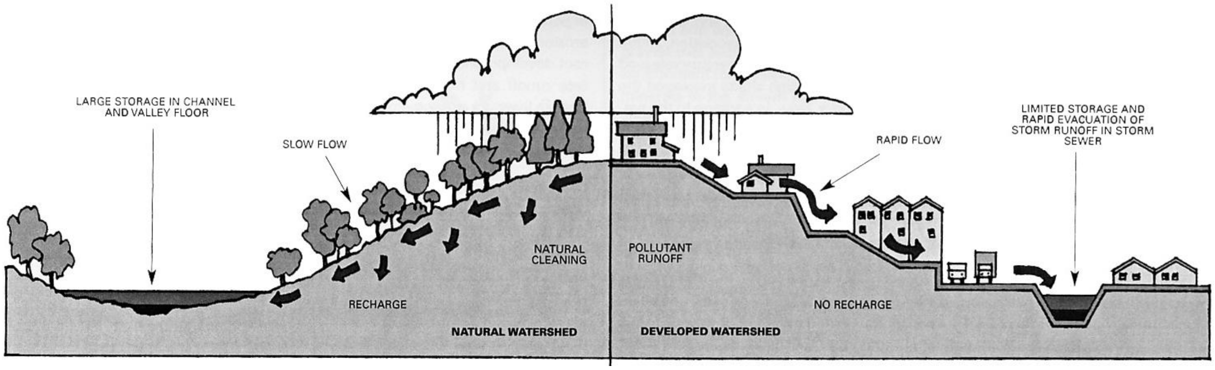


Figure 7.3: Effect of Urbanization on Groundwater Recharge and Water Quality.

Contaminants such as pesticides, heavy metals (including Cd, Cr, Cu, Hg, Pb, Ni, and Zn), dioxin, and n-nitroso compounds are common constituents in storm water in developed watersheds and have been correlated with developmental toxicity in a variety of aquatic organisms (Wisk and Cooper 1990; Pillard 1996; Skinner et al. 1999; Wenning et al. 1999). Developed watersheds also contribute runoff from septic systems, yard care products, automotive exhaust and oils, and other constituents commonly found in urban environments. Research indicates that the impacts of polluted runoff may be significant if contaminated surface waters empty into an enclosed area such as a bay, estuary, or reservoir (Katznelson et al. 1995). Thus, increases in polluted runoff from the Deer Creek watershed could inflict large and potentially irreversible ecological harm to bodies of water downstream. Urbanized streams typically incise, exhibit greater concentrations of fine sediments, and higher primary production, including harmful algal blooms, as a result of greater nutrient availability. Many adaptive management strategies and conservation measures exist to mitigate the impacts of increased development and urbanization on the ecosystem, with a brief discussion at the end of this chapter.

C. Climate Change and Air Quality

Climate Change

Introduction

There is consensus among scientists that the average global temperature is rising (Alliance 2007). Over the next century the effects of this change in climate will pose many challenges to the environment, economies, and communities throughout California (Alliance 2007). The consequences of climate change are projected to be significant in many of California's temperature-sensitive sectors, such as the current water supply infrastructure that serves millions of people each day (Alliance 2007). Numerous studies focusing on climate change impacts to California and specifically the Sierra Nevada mountains have been conducted. Although the precise prediction of the future climate is impossible, numerous scenarios representative of possible climate changes, targeted regionally on California, have been explored.

Methods and Results

Climate models were developed for the IPCC Third and Fourth Assessment, in order to simulate possible future climate scenarios at a variety of spatial scales. Many of these models produce a realistic simulation of aspects of California's recent historical climate, with particular emphasis on the distribution of monthly temperatures and the strong seasonal cycle of precipitation that occurs in the region. Additionally, models were chosen that realistically represent certain regional features, such as the spatial structure of precipitation. Because the observed California climate exhibits considerable natural variability at seasonal to interdecadal temporal scales, for climate models to be practical they should accurately capture the variability found in the observed record through historical simulations. Finally, global climate models should be designed with differing levels of sensitivity to greenhouse gas forcing (Cayan et al. 2008). Two global climate models, the Parallel Climate Model (PCM) and the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) CM2.1 model, were identified based upon the above criteria (Cayan et al. 2008). The two climate models evaluated two emission scenarios: a medium-high greenhouse gas emission scenario (A2), and a low emission scenario (B1). These emission scenarios were selected based upon implementation decisions made by the IPCC4 (Nakicenovic et al. 2000). In the A2 scenario, CO_2 emissions climb throughout the entire 21^{st} century, with CO_2 concentrations of ~850 ppm by 2100, more than triple pre-industrial level of 260-280ppm (Cayan et al. 2008). The B1 scenario makes the assumption that global CO_2 emission rates will peak during the mid-21^{st} century before leveling off by 2100, with concentrations around 550 ppm (Cayan et al. 2008). The B1 scenario results in a doubling of CO_2 concentrations relative to pre-industrial levels.

Temperature Regime

The two global models (PCM, GFDL) project a significant increase in annual Northern California temperatures between 2000 and 2100, with increases of 1.5°C in the low-emission B1 scenario using the less responsive PCM model, to 4.5°C in the higher emissions A2 scenario utilizing the more responsive GFDL model (Cayan et al. 2008). In an analysis by Dettinger (2005, 2006), projected temperature distributions were predicted for a much larger subset of the Fourth IPCC Assessment simulations, which included 12 climate models outputting 84 simulations. Three emission scenarios were evaluated with these simulations, A1b (high), A2 (medium-high), and B1 (low). This larger ensemble of model runs describes a range of projected temperature anomalies for the end of the 21^{st} century, all of which are positive, ranging from minimal to significant (+2 to +7°C) (Dettinger 2005, 2006). Northern California conditions projected by PCM are in the lower half of temperature distributions, with the PCM projecting a modest degree of warming by 2100 (Cayan et al. 2008). In contrast to this, the GFDL projects higher temperatures, in the warmer half of the overall temperature distribution (Cayan et al. 2008). Summer temperatures are projected to increase from 1.6°C in the low-emission B1 scenario with the PCM model, to 6.4°C in the higher-emission A2 scenario using the GFDL model (Cayan et. al 2008). Winter temperatures are projected to increase from 1.7°C to 3.4°C using the B1 PCM and A2 GFDL respectively. It is interesting to note that all simulations except for the PCM B1 projection, result in more pronounced warming during the summer than in winter. In the overall global climate models, summer warming is common for all continental areas, and is possibly affected by earlier and greater drying of land surfaces (Gershunov and Douville 2007). If this projected summer warming occurs, there will be important implications for ecosystems, agriculture, water supply, energy demand, and public health (Cayan et al. 2008). The projected shift in seasonal temperatures parallels a similar shift in daily mean temperatures. The occurrence of extremely warm daily mean temperatures, exceeding the 99.9 percentile of the historical distributions for summer months June-September, increases to 50-500 times their historical frequency by 2070-2099, with the respective B1 PCM and A2 GFDL scenarios (Cayan et al. 2008). This has important implications for public and environmental health, as incidents of wildfire, heat waves, and drought will also likely increase as extreme temperature days do. Changes to climate through variations in the temperature regime are likely to be coupled with changes to the other dominant climate variable, precipitation.

Precipitation Regime

Northern California currently experiences a Mediterranean seasonal precipitation regime, with most of the precipitation occurring in winter. The global models agree that California's current precipitation regime is not projected to change significantly through the end of the 21st century, as is indicated by monthly mean precipitation simulations for A2 and B1 scenarios (Cayan et al. 2008). In each simulation, the majority of the precipitation over northern California continues to occur during winter (Cayan et al. 2008). Model simulations are not in agreement concerning changes in summer precipitation, as gradual increases are simulated in some scenarios, while decreases occur in some of the simulations. This indicates that there is no simulated consensus of stronger thunderstorm activity during the summer months, as is suggested in previous studies (Wilkinson 2002; Cayan et al. 2008).

Overall, by the end of the 21st century, there is no simulated consensus regarding changes to mean precipitation. One simulation projects slight increases or no changes to the mean precipitation (PCM), while another suggests decreases by 10-20% (GFDL) (Cayan et al. 2008). Maurer (2007) conducted an analysis of California's precipitation change using B1 and A2 emissions scenarios and simulations from 11 global climate models. Results from this analysis project only a modest change in annual precipitation, with some increase in precipitation during winter months and decreases in spring months (Maurer 2007). This was also evaluated by Dettinger (2005, 2006), in which he found the distribution of precipitation totals includes both positive and negative anomalies, which are clustered with moderate changes around the present-day averages (Dettinger 2005, 2006). Model simulations evaluated by Dettinger did project modest increases in the range of precipitation variability and differences within the larger ensemble of simulations (Dettinger 2005). Analysis of the larger set of IPCC models marginally suggests these seasonal tendencies (Cayan et al. 2008).

The small changes to annual precipitation over Northern California are in agreement with the fact that, in general, global rates of precipitation are projected to increase with global climate change. These increases, however, tend to be geographically focused in the low-latitude (0° - 23.4°) tropics and high-latitude (66.5° - 90°) regions (Cayan et al. 2008). Although little change in northern California annual precipitation is projected to occur through the end of the 21st century, there is a slight tendency for increases in the frequency and magnitude of large precipitation events (**Table 7.1**) (Cayan et al. 2008).

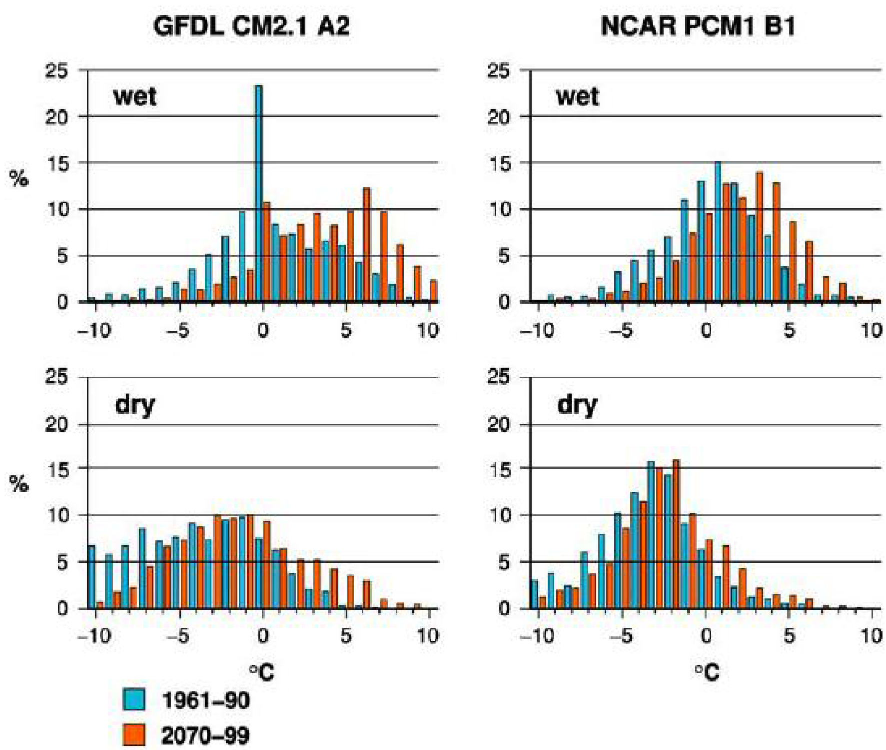
Daily extreme precipitation occurrences, PCM and GFDL A2 simulations

	No Cal				So Cal			
	PCM		GFDL		PCM		GFDL	
	99% ile	99.9% ile	99% ile	99.9% ile	99% ile	99.9% ile	99% ile	99.9% ile
1961–1990	111	12	111	12	111	12	111	12
2005–2034	117	8	129	19	129	19	93	12
2035–2064	129	14	130	40	130	40	129	7
2070–2099	161	25	127	30	127	30	98	10

Table 7.1: Daily extreme precipitation occurrences, PCM and GFDL A2 simulations (Cayan et al. 2008).

Reductions in Snowpack Accumulation

Despite climate models indicating that precipitation changes will be quite modest through the end of the 21st century, climate warming is projected to reduce snow accumulation in California (Lettenmaier and Gan 1990; Knowles and Cayan 2002; Miller et al. 2003). This reduction in snow accumulation results from increased temperatures, which causes more precipitation to fall as rain and less as snow, while raising the snowpack elevation (Knowles et al. 2007). Changes in precipitation type are indicated by substantial changes in daily temperature during days with precipitation, with minimum temperatures tending to be warmest during days with the heaviest precipitation (**Figure 7.4**- from Cayan et al. 2008). Notably, each model projects that all precipitation categories are warmer by the end of the 21st century, with wetter days warming more than dry days (Cayan et al. 2008). These changes in precipitation type and snowpack accumulation are already apparent in the observed period of record.



Distribution, binned by 1°C intervals (percentages of total counts in the range from −10 to +10°C), of daily northern California minimum temperatures (Tmin) for November-March 1961–1990 (*blue*) and 2070–2099 (*orange*) on days that are dry, and on days with precipitation, from GFDL A2 (*left*) and PCM B1 (*right*) simulations

Figure 7.4: Distribution of daily northern California minimum temperatures for 1961-1990, and 2070-2099, with plots for days that are dry and days with precipitation, using GFDL A2 and PCM B1 simulations (Cayan et al. 2008).

During the period of historical record for the western United States, snow accumulation losses on the order of 10% of the average April 1 snow water equivalent have already been exhibited (**Table 7.2**- from Mote et al. 2005), with snow also expected to melt earlier as climate warming becomes more pronounced (Knowles and Cayan 2002; Wood et al. 2004; Maurer and Duffy 2005). In order to evaluate potential snow accumulation losses in California, a combination of statistical bias and spatial downscaling techniques was used to generate data for simulation in the global climate models. To generate supplemental meteorological data that drives snow accumulation, as well as to derive land surface hydrological variables consistent with the downscaled forcing data, the variable infiltration capacity (VIC) model was used (Liang et al. 1994; Liang et al. 1996). VIC is a macro-scale, distributed, physically based hydrologic model that balances both surface energy and water over a grid mesh, and has been applied successfully at resolutions ranging from a fraction of a degree to several degrees latitude by longitude (Liang et al. 1994; Liang et al. 1996; Cayan et al. 2008). The VIC model allows for a statistical representation of sub-grid scale spatial variability in topography, vegetation, and land cover, which is particularly important when using global climate models to simulate hydrologic response to climate change in complex terrain and snow dominated regions (Cayan et al. 2008). The VIC model has been successfully applied at scales varying from global to watershed level (Abdulla et al. 1996; Maurer et al. 2001; Maurer et al. 2002; Nijssen et al. 1997; Nijssen et al. 2001), as well as in numerous studies of climate change impacts to the hydrologic system (Christensen et al. 2004; H04; Maurer and Duffy 2005; Payne et al. 2004; Wood et al. 2004). When using the PCM and GFDL global climate models to drive the VIC hydrologic model, substantial losses of April 1 snow accumulation are simulated for the Sierra Nevada Mountains, with the losses becoming progressively larger as the climate warms through the end of the 21st century (Cayan et al. 2008).

Change in April 1 snow water equivalent, San Joaquin, Sacramento, and parts of Trinity drainages from VIC hydrologic model

	Mean 1961–1990	2005–2034				2035–2064				2070–2099			
		Change (%) PCM		Change (%) GFDL		Change (%) PCM		Change (%) GFDL		Change (%) PCM		Change (%) GFDL	
	PCM	B1	A2	B1	A2	B1	A2	B1	A2	B1	A2	B1	A2
1,000–2,000 m elevation	4.0 km^3 (3.24 Maf)	−13	−35	−20	−48	−26	−52	−68	−61	−60	−76	−75	−93
2,000–3,000 m elevation	6.5 km^3 (5.27 Maf)	+12	−09	−04	−33	−08	−21	−36	−32	−25	−34	−56	−79
3,000–4,000 m elevation	2.49 km^3 (2.02 Maf)	+19	+01	+04	−13	−02	−05	−16	−11	−05	−02	−41	−55
All elevations	13.0 km^3 (10.54 Maf)	+06	−15	−07	−29	0.12	−27	−42	−37	−32	−41	−59	−79

Similar computations for HadCM3 A1fi and B1 simulations and for PCM A1fi simulation are presented in Tables 1 and 2 of Hayhoe et al. 2004. 1961–1990 mean snow water equivalent (SWE) given in km^3 and in million acre feet (MAF).

Table 7.2: Change in the April 1 snow water equivalent for the Sacramento, San Joaquin, and Trinity drainages using the VIC hydrologic model (from Mote et al. 2005).

California statewide average April 1 snow water equivalents from 1961–1990, 2005–2034, 2035–2064, and 2070–2099 simulations of PCM B1 and A2, and GFDL B1 and A2 conditions

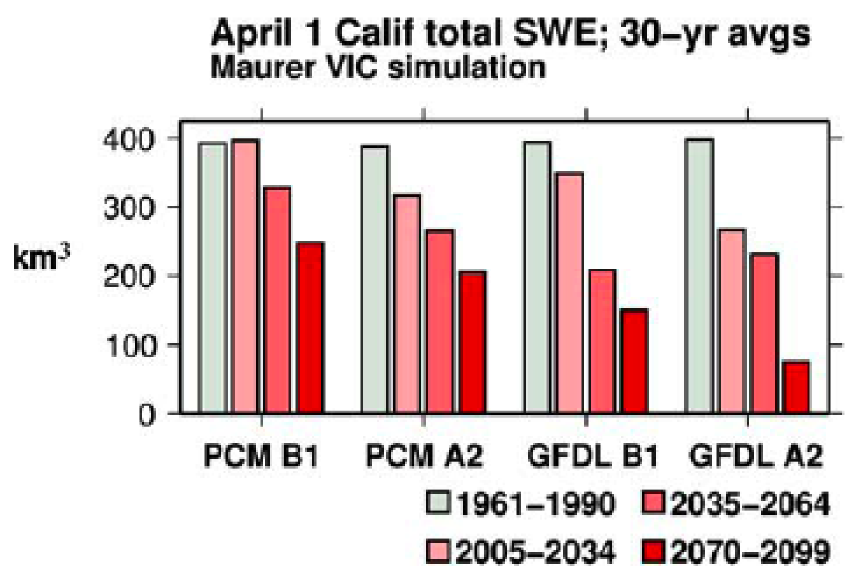


Figure 7.5: Statewide average April 1 snow water equivalents for California including past observations and projected future conditions.

Table 7.2 and **Figure 7.5** provide the results of simulations concerning changes in snow accumulation through the end of the 21st century. Projections indicate losses (negative) and gains (positive) of April 1 snow water equivalent in the San Joaquin, Sacramento, and Trinity drainages, as percentages of historical averages. These projections range from +6 to -29% (2005-2034 period), from -12 to -42% (2035-2064 period), and from -32 to -79% (2070-2099 period) (Cayan et al. 2008). As with the precipitation and temperature regime simulations, the GFDL reacts more sensitively to changes in temperature as a result of increased greenhouse gas concentrations, projecting snowpack accumulation losses twice as large as the PCM model. Both models project the greatest losses to snowpack accumulation in the higher-emission A2 scenario. By the end of the 21st century, the GFDL A2 scenario projects virtually no snow remaining below 1,000 m (Cayan et al. 2008). When thinking of snowpack accumulation in terms of water storage volume, losses are greatest in the relatively warm lower elevations (1000 – 2000 m), where losses of 60 - 93% are projected (Cayan et al. 2008). Between 2000 and 3000 m, losses of 25 - 79% are projected (Cayan et al. 2008). This has important implications in terms of the water management scheme that NID operates in the Deer Creek watershed, as roughly 25% of the watershed elevation is above 1000 m. The largest reductions in snow accumulation are projected to occur in the central and northern parts of the Sierra Nevada, as the highest elevations tend to be in the southern portion of the range (Cayan et al. 2008). In addition to snow accumulation decreasing, the warming climate could also lead to changes in the timing of snowmelt-driven runoff (SDR), affecting important hydrologic variables such as the timing of the spring pulse onset and center of mass of annual flow (Rauscher et al. 2008).

Changes to Snowmelt Driven Runoff

Runoff in mountainous regions, such as the Sierra Nevada, is dominated by climatic variables such as temperature and precipitation, with runoff timing varying with elevation (Aguado et al. 1992). The hydrograph in higher elevations of the Sierra Nevada is dominated by SDR, with 50% or more of the annual runoff occurring from April-July in many regions (Aguado et al. 1992). The upper 25% of the Deer Creek watershed is driven by SDR, with reservoirs and water diversions strategically located to capture SDR from April-July, and utilize it for irrigation purposes through October. Shifts in the timing of SDR have been detected in the period of observed record, with runoff occurring one to four weeks earlier in the year (Cayan et al. 2001; Stewart et al. 2005). These changes are more distinct at low and mid-elevations, while temperatures at higher elevations remain sufficiently low so as to not affect snowmelt timing to an observable degree (McGabe and Clark 2005). This has important implications for water management in the low to mid-elevation Deer Creek watershed.

To project changes in future SDR, two simulations were performed using the high-resolution ICTP Regional Climate Model (RegCM3) (Pal et al. 2007), driven with initial and lateral boundary conditions from the NASA Finite Volume atmospheric GCM (FV-GCM) (Atlas et al. 2005). Snow accumulation and runoff in RegCM3 are generated by the Biosphere-Atmosphere Transfer Scheme (BATS), which generates runoff based upon a simple function of precipitation rate and soil water content relative to saturation (Dickinson et al. 1993). Data from the USGS Hydro-Climatic Data Network were used to evaluate the model SDR timing. The Julian Day on which certain percentiles of the annual water year flow volume occurred were calculated, to capture changes to the early (25^{th}), middle (50^{th}), and late (75^{th}) season flows.

Results indicate that the RegCM3 model is capable of capturing the basic structure of observed SDR timing in the western United States, with particularly good agreement over the Sierra Nevada Mountains (Rauscher et al. 2008). The model projects that the Julian Day by which 25% of the annual flow occurs will be up to 70 days earlier or more in the Sierra Nevada by 2100 (Rauscher et al. 2008). The 25^{th} percentile of the water year's flow is analogous to the spring onset pulse of SDR. Other studies that use lower resolution global climate models to evaluate changes in SDR (Stewart et al. 2004; Maurer 2007) projected the center of mass of annual flow would occur 23-36 days earlier by 2100. The higher resolution RegCM3 model projects center of mass of annual flow changes between 30-70 days by 2100 over regions of the Sierra Nevada (Rauscher et al. 2008). The RegCM3 model tends to project larger changes than the other models, attributed to the higher resolution of the model, which demonstrates complex topography-related mechanisms more realistically than the lower resolution global climate models (Rauscher et al. 2008). Changes on the order of this magnitude will undoubtedly have implications for water storage and flood management operations in California. The greatest changes in SDR are projected to occur at elevations 1200-1800 m (Rauscher et al. 2008), which includes a large area of the Deer Creek watershed upstream of Scotts Flat reservoir. Changes in SDR will result in a widening of the annual hydrograph and a general trend towards an earlier center of mass (Rauscher et al. 2008). This has implications for water resource managers throughout California, as water supplies for agricultural, energy, and recreational use sectors could be severely affected (Hayhoe et al. 2004; Markoff and Cullen 2008; Purkey et al. 2008). This could require the construction of additional reservoirs, extending reservoir capacity, or both (Rauscher et al. 2008). Additionally, modifications to the hydrologic cycle will potentially lead to increased winter and spring flooding; changes in lake, stream, and wetland ecology; and reduced stream flow and snow and soil storage (Cayan et al. 2007).

Climate Change Discussion

It is clear that global climate change will alter the climate of Northern California and therefore also of the Deer Creek watershed. This includes changes to the temperature and precipitation regimes that have dominated California for centuries. Rising temperatures will lead to an increase in the frequency, magnitude, and duration of severe weather events and natural disasters such as heat waves and fires, floods, and drought (Westerling et al. 2006; Alliance 2007). It is important to note that climate change models and predicted scenarios are constantly changing and being downscaled, and therefore it is important to continually monitor and research changes that are predicted for the Deer Creek watershed and surrounding region.

A few examples of climate change impacts that are applicable to the Deer Creek watershed follow, with detailed recommendations and adaptive management strategies to address these and other climate change impacts provided in the Recommendations section at the end of this Chapter:

- Reduction in snowmelt accumulation; subsequent reduction in stream flow and water availability.
- Shift in the timing of the annual spring snowmelt runoff event.
- Increased temperature- and drought-related stress on plants and wildlife.
- Movement of plant and wildlife to different elevation zones; loss of biodiversity.
- Increased frequency of extreme events including large floods, heat waves, and droughts.

Air Quality

Ground-level ozone can have severe impacts to public health and welfare, including crops, animals, buildings, and vegetation (USEPA 2011b). Impacts to human health include coughing, irritation of the airway, and pain when breathing; breathing difficulties or wheezing while outdoors or exercising; aggravation of respiratory conditions such as asthma, and increased susceptibility to respiratory illnesses including pneumonia and bronchitis; permanent lung damage with repeated exposures (USEPA 2011b). Impacts to public welfare include interfering with the ability of sensitive plants to produce and store food, which makes the plants more susceptible to diseases, insects, pollutants, competition, and extreme weather conditions; damaging leaves of trees and other vegetation; reducing forest growth and crop yields and potentially reducing species diversity in ecosystems (USEPA 2011b).

Under the Clean Air Act the U.S. Environmental Protection Agency (USEPA) is required to establish air quality standards, known as National Ambient Air Quality Standards (NAAQS), for ground-level ozone as well as five additional pollutants (particulate matter, carbon monoxide, nitrogen oxides, sulfur dioxide, lead) (USEPA 2011b). The USEPA has developed primary standards, limits set to protect public health including sensitive populations such as children, elderly, or people with asthma, and secondary standards, limits set to protect public welfare, including protection against visibility impairment, damage to animals, crops, vegetation, and buildings. **Table 7.3** summarizes the primary and secondary standards for ground-level ozone (USEPA 2011b):

	Primary Standards		Secondary Standards	
	Level	Averaging Time	Level	Averaging Time
Ozone	0.075 ppm (2008 std)	8-hour [1]	Same as Primary	
	0.08 ppm (1997 std)	8-hour [2]	Same as Primary	
	0.12 ppm	1-hour [3]	Same as Primary	

1 To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. (effective May 27, 2008); 2 (a) To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.08 ppm.
(b) The 1997 standard—and the implementation rules for that standard—will remain in place for implementation purposes as EPA undertakes rulemaking to address the transition from the 1997 ozone standard to the 2008 ozone standard. (c) EPA is in the process of reconsidering these standards (set in March 2008); 3 (a) EPA revoked the 1-hour ozone standard in all areas, although some areas have continuing obligations under that standard ("anti-backsliding"). (b) The standard is attained when the expected number of days per calendar year with maximum hourly average concentrations above 0.12 ppm is ≤ 1.

Table 7.3: Summary of ground-level ozone standards established under the Clean Air Act (USEPA 2011b).

For several years now both the USEPA and the American Lung Association have ranked Nevada County among the dozen most ozone-polluted counties in the United States (STAinNC 2011). The majority of the ground-level ozone present in Nevada County is not generated locally, with most of the ozone transported to Nevada County through prevailing air currents from the Sacramento Valley and the San Francisco Bay Area. Based on 2006 – 2008 NAAQS data for 8-hour ground-level ozone, western Nevada County has been designated a nonattainment area for ground-level ozone, with a design value of 0.091 ppm measured at the Grass Valley-Litton Building site. The design value is the 3-year average, based on 2006-2008 data, of the annual fourth highest 8-hour ozone concentration at the highest monitor (if greater than 0.075 ppm = nonattainment; if less than or equal to 0.075 = attainment) (USEPA 2011b). Western Nevada County was recommended as an existing area with nonattainment for ozone, indicating that western Nevada County was not meeting ground-level ozone standards prior to 2006 (western Nevada County was designated for nonattainment in 2004) (NSAQMD 2011). Once nonattainment designations take effect, state and local governments have a three year timeframe to develop implementation plans that outline how areas will attain and maintain the standards through reducing air pollutant emissions contributing to ground-level ozone concentrations (USEPA 2011b).

Regionally the Northern Sierra Air Quality Management District (NSAQMD) works to preserve the air quality and protect the public health and public welfare in Nevada, Plumas, and Sierra counties, and is required by state law to achieve and maintain federal and state ambient air quality standards (NSAQMD 2011). Activities undertaken by the NSAQMD include:

- Develop and implement air quality plans to identify how much pollution is in our air, where it comes from, and ways to control it.

- Develop and enforce rules and regulations that reduce air pollution and protect public health.
- Help individuals and businesses understand and comply with federal, state, and local air pollution laws.
- Operate air monitoring equipment to measure and record air pollution levels.
- Evaluate plans for new projects that involve installing, altering, or operating equipment that either causes air pollution or is used to control it; issue permits; conduct compliance inspections; and issue violation notices.
- Implement transportation control measures to reduce the number of cars on the road and promote the use of cleaner fuels and vehicles.
- Investigate public complaints and respond to inquiries regarding air pollution.
- Provide public information regarding current air quality conditions and health implications.
- Educate the public on their role in cleaning up the air.

Attainment of ground-level ozone standards is important as non-attainment results in numerous impacts to the region, including potential loss of federal funding for highways and other large infrastructure projects, increased pollution offset requirements, prohibition by the EPA of major sources of ozone being constructed, and exposure of the County to lawsuits (NSAQMD 2011).

In western Nevada County, in addition to the NSAQMD monitoring ground-level ozone, STAinNC has been monitoring ground-level ozone concentrations since 2006 in Nevada City and Grass Valley, as well as conducting outreach to the local and regional communities. In early 2011 STAinNC members approached FODC/SSI staff regarding a collaboration to continue and expand ground-level ozone monitoring and outreach to the local and regional communities, as this would fit well with the other long-term monitoring projects on-going at FODC/SSI. Collaboration between STAinNC and FODC/SSI is on-going as of February 2011 and will be expanded in the future as the primary ground-level ozone monitoring season approaches.

With population and development levels projected to increase in the future, ground-level ozone is likely to remain a considerable health and public welfare issue for Nevada County. FODC/SSI should continue to collaborate with STAinNC and expand collaborations to include agencies and stakeholders at the regional and state levels, including the NSAQMD, the California Air Resources Control Board, the County of Nevada, and downwind stakeholders and agencies in Sacramento and the San Francisco Bay Area. If governments at the local and regional level were to adopt and implement many of the smart-growth principles from the USEPA and Sierra Climate Change toolkit, it would lead to a reduction in locally generated ozone. Ground-level ozone monitoring should be expanded in western Nevada County, particularly in the Deer Creek watershed, to investigate impacts to communities where monitoring does not regularly occur. Expanded monitoring in the Deer Creek watershed could include communities such as Cascade Shores, Rough and Ready, Penn Valley, Lake Wildwood, and Smartsville. In addition, long-term studies should be conducted to investigate impacts to public health and impacts to vegetation including crops. This could be accomplished by working with local medical clinics to conduct studies, and working with local farms and the County Agricultural Committee to determine impacts to crops grown in Nevada County.

D. Water Resource Development

Justin Wood

It is important to consider the future of water resources from a management perspective. NID has Pre and Post-1914 Consumptive Water Rights to Deer Creek, and Post-1914 to the

South Fork of Deer Creek, under licenses issued by the SWRCB (NID 2005b). Post-1914 Consumptive Water Rights include direct diversion and diversion for storage (NID 2005b). Considering NID uses Deer and Squirrel Creek as canals to convey water to other lateral canals, it is important to consider future water resources managed by NID. To prepare for water management over the next 25 years NID developed a Drought Contingency Plan in 1992, Raw Water Master Plan Update in 2005, and Urban Water Management Plan in 2006. The Drought Contingency Plan was updated with the Urban Water Management Plan in 2006. These plans address various matter of concern for NID including water management during drought and hypothetical extreme drought conditions, water supply and demand over the next 25 years, infrastructure capacity, and minimum environmental flows.

To develop a plan for raw water management over the next 25 years, NID developed a Raw Water Master Plan in September 2005 that serves as the primary source of information for this section. The discussion primarily focuses on the Deer Creek Service Area, which receives its annual water supply from releases to Deer Creek via the South Yuba Canal and runoff from the Deer Creek watershed that is stored in Scotts Flat Reservoir. NID delivers an average of 55,918 acre-feet of water to the Deer Creek Service Area, a portion of which flows through the Deer Creek watershed (NID 2005b). This discussion comprises multiple sections including Water Supply Analysis, Water Demand Analysis, and Water Supply and Demand Assessment. These sections provide information on NID's current water supply and demand as well as projections of water supply and demand through 2027. It is important to be aware of NID's current and future water management plans, as these will have a direct impact on the Deer Creek watershed.

Water Supply Analysis: Introduction

NID water supply originates from the western slopes of the Sierra Nevada Mountains. NID relies on surface water to supply raw water for both irrigation and urban water uses, with water sources falling into four main categories: 1) runoff from the watershed, 2) carryover storage in the surface water reservoirs, 3) contracted purchases, and 4) recycled water (NID 2005b). To capture these water sources for supply, NID owns and operates ten storage facilities in Placer, Nevada, and Sierra counties. The amount of water NID is able to capture is based upon pre-1914, riparian, and appropriative water rights (NID 2005b). Additionally the SWRCB has issued five permits and eight licenses allowing the consumptive use of water from various sources (NID 2005b). A discussion of NID's four primary water sources is presented below.

Water Supply Analysis: Water Sources

1) Watershed storage supply is the estimated runoff from the surrounding watershed into the storage reservoirs owned and operated by NID (NID 2005b). NID staff conduct a series of snow surveys each year, to estimate the volume of water supplies for the coming

year, with considerable annual variation in the amount of water content in the snowpack (NID 2005b). Depending on snowpack conditions the total available water supply can vary greatly, from less than 100,000 acre-feet in dry water years to over 400,000 acre-feet in wet water years (NID 2005b). From 1968 to 2004 the average annual watershed runoff was 239,000 acre-feet (NID 2005b).

2) The second main category of water sources for NID is carryover storage, the amount of water left in the reservoirs at the end of the normal irrigation season (NID 2005b). NID's ten reservoirs have a combined storage capacity of 280,000 acre-feet, with NID operating their reservoirs to maintain a minimum carryover storage of 70,000 acre-feet, which includes approximately 39,675 acre-feet of dead storage that cannot be relied upon as a source of water (NID 2005b). Dead storage is water that cannot be released, either because of minimum pool requirements or water that is stored below the lowest discharge elevation (NID 2005b). Carryover storage has averaged 146,000 acre-feet from 1968 through 2004 (NID 2005b).

3) The third main category of water sources for NID is contract water. In 1963 NID and PG&E agreed to develop additional storage capacity on both Deer Creek and the Bear River, with NID having contractual obligations with both PG&E and the California Department of Fish and Game (CDFG) (NID 2005b). These contractual obligations pertain to three categories: 1) contract water deliveries, 2) minimum pool requirements, and 3) contract water purchases (NID 2005b). The 1963 PG&E Consolidated Contract requires NID to deliver water to Spaulding Reservoir for power and non-power periods based upon the mountain diversion storage (NID 2005b). Minimum pool requirements were established between CDFG and NID for five reservoirs, including Scotts Flat on Deer Creek (NID 2005b). Approximately 31,397 acre-feet of water supply has been reserved for minimum pools for environmental purposes, with a 5,000 acre-feet minimum pool requirement for Scotts Flat Reservoir, reducing the capacity from 48,547 to 43,547 acre-feet (NID 2005b). Contract water is available for purchase by NID, made possible through the 1963 PG&E Consolidated Contract (NID 2005b). In years with normal precipitation the maximum amount available is 59,361 acre-feet, with 23,591 acre-feet available in dry years (NID 2005b).

4) The fourth primary source of water for NID consists of recycled water. Four wastewater treatment plants operate within NID's service area, each of which produces treated effluent that is captured by NID as recycled water and used for irrigation (NID 2005b). The amount of recycled water captured by the NID canal system in 2004 was 2,624 acre-feet, with this volume assumed to remain constant for future water supply planning purposes (NID 2005b). If growth continues within the NID service area, it is likely that the quantity of recycled water will increase and thus so will the overall supply.

Table 7.4 provides a summary of NID's water sources, detailing water volumes for each of the four categories from 2000 through 2004: 1) watershed runoff, 2) carryover storage, 3) contract purchases, 4) recycled.

Watershed Supply (af per water year)

	Year				
	2000	**2001**	**2002**	**2003**	**2004**
Watershed Runoff[a]	218,357	89,672	199,546	250,965	182,022
Carryover Storage[b]	144,295	140,473	81,568	129,768	135,451
Contract Purchases[c]	6,365	3,959	5,387	6,305	7,122
Recycled	3,200	3,200	3,065	3,065	2,624
Total Supply	**372,217**	**237,304**	**289,566**	**390,103**	**327,219**

[a] Includes Scotts Flat, Bowman, Jackson Meadows natural inflow and Texas-Fall Creek Diversions.
[b] Storage recorded at the end of September of the previous year and reduced by unusable pool of 39,675 af
[c] Purchased under PG&E contract. Includes contract B-9 (Deer Creek), B-12 (Rock Creek and Wise).

Table 7.4: NID watershed supply in acre-feet per water year, for 2000-2004 (NID 2005b).

Water Supply Analysis: Reservoir Storage

NID water supply originates from the western slope of the Sierra Nevada Mountains, northeast of the primary NID service area. NID owns and operates ten storage facilities in Placer, Nevada, and Sierra counties, with details about each of the NID reservoirs provided in the Chapter Appendix. Deer Creek receives water from Spaulding Reservoir via the South Yuba Canal. Existing water rights and PG&E agreements allow NID to divert water from Spaulding Reservoir to three foothill reservoirs, including Scotts Flat on Deer Creek (NID 2005b). NID stores Deer Creek flows at Scotts Flat, with Scotts Flat providing the Deer Creek Service Area its water supply (NID 2005b).

NID's total reservoir storage capacity is 280,270 acre-feet with a usable volume of approximately 240,595 acre-feet, after subtracting minimum pool requirements and dead storage volume (NID 2005b). Scotts Flat has a total storage capacity of 48,547 acre-feet with a usable volume of 43,547 acre-feet after minimum pool requirements. The extent of sedimentation and its potential impact on NID's usable reservoir storage is largely unknown, with the foothill reservoirs having the greatest potential for sediment accumulation, due to the local geology and impacts from hydraulic mining activities (NID 2005b). Evidence of hydraulic mining tailings piles can be seen in the tributaries to Scotts Flat reservoir. The extent to which Scotts Flat and Lower Scotts Flat have lost usable reservoir capacity due to accumulated sediment is unknown by NID (NID 2005b). Studies should be conducted to determine the extent of sediment accumulation and the rate of sediment accumulation in Scotts Flat and Lower Scotts Flat reservoirs. As the reservoirs accumulate sediment, less runoff will be captured and stored by the reservoir, which will lead to the reservoir filling earlier in the water year. This will impact flows downstream of the reservoirs and alter the flow regime. These studies should also target heavy metals, as Scotts Flat is on the 303(d) list for Mercury contamination, and mercury often associates with suspended sediments, which are accumulating in both reservoirs.

Water Supply Analysis: NID Water Rights

The quantity of water that NID can legally capture is determined by pre-1914, riparian, and appropriative water rights. The SWRCB issued NID five permits and eight licenses allowing the consumptive use of water from various sources (NID 2005b). The 1963 Yuba-Bear Consolidated Contract and supplemental agreements with PG&E provide additional sources of water, with this agreement ending July 13, 2013 (NID 2005b). NID has Pre and Post-1914 Consumptive Water Rights to Deer Creek and Post-1914 to the South Fork of Deer Creek, under licenses issued by the SWRCB (NID 2005b). Post-1914 Consumptive Water Rights include direct diversion and diversion to storage (NID 2005b). The current volume of NID water rights is approximately 450,000 acre-feet, with an average of 356,725 acre-feet available to NID (NID 2005b).

There are numerous issues related to water rights, which NID must consider both in the short and long term. Current and/or pending action by the SWRCB and other regulatory agencies, including Federal Energy Regulatory Commission (FERC), should be considered as it pertains to water rights (NID 2005b). NID identified five primary water rights issues, four of which are discussed here:

1) SWRCB Phase 8 Decision
2) Water Rights Compliance- The SWRCB, to ensure compliance with water rights, is becoming more stringent with enforcement. NID needs to be aware of these issues and ensure they are operating in compliance with their water rights (NID 2005b).
3) Pre-1914 Water Rights Quantification- The SWRCB is clarifying and quantifying pre-1914 water rights, which could impact NID's operations (NID 2005b). A review of water rights by NID identified numerous pre-1914 water rights claims, with the full extent of these rights difficult to quantify, including rights to Deer Creek (NID 2005b). If the SWRCB pursues the opportunity to identify NID's pre-1914 water rights, quantification of these diversions may impact NID's operations.
4) 1963 Yuba-Bear Project Consolidated Contract and Supplemental Agreements Signed with PG&E- The current contract with PG&E terminates on July 13, 2013. It is anticipated that this contract, a major source of water for NID, will be renegotiated and renewed with no reduction in available contract water (NID 2005b).

5) FERC Hydro-relicensing in 2013- The Yuba-Bear FERC license (FERC #2266) expires in July 2013. As part of the relicensing process there is the potential for increased environmental flow requirements, which could impact NID operations, specifically supply (NID 2005b). NID estimates no major losses in supply, as in most instances the minimum flow can be recovered with no loss in supply. However there may be some instances where providing increased environmental flows will be a net loss to NID (NID 2005b).

NID is well situated in regards to water rights, considering the authorized water amounts currently well exceed NID's water demands (NID 2005b). The major concerns for the future are the outcomes of the PG&E contract negotiations and potential FERC relicensing requirements (NID 2005b). This is an important area to watch, as re-licensing requirements often lead to opportunities to secure in-stream flows for environmental benefits.

In regards to water rights in general, water trusts such as those in Washington and Oregon, should be investigated. It is likely that there are private property owners in the watershed that would be willing to place their water rights in a trust that secures them for in-stream flows. This would be particularly important downstream of Lake Wildwood reservoir.

Water Supply Analysis: Water Deliveries and System Losses

The Deer Creek and Bear River canal systems are the primary delivery systems used by NID for raw water. From 2000 through 2004 NID delivered an average of 201,484 acre-feet annually, with details regarding NID's water distribution provided in Tables 4-10 and 4-11 (NID 2005b). These deliveries include raw and treated water sales, water used for power generation to meet non-consumptive use demands, in-stream minimum flow requirements, and system losses (NID 2005b).

NID Water Deliveries 2000 – 2004 (af Annually)

Category	2000	2001	2002	2003	2004	Average
Deer Creek[a]	55,577	51,189	55,599	55,794	61,430	55,918
Bear River[b]	67,855	55,828	69,139	60,512	67,162	64,099
Bear River Canal[c]	77,893	59,188	79,534	80,078	81,500	75,639
PG&E Purchases[d]	6,365	3,959	5,387	6,305	7,122	5,828
Total	**207,690**	**170,164**	**209,659**	**202,689**	**217,214**	**201,484**

[a] Deer Creek = DC102+DC125
[b] Bear River = BR 301 + BR386
[c] Not an NID facility
[d] Includes contract B-9 (Deer Creek), B-12 (Rock Creek), B-12 (Wise) water

Table 7.5: Annual NID water deliveries from 2000-2004, in acre-feet (NID 2005b).

Table 7.5 details water deliveries from 2000 through 2004, with 2001 having the lowest total storage during the period (NID 2005b). This reduction in available water supply corresponds with a reduction in water deliveries, as is evident in **Table 7.5**. The distribution of the deliveries for 2000-2004 is provided in **Table 7.6**, with information regarding water deliveries, water uses, and system losses (NID 2005b).

Estimate of System losses 2000 – 2004 (af Annually)

Category	2000	2001	2002	2003	2004	Average
Water Deliveries	**207,690**	**170,164**	**209,659**	**202,689**	**217,214**	**201,484**
Water Uses						
Raw and Treated Water Sales	124,806	128,977	131,594	130,225	131,683	129,457
Deer Creek Hydro[a]	8,194	1,758	3,631	2,390	6,978	4,590
Bear River Hydro.[b]	6,615	564	13,197	3,096	3,245	5,343
Bear River Canal Hydro.[c]	34,383	17,855	36,167	36,137	37,797	32,468
Bear River min flows[d]	3,620	3,620	3,620	3,620	3,620	3,620
Total Water Uses	177,618	152,773	188,209	175,468	183,323	175,479
System Losses	30,072	17,391	21,450	27,221	33,891	26,005
Percent Losses	**16.9**	**11.4**	**11.4**	**15.5**	**18.5**	**14.8**

[a] Water in DC125 assumed only to meet hydro-generation power needs
[b] Water in BR 301 assumed only to meet hydro-generation power needs
[c] PG&E's Bear River Canal. Water in Bear River Canal assumed only to meet hydro-generation power needs
[d] 5 cfs fish release below Combie Reservoir

Table 7.6: Annual NID estimates of system losses from 2000-2004, in acre-feet (NID 2005b).

NID water sales averaged approximately 129,500 acre-feet from 2000-2004 and includes treated domestic and commercial, municipal raw water, and irrigation water customers (NID 2005b). System losses ranged from 11.4 – 18.5 percent of water deliveries with an average of 14.8%. A comparison of water supplies, water deliveries, and system losses is provided in **Table 7.7** and shows that in each year the total water supply available to NID exceeds total water deliveries by an average of 121,798 acre-feet, corresponding to the average annual carryover storage volume (NID 2005b). This indicates that NID currently has adequate water supply to satisfy consumptive water demands in the near future, with excess water available for discretionary allocations to hydropower facilities and for export flows. To evaluate whether NID has adequate water supply to meet future demands an assessment was conducted to evaluate water resources through 2027. This analysis is provided in the Water Supply and Demand Assessment.

Supply and Deliveries of NID Raw Water 2000 – 2004 (af Annually)						
	2000	2001	2002	2003	2004	Average
Total Net Deliveries	177,618	152,773	188,209	175,468	183,323	175,479
Losses	30,072	17,391	21,450	27,221	33,891	26,005
Total Deliveries	**207,690**	**170,164**	**209,659**	**202,689**	**217,214**	**201,484**
Total Supply	**372,217**	**237,304**	**289,566**	**390,103**	**327,219**	**323,282**

Table 7.7: Annual NID supply and deliveries of raw water from 2000-2004, in acre-feet (NID 2005b)

Water Demand Analysis: Introduction

Water usage within the NID system consists of multiple components including raw water demand, treated water demand, environmental flows, system losses, and export (contract) flows (NID 2005b). The Water Demand Analysis focused on:

1. Determining the current and estimated future total demand on the NID system.
2. Facilitate the assessment of system water demands in the future.

Land use changes have led to changes in demand, with an increasing trend for treated water supplies as residential development encroaches on lands currently receiving raw water (NID 2005b). To analyze current and future water demands a parcel-based GIS approach methodology was developed, which integrates current and future land development into water use projections to allow for a precise assessment of use within the service area (NID 2005b). A detailed list of data sources and the GIS methodology is provided in the Chapter Appendix.

Water Demand Analysis: Methods

To begin the analysis the historic and current canal flows were determined and are provided in **Table 7.8**, with the relevant Main Laterals including D/S and Deer Creek. This provides insight to the range of peak flows experienced in each canal segment, as well as irrigation season flows in Deer Creek, because flows delivered to Newtown, Tunnel, China Union, and Keystone canals are conveyed through Deer Creek.

Historic and Current Canal Peak Flows (cfs)

Main Lateral	Peak Monthly Flows (CFS) Actual 1987	1992	2002	2004	2002 Computed
Cascade	47	48	48	50	56[a]
Snow Mountain	7	5	6	5	5
Chicago Park	25	26	26	23	29[a]
Rattlesnake	11	12	13	13	13[a]
D/S	59	61	78	75	67[b]
Lower Grass Valley	10	10	13	13	13
Allison Ranch	6	6	8	8	8
Rough & Ready	3	3	3	4	4
Tarr	50	49	56	55	54
B	19	19	15	17	17
Deer Creek					
Newtown	16	12	15	16	16
Tunnel	23	23	29	29	29
Keystone	1	1	1	2	2
Combie Phase I	125	132	147	152	141
Magnolia III	7	7	9	10	9
Combie Phase II & III	28	27	33	32	40
Combie Ophir I	89	88	95	101	94
Camp Far West	32	36	33	39	37
Combie-Ophir II	40	39	50	45	45
Combie -Ophir IV	30	30	30	31	31
Gold Hill II	15	12	14	16	16
Fiddler Green					
Ophir Pipe	16	11	10	11	16
Edgewood	2	2	2	2	2
Auburn Ravine					
Auburn Ravine I	56	57	57	55	69
Hemphill	15	16	19	10	15

[a] Pumping occurring in recent years DS to Cascade. Cascade is limited by physical capacity constraints. NID has been pumping from the DS canal since 2002 to meet irrigation demands.
[b] DS demands minus pumped flow to Cascade.

Table 7.8: NID data for historic and current peak canal flows in cubic feet per second (cfs) (NID 2005b).

The historic data indicate a wide range of variability in flows in particular canal segments from year to year. The 2002 computed value is the value calculated by the GIS Model and shows that the model provides reasonable estimates of current peak flows in each canal segment and thus should be capable of projecting flow demands in the future.

Water Demand Analysis: Results

Analysis of the Deer Creek canal service area soft boundaries was conducted to estimate the geographic extent of parcels that could be served in the future by the District's existing raw water system (NID 2005b). The service area soft boundaries indicate that the Deer Creek System could reasonably serve an area of 92,030 acres or approximately 144 mi^2 (NID 2005b). In 2001 NID was delivering water to 38,447 gross acres or approximately 60 mi^2 within these raw water service area soft boundaries, corresponding to 41.8% of the service area (NID 2005b). Using growth rate data (as described in the Appendix), the model estimated the total gross area that would be receiving water in 2027 to be 60,253 acres for the Deer Creek system, which results in an overall saturation of 65% (NID 2005b). The analysis targeted an upper saturation or build-out limit of 80% (NID 2005b). A map of the Deer Creek Service Area is provided in the Appendix.

The results of the irrigation season water demand analysis provide insight to the future of Deer Creek. **Table 7.9** summarizes the results of the Irrigation Season water demand analysis, with peak canal flow projections for each main lateral canal through 2027. Schematic 5-4 in the Chapter Appendix provides more detail for each of the major laterals listed in **Table 7.9**, with gage locations and the method of calculating flows to derive the total values for each system (NID 2005b).

The model estimated the total current peak demand for the Deer Creek System to be 157.8 cfs, which compares closely to the actual 2002 peak value of 157.2 cfs from NID gage data (NID 2005b). The Deer Creek subsystem has a current peak demand of 101.7 cfs, with a peak demand of 34.3 cfs in Deer Creek downstream of Lower Scotts Flat Reservoir (NID 2005b). It is important to note that the Deer Creek system downstream of Scotts Flat Reservoir is quite complex, due to a considerable portion of the water in Deer Creek consisting of return water and natural runoff from perennial tributaries (Little Deer, Gold Run, Mosquito, Slate Creeks). Return flow is accounted for in the flow analysis but natural runoff is not directly measured, and for this reason not all of the flow required by the Newtown and Tunnel canals, and Lake Wildwood water treatment plant and other canal segments downstream of Lake Wildwood reservoir are a demand on system storage (NID 2005b). This is demonstrated by the gage at the outlet of Lower Scotts Flat (DC124) reporting a 2002 peak flow of 34.3 cfs and an average of 21.2 cfs, with the total peak downstream demand totaling 50.4 cfs. NID staff indicates that gage data reported by DC124 is reliable and accurate and that the difference in flows between the gauged flows and the demand values is a direct result of return flow and natural runoff from perennial tributaries (NID 2005b). Therefore the releases from Lower Scotts Flat represent the system demand, with demand calculations using the DC124 gage data to assess total system demand. This could impact future projections, as any change to return flows or natural runoff in the future would require more flow from storage. As an indicator of this potential impact, NID estimated that a draw from storage of an additional 10 cfs for sixty days during the irrigation season would equate to approximately 1,200 acre-feet of water (NID 2005b).

Summary of Irrigation Season Demand for the Deer Creek System

ESTIMATED PEAK CANAL FLOWS (cfs)	Computed 2002	2007	2012	2017	2022	2027
Deer Creek System Total Flow (cfs)	158.0	184.6	201.2	218.7	234.1	244.2
Cascade Canal at Head (DC 102) [1]	56.2	72.7	83.6	94.8	104.1	107.8
Snow Mountain Canal at Head (DC 118)	5.4	5.2	5.7	5.9	6.0	6.2
Loma Rica Water Treatment Plant (High Est.)	9.70	11.40	11.70	13.60	15.30	15.70
Elizabeth George Water Treatment Plant (High Est.)	12.39	16.30	22.50	27.20	31.20	31.50
Chicago Park at Head (DC 105)	28.8	39.7	43.7	48.1	51.5	54.4
Rattlesnake at Head	13.3	22.9	25.3	28.1	29.8	31.6
Deer Creek (d/s of Lower Scotts Flat Lake)	101.7	112.0	117.7	123.8	130.0	136.4
DS Canal at Head (DC 145)	67.4	75.9	80.0	84.1	88.2	92.5
Lower Grass Valley at Head (DC 148)	12.8	13.7	14.6	15.7	16.9	18.0
Tarr at Head (DC 169)	53.6	59.8	62.0	64.3	66.4	68.6
DEER CREEK[2] (DC 124)	34.3	36.0	37.7	39.7	41.7	43.9
Newtown Canal at Head (DC 131)	15.3	16.4	17.4	18.7	20.2	21.7
Tunnel at Head (DC 140)	28.7	29.7	30.9	32.1	33.3	34.5
Lake Wildwood WTP	6.4	7.5	8.2	9.6	11.1	12.8

1 Analysis assumes no pumping flow from DS canal. Banner Cascade Pipeline is in place.
2. Flow to Deer Creek below Scotts Flat dam is sum of flows from DC124 plus return flow and natural inflow. Only flow measured at DC124 is included in total demand calculations.

Table 7.9: Summary of NID irrigation season demand for the Deer Creek system (NID 2005b).

From **Table 7.9** it is evident that peak irrigation season demand will increase through the year 2027, which means more water being conveyed through Deer Creek to lateral canals over time. DC124 indicates a peak demand of 34.3 cfs in 2002 with an increase to 43.9 cfs in 2027, corresponding to an increase of 1.7-2.2 cfs every five years. The results of the demand analysis indicate that the Deer Creek system has an average flow of 157.8 cfs with a corresponding peak flow of 157.8 cfs in 2002, and an increase in average flows to 171.3 cfs and peak flows to 251.6 cfs in 2027. This means an increasing amount of water will be conveyed through Deer Creek through 2027 and likely beyond that time, which has important implications for the Deer Creek ecosystem. This will, in some cases, push some canal segments over their current peak flow capacity, with many canals already at conveyance capacity (NID 2005b)

Water Supply and Demand Assessment: Introduction

To address whether existing water supplies are adequate to accommodate future water demand, NID's water supplies were compared against existing and projected future water demands. In order to assess NID's future supply and demand conditions it is important to understand the components of supply, delivery, and demand. Total supply is the total volume present within the system and available to NID, including watershed runoff, carryover storage, contract water, and recycled water (NID 2005b). Deliveries consist of the total supply conveyed to the system to meet allocated uses, and is the sum of volume of water supplies for uses such as raw water and treated water sales, environmental flows, and any discretionary uses by NID such as hydroelectric operations, with the difference between total supply delivered and total supply utilized corresponding to system losses (NID 2005b). Demand volumes consist of required deliveries for consumptive use, including water sales, environmental flows, and system losses (NID 2005b). The following two paragraphs provide a brief discussion of considerations taken into account for the water supply and demand assessment.

Historical data indicate a wide range of variability in total water supply volume, subject to a variety of conditions. The primary cause of variations in water supply volume is the annual fluctuations in rainfall and snowpack conditions, with the long-term annual precipitation average varying up to 40% (NID 2005b). The second major component of supply, carryover storage, is set at a minimum of 70,000 acre-feet, providing a buffer in case the following year is dry (NID 2005b). Carryover storage is dependent upon runoff and demands from the previous year. It is used to reduce the need for contract water and to provide a place to store water during wet years, and is impacted by reservoir capacities and minimum pool requirements (NID 2005b). Currently there is sufficient reservoir storage volume to maintain full demand deliveries during a multi year drought (NID 2005b).

Data indicate that the baseline total system demand in 2002 was approximately 152,000 acre-feet, which represents total required delivery demands, minimum flows, and system losses (NID 2005b). Water demand for 2027 was projected, based on current uses and growth projection within NID's service area, to be 212,000 acre-feet (NID 2005b). The demand analysis set the cap for saturation, or total build out, at 80%. Many canal segments are currently reaching this build out capacity, with the NID saturation level in 2027 approaching 64% (NID 2005b). **Table 7.10** provides a detailed overview of current and future water demands, projected at 5-yr intervals from 2002 through 2027.

Current and Future Water Demands

Demand	2002	2007	2012	2017	2022	2027
Irrigation Season Demand (includes raw and treated water demands and losses)						
Deer Creek Irrigation Season Demand (cfs)	110	134	145	155	165	171
Bear River Irrigation Season Demand (cfs)	201	229	243	257	269	281
Total Irrigation Season Average Demand (cfs)	310	364	388	412	434	452
Total Irrigation Season Demand (Acre feet)	112,595	131,941	140,725	149,509	157,459	164,065
Winter Water Demand (includes raw and treated water demands and losses)						
Deer Creek Winter Water Demand (cfs)	28					
Bear River Winter Water Demand (cfs)	60					
Total Winter Water Average Demand(cfs)	88	93	97	101	106	109
Total Winter Water Demand (Acre-feet)	31,906	33,648	35,158	36,827	38,454	39,412
Total Average Demand (cfs)						
Treated Water Average Demand[a] (peak/2.5)	17	22	26	31	35	38
Total Net Irrigation Season Average Demand (cfs)[b]	293	341	361	381	398	414
Total Net Winter Water Average Demand (cfs)[c]	70	70	70	70	70	70
Total Annual Average Demand (cfs)	380	433	457	482	503	1006
Total Demands (acre feet)[d]						
Treated Water Total Demand (acre-feet)	12,661	16,145	19,165	22,504	25,757	27,673
Raw Water Annual Demand (acre-feet)	131,839	149,444	156,718	163,833	170,155	175,804
Environmental Flow (acre-feet)	7,700	7,700	7,700	7,700	7,700	7,700
Total Annual Demand (acre-feet)	152,200	173,289	183,583	194,037	203,612	211,177

[a] Treated Water Average Demand = (M & I Peak Treated Water Demand)/2.5; as provided by NID.
[b] Net Irrigation Season Demand = Total Irrigation Season Demand – (Total Treated Water Demand/2).
[c] Net Winter Raw Water Demand is assumed to be constant at 70 cfs.
[d] Demand does not include contract sales such to South Sutter or other District deliveries.

Table 7.10: NID current and projected future water demands (NID 2005b).

Water Supply and Demand: Results

The results of the water supply and demand analysis indicate that NID has sufficient water supply to meet projected water demands through the year 2027 (NID 2005b). The current average annual runoff of 206,000 acre-feet is sufficient to meet the current water demands. However, based on data in **Table 7.10** the projected demand in 2022 will approach the average annual watershed runoff volume (NID 2005b). This will require careful consideration of increasing the carryover storage and contract water purchases, with supply components in the historical range leading to minimum contract water purchases (NID 2005b). Contract water typically amounts to less than 10,000 acre-feet. However, the 1963 Agreement with PG&E allows for the purchase of up to 59,361 acre-feet in years with normal precipitation and 23,591 acre-feet in dry years (NID 2005b). In addition to the considerations regarding carryover storage and contract water, NID will need to evaluate the current non-required deliveries that are made for hydropower production (NID 2005b). To address potential shortages through 2027, a drought analysis was performed for existing demands and projected demands through 2027.

A drought analysis was conducted to determine the water supply during scenarios, historic and hypothetical droughts, with the first scenario based on the three-year dry period from 1990 through 1992 (NID 2005b). **Table 7.11** shows water supply operations during the historic worst three-year drought period with existing water demands. **Table 7.10** indicates that NID would have sufficient water supply to satisfy existing water demands without declaring a drought emergency and implementing the demand reductions, but water used for power generation would be stored during dry years to ensure water availability for consumptive uses (NID 2005b). The results of the drought analysis indicate that NID currently has sufficient supply to cover both single and multiple year droughts. To determine if NID can meet projected 2027 demands during multiple dry years, further analysis was performed.

Historic Worst 3-Year Drought with Existing Demands

	Average Year	Hypothetical Drought Year-1	Year-2	Year-3
Watershed Runoff[a]	239,000	140,824	138,469	100,874
Carryover Storage[b,c]	106,000	106,000	104,248	100,141
Contract Purchases[d]	7,000	7,000	7,000	7,000
Recycled[e]	2,624	2,624	2,624	2,624
Total Supply	354,624	256,448	252,341	210,639
Drought action stage	I (0%)	I (0%)	I (0%)	I (0%)
Total Demand with reduction[f,g]	152,200	152,200	152,200	152,200
Shortage with reduction	0	0	0	0

a Assumed 1990-1992 watershed runoff
b Carryover storage is average annual carryover storage reduced by unusable pool of 39,675 af
c Carryover Storage = remainder of the difference between total supply and total demands of the previous year. Zero carryover storage means the unusable pool of 39,675 af remains
d Hypothetical drought shows no demand reduction and no need to increased purchased volume. Contract conditions with PG&E establish maximum dry year purchase of up to 23,591 af. This is subject to contract renewal with PG&E. In typical climate conditions, NID purchases an average of 7,000 af per year from PG&E. Purchased volume set equivalent to current average volume.
e Assumed constant recycled water supply
f Existing agricultural, municipal, institutional, and environmental demands; does not include releases for hydropower generation
g Reduced by water shortage contingency plan demand reduction goal

Table 7.11: NID scenario of a hypothetical historic 3-year drought, based on existing water demands.

Table 7.12 shows potential operations, based on the historic worst three-year drought period, with water demands projected for 2027. The results indicate that with the estimated water demands in 2027, NID would need to implement measures in their Drought Contingency Plan (NID 2005b). The Drought Contingency Plan is provided in the Chapter Appendix. This would require NID to declare increasing drought action stages as the drought continued, as identified in the Drought Contingency Plan, with a 35% reduction in consumptive demand required to proceed through the year while maintaining the necessary carryover storage (NID 2005b). Drought conditions of this magnitude and duration will likely impact Deer Creek, as NID will deliver less water through Deer Creek for irrigation purposes, with a decrease in the duration of the irrigation season. This might also mean less water returning to Deer Creek downstream of Lake Wildwood, via Squirrel Creek, as NID would pass less water through the system to these downstream reaches of the watershed. This has important implications for aquatic and riparian organisms. The second scenario involves evaluating NID water supplies during an extreme hypothetical drought with existing and projected 2027 demands.

Historic Worst 3-Year Drought with 2027 Demands

	Average	Hypothetical Drought		
	Year	Year-1	Year-2	Year-3
Watershed Runoff[a]	239,000	140,824	138,469	100,874
Carryover Storage[b,c]	106,000	106,000	45,331	51,677
Contract Purchases[d]	7,000	7,000	23,591	23,591
Recycled[e]	2,624	2,624	2,624	2,624
Total Supply	354,624	256,448	210,015	178,766
Drought action stage	I (0%)	I (0%)	III (25%)	IV (35%)
Total Demand with reduction[f,g]	211,117	211,117	158,338	137,226
Shortage with reduction	0	0	0	0

a Assumed 1990-1992 watershed runoff
b Carryover storage is average annual carryover storage reduced by unusable pool of 39,675 af
c Carryover Storage = remainder of the difference between total supply and total demands of the previous year. Zero carryover storage means the unusable pool of 39,675 af remains
d Assumed maximum dry year purchase of 23,591 af, subject to contract renewal by PG&E
e Assumed constant recycled water supply
f Projected 2027 agricultural, municipal, institutional, and environmental demands; does not include releases for hydropower generation
g Reduced by water shortage contingency plan demand reduction goal

Table 7.12: NID scenario of a hypothetical historic 3-year drought, based on projected demands in 2027.

Previous analysis focused on comparing existing and projected 2027 water supply and demands to a historic three-year drought. To evaluate NID water supplies in a much more extreme drought, a hypothetical single year and multiple year drought analysis was conducted. The hypothetical extreme drought represents years in which 50% of the runoff during the historic three-year drought (1990-1992) is available (NID 2005b). **Table 7.13** provides the results of the hypothetical drought analysis with existing (2004) NID water demands and indicates that with water supplies reduced by half, the Drought Contingency Plan would need to be implemented (NID 2005b).

Table 7.13 shows that in the first year of the drought a 15% reduction in demand would be required, corresponding to a Drought Action Stage I for years when the total supply, excluding PG&E purchases, is less than 225,000 acre-feet (NID 2005b). Demands of 35% would be required in the second and third years of the extreme drought, corresponding to Drought Action Stage IV, in order to provide sufficient carryover storage (NID 2005b).

Extreme Hypothetical Drought with Existing Demands[a]

	Average	Hypothetical Drought		
	Year	Year-1	Year-2	Year-3
Watershed Runoff[a]	239,000	70,412	69,235	50,437
Carryover Storage[b,c]	106,000	106,000	56,666	53,186
Contract Purchases[d]	7,000	7,000	23,591	23,591
Recycled[e]	2,624	2,624	2,624	2,624
Total Supply	354,624	186,036	152,116	129,838
Drought action stage	I (0%)	II (15%)	IV (35%)	IV (35%)
Total Demand with reduction[f,g]	152,200	129,370	98,930	98,930
Shortage with reduction	0	0	0	0

a Assumed 50 percent reduction of the 1990-1992 watershed runoff
b 2004 carryover storage is average annual carryover storage reduced by unusable pool of 39,675 af
c Carryover Storage = remainder of the difference between total supply and total demands of the previous year. Zero carryover storage means the unusable pool of 39,675 af remains
d Assumed maximum dry year purchase of 23,591 af, subject to contract renewal by PG&E
e Assumed constant recycled water supply
f Existing agricultural, municipal, institutional, and environmental demands; does not include releases for hydropower generation
g Reduced by water shortage contingency plan demand reduction goal

Table 7.13: NID scenario of a hypothetical extreme drought, based on existing water demands.

Discussion

The analysis in this section focused on NID water resources and attempted to quantify existing and long-term water supply and demands, describe long-term water supplies including a drought contingency plan, and provide guidelines for future maintenance and management of raw water operations. This included analysis and discussion of NID water sources, reservoir storage, water rights, water deliveries and system losses, water demand, and operations during extreme drought scenarios. The results of this analysis indicate that NID has adequate water rights to meet expected future growth and demands through 2027 (NID 2005b). The water supply and demand analysis indicates that NID has sufficient supply to meet both current and projected demand under normal conditions (NID 2005b). However, based on the projected demand there could be an insufficient water supply for NID if the average annual runoff volume were to decrease (NID 2005b).

NID estimates current total system losses to be approximately 15% of delivery volume, a volume typical of water management systems such as NID's (NID 2005b). The quantity of system losses becomes a greater concern in the future, with losses projected to increase to nearly 32,000 acre-feet annually by 2027 (NID 2005b). With demand projected to increase to near supply levels by 2027, system losses become increasingly important and an obvious target area for improvements. If NID were to address many of these system losses, such as operation waste or over delivery, it would have direct impacts on Deer Creek, with less water potentially available in the creek. NID has been installing flow gauges, to better monitor water levels and deliveries through the system (NID 2005b). These flow gages will help address system losses due to over delivery and operation waste. One aspect of system losses that is not addressed by NID in the Raw Water Plan is impacts related to climate change. If the environment continues to warm, system losses due to evaporation will undoubtedly increase, which is not accounted for in the analysis. Additionally climate change is projected to alter snowmelt and runoff dynamics, causing impacts to NID's water management system, with much of the system based and dependent on the historical timing of spring runoff and snowmelt.

While it appears NID may have adequate water, some infrastructure improvements are needed in the future, in order for NID to meet water demand. Analysis of NID's conveyance systems indicates that nineteen of NID's canal segments are either at or near current capacity, and will be unable to accommodate projected peak flows in 2027 (NID 2005b). This includes the China Union, Newtown, Rough and Ready, Keystone, and Tunnel canals in the Deer Creek watershed, with the Newtown Canal one of two highest priority canals, and indicates that NID intends to initiate capital improvement projects to upgrade these canals. Some of these repair and maintenance activities are as basic as removing and clearing excess sediment and vegetation, but this is not the case with all of the canals where major upgrades are needed to accommodate future demands. It is important that FODC be involved in these projects from the start, as they will have an impact on the project sites and watershed as a whole.

The drought contingency analysis indicates that NID has adequate supply to cover a one-year drought without implementing any drought management measures, but multiple dry years will prompt implementation of drought management measures in accordance with the Drought Contingency Plan (NID 2005b). An extreme hypothetical three-year drought was analyzed, with results indicating NID would have to reduce water deliveries by up to fifty percent in the second and third years of the drought (NID 2005b). It is possible based on the historic period of record and tree ring data that an extreme drought of longer than three years could occur, prompting an extended drought scenario that is not explored by NID in their drought contingency plan.

One aspect that could alter NID water management operations is the FERC process that is currently underway for NID's Yuba-Bear Hydroelectric Project. This process is discussed in the previous sections but it is difficult for NID to project what types of changes could result from the FERC re-licensing process. NID could potentially be forced to increase the allotment of in-stream environmental flows downstream of some of their reservoirs, which would affect water supply and operations. Although none of the NID reservoirs on Deer Creek is currently going through re-licensing, it is important to monitor and participate in this on-going process, because NID's Deer Creek Service Area receives significant water diversions through conveyance systems that are involved in the FERC process.

E. Regulatory Context

Justin Wood

Several local, State, and Federal laws and regulations form the regulatory framework governing Deer Creek. This includes the Federal Clean Water Act, Endangered Species Act, the California Central Valley Regional Water Quality Control Board Basin Plan, and California Department of Fish and Game Fish & Game Code to name a few. It is important to discuss the regulatory context that governs Deer Creek, as many of the recommendations and restoration projects in this plan will require coordination with regulatory agencies at the Federal, State, regional, and local levels.

Federal Regulatory Context

Several sections of the Clean Water Act (CWA) establish water quality standards that must be met, including both numerical and narrative standards. Under section 401 of the CWA and section 13240 of the Porter-Cologne Water Quality Control Act, activities that may result in a discharge to a water body must apply for and obtain State Water Quality Certification, indicating that the proposed activity will be in compliance with state water quality standards. These water quality standards include beneficial uses of water for drinking, recreation, fish and wildlife habitat, agriculture, navigation; objectives including both numerical and narrative limits on water quality characteristics; and the anti-degradation policy in which implementation procedures identify the steps and questions to be addressed when regulated activities are proposed that may affect water quality, and to protect or maintain existing high quality waters (USEPA 2009).

Section 303 of the CWA requires that water bodies be assessed for compliance with a list of water quality standards and, if found to be out of compliance, a plan must be developed that will bring the water body into compliance. This plan is known as the Total Maximum Daily Load, or TMDL. As mentioned above, numerous sections of creeks in the Deer Creek watershed are 303(d) listed, with FODC data submitted to the State as part of the TMDL process to list additional sections of creek. These listings will eventually result in a TMDL being developed to address the problem.

Section 404 of the CWA regulates the discharge of dredged and fill material into waters of the United States, and includes riparian areas and wetlands. Section 404 establishes authority to regulate a wide range of projects, including filling in water bodies or drainages for land development, infrastructure development, water resource development, in-stream restoration projects, and conversion of wetlands to uplands. In addition to discharges of dredged or fill material the CWA authorizes the National Pollutant Discharge Elimination System (NPDES) permit program, which controls water pollution through regulation of point sources that discharge into waters of the United States.

If an action is subject to a section 401 or section 404 permit, or an endangered species may be present within the project area, additional requirements exist at the federal level. This includes interagency consultation under Section 7 of the Endangered Species Act (ESA), with the National Marine Fisheries Service (NMFS) and US Fish and Wildlife Service (USFWS). The USFWS manages land and freshwater species, with NMFS managing marine and anadromous species. In addition to the biological consultations and requirements, additional Federal requirements exist for cultural and historic resources. Section 106 of the Natural Historic Preservation Act requires Federal agencies to consider the effects of their actions on historic properties and cultural resources. This involves a review process under Section 106 and requires consultation with the California State Historic Preservation Office to determine if an action will affect historic properties.

Additional laws administered by the EPA and potentially applicable to the Deer Creek watershed include:

- National Environmental Policy Act (NEPA), 1969: Establishes a broad national framework for environmental protection; assures that all branches of government properly consider the environment prior to undertaking an action on federal land that affects the environment (USEPA 2010). NEPA typically results in the development of Environmental Assessments or Environmental Impact Statements, which detail the likelihood of impacts from courses of action (USEPA 2010).
- Resource Conservation and Recovery Act (RCRA), 1976, amended 1984: Provides the EPA with authority to control and regulate hazardous waste, including the generation, transportation, treatment, storage, and disposal of hazardous waste (USEPA 2010). RCRA gives authority to the California Department of Toxic Substances Control (DTSC) to regulate hazardous waste within the state.
- Toxic Substances Control Act (TSCA), 1976: Gives EPA the authority to require reporting, record-keeping, and testing requirements, and restrictions pertaining to chemical substances and/or mixtures. The TSCA addresses the production, importation, use, and disposal of chemicals including PCB's, asbestos, radon, and lead-based paint (USEPA 2010).
- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund), 1980: Established a Federal "Superfund" to assist with cleanup of uncontrolled or abandoned hazardous waste sites, or emergencies (accidents, spills, releases) in which pollutants and contaminants are released into the environment (USEPA 2010). The EPA, when possible, identifies potentially responsible parties and requires their participation in the cleanup. If no potentially responsible party can be identified, the EPA cleans up the sites. The Superfund Amendments and Reauthorization Act (SARA) of 1986 reauthorized CERCLA to cleanup activities around the nation (USEPA 2010).

State and Regional Regulatory Context

The most applicable State regulatory agencies, when discussing an activity that involves a water body, are the State Water Resources Control Board (SWRCB), the nine Regional Water Quality Control Boards (RWQCB), with the Deer Creek watershed located in the Central Valley Region, the California Department of Fish and Game (CDFG), and the California Natural Resources Agency (CNRA). In addition, the California Environmental Quality Act (CEQA) requires state and local agencies to identify the environmental impacts of their actions and to avoid or mitigate those impacts if feasible.

The mission of the CNRA is to protect, manage, and restore the state's natural, historical, and cultural resources. The mission of the CDFG is to manage California's diverse fish, wildlife, and plant resources, and the habitats upon which they depend, for their ecological values and for their use and enjoyment by the public (CDFG 2010). Created in 1967, the goal of the SWRCB is to ensure the highest reasonable quality for waters of the State, while allocating those waters to achieve the optimum balance of beneficial uses (SWRCB 2010). The nine RWQCB's have a mission to develop and enforce water quality objectives and implementation plans, to best protect the beneficial uses of the State's waters, while recognizing local differences in climate, topography, geology, and hydrology (SWRCB 2010). Each Regional Board must develop a Basin Plan for their jurisdiction, take enforcement action against violators, issue waste discharge permits, and monitor water quality (SWRCB 2010).

The Basin Plan, administered by the Central Valley Regional Water Quality Control Board recognizes that Deer Creek is used as a municipal and domestic drinking water supply, and also recognizes the following beneficial uses, some of which are not applicable to the Deer Creek watershed:

- Municipal and domestic supply
- Industrial service supply
- Groundwater recharge
- Navigation
- Water contact recreation
- Commercial and sport fishing
- Warm freshwater habitat
- Migration of aquatic organisms
- Preservation of special significance biological habitats
- Spawning, reproduction, and/or early development
- Rare, threatened, or endangered species
- Agricultural supply
- Industrial process supply
- Freshwater replenishment
- Hydropower generation
- Non-contact water recreation
- Aquaculture
- Cold freshwater habitat
- Shellfish harvesting
- Wildlife habitat
- Estuarine habitat

In general, the Basin Plan requires that these beneficial uses be protected in perpetuity, but the plan provides little guidance on the priority of the various uses or how to resolve disputes when beneficial uses are in conflict.

Local and Municipal Regulatory Context

At the local level, multiple agencies and municipalities may have authority over a given activity, depending on the location in the watershed and nature of the activity. The Nevada County Community Development Agency, including the Planning Department and Building Department, regulate many development activities including grading and building. The NCEHD implements a range of state and local laws affecting the public health of citizens of Nevada County. In Nevada City the Public Works and Engineering Department may have regulatory authority over a project. Within Lake Wildwood the Board of Directors, Public Works Department, and Environmental Management Office may have authority over activities that occur within the community limits, with the Lake Committee acting on many conservation related issues.

F. Recommendations

Sol Henson

- **Continue long-term monitoring in the Deer Creek watershed.**
  Long-term water quality, biological, hydrological, geomorphological, and physical habitat data will be important for evaluating the impacts associated with population growth and development, climate change, and water resources development. Opportunities to expand monitoring capacity, such as collaborating with Save the Air

in Nevada County (STAinNC), should be investigated so that a long-term dataset is established for parameters that are not currently monitored by Friends of Deer Creek. Long-term weather stations should be established at locations in the watershed not currently monitored by the National Weather Service.

- **Work with private landowners in the Deer Creek watershed, to place conservation easements on their properties or to acquire land that will be set aside for conservation; establish to the extent possible a natural buffer zone along Deer Creek and its tributaries, through land acquisitions, conservation easements, and building ordinances.**
  There are many properties in the Deer Creek watershed that are not currently developed, but have development potential. Friends of Deer Creek should work with the Nevada County Land Trust and willing property owners to set aside properties for conservation whenever possible. Attempts should be made to establish a natural buffer zone along perennial tributaries in the watershed, with efforts focused on expanding to parcels adjacent to existing conservation easements, such as the 158 acre Hahn Easement on upper Deer Creek and the 114 acre Sheatsley Family Trust Easement on lower Deer Creek and Squirrel Creek.

- **Support the development of scientifically sound zoning and building regulations that protect creek health, including best management practice guidelines for preventing erosion associated with development.**

- **Ensure major development projects in the watershed comply with existing regulatory laws and requirements, so that the health of the ecosystem is protected and appropriate mitigation measures are implemented to offset impacts to the environment.**

- **Develop partnerships with neighborhood associations throughout the Deer Creek watershed, to disseminate information.**
  Numerous neighborhood associations and/or stakeholder groups exist in the Deer Creek watershed, including the Champion Mine Neighborhood Association and the Friends of Lower Deer Creek stakeholder group. Information should be disseminated regarding Best Management Practices for preventing erosion from development and land management practices that mitigate impacts caused by climate change.

- **Research changes and updates to climate change scenarios, climate models, and major climate change related reports.**
  As more research is done on climate change, models will become more refined, leading to more accurate predictions of future climate change-related impacts at

increasingly small spatial resolutions. In addition the Intergovernmental Panel on Climate Change will continue to meet and publish reports on climate change. All of these changes are important because they will help predict how the Deer Creek watershed and surrounding region will be impacted by a changing climate.

❖ **Adopt adaptation and mitigation strategies such as those listed in The Sierra Nevada Alliance's Sierra Climate Change Toolkit, which includes numerous suggestions that can be undertaken at varying spatial scales by local and regional government agencies, private landowners, and watershed organizations to address development and climate change impacts.**
These include community-scale and site-specific recommendations. The following provides some examples of strategies for local and regional government agencies and community groups, from the Sierra Climate Change Toolkit (Alliance 2007).

1. Prioritize projects that will succeed under multiple scenarios
Community Based:

- Promote infill and transit-oriented development.
- Encourage compact, orderly concentric outward growth.
- Cluster development.
- Don't build in unsafe places (Wildfire).
- In unsafe places, build in safe patterns to minimize exposure to environmental hazards.
- Adopt climate-friendly zoning and building codes.
- Reduce human water demand and change water use behavior.

Site Specific:

- Ensure that building structures withstand future climate change.
- Use water wisely.
- Design site layouts to be climate change friendly.
- Design outdoor spaces for a changing climate.
- Create defensible space.
- Use ignition resistant materials.

2. Use adaptive management strategies to maintain flexibility
Community Based:

- Examine climate change impacts and adaptation strategies as part of CEQA review.
- Preserve habitat connectivity
- Invest in new technologies to develop new water supply and improve reliability for human consumption and our environment.
- Encourage greater water efficiencies.
- Create adaptive wildfire management plans.

Site Specific:

- Install water meters where possible.

3. Monitor and track changes in weather, hydrology, and ecosystems

- Build water sustainable communities.

4. Integrate and coordinate local efforts

- Integrate land use and transportation planning.
- Use financial incentives to encourage conservation and smart growth.
- Plan at the landscape level.
- Support better land use planning.
- Bring fire and emergency agencies to the table
- Change county building codes and General Plans
- Promote conservation pricing and water recycling

❖ **Work with communities to implement smart growth principles**

Smart growth includes a range of conservation and development strategies that help to protect the natural environment while making communities more attractive, economically stronger, and more socially diverse (USEPA 2011a). Using smart growth principles, development can be guided to minimize air and water pollution, encourage Brownfields clean up and reuse, and preserve natural lands (USEPA 2011a). Smart growth practices reduce the environmental impacts associated with development, using techniques that include compact development, a reduction in impervious surfaces, improved on-site water retention through green infrastructure, safeguarding of environmentally sensitive areas, providing a mix of land uses including homes, offices and shops, transit accessibility, and improved pedestrian and bicycle amenities (USEPA 2011a). Friends of Deer Creek should work with the communities of Nevada City, Penn Valley, Lake Wildwood, and Rough and Ready to encourage implementation of smart growth principles. Brownfields clean up and reuse projects are currently underway in Nevada City, with potential to expand to additional contaminated properties.

A few smart growth strategies for communities dealing specifically with climate change include:

1. Discourage building in existing or projected floodplains.
2. Upgrade existing storm water systems to better manage higher storm flows; consider methods such as green infrastructure to reduce the amount of runoff from impervious surfaces.
3. Coordinate transportation infrastructure and land use decisions, incorporating climate change projections into these decisions.
4. Preserve large, contiguous areas of open space, to better protect ecosystems that are likely under pressure from climate change.
5. Encourage energy- and water-efficient buildings and land use patterns, so that communities can continue to thrive if energy prices rise.

Based on the experience of communities throughout the United States that have utilized smart growth approaches to create and maintain great neighborhoods, the Smart Growth Network developed a set of ten basic smart growth principles (USEPA 2011a):

1. Mix land uses
2. Take advantage of compact building design
3. Create a range of housing opportunities and choices
4. Create walkable neighborhoods
5. Foster distinctive, attractive communities with a strong sense of place
6. Preserve open space, farmland, natural beauty, and critical environmental areas
7. Strengthen and direct development towards existing communities
8. Provide a variety of transportation choices
9. Make development decisions predictable, fair, and cost effective
10. Encourage community and stakeholder collaboration in development decisions

❖ **Collaborate with the Nevada Irrigation District on projects such as infrastructure upgrades and water management.**

NID's Raw Water Master Plan indicates that sections of several canals in the Deer Creek watershed will need to undergo improvements over the next twenty-five years, to accommodate water delivery demand. Friends of Deer Creek should collaborate with NID on these projects to monitor the impacts to the aquatic ecosystem and ensure appropriate mitigation measures are implemented to protect ecosystem health. In addition, Friends of Deer Creek should work with NID to encourage water management that benefits ecosystem health. This includes appropriate management of water at the end of irrigation season, so as to not de-water the creek and strand aquatic organisms; experimenting with water management during winter and summer months, to promote small and large floods in order to restore geomorphic function and the riparian zone along upper Deer Creek; monitoring the impacts of climate change on water resources; ensuring that flow in lower Deer Creek downstream of Lake Wildwood reservoir meets the 5.0 cfs or natural flow requirement, to provide adequate in-stream flows for Chinook salmon and steelhead in Deer Creek. Rood et al. (2005) showed that proper flow management downstream of dams during high flow years can enable extensive riparian vegetation recruitment and improvements to river and floodplain function, while still providing sufficient water for environmental and economic needs. This type of restoration work should be explored with NID on Deer Creek.

❖ **Work with NID to explore the possibility of conducting a mercury and sediment removal study at Scotts Flat reservoir.**

Currently such a study and project is being implemented at Combie Reservoir on the Bear River. This pilot study, if successful, could potentially be used to remove mercury and contaminated sediment stored in Scotts Flat reservoir. Scotts Flat reservoir is 303(d) listed for mercury impairment and this type of restoration project might be needed to restore the health of this water body so that it satisfies all beneficial use requirements.

- **Conduct additional investigation into the regulatory opportunities of, and constraints on, maintaining healthy flows in the entire Deer Creek watershed, especially in the lower sections downstream of NID's major diversions and Lake Wildwood Reservoir, and mechanisms for increasing summer flows in this section to improve watershed health.**
  Lake Wildwood Association water rights indicate that Lake Wildwood reservoir must pass through a minimum of 5 cfs or the natural flow in lower Deer Creek. Opportunities to ensure the 5 cfs allotment is met during summer months should be investigated, through the Division of Water Rights, and by working with NID and Lake Wildwood.

- **Investigate opportunities to secure in-stream flows through water trusts, as has been done in Washington and Oregon and is beginning to occur throughout California.**
  It is possible that there are private property owners in the watershed that would be willing to place their water rights in a trust that secures them for in-stream flows. This would be particularly important downstream of Lake Wildwood reservoir.

- **Work with the State Water Resources Control Board and Central Valley Regional Water Quality Control Board to develop and implement a TMDL for the Deer Creek watershed for mercury contamination.**
  Numerous perennial water bodies in the watershed are 303(d) listed for mercury contamination and will require a TMDL plan for remediation. With the great number of listed creeks in the watershed, it only makes sense that mercury contamination be addressed over the entire watershed, as is currently happening in the American River watershed. This may require an amendment to the Basin Plan, as did the ongoing American River watershed TMDL project. With a strong citizen monitoring and stakeholder base, substantial data and expertise, Friends of Deer Creek is uniquely positioned to undertake such a project. Additionally, TMDL plan development is backlogged at the State and Regional level, and Water Boards are receptive to watershed groups such as Friends of Deer Creek undertaking tasks typically done by the Water Boards, because of the ability of these groups to complete such projects in a timely and cost-efficient manner.

- **Follow changes to important local, regional, state, and national planning and monitoring efforts.**
  It is important to follow changes to major planning documents, such as the Basin Plan or County General Plan. For example, recently the EPA adopted *E. coli* as the

most appropriate indicator of fecal contamination in freshwater bodies, replacing fecal coliform, the previous indicator. The EPA mandated that the States use the same indicator organisms to protect human health during water contact recreation. The State of California directed the Regional Water Boards to adopt the new indicator organism, with the Central Valley Water Board amending the Basin Plan to include *E. coli* as the indicator organism. Although the Basin Plan was amended to include *E. coli*, the State has yet to adopt *E. coli* as the indicator organism. This demonstrates the fact that complicated changes in agency planning at multiple levels can impact the work done by Friends of Deer Creek to protect environmental and human health.

- **Ensure the ban on suction dredging is being observed in Deer Creek and follow new developments related to the suction dredge ban.**
  At FODC/SSI site 6 within Lake Wildwood, a dredge was found on the stream bank, indicating that suction dredging occurred in 2009 and 2010. The dredging activity resulted in significant impacts to the streambed and degradation of aquatic habitat. Activity such as this, discovered in the course of monitoring and assessing the watershed, should be reported to the appropriate authority, such as the Department of Fish and Game.

- **Continue to collect water quality data for submission to the State as part of the 303(d) listing process.**
  In 2008 and 2010 Friends of Deer Creek submitted data to the State of California as part of the state's solicitation of data to make 303(d) listing decisions. In the past these data have resulted in sections of the creek being 303(d) listed for pH and mercury. Future efforts to place additional impaired water bodies on the 303(d) list should be pursued through data submission to the State.

- **Continue to collaborate with STAinNC and expand collaborations to include agencies and stakeholders at the regional and state levels, including the NSAQMD, the California Air Resources Control Board, the County of Nevada, and downwind in Sacramento and the San Francisco Bay Area, to further address the ground-level ozone problem in the County and throughout the region.**

- **Expand ground-level ozone monitoring in western Nevada County, particularly in the Deer Creek watershed, to investigate impacts to communities where monitoring does not regularly occur, such as Cascade Shores, Rough and Ready, Penn Valley, Lake Wildwood, and Smartsville.**

- **Conduct long-term studies to investigate impacts to public health and public welfare, including impacts to crops, as well as buildings.**

This could be accomplished by working with local medical clinics to conduct studies on human health, working with local farms and the County Agricultural Committee to determine impacts to crops grown in Nevada County, and working with Nevada City and Grass Valley to investigate impacts to buildings, such as those within their historic districts.

- **Work with the County and city agencies to develop road and conservation BMPs.**

- **Promote the use of permeable materials and green infrastructure when designing streets, sidewalks, and lawns in new developments, in order to reduce urban runoff.**
  Projects incorporating the use of these materials and design practices were recently implemented at the Rood Center and a co-housing development in Nevada City and should be expanded to additional developments throughout the watershed.

- **Require new developments to install landscaping and infrastructure that would limit impervious surface cover and promote on-site infiltration of precipitation, to promote groundwater recharge, decrease runoff rates, and reduce sediment and pollutant inputs to area creeks during precipitation events.**
  This could be accomplished through the use of French drains leading to leach fields.

Chapter VIII: Recommendations

Introduction

Recommendations for directing restoration efforts in the Deer Creek watershed are included in each chapter, and emerge from consideration of creek health as seen through a particular scientific prism. This chapter is an effort to make recommendations that emerge from a multi-disciplinary approach to the watershed, with consideration for hydrological, geological, geomorphological, ecological, sociological and cultural elements, and the way in which they interact. The recommendations are broadly grouped into four categories: Monitoring and Assessment; Restoration and Preservation; Education and Outreach; and Regulatory Recommendations and Compliance.

Data and discussion from which these recommendations are derived is found within the preceding chapters, which are referenced in parentheses. This chapter is intended to serve as a roadmap to overall watershed restoration goals, and will be revised on an annual basis, thereby serving as a report card of the state of the creek.

A. Monitoring and Assessment

Recommendations for monitoring and assessment of the creek begin with an overview of the current program. This is followed by areas of intended program expansion, in response to acknowledged data gaps. Finally, specific research projects are listed that make use of data collected in the course of regular monitoring and assessment, as well as published research conducted by the broader scientific community.

A1.Continue current program of comprehensive monitoring and assessment

Deer Creek is fortunate amongst small Sierra streams to have been subject to a comprehensive citizen-based program of monitoring and assessment conducted by SSI/FODC that began in 2000 and continues with a commitment in perpetuity. Additional parameters have been added to the monitoring program over the years. Further assessments and data collection efforts have been conducted in the watershed by American Rivers, Nevada County Land Trust, South Yuba River Citizens League, Nevada City Wastewater Treatment Plant, Nevada County Sanitation District #1, Nevada County Environmental Health Department, Nevada County Community Development Agency, Central Valley Regional Water Quality Control Board, State Water Resources Control Board USGS, and BLM. The ten year body of consistent data allows for restoration decisions to be made that are grounded in science.

The recommendation of this report is that the current program be continued in its entirety. Water quality data should continue to be submitted to the State as part of the 303(d) listing process. In 2008 and 2010 Friends of Deer Creek submitted data to the State of California as part of the state's solicitation of data to guide 303(d) listing decisions. In the past these data have resulted in sections of the creek being 303(d) listed for pH and mercury. Future efforts to place additional impaired water bodies on the 303(d) list should be pursued through data submission to the State.

Long term consistent monitoring that adheres to established protocols, and is compatible with state-wide data collection efforts is needed to guide restoration decisions, monitor the impacts of climate change, development, and water resources management, and make comparisons with other watersheds. The established monitoring and assessment program includes physical, chemical and biological parameters, as follows:

Monitoring Parameter	Frequency, location, duration
• Dissolved oxygen • Turbidity • Air and water temperature • pH • Conductivity	Monthly at 16 monitoring sites on Deer Creek, Little Deer Creek, and Squirrel Creek. 10 sites have been monitored since December 2000. Six sites have been added since then.
• Nutrients (nitrates and phosphates)	Monthly at 15 monitoring sites on Deer Creek,

A. Monitoring and Assessment

• Bacteria	Little Deer Creek, and Squirrel Creek since 2004 (nutrients) and 2005 (bacteria)
Water quality monitoring downstream of Lake Wildwood during the periodic dewatering. Monitor mercury concentration, mercury loads, total suspended solids and sediment loads in addition to water quality parameters listed above	Daily during periodic dewatering at Lake Wildwood weir (immediately downstream of the drawdown discharge location) and site 10, since 2007. (Hourly for the first three days of the release, then 4-hourly for the remainder.
• USGS flow gauge measures flow volume in cfs • Depth and flow at Lake Wildwood inlet and outlet	• Every 15 minutes at Site 10 since 1935. • Every 15 minutes at seven sites since November 2010. Two additional sites will be added in August 2011.
• Benthic macroinvertebrate (BMI) sampling and identification • Algae sampling • Algae biomass • Bird survey • Vegetation survey • Fish survey	• BMI twice yearly at 10 sites since 2000 • Algae sampling twice yearly at ten sites since 2010 • Algae biomass monthly at six sites since 2005 • Bird survey June 2010 • Vegetation survey July 2010 and July 2012 • Fish electroshock survey annually 2007-9
Survey including pebble count	6 sites in 2007 and 2008
Physical habitat assessment	• Annually at 10 sites since 2007 • Twice yearly rapid assessment at 10 sites since 2000 • Stocking Flat overbank flooding (timing, frequency, extent, duration), and changes in geomorphology and vegetation

A2. Expand current monitoring and assessment program

While Deer Creek is fortunate to have been the subject of a comprehensive monitoring program, data gaps have been identified in the course of restoration plan development. In some cases, the data have revealed areas that require new kinds of investigation. An example of this is bacterial contamination, in which five years of data have revealed the need to expand bacterial monitoring in an effort to identify sources of contamination. Additionally, the involvement in plan development of the native Maidu people has revealed a need for cultural assessments that shed light on the pre-contact condition of the watershed. Specific areas for expansion of the monitoring and assessment program have been identified as follows:

Water Quality and Biological Monitoring:

- ❖ **Re-establish FODC/SSI monitoring site 14 immediately upstream of the Deer Creek confluence with the Yuba River** *(Chapter VI)*

This area of Deer Creek is critical salmon and steelhead spawning habitat. Regular monitoring of the site should be conducted to evaluate water quality in this important section of the watershed. Recent landowner change and communication with FODC/SSI may lead to re-establishing this site.

- **Monitor selected chemical parameters, including temperature, pH, and conductivity, on a continuous basis to enhance evaluation of temporal and spatial fluctuations within the watershed** *(Chapter VI)*
- **Improve nutrient analysis to include ammonia and nitrite** *(Chapter VI)*
  Nitrate and phosphate data indicated the Lake Wildwood WWTP as a major point source for nutrient loading in lower Deer Creek that promotes excessive algal growth at downstream sites. Upgrades to the Lake Wildwood WWTP facilities in 2006-2007 indicate a reduction in nitrate levels in downstream sites; nonetheless, continued monitoring will determine the effectiveness of these upgrades and will help identify additional point and non-point sources of nutrients and provide insight into appropriate restoration actions. Analyzing ammonia and nitrite would provide more insight into nutrient loading and its effects on nutrient cycling and aquatic biota.
- **Increase algae monitoring efforts in the Deer Creek watershed including more frequent monitoring during summer months** *(Chapter VI)*
  Because algae samples are only currently collected once a month during the summer at each site, it is likely that peak-algae growth at sites is not being captured. Sampling should be increased to every 14 days on a regular basis in the summer.
- **Identify algae types and develop corresponding metrics to use as biological health indicator, including the prevalence of non-native species** *(Chapter VI)*
  Similar to BMI communities, specific algae species will grow in reaches based on water quality conditions. Identification of algae communities and development of a corresponding metric system in association with BMI bioassessments will provide better insight into the major stressors impacting biotic communities and most-impaired reaches. Additionally, identifying algae would allow evaluation of native and non-native species to aid in the prevention of spreading non-natives.
- **Expand bacterial sampling in Western Gateway Park and at upstream sites on Squirrel and Clear creeks during the recreational swimming season** *(Chapter VI)*
  Monitoring will include continued bacteria and water quality monitoring, with the addition of speciation of bacteria samples to determine the source. The primary parameter will be *E. coli* testing, working systematically upstream on Squirrel and Clear creeks and using cost-effective in-house testing. Any spikes in *E. coli* would lead to further testing for *E. coli 0157H7* and speciation at an outside lab. Microbial source tracking allows for identification of the source organism of fecal contamination by running markers for cattle, deer and non-ruminants, humans, and for hogs. Further testing to quantify the amount from each type of animal will follow identification of contamination sources. *Giardia*, *Cryptosporidium* and/or *Salmonella*

should be added as parameters. Collaboration with the Fish and Wildlife Commission, Nevada County Agricultural Commissioner's Office, Natural Resources Conservation Service, and Nevada County Resource Conservation District, to conduct a survey of land owners in the vicinity will allow for determination of their current practices and willingness to collaborate in an effort to reduce bacteria contamination. The feasibility of implementing remediation on land owned by willing land owners and the extent to which such implementation would benefit overall watershed health should be studied.

- **Expand hydrological and geomorphological monitoring in the Deer Creek watershed** *(Chapter IV; Chapter V)*
  In order to better understand the geomorphic function of Deer Creek, it is essential to collect additional hydrologic and geomorphic data. Monitoring should focus on expanding to major tributaries and sections of Deer Creek, including the north and south forks of Deer Creek upstream of Scotts Flat reservoir, the inlet to Scotts Flat reservoir, Squirrel Creek, Clear Creek, Grub Creek, Gold Run Creek, and Slate Creek.
- **Continue and expand fish surveys in the Deer Creek watershed** *(Chapter VI)*
  Further electro-shocking efforts should target the same reaches as in 2007 and 2008, while trying to incorporate stretches of major tributary creeks, including Squirrel and Clear Creek in Penn Valley, Gold Run Creek, Little Deer Creek, Mosquito Creek, and Willow Valley Creek in and around Nevada City, and upstream Scotts Flat Reservoir on the main stem, north, and south forks of Deer Creek. This will provide better insight into the diversity, abundance, and quality of fish species in the watershed.
- **Develop a regular program of Chinook salmon and steelhead surveys of lower Deer Creek at the confluence with the Yuba** *(Chapter VI)*
  Surveys should focus on surveying physical habitat parameters (velocity, depth, gravel attributes, water quality), the number of adult fish present in Deer Creek during spawning season, the number of redds created by salmon, and the success of fry and juvenile emergence from redds. In addition, surveys should attempt to identify other fish species present in Deer Creek, for comparison with sites that have been surveyed through fish shocking previously.
- **Investigate opportunities to expand monitoring capacity, so that a longterm dataset is established for parameters that are not currently monitored**
- **Collaborate with Save the Air in Nevada County (STAinNC) to expand ground-level ozone monitoring in western Nevada County, particularly in the Deer Creek watershed, to investigate impacts to communities where monitoring does not regularly occur, such as Cascade Shores, Rough and Ready, Penn Valley, Lake Wildwood, and Smartsville** *(Chapter VII)*

- **Establish long-term weather stations at locations in the watershed not currently monitored by the National Weather Service, such as at FODC/SSI monitoring sites and ozone monitoring sites** *(Chapter VII)*
- **Install rain gauges at locations near gauging stations, to better understand rainfall-runoff relationships** *(Chapter IV)*

  Two rain gauges are being installed in the watershed in 2011: one in Nevada City and one in Rough and Ready, to supplement the existing USGS, NID, and Sierra Water Trust stream flow gauging infrastructure. Additional rain gauges and precipitation loggers should be installed in areas upstream of Scotts Flat reservoir, and in the Squirrel Creek watershed.

Habitat Assessments:

- **Expand riparian zone assessments and analyses to include additional stream reaches and additional creeks within the watershed, and conduct a more thorough investigation of ecological impacts of degraded riparian zones** *(Chapter VI)*

  Riparian vegetation data indicated numerous concerns in the condition of the riparian zone including structural complexity, floodplain connectivity, periodic floodplain disturbance, canopy cover, riparian width, exposed groundcover, and dominance of invasive, non-native species. Once a PHab protocol for Deer Creek has been developed, an extensive survey in the entire watershed should be implemented to validate (or invalidate) previous assessment results and expand into sub-watersheds. Further investigation of water quality and biological implications from impaired riparian zones in the watershed will be crucial in prioritizing areas of concern and determining the most effective restoration actions in the riparian zone.
- **Expand invasive, non-native riparian vegetation assessments in the Deer Creek watershed** *(Chapter VI)*

  An extensive survey should be performed throughout the watershed to determine "hot-spots" where invasive species are dominant in the riparian zone. The assessment should include identification of non-natives at all riparian levels including upper canopy, lower canopy, shrubs, saplings, herbs, and grasses. Additionally, evaluation of competition attributes between native and non-native species should be performed to determine more insightful restoration projects.
- **Assess biological health before and after restoration projects to determine success** *(Chapter VI)*

  Restoration projects in the Deer Creek watershed should include pre and post bio-sampling of biotic communities that are trying to be restored or may be affected by restoration efforts. Additionally, FODC/SSI should collaborate with development/construction projects and conduct pre and post bio-sampling to investigate impacts on biotic communities.
- **Expand surveys on vertebrate communities in the watershed** *(Chapter VI)*

Assessments should be conducted in the watershed on birds, reptiles, amphibians, and mammals in the Deer Creek watershed to determine the diversity and abundance of native and non-native species and impacts associated with non-native species. FODC/SSI currently has limited data collected on these vertebrate communities in the Deer Creek watershed. Collecting baseline data on birds, fish, mammals, reptiles and amphibians will aid in determining which species work best as indicators for overall ecosystem health over time and effects on communities after impairments and improvements.

- **Conduct load assessments of mercury, nutrients and sediment in Deer Creek** *(Chapter VI)*
- **Conduct land-use/land-cover (LULC) analysis in the Deer Creek watershed** *(Chapter VI)*

  Analyzing LULC data will aid in identifying stressors that are adversely affecting the Deer Creek watershed. The assessment should include aerial imagery analysis, which can provide visual data on sites before detrimental activities (e.g. grazing, logging, development, construction) to make more informed restoration projects. A GIS-based analysis should be conducted that correlates land cover and land use impacts to water quality data in the watershed.
- **Monitor ephemeral stream channels that flow into perennial streams** *(Chapter VII)*

  In addition, ephemeral streams should be considered in development guidelines, such as the General Plan, as these drainage networks convey significant amounts of fine sediment and nutrient inputs to perennial water bodies. Currently, these drainages are not taken into account in development guidelines. Friends of Deer Creek developed a preliminary ephemeral drainage assessment in 2009, with two ephemeral drainages assessed in the Nevada City area. This assessment could be further used and expanded upon to investigate the health and function of ephemeral drainages throughout the watershed.

Mining-related Assessments:

- **Conduct more comprehensive sampling along Deer Creek main stem and its tributaries to determine mercury sources; inventory historic mine sites and mine waste areas within 500 ft of Deer Creek and its tributaries; create map of Deer Creek watershed mine sites and contamination hotspots for field use** *(Chapter III)*

  FODC/SSI data indicated elevated THg concentrations in sediment and storm-water samples throughout the watershed. Conducting more comprehensive sampling along the main stem of Deer Creek and major tributaries to increase spatial resolution will help determine major mercury sources and prioritize restoration sites.
- **Review field data to prioritize sites by amount of mine waste in contact with creek or trails, levels of mine toxins, potential impacts to stream channel**

morphology, impacts to stream environment, impacts to human health *(Chapter III)*

- **Develop partner projects to the EPA Brownfields projects at Providence Mine and Stiles Mill that focus on bank stabilization and reduction of environmental impacts, since the EPA Brownfields projects focus on human health impacts** *(Chapter III)*
- **Expand mercury analysis in sediment and storm events in sub-watersheds; expand analysis of the relationship between mercury and sediment and between mercury and algae; conduct mercury transport studies** *(Chapter VI)*
  FODC/SSI data indicated a strong relationship between THg and TSS during individual storm events suggesting that sediment transportation during storm-flows is a major mercury transport mechanism. This relationship needs to be more thoroughly evaluated to determine most effective restoration efforts. Additionally, storm-water sampling should continue to evaluate the effectiveness of Lake Wildwood reservoir as a barrier for downstream mercury transport.
- **Investigate acid mine drainage (AMD) in the Deer Creek watershed** *(Chapter VI)*
  Although no specific discharges of acid mine drainage have been documented in the Deer Creek watershed, uncharacterized mine sites may pose a threat to water quality in some locations, particularly in Squirrel Creek and lower Deer Creek where copper and zinc sulfide deposits have been mined on a small scale.
- **Investigate the extent of floodplain problems such as connectivity and disturbance in the Deer Creek watershed; address the problem associated with the infrequency of floodplain inundation** *(Chapter V)*
  To advance geomorphic restoration goals, more investigation is needed into the extent that floodplain problems are caused by historic mining practices or other factors, and the opportunities and constraints on removing hydraulic debris terraces to restore floodplain connectivity. To address the problem associated with the lack of frequent floodplain inundation, two approaches could be employed. First, during storm events releases from Scotts Flat could be increased enough to inundate floodplains on an average frequency of once in two years. The level of flow increase required would range from 500 - 4,000 cfs depending on location. At locations requiring increases of more than 1,000 cfs, floodplains are likely artificially elevated as a result of residual mining debris. At these locations floodplains have essentially become terraces, abandoned as the river cut down through mining deposits. In these locations the second approach could be employed: reshaping the river channel using heavy equipment to create a channel that reflects the altered hydrology and sediment supply of today. This approach has been used on the Trinity River, which has a mining and dam building history not unlike Deer Creek. On the Trinity, managers re-graded significant areas of abandoned floodplain terraces down to elevations that are now flooded on a regular basis. Initial attempts to re-grade the floodplain at Stocking

Flat began in 2009, but the project is currently on hold because the property owners, the Bureau of Land Management, found that there was mercury stored in the floodplain, which could potentially methylate with restored floodplain inundation. In addition to the floodplain at Stocking Flat a large floodplain exists at a downstream property, where the landowners are open to restoration of their property and the creek. The landowners have been very supportive of FODC/SSI's work and opportunities to restore the health and function of Deer Creek at this location should be pursued.

Cultural Assessments: *(Chapter I)*

- **Collect oral and written history of the area including all available resources**
- **Collect a list of historical documents for research database, including Maidu placename history in the Deer Creek watershed**

A3. Conduct targeted research that makes use of the existing body of FODC data and other data

- **Assess relationship between sediment and bacteria** *(Chapter VI)*
- **Assess the effects associated with nutrient loading on chemical and biological parameters and on nutrient cycling in the watershed** *(Chapter VI)*
- **Conduct N/P ratio studies above, upstream of, within, and downstream of Lake Wildwood, and upstream and downstream of Nevada City WWTP** *(Chapter VI)*

  An N/P ratio assessment has not been conducted in the Deer Creek watershed and would provide better insight into nutrient loading.
- **Investigate diurnal components of chemical parameters, such as water temperature and pH** *(Chapter VI)*

  FODC/SSI data indicated a strong diurnal effect in water temperature and pH at site 10 in lower Deer Creek in the summer. Expanding assessments on the diurnal component of chemical parameters would better characterize stream conditions in the Deer Creek watershed, especially in critical areas such as the quarter mile stretch on lower Deer Creek above the confluence of the Yuba which is important salmon spawning habitat. FODC/SSI has temperature loggers and collected some additional data at site 10 in late 2010. In addition to investigating diurnal components, sensors or continuous monitoring could be utilized to evaluate water quality changes in response to other factors such as dam releases and wastewater treatment plant effluent, as was done in 2007 and 2008 during the Lake Wildwood drawdown.
- **Work with the State Water Resources Control Board and Central Valley Regional Water Quality Control Board to develop and implement a TMDL for mercury for the Deer Creek watershed, and for pH for lower Deer Creek downstream of Lake Wildwood** *(Chapter VI)*

  Several areas in the Deer Creek watershed are 303(d) as impaired water bodies including Scotts Flat reservoir, Little Deer Creek, and Deer Creek upstream of the

Lake Wildwood reservoir for mercury; and Deer Creek downstream of the Lake Wildwood reservoir for pH. Total maximum daily loads have not been established and assisting in the development in these TMDLs is a great restoration opportunity in the Deer Creek watershed. With a strong citizen monitoring and stakeholder base, substantial data and expertise, Friends of Deer Creek is uniquely positioned to undertake such a project. Additionally, TMDL plan development is backlogged at the State and Regional level, and Water Boards are receptive to watershed groups such as Friends of Deer Creek undertaking tasks typically done by the Water Boards, because of the ability of these groups to complete such projects in a timely and cost-efficient manner.

- **Develop reference sites for riparian vegetation to conduct more informed restoration projects** *(Chapter VI)*
  Evaluation of reference sites would result in more effective restoration efforts by providing insight into types and densities of native species that should be planted, structural complexity, and more
- **Develop an Index of Biotic Integrity (IBI) for benthic macroinvertebrates (BMI) to be used as a numerical health scale in Deer Creek and other Sierra foothill watersheds** *(Chapter VI)*
- **Develop an integrated watershed scoring rubric that includes chemical, physical and biological parameters** *(Chapter VI)*
- **Study the use of UV to kill bacteria, convert methyl mercury to its elemental form, and eliminate the use of chlorine** *(Chapter VI)*
  Elevated THg concentrations in BMI and fish tissue indicate MeHg concerns in the Deer Creek watershed. Restoration possibilities need to be researched to ensure effectiveness. Investigating the use of UV to kill bacteria to lower MeHg as well as stop the use of chlorine, and the use of plants for heavy metal bioremediation are examples of potential restoration actions. Plants that might be used for mercury and other heavy metal bioremediation should be investigated.
- **Conduct living tissue analysis on organisms to better understand the process of heavy metal bioaccumulation; investigate the mechanism of bioaccumulation** *(Chapter VI)*
- **Study the methylating capacity in Deer Creek and how methylating conditions differ between sites** *(Chapter VI)*
  BMI and fish tissue data indicated appreciable THg concentrations in aquatic biota, especially in Scotts Flat and Lake Wildwood reservoirs; however, little is known about the methylating capacity in the Deer Creek watershed. Assessing methylating capacities would provide better insight into MeHg "hot-spots" and prioritize major restoration sites.
- **Expand the physical habitat assessment protocol to include parameters that are specific to Deer Creek** *(Chapter VI)*

The physical characteristics of a mountainous stream, such as Deer Creek and its tributaries, differ greatly from streams flowing through the Central Valley. The protocol that has been used in the Deer Creek watershed is a general physical habitat assessment that does not specifically apply to mountainous streams. Development or utilization of a protocol that addresses physical parameters present in a mountainous stream is necessary to better characterize physical habitat conditions in the Deer Creek watershed and provide more insight into impaired riparian zones.

- **Compare the timing, both seasonally and between years, of peak flows in Oregon Creek (to serve as a reference creek) and Deer Creek, in order to better understand the impact of Scotts Flat reservoir on Deer Creek's peak flows** *(Chapter IV)*
- **Research changes and updates to climate change scenarios, climate models, and major climate change related reports** *(Chapter VII)*
  As more research is done on climate change, models will become more refined, leading to more accurate predictions of future climate change-related impacts at increasingly small spatial resolutions. In addition the Intergovernmental Panel on Climate Change will continue to meet and publish reports on climate change. All of these changes are important because they will help predict how the Deer Creek watershed and surrounding region will be impacted by a changing climate.

B. Restoration and Preservation

B1.Restore native habitat:

- **Survey and prioritize most likely areas for habitat restoration** *(Chapter VI)*
- **Remove invasive, non-native species from the riparian and upland zones of the Deer Creek watershed and replace with native species, including species of significance to indigenous people** *(Chapter VI)*

  Black locust was identified as the most prevalent non-native species in the upper and lower canopy of the riparian zone in the Deer Creek watershed. Himalayan Blackberry is a dominant shrub throughout the watershed and other non-native species such as Scotch Broom and English Ivy are also prominent. As mentioned earlier, restoration projects throughout the watershed should coordinate with public and private landowners. Assessments recommended above would provide insight into invasive, non-native riparian vegetation "hot-spots", invasive, non-native herbs and grasses, and most effective restoration possibilities in the watershed. Future restoration projects should continue to collaborate with public and private landowners and coordinate with ongoing projects, such as the Scotch Broom Challenge, to target additional sites within the Deer Creek watershed. Restoration of native species in the riparian zone provides important food sources for aquatic and terrestrial biota and provides habitat benefits.
- **Target sites with exposed soil to reduce erosion potential; focus ground cover vegetation restoration projects on sites with moderate woody shrub and sapling cover; target sites with marginal or poor canopy cover** *(Chapter VI)*

  Sites that exhibited heavy amounts of bare ground are sites 1, 6, 9, 10, 11, 13, and 15. At site 12 on Little Deer Creek and site 16 on Squirrel Creek both the upper and lower canopy exhibit only moderate coverage, and restoration projects have occurred previously. Sites 8, 9, 10, and 16 in the lower watershed exhibit moderate upper canopy cover and should be targeted for restoration. No site was classified as having very heavy cover in the upper or lower canopy, indicating the potential for restoration at each monitoring site.
- **Recreate conditions to allow salmon spawning in Deer Creek, including gravel augmentation and spawning bed enhancement projects on Deer Creek** *(Chapter V; VI)*

  Downstream of both Scotts Flat and Lake Wildwood reservoirs a sediment supply deficit exists, due to the dams capturing the majority of sediment, which would have historically been transported to downstream reaches. While gravel supplies have been depleted in the bedrock section just downstream of lower Scotts Flat dam, the lack of channel downcutting and difficulty of access make gravel augmentation a low priority at this location. Reaches downstream of Lake Wildwood Reservoir, including at the spillway (LWW Weir), site 8, and site 10, are a high priority for gravel augmentation and habitat restoration, based upon ease of access and permission from landowners, lack of adequate in-stream habitat, and importance of aquatic habitat to critical species such as Chinook salmon and steelhead. A pilot gravel augmentation project is scheduled for implementation during summer 2011 at site 10, and the results from this project will inform larger scale gravel augmentation work in the lower Deer Creek watershed.

❖ **Develop a collaborative plan to remediate swimming holes in Western Gateway Park** *(Chapter VI)*

The remediation plan should include recommendations and implementation strategies that can be used by specific willing private landowners, and general recommendations for landowners and other stakeholders in the project vicinity.

❖ **Restore riparian vegetation width, with a focus on areas with sub-optimal scores** *(Chapter VI)*

❖ **Implement stream bank stabilization projects** *(Chapter V)*

Site 2 adjacent to Willow Valley Road upstream of Nevada City, site 12 in Pioneer Park in Nevada City, and site 15 in Creek Side Mobile Home Village in Penn Valley exhibited the most unstable banks in this assessment.

- At site 2 restoration work would involve the County Transportation Department, as much of the erosion is associated with Willow Valley Road on river right, and the existing low-water crossing of Deer Creek at this location. To restore bank stability the low-water crossing should be closed and access to the creek for vehicles should be blocked. This would reduce bank erosion on both banks and allow vegetation to re-establish. Native vegetation should be planted at this site, particularly on river left, where a large bare stretch of riparian zone exists due to clearing for vehicle and recreational access. Contact with the property owners on river left needs to be established before any restoration efforts begin.
- At site 12 in Pioneer Park, the banks of Little Deer Creek are quite unstable and suffer from a lack of adequate riparian vegetation. Historically Little Deer Creek flowed through a wide wetland at this location. The creek was channelized and wetland filled in to create a park. The unstable banks are due to the stress on the stream channel during high flows, caused by channelization of the creek. Evidence of channelization still exists, with concrete walls and gabion in the creek. A previous restoration project at site 12 focused on removal of non-natives and planting of native species in the riparian zone, and also strategic placement of a number of large boulders to increase bank stability. Further restoration projects at this site should expand upon this initial effort to increase bank stability and riparian vegetation. Planting of native species and removal of non-natives should occur, in an attempt to expand the width of the riparian zone and increase ground and tree cover. Concrete, gabion, and angular pieces of rock should be removed from the creek channel using heavy equipment, and the bank should be

stabilized using natural materials, including large boulders, willow wattles, and native plantings. Opportunities to "de-channelize" Little Deer Creek should be explored with the city of Nevada City, owners of Pioneer Park.

- At site 15 both banks are actively eroding into Squirrel Creek, with impacts associated with human development and recreation impacting the banks on river left. On river right there are large sections of steep, bare bank in the riparian zone that are actively eroding. Restoration of this section of the creek would include multiple aspects, including outreach to residents of the mobile home park, removal of non-native plant species, planting of native species, and bank stabilization through large boulders or other methods. Outreach to the residents is necessary, as their activities are impacting the riparian zone with residents creating access routes to the creek, disturbing new vegetative growth, and contributing to the spread of non-native species. Non-native Himalayan blackberry is present in many locations along this section of Squirrel Creek, and attempts to remove it should be undertaken. In some circumstances, blackberry may be important for stabilizing the bank, and restoration efforts should consider the impacts associated with its removal. Planting of native species, including willows and alders, as well as larger trees such as cottonwoods, should be implemented. There is a lack of native vegetation to secure the banks at this site. Re-vegetation efforts should include methods for keeping humans and animals out of the riparian zone, as there is considerable human activity at this site, especially on river left. Property owners on both river right and left should be identified and contacted prior to undertaking any restoration projects at this site. The mobile home park owns the majority of river left, but the river right property owners have not been identified.

❖ **Restore sediment transport capacity to the Deer Creek watershed** *(Chapter V)*

To address the problem associated with mobilizing substrates in upper Deer Creek and at the Lake Wildwood weir site, two methods could be used. First, releases from Scotts Flat reservoirs could be increased during certain storm events to reach mobilization thresholds. During 2-year events, flows would need to be increased by at least 400 cfs, and for 10-year events flows should be increased by at least 1000cfs. Second, certain reaches with significant riffle habitat could be "mechanically mobilized," a strategy used in restoration efforts downstream of dams on streams that support anadromous fish such as salmon and steelhead. Mechanical mobilization involves using tractors pulling implements that rip up the top layer of gravel bars to facilitate mobilization when significant flow events occur. This, combined with supplementation of gravels through gravel augmentation, would reduce the dominant size of channel substrates, and would reduce the flows at which substrates would be mobilized.

B2. Implement improvements to flow:

- **Investigate opportunities to secure instream flows through water trusts** *(Chapter VII)*
  It is possible that there are private property owners in the watershed that would be willing to place their water rights in a trust that secures them for in-stream flows. This would be particularly important downstream of Lake Wildwood reservoir.
- **Restore the natural peak flood flow regime in Deer Creek** *(Chapter IV)*
  Current peak flood flow magnitudes and return intervals near Scotts Flat reservoir and downstream of Lake Wildwood reservoir are potentially outside the predicted natural range due to reservoir development and water management. In addition, the Scotts Flat reservoir upgrade and base flow change in 1964 has resulted in alterations to the flood regime, with potential reductions in the magnitude and frequency of peak flood flows in the period after the reservoir upgrade, which further indicates there have been alterations to the annual peak flow regime. When compared to the predicted natural flows, current peak flows at Scotts Flat reservoir in the upper Deer Creek watershed have been reduced from the Q2 – Q10 range, possibly due to the dam capturing runoff from one-quarter of the watershed. Peak flows downstream of Lake Wildwood reservoir in the lower Deer Creek watershed have potentially been reduced from the Q25 – Q100 range, due to reservoirs capturing runoff and reducing the magnitude and frequency of large flood flows. Restoration would involve experimenting with the flood regime, through releases from Scotts Flat reservoir during storm events, to ensure that natural peak flows are achieved throughout the watershed. In addition, restoring the flood regime would also lead to more natural annual and monthly FDCs, increased duration of high flow pulses, increased monthly median flows, and an increase in monthly low flows. The FDCs indicated there is much less water in the creek annually and during the wet season months (November – June), with high flow pulse durations, monthly median, and monthly low flows reduced during wet months after Scotts Flat reservoir upgraded in 1964. Efforts to allow more natural runoff patterns, such as snowmelt and upper tributary flow through Scotts Flat reservoir, should be explored during April, May, and June, with reductions to the median monthly flow volumes in these months, due to water management and diversions of water away from the main stem of Deer Creek.
- **Restore a more natural hydrograph to the October flow regime downstream of Lake Wildwood reservoir** *(Chapter IV)*
  The periodic Lake Wildwood reservoir drawdown release alters the flood regime during the month of October, increasing peak stream flow magnitudes for each return interval from Q2 – Q100. Large releases of water in October can potentially have negative impacts on stream biota because flows of these magnitudes and durations would not occur naturally. By experimenting with drawdown release magnitudes and durations it may be possible to restore hydrologic function to the

October hydrograph and improve the conditions and habitat for macroinvertebrates and fish, such as Chinook salmon and steelhead trout, in lower Deer Creek. Analysis should be conducted on historic October flows that are not associated with the drawdown release, to investigate the magnitude, duration, frequency, and rise and fall rates for rainfall events that trigger rises in stream flow during the month of October. By investigating historic, pre-Lake Wildwood reservoir October rise and fall rates, and flow magnitudes and durations, drawdown releases could potentially be designed to be more in line with natural flow conditions. Experiments should be conducted into whether a shorter duration, higher magnitude release or a longer duration, lower magnitude release impacts the ecosystem more. This could be investigated through collecting water quality and macroinvertebrate data, sediment and mercury transport and deposition rates, and monitoring the impacts of the release on Chinook salmon and steelhead trout. Anadromous fish enter Deer Creek during the months of September or October and could potentially be affected by the drawdown release. Therefore investigations should be made into impacts to these threatened and endangered fish species.

- **Restore a more natural hydrograph to mainstem Deer Creek and investigate changes to the aquatic ecosystem as a result of the drawdown releases** *(Chapter IV; V)*

  The absence of a natural hydrograph results in reduced winter flood flows, reduced spring flows, and increased summer low-flows. The reduction in winter flood flows and spring flows leads to a decrease in the frequency of floodplain inundation. This, combined with increased summer low-flows, results in a narrow band of riparian vegetation in many portions of upper Deer Creek. Restoring the natural hydrograph would promote floodplain inundation, disturbance of the floodplain surface, deposition of silt and sands, and deposition of seed sources, all of which would increase the health and function of the riparian zone.

B3. Restore mine-scarred lands:

- **Work with NID to explore the possibility of conducting a mercury and sediment removal study at Scotts Flat Reservoir** *(Chapter VII)*

  Currently such a study and project is being implemented at Combie Reservoir on the Bear River. This pilot study, if successful, could potentially be used to remove mercury and contaminated sediment stored in Scotts Flat reservoir. Scotts Flat reservoir is 303(d) listed for mercury impairment and this type of restoration project might be needed to restore the health of this water body so that it satisfies all beneficial use requirements.

- **Clean up contaminated mine sites** *(Chapter II, III)*

B4. Preserve sites of ancient cultural significance:

- **Prioritize restoration efforts, using techniques derived from traditional ecological knowledge, with a focus on primary traditional cultural properties, including the village sites at Mooney Flat and at the Deer Creek headwaters** *(Chapter II)*
- **Identify threatened artifacts and if necessary remove them to safer locations for protection** *(Chapter II)*

C. Education and Outreach

C1. Build collaborations:

- **Continue to collaborate with STAinNC and expand collaborations to include agencies and stakeholders at the regional and state levels, including the NSAQMD, the California Air Resources Control Board, the County of Nevada, and downwind in Sacramento and the San Francisco Bay Area, to further address the ground-level ozone problem in the County and throughout the region** *(Chapter VII)*
- **Coordinate with ongoing invasive species removal projects such as Scotch Broom Challenge** *(Chapter VI)*
- **Develop partnerships with neighborhood associations throughout the Deer Creek watershed, to disseminate information and facilitate outreach** *(Chapter VII)*

  Numerous neighborhood associations and/or stakeholder groups exist in the Deer Creek watershed, including the Champion Mine Neighborhood Association and the Friends of Lower Deer Creek stakeholder group. Information should be disseminated regarding Best Management Practices for preventing erosion from development and land management practices that mitigate impacts caused by climate change.
- **Collaborate with local doctors and hospitals to include exposure to heavy metal contamination in health histories, and to educate patients in ways to limit exposure**
- **Collaborate with the NID on projects such as infrastructure upgrades and water management** *(Chapter VII)*

  NID's Raw Water Master Plan indicates that sections of several canals in the Deer Creek watershed will need to undergo improvements over the next twenty-five years, to accommodate water delivery demand. Friends of Deer Creek should collaborate with NID on these projects to monitor the impacts to the aquatic ecosystem and ensure appropriate mitigation measures are implemented to protect ecosystem health. In addition, Friends of Deer Creek should work with NID to encourage water management that benefits ecosystem health. This includes appropriate management of water at the end of irrigation season, so as to not de-water the creek and strand aquatic organisms; experimenting with water management during winter and summer months, to promote small and large floods in order to restore geomorphic function and the riparian zone along upper Deer Creek; monitoring the impacts of climate change on water resources; ensuring that flow in lower Deer Creek downstream of Lake Wildwood reservoir meets the 5.0 cfs or natural flow requirement, to provide adequate in-stream flows for Chinook salmon and steelhead in Deer Creek. Rood et al. (2005) showed that proper flow management downstream of dams during high flow years can enable extensive riparian vegetation recruitment and improvements to river and floodplain function, while still providing sufficient water for environmental and economic needs. This type of restoration work should be explored with NID on Deer Creek.

- **Collaborate with Lake Wildwood, NID, and the State Division of Water Rights to ensure in-stream flows are achieved downstream of Lake Wildwood reservoir, as outlined in Lake Wildwood Association water rights documents** *(Chapter IV)*

  Currently water rights state that 5 cfs or the natural flow volume must be passed through Lake Wildwood reservoir. Efforts to quantify natural flows indicate that in a natural system during summer and early fall low flow months there would be 5.0 cfs in Deer Creek downstream of Lake Wildwood reservoir during most water years, except for potentially dry and critical water years. Overall the results indicate that the 5.0 cfs or the natural flow volume requirement is not being achieved downstream of Lake Wildwood reservoir all the time, and efforts should be undertaken to ensure the required in-stream flow allotment is received. It is important to ensure these flow volumes are achieved because they improve water quality by reducing the impact of Lake Wildwood reservoir WWTP effluent discharges on lower Deer Creek through reduced nutrient concentrations and water temperatures, and increased dissolved oxygen levels. It is of particular importance that the 5.0 cfs or natural flow requirement is achieved during September, October, and November, as these are the months in which Chinook salmon begin to enter Deer Creek to spawn. This could possibly be achieved through effective management of the Lake Wildwood reservoir drawdown release.

- **Continue to collaborate with Nevada County Sanitation District #1 WWTP to reduce its impact on lower Deer Creek from effluent discharge** *(Chapter VI)*

  Nitrate and phosphate results indicate Lake Wildwood's WWTP as a major point source for nutrient loading in lower Deer Creek, which likely influences excessive algal growth which has been measured and observed at sites 8 and 9.

- **Work with private landowners in the Deer Creek watershed to place conservation easements on their properties or to acquire land that will be set aside for conservation** *(Chapter VII)*

C2. Conduct outreach:

- **Work with communities to implement smart growth principles** *(Chapter VII)*

  Smart growth includes a range of conservation and development strategies that help to protect the natural environment while making communities more attractive, economically stronger, and more socially diverse (USEPA 2011a). Using smart growth principles, development can be guided to minimize air and water pollution, encourage Brownfields clean-up and reuse, and preserve natural lands (USEPA 2011a). Smart growth practices reduce the environmental impacts associated with development, using techniques that include compact development, a reduction in impervious surfaces, improved on-site water retention through green infrastructure, safeguarding of environmentally sensitive areas, providing a mix of land uses including homes, offices and shops, transit accessibility, and improved pedestrian and bicycle amenities (USEPA 2011a). Friends of Deer Creek should work with the communities of Nevada City, Penn Valley, Lake Wildwood, and Rough and Ready to encourage implementation of smart growth principles. Brownfields clean-up and reuse projects are currently underway in Nevada City, with potential to expand to additional contaminated properties.

- ❖ **Encourage the adoption of adaptation and mitigation strategies such as those listed in the Sierra Nevada Alliance's Sierra Climate Change Toolkit, for use by local and regional government agencies, private landowners, and watershed organizations** *(Chapter VII)*
- ❖ **Conduct outreach to landowners in major communities in the watershed to educate citizens about the importance of the riparian zone** *(Chapter VI)*

  Data indicated invasive species were most prominent around major communities such as Nevada City, Lake Wildwood, and Penn Valley. Additionally, deficient lower canopy cover and exposed groundcover were apparent in major communities. Outreach and education efforts to these communities will be crucial for the effectiveness of future restoration projects and decreasing riparian zone impacts from anthropogenic activities.
- ❖ **Develop land restoration plans and best management practice guidelines for agricultural landowners in the vicinity of the creek, to reduce bacterial contamination from runoff and grazing** *(Chapter VI)*
- ❖ **Develop trainings for bacterial remediation to be offered regionally** *(Chapter VI)*

  Trainings would aid other watershed organizations and stakeholder groups in determining public health implications of water bodies used for recreation. Trainings would cover sampling, assessments, data analysis, selection and implementation of remediation options, securing of funding, and public outreach.
- ❖ **Post warnings and conduct other forms of outreach to alert the public of bacterial contamination** *(Chapter VI)*

  This would include dissemination of findings through the FODC/SSI website, local news outlets, and the community center at Western Gateway Park; posting data on the State's Safe to Swim Water Quality Portal http://www.swrcb.ca.gov/mywaterquality/safe_to_swim/; and conducting public outreach aimed at providing information and making connections with area ranchers and farmers through Fish and Wildlife Commission public meetings.
- ❖ **Post warnings and conduct other forms of outreach to alert the public of fish consumption advisories** *(Chapter II)*

  Data indicate THg concentrations in fish tissue that could have public health implications if consumed on a regular basis. Outreach and education should be conducted to ensure the public is aware of potential mercury contamination in fish caught in the Deer Creek watershed.

- **Ensure the preservation of Maidu artifacts such as millstones and arrowheads by creating and disseminating protocols for handling found items** *(Chapter II)*
- **Implement a program to build understanding of Maidu ecosystem stewardship as a baseline for restoration planning** *(Chapter II)*

C3. Enhance recreational opportunities:

- **Complete the connection between the Tribute Trail sections, including securing funding for a footbridge connecting river left and river right trails in the vicinity of Providence Mine**
- **Develop a lower watershed trail system around Lake Wildwood**
- **Identify historic and pre-historic trails in the watershed** *(Chapter II)*
- **Create a map of trails in the Deer Creek watershed and make it available online**
- **Create a pre-contact map and model of the Nevada City area, including roundhouse sites, trails, settlement areas, cemeteries and springs** *(Chapter II)*
- **Work with Lake Wildwood Association to erect a monument at Lake Wildwood for the Anthony House** *(Chapter II)*
- **Create signage denoting the importance of historic sites to indigenous people** *(Chapter II)*
- **Work with Western Gateway Park Association to erect statues of bears in the park in Penn Valley, where bears were once abundant** *(Chapter II)*

D. Regulatory Recommendations and Compliance

(All Recommendations from Chapter VII)

- **Follow changes to important local, regional, state and national planning, regulation and monitoring efforts**

  It is important to follow changes to major planning documents, such as the Basin Plan or County General Plan. For example, recently the EPA adopted *E. coli* as the most appropriate indicator of fecal contamination in freshwater bodies, replacing fecal coliform, the previous indicator. The EPA mandated that the States use the same indicator organisms to protect human health during water contact recreation. The State of California directed the Regional Water Boards to adopt the new indicator organism, with the Central Valley Water Board amending the Basin Plan to include *E. coli* as the indicator organism. Although the Basin Plan was amended to include *E. coli*, the State has yet to adopt *E. coli* as the indicator organism. This demonstrates the fact that complicated changes in agency planning at multiple levels can impact the work done by Friends of Deer Creek to protect environmental and human health.

- **Ensure the ban on suction dredging is being observed in the watershed and follow new developments related to the suction dredge ban**

  At FODC/SSI site 6 within Lake Wildwood, a dredge was found on the stream bank, indicating that suction dredging occurred in 2009 and 2010. The dredging activity resulted in significant impacts to the stream bed and degradation of aquatic habitat. Activity such as this, discovered in the course of monitoring and assessing the watershed, should be reported to the appropriate authority, such as the Department of Fish and Game.

- **Establish to the extent possible a natural buffer zone along Deer Creek and its tributaries, through land acquisitions, conservation easements, and building ordinances**

  There are many properties in the Deer Creek watershed that are not currently developed, but have development potential. Friends of Deer Creek should work with the Nevada County Land Trust and willing property owners to set aside properties for conservation whenever possible. Attempts should be made to establish a natural buffer zone along perennial tributaries in the watershed, with efforts focused on expanding to parcels adjacent to existing conservation easements, such as the 158 acre Hahn Easement on upper Deer Creek and the 114 acre Sheatsley Family Trust Easement on lower Deer Creek and Squirrel Creek.

- **Conduct additional investigation into the regulatory opportunities of, and constraints on, maintaining healthy flows in the entire Deer Creek watershed**

  Water rights conferred by the License for Diversion of Use of Water (Application# 23047, Permit# 15779, License# 10779) to Lake Wildwood Association indicate that Lake Wildwood reservoir must pass through a minimum of 5 cfs or the natural flow in lower Deer Creek. Efforts to ensure the 5 cfs allotment is met during summer months should be investigated, through the Division of Water Rights, and by working with NID, Lake Wildwood, the State Water Resources Control Board, and the Division of Water Rights. In addition, efforts should be undertaken to ensure that after the drawdown release, Lake Wildwood passes through all inflow until November 1, as flow is not allowed to be stored until that date. Both of these efforts will help to ensure that there is adequate stream flow to provide habitat and water quality benefits, so that aquatic organisms such as macroinvertebrates and anadromous fish may thrive in Deer Creek.

- **Ensure major development projects in the watershed comply with existing laws and regulations, so that the health of the ecosystem is protected and that appropriate mitigation measures are implemented to offset impacts to the environment**
- **Support the development of scientifically sound zoning and building regulations that protect creek health, including best management practice guidelines for preventing erosion associated with development**
- **Promote the requirement that new developments install landscaping and infrastructure that would limit impervious surface cover and promote on-site infiltration of precipitation, and reduce sediment and pollutant inputs to area creeks during precipitation events**

  Projects incorporating the use of these materials and design practices were recently implemented at the Rood Center and a co-housing development in Nevada City and should be expanded to additional developments throughout the watershed.
- **Work with county and city agencies to develop best management practices to limit erosion associated with roads; incorporate erosion control best management practices into development guidelines such as the County General Plan**

  With the likelihood of continued rapid growth leading to more soil disturbance in the watershed, fine sediment levels should be monitored over time and erosion control Best Management Practices incorporated into development guidelines, including the county General Plan, to insure that fine sediments levels do not become serious water quality concerns. Friends of Deer Creek has been monitoring turbidity and total suspended solids since 2000 in the Deer Creek watershed, providing a baseline dataset to evaluate future changes. In addition, benthic macroinvertebrates make ideal bio-indicators for assessing the impacts of fine sediment associated with developments that impact Deer Creek and its tributaries. Benthic macroinvertebrates were recently added to the monitoring requirements for General Construction Permits under the Storm Water Program of the California State Water Resources Control Board, to help evaluate impacts associated with development, such as fine sediment loading to creeks. With a long-term macroinvertebrate dataset dating back to 2000, Friends of Deer Creek is well positioned to monitor the impacts of development on the watershed. When possible, Friends of Deer Creek should collaborate with developers to monitor major construction activities that are undertaken in the watershed, using macroinvertebrates as indicators of stream health.

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Abbreviations

BMI= Benthic Macroinvertebrates

cfs= cubic feet per second

EFC= Environmental Flow Components

EP or EPQ(q)= Exceedence Probability

FDC= Flow Duration Curve

FQ(q)=cumulative distribution function (non-exceedence probablitity) of q

ft= feet

HA= Hydrologic Alteration

HEC-SSP= Hydrologic Engineering Center Statistical Software Package

IBI= Index of Biotic Integrity

Ma B.P.= million years before present

mi^2= square miles

ml= millileters

mm= millimeters

msl= mean sea level

NID= Nevada Irrigation District

PostSF= after Scotts Flat reservoir upgrade

PreSF= before Scotts Flat reservoir upgrade

q= daily average flow magnitude

Q2, Q5, Q10, Q25, Q50, Q100, Q200, Q500= Flood intensity (Q2= 2 year flood, Q5= 5 year flood, Q10= 10 year flood, etc.)

RVA= Range of Variability Approach

SSI/FODC= Sierra Streams Institute/Friends of Deer Creek

TNC= The Nature Conservancy

USACE= United States Army Corps of Engineers

USDA- United States Department of Agriculture

USGS= United States Geological Survey

UV= Ultra-violet

WWTP= Waste Water Treatment Plant

yd^3= cubic yards