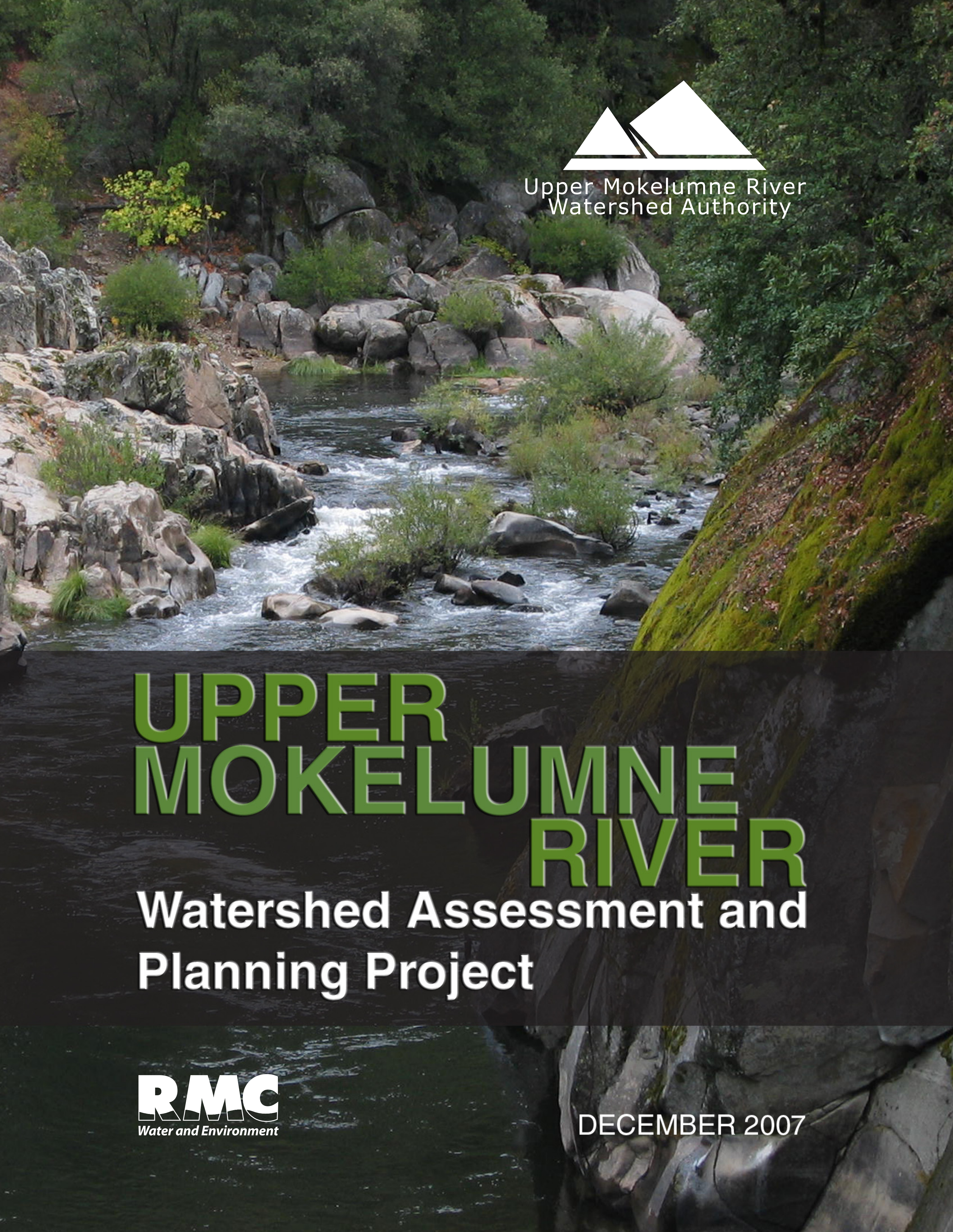


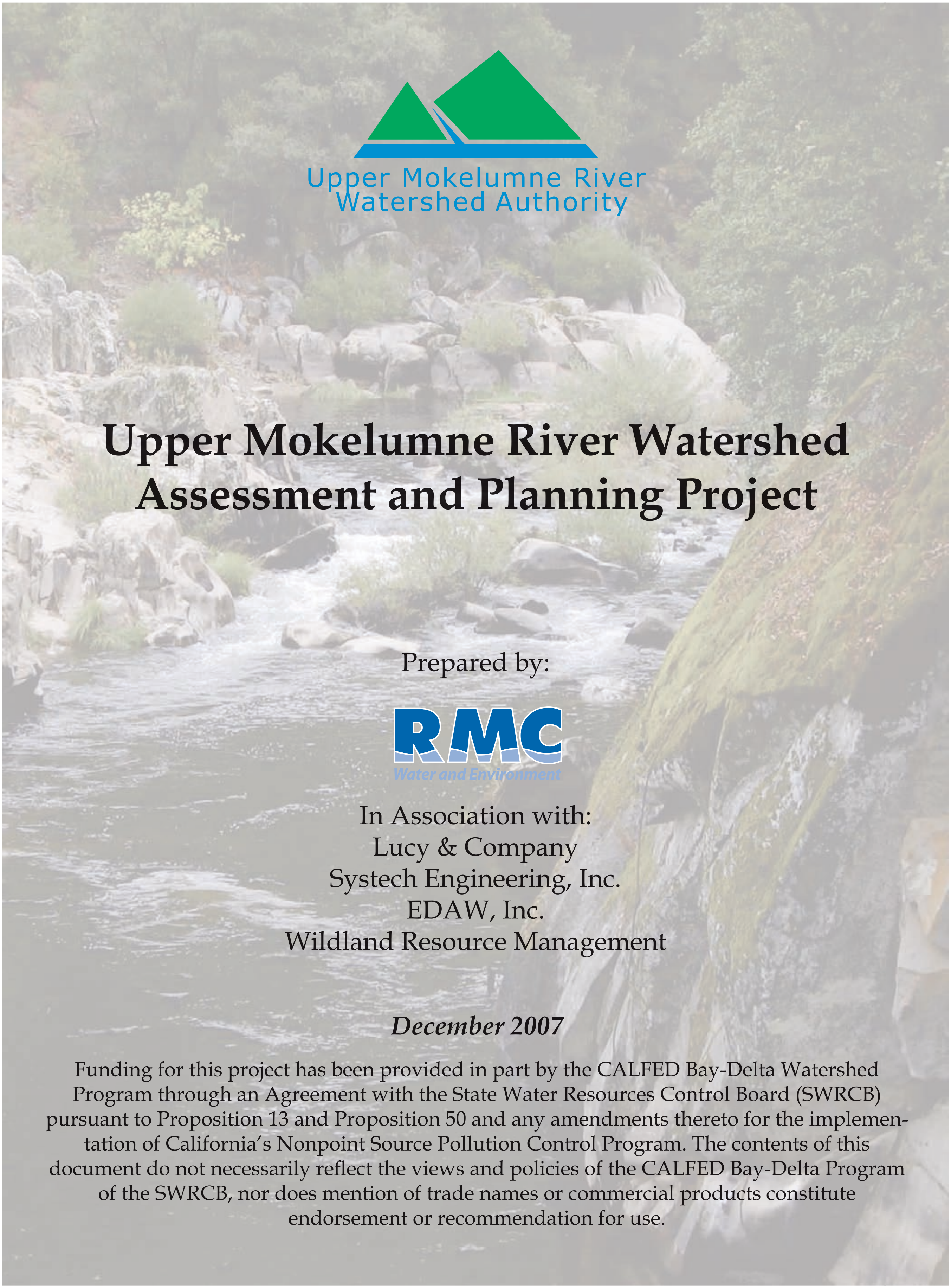
Upper Mokelumne River Watershed Authority

UPPER MOKELUMNE RIVER

Watershed Assessment and Planning Project

RMC Water and Environment

DECEMBER 2007



Upper Mokelumne River
Watershed Authority

Upper Mokelumne River Watershed Assessment and Planning Project

Prepared by:

RMC
Water and Environment

In Association with:
Lucy & Company
Systech Engineering, Inc.
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Wildland Resource Management

December 2007

Funding for this project has been provided in part by the CALFED Bay-Delta Watershed Program through an Agreement with the State Water Resources Control Board (SWRCB) pursuant to Proposition 13 and Proposition 50 and any amendments thereto for the implementation of California's Nonpoint Source Pollution Control Program. The contents of this document do not necessarily reflect the views and policies of the CALFED Bay-Delta Program of the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Upper Mokelumne River Watershed Assessment and Planning Project

Contract number:

04-125-555-0 (Part 2) and 03-250-555-0 (Part 1)

Study Area:

Upper Mokelumne River watershed, east of Highway 49

Project Summary:

The Upper Mokelumne River Watershed (Authority) undertook the Upper Mokelumne River Watershed Assessment and Planning Project (project) to advance a broader understanding of watershed water quality issues of concern and to develop a method and tools for the long-term evaluation of Upper Mokelumne River watershed water quality. A Project Advisory Committee was formed and an outreach plan developed to guide the stakeholder-driven process. A methodology was developed to identify and address potential source water quality issues. Extensive data were collected and evaluated, with data gaps determined and a data development plan implemented. A watershed water quality assessment was performed based on the establishment of baseline water quality conditions, the application of developed benchmarks, and the resulting identification of parameters of interest.

A watershed hydrologic simulation model was developed as a tool to analyze the entire watershed's existing hydrologic and water quality characteristics with the ability to analyze future potential water quality conditions based on changes to land uses and activities. In addition to baseline water quality and the watershed model, other tools such as Water Quality Vulnerability Zones and fire modeling, are now available for use. The watershed management plan developed for this project is derived from the watershed water quality assessment, with technically based recommendations to maintain and improve source water quality. The most critical recommendations are in response to leaky septic systems.

Proposition 13 and Proposition 50 grants of $950,000 were provided by the CALFED Watershed Program for the two-phased project with matching funds of $317,500 provided by the Authority; the grant funding was administered by the State Water Resources Control Board (SWRCB).

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Chapter One
Introduction

1.1 Project Background

The Upper Mokelumne River Watershed Authority (Authority) is a joint powers authority consisting of the nine members listed below. The Authority was formed to address areas of mutual concern pertaining to drinking water quality, water supply, and the environment within the Upper Mokelumne River watershed. The Authority undertook the Upper Mokelumne River Watershed Assessment and Planning Project (project) to advance a broader understanding of watershed water quality issues of concern and to develop a method and tools for the long-term evaluation of Upper Mokelumne River watershed water quality.

AUTHORITY MEMBER AGENCIES
Alpine County
Alpine County Water Agency (ACWA)
Amador County
Amador Water Agency (AWA)
Calaveras County
Calaveras County Water District (CCWD)
Calaveras Public Utility District (CPUD)
East Bay Municipal Utility District (EBMUD)
Jackson Valley Irrigation District (JVID)

Partly because this was the first project undertaken by the Authority, and it was a significant project, it was important that the process be collaborative in working with watershed stakeholders, with respect given to all ideas and opinions. It was also important to the Authority that the work be focused on the project goal(s) and be completed within the allocated budget and scheduled completion date of February 2008. Proposition 13 and Proposition 50 grants were provided by the CALFED Watershed Program for the two-phased project with some matching funds provided by the Authority; the grant funding was administered by the State Water Resources Control Board (SWRCB). Representatives of the funding and administration agencies were active participants in the project.

This report summarizes key project activities. Detailed information regarding each of the tasks and activities can be found in the appendices located on a CD in the back pocket of this document. There were two parts to this planning and assessment project.

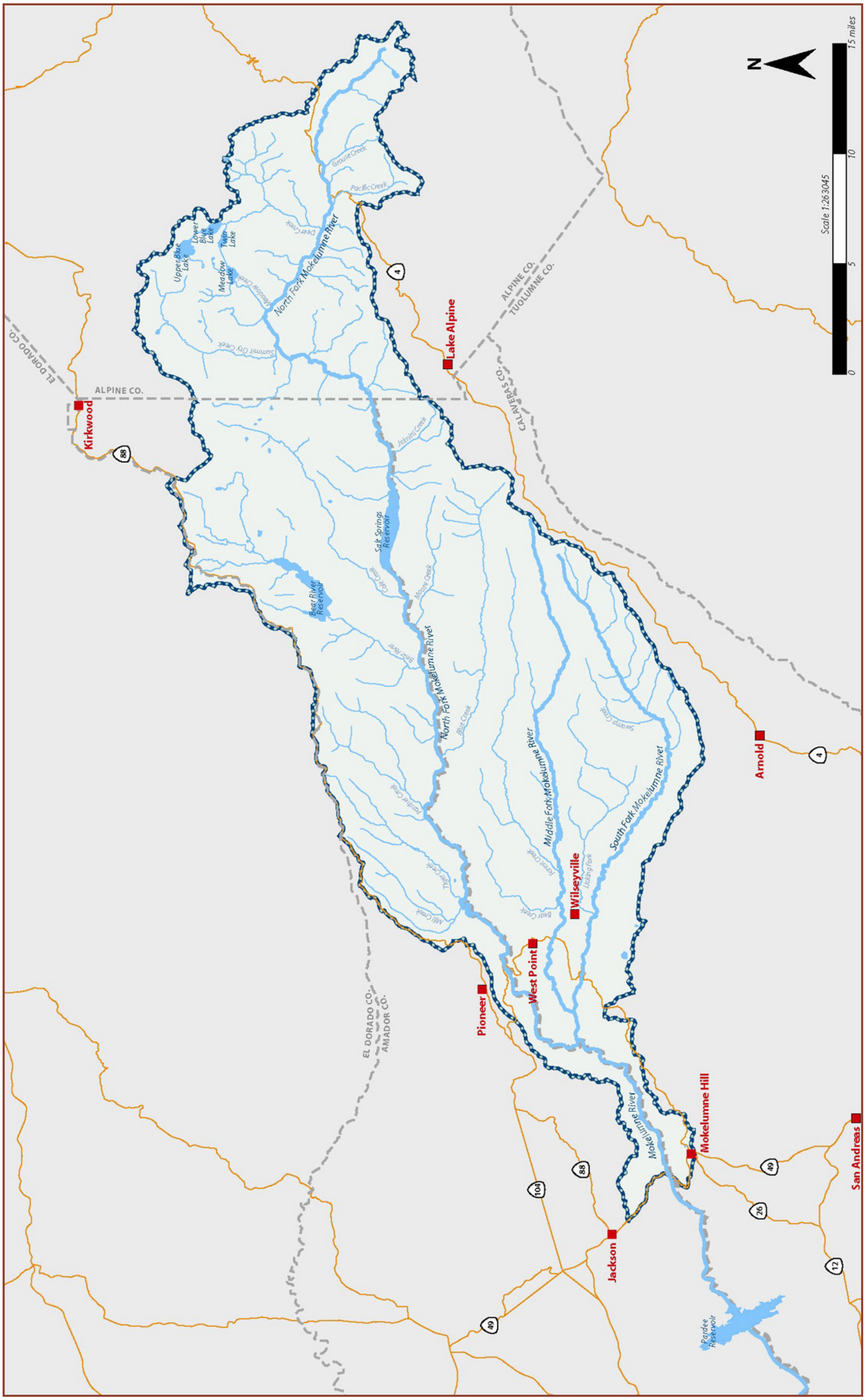
- **Part 1** of the project focused on developing a Project Advisory Committee (PAC) to establish the planning and implementation framework for the project. As presented in the Part 1 report (Appendices A and B), the PAC specifically agreed upon the governing procedures for the project, selected a watershed assessment approach, and developed a data collection strategy. The PAC also developed the following project goal.

  Maintain and improve source water quality

Salt Springs Reservoir on North Fork Mokelumne River

- **Part 2** of the project documented existing baseline water quality and watershed conditions, identified existing and potential risks to beneficial uses, and established a program to evaluate long-term water quality. An assessment tool was developed to provide a better understanding of watershed processes, particularly in areas of the watershed with limited data; identify potential responses to changing watershed conditions; and inform future decision-making in the watershed.

Figure 1-1: Upper Mokelumne River Watershed



1.2 Setting and Project Needs

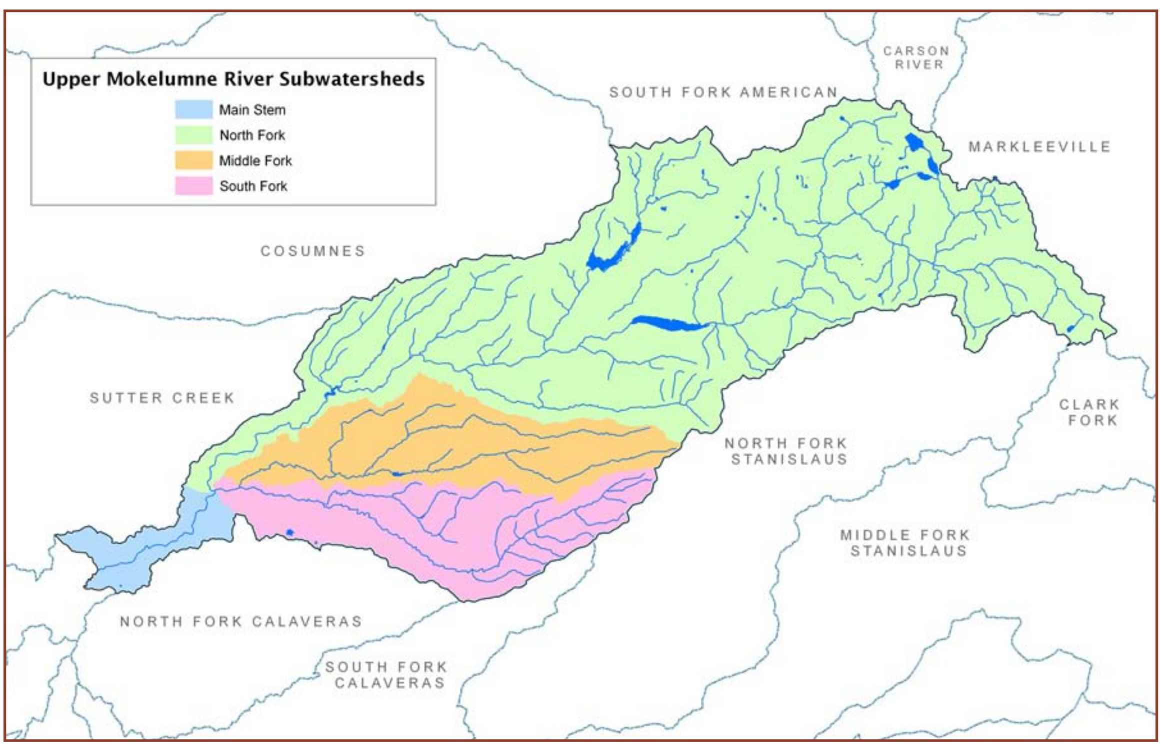
The Upper Mokelumne River watershed consists of all lands that drain into the North Fork, Middle Fork, South Fork, and Main Stem of the Mokelumne River with Highway 49 as the downstream boundary. This 550-square-mile watershed is located within Alpine, Amador, and Calaveras counties. The North Fork subwatershed is the largest, spanning 370 square miles and contributing approximately 85 percent of the river flow. The topography of the watershed is rugged with elevations ranging from 600 to 10,400 feet. Figure 1-1 presents the watershed boundary.

The watershed is a source of drinking water for about 1.3 million people living within and outside of the watershed. Water suppliers which depend on water from the Upper Mokelumne River include the CPUD, CCWD, AWA, EBMUD, and JVID. Issues of concern in the watershed include the protection of water quality for drinking water supplies and protection of aquatic species from impacts caused by land uses and activities. Potential contaminants in the Upper Mokelumne River can result from activities such as timber harvesting, hydropower production, recreation, rural residential land uses, and events such as wildfires and floods. In addition, the western part of the watershed is experiencing pressure for increased urbanization which can increase risks to water quality.

The watershed contains important habitat for sensitive species and is utilized by outdoor recreation enthusiasts throughout the year. Land and water resource management decisions in the watershed are made by a variety of public and private entities. There are several large landowners in the watershed, such as the U.S. Forest Service (USFS), Sierra Pacific Industries (SPI), Bureau of Land Management (BLM), and Pacific Gas & Electric (PG&E), and many small landowners and other interested parties advocating for the various beneficial uses of the streams, lakes, and reservoirs.

The Upper Mokelumne River watershed is divided into four major subwatersheds: North Fork, Middle Fork, South Fork, and Main Stem. These subwatersheds are shown in Figure 1-2 This subwatershed map is used throughout this report as a base map.

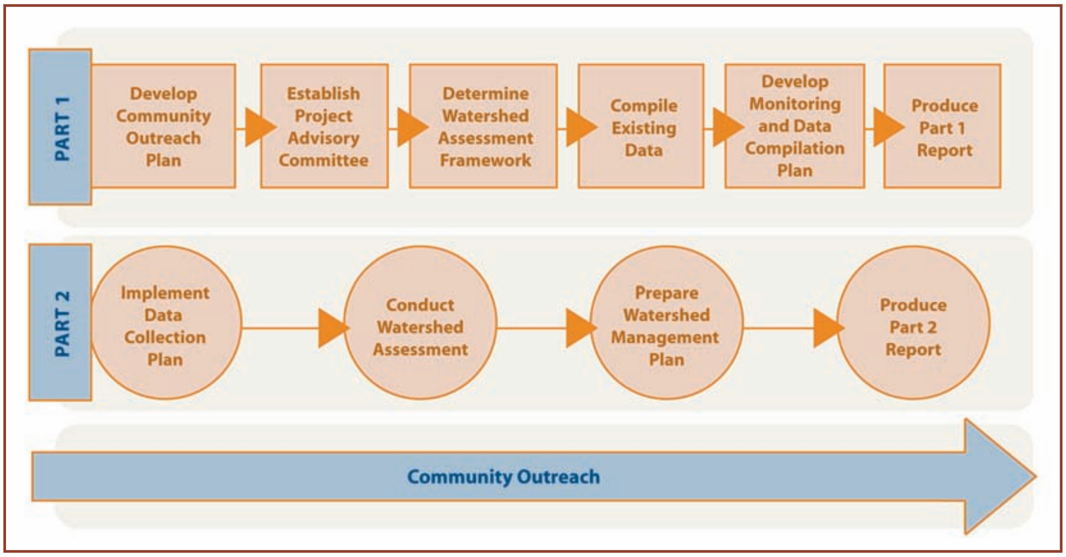
Figure 1-2: Upper Mokelumne River Subwatersheds



1.3 Project Tasks

To ensure that this project reflects local knowledge, conditions, and interests, local stakeholders were involved in the project through implementation of a targeted outreach process. Engagement of key stakeholders was accomplished through the use of the Project Advisory Committee's regularly scheduled meetings, and public involvement was achieved through six community workshops where members of the public were invited to contribute to the process. Chapter 2 describes this outreach effort. Figure 1-3 presents an overview of the primary tasks conducted for the project.

Figure 1-3: Work Tasks



As interim project milestones were met, descriptions of each task were captured in technical memoranda (TMs). Draft TMs were submitted by the project team for review by the PAC. Following PAC review, the TMs were edited to incorporate PAC feedback and submitted to the SWRCB for review. TMs were then updated to address SWRCB comments and finalized. The TMs produced throughout project implementation are provided as appendices to this document along with a formal list of contract deliverables to the SWRCB (Appendix C). Key work products capturing the technical analyses conducted for this project include those listed in the box below.

1.4 Where Do We Go From Here?

As mentioned earlier in this chapter, key purposes of the project were to provide a broader understanding of Upper Mokelumne River watershed water quality conditions and develop a method and provide tools for the long-term evaluation of water quality conditions. Due to the in-depth nature of the technical tasks presented in this document, a broader understanding of water quality conditions has been achieved. An important task after the project is complete is to ensure that those who are interested in the state of the watershed are informed of the availability and usefulness of this information and data.

The methodology for assessing watershed water quality conditions, developed under these project tasks, allows for future assessments using data from ongoing monitoring programs as well as using the project-developed hydrologic simulation model of the watershed – WARMF – for subbasins without water quality data. The WARMF tool, as well as several other tools developed for this project (water quality vulnerability zones and fire modeling) must be periodically updated and maintained on a regular basis or as they are used in practical applications, to ensure their viability and usefulness. It is imperative that the

Authority, as a leader in establishing a collaborative stakeholder process for this project, ensure that the water quality monitoring currently occurring in the watershed be maintained to allow for continual updates of the watershed model and for the detection in changes of the parameters focused on here.

When water quality data indicate a change from baseline conditions, it is often too late to correct the causes of the impact. This project provides a sound technical basis for the watershed management plan recommendations, recommendations specifically developed by the PAC to target the sources, causes, and transport of contaminants and to encourage regulatory actions to protect source water quality. As demonstrated by the water quality assessment and its associated findings, existing water quality problems will not be mitigated, nor future problems avoided, absent implementation of the recommended management measures. For example, concentrations of parameters of interest, such as microorganisms associated with leaking septic systems, will increase in response to development in the area, if management measures are not implemented. A key action item is to follow through on the recommendations for a septic survey to substantiate the problem.

The watershed contains hydroelectric generating facilities

Several key recommendations are tied to the General Plan update process that Amador and Calaveras counties are currently undertaking. This is an opportune time to integrate the water quality protection measures into the county planning and policy development process. It is important for the Authority, the PAC members, and other watershed stakeholders to continue to seek funding needed to implement the various management measures provided here – particularly in regards to eliminating leaking septic systems - to ensure that source water quality is maintained or improved in the Upper Mokelumne River watershed.

Key Products

- Community Outreach/Stakeholder Participation Plan
- PAC Governing Procedures Guidebook
- Project Goal
- Technical Memorandum Number 1: Assessment Tool Comparison
- Technical Memorandum Number 2: Assessment Methodology
- Technical Memorandum Number 3: Data Development Plan
- Technical Memorandum Number 4: Data Collection and Monitoring Plan
- Part 1 Report
- Quality Assurance Project Plan
- Project Assessment and Evaluation Plan
- Technical Memorandum Number 5: Baseline Water Quality
- Technical Memorandum Number 6: WARMF Assessment Tool Development and Calibration
- Technical Memorandum Number 7: Water Quality Vulnerability Zone Development
- Technical Memorandum Number 8: Fire Modeling
- Technical Memorandum Number 9: Watershed Assessment Report
- Technical Memorandum Number 10: Watershed Management Plan
- Newsletters (10)
- Final Report
- Septic System Management Program

Chapter Two

Stakeholder and Community Involvement

A critical aspect of this project was the effective involvement of residents and the community interested in the Upper Mokelumne River watershed. The primary stakeholder outreach efforts were the formation of an active and dedicated PAC to provide guidance throughout all major steps in the process and the solicitation of public input at project milestones.

2.1 Project Advisory Committee

Knowledgeable members of the public were recruited to serve on the PAC. The goal was to enlist members of the public that represented a broad range of interests, had specific expertise or knowledge of the Upper Mokelumne River watershed, and had experience on collaborative efforts.

PAC members representing a variety of organizations assisted in providing data for use in the watershed assessment.

As shown in Table 2-1, balanced representation of regional business interests such as logging, agriculture, and forestry was sought for participation in the PAC along with public service, environmental, resource management, water purveyor, recreational, local landowners – both large land holdings and individual landowners, and general watershed knowledge and interests. The personal time commitment began in January 2005 and continued through December 2007, an intensive three year effort. PAC membership remained constant throughout Part 1 of the project. In Part 2, several members moved or changed positions in their organization and were replaced.

Table 2-1: PAC Members

PAC Member	Organization or Agency Represented
Pete Bell	Foothill Conservancy; Project 137 Ecological Resources Committee; Upper Mokelumne River Watershed Council
Dan Brown *(replaced by Heinz Hamann October 2007)*	Amador Water Agency
Chuck Loffland	USDA Forest Service, Amador Ranger District
Dick McCleery	Central Sierra Resource Conservation and Development
Kent Lambert *(replaced Jerry Ongerth April 2006)*	East Bay Municipal Utility District
Laura Lueders *(replaced by Hannah Schembri April 2007 for 2 months)*	Alpine Watershed Group
Susan Snoke *(replaced Terry Strange May 2007)*	Upper Mokelumne River Watershed Council
Ed Struffenegger	Sierra Pacific Industries
Tracey Towner-Yep	Amador County Recreation Agency
Hank Willy	Jackson Valley Irrigation District

In addition to the official PAC members listed in Table 2-1, Bob Dean (CCWD Board of Directors, Authority Board of Directors, and Upper Mokelumne River Watershed Council), and Edwin Pattison (CCWD staff) actively contributed to Part 2 of the project.

Community members participate at local workshops

The project goal, watershed assessment, and management plan recommendations clearly reflect PAC member contributions. PAC members were tasked with providing guidance on all aspects of the project; this collaborative structure led to the development of practical recommendations at each stage.

The agenda, attendees, and minutes from each of the 16 PAC meeting are provided in Appendix B (Part 1) and Appendix D (Part 2). A significant effort was required on the part of the PAC members to accomplish the project tasks while remaining on schedule. PAC materials were mailed as early as three weeks prior to meetings to allow PAC members adequate time to review materials prior to meetings and arrive at meetings ready for discussion. Due to the collaborative and productive nature of the PAC, a significant amount of work was accomplished in a relatively short period of time.

2.2 Community Outreach and Stakeholder Involvement Strategy

Because the watershed spans three counties and numerous communities, an outreach strategy was developed for a semi-rural to rural watershed. A two-tiered approach was adopted that separated stakeholder-specific participation (the PAC) from general community outreach. A database of stakeholders and key contacts was developed and maintained to expedite communication, providing a central mailing list for workshop invitations and project status updates.

An important goal of the project was to provide an opportunity for the general public living within or near the watershed to become involved in the project, learn about project developments, and provide input into PAC work products. A calendar of community workshops was developed and publicized via word of mouth (PAC member outreach), handbills, paid advertisements, media relations, and newsletters.

2.2.1 | Community Outreach

ASSESSING WATER QUALITY AND WATERSHED CONDITIONS TODAY, PLANNING FOR TOMORROW

Upper Mokelumne River Watershed Authority

WE WANT YOUR HELP IN PROTECTING AND IMPROVING THE QUALITY OF DRINKING WATER IN THE UPPER MOKELUMNE RIVER WATERSHED!

PROJECT OVERVIEW

The Upper Mokelumne River Watershed Authority (Authority) is conducting the Upper Mokelumne River Watershed Assessment and Planning Project (project) to document existing water quality conditions and establish a program to evaluate long-term drinking water quality and watershed trends. Information from the process will be used to develop a watershed assessment and management plan that aims to protect the waters of the Upper Mokelumne River watershed from pollution. The project will be carried out through a series of steps including defining project goals, establishing the assessment methodology, and collecting data.

TO DATE

On November 4, 2004, the Authority hosted a public workshop to provide an overview of the project and to:

- **Gather public input on the project Community Outreach and Stakeholder Participation Plan;**
- **Solicit interest from potential members for the Project Advisory Committee (PAC); and**
- **Answer any questions that members of the public had about the project.**

THE PROJECT ADVISORY COMMITTEE

Ten members from diverse backgrounds within the watershed are serving on the PAC for the purposes of providing recommendations on all aspects of the project.

The PAC first met in January to define meeting schedules, agree on meeting logistics and to finalize the Community Outreach and Stakeholder Participation Plan. At the second PAC meeting in March, PAC members contributed their insight about project goals and the assessment tool that will be used to help determine how water quality within the Upper Mokelumne River watershed is impacted by factors such as wildfires, road runoff, wastewater facilities and erosion.

WHAT'S NEXT!

For the remaining portion of Part 1 of the project, expected to run through 2005, project goals and an assessment methodology will be finalized. The information that is needed for the assessment tool will be identified, data gathered and gaps in data targeted. Part 2, conducting the watershed assessment and developing the drinking water watershed management plan, will begin in 2006 and continue through 2007.

WHY YOU SHOULD ATTEND THE WORKSHOPS!

May 11 is a chance for you to learn about what is happening with the project and the next steps that will be taken to protect or improve Mokelumne River water quality!

When you turn on your faucet to get a glass of water to drink, do you think about where that water is coming from? If you live in portions of Alpine, Amador or Calaveras counties, your water may come from the Mokelumne River. Within this watershed surrounding the river, there are a number of factors that can impact drinking water quality. Identifying these factors, how they impact the river's watershed and what steps can be taken to help reduce or avoid these impacts, are the primary purposes of the project. This workshop provides you, a watershed resident, the opportunity to learn about these issues, how they may affect you and how you can assist with developing a plan to address them.

These community workshops provide a chance for the public to give input on the direction this important project is taking. Workshop participants have a chance to voice their concerns about what they view as threats to the watershed and river water quality. Attendees also can help greatly by identifying sources of data for use during the assessment stage.

UPPER MOKELUMNE RIVER WATERSHED ASSESSMENT AND PLANNING PROJECT

Newsletters were distributed throughout the community, inviting interested people to attend each informational public workshop.

In general, the project was not perceived by the local public as being controversial. As a result, watershed residents did not attend the community workshops in great numbers, and a media campaign was developed to keep the general public informed of project developments and invite their input. The workshops were advertised within the communities of Alpine, Amador, and Calaveras counties. Media releases and newsletters were sent to the *Record Courier*, *Calaveras Enterprise*, *West Point Press*, and the *Ledger Dispatch,* and follow up phone calls were made to encourage press coverage of each community workshop.

Project newsletters were developed to provide concise summaries of the project activities that occurred since the previous newsletter. The newsletters were timed to announce upcoming workshops and provide contact information if the recipients had questions. The newsletters were distributed to the entire stakeholder database as well as to the media and are provided in Appendix E. Names of database contacts are provided in Appendix F.

2.2.2 | Community Workshops

The community workshops were professionally facilitated, contributing to an atmosphere that encouraged feedback. All community workshops were held within or adjacent to the watershed for ease of community accessibility.

The community workshops were intended to provide an opportunity for the public to learn about the project; give attendees opportunities to comment; solicit suggestions, data sources, and provide other local knowledge about the issue at hand; and ensure that the process was inclusive. Appendix G contains the minutes from each of the six workshops along with attendees.

Community workshop number 6 at the Hotel Legar in Mokelumne Hill.

To attract the greatest number of interested attendees possible, the community workshops were frequently held in conjunction with either or both the Upper Mokelumne River Watershed Council and the Central Sierra Resource Conservation & Development meetings. Advertising for community meetings was tailored to describe the Upper Mokelumne River Watershed Assessment and Planning project as well as the meeting being held by the partnering entity. This combined approach resulted in improved attendance for both the project and the partnering meeting by minimizing the effort required by attendees to maintain involvement in multiple organizations and efforts.

Chapter Three

Data and Model Development

The watershed assessment and management plan are based on a solid understanding of the watershed developed through detailed analyses of watershed data. This understanding was enhanced through the use of tools that build on existing data to simulate watershed conditions where data are not currently available. This section reviews the data collection process described in both Appendix A - the Part 1 Report, and Appendix B - TM No. 4, as well as the post-processing steps completed to convert data to a useful format.

3.1 Data Collection and Organization

3.1.1 | Purpose

The initial data collection needs were determined based on the input and calibration requirements of the primary assessment tool selected for this project: Watershed Analysis and Risk Management Framework (WARMF) hydrologic simulation model. The process for selecting the primary assessment tool and data requirements are presented in Appendix B - TM No. 2: Assessment Methodology, and TM No. 3: Data Development Plan. The data sets compiled for use by the WARMF model were also used to establish baseline water quality, develop a Water Quality Vulnerability Zone (WQVZ) map, and simulate fire behavior. Because a significant quantity of data was collected as part of this effort, datasets were organized into non-spatial databases (stored in Microsoft Excel and Access databases) and spatial databases (stored in a Geographic Information System [GIS]).

3.1.2 | Existing Data Development

Local climate data were collected for the project

In order to fulfill the data needs associated with the assessment tool and baseline water quality analysis (presented in Appendix H), a wide variety of existing data was collected from various agencies, including anthropogenic conditions and land management, air quality, hydrography, meteorology, land cover and land use, streamflow, topography, water quality, and geology.

Most of the data were obtained from existing electronic or hard copy documents. Data were also provided by PAC members representing agencies such as the U.S. Forest Service, Sierra Pacific Industries, and the Foothill Conservancy. Data was also provided by PG&E, as well as the counties of Alpine, Amador, and Calaveras.

Initial evaluations (or screenings) were performed to gauge the potential utility of datasets in addressing the identified data needs. From this process, project data gaps were also identified, and a Data Collection and Monitoring Plan (Appendix B - TM No. 4) was developed to establish a methodology for filling those gaps. TM No. 4 also provides a detailed description of all existing datasets used in support of the project.

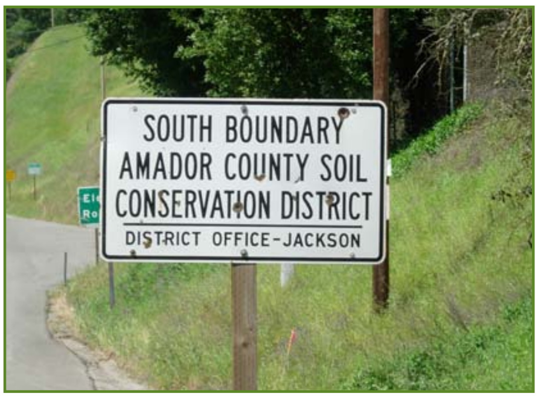
3.1.3 | Additional Data Collection and Data Creation

Additional datasets collected through implementation of the Data Collection and Monitoring Program included septic tank locations, human impact areas (campgrounds, heavily used hiking trails, illegal dumping locations, and other uses that could contribute to water quality degradation), and additional water quality monitoring data.

Because many of the human impact areas were largely undocumented, community input and PAC member discussions were essential to obtaining accurate information on the location and extent of activity. The information obtained through this process was later verified through field visits aimed at ground-truthing both the anecdotal and documented human impact area data collected.

The targeted water quality data collection filled data gaps in existing datasets for WARMF model calibration and the baseline water quality assessment. For efficiency and consistency in monitoring, it was recommended that additional monitoring data be collected at existing monitoring sites on the Middle and South Forks of the Mokelumne River. The monitoring locations and constituents included in the data collection plan were selected to provide data that would be comparable to the existing data being collected in the North Fork and Main Stem of the river. These data were collected in accordance with the project's Quality Assurance Project Plan (QAPP) submitted and approved by the SWRCB in April of 2006 (the QAPP is provided in Appendix I).

3.1.4 | Data Processing and Compositing



Many agencies provided existing data

This section describes the process that was taken to compile and process the data collected in Part 2 to achieve a format that was compatible with both existing spatial and non-spatial datasets. In addition, this section discusses the process used to combine several spatial data sets (or GIS layers) to create one land use layer. The resulting land use layer was used in the WARMF model (presented in Appendix J), for the WQVZ analysis (presented in Appendix K), and for the fire models (presented in Appendix L). In addition to the full analyses provided in the noted appendices, development and use of these tools are described later in this report.

Spatial Database

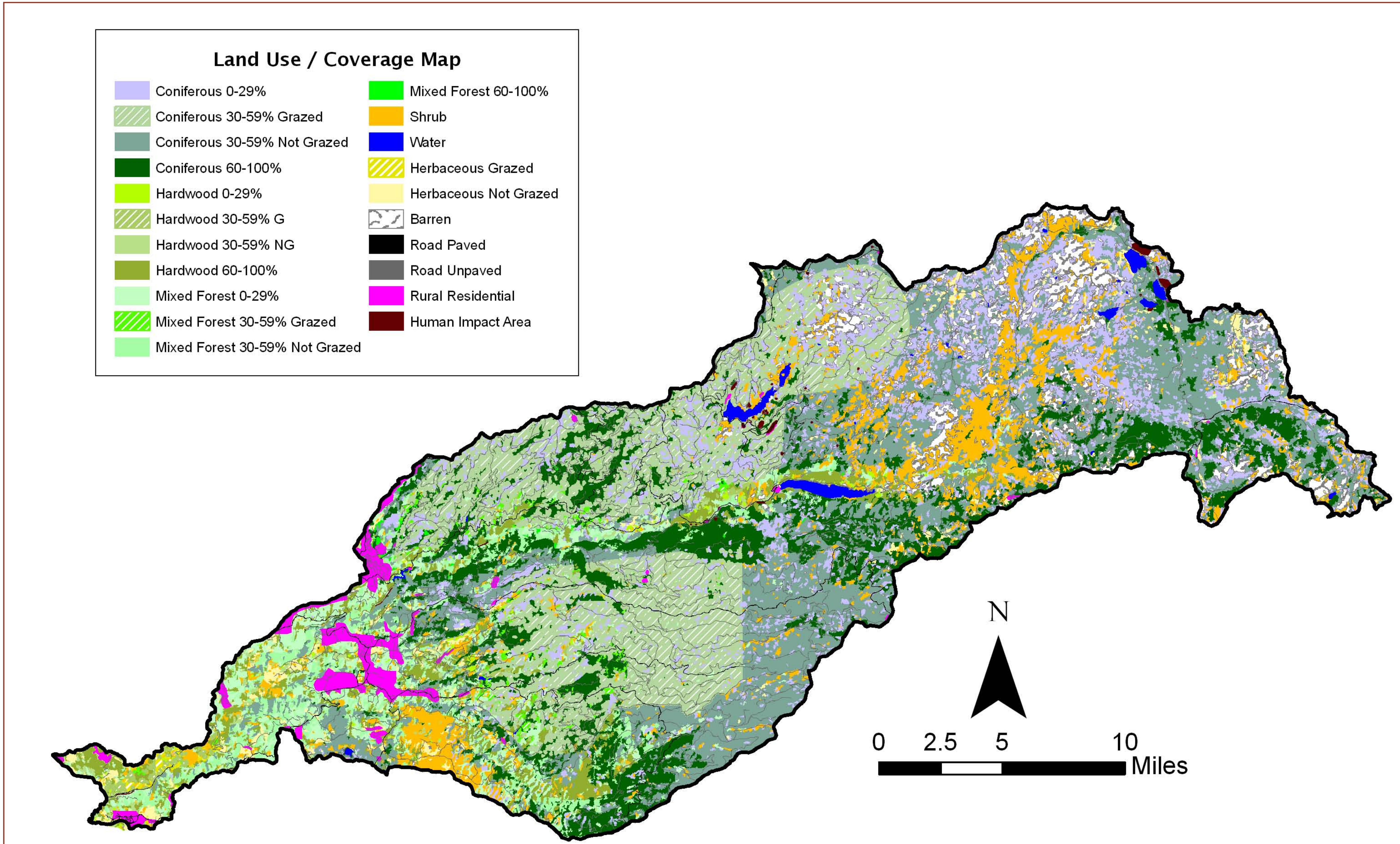
A detailed dataset was developed to represent land use and land cover within the watershed. The layer was created by compositing multiple GIS layers capturing natural and anthropogenic watershed conditions such as vegetation, roads, county general plan land use, hydrography, and other new datasets described in Section 3.1.3. Twenty-one distinct land uses, or land coverage categories, were identified to capture those land use factors with the greatest influence on water quality. The resulting GIS land use/land cover layer is shown as Figure 3-1.

Data from water quality monitoring activities are included in the project database

Non-Spatial Database

Water quality within the watershed varies significantly over time as ambient conditions fluctuate. As such, data were compiled over the time frame of 1990 to 2005 with newly developed water quality data extending into 2006. These data include seasonal and annual water quality variations, as well as variations observed in a variety of hydrologic water year types. The dataset includes both long-term average water quality conditions, as well as periods of high flow and low flow. Water quantity data were compiled to capture the differences in precipitation patterns, climate, and streamflow throughout the watershed. In addition, reservoir storage and release data were gathered, as the retention of sediment and releases have an impact on downstream water quality.

Figure 3-1: Land Use/Land Coverage



Water quality and quantity data were processed for the particular needs of the project: to perform a baseline water quality analysis, calibrate WARMF, and provide input for establishing water quality benchmarks. Processing and applying data for these uses required a variety of methodologies that are described in greater detail in the Watershed Assessment (Appendix M - TM No. 9), discussed later in this report.

3.1.5 | Finalized Spatial Data Organization

All spatial data (GIS) files are stored as shapefiles within a logical file structure organized by thematic categories. An ArcGIS project file including all spatial data files was also created. The shapefiles are intended for use with the ArcGIS 9.1 software, but may also be used with other similar software. The files are attached to this report as CD 3.

All files included in the GIS database include metadata that records important information about the data such as data source, author(s), dates of creation and updates, data preparation history, projection information, and attribute structure. If these data were not included with the original dataset, they were created and documented to reflect known information about the file. The metadata reflect any changes made to the spatial datasets over the course of the project.

3.1.6 | Finalized Non-spatial Data Organization

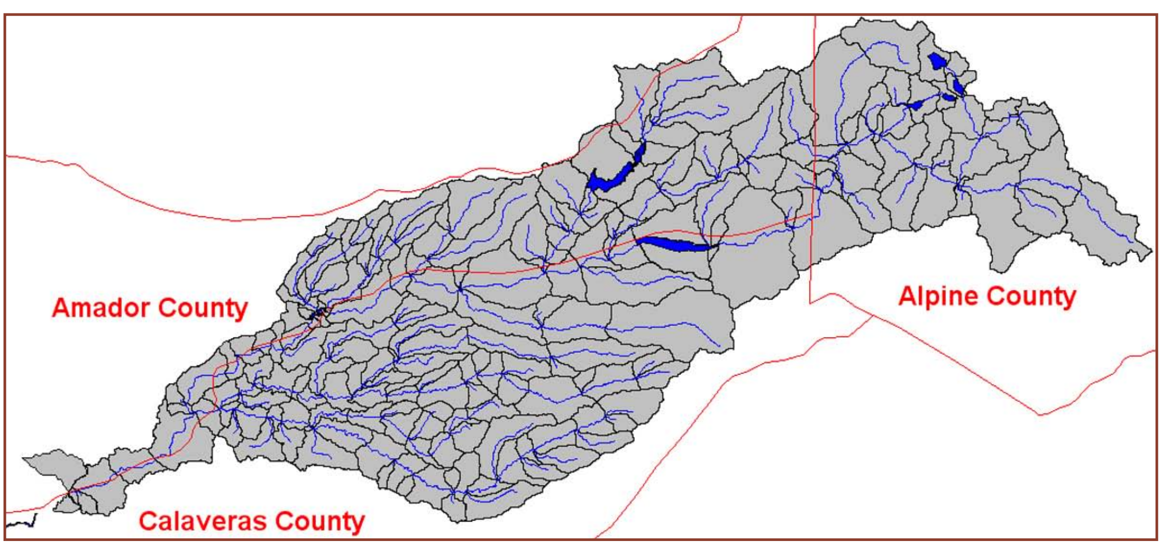
All non-spatial data are stored within both Microsoft Excel workbooks and a Microsoft Access database to facilitate use by stakeholders with experience using either platform (CD 2, attached).

In addition, the data module of WARMF provides an alternate mechanism to view and store time-series input for climate, air quality, stream flows, point sources, and observed water quality data in graphical or tabular format. Some WARMF input data such as topography, land use/land cover, and septic tank locations originate as spatial data, but are transformed to spatially-referenced model input coefficients upon input to WARMF. These coefficients can be viewed and edited by clicking on watershed map locations. All data included in the WARMF model are also stored separately to provide external data access and flexibility.

3.2 Primary Assessment Tool: WARMF Model

The WARMF model is the primary assessment tool developed for the watershed assessment. This section describes the WARMF model, as well as the processes for building and calibrating the Upper Mokelumne River WARMF application.

Figure 3-2: Upper Mokelumne River Watershed Catchment Delineation Map



3.2.2 | Assessment Tool Description

WARMF is a decision support system for watershed management. WARMF uses physically-based algorithms in a dynamic watershed simulation model to calculate streamflow and water quality conditions within a watershed. WARMF performs daily simulations of snow and soil hydrology to calculate surface runoff and groundwater accretion to river segments. The water is then routed from one river segment to the next downstream river segment until it reaches the terminus of the watershed. Water quality concentrations can then be simulated based on the interaction of these hydrologic flows with other watershed conditions and characteristics such as land use/land cover.

WARMF contributed to the assessment of baseline water quality conditions and was used to graphically display exceedances of benchmarks for water quality parameters of concern. The decision support tools in WARMF can also be used to generate alternative scenarios and graphically display cumulative water quality impacts of future land uses and activities. Detailed information on the development and calibration of the WARMF application can be found in WARMF Assessment Tool Development and Calibration (Appendix J - TM No. 6). It should be noted that models, including WARMF, are only theoretical tools used to represent actual conditions as accurately as possible.

Adapting the WARMF assessment tool to the Upper Mokelumne River watershed involved several steps.

- Set up model to delineate 207 catchments, 202 river segments, and seven reservoirs/lakes shown in Figure 3-2
- Gather and input land use/land cover, meterology, streamflow, reservoir elevations, water quality, and air quality data
- Define model assumptions required to characterize watershed processes and anthropogenic influences

3.2.3 | Model Calibration

After populating WARMF with data to characterize the watershed, simulations were run to produce both streamflow and water quality outputs that could be compared to observed data at similar locations. Model calibration is performed by adjusting model parameters and reaction rates until simulated flow and concentrations are as close as possible to the observed data, while maintaining calibration parameters within a reasonable range.

The goal of calibration is to improve the agreement between simulated and observed conditions, including the global water balance for the entire time period, the seasonal water balance, and the magnitude of peaks and valleys caused by specific rain events. For example, Figure 3-3 compares the simulated (blue lines) and observed (black circles) stream flow of the Main Stem at Highway 49 for years 2000 through 2005. The model captures the peaks during high flow and simulates the base flow very well, reflecting good agreement between simulated and observed conditions.

Similarly, example water quality calibration results are presented in Figure 3-4. In this figure, simulated stream temperature in the North Fork above Tiger Creek Afterbay is compared with observed data. These visual comparisons, as well as statistical error analyses, were performed for all simulated water quality constituents as described in Appendix J - TM No. 6.

The Upper Mokelumne River watershed dataset includes records from 1990 through 2005. The years 2000 to 2005 have the most extensive water quality records and were therefore chosen as calibration years. Model verification was performed for years 1990 to 1999 as discussed below.

Figure 3-3: Stream Flow Calibration on Main Stem

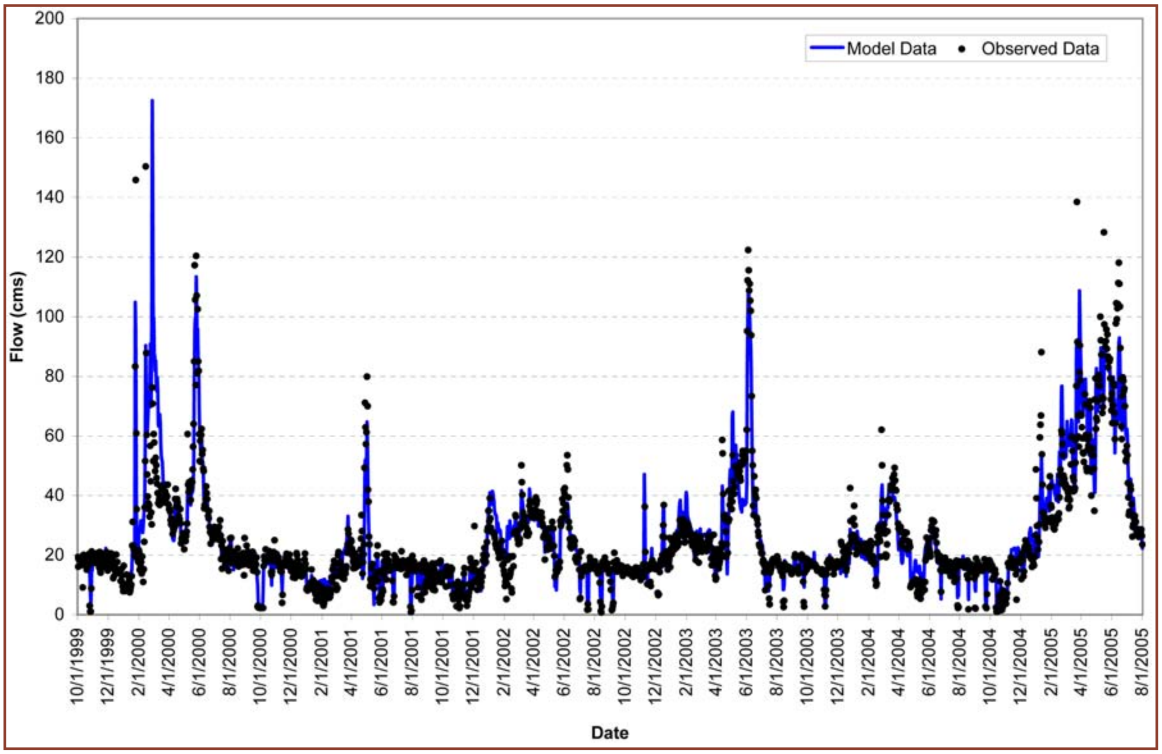
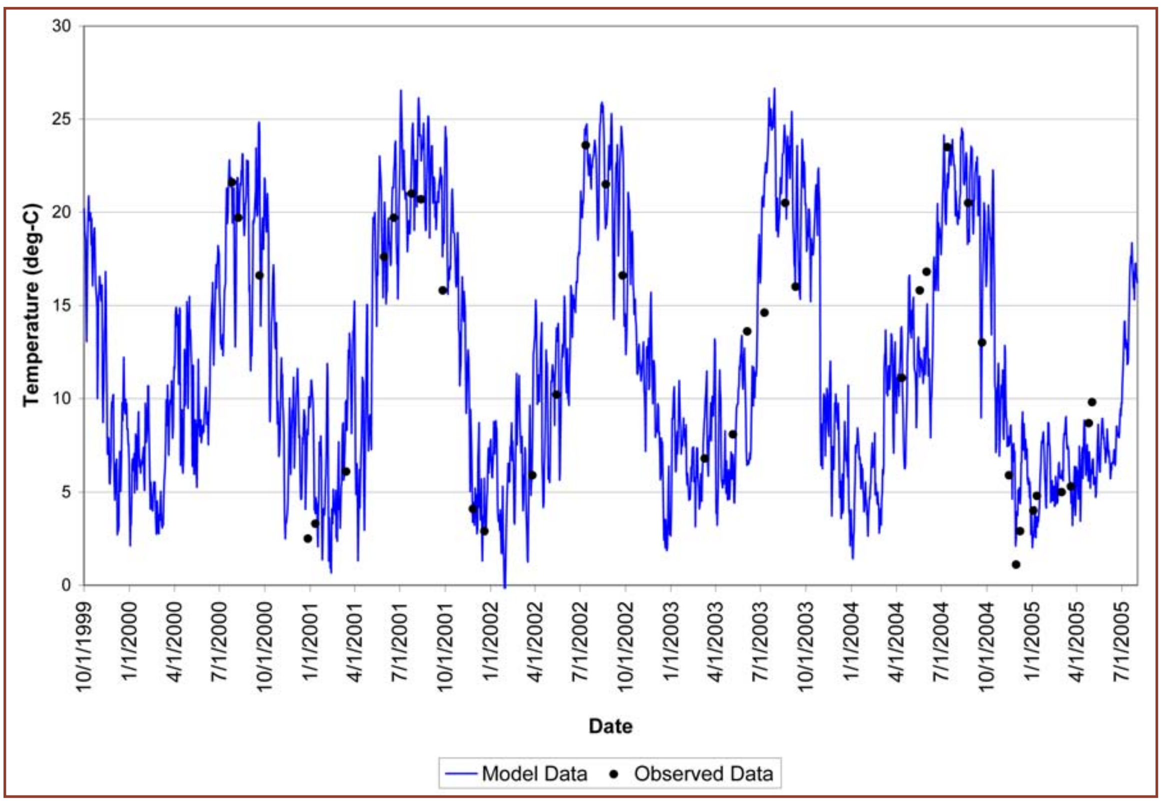


Figure 3-4: Simulated and Observed Temperature in North Fork Mokelumne River



3.2.4 | Model Verification

In addition to model calibration, hydrology and water quality verification was performed. Verification allows for the model to be run under a different timeframe and compared with observed data. WARMF was run for the time period of 1990 to 1999 using model parameters set during calibration. Simulated results were compared with observed data, where available. During this time period, observed data consisted of fecal coliform and total suspended sediment for several locations as well nutrient data.

Results indicate that WARMF was able to predict flow and water quality concentrations during the verification time period using model parameters that were set during the calibration process for the calibration time period. This verifies that adjustments to model parameters made during calibration were reasonable, and that given appropriate input data, the calibrated WARMF model can be used to simulate flow and water quality during other time periods as well.

3.2.5 | Calibration of WARMF Using the Power Fire

Forest near Salt Springs Reservoir after the Power Fire

In mid-October 2004, a fire ignited north of the North Fork Mokelumne River in the vicinity of Salt Springs Dam and Powerhouse. The fire, now known as the Power Fire, burned nearly 17,000 acres of mixed forest. Water quality monitoring after the fire revealed elevated concentrations of many parameters at sampling stations downstream of the burned area.

Sampling data performed following the Power Fire offers a unique look at the impacts of wildland fire on water quality in the Mokelumne River. Because these data were readily available to the project, the WARMF model could be calibrated to reflect the impacts of fire on water quality. Figure 3-5 shows the area between Salt Springs Reservoir and Salt Springs Powerhouse before the Power Fire as primarily forested. Figure 3-6 shows the modified land use/land cover GIS layer, which highlights burned areas from the Power Fire with different degrees of burn severity. This revised land use / land cover GIS layer was imported into WARMF to reflect the burned area, and the model was calibrated to simulate the unique impacts of wildland fire on water quality, including elevated levels of total suspended solids (TSS), total phosphorus, and metals (lead, iron, and copper). Additional information on the impacts of wildland fires on water quality can be found in Appendix J - TM No. 6.

3.2.6 | Summary of Calibration and Verification Results

The Mokelumne River at Highway 49

The model was calibrated for the years 1999 through 2005 and validated for 1990 through 1999. The calibration and verification processes indicated that the model simulates the watershed observed stream flow and water quality data well, and captures the changes to water quality observed following the 2004 Power Fire.

The quantitative streamflow and water quality calibration statistics vary from catchment to catchment. The relative error of the streamflow simulation at Highway 49 was found to be 4 percent, well below the targeted relative error of 10 percent for streamflow calibration. For water quality, relative error varies both by catchment and by parameter, with a target calibration relative error of less than 25 percent. Relative error for pH, temperature, dissolved oxygen, total organic carbon, ammonia, and nitrate were approximately 0.1, 5.9, -6.0, -1.0, 15.2, and 24.3 percent, respectively.

Figure 3-5: Land Use Before the Power Fire

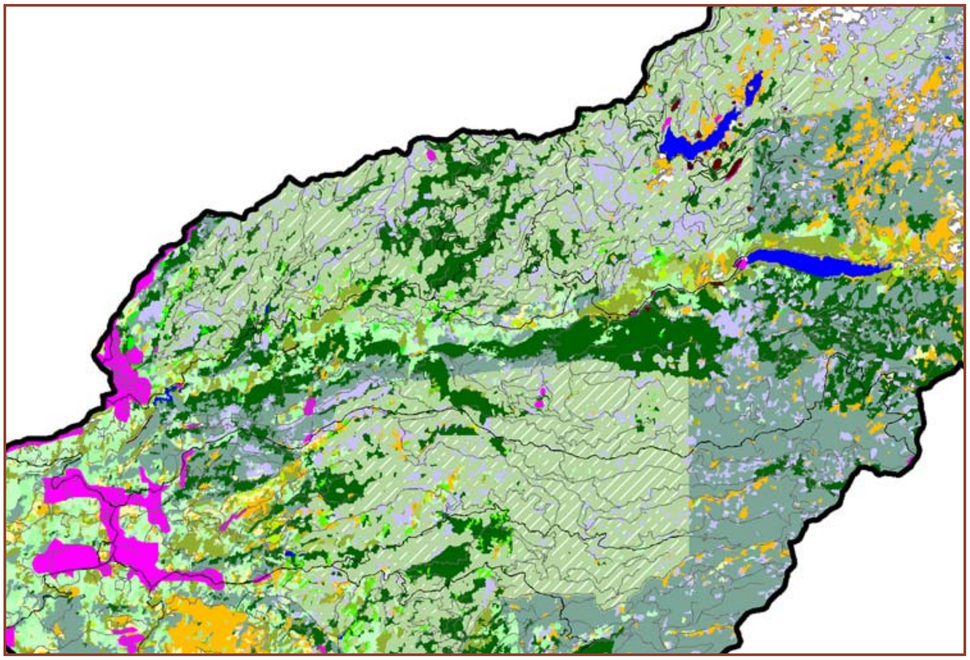
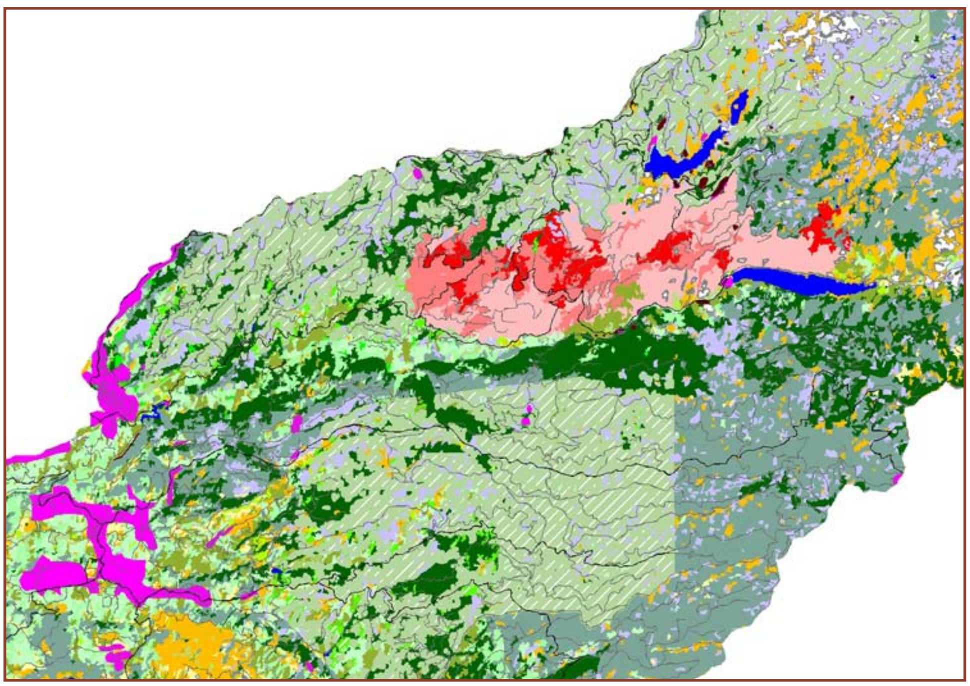
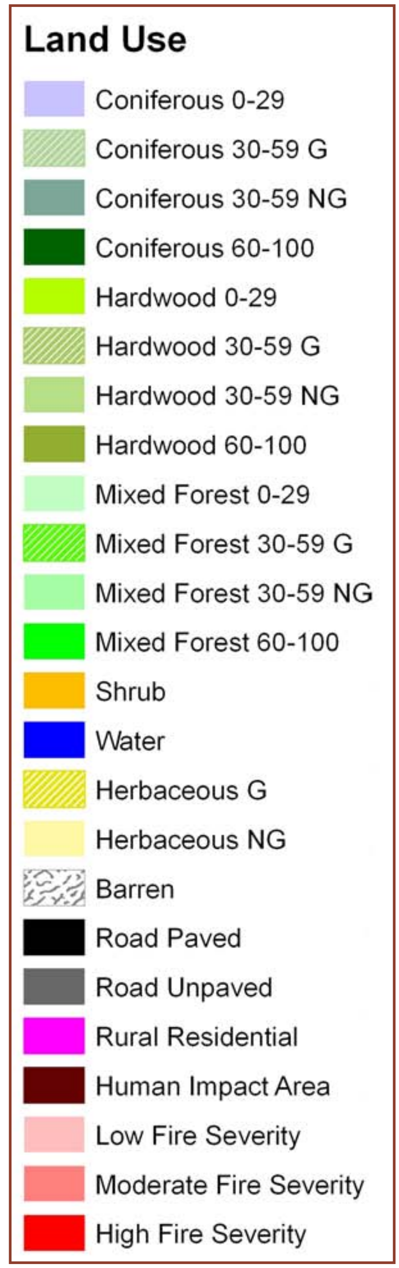


Figure 3-6: Land Use After the Power Fire





Chapter Four

Watershed Characteristics

This section provides a summary of the physical and cultural characteristics of the Upper Mokelumne River watershed. Current land management activities and practices within the watershed are also described.

4.1 Physical Geography

Natural conditions within the watershed include topography and drainage, precipitation, geology, vegetation, and wildlife populations.

4.1.1 | Topography and Drainage

The Upper Mokelumne River watershed extends from the headwaters in Alpine County downstream to the Highway 49 capturing a portion of the community of Mokelumne Hill, but located outside of the City of Jackson. Covering 544 square miles of the western slope of the Sierra Nevada, the watershed ranges in elevation from 585 feet (ft) at Highway 49 near Mokelumne Hill to 10,381 ft at Round Top peak, as shown in Figure 4-1. The rolling foothills in the lower elevations transition to rocky, steep slopes in the upper elevations. In Alpine County, there are several upper elevation reservoirs such as Upper and Lower Blue Lakes, Meadow Lake, and Twin Lakes. Highland Lake forms the headwaters of the North Fork.

The Upper Mokelumne River is fed by three major tributaries: the North Fork, Middle Fork, and South Fork. The confluence of these major tributaries is located approximately five miles west of West Point, where the tributaries combine to form the Main Stem of the river. These tributaries can also be seen in Figure 4-1.

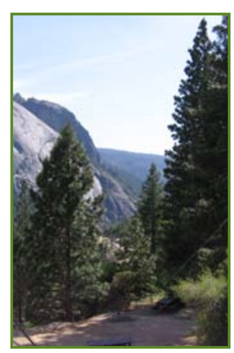
4.1.2 | Precipitation and Runoff

Figure 4-2 presents the long-term mean annual precipitation in the watershed. Rainfall amounts vary from approximately 27 inches per year near Mokelumne Hill to over 60 inches per year in the upper elevations of the watershed.

In the winter, precipitation generally falls as snow above 5,000 feet elevation and as rain at lower elevations. The average long-term annual runoff for the entire Upper Mokelumne River as measured at Pardee Reservoir (downstream of the study area) is 758,000 acre-feet per year. Stream flow typically peaks in June with snowpack runoff contributing to the peak flow.

4.1.3 | Geology and Soils

The geology of the Upper Mokelumne River watershed is characterized by two general geological classifications corresponding to elevation. In the higher elevations to the eastern part of the watershed, the geology is typically granitic of the Mesozoic age. As elevation decreases toward the western portions of the watershed, the geology is typified by Paleozoic sedimentary and volcanic metamorphosed rocks. Soils throughout the watershed are categorized as sandy to gravely, shallow to deep soils.



Granite outcropping near Salt Springs Reservoir

The lower elevations of the watershed coincide with the Mother Lode Region – a belt of gold-bearing quartz veins that extend from Mariposa in the south to Placer County in the north. This region has provided for productive mining in the Upper Mokelumne River watershed.

Figure 4-1: Land Elevation

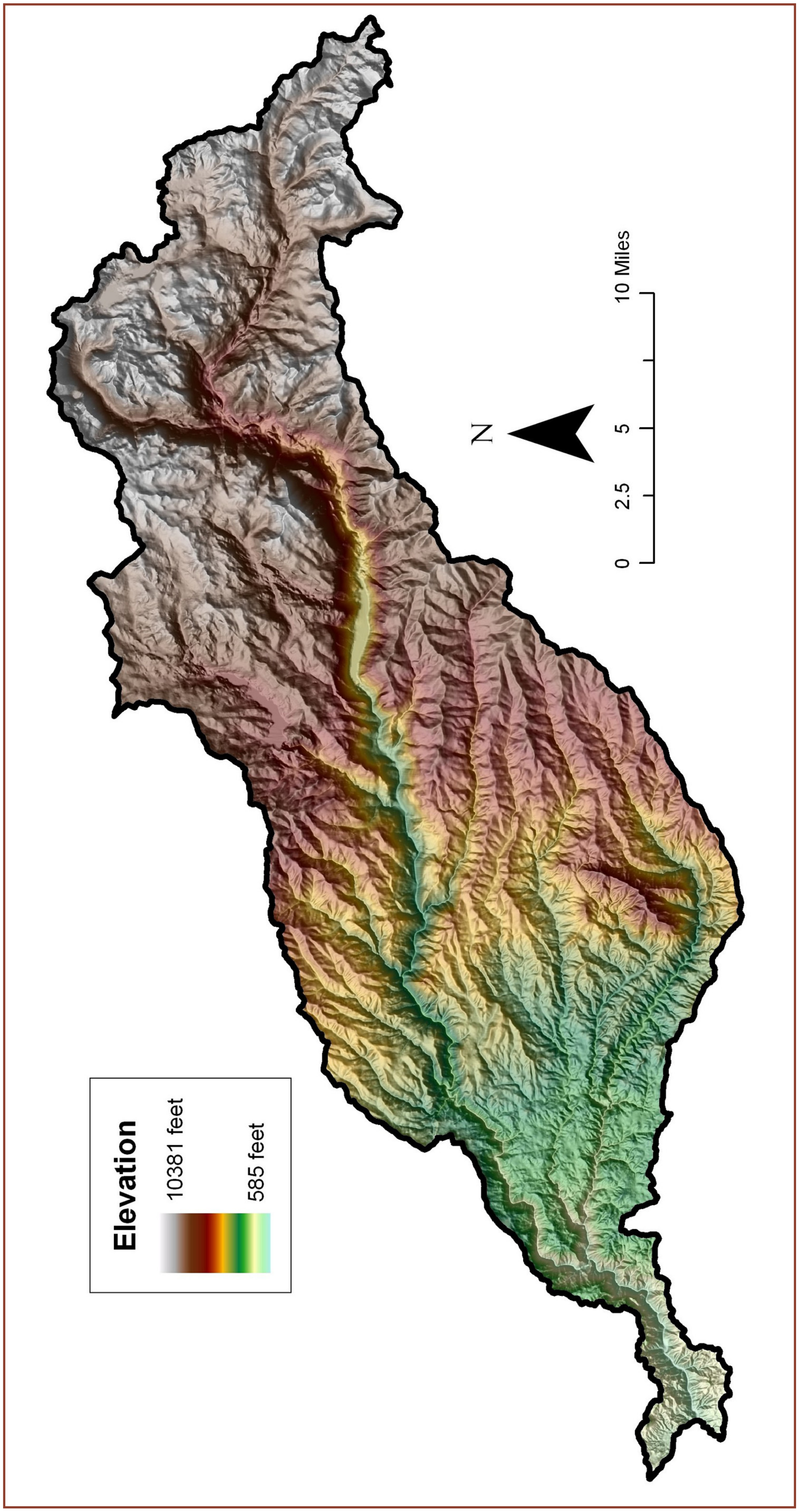
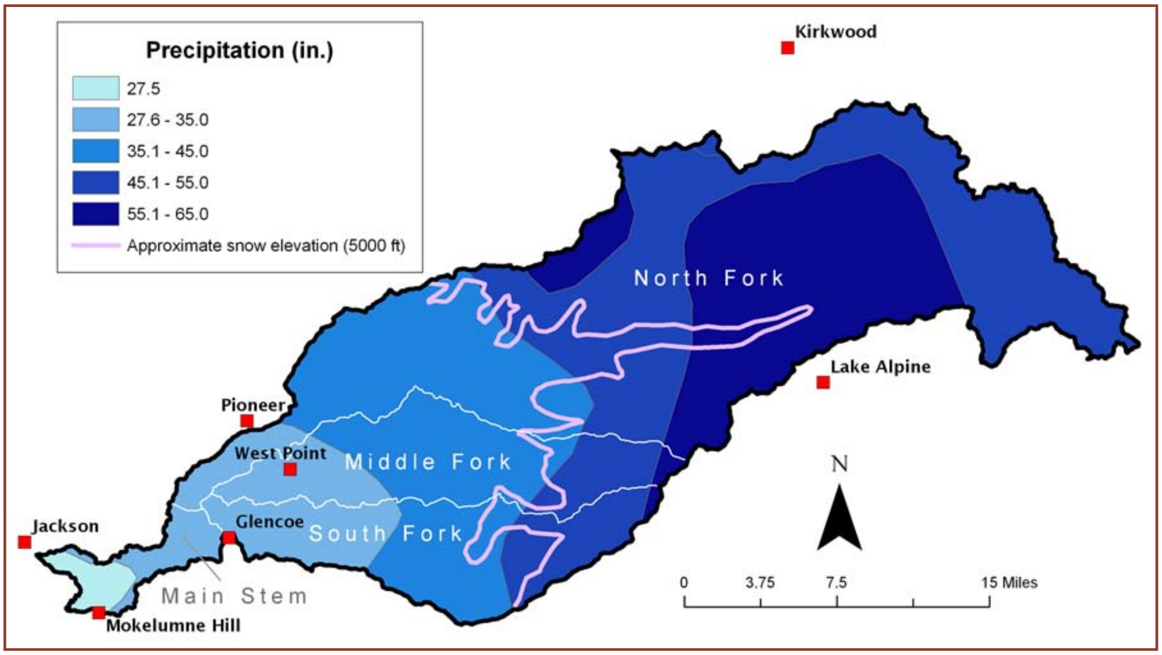


Figure 4-2: Average Annual Precipitation



4.1.4 | Vegetation

The watershed is largely undeveloped, with vegetation typical of the western slope of the Sierra Nevada. The vegetation is dominated by mixed coniferous forests including species of ponderosa pine and Douglas fir in the lower elevations and red fir in the upper elevations. Riparian areas contain mixed hardwood forest with species of live oak and black oak. Shrub and chaparral exist throughout the watershed spanning elevations of 585 to 5,000 feet. Open grasslands exist throughout the lower elevation areas of the watershed. The California Natural Diversity Database (CNDDB), which maintains the status and locations of rare plants and animals in California as well as all federal and state listed species, lists two endangered or threatened plant species in the watershed area: Ione manzanita and Ione buckwheat.

Mixed forest and grasslands in the watershed

4.1.5 | Wildlife

The watershed contains a rich diversity of wildlife. Terrestrial areas are home to rodents such as the Beechy ground squirrel; carnivores such as fox, bear, mountain lions and coyotes; and herbivores including badger, deer, rabbits and opossum. Before active fish stocking, Sierra Nevada streams above 6,000 feet typically lacked any fish species. Active fish management introduced several species of trout that thrive in the watershed today. Spawning Kokanee have been observed migrating up to the Electra Powerhouse.

California Red-legged Frog

According to the CNDDB, there are potentially 40 species of rare plants and animals within the watershed. Of the 40 rare species, six are listed by either the state or federal government as threatened species and five are listed as endangered species including the California red-legged frog (Figure 4-3), Lahontan cutthroat trout, valley elderberry longhorn beetle, Sierra Nevada red fox, and California wolverine. California-listed endangered species include the mountain yellow-legged frog, American peregrine falcon, great gray owl, and willow flycatcher.

4.2 Cultural Geography

Anthropogenic conditions within the watershed include land ownership, rural residential areas, pesticide usage, recreation, and mining.

4.2.1 | Land Ownership

Figure 4-4 shows the major landowners in the watershed. Private land ownership accounts for a significant portion of the watershed area with SPI and PG&E as the major private landowners.

4.2.2 | Rural Residential Areas

The town of Mokelumne Hill lies primarily within the watershed

Alpine, Amador, and Calaveras Counties have experienced significant urbanization pressure and relatively rapid development in recent years. Most of the development in the watershed has been limited to rural residential communities concentrated along Highways 49, 88, 26, and 4, and in the communities of Mokelumne Hill, Pioneer, West Point, and Wilseyville. Typically, the residential areas in the watershed are sparsely populated with large parcels. Many homes are vacation homes occupied seasonally and on weekends. It is estimated that the watershed's population is approximately 10,000 people, although this may be a high estimate.

4.2.3 | Pesticide Usage

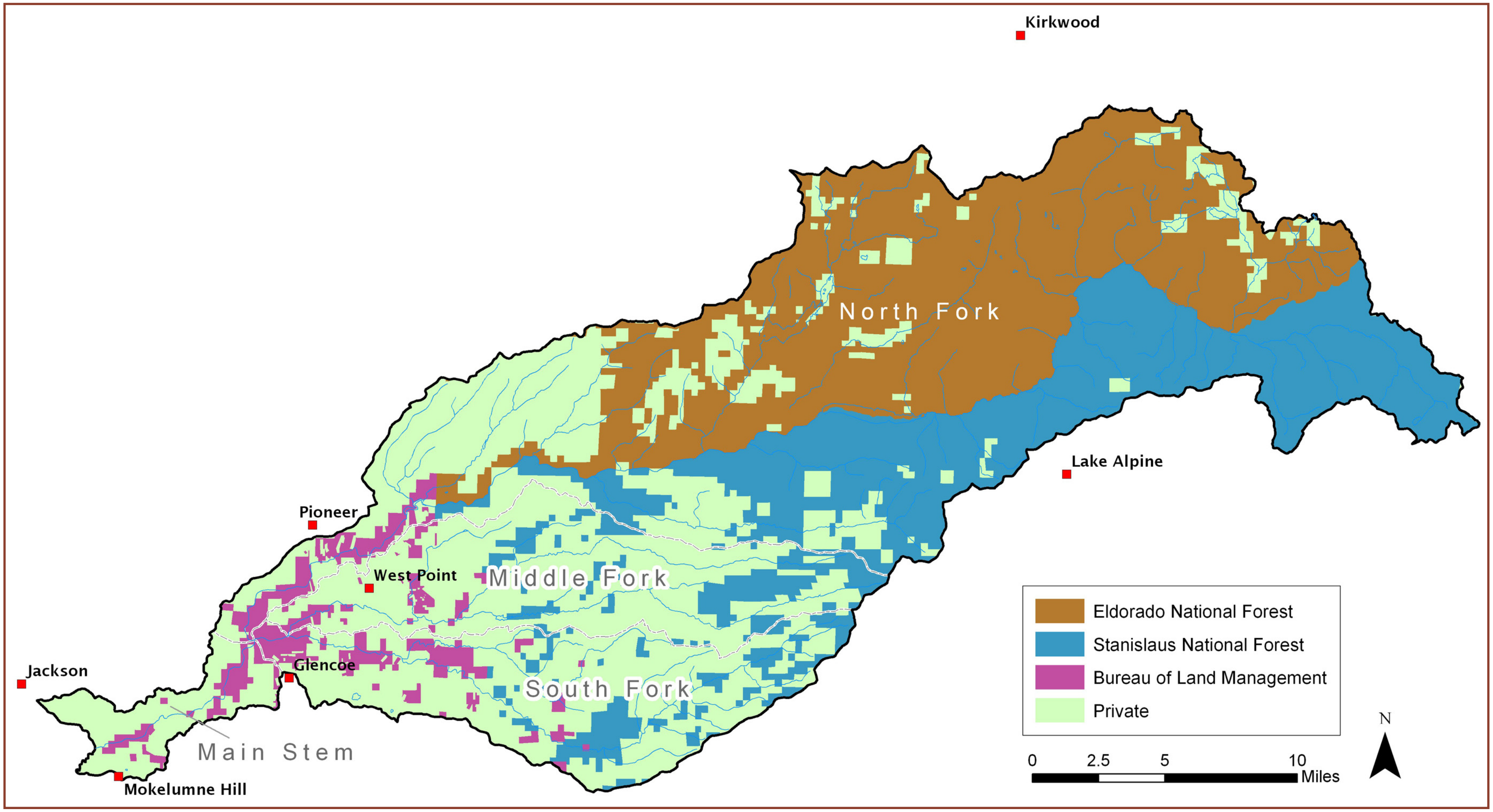
Based on reported data in the California Department of Pesticide Regulation, Pesticide Information Portal, several regulated pesticides are regularly used in the watershed. The three pesticides in greatest use from 2000 through 2003 were hexazinone, glyphosate, and 2,4-D. Because total pesticide use includes both reported and unreported pesticide, reported pesticide represents a subset of total pesticide use in the watershed.

4.2.4 | Recreation

Local swimming hole on the river

The watershed is a popular destination for outdoor enthusiasts, and is home to a wealth of recreation opportunities. The Eldorado and Stanislaus National Forests contain multiple campgrounds along with wilderness camping and hiking opportunities. Rafting and boating are popular activities along the Main Stem near Electra Powerhouse. Salt Springs Reservoir and Bear River Reservoir also have facilities for boating, fishing, and swimming. The Bear River Resort Area at Lower Bear River Reservoir and Roaring Camp along the Main Stem maintain swimming areas, but swimming also occurs throughout the watershed at areas of the river that are accessible by vehicle or hiking. White water

Figure 4-4: Major Land Ownership



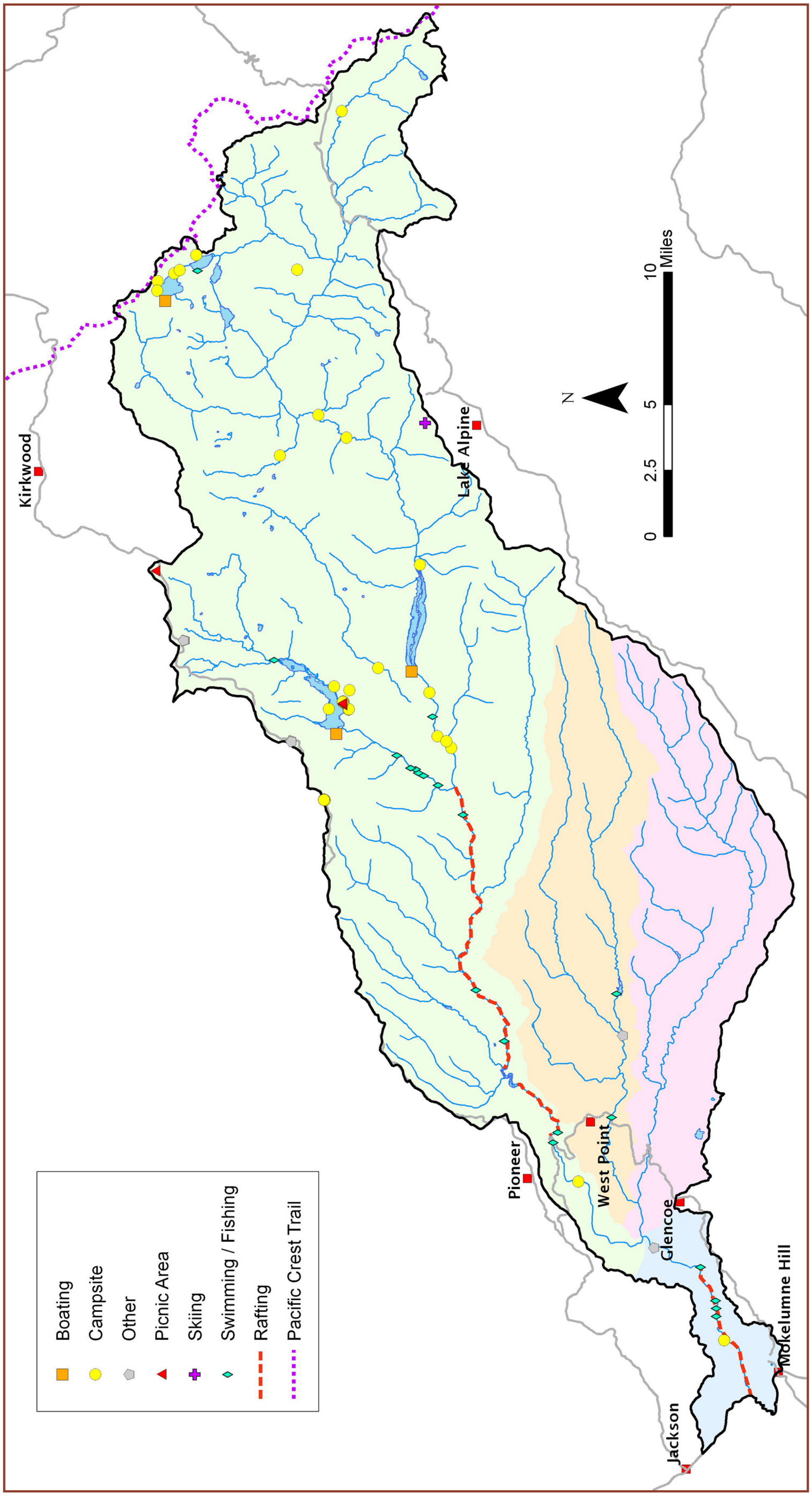


Figure 4-5: Recreation Sites

rafting and kayaking are popular sports, particularly on the North Fork.

Regulated and unregulated off-highway vehicle (OHV) use occurs in areas around Forest Creek, the Blue Lakes area, and Schaads Reservoir on the Middle Fork. Private companies provide recreational gold mining tours with gold panning and barbecue/picnic trips along the Main Stem and North Fork. Although there are several ski resort operations near the watershed, only Bear Valley has ski areas located within the watershed. Known recreation locations are shown in Figure 4-5.

4.2.5 | Mining Operations

Based on the Department of Conservation's Office of Mine Reclamation, there are approximately 63 active and abandoned mines in the watershed as noted on USGS topographic maps. The majority of these mines are located within several miles of Highway 26 in the lower elevations of the watershed. As of 1989, there are three permitted mines within the watershed, all producing gold: one in the North Fork subwatershed and two in the Middle Fork subwatershed.

4.3 Water and Land Management

This section describes the management of watershed lands and water resources, including hydropower operations, water supply projects, wastewater collection and treatment, forest and livestock management, and solid waste and hazardous materials, stormwater management, road maintenance, and unauthorized watershed activities.

4.3.1 | Hydropower Generation

Within the Upper Mokelumne River watershed, PG&E is authorized to manage certain river flows for the purpose of hydroelectric power generation. The PG&E Mokelumne Hydroelectric Project (Project 137) consists of seven storage reservoirs, 12 regulating reservoirs, numerous tunnels and channels, and four powerhouses containing eight power generating units. Figure 4-6 shows the major diversion points of the PG&E system.

PG&E Electra Powerhouse

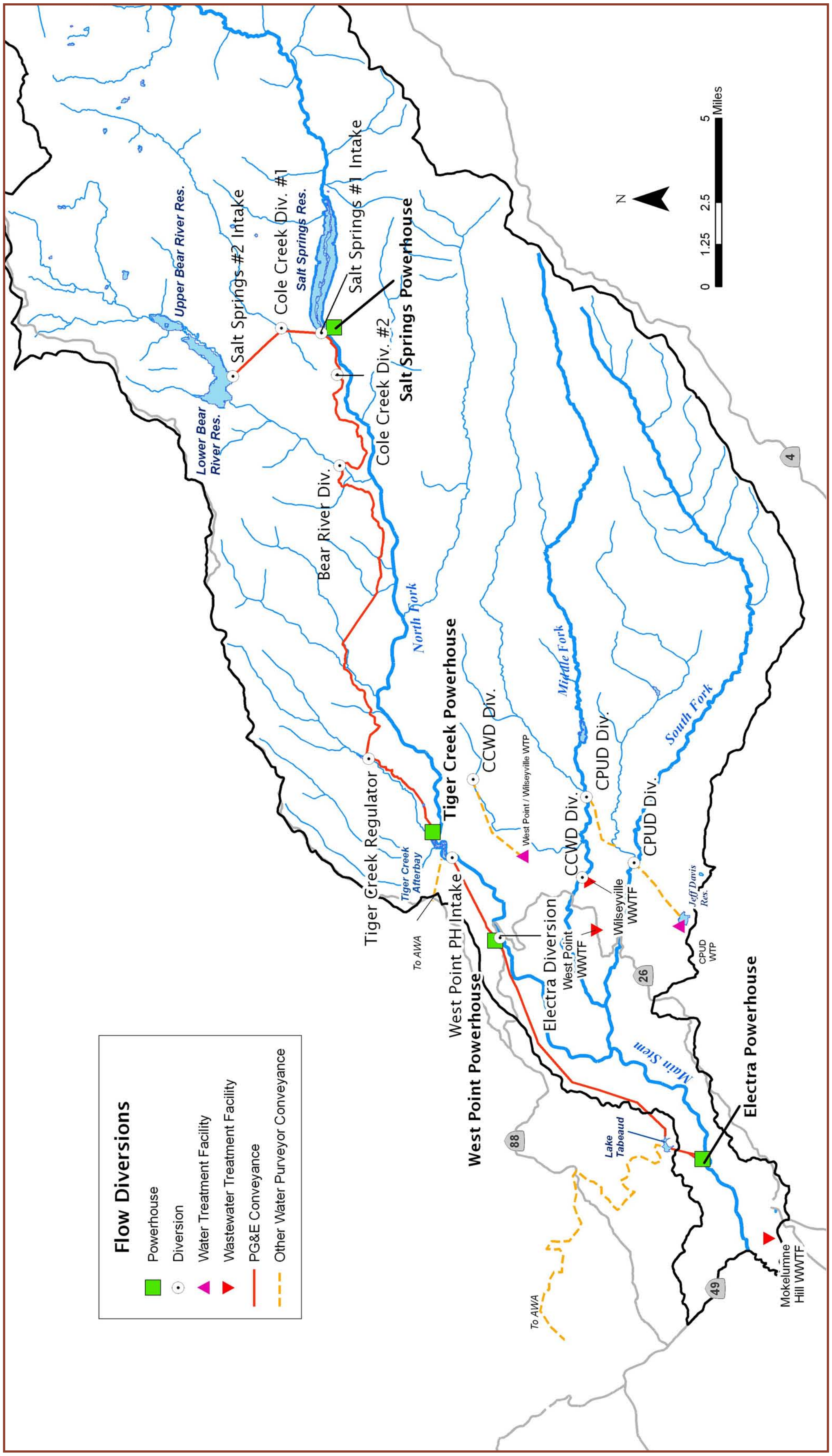
In normal, non-dry years, PG&E must maintain 500 cubic feet per second (cfs) of natural flow from June through December and must maintain 300 cfs in the following January as measured below the Electra Powerhouse. In dry years, PG&E must maintain 300 cfs of natural flow from May through September and 200 cfs in other months.

4.3.2 | Water Resources Development

Three agencies divert water from the Upper Mokelumne River watershed (the study area) for use as local and regional drinking water supply. Figure 4-6 provides the locations of the diversion points and storage facilities within the study area.

- CCWD: Diverts water at Bear Creek for use by 500 customers in the West Point, Wilseyville, and Bummerville areas
- AWA: Diverts 15,000 acre-feet per year in average years at Lake Tabeaud and Tiger Creek Afterbay for customers outside of the watershed in Jackson, Martell, Sutter Creek, Sutter Hill, Ione, Amador City, and Drytown, Pine Grove and Pioneer.
- CPUD: Diverts water from confluence of the Licking and South Forks to supply Mokelumne Hill and other communities in the watershed as well as San Andreas and Paloma outside of the study area.

Figure 4-6: Flow Diversions

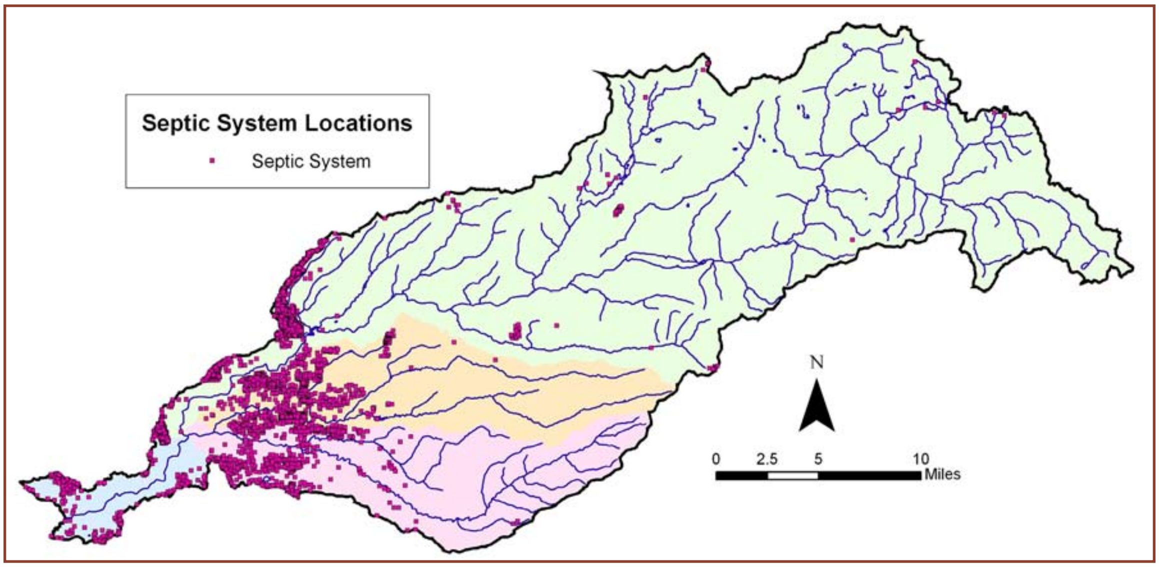


4.3.3 | Wastewater Collection and Treatment

The majority of developed lands within the Upper Mokelumne River watershed use septic systems to manage residential sewage. Locations of assumed septic systems in the watershed are presented in Figure 4-7. In Amador County, septic system locations are based on granted septic system permits. In Calaveras County, septic system locations are based on occupied parcels outside of centralized sewage treatment areas. In Alpine County, septic system locations were provided by the county. Many septic systems in the watershed are old, designed for seasonal use, and do not have permits.

In Mokelumne Hill, the Mokelumne Hill Wastewater Treatment Facility (WWTF) treats collected wastewater. CCWD collects wastewater for treatment in parts of West Point and Wilseyville. Neither of these wastewater treatment systems discharges to surface water. CCWD discharges to spray fields and holding ponds at its West Point and Wilseyville facilities. Mokelumne Hill WWTF also discharges to spray fields and holding ponds.

Figure 4-7: Septic System Locations



4.3.4 | Forest Management

The watershed is largely forested and logging is prevalent throughout. The two largest public forest management areas within the watershed are the Eldorado and Stanislaus National Forests. SPI is the largest private logging company in the watershed. Commonly occurring management practices on federal and SPI lands address watercourse protection, road construction, site preparation, and soil erosion.

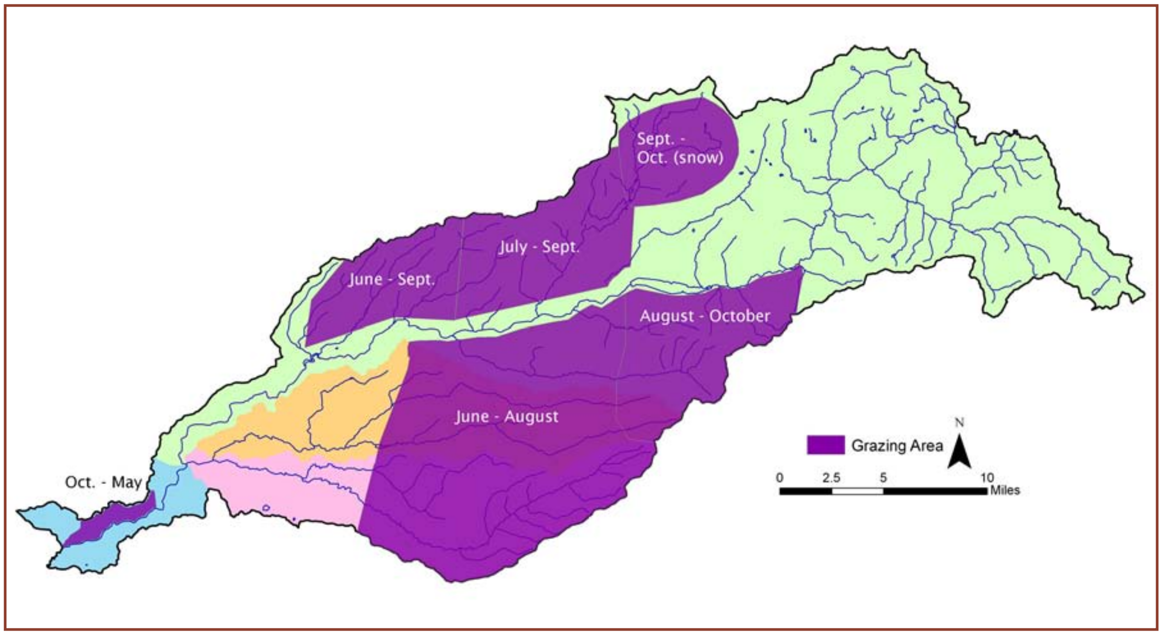
Logging in the watershed

4.3.5 | Livestock Management

Livestock grazing in the Upper Mokelumne River watershed is permitted in the Eldorado and Stanislaus National Forests and on private lands, including SPI's. During winter months, cattle are restricted to low elevation grazing areas outside of the watershed and within the Main Stem subwatershed. As summer approaches, cattle are progressively moved to higher elevations within each of the three subwatersheds. Figure 4-8 shows each of the watershed's four sub-basins overlaid with blue areas indicating the grazing patterns in the watershed provided by local ranchers.

The density of cattle grazing in the watershed is very low, with approximately one animal grazing per 100 acres depending on the terrain and vegetation of the grazed area. Cattle ranchers within the watershed work to protect the cattle grazing areas in order to maintain permit status and the long-term health of their herd and availability of a healthy grazing environment. Salt licks located away from waterbodies, fencing of streams, dedicated watering containers, and other BMPs are used throughout the watershed.

Figure 4-8: Grazing Patterns



4.3.6 | Solid Waste and Hazardous Materials

The California Solid Waste Management Board oversees the regulation and management of solid waste disposal sites in California. Within the watershed, the only operational solid waste facility is the Wilseyville Transfer Station near Wilseyville in the South Fork watershed.

The SWRCB has documented several leaking underground fuel tanks (LUFTs) within the watershed or on the border of the watershed. A listing of those with ongoing investigations is provided in Appendix M - TM No. 9.

4.3.7 | Stormwater Management

Counties within the watershed share the responsibility for managing water flows in their jurisdictions for the purposes of flood prevention, flood control project planning, and drainage services. Rural residential areas and construction sites are often sources of sediment, pathogens, pesticides, and fertilizers in runoff. The Central Valley Regional Water Quality Control Board (RWQCB) regulates runoff from construction sites and mandates the use of Best Management Practices to reduce pollutants and sediment in runoff. Due to the rural nature of the watershed, there are few concentrated sources of urban stormwater runoff to the Mokelumne River and its tributaries.

4.3.8 | Road Maintenance

Roads within the Upper Mokelumne River watershed are maintained by a variety of entities. Caltrans maintains all state and federal highways including Highways 88, 26, and 49 in the watershed. Amador, Alpine, and Calaveras Counties maintain the majority of roads within the watershed outside of federal lands. SPI is responsible for maintaining logging and transportation roads on its privately held lands.

Within the Eldorado and Stanislaus National Forests, road maintenance is conducted by the Forest Service. The USFS is currently engaged in a program to comply with a court order to limit all motorized and off-highway vehicle use to designated roads and trails. Each national forest in California is complying with the court order and designating their route system.

A sign indicates areas where OHVs are not allowed

4.3.9 | Unauthorized Activities

The rural nature of the Upper Mokelumne River watershed allows for many unauthorized activities to occur. While OHVs are permitted on posted USFS roads, unauthorized OHV activities are known to occur in locations throughout the watershed. Unauthorized and unrestricted OHV use causes increased soil erosion, increased sediment runoff to receiving waters, and habitat destruction. Additionally, unauthorized OHV use can create a liability for property owners. Other unauthorized activities that occur within the watershed include illegal dumping of household appliances and chemicals, cars, and construction materials, and illegal camping and campfires.

Illegally dumped trash contributes contaminants to runoff

Chapter Five

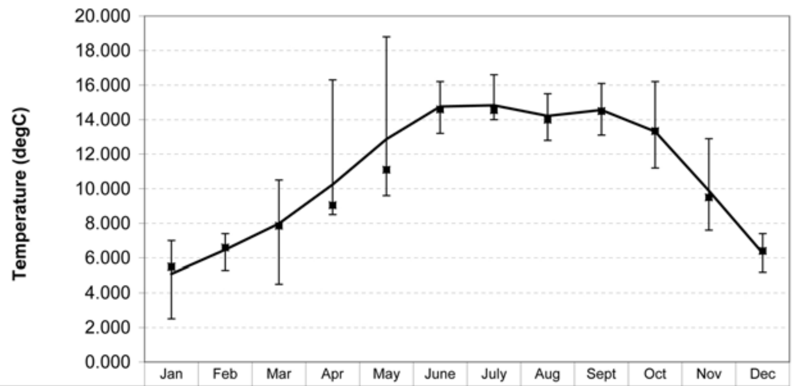
Baseline Water Quality

The Upper Mokelumne River watershed is generally a pristine watershed, with minimal urban development. Establishing baseline water quality, or a measure of existing water quality conditions, characterizes the water quality of the watershed and provides a reference point for assessing water quality impacts associated with future changes in the watershed.

5.1 Methodology

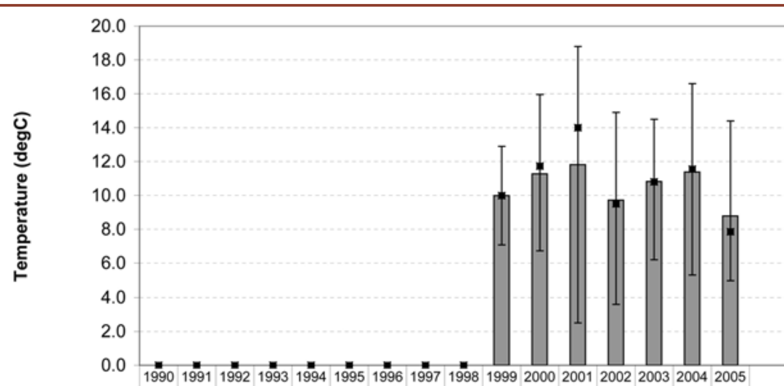
Baseline water quality was established by analyzing and summarizing historical water quality monitoring data. A multi-step methodology was used to develop baseline water quality. Additional information and results from this analysis can be found in Appendix H - TM No. 5: Baseline Water Quality. Figure 5-1, Figure 5-2, and Figure 5-3 are examples of plots prepared to visually depict observed historical water temperature fluctuations at Highway 49 by month, year, and hydrologic year type, respectively. Similar plots were prepared for all parameters and representative locations.

Figure 5-1: Monthly Temperature at MRHW49 (Main Stem)



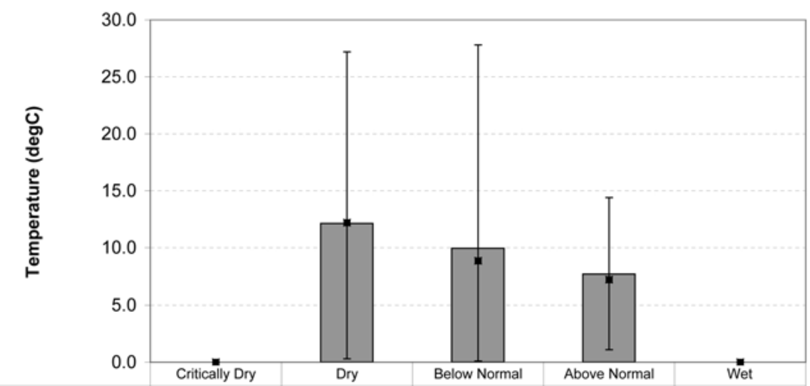
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Maximum	7.000	7.400	10.500	16.300	18.800	16.200	16.600	15.500	16.100	16.200	12.900	7.400
Average	5.100	6.470	7.983	10.242	12.867	14.760	14.833	14.220	14.560	13.312	9.889	6.276
Median	5.500	6.600	7.850	9.050	11.100	14.600	14.550	14.000	14.500	13.335	9.500	6.400
Minimum	2.500	5.300	4.500	8.500	9.600	13.200	14.000	12.800	13.100	11.200	7.600	5.200
Count	7	6	8	6	6	6	6	5	5	6	9	5
0.5*Min. Detection Limit	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5-2: Annual Temperature at MRHW49 (Main Stem)



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Average	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	11.3	11.8	9.7	10.8	11.4	8.8
Maximum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.9	16.0	18.8	14.9	14.5	16.6	14.4
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	11.7	14.0	9.5	10.8	11.6	7.9
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	6.7	2.5	3.6	6.2	5.3	5.0
Count	0	0	0	0	0	0	0	0	0	2	10	11	11	11	18	12
0.5*Min. Detection Limit	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 5-3: Temperature by Year Type



	Critically Dry	Dry	Below Normal	Above Normal	Wet
Average	0.0	12.1	10.0	7.7	0.0
Maximum	0.0	27.2	27.8	14.4	0.0
Median	0.0	12.2	8.9	7.3	0.0
Minimum	0.0	0.3	0.1	1.1	0.0
Count	0	161	338	52	0
0.5*Min. Detection Limit	0	0	0	0	0

5.2 Parameters Analyzed

Table 5-1 presents the water quality parameters analyzed by category. This section presents an overview of the water quality constituents by category. Additional description, data, and plots for each individual parameter are provided in Appendix H.

Table 5-1: Parameters Analyzed by Category

Category	Parameters
Microorganisms	total coliform, fecal coliform, Cryptosporidium, Giardia lamblia, Escherichia coli
Particulates	total dissolved solids, total suspended solids, turbidity
General Properties	alkalinity, dissolved oxygen, electrical Conductivity, hardness, pH, temperature
Nutrients	ammonia, nitrate, nitrite, total kjeldahl nitrogen, potassium, orthophosphate, total phosphate
Metals, Cations and Anions	aluminum, antimony, arsenic, barium, beryllium, cadmium, calcium, chromium, magnesium, mercury, nickel, selenium, sodium, sulfate, copper, iron, manganese, lead, thallium, zinc
SOCs, VOCs, and Pesticides	2,4-D, alachlor, benzene, carbon tetrachloride, glyphosate, hexazinone, methyl tert-butyl ether, thiobencarb, vinyl chloride

5.2.1 | Microorganisms

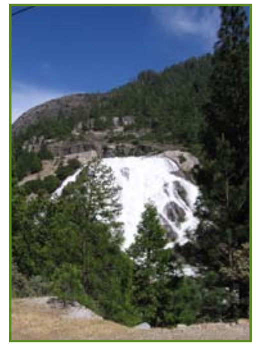
Microorganisms are of primary concern due to their risk to human health and potential to contaminate drinking water supplies. They can act as agents of waterborne outbreaks of infectious disease or indicators of potential contamination in water quality.

5.2.2 | Particulates

Particulates are of concern to drinking water and aquatic species in terms of turbidity or suspended solids, and sedimentation, respectively. Turbidity itself is not a public health concern, but other constituents that are of concern can absorb onto the surfaces or into the pores of the particulates. The presence of suspended solids is a general indicator of surface erosion and runoff into waterbodies, resuspension of sediment material, or biological productivity.

5.2.3 | General Properties

General properties considered in this analysis included physical and chemical source water characteristics that may be of importance from a drinking water treatment perspective. In addition, these general properties can be considered basic indicators of water quality and watershed health. Among these properties are parameters of particular importance for aquatic habitat, such as dissolved oxygen.



Upper Mokelumne River watershed is generally pristine with minimal urban development

5.2.4 | Nutrients

As nutrient concentrations increase, specifically nitrogen and phosphorus, algal productivity increases, causing problems with oxygen depletion, a significant concern to aquatic species. Phosphorus is typically the most critical because it is the most common limiting nutrient for algal growth. Nutrients are of concern for this project as they impact aquatic species and contribute to disinfection by-product (DBP) precursors.

5.2.5 | Metals, Anions, and Cations

Some cations (calcium and magnesium, in particular) are of importance in drinking water treatment due to their influence on alkalinity. Anions can have a strong influence on disinfection byproduct formation, and can contribute to negative taste and odor impacts. Metals can have toxic effects on human health if high enough concentrations are found in the water or in the fish consumed by humans.

5.2.6 | SOCs, VOCs, and Pesticides

Synthetic Organic Compounds (SOCs), including Volatile Organic Compounds (VOCs), represent the largest group of water quality parameters currently regulated. Many SOCs are formulated for, or are the result of, industrial processes. Pesticides and herbicides are one of the main subgroups of SOCs. From a public health perspective, these organics are identified as being, or are suspected of being carcinogens, mutagens, or teratogens. Pesticides and herbicides can be transported into waterbodies due to applications on urban and rural lands.

River diversions can impact water temperatures

Chapter Six
Water Quality Benchmarks

Establishing baseline water quality involved describing the general behavior of various water quality constituents throughout the watershed, as described in Chapter 5. Once the baseline water quality was established, the watershed was assessed using water quality benchmarks. The water quality benchmarks and assessment methodology are described below.

6.1 Benchmark Assessment Methodology

The following steps were implemented to assess water quality throughout the watershed.

- **Develop Benchmarks.** In order to assess the condition of watershed water quality, benchmarks were developed. Benchmarks are numeric values against which the watershed baseline water quality can be compared to determine the health of the watershed from a water quality perspective. These benchmarks are intended to serve as a point of comparison to determine whether concentrations of parameters in the watershed are of potential concern for human and/or aquatic health.
- **Identify Potential Parameter Sources and Spatial Variability.** Potential sources of each parameter in the watershed were identified. In addition, historical and simulated water quality from different tributaries and locations in the watershed were compared to identify spatial variability to provide additional insight as to the relative influence of potential sources of each parameter in the watershed.
- **Identify and Assess Parameters of Potential Interest.** Baseline water quality was compared to the benchmarks to determine exceedances. In addition, WARMF-simulated water quality was evaluated to determine whether simulated concentrations revealed potential exceedances not reflected in historical data. Parameters exhibiting historical exceedances were considered to be parameters of interest.

6.2 Benchmarks and Mean Water Quality Concentrations

Based on thorough discussions at the PAC meetings, it was determined that water quality objectives should address the health of humans as well as aquatic organisms in the watershed. Therefore, water quality objectives identified in the Region 5 Basin Plan were used for this assessment, where available, and drinking water maximum contaminant loads (MCLs) and California Department of Health Services (DHS) microbiological standards would be used to supplement the water quality objectives for human health benchmarks. For some parameters, where no water quality objective was identified by the Basin Plan and where no MCL or DHS microbiological standards exist, alternative appropriate human health benchmarks were identified, such as regulatory-driven source water concentration targets.

Given its relatively pristine setting, the watershed does not exceed the majority of the benchmarks identified for this project. The Region 5 Basin Plan includes the SWRCB Resolution No. 68-16 which restricts water quality degradation, consistent with this project's goal of protecting and improving source water quality. Rather than reflecting acceptable concentrations of each parameter, these benchmarks are intended to establish an objective lens through which existing water quality can be assessed. This allowed the project to identify parameters of interest, focusing the development and implementation of the watershed management plan.

It was requested by the PAC that long-term mean values for each parameter also be developed for representative locations. These long-term average values provide a general characterization of current conditions on each major tributary for each parameter.

The sites containing the most complete set of sampling data for each parameter, located furthest downstream on the selected tributary, were selected as "representative sites" for each parameter. A complete list of benchmarks and long-term mean observed concentrations for each parameter can be found in Appendix M - TM No. 9.

6.3 Application of Benchmarks to Water Quality

Watershed water quality was assessed for each parameter using the benchmarks established. Baseline and WARMF-simulated water quality were compared to benchmarks to determine whether any parameters have exceeded benchmarks based on historical or simulated data. Observed benchmark exceedances are summarized in Table 6-1, and described in further detail below.

Table 6-1: Observed Benchmark Exceedances

Parameter of Interest	Units	Location of Benchmark Exceedance	Concentration of Maximum Benchmark Exceedance	Benchmark Concentration
Fecal coliform	#/100mL	Middle Fork	240	≥ 200
Cryptosporidium	oocysts/L	Main Stem	0.10	≥0.075
E. coli - single sample	#/100mL	Middle Fork	300	≥ 235
		Main Stem	500	≥ 235
Turbidity	NTU	Middle Fork	8	≥ 6
Nitrate	mg/L as N	Middle Fork	0.04	≥ 0.04
		South Fork	0.05	≥ 0.04
		Main Stem	0.04	≥ 0.04
Alkalinity	mg/L	North Fork	7	≤ 20
		Middle Fork	14	≤ 20
		South Fork	17	≤ 20
		Main Stem	9	≤ 20
Aluminum	mg/L	Middle Fork	0.10	≥ 0.09
		South Fork	0.09	≥ 0.09

6.3.1 | Fecal coliform

Fecal coliform is a subset of coliform bacteria that is found in the intestines of warm-blooded animals. The presence of fecal coliform indicates presence of fecal matter from animals and/or humans. The fecal coliform benchmark of 200/100 mL, calculated as 30-day geometric mean, was developed based on the Basin Plan water quality objective for fecal coliform.

Fecal coliform concentrations are influenced by factors such as body contact recreation (e.g., swimming), wildlife, grazing operations, and failing septic systems. Relative contributions from livestock and wildlife appear to be greatest in the less humanly-populated upper reaches of the watershed, decreasing in downstream portions. Body contact recreation is prevalent on all three forks, though the bulk of informal swimming occurs at downstream locations in the watershed. Grazing operations are primarily found along the North Fork, Middle Fork and Main Stem, with some grazing occurring near the South Fork as well. Despite the cluster of septic systems near Pioneer to the north of the North Fork, the density of septic systems in the watershed is greatest along the Middle and South Forks. Based on an analysis of the microorganism data and river flows under monthly, annual, and various year types, septic systems are believed to be a significant contributor of fecal coliform loading along these forks.

Monthly geometric mean fecal coliform concentrations were calculated from historical monitoring data in the watershed, and are presented in Figure 6-1 as well as modeled in WARMF using simulated data shown in Figure 6-2. The analysis using only observed monitoring data showed no exceedances but the simulated run identified one exceedance along the Middle Fork in September. Simulated geometric mean fecal coliform concentrations are expected to differ slightly from geometric means calculated using historical, observed data. First, simulated data were developed using a watershed hydrologic model, and the simulation accuracy is not expected to be 100 percent. Further, while geometric mean values for historical and simulated data were both calculated by averaging all historical or simulated samples for a given month over the study period (1990 to 2005), data availability differed significantly between the two data sources. Historical sampling generally occurred on a monthly basis, and data were not collected in all months. In contrast, simulated fecal coliform concentrations were generated on a daily basis for the duration of the study period. Because simulated data were available for every day over the course of the study period, and historical data were only available on a monthly basis for most years, the geometric mean values for the simulated data would be expected to differ from the geometric mean values for the historical data. However, the simulated data mirror the historical data in general magnitude, as well as trends associated with changing seasons and hydrologic year types.

Figure 6-1: Monthly Geometric Mean Fecal Coliform Concentrations at Representative Locations

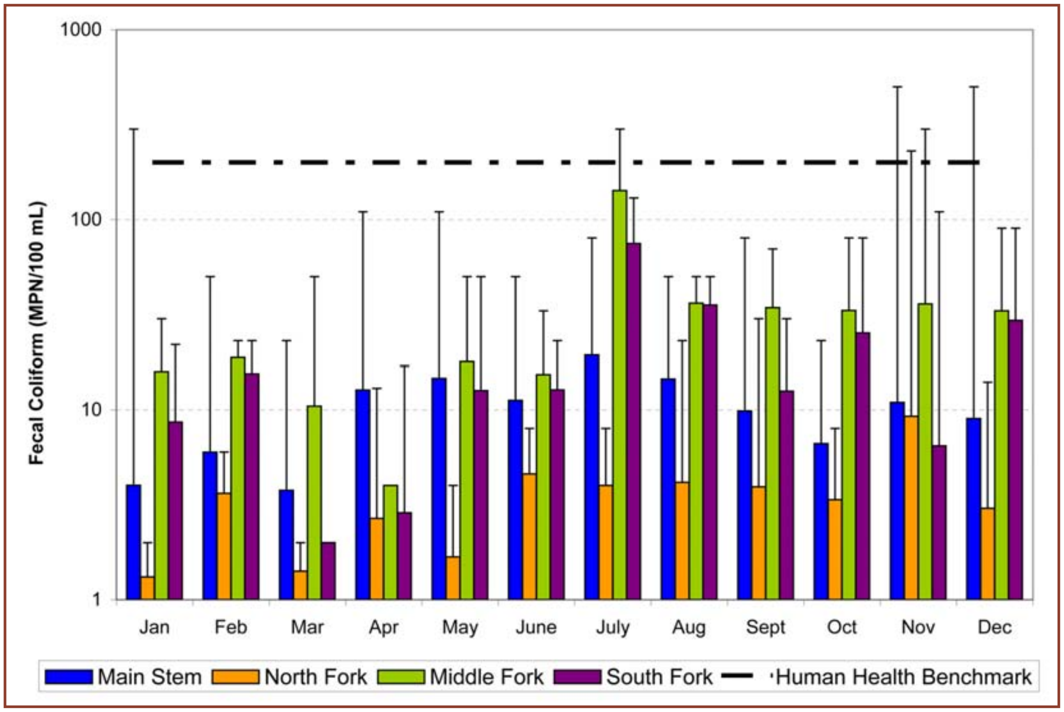
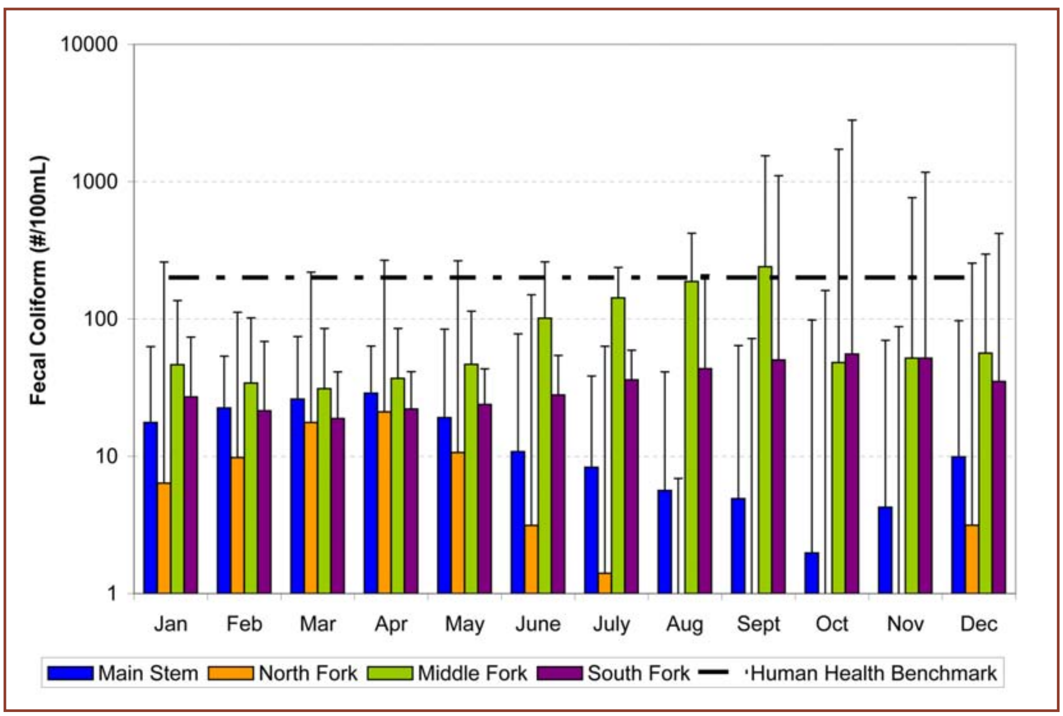
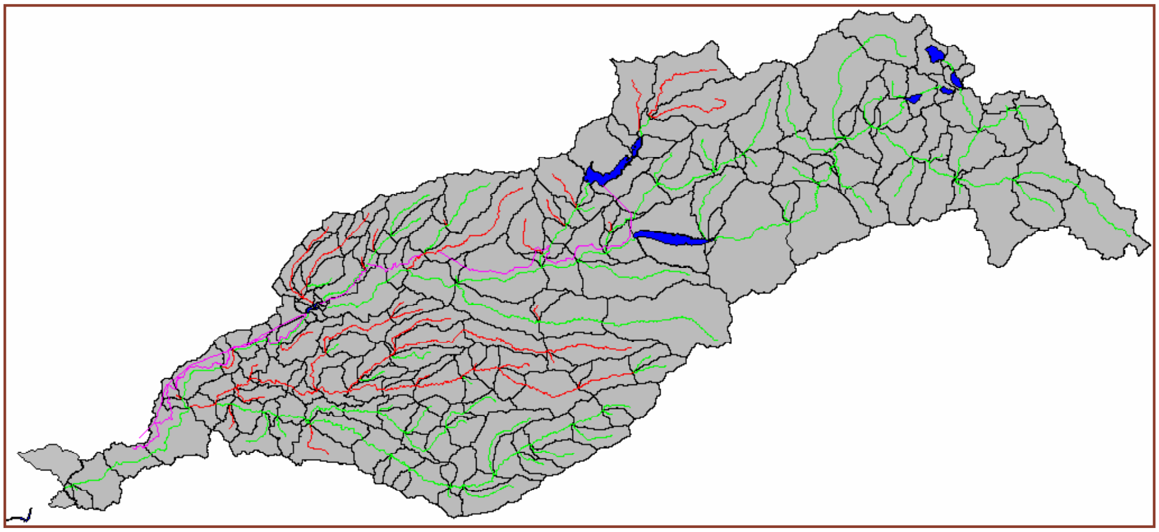


Figure 6-2: Monthly Geometric Mean Fecal Coliform Concentrations at Representative Locations (SIMULATED)



To more accurately reflect the condition established by the Basin Plan, an additional WARMF simulation was performed to determine which of the smaller catchment segments experienced an exceedance for every possible 30-day period from 1990 through 2005. The results of this simulation are displayed as red (exceedance) and green (no exceedance) segments in Figure 6-3. This type of analysis can help determine where future monitoring would be best located.

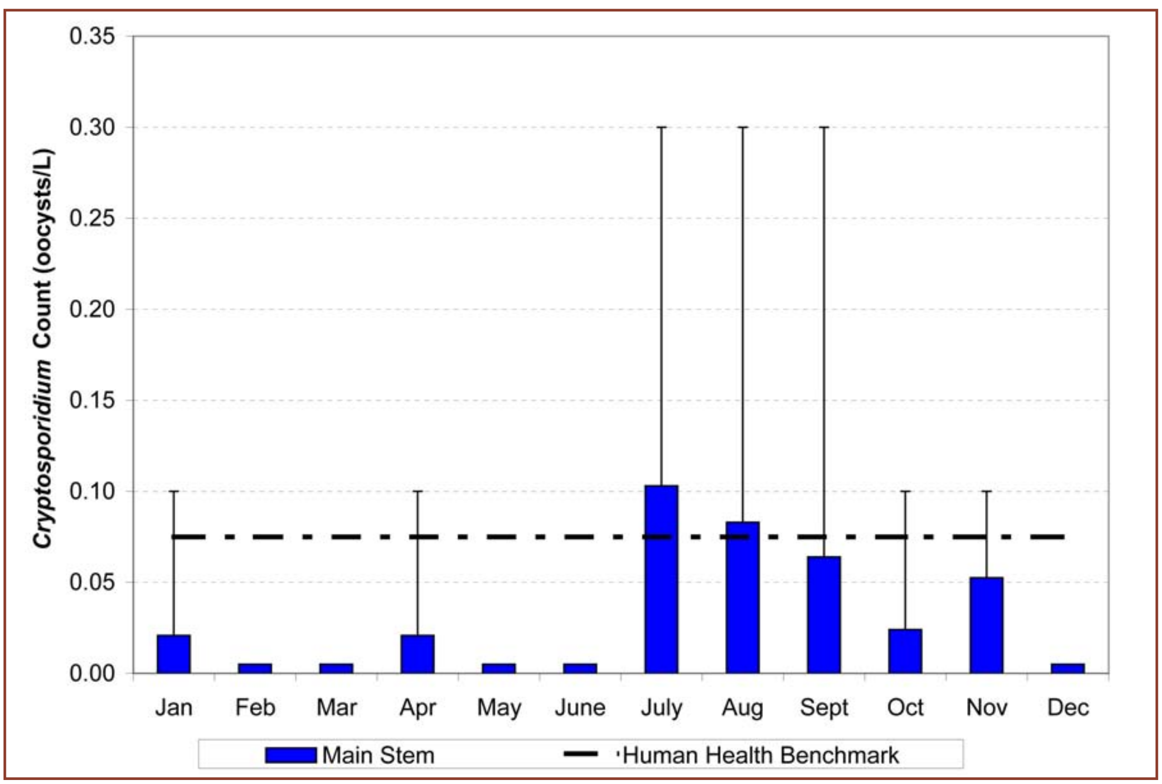
Figure 6-3: Stream Segments Exceeding Fecal Coliform Human Health Benchmark (SIMULATED)



6.3.2 | Cryptosporidium

Cryptosporidium is a single-celled protozoan commonly found in lakes and rivers, particularly where fecal contamination is present. *Cryptosporidium* is of particular health concern because

Figure 6-4: Monthly Mean *Cryptosporidium* Concentrations at Representative Locations



it is can causes outbreaks of gastrointestinal illness, with symptoms including diarrhea, nausea, and/or stomach cramps. Infection in sensitive populations can cause death. The human health benchmark of 0.075 oocycts/L established for *Cryptosporidium* is adapted from the recently passed Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR).

Cryptosporidium is recognized as an indicator of fecal contamination. As a result, *Cryptosporidium* concentrations are expected to be influenced by similar factors to those affecting fecal coliform. The density of septic systems is greatest along the Middle and South Forks and are expected to contribute heavily to *Cryptosporidium* concentrations.

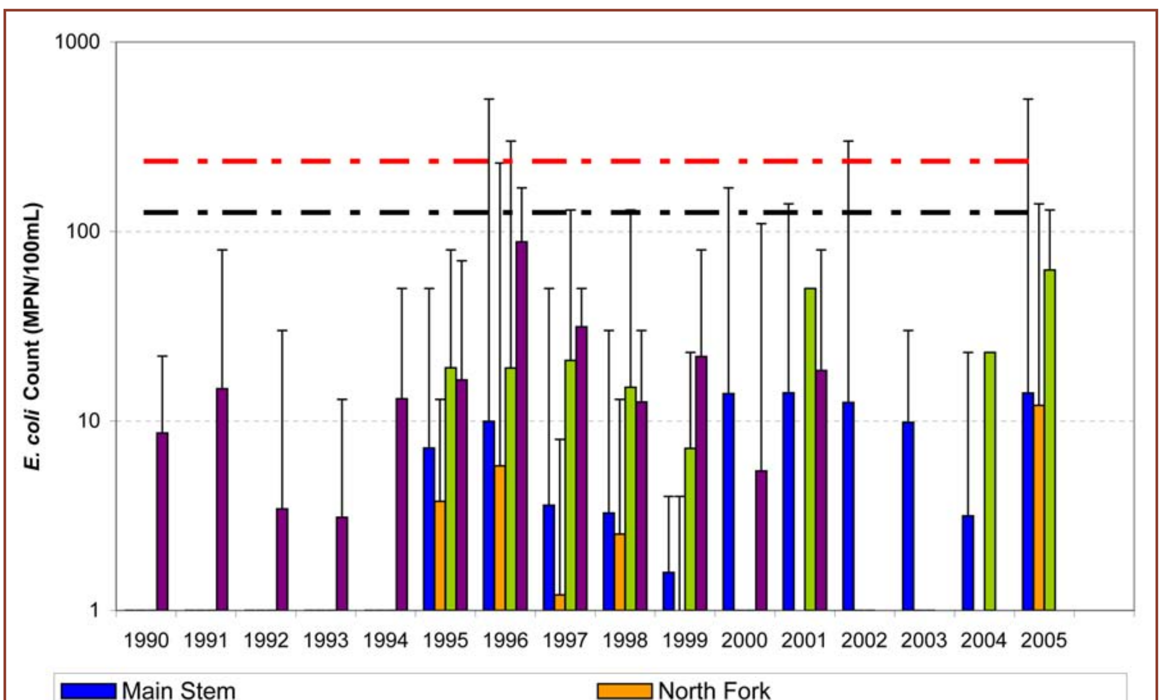
The average concentration of historical *Cryptosporidium* monitoring data for each month has been calculated and compared to the human health benchmark. Monthly mean *Cryptosporidium* concentrations were calculated from a limited data set of historical monitoring data in the watershed, and are presented in Figure 6-4. The analysis shows exceedances in July and August.

The greatest threat to water quality is from pathogens

6.3.3 | E. coli

Escherichia coli (*E. coli*) is a strain of fecal coliform commonly found in the intestines of animals and humans. The presence of *E. coli* is a strong indicator for recent animal or human fecal contamination. Due to its importance as the primary indicator organism for identifying fecal contamination, two human health benchmarks have been specified for *E. coli.* The DHS Draft Guidance for Freshwater Beaches, recommends beach posting when the concentration of a single *E. coli* sample exceeds 235/100 mL, or when the 30-day geometric mean *E. coli* concentration exceeds 126/100 mL, so these are the two benchmarks used here.

Figure 6-5: Annual Geometric Mean *E. coli* Concentrations at Representative Locations



An indicator of fecal contamination, higher *E. coli* concentrations are found in areas with body contact recreation, wildlife, grazing operations, and leaking septics, as with fecal coliform and *cryptosporidium*, described above. The high density of septic systems along the Middle and South Forks are expected to contribute significantly to *E. coli* loading along these forks.

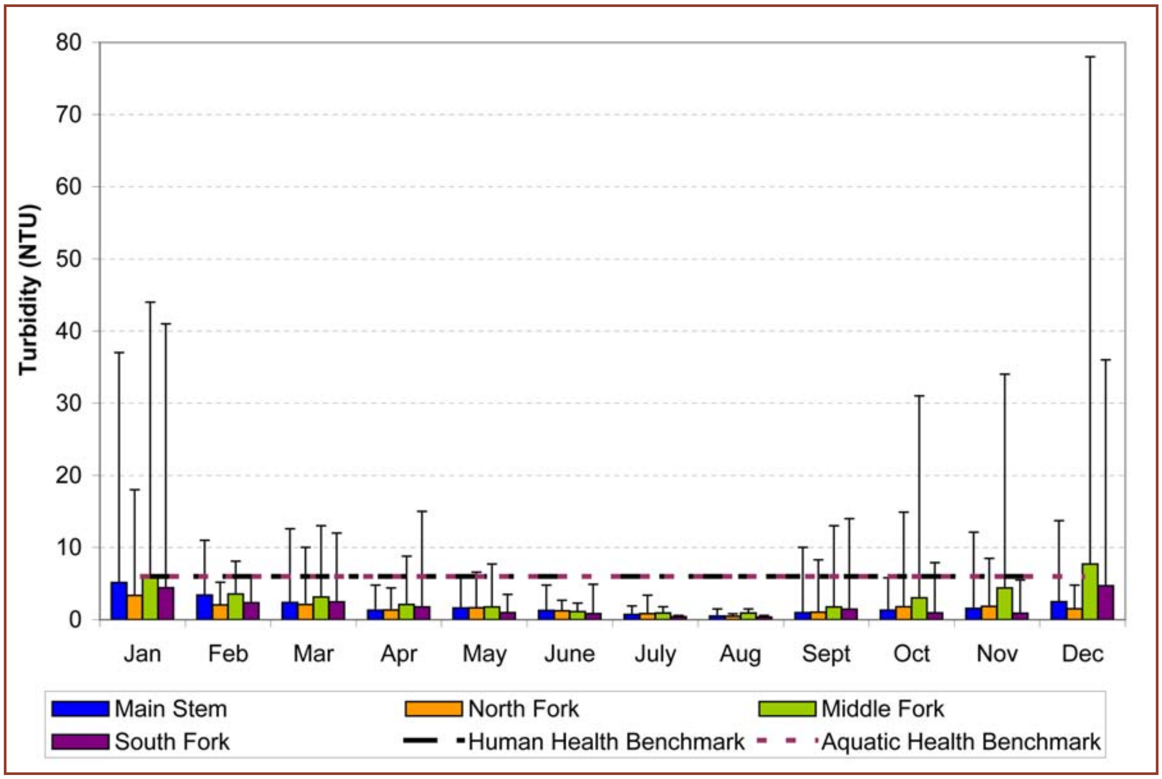
Monthly geometric mean E. coli concentrations were calculated from historical monitoring data in the watershed, and are presented along with maximum values in Figure 6-5. As shown in this figure, monthly concentrations are below the benchmark on all forks, but geometric mean concentrations on the Middle and South Forks approach the human health benchmark in July.

Maximum values on the Main Stem have historically exceeded the single sample human health benchmark in May, November, and December. Maximum values on the Middle Fork have historically exceeded the single sample human health benchmark in July.

6.3.4 | Turbidity

Turbidity is a measure of the water's clarity (low turbidity) or murkiness (high turbidity) caused by soluble, colored, organic compounds, and suspended particulate matter such as clay and silt, detritus and organisms. The Basin Plan water quality objective for turbidity states that, where natural turbidity is between 0 and 5 NTUs, increases shall not exceed 1 NTU. Because the natural turbidity in the Upper Mokelumne River is generally very low, the most restrictive objective, a concentration of 6 NTU, was identified as an appropriate benchmark. This benchmark is calculated as 30-day arithmetic mean, and is considered both a human health benchmark and an aquatic health benchmark. Significant changes in turbidity can kill aquatic organisms or reduce their growth rates, damage invertebrate populations, block gravel spawning beds, and remove dissolved oxygen. Turbidity changes are also of concern to human health, as they can interfere with water treatment and disinfection processes.

Figure 6-6: Monthly Mean Turbidity Concentrations at Representative Locations



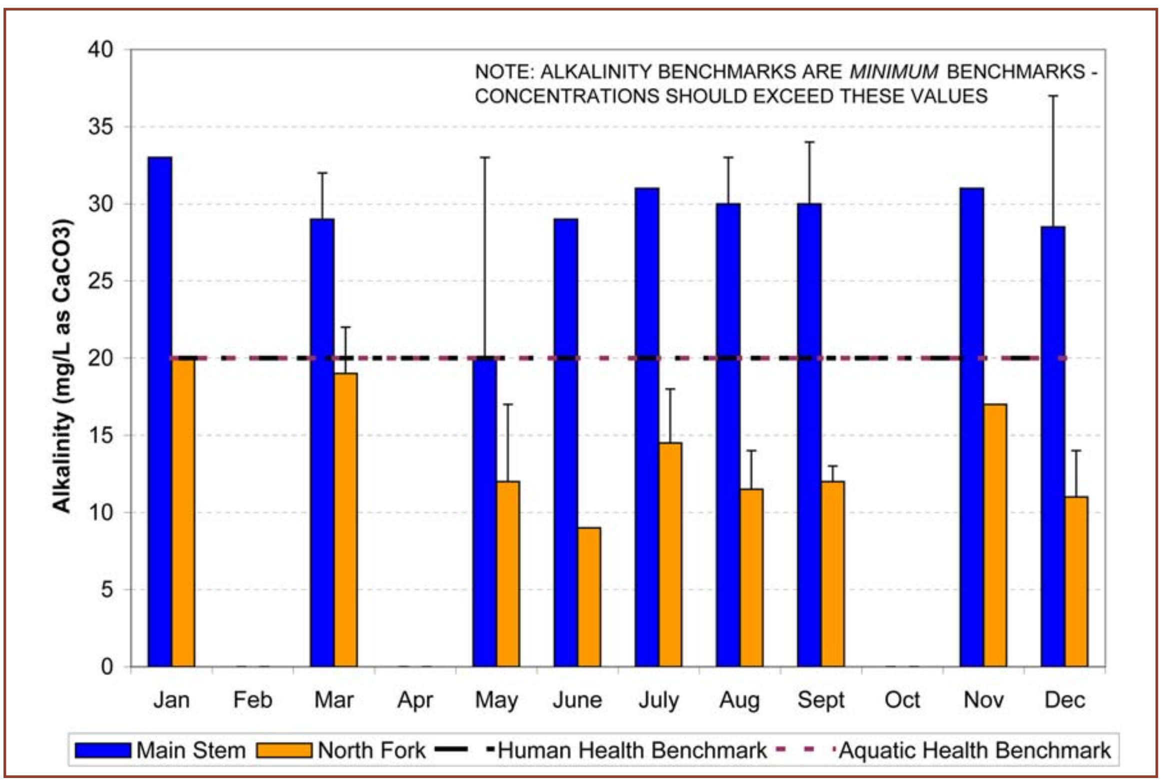
Turbidity is expected to be influenced by factors similar to those affecting total suspended solids, including agricultural and stormwater runoff and natural weathering processes which cause soil erosion. Due to the rural nature of the watershed, it is anticipated that the primary cause of turbidity in the watershed is soil erosion. This is expected to be most pronounced in areas of the watershed with less vegetative cover or disturbed soils, as these regions are directly exposed to weathering processes. Rural residential areas and areas of human influence are expected to contribute to turbidity through increased runoff and erosion potential.

Monthly mean turbidity was calculated from historical monitoring data in the watershed, and is presented in Figure 6-6. As shown in this figure, monthly mean turbidity concentrations exceed the benchmark in Middle Fork in December. It should be noted that the Basin Plan contains different objectives based on ambient turbidity so the most restrictive objective is used here. The Basin Plan also indicates that controllable processes should not contribute to exceedances. Because the controllability of natural weathering and erosion responsible for turbidity in the watershed is limited, turbidity produced in this way is not considered to violate the water quality objectives.

6.3.5 | Alkalinity

Alkalinity is a measure of the buffering capacity of water, or the ability of water to resist change in pH. Alkalinity reflects a stream's ability to neutralize acidic pollution and rainfall and also helps to regulate the metal content of a water body. While alkalinity is not generally considered a threat to human health, changes in alkalinity can affect water treatment processes as well as corrosivity of water in distribution systems. Alkalinity is important for aquatic species because it buffers pH changes resulting from chlorophyll-bearing vegetation and can reduce heavy metal toxicity. Concentrations from 20-200 mg/L as $CaCO_3$ are typically found in freshwater, and concentrations less than 10 mg/L as $CaCO_3$ are considered poorly buffered. The watershed exhibits extremely low alkalinity concentrations. As such, the low end of the natural concentrations found in freshwater – 20 mg/L as $CaCO_3$ – was identified as an appropriate human health benchmark for alkalinity.

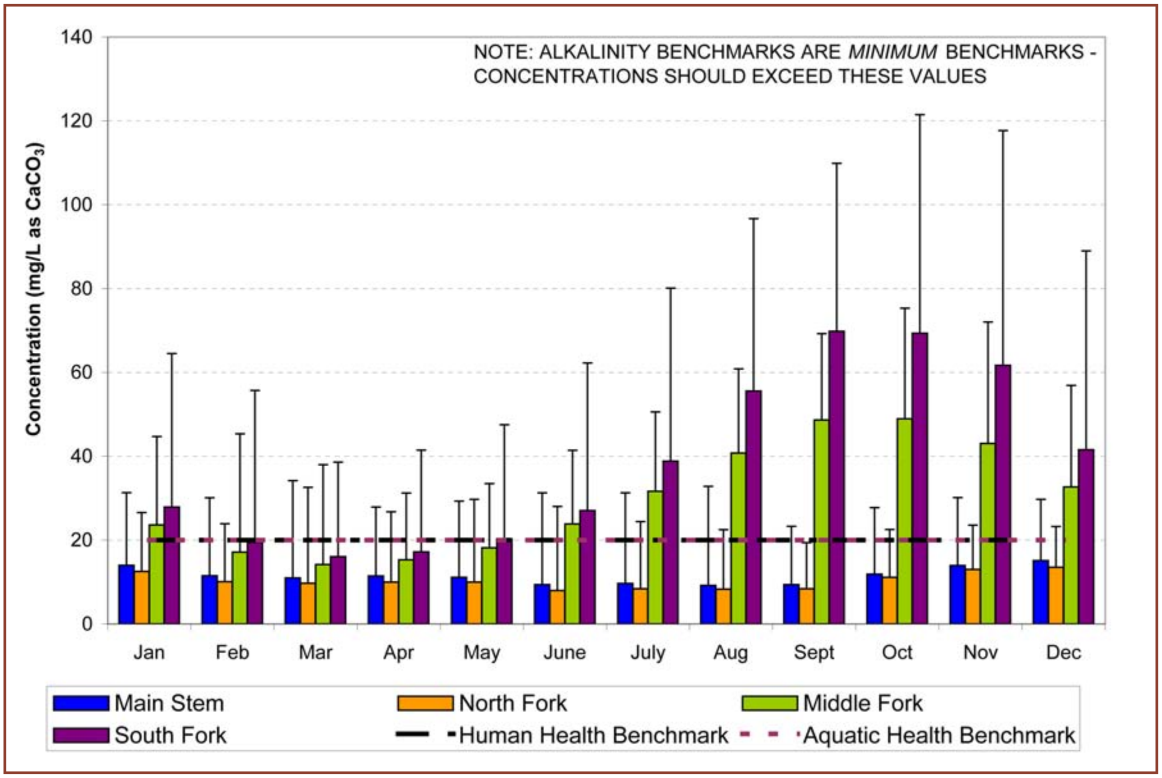
Figure 6-7: Monthly Mean Alkalinity Concentrations at Representative Locations



The primary source of alkalinity in the watershed is weathering of rock and soils. As water passes through rock and soil containing carbonates such as calcite ($CaCO_3$), calcite dissolves and alkalinity is added to the water. High alkalinity waters are generally found in regions containing limestone and sedimentary rocks and carbonate-rich soils. Based on the geology of the watershed, alkalinity is expected to be extremely low, particularly in upper portions of the watershed. Alkalinity is expected to increase somewhat in lower watershed elevations, where dominant geology includes sedimentary rock. Additionally, alkalinity would be expected to be greatest under conditions in which groundwater exfiltration is a significant contributor to streamflow.

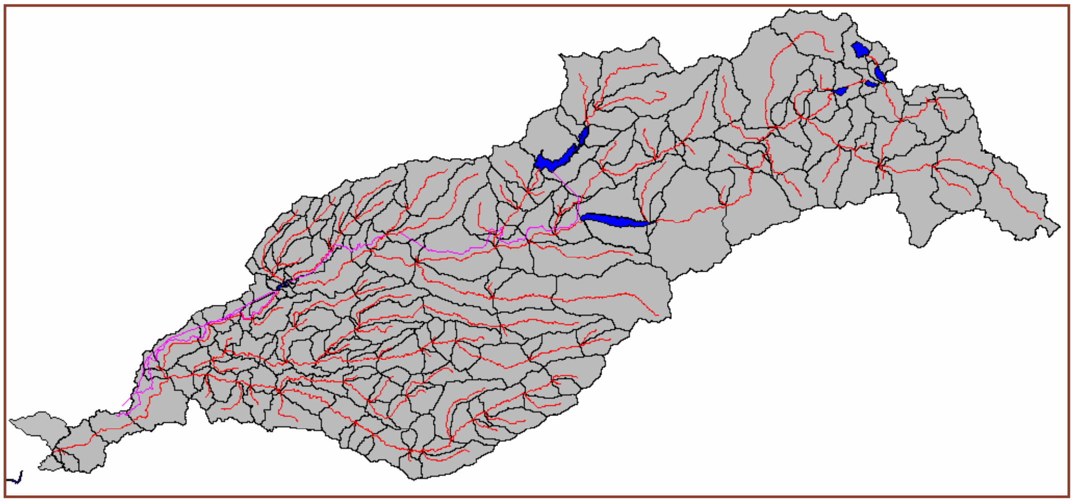
Monthly mean alkalinity concentrations were calculated from historical monitoring data in the watershed, and are presented in Figure 6-7. Figure 6-8 displays the same information, calculated using simulated daily data for 1990 through 2005. These concentrations are based on the average of all historical samples for a given month, with historical sampling occurring generally on a monthly basis. Based on observed historical data, monthly mean alkalinity concentrations fall below the minimum human/aquatic health benchmark on the North Fork only. Based on simulated data, the North Fork and Main Stem fall below the human/aquatic health benchmark in all months, and the South and Middle Forks drop below this benchmark in February, March, April and May.

Figure 6-8: Monthly Mean Alkalinity Concentrations at Representative Locations (SIMULATED)



An additional WARMF simulation was performed to determine which of the smaller catchment segments experienced an exceedance for every possible 30-day period from 1990 through 2005. The results of this simulation are displayed as red (exceedance) and green (no exceedance) segments in Figure 6-9. As shown in this figure, the WARMF simulation has projected alkalinity to drop below the minimum human/aquatic health benchmark between 1990 and 2005 at every location in the watershed.

Figure 6-9: Stream Segments Falling Below Alkalinity Minimum Human and Aquatic Health Benchmark (SIMULATED)



6.3.6 | Nitrate

Nitrate is highly soluble in water and easily transported in streams and groundwater. Plankton, aquatic plants, and algae all require nitrate for respiration. Elevated concentrations of nitrate in drinking water may cause serious illness and death. Nitrate is converted to nitrite in the intestine. Nitrite reacts with hemoglobin in human blood to produce methemoglobin, which limits the ability of red blood cells to carry oxygen. This condition, termed methemoglobinemia, is especially serious for infants, because they lack the enzyme necessary to correct this condition, and is commonly referred to as "blue baby syndrome."

Excessive amounts of nitrate also encourage algal growth and potential eutrophication. Eutrophication causes dissolved oxygen concentrations to drop, potentially causing fish kills. Excessive algal growth can also pose a significant treatment challenge, causing severe filter clogging. In a 2006 report, nitrate concentrations in excess of 0.040 mg/L as N, were responsible for algal blooms in Pardee Reservoir[1]. Based on the analysis presented in that report, 0.040 mg/L as N has been identified as an appropriate benchmark for nitrate.

Major sources of nitrate in the watershed are expected to be similar to ammonia sources, including atmospheric deposition, natural geologic contributions, fertilizer application, and animal waste. Nitrate can enter waterways through deposition or runoff. In this watershed, it is anticipated that animal waste and failing septic systems are the major sources of nitrogen loading. The Power Fire of 2004 contributed nitrogen loading.

Monthly mean nitrate concentrations were calculated from historical monitoring data in the watershed, and are presented in Figure 6-10. This plot was recreated using a full set of simulated daily nitrate data, presented in Figure 6-11. Monthly mean values on the Main Stem have historically exceeded the human health benchmark in January. Simulated monthly mean concentrations on the South Fork exceed the benchmark in January, and simulated mean concentrations on the Main Stem, South Fork, and Middle Fork exceed the benchmark in February.

1 Alex Horne, Ph.D. Report for Water Quality Section, EBMUD. Draft Causes and Solutions for Filter Clogging in EBMUD Water Treatment Plants Due to Large Aulacoseira (Melosira) Algae Blooms in Pardee Reservoir in Winter 2005-06. 13 August 2006.

Figure 6-10: Monthly Mean Nitrate Concentrations at Representative Locations

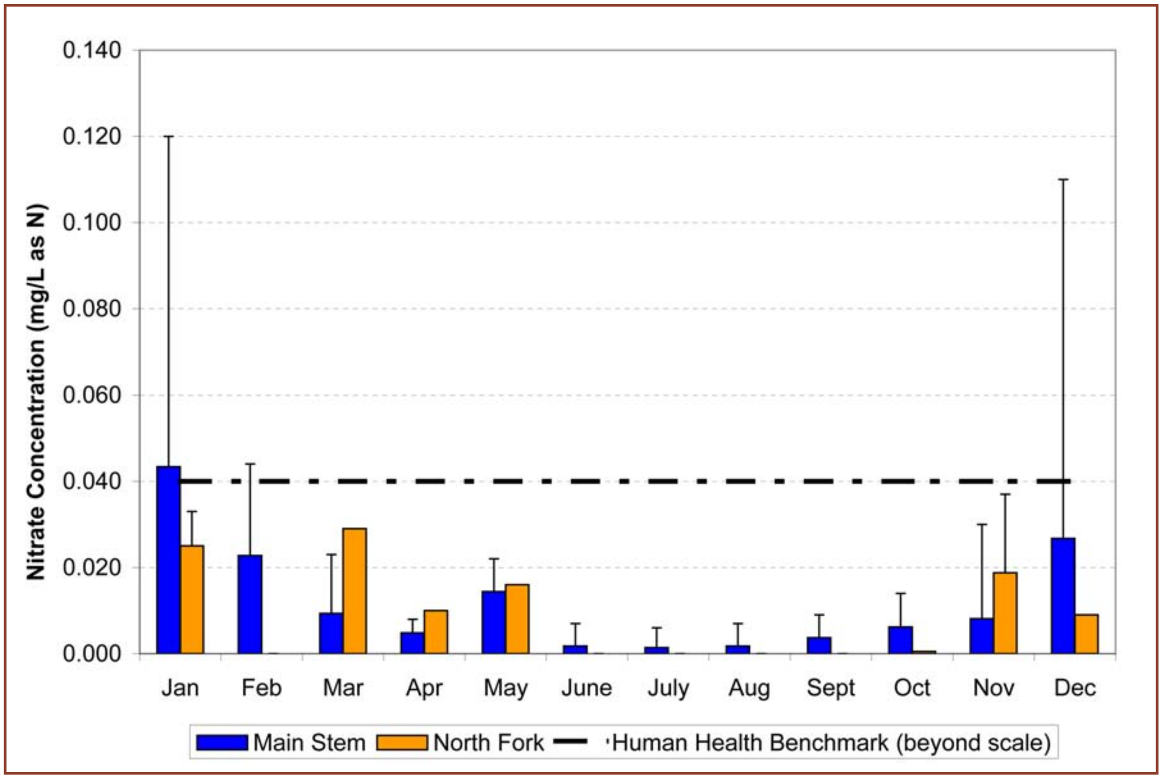
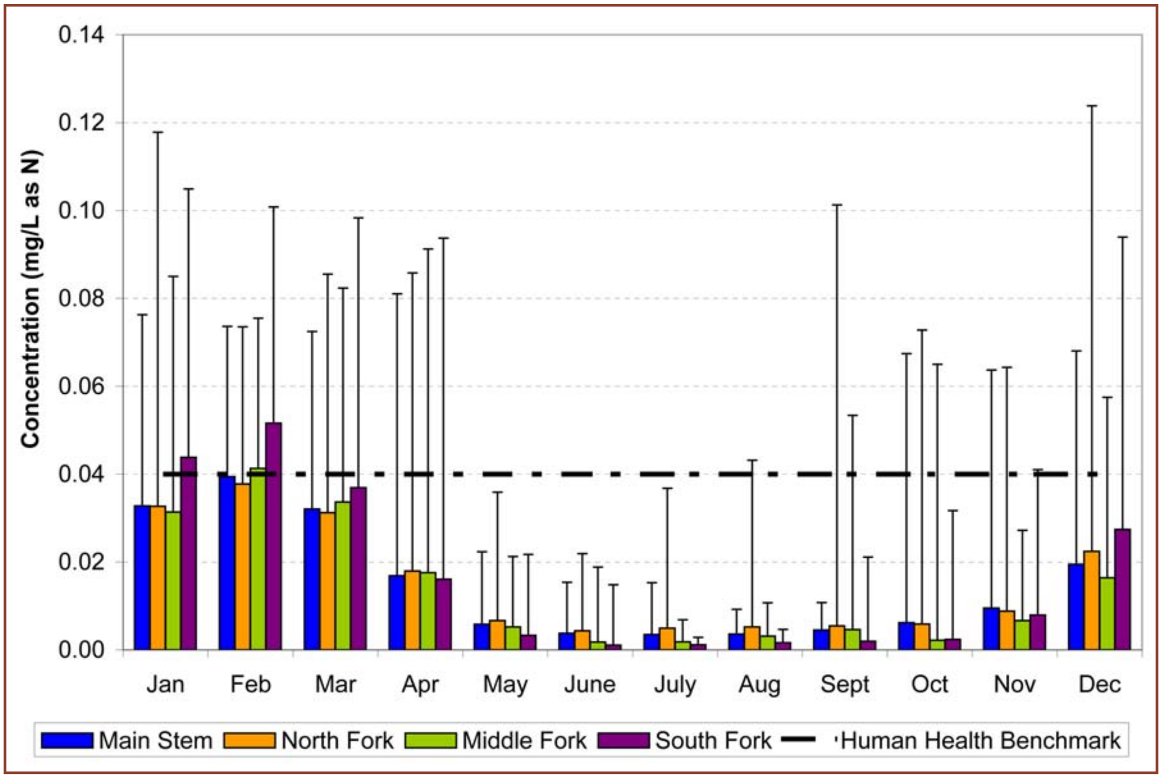


Figure 6-11: Monthly Mean Nitrate Concentrations at Representative Locations (SIMULATED)



6.3.7 | Aluminum

Aluminum is used in many everyday products as well is in the production of glass, paints, rubber, and ceramics, and in the coagulation step of drinking water treatment (as aluminum sulfate). Aluminum is naturally found in mineral deposits and soils, and watershed concentrations are expected to be the result of erosion and weathering, exacerbated by acid rain in a poorly buffered watershed.

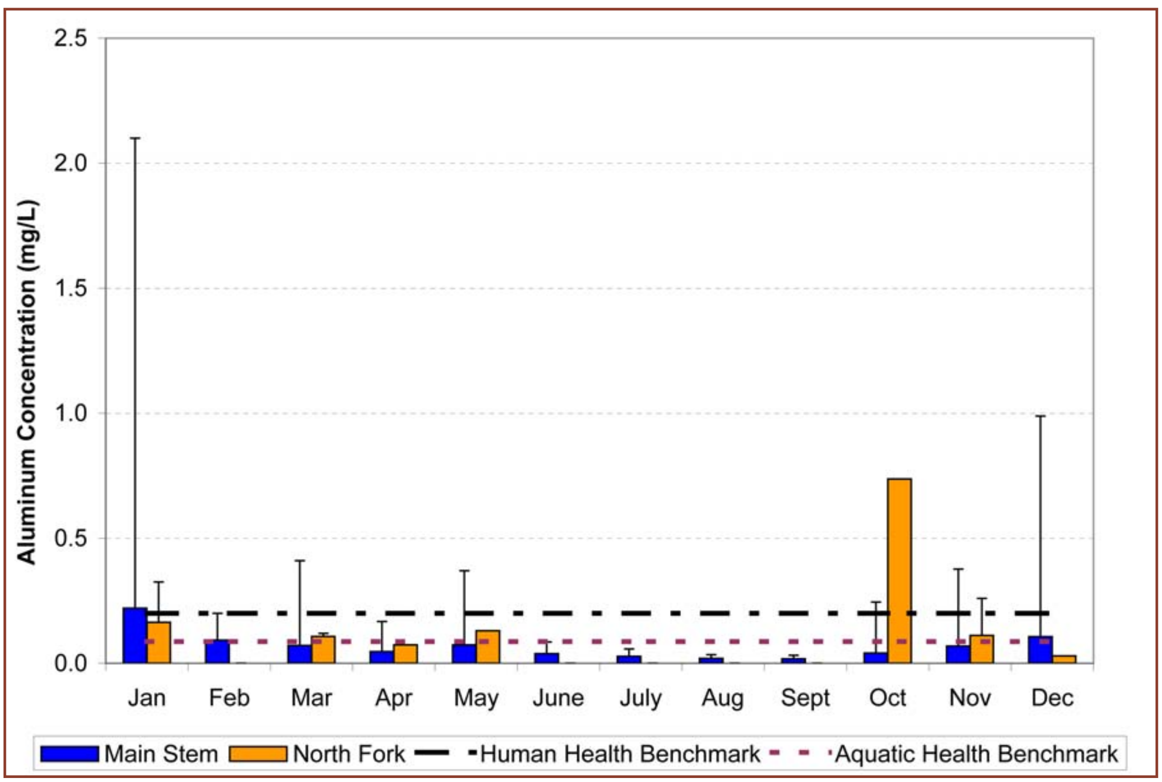
Excessive aluminum consumption may result in impaired neurological function. The human health benchmark for aluminum was based on EPA's secondary standard of 0.2 mg/L for aluminum to control color in drinking water. In areas such as this watershed, where alkalinity (buffering capacity) is low, acid rain can release aluminum from soils into lakes and streams. Aluminum is highly toxic to many species of aquatic organisms. The Clean Water Act (CWA) Section 304(a) aquatic life criterion for aluminum of 87 ug/L was used as the aquatic health benchmark.

The watershed is rich in geologic diversity

Monthly mean aluminum concentrations were calculated from historical monitoring data in the watershed, and are presented in Figure 6-12. Historical data shows average concentrations on the North Fork exceed the human health benchmark in October, and the aquatic health benchmark in January, March, May, October and November. These exceedance are thought to have been caused by the October, 2004 Power Fire, which increases the availability of metals in soil. Exceedances of the aquatic health benchmark along the main stem were observed for January, February and December. As seen in Figure 6-13, the simulated dataset reveals monthly exceedances on the Middle Fork in January through April, and on the South Fork in March and April.

Results of the WARMF analysis of potential historical 30-day exceedances of the aluminum human health benchmark are shown in Figure 6-14 with green segments showing no exceedance and red segments identifying potential exceedances. Historical exceedances

Figure 6-12: Monthly Mean Aluminum Concentrations at Representative Locations



of the human health benchmark have been predicted along nearly every stream segment in the watershed, with the exception of locations along the Main Stem, downstream locations on the North Fork, and stream segments immediately downstream from Salt Springs, Upper and Lower Bear, and Tiger Creek Reservoirs, where settling is expected to reduce concentrations. Because the human health benchmark is significantly greater than the aquatic health benchmark, stream segments exceeding the human health benchmark constitute significant exceedances of the aquatic health benchmark for aluminum.

Figure 6-13: Monthly Mean Aluminum Concentrations at Representative Locations (SIMULATED)

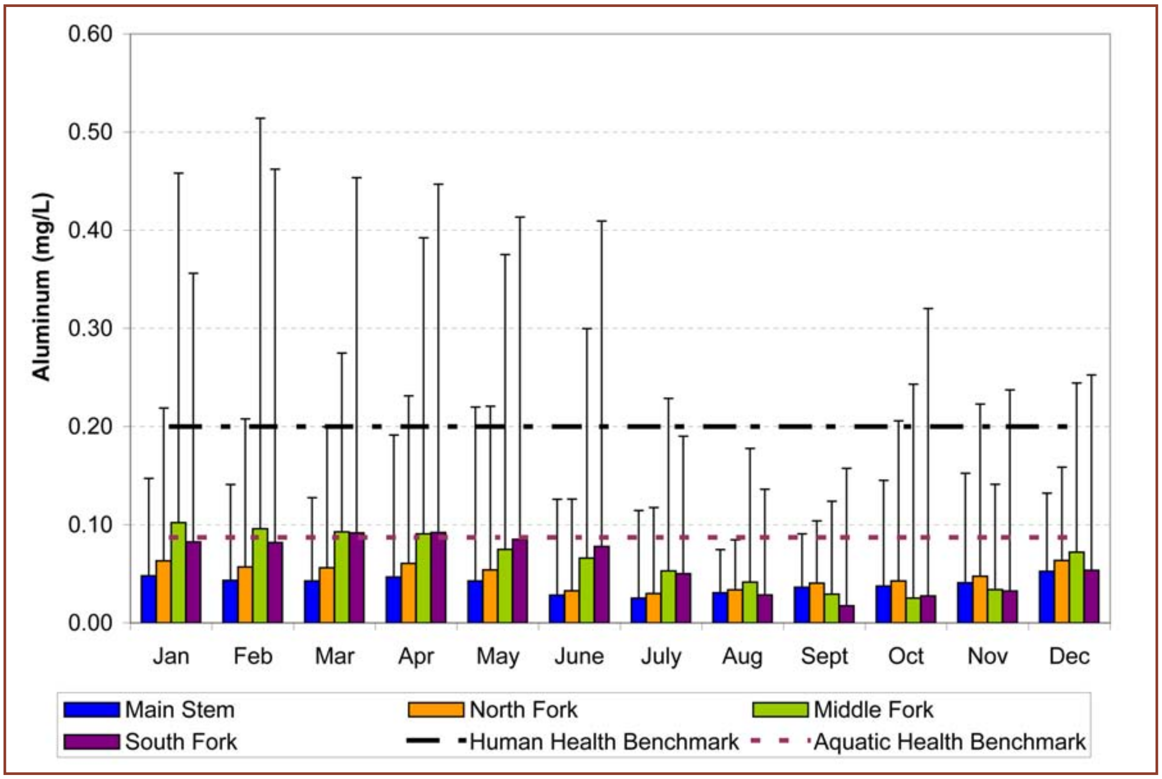
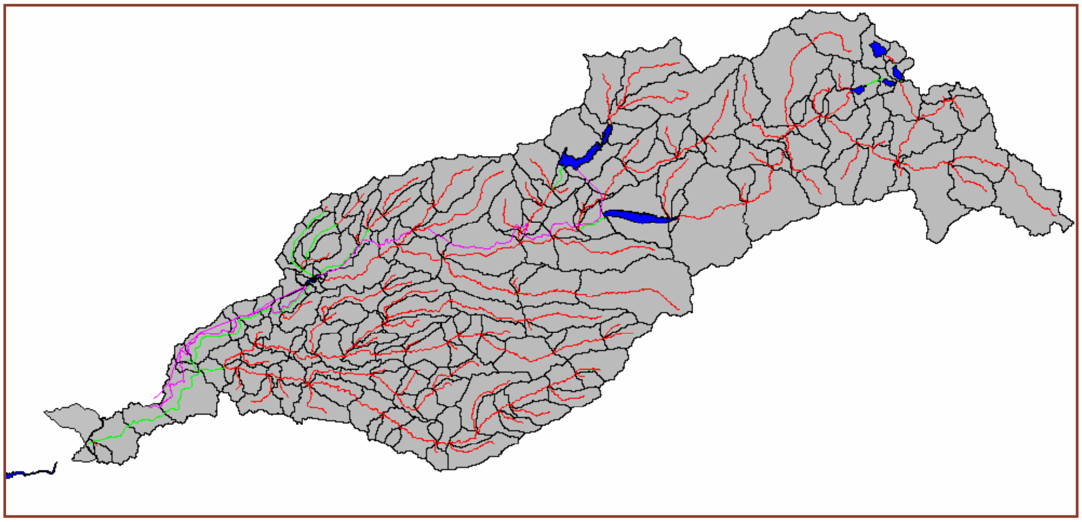


Figure 6-14: Stream Segments Exceeding Aluminum Human Health Benchmark (SIMULATED)



Chapter Seven

Key Watershed Assessment Findings

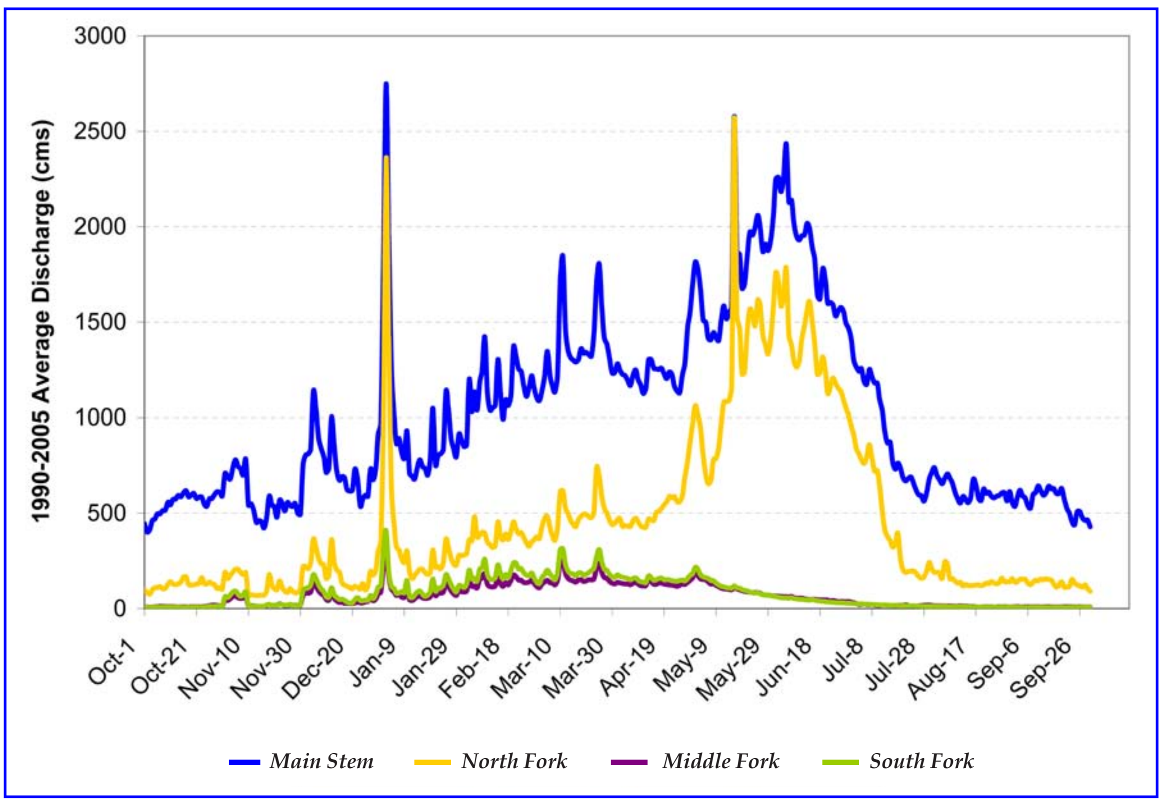
This section provides a brief overview of the watershed assessment findings. Additional information is provided in Appendix M - TM No. 9.

7.1 Overall Watershed and Subbasin Water Quality Conditions

Spatially, water quality varies between the major subwatersheds (North Fork, Middle Fork, South Fork, and Main Stem). The North Fork is the most pristine of the major subwatersheds, partially because of the dilution effects of higher flows, coupled with a lack of development in the upper watershed. Because Main Stem flow is dominated by contributions from the North Fork, Main Stem water quality is also very good. Water quality along the Middle and South Forks, while well below benchmarks for most parameters, does have higher levels of several contaminants as compared with the North Fork and Main Stem.

Of primary interest in the watershed are elevated pathogen concentrations. Elevated fecal coliform concentrations have been observed along the Middle Fork, with high peaks also seen on the South Fork. *E. coli* concentrations on the Main Stem, Middle Fork, and North Fork have exceeded the single sample benchmark, and concentrations on the Middle Fork have also exceeded the geometric mean benchmark. *Cryptosporidium* concentrations on the Main Stem have historically exceeded the human health benchmark, and concentrations along the Middle and South Forks – though not currently monitored – are likely to exceed concentrations observed along the Main Stem. Microbial contamination is currently the most significant water quality challenge facing the watershed.

Figure 7-1: Historical Average Hydrographs (1990 through 2004)



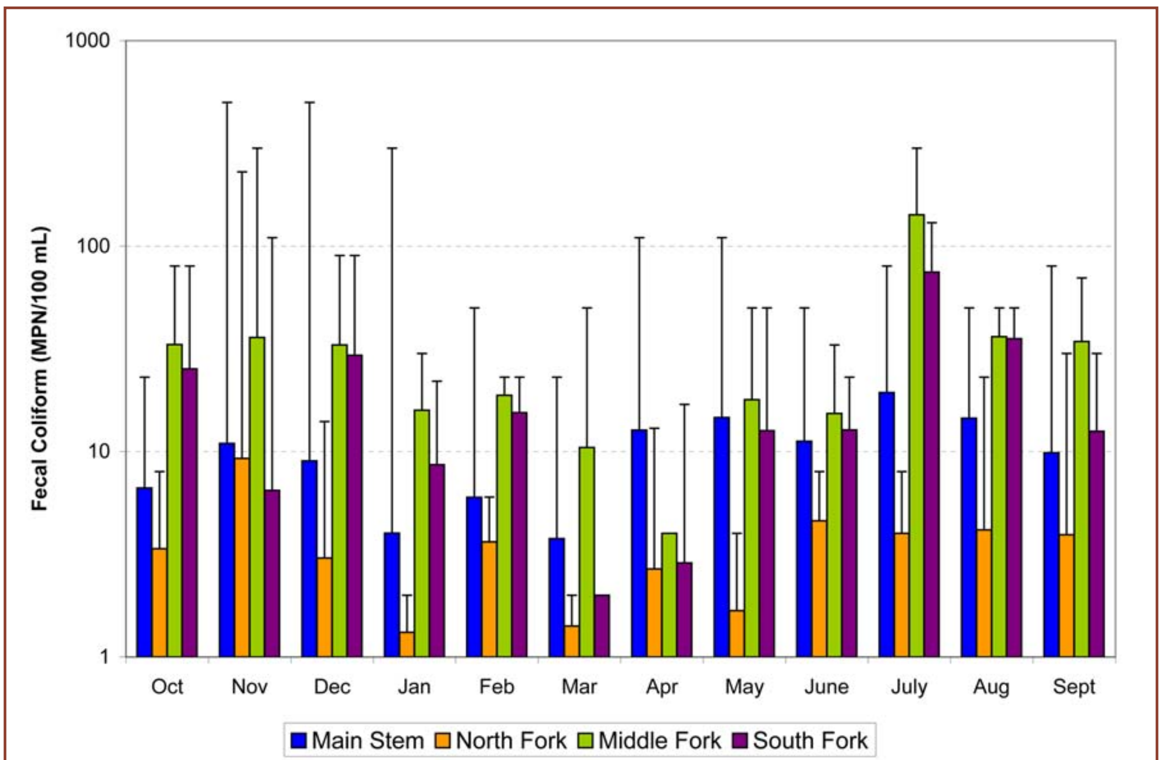
Note: *Most of the average discharge for January can be attributed to a single storm event in 1997.*

Upper Bear River is a tributary of the North Fork

Based on an analysis of the microorganism data and river flows, septic systems are believed to be a significant contributor of fecal coliform loading along the Middle and South Forks of the Mokelumne River. Figure 7-1 on the previous page, presents the average hydrographs for each major tributary based on USGS streamflow data for 1990 through 2004. The data are presented by monitoring station representing, in order, the Main Stem, North Fork, Middle Fork, and South Fork. The hydrograph includes data from a major storm occurring from January 1 through January 4 of 1997. If data collected during this single storm are excluded, the average Main Stem discharge drops from over 2500 cfs to below 1000 cfs for early January. The North Fork and Main Stem (dominated by North Fork flow volumes) are generally snowmelt-dominated regimes, with the hydrograph rising from late January through May and the snowmelt peak observed in the June timeframe. The Middle Fork and South Fork display a combination rainfall-snowmelt regime, with the snowmelt peak occurring in the March to April timeframe. The snowmelt recession on these tributaries is observed from July through the end of the water year. If elevated microbial concentrations are caused by runoff, it would be expected that microbial concentrations would mirror the hydrograph, peaking with early runoff.

Figure 7-2 presents monthly average historical fecal coliform concentrations, calculated as described in Section 6 and plotted on a water year basis. As seen in this figure, while winter storms have historically caused sharp peaks in the hydrographs for all major tributaries in January, fecal coliform concentrations in this month have generally exhibited a decline compared to previous months. For the combination rainfall-snowmelt regime observed on the South and Middle Forks, the snowmelt peak is observed in the March to April timeframe. Fecal coliform concentrations during this period exhibit an opposite trend, appearing to drop slightly on these

Figure 7-2: Monthly Geometric Mean Fecal Coliform Concentrations



tributaries. Concentrations appear to increase from May through the end of the water year, counter to the trend observed in the hydrograph. This suggests that, rather than causing an increase in microbial concentrations, runoff has a diluting effect on fecal coliform concentrations, consistent with an alternate source of constant loading such as failing septic systems. Many of the homes in the lower portion of the watershed are seasonal vacation homes, which could explain the elevated microbial concentrations observed during late summer and fall.

If grazing practices in the watershed dominated microbial concentrations, it would be expected that periods of intense grazing along a particular tributary should contribute to elevated microbial concentrations during that time along that tributary. Reviewing the grazing patterns in the watershed, shown on Figure 4-10, cattle are most concentrated in the Main Stem subwatershed from October through May. If grazing practices have a significant influence over microbial concentrations, fecal coliform concentrations would be expected to increase along the Main Stem during this timeframe. In contrast, historical data reveal that concentrations in this subwatershed are lower during the period of intense grazing than during later months, suggesting that cattle contributions are not a major factor dominating fecal coliform behavior.

The WARMF model was also used to seek out the relative contributions of various sources of microbial loading in the watershed, including grazing, recreation, and septic systems. Comparing the simulated nonpoint source loading calculated by the WARMF model from each of these sources, septic systems were found to be responsible for approximately 95 percent of the overall fecal coliform loading, compared to less than four percent contribution from all grazed areas, and well under one percent contributed by areas of human impact.

While these conclusions are based on limited data, the evidence that failing septic systems are a major contributor to elevated microbial concentrations observed in the Upper Mokelumne River watershed is compelling. As a result, management measures to mitigate this potential source should be initiated to the greatest extent feasible to limit future loading and protect water quality in the watershed. Concurrently, additional studies should be performed to confirm the source of microbial loading as human and clearly identify the contributing source(s) and areas of greatest impact. Additional information on management recommendations to minimize the impacts from failing septic systems and develop targeted monitoring programs is provided in Section 8.

Both natural and anthropogenic activities impact water quality

Other parameters of particular interest in the watershed are turbidity, alkalinity, aluminum, and nitrate,. Elevated turbidity events and low alkalinity in the watershed are the result of natural watershed conditions. Elevated concentrations of aluminum observed throughout the watershed likely result from natural weathering processes as well as the large number of abandoned mines. Elevated nitrate concentrations are expected to result both from natural watershed conditions and human influence such as failing septic systems.

7.2 Fire Behavior and Intensity

Fire behavior was modeled throughout the Upper Mokelumne River watershed to gain a better understanding of high risk areas and potential impacts from a fire. Ignition sites were selected to represent potential wildland fire scenarios to compare fire behavior in the various subwatersheds. WARMF was used to analyze water quality impacts resulting from several simulated fires based on the fire behavior modeling.

7.2.1 | Methodology

Two distinct fire models developed by the USFS were used in this project.

- **FlamMap** was used to determine the relative hazard and flammability of areas throughout the watershed. FlamMap allows prediction of fire behavior on a spatial basis, by modeling the flame length, heat release, and rate of spreads along with type of fire (crown fire, surface fire, or a fire that torches trees) throughout an entire area. FlamMap simulates as though the entire area were aflame under the same conditions at the same time to determine how fire behavior in specific areas differ.
- **FARSITE** predicts fire behavior only in the predicted burn area, rather than the entire study area. It also simulates where and how fast a fire would spread from pre-selected ignition sites. The fire behavior prediction outputs of FARSITE were translated into three burn severity categories: low, moderate, and high.

Fire model results were used for water quality modeling

Locations of potential ignitions sites (places where fires could start) were identified based on the relative hazards and flammability in the watershed as simulated by FlamMap, as well as proximity to human contact. FARSITE was then run and the distribution of predicted burn severity was identified for the entire watershed. The spatial distribution of the burn severity categories for the selected ignition sites was used as an input to WARMF in order to simulate potential effects on water quantity and quality.

Appendix L - TM No. 8: Fire Modeling provides a description of fire behavior prediction, inputs required for these models, and interpretation of the outputs. Maps of fire growth and fire behavior characteristics are provided in Appendix L for each ignition simulation.

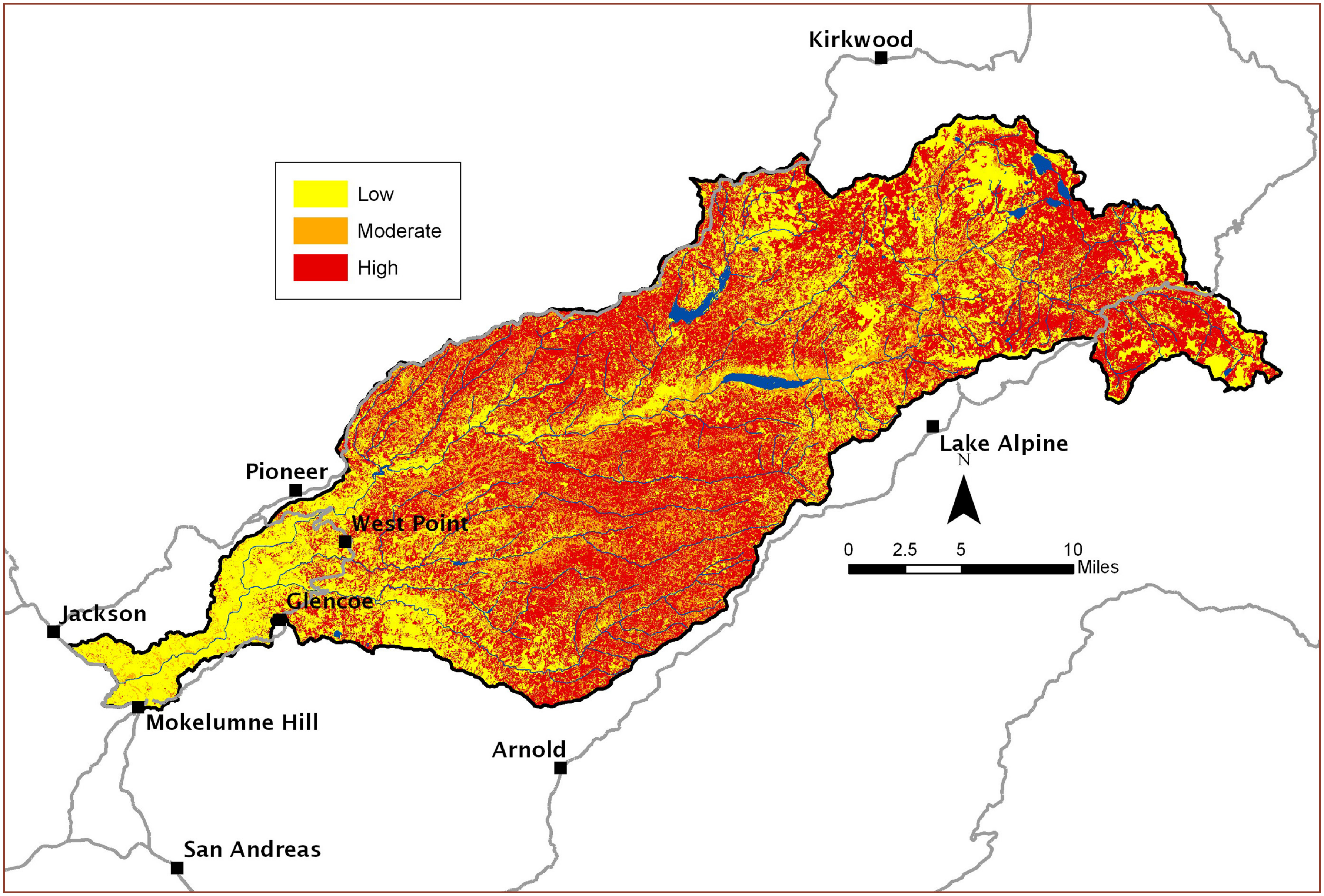
7.2.2 | Modeling Results

Fire behavior was modeled using a variety of data inputs, including elevation, slope, aspect, fuel model, canopy cover, tree height, crown base height, weather, and wind. Predicted fire behavior was then translated into burn severity, or the degree to which a site has been altered or disturbed by fire. Figure 7-3 displays the spatial distribution of the predicted burn severity throughout the watershed.

Several potential ignition sites were selected by the PAC to be modeled in FARSITE. These sites are located on Figure 7-4. Ignition sites were selected that were reasonable possibilities for ignition occurring, and where significant effects on water quality would be expected if a fire was allowed to burn to a sizeable acreage. The duration of the FARSITE simulations varied by ignition site because of the variability in fire growth rate; some sites took longer to achieve a significant fire size than others. Fires were generally allowed to burn until they reached approximately 5,000 acres.

Burn severity results were used as inputs to the calibrated WARMF model for analysis of potential water quality impacts. The results of this analysis are provided in Appendix M - TM No. 9. In general, the greatest impacts, as expected, were associated with high severity burn areas. The most significant aspect of the analyses was the lightning ignition

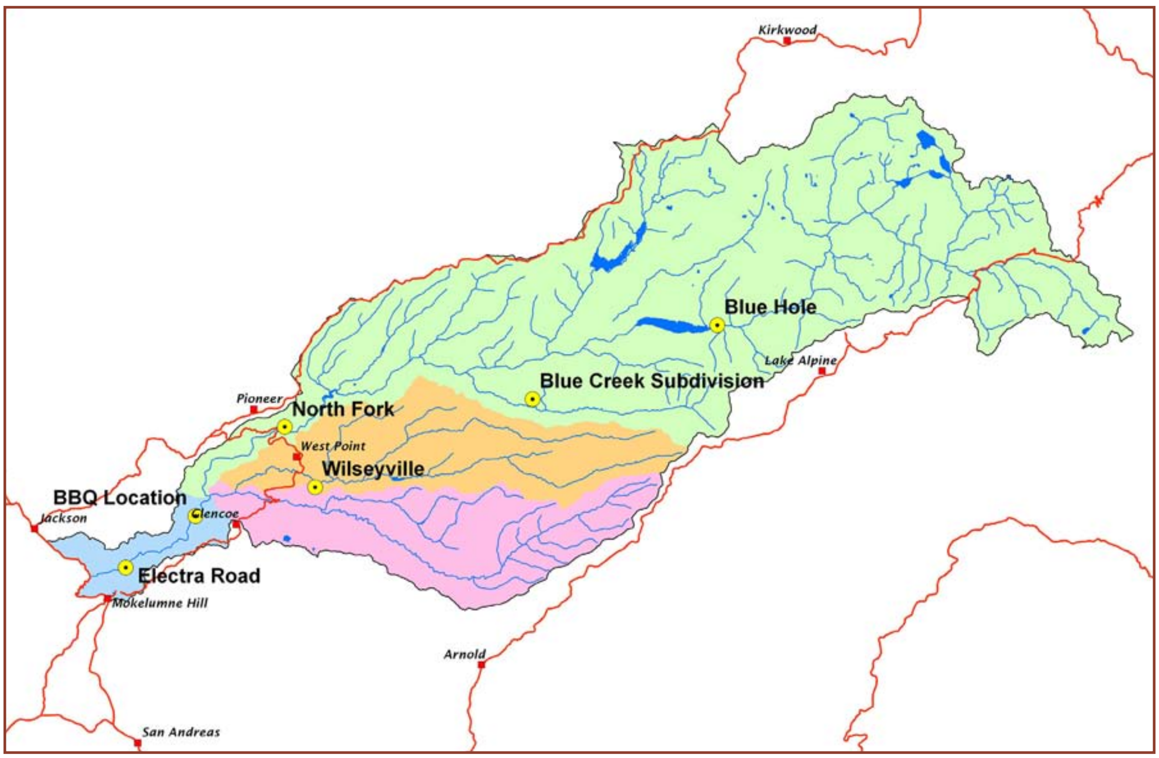
Figure 7-3: Burn Severity Throughout the Upper Mokelumne River Watershed



scenario. The lightning ignition scenario was intended to represent a scattering of small fires throughout the watershed, similar to what naturally occurs in the watershed over time. The water quality impacts associated with this scenario are an exaggerated example of loadings embedded in baseline water quality conditions, resulting from the many small fires occurring throughout the watershed each year. Reducing the impacts from these fires could result in improved baseline water quality.

The WARMF model proved to be an excellent tool for simulating the effects of wildland fires on water quality in the watershed. In the future, the model may be used after actual fires to tailor specific mitigations to achieve maximum water quality benefit. In addition, use of the WARMF model in conjunction with the fire models could be used in the General Plan update process currently underway for Calaveras and Amador Counties. Potential fire severity and spread for alternative land use scenarios could be analyzed using FlamMap and FARSITE, based on the location of proposed increased density of urban development. In addition, the alternative scenarios could be simulated in WARMF to determine any potential effects to water quality with and without wildland fire effects.

Figure 7-4: Ignition Sites for Modeling Scenarios



7.3 Areas of Greater Water Quality Vulnerability

Water Quality Vulnerability Zones were developed to provide a useful tool in determining watershed lands most vulnerable to the transport of contaminants to waterbodies. The goal of this evaluation was to develop vulnerability zones that identify areas in the watershed considered to have very high, moderate, and low vulnerability with regard to the potential for increasing the concentration of a water quality parameter of concern in the receiving waterbodies. When considering new activities and land uses in the watershed, or in managing existing activities in the watershed, the high and very high vulnerability zones, in particular, should be managed more closely to reflect the increased potential for water quality degradation.

7.3.1 | Approach

Vulnerability zones were defined based on physical characteristics of the watershed: slope, soils, vegetation, and proximity to water. Data for each of these physical characteristics were evaluated, grouped to reflect their influence on the transport of potential contaminants to waterbodies using a ranking of high, medium, and low, and plotted on separate GIS data-interpreted layers. These resulting GIS layers were then overlaid on each other to develop an overall high, moderate, and low vulnerability zone map. This process is presented graphically in Figure 7-5.

Soils, vegetation, and proximity to water all have potential sources of concern associated with them, such as wildlife concentrating at waterbodies and thus contributing microorganisms, but current and future sources of pollutants within the watershed are more specifically addressed using the WARMF assessment tool and are not the focus of this vulnerability analysis. However, the disturbance of soils due to wildlife was taken into account through vulnerability associated with the proximity to water factor. Another overlapping example is soil type. Soils high in clay content may not erode as quickly as sandy soils, but once eroded, clay particles remain suspended longer during aqueous transport (measured as turbidity). Contaminants such as microorganisms or SOCs may adsorb onto the clay particles and be transported further.

Steep slopes and vegetation removed due to power fire increase erosion potential

7.3.2 | Compositing Methodology and Results

The rationale for overlaying, or compositing the data from each of these four watershed characteristic layers was based on the relative importance of the specific watershed characteristics. Numerical weighting factors were avoided in the composite process because of the subjective nature associated with the assignment of the numerical values

Because of its importance to the control (reduction) of the concentration of water quality parameters entering the waterbodies, the high vulnerability areas defined for the proximity to water layer take precedence over all other characteristics and, therefore, translate into high vulnerability zones on the composite map. The very high vulnerability areas reflect lands with a high classification of slope, soils, or vegetation within the proximity to water boundary or are within a documented floodplain. A more detailed description of this analysis is provided in Appendix K - TM No. 7. The resulting Water Quality Vulnerability Zone map is presented on Figure 7-6. This map can be used to identify lands which should have greater land management protection measures, such as stormwater runoff best management practices or areas where septic systems should have higher standards to ensure the protection of water quality. These protection measures could be implemented now for existing land uses and in the future if the lands are developed or used for any purpose that may involve water quality contaminants.

Figure 7-5: GIS Compositing Process

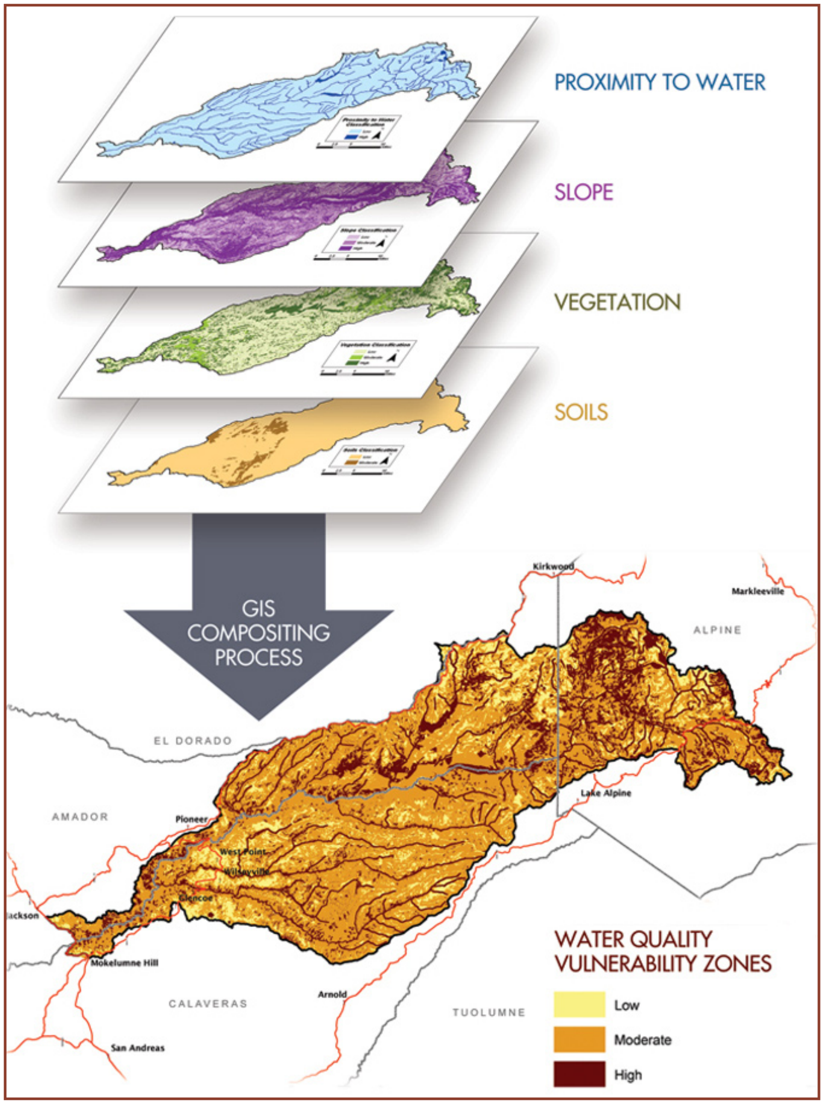
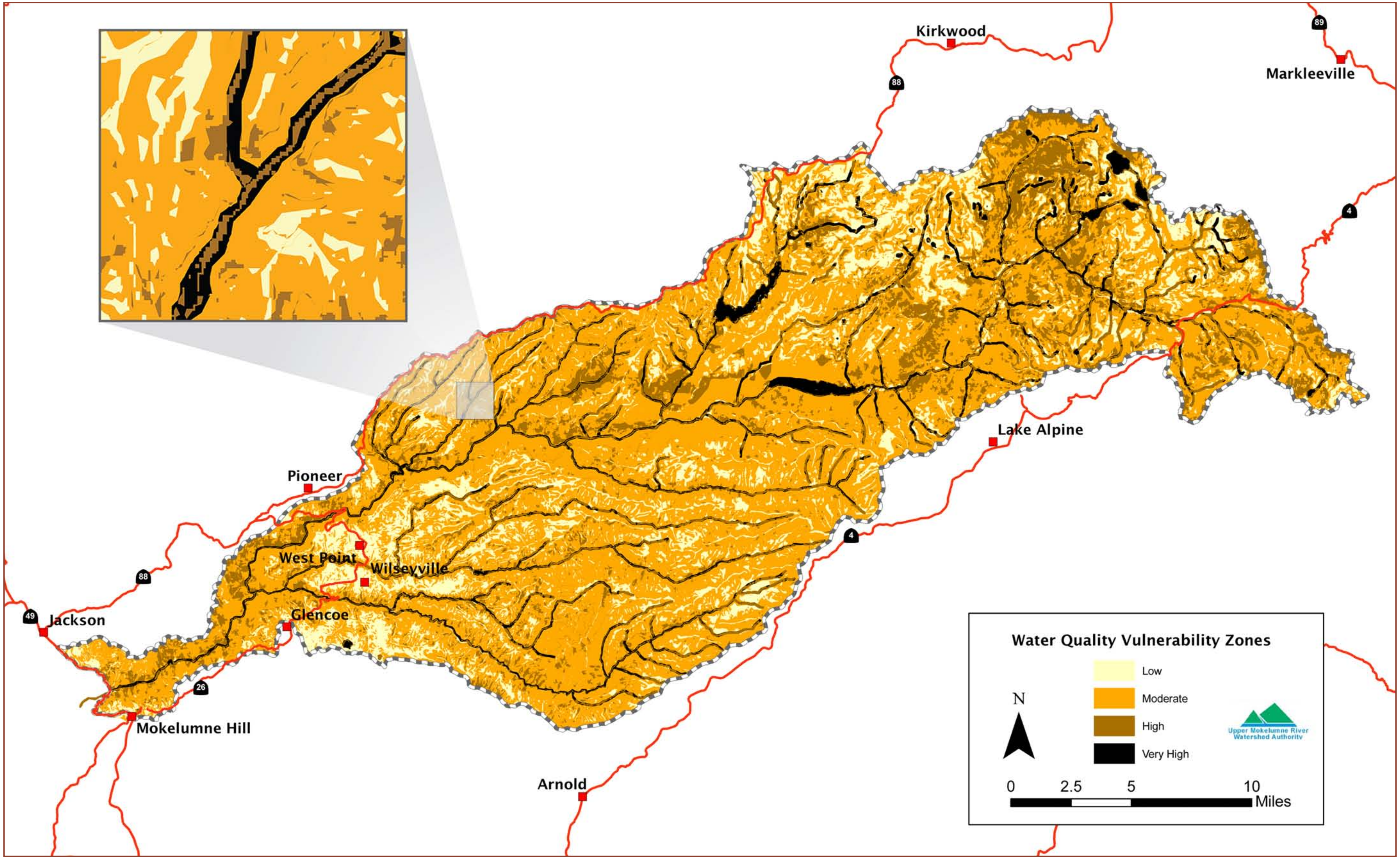


Figure 7-6: Water Quality Vulnerability Zones



Chapter Eight
Watershed Management Plan

8.1 Management Plan Linkage to the Watershed Assessment

A watershed management plan was developed based on the findings of the full watershed assessment summarized in Chapter 7. It was important that the management plan be directly related to the assessment to add validity and reasoning behind the recommendation of management measures. This section summarizes the main components of the management plan which is provided in full as Appendix N - TM No. 10.

8.1.1 | Relation to Project Goals and Objectives

The PAC-developed project goal: Maintain and Improve Source Water Quality, implicitly suggests two sets of project objectives. One set of objectives responds to the maintain portion of the project goal by focusing on the existing water quality parameters in the Upper Mokelumne River watershed which do not currently exceed benchmarks. For these parameters, the objective is to maintain source water quality conditions as reflected in baseline water quality conditions.

The second set of objectives responds to the improve portion of the project goal. This set of objectives focuses on parameters which currently exceed either human or aquatic health benchmarks. Watershed management recommendations are focused on improving concentrations of these parameters. Because watershed management recommendations frequently address multiple parameters simultaneously, implementation of recommendations targeted at improving concentrations of parameters of interest is expected to provide ancillary benefits by improving the concentrations of parameters not currently considered to be of interest.

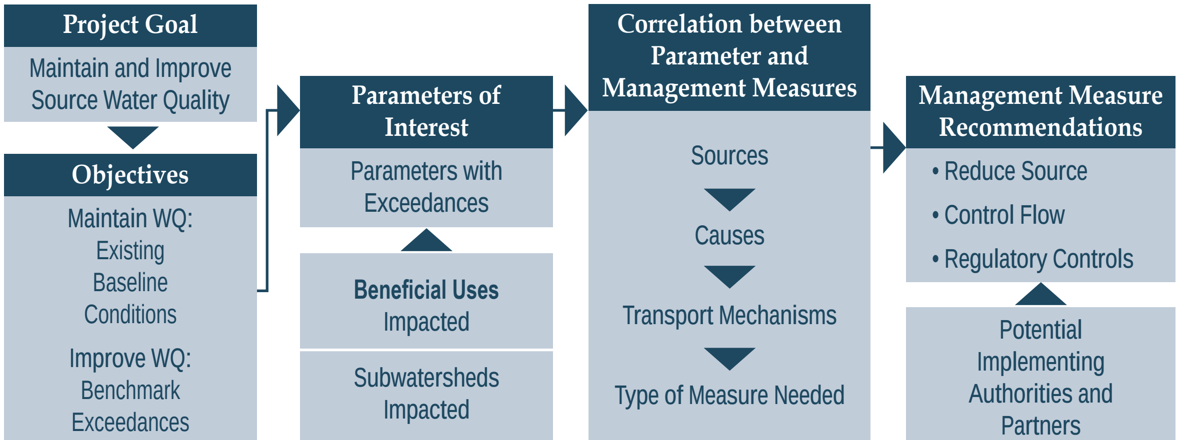
8.1.2 | Linkage Between Objectives and Recommendations

In order to reduce loading of parameters of interest, and to maintain current concentrations of other parameters, management measure recommendations have been developed. An overview of the linkage between the project goal and objectives, the parameters of interest identified through the assessment process, and the process used to identify management measures is presented in Figure 8 1. For each water quality parameter identified as being of interest, potential sources were identified. In addition to the source of each parameter of interest, the cause of loading (i.e., how the source gets released into the environment), and the physical watershed processes related to transporting the source to a waterbody, were identified. This background information is provided in Appendix N - TM No. 10.

The potential contaminant sources are organized into the same groupings as those presented in the watershed assessment: microorganisms; particulates; general properties; nutrients; metals, cations, and anions; and synthetic organic compounds (SOCs), volatile organic compounds (VOCs), and pesticides. The parameter of interest is identified by the subwatershed in which benchmark exceedences are observed or simulated, and for which target load reductions have been developed. The beneficial uses which may be impacted by these parameters of interest are also identified. Management measures aimed at reducing loadings of parameters of interest are presented in the following categories.

- Reduce Sources of Contaminants
- Manage Contaminated Flows/Sediment
- Encourage Regulatory/Institutional Controls

Figure 8-1: Linkage between Watershed Assessment and Management Measures



8.2 Agencies with Watershed Water Quality Control/Partnering Potential

The Upper Mokelumne River Watershed Authority does not have jurisdiction over water quality in the watershed, and therefore does not have the authority to implement management measures. The primary agencies within the Upper Mokelumne River watershed with water quality control authority include the U.S. Forest Service; State Water Resources Control Board – Regional Water Quality Control Board, the State Department of Forestry and Fire Protection (CalFire), the California Department of Transportation (CalTrans); and the Amador and Calaveras County (Alpine County to a lesser extent) Departments of Environmental Health, Public Works, Planning and Community Development, and Building. A full list of agencies, along with the permits and issues regulated by these agencies, is provided in Appendix N and can be used in the future during project implementation.

8.3 Management Measure Recommendations

Table 8 1 presents a summary of the management measures that were specifically developed to target the sources, causes, and transport of contaminants and to encourage regulatory actions to eliminate or reduce degradation of source water quality. As demonstrated by the water quality assessment and its associated findings, existing water quality problems will not be mitigated, nor future problems avoided, absent implementation of the recommended management measures. Protecting and maintaining existing water quality will require consistent ongoing monitoring for detection of changes as well as good management of watershed lands. The measures outlined in this section are particularly responsive to concerns associated with the indication of water quality issues. As discussed in previous sections, concentrations of parameters of interest such as microorganisms will increase in response to development in the area, if management measures are not implemented.

The management measures described in this section are grouped into the following three main categories based on the type of implementation required for these measures.

- Reduce Source of Contaminants
- Manage Contaminated Flows/Sediment
- Encourage Regulatory/Institutional Controls

These categories are not independent of each other. For example, reducing the presence of a given source often requires regulatory controls. This organizational structure highlights the importance of implementing measures to control pollutants at their source as well as managing the transport of contaminants through the watershed.

Table 8-1: Summary of Management Measure Recommendations and Water Quality Parameters Addressed

	Management Measure Recommendations	Water Quality Parameter Addressed: Microorganisms	Particulates	General Physical	Nutrients	Metals	S/VOCs & Pesticides
Reduce Sources of Contaminants							
S1	Eliminate leakage from septic systems	●			●	●	●
S2	Increase bulky waste pickup programs and collection of illegally dumped trash (e.g., abandoned cars, appliances, pharmaceuticals)					●	●
S3	Provide toilets and trash/debris receptacles at informal recreation sites	●			●		
S4	Manage fire fuels for landowner and water quality objectives		●	●	●	●	●
Manage Contaminated Flows/Sediment							
F1	Implement measures to control inactive mine flows/sediment		●	●	●	●	
F2	Implement green streets design principles for reducing peak flows, minimizing runoff, and removing contaminants during flow	●	●	●	●	●	●
F3	Implement road maintenance practices intended to minimize water quality impacts	●	●	●	●	●	●
F4	Enhance grazing practices to encourage off-stream watering	●	●		●		
R1	Implement water quality and temperature monitoring	●	●	●	●	●	●
R2	Educate public on contaminant source reduction and impacts of contaminated stormwater to waterbodies	●	●	●	●	●	●
R3	Include watershed water quality protection policies in general plan update along with ordinances and design guidelines for high vulnerability zones	●	●	●	●	●	●
R4	Encourage compact development in the general plan updates for water quality protection	●	●	●	●	●	●
R5	Purchase land and/or development rights, and encourage landowners to obtain conservation easements in high vulnerability areas	●	●	●	●	●	●
R6	Supplemental Watershed Assessments for Non-Water Quality Conditions**		●	●		●	

* *Management measure recommendations are encouraged; the Authority does not have authority to implement.*

** *This management measure is not targeted as maintaing or improving source water quality, but may generate incidental water quality benefits.*

General descriptions of and recommendations for each management measure are summarized below. More detailed descriptions of recommendations are provided in Appendix N - TM No. 10.

8.3.1 | S1 – Eliminate Leakage from Septic Systems

The majority of residents that live in the Upper Mokelumne River watershed live in homes with septic systems (also called on-site sewage disposal systems). Given the terrain and age of many of the homes in the area, it is expected that many of these systems were either built before permits were required or are in need of repair or replacement. Failing or poorly maintained septic systems are likely the primary pollution source in the watershed. In addition, the sheer number of septic systems, permitted and unpermitted, proximate to streams poses an even greater threat to water quality in the future as these systems age. Eliminate Leakage from Septic Systems is the highest priority management measure due to the risk to human health. This measure has several recommendations of which the most effective action is to convert septic systems to a sewage collection and treatment system in areas of concentrated population proximate to an existing collection system. However, due to the difficulties in obtaining funds to support this long term goal, actions are identified to better manage the existing and future permitted and unpermitted septic systems throughout the watershed. Implementation of the following items requires funding and should occur concurrently unless otherwise noted.

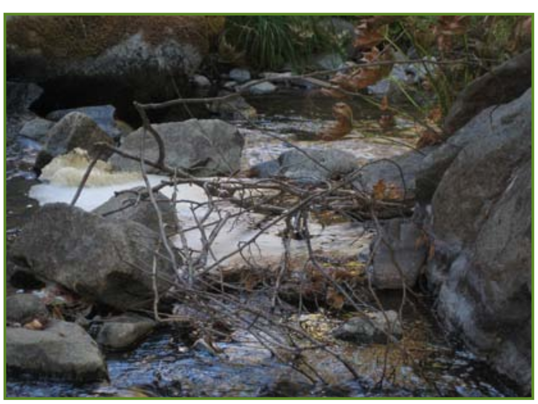
The S1 recommendations reflect residents' concerns over privacy

S1 Recommendations

1. The primary recommendation is to pursue grants and outside funds to extend the existing sewage collection systems in West Point, Wilseyville, and Mokelumne Hill when and wherever possible, in order to reduce microorganisms reaching the waterbodies from failing septic systems, particularly in the Middle and South Fork watersheds.

2. It is understood that the expansion of a collection and treatment system can be very costly, but with growth in the watershed anticipated, new development could be planned by the counties to be compact and located near already developed areas. It is recommended that new development projects greater than two homes be required to connect to an existing collection and treatment system. This requirement will not only focus future growth in areas with existing wastewater treatment service, but would also increase the cost-effectiveness of connecting existing homes and businesses currently relying on septic systems by extending the existing collection system to new developments.

3. A Septic System Management Program is recommended for each county to implement, to characterize the extent of the contamination problem, to manage septic systems as infrastructure assets, and to reach out to the community to inform them on managing septic systems and solicit input on the recommended actions. A draft Septic System Management Program was developed for this project, located in Appendix Q. Key recommendations, which should be pursued simultaneously, are summarized below.



Assumed contamination from septic system leakage in the Middle Fork (Source: UMRWC)

4. Conduct a septic survey to substantiate the problems and needs. The survey should include the identification of geotechnical and groundwater watershed characteristics relevant to siting of septic systems. The survey should also include water quality monitoring to identify the sources of microbial

contamination from leaking septic systems, in terms of areas of greatest contribution, and analyses of the monitoring data to identity microbial species of origin. This will allow confirmation that microbial contamination is human in origin, rather than being contributed by non-human sources. These water quality monitoring recommendations are also presented in management measure R1. In addition, the septic survey should inventory septic system infrastructure and its condition. Locations of documented and undocumented systems should be mapped, and a sampling of the condition of septic systems conducted.

5. Although the counties in the watershed have regulations governing septic systems, these are for permitted systems. Funding constraints prevent the counties from conducting regularly scheduled inspections or requiring mandatory maintenance practices for permitted systems. The following management practices are recommended.

- Identify septic system suitability zones
- Establish rigorous design and maintenance standards
- Require mandatory inspections
- Mandate pumping of tanks
- Collect a water quality protection fee

To avoid permitting septic systems in unsuitable locations, the suitability of the watershed to support septic systems should be identified and No Septic Zones be established. New systems within these zones should be subject to a performance design process to accommodate site specific needs, and new and existing systems be required to either connect to an existing sewage collection system, convey sewage to a community leachfield in a nearby septic zone, or replace the existing septic system with a holding tank to be pumped on a biannual basis.

More rigorous siting and maintenance standards should be mandated, patterned after the State of California AB885 draft regulations. These regulations should apply to new and replaced septic systems and have provisions for higher standards of design and maintenance than that currently required. It is also recommended that owners verify separation to groundwater as part of the permitting process.

Mandatory inspections of permitted and known unpermitted septic systems should be required. There are several methods to implement inspections: 1) prevent a real estate transaction without a recently inspected, fully functioning, and permitted system including verification of separation from groundwater; 2) visual inspections for malfunctions required when the tank is pumped or on a regular five-year schedule, whichever is more frequent which the pumpers required to submit the reports as a condition of doing business in the county; and 3) inspections required for all remodels or expansions costing over $20,000 and requiring any county construction permits.

Owners of new septic systems must have the tanks pumped by a licensed septage hauler on a two year bases. For existing systems, pumping is required if an inspection determines that the tank is greater than one-quarter full of sludge and scum, if the property has a history of violations, or if the septic system is located in a No Septic Zone.

A management program whereby annual fees are collected from all property owners using septic systems or alternative on-site systems is recommended. These Water Quality Management Fees could fund several of the recommended actions in the Septic System Management Program, as determined by the counties.

6. Educational outreach is critical to raise awareness in the watershed of basic septic system design and maintenance, what to look for with regard to septic system failures, the importance of converting to a sewage collection system, the reasons behind the interim

actions recommended here, as well as the value of improving microbial water quality conditions. Outreach is also recommended to solicit input on the implementation of the actions recommended here and in the Septic System Management Program. Communication tools are critical to successfully overcoming the technical, financial, and privacy issues associated with substantiating the septic system conditions and extent of problems and asking for support to implement these recommended actions. An outreach program is recommended for both residents and owners of second homes in the watershed.

The outreach program should expand on the Authority's current partnerships with schools and other organizations to not only invest in the future by educating young people about water quality issues, but also to provide educational materials that will be brought home and read by the adults. Good examples of septic system outreach can be found for the Tomales Bay watershed in Marin County at ***www.septicmatters.org***.

7. It is recommended that Amador and Calaveras counties include policies in the general plan updates to mandate the above recommendations, including implementation of the Septic System Management Program. The general plan updates should also contain location constraints to limit new septic system development in areas susceptible to water quality contamination. Until No Septic Zones can be established per the Septic System Management Program, the Water Quality Vulnerability Zone designations of high and very high vulnerability zones are recommended to be restricted from allowing new septic systems without performance based design requirements and separation of groundwater verified.

8. The WARMF model should be expanded to include adjacent watersheds. This coverage allows the counties of Amador and Calaveras to use the model to assess potential septic system impacts and determine collection system water quality improvements associated with new development throughout the counties, not just the Upper Mokelumne River watershed.

9. All of the recommendations provided in management measure S1 should be implemented as soon as possible to maintain and improve water quality in the watershed. In addition to the Water Quality Protection fee, grant funding, developer fees, assessment district formation, low interest rate loans, and voter approved bonds should be investigated to offset the costs associated with the implementation of the septic survey, recommended management practices, community outreach, expansion of existing collection and treatment systems, and construction of new, small-capacity wastewater treatment and collection infrastructure. Outside funding sources are presented in Chapter 9.

Background information on septic system maintenance and replacements, and sewer collection and treatment systems is provided here.

Septic Tank Maintenance

In order to operate properly, septic systems must be regularly maintained. Typical septic system maintenance eliminates buildup of irreducible substances such as greases, oils and other insoluble substances. Periodic septic system inspection also ensures that all septic system parts are working properly.

Based on recent information provided by El Dorado County, the University of Minnesota Extension, and other septic system maintenance sources, typical septic tank pumping and maintenance costs range from approximately $100 to $300 per occurrence. Maintenance should occur approximately every 18 to 30 months, with maintenance frequency increasing with septic system age. Septic tanks should be inspected at least once every three years. Minor septic system repairs may be needed as determined by inspection and can cost approximately $2,000 to $4,000 per occurrence.

Septic System Replacement

With proper maintenance, a septic system can last 15 to 30 years or longer. Septic systems not receiving proper maintenance can become damaged beyond repair and may require replacement. Septic system replacement costs vary depending on the type of system and the portion of the system requiring replacement. A new septic tank can cost approximately $4,000 (including installation), but an entire septic system replacement (including drain field, household connections, etc.), which is often required for failed septic systems, can range from $4,000 to $20,000. The counties should also consider "performance based" septic system design review that focuses on the function of the system and localized conditions rather than a strict adherence to design standards. Individual household waste technologies, such as composting toilets, could then be considered as an alternative to tank and drain field systems.

Collection System Expansion

Based on the rural residential nature of the Upper Mokelumne River watershed, sewer system expansion costs are expected to be highly variable. In rural areas with a high proportion of residential units and no existing wastewater treatment facilities, satellite wastewater treatment could provide an economical alternative to expanding the existing wastewater collection system. For example, population centers of Buckhorn/Pioneer, Tabeau Road/Mt. Zion, Glencoe, and Railroad Flat (the lands within the watershed) may all be feasible, in terms of concentration of effluent, to support satellite facilities. In areas near Mokelumne Hill, West Point, and Wilseyville where wastewater treatment facilities already exist, collection system expansion may be a viable alternative. A full analysis of the costs and benefits of several potential wastewater treatment and collection alternatives is needed to determine the most cost-effective approach to eliminating failed septic systems in the watershed.

Expanding the existing collection systems within the watershed would require extending the wastewater conveyance infrastructure currently in place, and potentially replacing existing infrastructure to increase capacity. Costs for pipe materials and installation can generally be assumed to be $10 per linear foot per inch diameter of pipe in rural areas, based on costs for several recently completed projects in rural environments throughout California. These costs could be greater in the watershed due to the rugged terrain. Assuming an 8-inch diameter gravity sewer, the cost for pipeline expansion can be estimated at approximately $80 per linear foot or $422,000 per mile, based on recent costs developed for several wastewater projects in the state including the City of Malibu and Sunnyslope County Water District in San Benito County. This cost does not include individual home connections or replacement of existing infrastructure that may be necessary to ensure adequate conveyance capacity for peak flows.

In areas where homes lie below the elevation of the road and the sewer trunk line, a grinder pump system would be required to pump domestic wastewater to a pressurized pipe. Costs for grinder pumps vary based on size and pumping capacity. A 1,500 gallons per day (gpd) grinder pump costs approximately $13,000 (including installation) for a residential unit.

In both cases, a lateral connection from the collection main to the house would be required. Costs for these connections vary greatly depending on the distance from the house to the road. Recent projects in more urbanized areas of California have estimated customer connection costs at approximately $6,000 per connection for materials and labor. Connection costs in the Upper Mokelumne River watershed could be lower due to the lack of conflicting utilities likely to be present in the watershed. Conversely, costs in the watershed would be expected to be greater than for more urbanized areas due to the relatively large distances from homes to the road and the sewer trunk line.

Additional Wastewater Treatment Capacity

The existing Mokelumne Hill Wastewater Treatment Plant (WWTP) serves approximately 300 service connections, for an average dry weather flow (ADWF) of approximately 55,000 gpd. The plant has a permitted capacity of 150,000 gpd. The existing West Point WWTP serves approximately 600 service connections, and was designed to serve up to approximately 900 service connections. The current average dry weather flows into the WWTP are approximately 320,000 gpd, with a permitted ADWF capacity of 450,000 gpd. The existing West Point WWTP uses sand filtration and ultraviolet (UV) disinfection.

It is uncertain whether there is treatment capacity available at these WWTPs. Should it become feasible to extend either collection system to incorporate more flow than can be accommodated by the current treatment capacity of the affected WWTP, it would become necessary to expand the affected WWTP to increase treatment capacity. In addition, it may become necessary to upgrade existing collection system infrastructure to ensure adequate pipe capacity and pumping availability to convey the increased flow.

Expansion of these facilities to accommodate flows conveyed from adjacent areas currently served by private septic systems should be considered. Conversely, a new wastewater treatment plant could be built to accommodate flows from residential developments currently on septic systems. Because residences in the watershed are largely decentralized, new, small-capacity wastewater treatment facilities could be developed to cost-effectively serve areas of relatively clustered residential development. Several options exist for small-capacity wastewater treatment facilities.

- ***Membrane bioreactor (MBR) -*** Membrane bioreactor systems can replace conventional treatment, combining clarification, aeration and filtration into a simple and cost-effective process that reduces capital and operating costs. Effluent from MBR plants is suitable for many applications, including recycled water.
- ***Sequencing batch reactor (SBR) –*** The SBR is a fill-and-draw activated sludge system for wastewater treatment. SBR systems have been successfully used to treat both municipal and industrial wastewater. They are uniquely suited for wastewater treatment applications characterized by low or intermittent flow conditions.
- ***Oxidation ditch -*** An oxidation ditch is a modified activated sludge biological treatment process that utilizes long solids retention times to remove biodegradable organics. This technology is effective in small installations, small communities, and isolated institutions, because it requires more land than conventional treatment plants.
- ***Aerated lagoons –*** Lagoons are commonly used to treat municipal and industrial wastewaters. This technology has been widely used in the United States for at least 40 years. Aeration is provided by either mechanical surface aerators or submerged diffused aeration systems.

These are examples of wastewater treatment technologies; other technologies may exist that could provide better and more economical treatment depending on the specifics of a given site. For each of these options, the cost of treatment can vary from $50 to $100 per gallon per capita per day (gpcd) of ADWF based on other wastewater collection system expansion projects throughout California. The ADWF from a typical residential household is approximately 70 gpcd. The base cost for treatment varies with wastewater quantity and quality. In addition, areas with intermittent wastewater flows, such as areas with a high proportion of vacation homes, will be more expensive per capita than areas with consistent wastewater flows. For new plants, additional costs will be incurred for developing disposal options such as filtration lagoons or spray fields.

8.3.2 | S2 – Increase Bulky Waste Pickup Programs and Collection of Illegally Dumped Trash

Illegal disposal of cars, large appliances, household hazardous waste and pharmaceuticals, and other potentially hazardous waste particularly on roadsides and in streambeds is common in rural areas and occurs in the Upper Mokelumne River watershed. Bulky waste pickup programs provide inexpensive or free means for disposing of large objects that can contaminate surface and groundwater. Currently, Calaveras and Amador Counties provide a bulky waste drop-off program at several locations on a continuous, fee-free basis. Both Amador and Calaveras counties provide free household hazardous waste drop-offs on a continuous fee-free basis. In addition to bulky waste, pharmaceuticals can also be hazardous to receiving waters when disposed as regular waste or disposed of in toilets due to high levels of hormones and other emerging contaminants. Septic tanks and water and wastewater treatment plants are unable to completely treat endocrine disruptors associated with pharmaceuticals. These chemicals are not only harmful to humans; they can also accumulate in aquatic species in receiving waters.

It is recommended that the bulky waste pickup, hazardous waste drop-off, and pharmaceutical drop-off programs should be continued and expanded as possible. Expanding on existing programs, in terms of frequency and drop-off locations, offers an opportunity to improve water quality in the watershed while informing the public about contamination implications. Because it is difficult to disseminate information on these types of programs, it is also recommended that educational outreach in the counties is enhanced through the use of special mailings to landowners as well as residents to reach a greater target audience (e.g., renters).

As with septic systems, it is also recommended that partnerships be formed between the counties and local schools to expand educational outreach about waste disposal practices. Partnerships with local schools will provide an opportunity to effectively distribute information on waste disposal programs, educating not only the students, but also their families.

8.3.3 | S3 – Provide Toilets and Trash/Debris Receptacles at Informal Recreation Sites

The watershed is a popular destination for outdoor enthusiasts, and is home to a wealth of recreational opportunities. In addition to formal recreation areas, there are a variety of informal recreation sites (meaning no public agency is responsible for the site) in the watershed where body contact recreation occurs regularly. Because these locations are informal, toilet facilities and debris/trash receptacles are frequently not present. The lack of appropriate facilities for disposing of fecal and non-fecal waste increases the likelihood of improper waste disposal. Because many of these informal recreation areas are adjacent to the river and its tributaries, this improper disposal is likely to occur within watershed areas designated as high or very high vulnerability for pollutant transport.

Providing toilets in recreation areas reduces water quality risks

It is recommended that local agencies seek grand funding to provide trash receptacles and outdoor toilet facilities at all formal and informal recreation areas within 300 feet of a waterway. Alternatives for outdoor toilet facilities and trash receptacles include pit, vault, and composting toilets, including tree bogs. Tree bogs utilize nutrient decomposing plants to quickly convert waste to biomass and do not require pumping, For organized recreation in the watershed, recreation providers must emphasize the importance of proper waste disposal to the health of the Upper Mokelumne River watershed.

8.3.4 | S4 – Manage Fire Fuels for Landowner and Water Quality Objectives

The effects of wildland fires on water quality are strongly influenced by the location, extent, and severity of the fire. Wildland fires generally effect hydrology and water quality through a variety of mechanisms.

The Power Fire occurred October 2004

Because of the potential water quality impacts associated with fires and the strong influence of fire severity and extent on water quality degradation, fuel management should be designed to minimize human-caused ignitions, spread, and/or fire severity in vulnerable areas of the watershed. Potential fuel management approaches such as taking advantage of naturally occurring fires (through Fire Use and Appropriate Management Response practices), prescribed burning, harvesting of biomass fuel followed by prescribed burning, and sanitation-salvage or group-selection harvests with slash and landscape fuel treatments have been shown to minimize average fireline intensities, heat per unit area, rate of spread, area burned, and scorch heights. All of the suggested measures described may have potential water quality impacts, though these effects are expected to be lower in magnitude and shorter in duration than those resulting from high severity wildfire.

8.3.5 | F1 – Implement Measures to Control Abandoned Mine Flows/Sediment

Many inactive mining locations exist throughout the Upper Mokelumne River watershed: 63 that are known sites, and possibly many unknown sites. There is very little known about the capability and risks of these mines to contribute contaminated runoff and sediment. Historical mining operations had little regard for environmental impacts, and the sites did not require reclamation plans when operations ceased. Inactive mines contributing high levels of metals from exposed soils and tailings and from runoff pose the greatest risk to aquatic species and humans.

It is recommended that inactive mine flows and sediment be controlled, where known problems exist. There are several approaches to controlling contaminated inactive mine flows.

- Isolation, removal, or treatment of toxic materials (such as tailings or exposed rock)
- Stabilization of disturbed lands
- Regeneration of native vegetative cover
- Maintenance of site

Reclamation of inactive mines on private lands is further complicated by the fact that mineral rights for the mine may be owned by a party other than the landowner, causing complications in determining responsibility for cleanup. It is also recommended that new mining claims not be allowed in the watershed without a good water quality control plan in place for operations and a state-of-the-art restoration plan in place prior to approvals.

8.3.6 | F2 – Implement Green Streets Design Principles for Reducing Peak Flows, Minimizing Runoff, and Removing Contaminants During Flow

It is recommended that Alpine, Amador, and Calaveras counties use the SWRCB's Stormwater Pollution Prevention Program (SWPPP) requirements to prevent water quality impacts associated with construction and post-construction of any disturbance of a land surface one acre or greater. It is recommended that the WARMF model be required to determine impacts associated with water quality parameters of interest. If a measureable impact to water quality is anticipated, the counties should mandate that the impacts be mitigated through the use of green streets design principles discussed here. WARMF can also be used to assess the effectiveness of water quality improvement measures.

The trigger for the water quality impacts assessment is any project requiring a SWPPP. A SWPPP is required by the SWRCB (the primacy agency implementing EPA stormwater regulations) for any construction project that disturbs one acre or greater of soil or a project that disturbs less than one acre but is part of a larger common plan of development that in total disturbs one or more acres. The RWQCB oversees, monitors, and enforces the SWPPP activities, but it is recommended that the counties adopt SWPPP regulations as their own tool for preventing water quality impacts. The SWPPP focuses on best management practices to protect runoff from construction or post construction activities; green street design principles can be integrated into these requirements to reduce impervious surfaces and manage the contaminated flow resulting from pervious surfaces, as described below. See SWPPP requirements (www.swrcb.ca.gov/stormwtr/construction.html or http://cfpub.epa.gov/npdes/stormwater/swppp.cfm) for more information.

Green streets principles, as well as low impact development green infrastructure, recognize that streets and other large impervious lands affect stormwater runoff and water quality. A "green" street or parking lot has incorporated a system of stormwater treatment within its right-of-way, minimized the quantity of water that is piped directly to streams, incorporated the stormwater system into the aesthetics of the community, etc. The "hydro-modification" and runoff water quality treatment associated with green streets are similar to those associated with Low Impact Development concepts:

- Reduce peak flows through infiltration
- Naturally filter surface water runoff to decrease pollutant transport
- Decrease impermeable surfaces

This can be accomplished by designing projects that encourage pedestrian oriented street and road designs, curb designs that encourage diffuse stormwater runoff, dedicated runoff areas, and onsite improvements including decreasing impermeable areas, planting native vegetation, and collecting rain water for on-site use. For more information on innovative stormwater management concepts, see the following websites.

- www.metro-region.org/article.cfm?ArticleID=262
- www.lowimpactdevelopment.org
- www.tahoebmp.org
- www.epa.gov/owow/nps/bioretention.pdf
- www.sacramentostormwater. org/SSQP/Riverfriendly

As the Upper Mokelumne River watershed develops, it is recommended that the Amador, Calaveras, and Alpine counties implement the following.

- Require the use of WARMF for analyzing water quality impacts associated with land disturbance of one acre or greater
- Adopt SWPPP regulations into county code
- Incorporate green streets design principles into general plan policies, particularly during the general plan updates
- Adopt green streets design principles into standard street design ordinances and guidelines

Outreach programs are also recommended for on-site green streets principles to encourage public acceptance since curbs and gutters are often associated with a higher design standard for rural areas and adding vegetative roofs is not a standard practice. Since much of the watershed is rural, many of the benefits of green street design will be observed as future street development occurs.

8.3.7 | F3 – Implement Road Maintenance Practices

As a source of impermeable surface with its resulting erosion, increased peak runoff, and transport of contaminants in runoff to the Mokelumne River, the maintenance of existing roads is an important factor in reducing pathogens, particulates, and metals. Streets collect sediment, metals, and trash during dry periods that is washed away with rain and runoff. It is recommended for paved roads that regular street sweeping, especially during dry periods, be conducted to effectively prevent contaminants from collecting on the street. Curbs and gutters must be cleaned regularly to eliminate trash and debris buildup, especially in areas used for concentrated runoff. In order to assist often over-extended agencies (e.g., the three counties, USFS, CalTrans) with the heightened road maintenance included in this measure, it is recommended that a system of ranking or prioritizing roads most critical for maintenance be developed based on the potential to impact water quality.

For dirt and gravel roads, sediment is a major source of runoff contamination. It is recommended that seasonal closing of rural dirt and gravel roads occur during periods of high runoff to decrease erosion and sediment runoff potential. Roads should be regularly maintained to ensure proper crown height, smooth surface, and uniform grade to facilitate dispersed drainage to the surrounding ground surface. Storm drains, where applicable, should be cleaned regularly and remain free of debris to prevent flooding and contaminant build-up. It is recommended that standards be developed where they do not currently exist with regard to the grading of dirt and gravel roads and disposal of earthen spoils, and enforced where they do exist. Standards are also needed to ensure roadside pesticide use is managed and used only at necessary levels.

8.3.8 | F4 – Enhance Grazing Practices to Encourage Off-Stream Watering

Grazing, particularly high densities of cattle in riparian areas and other high water quality vulnerability zones, contribute contaminants, although data do not indicate that this is a significant source of pathogens in the watershed. In areas where high concentrations of cattle access streams as a water source, livestock trample stream banks and release waste onto lands and into the water. Both deposition of waste onto proximate lands and direct waste deposit into surface water contribute pathogens. Encouraging livestock practices that provide an incentive for cattle to avoid or minimize access to waterbodies reduces the risk of contamination.

Protecting stream banks

It is recommended that alternate water sources be provided which are located away from streams to encourage cattle to leave stream areas to drink. However, due to the remote and inaccessible terrain found throughout much of the watershed, there are no easy solutions for providing alternate water sources. Where practical, provision of alternate water sources should be encouraged. These sources may include the following.

- Watering troughs with small stream diversions providing a supply (if no water rights needed)

- Spring water supplies diverted away from sensitive areas
- Hauled-in water supplies

In highly sensitive riparian areas, fencing or other structural range improvements may be required to protect these areas. In general, range livestock production Best management Practices should be followed. For more information, see the California Rangeland Water Quality Management Plan approved by the SWRCB (www.californiarangeland.ucdavis.edu).

8.3.9 | R1 – Implement Water Quality and Temperature Monitoring

The following parameters were identified as being of potential interest in one or more subwatershed.

- Fecal Coliform
- Cryptosporidium
- E. coli
- Aluminum
- Turbidity
- Alkalinity
- Nitrate

In general, it is recommended that monthly monitoring be implemented on the same day each month at a minimum of four locations in the watershed (North Fork near confluence, Middle Fork near confluence, South Fork near confluence, and Main Stem near Highway 49). This collection of data will allow changes in baseline water quality to be tracked over time. However, if degradation of water quality occurs, it is often too difficult and expensive to correct the cause. The monitoring results should be reviewed every two to three years to identify new data trends. At that time, the parameters themselves should be reviewed as well to determine whether parameters should be removed from the list. Conversely, additional parameters may be recommended at that time based on new regulatory requirements and/or emerging contaminants of concern.

Lower Bear Dam materials are likely source of copper

Where parameters have been identified as being of potential interest, particularly pathogens in the Middle and South Forks, it is recommended that water quality monitoring programs be designed and implemented to identify the contaminant sources. A monitoring program at several locations in areas of high septic system concentrations or older septic systems (e.g., Barney Way) would particularly help identify sources. The samples should be analyzed for bacteriodes fragilis phage to confirm human origins.

Temperature varies significantly throughout the watershed on both a daily and seasonal basis. Due to the relatively limited set of temperature monitoring data available at this time, temperature was not evaluated with respect to its benchmark: the Basin Plan Water Quality Objective. Temperature throughout the watershed should be monitored to confirm consistency with the Basin Plan Water Quality Objectives and to identify potential impacts to aquatic life posed by temperature fluctuations caused by natural conditions and human influences in the watershed.

Lower Bear Dam is currently suspected of leaching copper into the reservoir as well as to the river downstream of the dam. The stream segment immediately downstream of the dam is currently classified as impaired for copper based on the California Toxics Rule ambient water quality criteria. Because of the potential negative effect elevated copper concentrations may have on aquatic life downstream of the dam, copper concentrations should continue to be monitored to identify trends associated with copper loading in that reach, assess the degree of the potential copper problem, and support identification of a solution.

8.3.10 | R2 – Educate Public about Water Quality Issues

As the Upper Mokelumne River watershed continues to become more developed, increases in population and changes in land use/management are likely to also increase the presence and expedite the transport of contaminants to waterbodies. It is recommended that an extensive education outreach program be developed and implemented on topics such as where common pollutants originate, how they impact water quality, and how easily such impacts can be prevented. An outreach program is critical to ensuring that the health of the watershed is maintained. By educating existing residents on how they can reduce water pollution, new residents will be greeted by an informed community and are more likely to follow suit. Pollution prevention education can include messaging and programs geared toward both source reduction and transport reduction. Areas that could be targeted include the septic system outreach program described in S1; an integrated pest management program for households; bulky waste, hazardous waste, pharmaceuticals, and recyclable materials program; green streets concepts; a stormwater awareness program; and the use of conservation easements.

Signage is an important water quality education tool

As with other outreach programs, it is recommended that partnerships be continued and new ones formed with local schools by the agencies involved in implementing these measures. Bringing water quality and environmental education to schools will allow for students and their families to be better informed and more involved in watershed water quality issues.

8.3.11 | R3 – Include Watershed Water Quality Protection Policies in General Plan Update

Every city and county in the state must have an adopted general plan. Seven elements of a general plan are required by the state: land use, transportation, housing, resource conservation, open space, health and safety, and noise. Water resources-related information is typically fragmented throughout the various elements. It is recommended that the general plans identify and analyze the quality of water resources and establish policies and programs to preserve its quality. It is recommended that a separate water element be developed for the Amador and Calaveras general plans to compile and address water resources issues into one location instead of throughout the various elements. The water element is an optional element of the general plan as permitted by Section 65303 of the California Government Code. It is recommended that the general principles described in Appendix N – TM No. 10, be incorporated into a separate water element or the various other elements of the updated general plans.


The lower study area feels growth pressures

It is recommended that the general plans for the three counties contain an assessment of issues to support the development of goals, objectives, policies, and actions related to maintaining and improving source water quality. The linkage between land use decisions in the land use element and water quality impacts in other elements should be presented.

It is also recommended that the general plan updates include policies and programs to require an assessment of water quality impacts associated with any new development greater than one acre located within the high and very high water quality vulnerability zones. This assessment, using the WARMF model as a tool, is to be required for new development. Chapter 9 (Section 9.2) provides additional information on this recommendation.

8.3.12 | R4 – Encourage Compact Development

Clustering development accommodates more people in less space with the intent of preserving natural areas. Compact growth consumes less land and reduces infrastructure costs. Sprawl contributes more impervious surfaces. Paved surfaces increase stormwater runoff in areas that once absorbed rainfall.

It is recommended that the counties adopt compact development principles to not only encourage walking and less automobile use, but also reduce the automobile-generated pollutants that are washed away in stormwater. With compact development, less impervious surfaces are created and there are opportunities to manage the stormwater runoff through the use of streetscape design features. Of particular interest in the Upper Mokelumne River watershed is the extension and addition of sewage collection and treatment systems which are more cost effective to implement if development is concentrated.

It is also recommended that counties adopt another form of this measure to encourage compact development on individual large lots: clustering homes in a subdivision should be allowed to reduce impervious surfaces and encourage cost-effective infrastructure improvements. Siting homes on a lot to reduce water quality impacts may be as simple as building a two story home with a smaller footprint or locating homes far from waterbodies to allow for stormwater runoff to filter through vegetation before reaching the stream.

Encouraging compact development as the three counties grow will aid in minimizing watershed water quality impacts associated with growth. It is recommended that Amador and Calaveras counties incorporate compact development in community design through the General Plan update process of developing policies and ordinances. Most zoning ordinances do not allow for compact development; adopting form-based codes in combination with more traditional use-based zoning codes can overcome this problem.

8.3.13 | R5 – Purchase Land and/or Development Rights

Development control over lands within the Upper Mokelumne River watershed, and specifically within the high and very high water quality vulnerability zones, could have a significant impact on maintaining watershed water quality. It is recommended that funding be pursued to utilize this type of development control through outright purchasing of lands by a governmental or non-profit entity, purchasing development rights to lands without having to purchase the property itself, and/or encouraging landowners to file conservation easements on their own property.

8.3.14 | R6 – Supplemental Watershed Assessment

The project has been conducted with a specific, targeted objective: Maintain and Improve Source Water Quality. Management measures have been designed to achieve this goal by maintaining water quality conditions for parameters present at concentrations below the benchmarks and improving water quality for parameters present at concentrations in exceedence of the benchmarks.

The watershed assessment performed as part of this project established and assessed baseline water quality conditions throughout the watershed. The assessment did not address fluvial processes, terrestrial and aquatic species and habitat conditions, etc. in the watershed. It is recommended that alternative approaches to assessing and addressing specific issues or concerns associated with the watershed should be identified and implemented. Additional assessments of issues indirectly related to water quality would generate supplemental information supporting a broader understanding of watershed conditions. Complementary watershed assessments would provide valuable information on issues such as stream function and condition, condition of terrestrial and aquatic habitats, species present, and wildlife corridors, to name a few.

Chapter Nine
Conclusions

This section summarizes key steps for implementation of the watershed management plan associated with housing and maintaining the assessment tools and providing periodic reports to the Authority. A review of the Project Assessment and Evaluation Plan goals and desired outcomes is also provided.

9.1 House, Maintain, and Update Assessment Tools

Implementation of the project recommendations discussed in Chapter 8 involves housing and maintaining project tools and periodically evaluating progress toward management measure implementation. The following tools were developed for the project:

- Baseline water quality
- Watershed simulation of water quality (WARMF)
- Water Quality Vulnerability Zones (WQVZ)
- Fire Models (FlamMap and FARSITE)

Recommendations must be implemented to maintain source water quality

One of the primary purposes for developing assessment tools is to enable the Authority, its members, and others to track changing water quality conditions throughout the watershed. The WARMF tool provides a method for tracking long-term water quality conditions in the Upper Mokelumne River watershed, and can be utilized to simulate source water quality conditions under various land use and land management scenarios. Similarly, the WQVZ results serve as a tool for land use planning entities to prioritize and protect those watershed lands that are most vulnerable to transporting water quality constituents of concern to the water bodies on a long-term basis. The fire model tools generate information that can be used on a long-term basis to allow optimization of fuels management and assessment of future fuels management efforts.

Housing of these tools requires the identification of an entity to serve as the steward of these tools. EBMUD volunteered to be the steward because of its in-house modeling resources. If EBMUD is not available to serve in this capacity in the future, an alternate steward would be identified. Potential alternate stewards may include another Authority member agency, a local water district, a county agency, a local non-governmental organization, or a federal or state agency. If another stakeholder is interested in assuming responsibility for stewardship of the project tools, or if the WARMF model is expanded to include other watersheds, a change in stewardship may be warranted. Flexibility in implementation of this project will be accommodated through continual review and update of project progress and changes, allowing key decisions such as a change of stewardship of project tools, to be made over time on a case-by-case basis.

All project tools will be made available by the steward upon request. Monitoring data and other information developed by others should be submitted to the steward and maintained in a central database or clearinghouse for future updates. Updates to the tools, particularly the WARMF model, may occur on a regular schedule if not needed sooner than the scheduled date. A schedule for updates is identified.

- **Baseline water quality**. It would be expensive to repeat the analyses of all variables assessed in baseline water quality. It is recommended that baseline water quality reflecting average monthly conditions be updated by the Authority once per year for the parameters of interest, and once every 2 to 3 years for all other parameters. This will ensure that any preexisting or new benchmark exceedences can be tracked.

- **WARMF**. The WARMF land use layer should be updated annually by the Authority. The model should be updated with new hydrology, water quality, and GIS watershed characteristic data at least once every two years to ensure that changing water quality conditions will be captured, and benchmark exceedences by subwatershed may be observed. Updates may occur more frequently than once every two years as needed for specific uses. Calibration with new data should occur every 5 to 10 years.
- **Water Quality Vulnerability Zones**: Updates are needed to the WQVZ data only if natural characteristics of the watershed are altered.
- **Fire Models**: Updates to FlamMap and FARSITE are needed when the models are to be used for analyses.

The tools reflect a significant level of effort by the Authority and PAC. They will serve as useful and sustainable assessment tools for various uses in the future.

9.2 Next Steps

This section describes the role of the PAC advocates and identifies specific actions related to the highest priority actions associated with the Septic System Management Program, sewage collection system extensions, and the use of the General Plan process. Also described here is the recommendation for annual reporting of implementation activities, detecting and bringing water quality changes to the Authority's attention, and using the results of this assessment project to support requests for funds.

9.2.1 | Schedule for Implementing Management Measures

Salt Springs Reservoir on North Fork

Implementing the management measures presented in Chapter 8 will ensure that water quality in the Upper Mokelumne River watershed is maintained as well as improved. Unfortunately, by the time an exceedence of a benchmark, or any increase in a water quality parameter, is indicated in monitoring data, it will be difficult to correct the cause. Therefore, it is of utmost importance that the management measures begin to be implemented now. Early implementation of these focused measures will result in an improvement to Upper Mokelumne River water quality, and will minimize impacts associated with growth in the watershed in the future. However, since the Authority is not a regulatory agency and has limited resources, the measures cannot be implemented on a schedule but must be implemented through the active efforts of watershed stakeholders interested in maintaining and improving water quality in the river, and as opportunities arise.

PAC advocates were identified for measures that had a strong personal commitment by a PAC member or the agencies they represent, to advocate for its implementation. See Table 0-1 for a list of advocates. The Foothill Conservancy volunteered to be the advocate for unassigned measures, since these measures reflect the organization's interests and activities in the watershed. It is anticipated that the PAC Advocates will report to the Authority on a quarterly or semi-annual basis the status of pursuing the implementation of the measure(s). Since the PAC Advocate speaks for many pubic interests including local residents, water districts, and non-governmental organizations, their actions in pursuing these measures should be supported by the Authority as well as other potential partners/ agencies, wherever feasible.

Table 0-1: PAC Advocates

Management Measure Recommendations		PAC Advocates
S1	Eliminate leakage from septic systems	Pete Bell, Dan Brown, Bob Dean, Susan Snoke, UMRWC
S2	Increase bulky waste pickup programs and collection of illegally dumped trash (e.g., abandoned cars, appliances, pharmaceuticals)	Kent Lambert
S3	Provide toilets and trash/debris receptacles at informal recreation sites	Tracey Towner-Yep, Kent Lambert
S4	Manage fire fuels for landowner and water quality objectives	Chuck Loffland
F1	Implement measures to control abandoned mine flows/sediment	Foothill Conservancy
F2	Implement green streets design principles for reducing peak flows, minimizing runoff, and removing contaminants during flow	Foothill Conservancy
F3	Implement road maintenance practices intended to minimize water quality impacts	Foothill Conservancy
F4	Enhance grazing practices to encourage off-stream watering	Foothill Conservancy
R1	Implement water quality and temperature monitoring	Foothill Conservancy, Alpine Watershed Group
R2	Educate public on contaminant source reduction and impacts of contaminated stormwater to waterbodies	UMRWC
R3	Include watershed water quality protection policies in general plan update along with ordinances and design guidelines for high vulnerability zones	Foothill Conservancy
R4	Encourage compact development in the general plan updates for water quality protection	Foothill Conservancy
R5	Purchase land and/or development rights, and encourage landowners to obtain conservation easements in high vulnerability areas	UMRWC
R6	Supplemental watershed assessments for non-water quality conditions	Foothill Conservancy

9.2.2 | Implement Septic System Management Practices and Outreach

Implementation by the counties of many of the Septic System Management Program management practices identified in Chapter 8 can begin right away. In particular, actions should be undertaken to establish rigorous design and maintenance standards, require mandatory inspections, mandate pumping of new tanks, and collect a Water Quality Protection Fee. Outreach efforts should be initiated to solicit input and inform residents to gain support of these additional regulations and fees. Actions required to obtain funding for these programs should also be initiated.

9.2.3 | Solicit Funds to Conduct Septic Survey

Substantiating the problems and needs associated with leaky septic systems contaminating the Upper Mokelumne River is critical to soliciting resident support and funding for corrective actions. The recommended septic survey is based on identifying watershed characteristics, conducting water quality monitoring for locations of concentration and species, and inventorying septic system locations and conditions. Funds should be solicited as soon as possible to support these efforts.

9.2.4 | Solicit Funds for Sewage Collection System Expansion

Funds are needed to plan, design, and implement the expansion of the existing sewage collection and treatment systems in West Point, Wilseyville, and Mokelumne Hill, or development of smaller satellite treatment systems, as needed.

9.2.5 Utilization of County General Plans

The updating of both the Amador and Calaveras county general plans provides an opportunity for the counties to adopt new and innovative policies related to maintaining and improving water quality in the Upper Mokelumne River watershed. These policies should:

- encourage compact growth for more cost-effective sewer infrastructure improvements
- require connections to sewer collection systems for all new developments of two units or greater
- mandate green streets design principles for stormwater water quality management
- include a water resources element linking all aspects of land development to watershed water quality implications.

Mokelumne Hill provides an example of compact growth

It is recommended that the WARMF model be expanded to include adjacent watersheds in Amador and Calaveras Counties. The use of the model should be mandated for assessing water quality impacts of all development proposals with one acre of land disturbance or greater.

9.2.6 | Annual Reporting

In order to keep the watershed tools current and useful, annual reporting on the status of the tools and evaluation of management measure implementation is critical. An annual report to the Authority and other stakeholders by the steward, with contributions from stakeholders, should provide the following information.

- Requests by others for use of project tools, purpose of use, modifications made by others, etc.
- Data obtained during the year for updates to the tools.
- Updates, modifications, recalibration for specific areas of study, if any, made to any of the tools during the year.
- Notification of any changes to water quality conditions, particularly parameters of interest and any new benchmark exceedences.
- Status of the management measures.
- Progress toward achieving target load reductions.

As the use of the tools and implementation of the management measures progresses in the future, periodic review is recommended to identify whether the tools and measures continue to provide value. The measures and tools may need to be adapted (through an adaptive management process) to better accommodate changing conditions.

9.2.7 | Revisit Parameters of Interest and Benchmarks

If a water quality parameter of interest or a parameter concentration being maintained exhibits signs of water quality degradation, the entity noting the changing conditions should bring this observation to the attention of the Authority and other stakeholders, and a correction strategy should be developed cooperatively. By the time water quality degradation is indicated in monitoring data, it is difficult to correct the cause. Proactive implementation of the management measures is strongly encouraged.

9.2.8 | Obtain Technical and Financial Assistance

To implement and evaluate the effectiveness of the recommended management measures, funding is needed. The project tools and analyses were conducted with technical rigor to be able to support grant applications and other sources of funds for implementation programs. These management measures could be funded by individual residents (e.g., the water quality protection fee), grant funding, and developer fees. Potential funding sources are presented below. In addition, financing techniques such as the formation of special assessment districts or placing county-wide bonds on a ballet, should be investigated.

State Water Resources Control Board: Small Communities Wastewater Grant

The Small Community Wastewater Grant (SCWG) Program, funded by Proposition 40 and Proposition 50, provides grant assistance for the construction of publicly owned wastewater treatment and collection facilities. This program funds projects in communities that lack or may have historically lacked the staff or resources to successfully compete for various funding opportunities, communities with a relatively low MHI, communities that may reflect environmental justice considerations, and communities facing other cultural or financial barriers that limit their access to funding opportunities. $20 million was available for this program in 2007.

Housing Assistance Council: Rural Housing Loan Fund

The purpose of this program is to provide funds to eligible developers and public agencies to improve housing and living standards for low- and very low-income rural households. Goals of the program include improving water and wastewater disposal systems in rural communities. An unspecified amount of funding is available through this program.

State of California Department of Health and Human Services: Safe Drinking Water State Revolving Fund

The purpose of this program is to enhance the capacity of public water systems to deliver safe and affordable drinking water. The program offers low-interest loans for improvement projects to meet health-based drinking water standards including septic system upgrades or abatement. An unspecified amount of funding is available through this program.

U.S. Department of Agriculture: Revolving Fund Program for Financing Water and Wastewater Projects

The purpose of this program is to provide financing for predevelopment costs associated with proposed rural water and wastewater projects by making grants available to qualified local private nonprofit entities to maintain a revolving loan fund. Grant funds must be used to capitalize a revolving fund for the purpose of providing loan financing for predevelopment costs associated with proposed or with existing water and wastewater systems. Approximately $495,000 is available to fund awards of up to $100,000.

State Water Resources Control Board: State Clean Beaches Initiative Grant Program

The purpose of this program is to protect and restore coastal water quality by supporting projects that preserve water and environmental resources found in California's estuaries, bays, near-shore waters, and other coastal waters. The program funds projects including those that make improvements to existing sewer collection and septic systems. Approximately $27 million is available through this program in total.

U.S. Environmental Protection Agency: Environmental Justice Collaborative Problem-Solving Cooperative Agreement Program and Small Grants Program

The purpose of this program is to support and empower community-based organizations in building collaborative partnerships while developing solutions to address local environmental and public health problems. Previously supported projects include assisting residents with replacement of failing septic systems. Supported projects will be expected to demonstrate quantifiable environmental results and elements of sustainability. $500,000 was available in fiscal year 2006 to support ten awards of $50,000.

Sierra Nevada Conservancy: Proposition 84 – The Clean Water, Parks, and Coastal Protection Bond Act

The purpose of this program is to fund projects related to drinking water, water quality and supply, flood control, water pollution and contamination control, an emergency water supply, and protection of natural waterways. The Sierra Nevada Conservancy is to receive over $17 million in funding for the protection and conservation of natural resources in the Sierra Nevada, not including that allocated to the California Tahoe Conservancy.

U.S. Department of Agriculture: Water and Waste Disposal Systems for Rural Communities

The purpose of this program is to support programs that provide basic human amenities, alleviate health hazards, and promote the orderly growth of the rural areas of the nation by meeting the need for new and improved rural water and waste disposal facilities. Funds may be use for the installation, repair, improvement, or expansion of a rural waste disposal facility, including the collection and treatment of sanitary waste stream stormwater, and solid wastes. Approximately $349 million in grants and $990 million in loans is available through this program.

U.S. Environmental Protection Agency: Targeted Watershed Grants Program

The purpose of this program is to provide funding to support collaborative partnerships to protect and restore the nation's water resources. Two separate types of grants will be awarded in 2007. The Agency will select up to 12 watershed organizations to receive grants to implement watershed-based, on-the-ground implementation projects and up to 5 training and educational organizations to receive grants or cooperative agreements to help build capacity of the many grass roots watershed organizations across the country. Both grants will focus on strong stakeholder support and producing improved environmental change. $6.9 million is available through this program.

U.S. Environmental Protection Agency: Nonpoint Source Implementation Grants

The purpose of this program is to support projects that protect source water areas and the general quality of water resources in a watershed. Examples of previously funded projects include installation of best management practices (BMPs) for animal waste; design and implementation of BMP systems for stream, lake, and estuary watersheds; basinwide landowner education programs; and lake projects previously funded under the Clean Water Act (CWA) section 314 Clean Lakes Program. $194 million was available through this program in 2007.

U.S. Environmental Protection Agency: Communities for a Renewed Environment (CARE)

CARE is a competitive grant program that offers an innovative way for a community to organize and take action to reduce toxic pollution in its local environment. Through CARE, a community creates a partnership that implements solutions to reduce releases of toxic pollutants and minimize people's exposure to them. By providing financial and technical assistance, EPA helps CARE communities get on the path to a renewed environment. $2.7 million was available in 2007 through this program.

U.S. Department of Housing and Urban Development: Community Development Block Grants

The purpose of this program is to develop viable urban communities, by providing decent housing and a suitable living environment, and by expanding economic opportunities, principally for persons of low and moderate income. Recipients may undertake a wide range of activities directed toward neighborhood revitalization, economic development, and provision of improved community facilities and services. $2.1 billion was available through this program in 2007.

U.S. Army Corps of Engineers: Aquatic Ecosystem Restoration (CAP Section 206)

The U.S. Army Corps of Engineers is authorized to perform work under this authority to carry out aquatic ecosystem restoration projects that will improve the quality of the environment, are in the public interest, and are cost-effective. There is no requirement that an existing Corps project be involved. $29.7 million was available through this program in 2007.

9.3 Project Evaluation and Effectiveness

A Project Assessment and Evaluation Plan (PAEP) was prepared in accordance with SWRCB guidance and can be found in Appendix O. The PAEP is required of all grant recipients to outline how they will assess and evaluate performance of the project process and report on project achievements. These PAEP project goals are related to the project process versus the project goal developed by the PAC.

The PAEP project goals for Part 2 were as follows.

- Identify potential water quality responses to watershed land uses
- Identify management measures and corrective actions to maintain and improve source water quality
- Involve watershed residents in the development of the assessment and management plan

The desired outcomes of this project were as follows.

- Analysis of baseline water quality conditions within the study area
- Identification and mapping of land uses and management activities with potential for impacts to waterbodies.
- Development of site-specific and/or watershed-wide management recommendations capable of reducing potential pollutant contributions to waterbodies for parameters of interest.
- Identification of processes to incorporate recommendations into local General Plans and permits.
- Increased community knowledge regarding watershed issues.

Performance indicators based on the project goals and desired outcomes for the project are presented in Table 0-2. All targets listed were achieved.

In addition to the PAEP project goals, the original Authority goals for undertaking the project were to provide: 1) a broader understanding of watershed water quality issues, 2) a method for long-term watershed water quality tracking, and 3) assessment tools to aid watershed management in the future. The project achieved these Authority goals and in the process, established a sound and rigorous basis for additional watershed assessments and analyses to more specifically further the goal of the project: Maintain and Improve Source Water Quality.

Other benefits realized from the project are less tangible but relate to the continued spirit of cooperation and working relationships between PAC members, and a rigorous, scientific approach both supporting and rejecting presumed watershed water quality conditions and sources of contamination. Lessons learned during the course of the project include the need to involve the representatives of the funding and administration agencies early in the project to work out any perceived differences in the project goals and ensure that there is agreement in the process to achieve the goals. Once they were more actively included, having the representatives of the funding and administration agencies actively involved greatly aided the project process and results because of their individual expertise and contributions.

Table 9-1: Performance Indicators for Part 2 Project

Project Goals	Baseline Measurement and Information	Output Indicators	Outcome Indicators	Measurement Tools and Methods	Targets
1. Identify potential water quality responses to watershed land uses, management, and activities	1. Documentation of current natural watershed characteristics such as vegetation, soils, topography, hydrology, climate, air quality; 2. Documentation of current anthropologic characteristics such as existing land uses, management practices, infrastructure; 3. Documentation of simulated current water quality conditions by subwatershed	1. Digitized maps of current watershed characteristics; 2. Digitized maps of land uses, land management, and activities with potential for impacts to waterbodies; 3. A calibrated hydrologic simulation model; 4. Documentation of baseline water quality conditions for parameters of concern	1. Analysis of baseline water quality conditions within the study area; 2. Development of water quality thresholds for parameters of concern; 3. Accepted watershed assessment report; 4. Anthropogenic stressors identified by general location	1. WARMF, A Decision Support System for Watershed Management, Systech Engineering, Inc.	1. Authority acceptance of assessment; 2. PAC development of baseline water quality conditions; 3. PAC development of assessment tool for use in future decision-making; 4. PAC development of water quality benchmarks or risks for parameters of concern
2. Identify management measures to maintain and improve source water quality	1. Identification of existing management practices and activities in place or considered for implementation; 2. List of County General Plans and local permits to be considered for implementation	1. Digitized maps of locations of potential pollutants of concern; 2. Summary description of general plans and local permits with potential for inclusion of water quality protection measures	1. Development of site specific and/or watershed-wide management recommendations capable of reducing potential pollutant contributions to waterbodies; 2. Method to prioritize, schedule, and fund watershed activities; 3. Identification of processes to incorporate recommendations into local community plans and permits; 4. Adopted watershed management plan	1. www.water boards.ca.gov/nps/volunteer.html; 2. http:// cwam.ucdavis.edu/	1. Authority acceptance of management plan; 2. PAC development of recommended management measures and corrective actions for water quality protection and improvement

Table 9-1: Performance Indicators for Part 2 Project

Project Goals	Baseline Measurement and Information	Output Indicators	Outcome Indicators	Measurement Tools and Methods	Targets
3. Involve watershed residents in the development of the assessment and management plan	1. Increased community knowledge regarding watershed issues	1. Number of residents attending community workshops	1. Broad understanding of Upper Mokelumne River watershed conditions and water quality protection and improvement activities	NA	1. Three community workshops will be held; 2. Five project newsletters will be distributed to keep the public informed of project activities; 3. Attendance at community workshops should include at least 10 people from this very rural watershed, not including PAC members; 4. Counties to consider incorporation of BMPs and other management plan recommendations in their general plan updates

Chapter Ten

Abbreviations/Acronyms

The following abbreviations and acronyms were used in this report.

304(a)	Clean Water Act Section 304(a)
Ac-ft	Acre-feet
ACWA	Alpine County Water Agency
Authority	Upper Mokelumne River Watershed Authority
AWA	Amador Water Agency
BLM	U.S. Bureau of Land Management
$CaCO_3$	calcite
CaSIL	California Spatial Information Library
CCC	criterion continuous concentration
CCWD	Calaveras County Water District
CDF	California Department of Forestry
CFC	chlorofluorocarbon
cfs	cubic feet per second
CMC	criterion maximum concentration
cms	cubic meters per second
CNDDB	California Natural Diversity Database
CPUD	Calaveras Public Utility District
CTR	California Toxics Rule
CWA	Clean Water Act
DBP	disinfection byproduct
DDD	data development database
DFG	California Department of Fish and Game
DHS	California Department of Health Services
DO	dissolved oxygen
DOQQ	Digital Ortho Quarter Quad
E. coli	Escherichia coli
EBMUD	East Bay Municipal Utility District
EC	electrical conductivity
EPA	United States Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
Giardia	*Giardia lamblia*
GIS	Geographic Information System
HSPF	Hydrological Simulation Program – FORTRAN
IRIS	Integrated Risk Information System
JVID	Jackson Valley Irrigation District

LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
LUFT	leaking underground fuel tank
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
mg/L	milligrams per liter or parts per million
NFS	National Forest Service
NTR	National Toxics Rule
NTU	nephelometric turbidity units
OEHHA	California Office of Environmental Health Hazard Assessment
OHV	off-highway vehicle
PAC	Project Advisory Committee
PAEP	Project Assessment and Evaluation Plan
PG&E	Pacific Gas and Electric Company
PHG	public health goal
project	Upper Mokelumne River Watershed Assessment and Planning Project
Project 137	PG&E Mokelumne Hydroelectric Project
QAPP	Quality Assurance Project Plan
REC-1	body contact recreation designation
Region 5	Central Valley Region of the Regional Water Quality Control Board
RWQCB	Regional Water Quality Control Board
SDWA	Safe Drinking Water Act
SOCs	synthetic organic compounds
SPI	Sierra Pacific Industries
SWAT	Soil and Water Assessment Tool
SWRCB	State Water Resources Control Board
SWTR	California Surface Water Treatment Rule
TDS	total dissolved solids
THP	timber harvesting plan
TKN	total kjehldahl nitrogen
TM	Technical Memorandum
TMDL	total maximum daily load
TOC	total organic carbon
TSS	total suspended solids
ug/L	micrograms per liter or parts per billion
USFS	United States Department of Agriculture, Forest Service
UST	underground storage tanks
VOCs	volatile organic compounds
WARMF	Watershed Analysis and Risk Management Framework
WQVZ	water quality vulnerability zones
WWTF	wastewater treatment facility

Chapter Eleven
Glossary

acre-foot The volume of water covering one acre of land one foot deep, or 325,851 gallons. On average, an acre-foot can supply one to two households with water for one year.

adaptive management A type of natural resource management in which decisions are made as part of an ongoing science-based process. Adaptive management involves testing, monitoring, and evaluating applied strategies, and incorporating new knowledge into management approaches that are based on scientific findings and the needs of society. Results are used to modify management policy, strategies, and practices.

aquifer An identified volume of water-bearing materials under the ground surface that can produce groundwater.

benchmark Numeric values against which the watershed baseline water quality can be compared to determine the health of the watershed from a water quality perspective. They are intended to serve as a point of comparison to determine whether concentrations of parameters in the watershed are of potential concern for human and/or aquatic health.

beneficial use Use of an amount of water that is reasonable and appropriate under efficient practices to accomplish, without waste, the purpose for which the diversion is made.

CALFED/Bay-Delta Authority A cooperative State and federal effort established to resolve a series of water and eco-system management problems in the San Francisco Bay and Sacramento River- San Joaquin River Delta.

California Natural Diversity Database (CNDDB) A program that inventories the status and locations of rare plants and animals in California . CNDDB staff work with partners to maintain current lists of rare species as well as maintain a database of locations for these species.

conservation element One of the seven elements of a general plan required under State planning law, addressing natural resources, including water.

Delta	The Sacramento River-San Joaquin River Delta.
discharge	Volume of water that passes a given location within a given period of time.
diversion	The action of taking water out of a river system or changing the flow of water in a system for use in another location.
drought	A dry year followed by one or more dry years.
ecosystem	A biological community together with the physical and chemical environment with which it interacts.
Endangered Species Act	Federal Endangered Species Act (ESA) and State (CESA) statutes designed to protect threatened and endangered plant and animal species and their habitats and enable the species to recover their populations on a sustained basis.
erosion	The process in which a material is removed from the earth's surface by running water, waves, or wind.
evapotranspiration	Quantity of water transpired or given off, retained in plant tissues, and evaporated from plant tissues and surrounding soil surfaces.
FARSITE	A fire behavior and growth simulator. FARSITE is widely used by the USDI National Park Service, USDA Forest Service, and other federal and state land management agencies to simulate the spread of wildfires and fire use for resource benefit across the landscape.
first flush	Surface runoff resulting from the first significant rainfall of a season. The first flush usually contains the highest levels of nonpoint sources of pollution.
FlamMap	A fire behavior mapping and analysis program that computes potential fire behavior characteristics (spread rate, flame length, fireline intensity, etc.) over an entire landscape for constant weather and fuel moisture conditions.
floodplain	Land area subject to flooding from a contiguous body of water. Floodplains are delineated by the expected frequency of flooding.
gaging station	A site on a stream, lake, reservoir, or other body of water where observations and hydrologic data are obtained.

general plan Required for all cities and countries, a comprehensive planning document that governs the future growth, development, and conservation of California communities.

habitats Areas that provide specific conditions necessary to support plant, fish, and wildlife communities.

hydrologic year See *water year*

hydrology The study of water: its occurrence, circulation, and distribution; their chemical and physical properties; and its reaction with the environment and relation to living things.

mass balance An accounting of material entering and leaving a system, such as water entering a watershed as rain and leaving a watershed through runoff, evaporation, soil infiltration, etc.

model calibration Ensuring a model accurately reflects field conditions by systematically adjusting the model until it reaches accepted criteria.

non-point source pollution Discharge other than from point sources; erosion of soils and street runoff containing hydrocarbons are examples of non-point sources of pollution.

off-stream storage Storage of water in a reservoir that is not located on a major river or stream. Involves the conveyance of water into the reservoir for storage.

parameter of interest For this project, water quality parameters that have monthly averages exceeding established benchmarks.

pH A measure of the relative acidity or alkalinity of water. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly basic solutions

peak flow The maximum instantaneous discharge of a stream or river at a given location.

point source Water pollution coming from a single point.

precipitation Rain, snow, hail, sleet, dew, and frost.

Project 137 Pacific Gas and Electric's Upper Mokelumne watershed hydropower facilities licensed by the Federal Energy Regulatory Commission.

raw water Refers to water that is not used directly for drinking water purposes based on water quality considerations. Raw water is typically used in reference to water that is not treated for drinking water or may be used for agriculture.

reservoir A natural or artificial pond or lake used for the storage and regulation of water.

runoff That part of the precipitation or snow melt that flows down hillslopes and or is discharged through subsurface processes to surface streams; or in urban areas, from streets, rooftops, or other impermeable areas to drains or sewers.

septic system An on-site, self-contained sewage treatment system that distributes wastewater to an underground storage area and relies on bacterial action to decompose solid waste matter.

service area boundary A delineated area of land within which a public or private entity (district, agency, private company) serves customers with basic services such as water or wastewater.

smart growth A relatively recent umbrella term describing a philosophy of land use planning and community building that relies on compact and contiguous growth within and around established urban areas. This style of growth avoids low-density, single-use development that impact on open land in favor of mixed-use, transit-oriented, and infill development.

stakeholder A person or group with an interest in the outcome of a policy or decision. Stakeholders typically represent different interests in collaborative policy processes and include those with financial "stakes," as well as those with policy or value interests.

stormwater runoff Water runoff from precipitation that flows into storm sewers or surface waters instead of infiltrating into the soil or evaporating.

Total Maximum Daily Load The maximum amounts of individual pollutants contributing to impairment of the "beneficial uses" of the waterbody allowed to enter a waterbody from watershed sources. Legally defined by EPA and local RWQCBs

tributary A smaller river or stream that flows into a larger river or stream. A three-dimensional network of tributaries join to from a watershed's river system.

turbidity	The amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases.
Watershed Analysis and Risk Management Framework (WARMF)	A hydrologic model and decision tool used to facilitate watershed planning and investigate water quality and hydrology scenarios.
water balance	An accounting of all water inflow to, water outflow from, and changes in water storage within a hydrologic unit over a specified period of time.
water year	The State of California has defined the Water Year from October 1 through September 30,, designated by the calendar year in which it ends and which includes 9 of the 12 months. Various agencies use different 12-month periods.
watershed	The area from which water drains to a single point. Also called drainage basin.
wet year, above normal year, below normal year, dry year, critically dry year	Water year types as determined by the Department of Water Resources or water purveyor.
wildland fire	An uncontrolled fire often occurring in wildland areas, which can also consume houses or agricultural resources.

Chapter Twelve

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References used during the course of the project analyses are provided here. Also included are a few website references that provide background information on relevant topics.

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12.2 Website Recommendations

The following websites represent a broad range of watershed management, water quality, and hydrology concepts that are discussed within this report. These references are provided to enhance the understanding of the information presented.

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California Environmental Resources Evaluation System
www.ceres.ca.gov

California Water Science Center through the United States Geological Survey
www.ca.water.usgs.gov

California Watershed Portal
www.cwp.resources.ca.gov

EPA Low Impact Development Page
www.epa.gov/owow/nps/lid

Land Use Planning Information Network (LUPIN)
www.ceres.ca.gov/planning

Local Government Commission First Stop Shop for Water Resources
www.water.lgc.org

Marin County Septic System Public Education Efforts
www.septicmatters.org

U.S. Geological Survey Science in Your Watershed
www.water.usgs.gov/wsc/watersheds.html

U.S. Geological Survey. Study and Interpretation of the Chemical Characteristics of Natural Water.
www.pubs.usgs.gov/wsp/wsp2254/pdf/wsp2254a.pdf

WARMF EPA Resources Page
www.epa.gov/ATHENS/wwqtsc/html/warmf.html

WARMF Information – Systech Engineering
www.systechengineering.com/WARMF.htm

Chapter Thirteen

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UMRWAP was a PAC-driven project