Upper Elk River:
Technical Analysis for Sediment

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North Coast Regional Water Quality
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Table of Contents

Tables

Figures

List of Abbreviations

303(d) list	*Clean Water Act Section 303(d) List of Impaired Waterbodies*
ac	acres
AHCP	Aquatic Habitat Conservation Plan
Basin Plan	*Water Quality Control Plan for the North Coast Region*
BLM	Bureau of Land Management
BMP	Best management practice
CalFire	California Department of Forestry and Fire Protection (formerly CDF)
CAO	Cleanup and Abatement Order
CDFG	California Department of Fish and Game (now California Department of Fish and Wildlife)
CDFW	California Department of Fish and Wildlife (formerly California Department of Fish and Game)
cfs	cubic feet per second
CGS	California Geologic Survey
CSDS	Controllable sediment discharge sources
CWA	Clean Water Act
DEM	Digital Elevation Model
DSLED	Deep-seated landslide and earthflow detection model
DWR	Department of Water Resources
EPA	United States Environmental Protection Agency
FPR	Forest Practice Rules
ft^2	Square feet
GDRC	Green Diamond Resources Company
GIS	Geographic Information System
HCP	Habitat Conservation Plan
HRC	Humboldt Redwood Company
ISRP	Independent Scientific Review Panel
kg/m^3	Kilograms per cubic meter
LA	Load allocations
LiDAR	Light Detection and Ranging
LWD	Large woody debris
m^3/yr	Cubic meters per year
mg/L	Milligrams per liter
mi	miles
mi^2	square mile

mm	millimeters
MOS	Margin of safety
MRP	Monitoring and Reporting Program
mT/yr	Metric tons per year
NHE	Northern Hydrologic Engineering
NOAA	National Oceanic and Atmospheric Agency
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint source
NPS Policy	*Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program* (2004)
Palco	Pacific Lumber Company, Scotia Pacific Corporation, and Salmon Creek Corporation (collectively referred to as Palco)
Peer Review Draft	*Staff Report to Support the Technical Sediment Total Maximum Daily Load for the Upper Elk River* (2013)
Porter Cologne	Porter-Cologne Water Quality Control Act
Preliminary Review Draft	Preliminary Review Draft Sediment Source Analysis
PWA	Pacific Watershed Associates
RCAA	Redwood Community Action Agency
Regional Water Board	North Coast Regional Water Quality Control Board
ROWD	Report of Waste Discharge
SSC	Suspended sediment concentration
State Water Board	State Water Resources Control Board
SYP	Sustain Yield Plan
THP	Timber Harvest Plan
TMDL	Total Maximum Daily Load
USGS	United States Geologic Survey
WDR	Waste Discharge Requirements
WLA	Wasteload allocations
WQI	Water Quality Indices
WQO	Water quality objective
WQS	Water quality standards
WY	Water year
yd^3	Cubic yards
$yd^3/mi^2/yr$	Cubic yards per square mile per year
yd^3/yr	Cubic yards per year

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Chapter 1 – Introduction

The Elk River watershed is identified on the Clean Water Act (CWA) Section 303(d) List of Impaired Waterbodies (303(d) list) as impaired for sediment[1]. The North Coast Regional Water Quality Control Board (Regional Water Board) has been working with watershed partners over the past two decades to investigate this impairment, resulting in an extensive suite of data and information. The Regional Water Board contracted with Tetra Tech, Inc. (through the United States Environmental Protection Agency [EPA] Region 9) to perform an independent review of the work completed to date. This document presents Tetra Tech's synthesis of the technical analyses and documentation.

Specifically, the *Upper Elk River Technical Analysis for Sediment* presents the data, analyses, results, and conclusions derived from watershed assessment efforts, as well as a review of the historical, management, and regulatory factors in the Elk River watershed that have influenced its sediment impairment. This builds upon the framework and information that were first reported in the *Peer Review Draft Staff Report to Support the Technical Sediment [Total Maximum Daily Load] TMDL for the Upper Elk River* (Peer Review Draft [Regional Water Board 2013a]), which was distributed for scientific peer review in April 2013. Scientific peer review comments and staff's responses to comments were posted on the Regional Water Board website, following which informal public comments were received and also posted[2] (Regional Water Board 2013b). The Regional Water Board subsequently developed an Internal Draft Staff Report[3], which included elements of the Peer Review Draft (Regional Water Board 2013a), along with additional content and analyses developed in response to the scientific peer review and informal public comments. These documents, along with other relevant sources (see Chapter 1.3), were used to develop this report.

The remainder of this chapter describes the overall project history, the iterative and collaborative approach in the watershed, existing documentation, and a brief synopsis of the report components. This document provides the technical basis for a sediment TMDL and/or a Waste Discharge Requirements (WDR). Further, the technical analysis supports the conclusion that a four prong approach to returning the Elk River to a trajectory of recovery is warranted, as described in Chapter 1.2.

1.1 Project History and Context

Due to water quality and beneficial use impairments, the Regional Water Board has taken a variety of regulatory and non-regulatory actions in the Elk River watershed to protect and restore beneficial uses and abate flooding conditions. Following an intensive period of petitions, hearings, investigations, and analyses between 1997 and 2006, the Regional Water Board undertook a series of actions including the placement of Elk River on the 303(d) list, issuing Cleanup and Abatement Orders (CAOs) and Monitoring and Reporting

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[1] The Elk River watershed is listed as impaired for sediment. Much of this document applies to the entire watershed; however, the desired watershed conditions, problem statement, sediment source assessment, and loading capacity chapters focus on the Upper Elk River watershed as it is the drainage area contributing to the impacted reach.

[2] http://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/elk_river/

[3] The internal draft is not publically available.

Programs (MRPs), undertaking TMDL development, and developing and adopting property-wide WDRs for industrial timberland owners. Appendix 2-C (History of Regional Water Board Regulatory and Non Regulatory Actions in the Upper Elk River Watershed) of the Peer Review Draft (Regional Water Board 2013a) provides a review of regulatory actions in the watershed.

The Regional Water Board sponsored two phases of evaluations by an Independent Scientific Review Panel (ISRP). The ISRP authored two reports (December 27, 2002 and August 12, 2003) and concluded that 1) a rate of harvest aimed at reduction of harvest-related landslides could be determined with available landslide inventories and harvest history data, and 2) flooding and water quality standard impairment would continue as long as sediment loads remained elevated. The ISRP recommended that detailed sediment process data be collected to inform future analysis. They further found that the Timber Harvest Plan (THP) process defined by the Forest Practice Rules (FPR) and the Habitat Conservation Plan/ Sustained Yield Plan (HCP/SYP) process was not sufficient to guarantee water quality protection and recovery.

1.2 An Evolving Collaborative Approach

The Regional Water Board has a duty to implement the CWA, the Porter Cologne Water Quality Control Act (Porter Cologne), the *Water Quality Control Plan for the North Coast Region (*Basin Plan; Regional Water Board 2011a), and other plans and policies of the State Water Resources Control Board (State Water Board) and Regional Water Board for the protection of water quality. The Regional Water Board has attempted to fulfill these duties through the implementation of permits, monitoring and reporting requirements, and compliance orders, as described above. These regulatory actions also have been augmented by collaborative efforts, such as the Elk River Restoration Summit held in February 2012. Conclusions drawn from the Restoration Summit led to the development of the Elk River Recovery Assessment, an effort to model the fate and transport of sediment and flows from the top of the impacted reach to the outlet of the river to Humboldt Bay under various sediment remediation and channel restoration scenarios. This exercise was viewed by the members of the Restoration Summit as critical to the design and implementation of a sediment remediation and restoration strategy suitable to augment regulatory actions, and return the watershed to a trajectory of recovery.

To build on these early collaborative efforts, an Elk River Watershed Stewardship Program (Stewardship Program) has been proposed by the Regional Water Board and is modeled after the success of a similar collaborative approach used in the Klamath Basin. As described by Regional Water Board staff, the Stewardship Program will coordinate directly with watershed residents and other stakeholders to solicit their input and transmit information on recovery program activities that are ongoing throughout the watershed. It will ultimately provide a broad umbrella within which specific working groups can form to coordinate resource management issues in a collaborative and transparent way. A framework for how the stewardship program is envisioned to work is provided in Chapter 8.

The combination of regulatory and non-regulatory activities, now under the umbrella of stewardship, is intended to address the following four components of a recovery strategy:

1. Control of new sources of sediment (current operations),
2. Control of existing sources of sediments (areas of elevated erosion risk),
3. Expansion of the assimilative capacity for sediment in the impacted reach through remediation of deposited sediment and restoration of hydrologic function, and
4. Installation of physical infrastructure to address nuisance conditions (e.g., flooding, water supplies)

These components are described in more detail in Chapter 8.

1.3 Supporting Documentation

Information and conclusions presented in this *Upper Elk River Technical Analysis for Sediment* were developed after review and synthesis of a suite of documents and reports that have been developed over a period of years. This documentation addresses a range of issues associated with sediment production, delivery and transport in the watershed. These documents include previous drafts of the TMDL, comments and their responses, and additional watershed analyses. The supporting documentation provides background information as well as data on sediment load estimates in the Elk River watershed. Table 1 describes the materials and their use for this effort.

Table 1. Supporting Documentation Used in Technical Analysis

Description of Documentation	Use in this Technical Analysis
Peer Review Draft TMDL Staff Report (Peer Review Draft) (Regional Water Board 2013a)	
Revision of the Regional Water Board 2011 preliminary TMDL analysis Regional Water Board 2011b), which focused on sediment loadings for 1955-2003. Included new loading estimates with an extended period through 2004-2011.	Provided background information, graphics, maps, and text related to the watershed setting, problem statement, and background information on the desired watershed conditions and sediment source assessment methodology.
Internal Draft Staff Report (internal, March 2015)	
Third version of the Elk River sediment TMDL documentation; an internal document drafted by the Regional Board in 2015 to serve as the basis for a revised TMDL. Includes rationale for updates to the report based on formal and informal comments and new data available after the Peer Review Draft. Reflects several key changes to the technical analyses, including inclusion of a conceptual model and revised estimate for natural sediment loading, and implementation framework.	Provided context and background for conclusions made by Regional Water Board staff. These decisions were reviewed and verified during development of this report. Also documented conceptual model.
Formal Peer Reviews; and Staff Response to Peer Review Comments 2013 (Regional Water Board 2013b)	
Comments provided by four peer reviewers. Response to comments provides detailed review of comments along with Regional Water Board staff responses and any recommended changes to the staff report.	Provided additional context and explanations regarding the issues and analyses contained in the various supporting documents that were not explicitly discussed in other documentation.

Description of Documentation	Use in this Technical Analysis
Informal Comments on the Peer Review Draft; and Staff Response to Informal Comments (internal, July 2015)	
Written comment letters by watershed stakeholders in response to the Peer Review Draft. Regional Water Board staff drafted responses to informal comments, including proposed revisions to the draft TMDL and implementation program.	Provided additional context and explanations regarding the issues and analyses contained in the various supporting documents that were not explicitly discussed in the draft TMDLs.
Humboldt Redwood Company Watershed Analysis Revisited (HRC 2014)	
Most recent revision of the Humboldt Redwood Company's (HRC) Watershed Analysis Monitoring Report as required under its Aquatic Habitat Conservation Plan (AHCP). Establishes and maintains an inventory of hillslope, riparian, and in-stream conditions, related to sediment, wood, and temperature. Documents conditions and processes related to mass wasting, surface erosion, riparian function, and stream channels.	Provided additional context and explanations regarding information used in sediment source assessment loading rates. Loading values for North Fork Elk River watershed area compared to TMDL sediment source assessment estimates.
Salmon Forever Analysis 2013 (Lewis 2013)	
Provides updated information to augment June 2010 report to Redwood Community Action Agency (RCAA). Presents analyses of trends in storm peak flows, storm event loads, storm mean suspended sediment concentration (SSC), and instantaneous SSC as well as results of stream cross-sectional surveys at multiple locations in Elk River.	Provided additional context and explanations regarding the information used in analyses contained in the sediment source assessment. Loading values at two monitoring stations compared to TMDL sediment source assessment estimates.
Elk River Hydrodynamic and Sediment Transport Modeling Pilot Project (Northern Hydrology Engineering and Stillwater 2013)	
Presents results of a predictive hydrodynamic and sediment transport model in a pilot reach of Elk River. Includes information on cross-sections, sediment composition, and other data.	Provided information to support mass balance calculation presented in the sediment source assessment.

The approach and structure presented in the Internal Draft Staff Report was used as a foundation for this document. As part of Tetra Tech's independent review, we performed quality control checks on calculations and significant editing and synthesis to produce a document suitable for public review. In addition, several key changes to the Peer Review Draft (Regional Water Board 2013a) are presented throughout this document. These include:

- A conceptual model of the ecological risks associated with natural and anthropogenic influences in the Upper Elk River watershed;
- Changes to the estimates of natural sediment loading in the sediment source assessment;
- A comparison of the estimated loads to other loading calculations;

- Mass-balance estimates for the impacted reach[4] (2003 – 2011);
- Alternative presentation of the assimilative capacity; and
- Implementation framework divided into two phases.

These changes do not constitute a new TMDL, rather they reflect a refinement to the Peer Review Draft that considers new information from the stakeholders and peer reviewers.

1.4 Document Organization

This document is composed of seven additional chapters, which are described below.

Chapter 2: Watershed Setting

The Watershed Setting chapter describes the location and general characteristics of the Elk River watershed, including climate, hydrology, land cover, soils, and geology. The chapter also discusses landslides—a potential significant source of sediment—and their relationship to watershed characteristics, such as climate, soils, geology, and vegetation.

Chapter 3: Regulatory Setting

The Regulatory Setting chapter reviews the Regional Water Board's authority and overarching environmental regulations that affect the watershed. This chapter introduces the watershed's impaired reaches and discusses WDRs for major timber operators.

Chapter 4: Desired Watershed Conditions

This chapter contains the water quality standards (WQS) applicable to the waters of the North Coast Regional Water Board, including the Elk River watershed. To evaluate improvements towards beneficial use attainment, as well as to provide potential adaptive management thresholds, this chapter also presents both instream and hillslope water quality indicators (WQI).

Chapter 5: Problem Statement

Impacts to the watershed from excess sediment are described in the problem statement chapter and include downstream flooding (a nuisance condition) and beneficial use impairments (impaired fisheries and impaired water supplies). The chapter also describes the factors and processes critical to understanding the elevated erosion risk and impaired hydrologic function as well as some of the restoration activities that have occurred in the watershed.

Chapter 6: Sediment Source Assessment

The Sediment Source Assessment chapter presents a conceptual model of sediment behavior in the Upper Elk River watershed. The chapter also presents quantitative estimates of 1) sediment loading, 2) channel filling, and 3) sediment output from the impacted reach.

Chapter 7: Sediment Loading Capacity and Load Allocations

Building on the findings presented throughout the document, the assimilative capacity and a phased approach to the loading capacity are presented in this chapter. Phase I will be

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[4] The impacted reach extends from the confluence of Browns Gulch on North Fork Elk and Tom's Gulch on South Fork Elk downstream to the mainstem Elk River to Berta Road (Figure 9).

designed by the Regional Water Board and is anticipated to include instream sediment remediation and channel restoration activities in the impacted reach, while Phase II is expected to include a recalculation of the loading capacity after Phase I is complete.

Chapter 8: Framework for Implementation, Monitoring, and Adaptive Management

The Regional Water Board has many regulatory and non-regulatory tools to implement the requirements of the Basin Plan, including CAOs, WDRs, MRPs, grant funding, and watershed stewardship. This chapter describes a framework within which to implement water quality improvements. There are multiple strategies available to address the conditions of impairment; however, the implementation framework described builds upon historic and existing implementation efforts, is based on the Regional Water Board's revised strategy derived from scientific peer review and public review comments, and is consistent with the technical findings of this analysis.

Chapter 2 – Watershed Setting

The Elk River watershed is in the coastal temperate rain forest of Humboldt County, California. Elk River is one of the largest freshwater tributaries to Humboldt Bay, which is the second largest estuary in California. Humboldt Bay is an important economic resource for the local community including its port and marinas, recreation opportunities, the numerous shellfish rearing operations as well as providing important habitat for aquatic species.

The Elk River watershed is located in the Eureka Plain Hydrologic Unit 110.00 (Regional Water Board 2011a). It originates from the relatively steep forested headwater slopes and flows across a primarily grassland coastal plain into the central portion of Humboldt Bay, across from the bay inlet.

2.1 Delineation of the Upper Elk River Watershed

In its Peer Review Draft, the Regional Water Board (2013a) defined the reach of the Elk River watershed most impacted by excess sediment delivery (e.g., experiencing elevated rates of flooding, causing nuisance conditions and health and safety concerns). This reach is described here as the impacted reach. The Regional Water Board also delineated that portion of the 58 square mile (mi^2) Elk River watershed that drains to the impacted reach. This area is referred to as the Upper Elk River watershed (Figure 1; 44 mi^2). This document uses these terms in a manner consistent with the Regional Water Board's delineation.

The drainage area to the impacted reach includes a portion of the Lower Elk River subbasin (Figure 1). While this portion of the Lower Elk River subbasin drains to the impacted reach, it is not anticipated to contribute significant sediment loads; therefore, the upper 17 subbasins were used to calculate sediment loading in Chapter 6 (note: this is also consistent with the load estimates in all of the supporting documentation).

The Upper Elk River watershed is defined as the area draining to the downstream point at Berta Road, with the exception of upper Little South Fork Elk River (Figure 1). The Regional Water Board intends to recommend the upper Little South Fork Elk River (e.g., Headwaters Forest Reserve) for delisting in the next integrated report cycle. In addition, the Regional Water Board intends that sediment impairment in the remainder of the greater Elk River watershed (e.g., Martin Slough and most of the Lower Elk River sub-basins) be addressed under other developing and expanding programs.

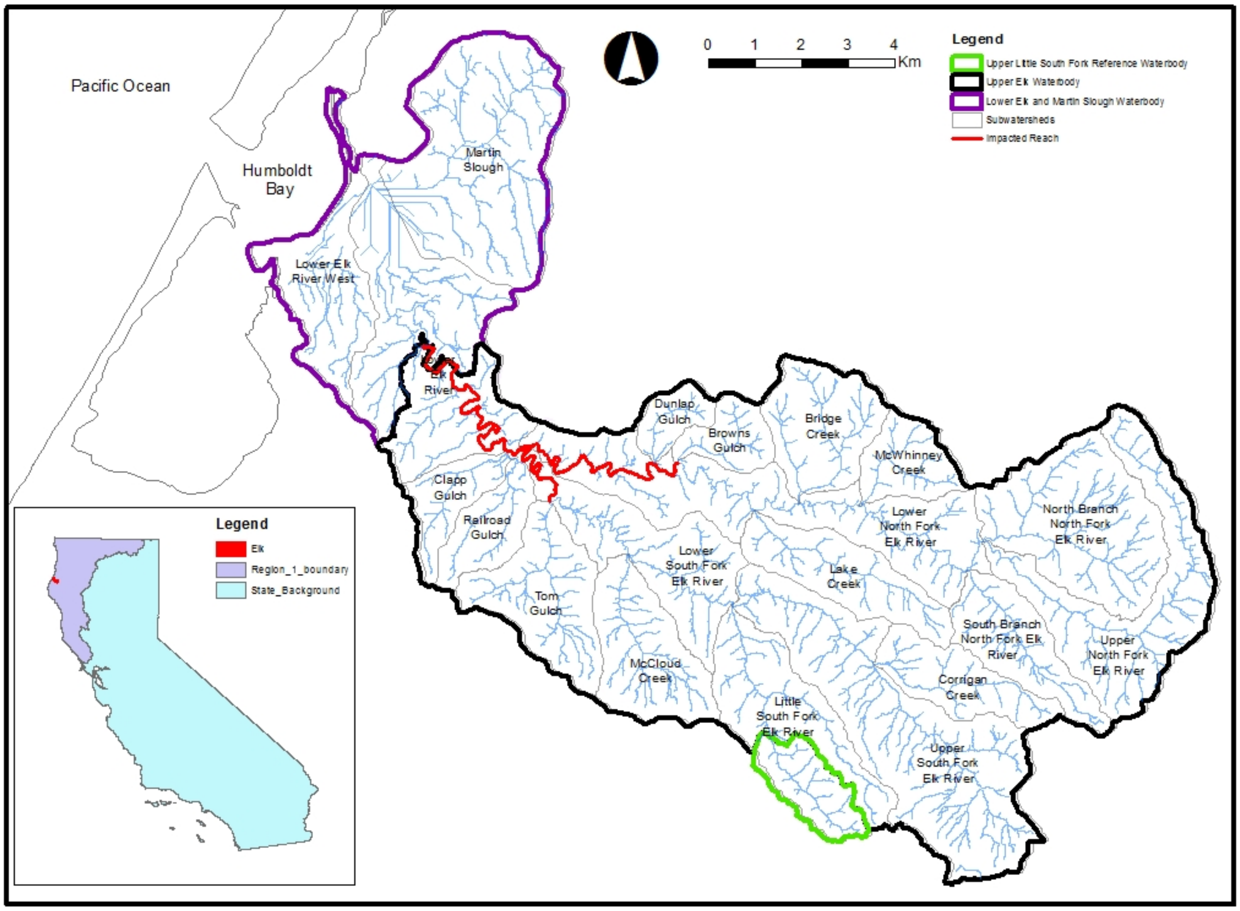

Figure 1. Delineation of the Upper Elk River watershed and impacted reach

2.2 Land Cover/Vegetation and Ownership

Five vegetation cover types, including conifer/hardwood forest, shrub, herbaceous, agricultural, and urban/bare ground, are present in the Elk River watershed (Figure 2). Urban areas are generally located near the coast, while agricultural lands include areas along the Elk River valley. Prime agricultural lands along Elk River exist mostly on the south side of the river and on the gentle slopes of the Humboldt Hill area. Cattle grazing dominates streamside land use along the lower mainstem Elk River and lower Martin Slough.

The upland areas are mostly conifer/hardwood forests with some shrub coverage. Specifically, the maritime coastal climate of the Elk River watershed supports a coniferous lowland forest community dominated by redwood (*Sequoia sempervirens*), western hemlock (*Tsuga heferophylla*), Sitka spruce (*Picea sifchensis*), grand fir (*Abies grandis*), and Douglas-fir (*Pseudotsuga menziesii*).

Un-managed redwood forests can contribute large diameter trees and branches (large woody debris [LWD]) that are delivered to or adjacent to watercourses. LWD is an important source of instream wood, which is a critical component in the formation of the complex habitat needed to support salmonid fisheries. LWD provides cover and is also an effective mechanism in metering and sorting instream sediment. When large scale mass wasting events, such as landslides and debris flows, reach a watercourse they deliver not only large volumes of coarse and fine grained sediment; but, they also deliver important LWD to the stream system (Keller and Swanson 1979; Benda et al. 2002).

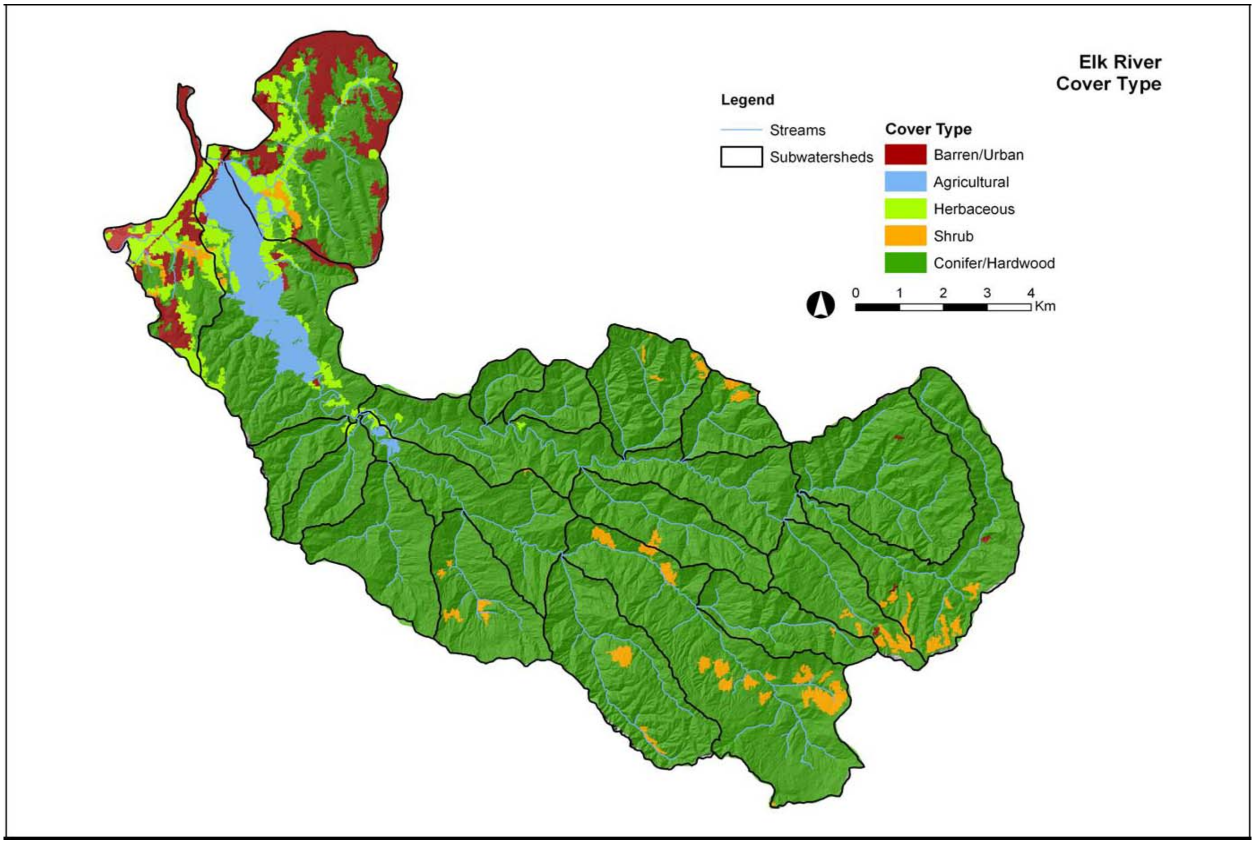

Figure 2. Land cover in the Elk River watershed (Stillwater 2007)

Figure 3 depicts land use and major land owners in the watershed and Table 2 quantifies the land use areas. HRC and Green Diamond Resource Company (GDRC) are the major private landowners in the Upper Elk River watershed. Lands owned by HRC and GDRC are primarily managed for commercial timber production (Figure 3; Table 2). HRC purchased the holdings of the former Pacific Lumber Company (Palco) in 2008 and owns the majority of land in the Upper Elk River watershed (Figure 3). GDRC land is primarily in the McCloud Creek sub-basin, draining to the South Fork Elk River. Thirteen percent of the Elk River watershed is public land, including lands owned by the Bureau of Land Management (BLM) (Figure 3; Table 2). BLM owns and operates the Headwaters Forest Reserve as an ecological refuge and for environmental education in the South Fork Elk River watershed. The lower extent of the Upper Elk River watershed includes residential (1.3 mi^2), agriculture (0.5 mi^2), or non-industrial timber lands uses (Figure 3; Table 2).

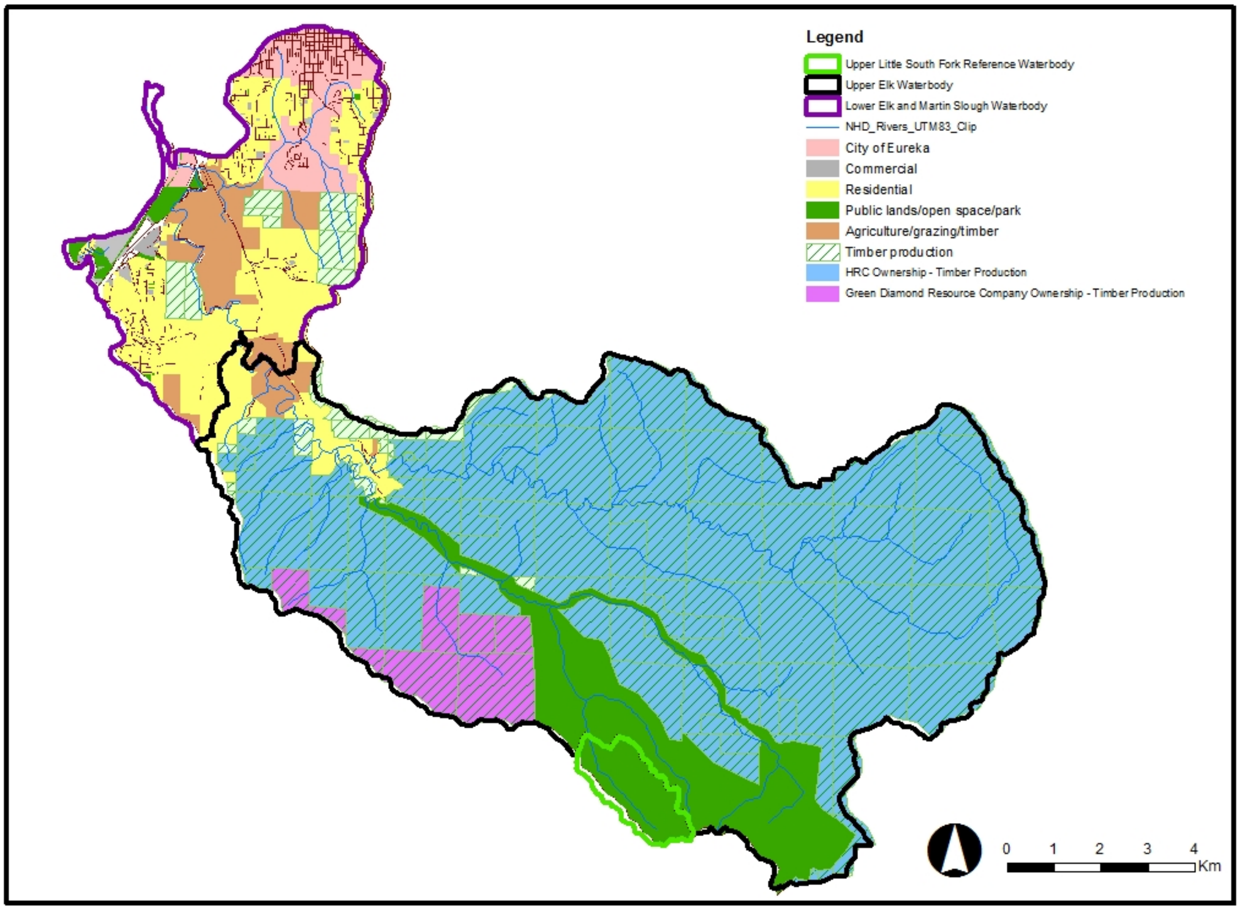

Figure 3. Land use and ownership in the Elk River watershed

Table 2. Land Use Area

Land Use Category	Elk River Watershed Area (mi^2)	Upper Elk River Watershed Area (mi^2)
Residential	6.3	1.3
City of Eureka	2.0	0.0
Timber Production	38.8	37.0
Commercial	0.3	0.0
Agriculture	2.5	0.5
Unnamed	0.1	0.0
Public	7.3	5.9
Total	**57.3**	**44.6**

In the Lower Elk River watershed, the Elk River Wildlife Sanctuary comprises 0.5 mi^2 at the mouth of the Elk River. The Wildlife Sanctuary is managed through a partnership between the California Department of Fish and Wildlife (CDFW) and the City of Eureka. Additionally, just upstream, CDFW owns and manages the 0.2 mi^2 Elk River Wildlife Area.

Ridgewood Heights is a major residential area in the Elk River watershed, characterized by both urban and rural land uses. According to the Humboldt County General Plan update, currently underway, the Martin Slough sub-basin is to be the focus of growth for the City of Eureka, potentially growing by up to 8,000 new residences. According to California Department of Fish and Game ([CDFG]; 2008) Martin Slough currently has 10 percent impervious area.

2.3 Climate and Hydrology

The Mediterranean climate of the Elk River watershed is characterized by mild, wet winters and a prolonged summer dry season. Mean surface air temperature at the coast fluctuates from 48 °F (9 °C) in January to 55 °F (13 °C) in June, with summer temperature moderated by fog. Rainfall totals are higher in the Elk River watershed than at the bay, as rainfall increases with elevation (Figure 4). Mean annual precipitation ranges from 39 inches at Eureka, located on the coast, to 60 inches in Kneeland, which is near the top of the watershed (2,657 feet above sea level) and approximately 12 miles inland from Humboldt Bay. Roughly 90 percent of the annual precipitation occurs as rainfall between October and April. Winter rainfall intensity and storm runoff are highly variable due to orographic lifting of moisture-laden, frontal air masses as they intersect the outer Coast Range.

> The extensive canopy of the redwood forest offers interception, storage, and cycling of water through evapotranspiration. Canopy intercepts the rainfall, reducing its intensity as it reaches the forest floor and decreasing the potential for accelerated soil erosion. Additionally, the interception allows rainfall to be delivered in a metered fashion over time, tempering the peak flows associated with storms. Reid and Lewis (2007) found that in second growth redwood forests, interception and evapotranspiration accounted for 20 percent of the overall rainfall, even in the largest of the measured storms.

The United States Geologic Survey (USGS), in cooperation with the California Department of Water Resources (DWR), established a stream gage station (USGS Station 11-479700) on the mainstem Elk River in 1957, just downstream of the confluence of two of Elk River's main tributaries, North Fork Elk River and South Fork Elk River (Figure 5). Railroad Gulch and Clapp Gulch, respectively, are upstream and downstream of the historic gage site. The drainage area above this gage station is 44.2 mi^2. The gage was situated where the watershed geomorphology transitions from steeper forested uplands onto the flatter coastal plain.

Monthly gage records were maintained at this USGS gage station for ten water years (WY; October through September) from 1958 to 1967 (e.g., water year 1958 starts October 1, 1957 and ends September 30, 1958). Regional Water Board staff compiled and analyzed available gage records to characterize hydrologic and hydraulic conditions during the 10-year period of record. According to the Regional Water Board's assessment, the domestic water supply beneficial use was supported and there was evidence that suggests excessive flooding did not regularly impact residents in the Upper Elk River during this period (Dudik 1998; RCAA 2003; Wrigley 2003). As such, these data offer a baseline condition on the mainstem of the Elk River, which represents a target condition. The estimated recurrence intervals of various peak flow events that are derived from these data are presented in Table 3.

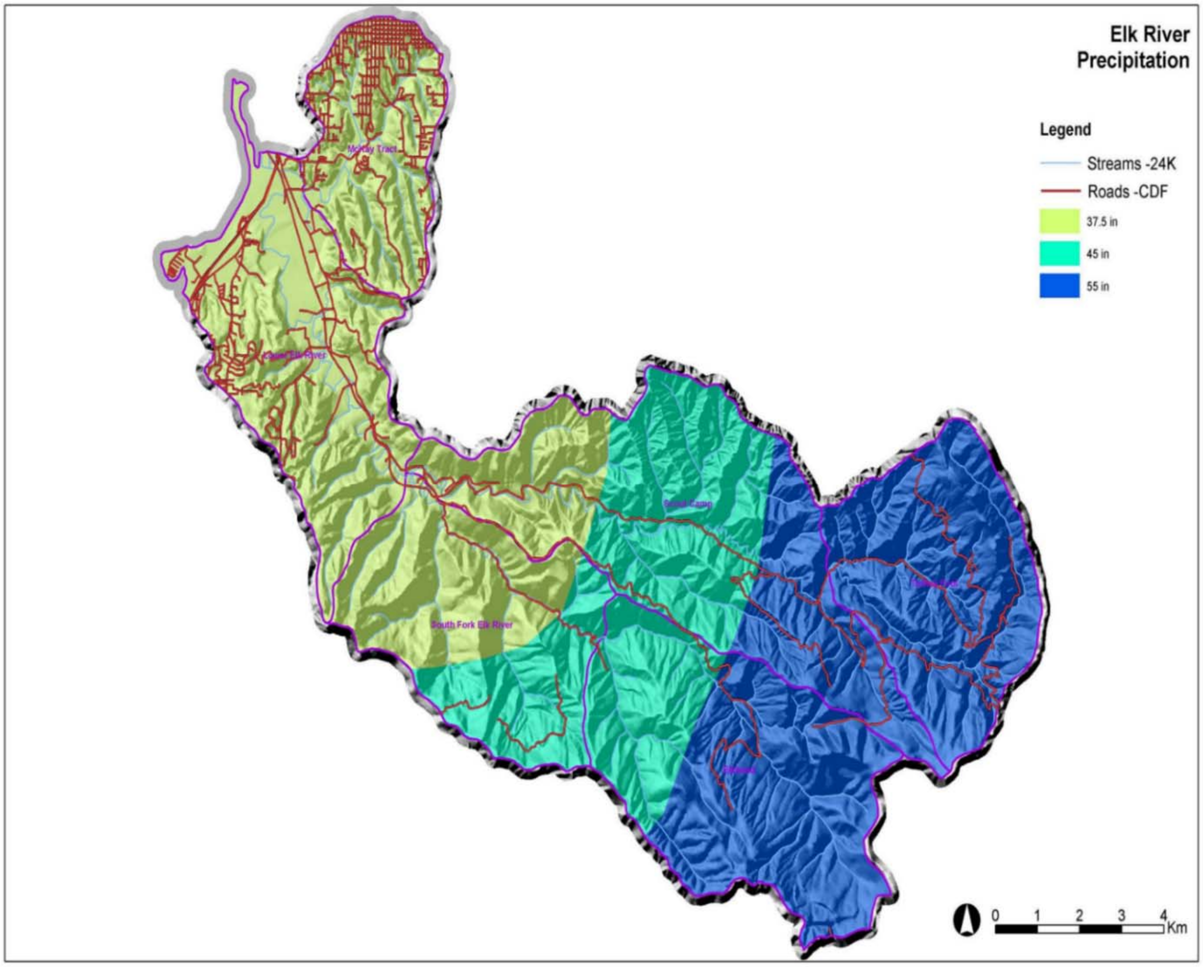

Figure 4. Annual precipitation, streams, and road network in the Elk River watershed (Stillwater 2007)

Sea level elevations have changed over time in response to climate changes and other factors. During the interglacial periods of the late Pleistocene, sea level rose and flooded the coastal portion of California numerous times, including the valley and plain of the Elk River, filling it with sediment and creating the wetland conditions associated with Martin Slough and the Lower Elk River sub-basins. During this next century, global sea levels are predicted to rise at an increasing rate due to climate change. Conservative estimates are 6 inches by 2030, 12 inches by 2050, and 36 inches by 2100 (Griggs 2012 as cited by Laird et al. 2013). Relative sea level rise rates may be greater on Humboldt Bay due to the tectonic subsidence of the land and compaction of former tidelands (Laird et al. 2013). The impacted reach passes water and sediment (see Chapter 6.2.4.4), although not efficiently enough to eliminate nuisance flooding conditions. Without restoring the hydrologic function of this reach, a back water effect could occur as a result of sea level rise, increasing the flood potential in the impacted reach.

Also associated with climate change, the future landscape condition of Elk River is likely to be influenced by increased "storminess" with the potential to trigger erosional processes that are typically episodic, including landslides. An alteration in the historic frequency and magnitude of storms has the potential to interact with natural and management-induced landscape vulnerability to increase ambient sediment loading and turbidity, as well as the frequency of floods.

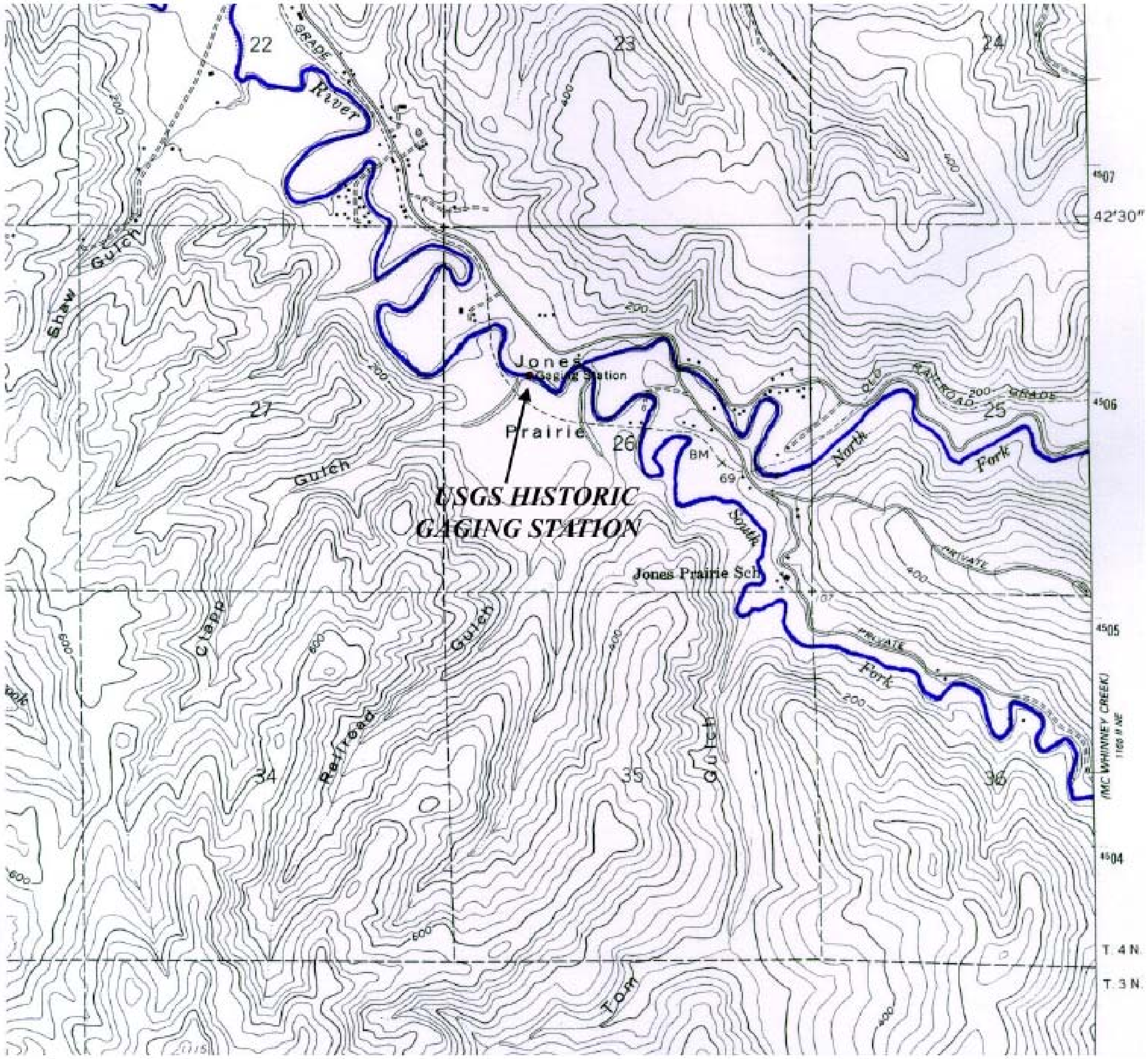

Figure 5. Location of historic USGS Gage 11-479700 (Patenaude 2004)

Table 3. Summary of Recurrence Interval at USGS Station 11-479700

Recurrence Interval (years)	Estimated Peak Flow Discharge (cfs)
1.5	2,483
2	2,713
5	3,191
10	3,456
25	3,748

2.4 Topography

The topography of the Elk River watershed shows extreme differences (Figure 6). The forested headwaters are generally steep slopes, while the grassland coastal plain is relatively flat. Hillslope gradients in the Elk River watershed have been stratified into six hillslope terrain categories based on slope gradients. Slope categories include: 0–5, 5–15, 15–35, 35–50, 50–65, and >65 percent. These categories were selected based on values that have either been mandated in regulation or have emerged as practical thresholds to aid in the identification and management of landslide hazards (Stillwater 2007).

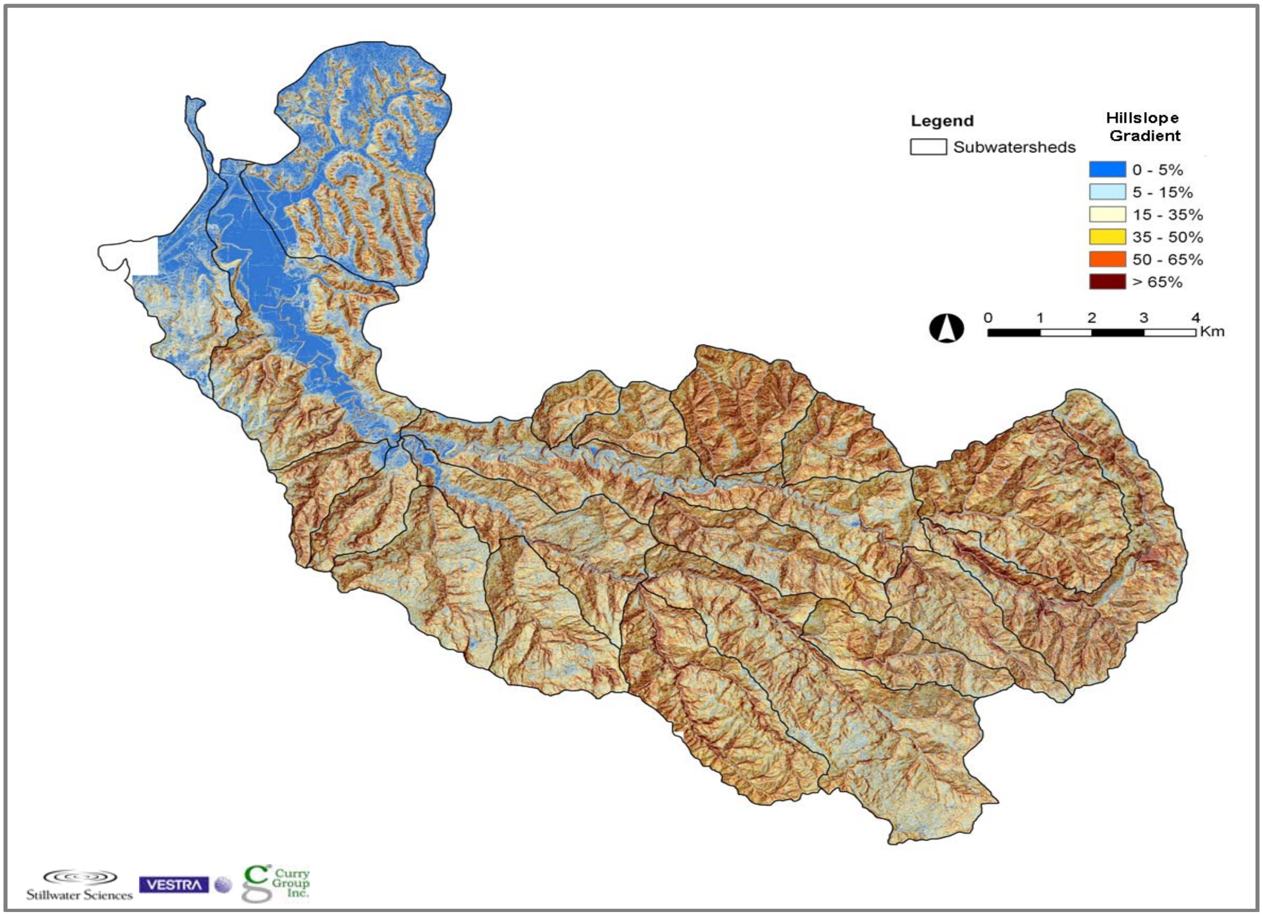

Figure 6. Slope gradients of the Elk River watershed (derived from the LiDAR-based 1-meter digital elevation model) (Stillwater 2007)

Approximately 9 percent of the watershed is in the 0-5 percent slope category, 13 percent is in the 5–15 percent slope category, 28 percent is in the 15–35 percent slope category, 20 percent is in the 35–50 percent slope category, 15 percent is in the 50–65 percent slope category, and 14 percent is in the >65 percent slope category (derived from the Light Detection and Ranging [LiDAR]-based 1-meter digital elevation model [DEM]). Figure 6 illustrates slope gradient conditions within the Elk River watershed.

2.5 Geological Setting

The Elk River watershed originates in the northwestern California Coast Range geologic province and flows northwest across the low gradient Humboldt Plain into Humboldt Bay. Elk River is unique among Humboldt Bay tributaries in that the majority of the watershed is underlain by weak Hookton and Wildcat rocks and sheared Yager rocks, allowing for rapid denudation as the drainage network incises through the formations. The long-term erosional processes in the watershed are heavily influenced by sea level and its changes due to climate, base level changes and uplift caused by tectonic movement, localized uplift due to folds and faults, and resulting channel incision in response to uplift.

The watershed is comprised primarily of geologically recent and erodible geologic formations (Figure 7). The dominant geologic unit is the Wildcat Group, which underlies nearly 60 percent of the Elk River watershed. The Wildcat Group typically consists of poorly to moderately consolidated siltstone and fine-grained silty sandstone that weather to become granular, non-cohesive, non-plastic, clayey silts and clayey sands (Marshall and Mendes 2005). The Franciscan Complex Central Belt underlies approximately 5 percent of the Elk River watershed, while the Yager terrain makes up nearly 13 percent of the watershed (Stillwater 2007). The sandstone-dominated rock units commonly form cliffs and exert local base level control where streams have cut down through younger, less resistant deposits upslope.

Ridge crests in the western part of the Elk River watershed are undifferentiated shallow-water marine and fluvial deposits (gravel, sand, and silt) of the Hookton Formation. These deposits and similar Quaternary marine and river deposits consist of poorly consolidated sand and gravel that are prone to shallow landsliding on the steep hillslopes. Combined, these deposits underlie 17 percent of the watershed and the remaining 7 percent is Quaternary alluvium, dune sand deposits. These are poorly consolidated and have relatively high infiltration rates, but are extremely erodible if vegetative cover or runoff patterns are altered.

The nature and predominance of individual geologic formations underlying a landscape is a major factor of sediment delivery to stream channels. The rocks that underlie the landscape form the source material for the in-channel substrate, including the presence or absence of spawning gravels. Historical observations indicate that both the North and South Forks of the Elk River were gravel bedded streams, with cobble present in lower South Fork Elk River (RCAA 2003). Small gravel and sand were observed in the 1960s by USGS in the mainstem Elk River (Patenaude 2004). Additionally, gravel was apparently mined from the mouth of Elk River to build streets in what is now Eureka (Winzler 2002). Current stream bed conditions are substantially degraded by fine sediment, which coats the stream bed and banks. Stream substrate is very fine, potential spawning gravels are significantly embedded, and pool depths have been decreased by sediment filling (Regional Water Board 2013a).

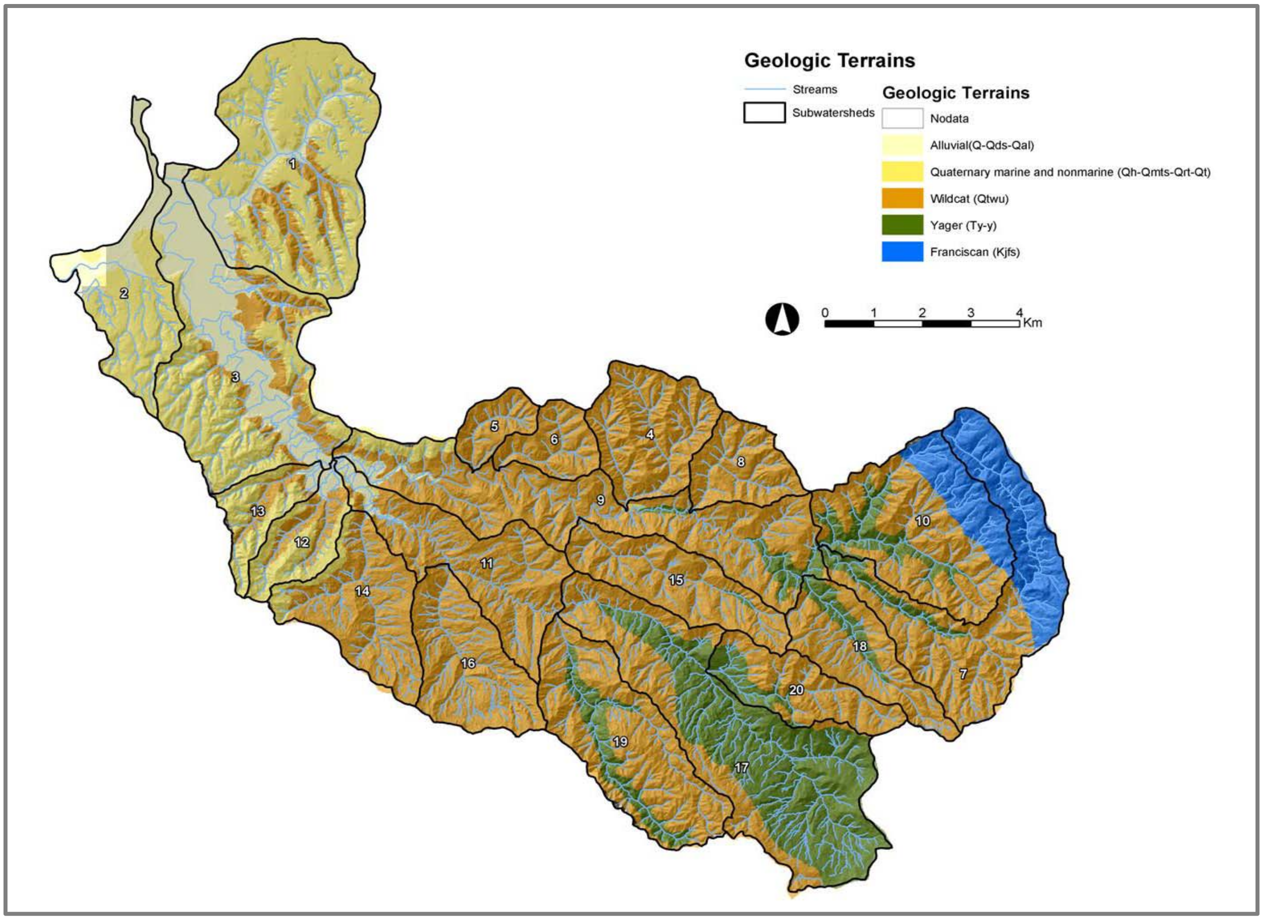

Figure 7. Geologic formations of the Elk River watershed (Stillwater 2007)

2.5.1 Soil Characteristics

The redwood forest is a source of much organic material, in the form of needle and leaf drop (duff), limbs, and tree fall. All of these sources of organic material contribute to soil formation, protect the soil from erosion, and ultimately support networks of microorganisms. These microorganisms play crucial roles in nutrient cycling, including fixing atmospheric nitrogen into the soil, enhancing the fertility of the forest and contributing to forest health. The organic rich soil supports shrubs and herbaceous understory where other site conditions allow. This understory layer in combination with duff, provides a virtual vegetative blanket over the unmanaged portions of redwood forests, thereby stabilizing the soil.

2.5.2 Tectonics

The Mendocino Triple Junction, just offshore of Cape Mendocino in northern California, is where the Pacific Plate, the North American Plate, and the Gorda Plate meet. The Gorda Plate is the southern-most portion of the Cascadia Subduction Zone and is subducting beneath the North American Plate. The Little Salmon Fault Zone is near the headwaters of Elk River. This zone is a series of northwest-trending thrust faults associated with the regional compression of the Cascadia Subduction Zone and contributes to the regional uplift of the Elk River watershed. The area is also affected by the convergence between the northwest-trending San Andreas Fault with the Cascadia Subduction Zone at the

Mendocino Triple Junction. Additionally, there are likely smaller, unmapped faults that influence localized uplift.

Subsidence of the baylands in the Elk River flood plain is occurring due to the down-warping related to tectonic activity and to compaction and diking of the lower portions of the watershed. Uplift, caused by tectonic movement, is balanced by erosion via channel incision and steep slopes. Additionally, high uplift rates result in steep slopes and shallow soil. Figure 8 presents the relationships between tectonic uplift, subsidence, and sea level rise. The net effect of this relationship is:

- Steeper slopes that affect soil stability and landslide frequency;
- High rates of channel denudation;
- Steeper stream gradients with higher energy profiles in the upper watershed;
- Lower stream gradients and elevations creating a longer depositional area and length of stream under tidal influence in the lower reaches; and
- Back water effect from sea level rise, which affects the flood potential in the impacted reach.

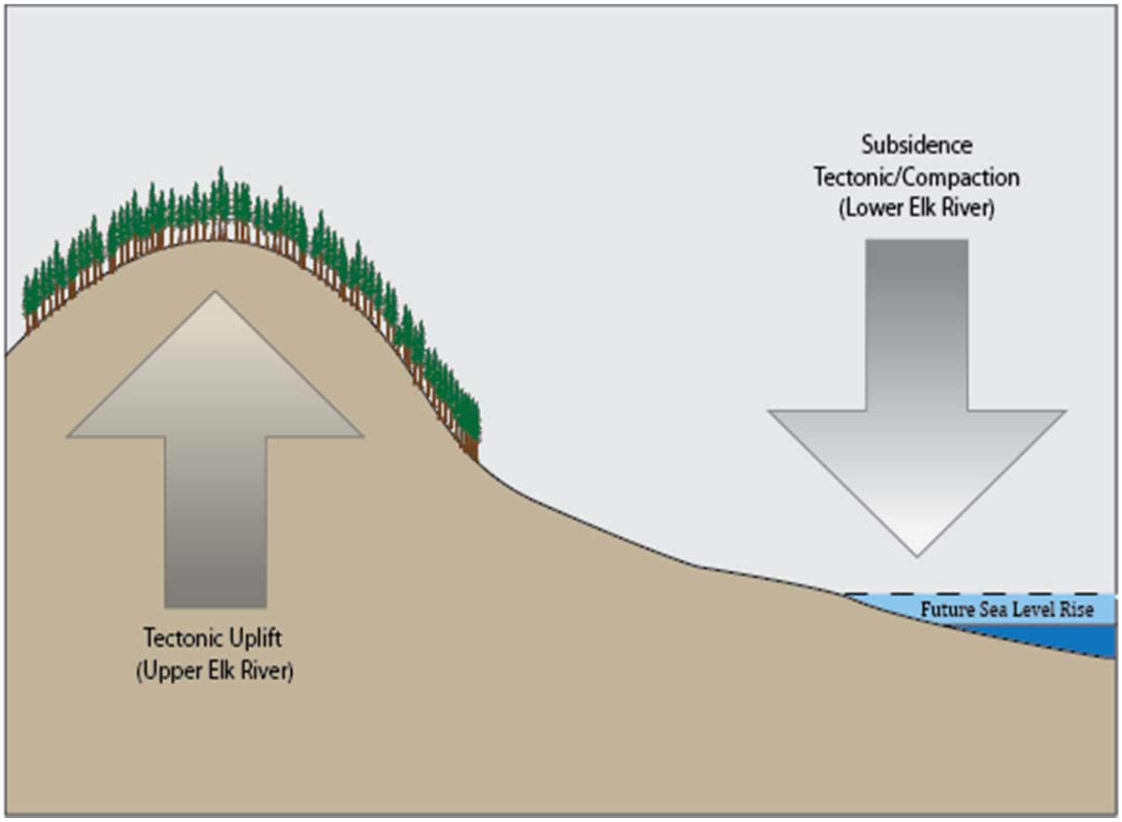

Figure 8. Relationship of tectonic uplift, subsidence, and sea level rise

Chapter 3 – Regulatory Setting

The regulatory setting influencing restoration of sediment-related beneficial uses in the Elk River watershed includes federal, state, and local regulatory requirements. The North Coast Regional Water Board is one of nine regional water boards that function as part of the California State Water Board system within the California Environmental Protection Agency. The Regional Water Board is the state agency responsible for the protection of water quality in the Elk River watershed. The Regional Water Board implements the Porter Cologne Act[5], which is the state law governing water quality protection activities as authorized by the State Legislature. The Regional Water Board, in part, is also tasked with implementing the requirements of the federal CWA.

3.1 Impaired Waters

The State Water Board, with Regional Water Board input, periodically identifies waters that are not meeting WQS. The State Water Board is required, under Section 303(d) of the federal CWA, to develop a list of those waterbodies in California where technology-based effluent limits or other legally required pollution control mechanisms are not sufficient or stringent enough to meet the WQS applicable to such waters. This list, referred to as the 303(d) list also identifies the pollutant/stressor causing the impairment, and establishes a prioritized schedule for developing a control plan to address the impairment.

Placement of a waterbody on this list generally triggers development of a pollution control plan, referred to as a TMDL. In California, the authority and responsibility to develop TMDLs rests with the nine regional water boards. The TMDL process leads to a “pollution budget” which quantifies the pollution reductions necessary to restore the health of a polluted body of water. Specifically, a TMDL is the calculation of the maximum amount of a pollutant that a waterbody can receive and still meet WQS and provide supportive conditions for the beneficial uses of water. EPA has federal oversight authority and may approve or disapprove TMDLs developed by the state. There are a number of specific components that must be included in a TMDL in order for EPA to approve it.

Consistent with recommendations by the Regional Water Board, Elk River was added to the 303(d) list in 1998. The listing was based on evidence of excessive sedimentation/siltation loads from land management activities in the upper portion of the watershed. Water quality problems cited under the listing include the following:

- Sedimentation and threat of sedimentation;
- Impaired domestic and agricultural water quality;
- Impaired spawning habitat;
- Increased rate and depth of flooding due to sediment; and
- Property damage.

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[5] Water Code §§ 1300 et seq.

The Elk River, from its confluence with Humboldt Bay to its tributary headwater streams has continued to be identified as an impaired waterbody on subsequent 303(d) lists, including the latest list approved by USEPA in 2012.

3.2 Waste Discharge Requirements and Cleanup and Abatement Orders

Current management of the Elk River watershed for timber harvest is conducted under several permits issued by the Regional Water Board. These permits or other regulatory mechanisms are described below by owner. Appendix 2-C (History of Regional Water Board Regulatory and Non Regulatory Actions in the Upper Elk River Watershed) of the Peer Review Draft (Regional Water Board 2013a) provide additional information on past WDRs.

3.2.1 Humboldt Redwood Company

HRC currently operates under Order No. R1-2006-0039, an Elk River watershed-specific WDR issued by the Regional Water Board in 2006 (Regional Water Board 2006a). Treatment of road-related controllable sediment discharge sources (CSDS) have been conducted under CAO Nos. R1-2004-0028 (for the South Fork and Mainstem Elk River) and R1-2006-0055 (for the North Fork Elk River). All Orders that pertain to HRC's current activities were originally issued to Palco and amended by Order No. R1-2008-0100 to reflect HRC's ownership of the former Palco holdings. These orders were developed to compliment the HCP that covers the HRC properties (Palco 1999).

3.2.2 Green Diamond Resources Company

GDRC currently operates in the South Fork Elk River watershed under two WDRs. In 2010, GDRC was issued a WDR (Order No. R1-2010-0044) by the Regional Water Board for discharges related to road management and maintenance activities conducted ownership-wide. Subsequently, in 2012, a WDR (Order No. R1-2012) was issued for discharges related to GDRC's forest management activities ownership-wide. The 2012 forest management WDR relies on the prescriptions contained within GDRC's 2012 updates to its South Fork Elk River Management Plan. These orders were developed to compliment and make enforceable by the Regional Water Board portions of the AHCP (2007) that covers the GDRC properties.

3.2.3 Bureau of Land Management

BLM's management of the Headwaters Forest Reserve does not include commercial timber harvest activities and currently is not under any ownership-wide WDR. The primary activities conducted by BLM within the Headwaters Forest Reserve are road decommissioning and forest restoration under the Headwaters Forest Reserve Resource Management Plan.

3.2.4 TMDL Analysis and Implementation

This document confirms several important findings, which can be addressed through TMDL analyses and implementation. Specifically, existing control mechanisms are not correcting the sediment impairment and the sediment source analysis confirms that the impairment continues to persist and worsen. It is also important to consider that the CWA requires a TMDL when waters are impaired and a TMDL can be adopted as a single action if a single regulatory mechanism will attain beneficial uses. However, EPA has a new TMDL vision[6] that allows for an alternative restoration plan in lieu of a TMDL. As noted previously, this document provides the technical basis for a sediment TMDL and/or a WDR. It is a synthesis of all readily available information, which can be used to calculate a TMDL, support development of an alternative restoration plan, and/or revise the WDRs to ensure they provide reasonable assurance that the impairment will be corrected through their implementation.

3.2.5 Waste Discharge Requirements Under Development

Regional Water Board staff is currently developing revised WDRs for timberland owners in the Elk River watershed. The information and findings of the sediment analysis presented in this report are developed to inform such revisions and the development of additional permits, as necessary. The revision of WDRs is further discussed in Chapter 8.

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[6] http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/programvision.cfm

Chapter 4 – Desired Watershed Conditions

This chapter includes a description of the water quality standards (WQS) applicable to the Elk River watershed (Regional Water Board 2011a). By defining instream and hillslope water quality indicators (WQIs), it also describes the desired watershed conditions that represent a functioning hydrologic and ecologic system. Collectively, these are presented as numeric targets and are appropriate for inclusion in the TMDL and WDR(s). The narrative water quality objectives (WQOs) for sediment are interpreted by deriving numeric instream WQIs and target conditions from the scientific literature and other agencies. Attainment of the instream targets is further interpreted by deriving numeric hillslope WQIs and target conditions (also obtained from scientific literature and documentation from other agencies). The goal condition described by the narrative WQOs, numeric instream targets, and numeric hillslope targets is a dynamic equilibrium (Chapter 6.1.1) in which WQS are attained, including supporting conditions for beneficial uses and abatement of flooding risks in the impacted reach[7] (Figure 9).

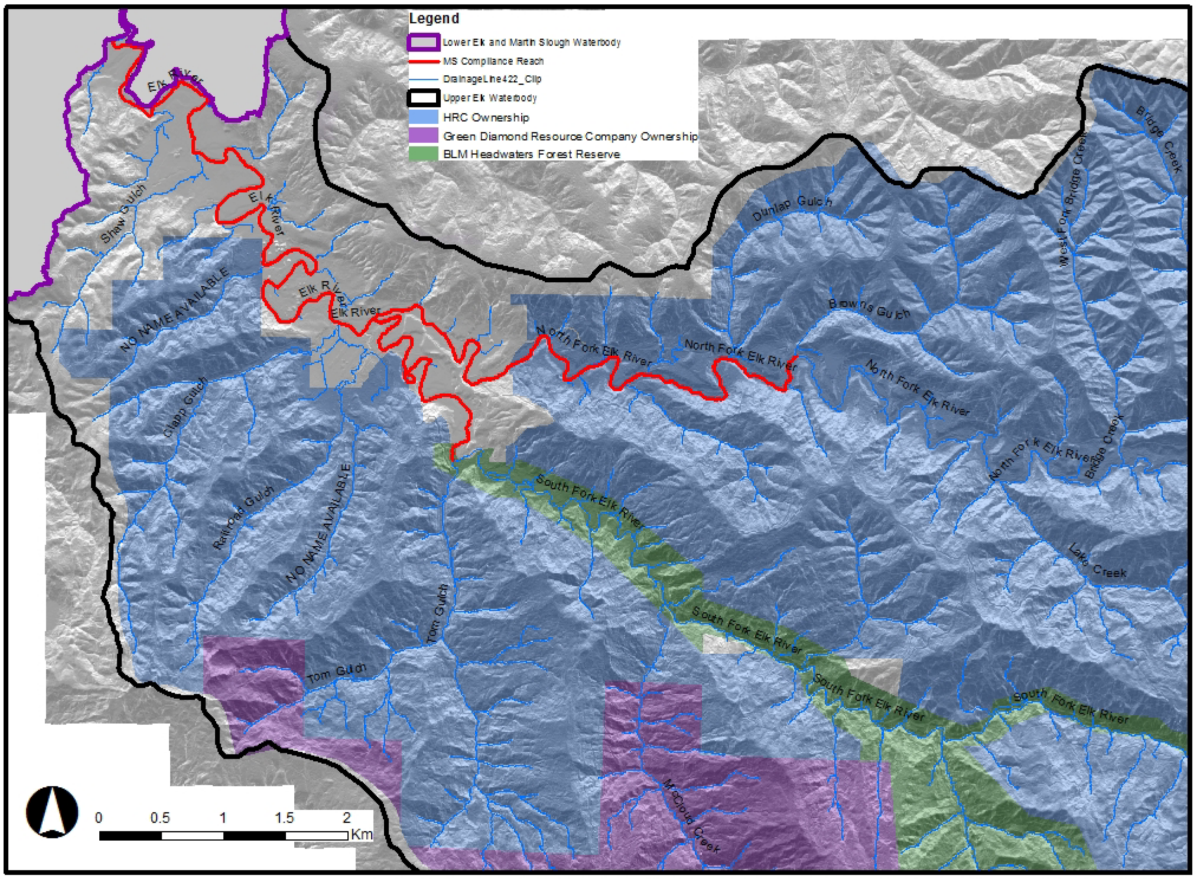

Figure 9. Upper Elk River watershed impacted reach

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[7] The impacted reach extends from the confluence of Browns Gulch on North Fork Elk and Tom's Gulch on South Fork Elk downstream to the mainstem Elk River to Berta Road.

The desired watershed conditions and numeric targets are based on the current understanding of recovery potential and the conditions necessary to support beneficial uses. Under the Regional Water Board's proposed implementation strategy, these conditions and targets are expected to be continuously evaluated as part of the adaptive watershed management approach. This chapter can be considered as the initial starting point for the adaptive management process.

4.1 Water Quality Standards

WQS are adopted by the Regional Water Board to protect public health and welfare, enhance the quality of water, and serve the purposes of the federal CWA (as defined in Sections 101(a)(2), and 303(c) of the CWA). WQS, as described in the Basin Plan (Regional Water Board 2011a), consist of 1) designated beneficial uses, 2) the WQOs to protect those beneficial uses, and 3) implementation of the Federal and State policies for antidegradation. In accordance with the federal CWA, TMDLs are set at a level necessary to achieve applicable WQS. This chapter describes the state WQS for the Elk River watershed.

4.1.1 Beneficial Uses

Beneficial uses of water (beneficial uses or uses) are those uses of water that may be protected against quality degradation such as, but not limited to, domestic, municipal, agricultural supply, industrial supply, power generation, recreation, aesthetic enjoyment, navigation, preservation and enhancement of fish, wildlife and other aquatic resources or preserves.

Beneficial uses of water in the Elk River watershed include:

- **Municipal Water Supply (MUN)**
- Non-Contact Water Recreation (REC-2)
- **Agricultural Supply (AGR)**
- Commercial or Sport Fishing (COMM)
- Industrial Service Supply (IND)
- **Cold Freshwater Habitat (COLD)**
- Industrial Process Supply (PRO)
- Wildlife Habitat (WILD)
- Groundwater Recharge (GWR)
- **Rare, Threatened, or Endangered Species (RARE)**
- Freshwater Replenishment (FRSH)
- **Migration of Aquatic Organisms (MIGR)**
- Navigation (NAV)
- **Spawning, Reproduction, and/or Early Development (SPWN)**
- Hydropower Generation (POW)
- Aquaculture (AQUA)
- **Water Contact Recreation (REC-1)**
- Estuarine Habitat (EST) (applies only to estuarine portion of the watershed)
- Flood Peak Attenuation/Flood Water Storage (FLD)
- Wetland Habitat (WET)
- Water Quality Enhancement (WQE)

As noted above, there are many beneficial uses of the Elk River watershed. The beneficial uses of primary focus in this document for the Upper Elk River include: domestic drinking water (MUN) and agricultural (AGR) water supplies and salmonid habitat (including cold freshwater habitat [COLD]; rare, threatened and endangered species [RARE]; migration of aquatic organisms [MIGR]; spawning, reproduction, and/or early development [SPWN]). These are shown in bold in the list above. Water contact recreation (REC-1) is also a key beneficial use in the watershed; however, the other bolded beneficial uses represented more sensitive uses. Therefore, protection of the water supply and salmonid habitat uses are expected to adequately protect REC-1, as well.

4.1.2 Sediment-Related Water Quality Objectives

Basin Plans contain both numeric and narrative WQOs to support beneficial uses. These WQOs specify limitations on certain water quality parameters that are not to be exceeded. The sediment-related objectives pertinent to the Elk River watershed are:

- **Suspended material**: Waters shall not contain suspended material in concentrations that cause nuisance[8] or adversely affect beneficial uses.
- **Settleable material**: Waters shall not contain substances in concentrations that result in deposition of material that causes nuisance or adversely affect beneficial uses.
- **Sediment**: The suspended sediment load and suspended sediment discharge rate of surface waters shall not be altered in such a manner as to cause nuisance or adversely affect beneficial uses.
- **Turbidity**: Turbidity shall not be increased more than 20 percent above naturally occurring background levels. Allowable zones of dilution within which higher percentages can be tolerated may be defined for specific discharges upon the issuance of discharge permits or waiver thereof.

All four of these WQOs are associated with the salmonid habitat beneficial uses of concern (COLD, MIGR, RARE, and SPWN). In addition, the turbidity, suspended sediment, and settleable material WQOs directly protect the water supply uses (MUN and AGR). WQOs are either explicitly or implicitly designed to prevent nuisance conditions.

4.1.3 Controllable Water Quality Factors

Porter Cologne and the Basin Plan also contain a provision for “controllable water quality factors” as described below:

> Controllable water quality factors shall conform to the water quality objectives contained herein. When other factors result in the degradation of water quality beyond the levels or limits established herein as water quality objectives, then controllable factors shall not cause further degradation of water quality. Controllable water quality factors are those actions, conditions, or circumstances resulting from man's activities that may influence the quality of the waters of the State and that may be reasonably controlled.

If controllable water quality factors are affecting the support of WQS, actions must be taken to bring those factors into conformance with Basin Plan objectives such that beneficial uses of water are maintained and restored. This provision specifically supports the development of hillslope WQIs, as described below.

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[8] CWC § 13050(m) defines nuisance to mean anything which meets all of the following requirements: (1) Is injurious to health, or is indecent or offensive to the senses, or an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property. (2) Affects at the same time an entire community or neighborhood, or any considerable number of persons, although the extent of the annoyance or damage inflicted upon individuals may be unequal. (3) Occurs during, or as a result of, the treatment or disposal of waste.

4.1.4 Antidegradation Policies

There are two antidegradation policies that are applicable to all waters in the North Coast Region — a State policy and a federal policy. The State antidegradation policy is titled the *Statement of Policy with Respect to Maintaining High Quality Waters in California* (Resolution 68-16). The federal antidegradation policy is found at title 40, Code of Federal Regulations, Section 131.12. Both policies are incorporated in the Basin Plan for the North Coast Region (Regional Water Board 2011a). Although there are some differences in the state and federal policies, both require that whenever surface waters are of higher quality than necessary to protect the designated beneficial uses, such existing quality shall be maintained unless otherwise provided by the policies. High quality waters are defined by the highest water quality existing since 1975. The Elk River watershed is described by CDFW as a critical habitat for endangered coho, which infers a historic presence of clear, cold water, an adequate area of gravel-sized substrate for spawning, and adequate channel complexity. Nonetheless, both the geologic setting (Chapter 2) and results of the sediment source analysis (Chapter 6) suggest that since 1975 sediment-related conditions in the Upper Elk River are unlikely to have been of higher quality than necessary to protect beneficial uses.

4.1.5 State Policy for Control of Nonpoint Sources of Pollution

The 2004 State Water Board *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program* (NPS Policy) establishes requirements for both nonpoint source dischargers and Regional Water Board regulation of those dischargers (State Water Board 2004). The NPS Policy requires that the Regional Water Board use its administrative tools (e.g., WDR, waiver of WDRs, and prohibition) to address all nonpoint source discharges of waste and ensure compliance with all nonpoint source (NPS) pollution control requirements. In this way, the NPS Policy "provides a bridge between the NPS Program Plan and the [State Water Board] Water Quality Enforcement Policy" (State Water Board 2004).

Following is a summary of the three administrative tools required to control nonpoint sources of pollution, as reaffirmed in the 2004 State NPS Policy.

- **Waste Discharge Requirements (WDRs):** WDRs are the Regional Water Board's water quality control permits that may include effluent limitations or other requirements that are designed to implement applicable water quality control plans, including designated beneficial uses and the WQOs established to protect those uses and prevent the creation of nuisance conditions.
- **Waivers of WDRs:** The requirements for a discharger to apply for WDRs may be waived for a specific discharge or a specific category of discharge if the Regional Water Board determines that the waiver is consistent with the Basin Plan and is in the public interest. All waivers are conditional and may include specific management practices that must be implemented to be eligible for the waiver. Waivers may be terminated at any time and may not exceed five years in duration without being renewed through a public Regional Water Board adoption hearing.
- **Prohibitions:** The Regional Water Board may prohibit discharges of waste or types of waste through WDRs or through waste discharge prohibitions amended into the

> Basin Plan. The prohibition may be made conditional by including specific conditions under which application or enforcement of the prohibition may be waived. Regional Water Boards may also use conditional Basin Plan prohibitions as the primary administrative tool for implementation programs. For example, in cases where a Regional Water Board desires to prohibit discharges unless certain procedural or substantive conditions are met.

4.2 Numeric Targets: Water Quality Indicators

Numeric targets are used as a means to express narrative WQOs. Specifically, numeric targets offer a means to evaluate attainment of WQOs and the beneficial uses they protect. They are a mechanism to document measureable improvement. However, it is important to note that numeric targets are not WQOs; they are not enforceable unless they are incorporated into future permitting or regulatory actions (it is anticipated that a subset of the numeric targets identified below could eventually be incorporated into permits). If targets are incorporated into permits (and therefore become enforceable), it must be understood that not all of the proposed numeric targets may be attainable within the life of a permit. Any change from pre-permit condition toward the numeric targets will be considered as making measurable progress.

Numeric targets are useful in linking hillslope and instream conditions to narrative WQOs and associated beneficial uses. The numeric targets selected are based on Instream WQIs and Hillslope WQIs. The proposed numeric targets represent a conceptual linkage between hillslope erosion and aquatic ecosystem functioning, including the physical, chemical, and biological components of the system that support achievement of WQOs and protection of beneficial uses and prevention of nuisance flooding conditions.

The Instream WQIs describe a condition under which water quality and hydrogeomorphic features in the Upper Elk River stream network are able to meet the following three instream goals:

1. Support salmonids[9] throughout their historical range;
2. Support the use of surface water for domestic drinking water and agricultural water supplies, particularly within the impacted reach; and
3. Contain historic bankfull discharges[10] within the bankfull channel, particularly within the impacted reach.

The first two instream goals above tie directly to the salmon habitat and water supply beneficial uses, respectively. The third goal is associated with prevention of nuisance flooding conditions, which is another critical problem in the watershed (Chapter 5.2.2). These goals (and, therefore, the associated beneficial uses) are linked to the specific Instream WQIs in Table 4 below.

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[9] Coho salmon (*Oncorhynchus kisutch*), Chinook salmon (*Oncorhynchus tshawytscha*), Coastal cutthroat trout (*Oncorhynchus clarki clarki*) and Steelhead (*Oncorhynchus mykiss*) are historically present in the Elk River watershed.

[10] Bankfull discharge is the discharge at which water fills the channel completely and the water surface is level with the floodplain.

While the Instream WQIs focus on conditions within the stream channel, it is also important to manage and improve conditions on the land. The Hillslope WQIs collectively describe hillslope conditions that are expected to support attainment of beneficial uses. This is accomplished by reducing the signature left on the landscape from land use activities. The Hillslope WQIs describe conditions in which sediment delivery, hydrology, and large woody debris recruitment supports attainment of beneficial uses, as measured by trends in the Instream WQIs.

4.2.1 Instream Water Quality Indicators

Instream WQIs offer a suite of numeric targets to strive for and to gage improvements in the aquatic system. Table 4 identifies the Instream WQIs, their associated instream goal, numeric target, and the associated stream type.

Table 4. Summary of Instream Water Quality Indicators

Instream Indicator	Instream Goal[a]	Numeric Target[b]	Associated Stream Type
Bankfull Channel Capacity	FLOOD	Channel cross-sectional area sufficient to contain the historic bankfull discharges (see Regional Water Board 2013a for additional details): Upper Mainstem = 2,250 cfs Lower North Fork, = 1,172 cfs Lower South Fork = 1,015 cfs	Area of impacted reach near confluence of North and South Forks Elk River
Chronic turbidity[c]	SALMON; SUPPLY	Clearing of turbidity between storms to a level sufficient for salmonid feeding and surface water pumping for domestic and agricultural water supplies	Salmonid feeding—watershed-wide historic range of salmonids Water supplies—Impacted reach

[a] Key for Instream Goals:

SALMON: Support salmonids throughout their historical range in Elk River

SUPPLY: Support the use of surface water for domestic drinking water and agricultural water supplies

FLOOD: Contain flood flows within the channel bankfull discharge

[b] cfs = cubic feet per second.

[c] The WQO for turbidity also applies (Chapter 4.1.2). The Instream WQI target condition focuses specifically on turbidity values between storms.

Numerous sediment TMDLs throughout the region[11] adopted by the Regional Water Board and EPA include Instream WQIs generally focusing on salmonid habitat quality, including sediment composition, pool depth and frequency, and large wood. While this report does not identify WQIs for those aspects of salmonid habitat, they may be adapted from a variety of applicable studies as well as compilations of habitat indictors and values including the *Desired Salmonid Freshwater Habitat Conditions for Sediment-Related Indices* (Regional Water Board 2006b; see also Regional Water Board 2013a, 2013b for additional rationale on use of specific indicators) as well as the National Oceanic and Atmospheric Association (NOAA) National Marine Fisheries Service *Properly Functioning Conditions Matrix* as incorporated into the HCP for HRC (USFWS and Calfire 1999).

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[11] See http://www.waterboards.ca.gov/northcoast/water_issues/programs/tmdls/ for sediment TMDLs adopted by the Regional Water Board.

Monitoring of Instream WQIs is critical to track progress toward attainment of WQOs and beneficial use protection and restoration. The stewardship process can assist with coordinated monitoring to track progress towards improved salmon habitat and water supplies and elimination of nuisance conditions. Evaluation of the proposed instream numeric targets or other salmonid habitat-related targets through special studies is encouraged and could be guided by the proposed watershed stewardship group, as appropriate. Similarly, landowners could propose alternative targets, as determined necessary, through monitoring and adaptive management.

The Peer Review Draft (Regional Water Board 2013a) provides examples of instream targets that are under consideration for further development and refinement as part of the adaptive management stewardship program in Elk River. The development of salmonid habitat-related targets specific to Elk River should include the following considerations: (1) commonly applied salmonid habitat indices have been developed primarily for Franciscan geology (produces both course and fine sediment) and Elk River is primarily comprised of Wildcat Formation (producing primarily fine sediment); (2) sediment-related habitat needs vary by life stage for different salmonid species and specific values may not be appropriate for all life stages of all salmonids; and (3) generally with WQIs, a series of environmental conditions that trend toward the target conditions is the desired condition. When evaluated comprehensively, numeric targets can demonstrate attainment of beneficial uses; however, when evaluated individually, they should be interpreted as recommendations.

4.2.2 Hillslope Water Quality Indicators

The proposed Hillslope WQIs are divided into two categories: 1) common indicators that are comparable to those adopted by the Regional Water Board in numerous sediment TMDLs or WDRs and 2) Hillslope WQIs that are specific to the Upper Elk River watershed due to its unique characteristics. A subset of these indicators may be translated to permit terms, so they become enforceable.

The Hillslope WQIs offer a suite of controllable factors that can be managed through the use of best management practices (BMPs) that can be implemented in support of beneficial use attainment (see Chapter 4.2.3 for a discussion on the application of WQIs). Table 5 depicts the Hillslope WQIs, associated instream goal, numeric target for each indicator, and the applicable area in the Upper Elk River watershed. This table includes both the common and specific indicators. The Peer Review Draft provides detail on these indicators, including applicable source categories (Regional Water Board 2013a).

It is important to recognize that these Hillslope WQIs require careful interpretation. Similar to the Instream WQIs, when evaluated comprehensively (Chapter 4.2.3), these are numeric targets that demonstrate attainment of beneficial uses; however, when evaluated individually, they should be interpreted as recommendations. They focus on the controllable sources of sediment in the watershed and their implementation is expected to support attainment of instream WQOs. The pertinent instream goals are generally associated with salmon habitat; however, meeting Hillslope WQIs is also expected to indirectly support the other instream goals through reduction in sediment loads, including fine sediments, which can reduce aggradation and turbidity (thereby improving nuisance flooding and water supply, respectively).

Table 5. Summary of Hillslope Water Quality Indicators

Indicator	Instream Goal[a]	Numeric Target	Associated Area
Common Road Indicators			
Hydrologic connectivity of roads to watercourses	SALMON SUPPLY FLOOD	100% of road segments hydrologically disconnected from watercourses	All roads
Sediment delivery due to surface erosion from roads	SALMON SUPPLY FLOOD	Decreasing road surface erosion	
Sediment delivery due to road-related landslides	SALMON SUPPLY FLOOD	Decrease in sediment delivery from new and reactivated road-related landslides	
Common Harvest-Related Indicators			
Sediment delivery due to surface erosion from harvest areas	SALMON SUPPLY FLOOD	100% of harvest areas have ground cover sufficient to prevent surface erosion	All harvest areas
Sediment delivery from open slope landslides due to harvest-related activities	SALMON SUPPLY FLOOD	Decrease in sediment delivery from new and reactivated open-slope landslides	All open slopes
Sediment delivery from deep seated landslides due to harvest-related activities	SALMON SUPPLY FLOOD	Zero increase in discharge from deep-seated landslides due to management-related activities	All deep-seated landslides
Common Management Discharge Site Indicators			
New management discharge sites	SALMON SUPPLY FLOOD	No new management discharge sites created	Across ownership
Specific Upper Elk River Watershed Indicators			
Headward incision in low order channels	SALMON SUPPLY FLOOD	Zero increase in the existing drainage network	Lower order channels
Peak flows	SALMON SUPPLY FLOOD	Less than 10% increase in peak flows in 10 years related to timber harvest	Class II/III catchments
Channels with actively eroding banks	SALMON SUPPLY FLOOD	Decreasing length of channel with actively eroding banks within sub-basins	Across ownership
Characteristics of riparian zones (i.e., 300 feet on either side of the channel) associated with Class I and II watercourses	SALMON SUPPLY FLOOD	Improvement in the quality/health of the riparian stand so as to promote 1) delivery of wood to channels, 2) slope stability, and 3) ground cover	Class I and II watercourses
Characteristics of riparian zones (150' on either side of the channel) associated with Class III watercourses	SALMON SUPPLY FLOOD	Improvement in the quality/health of the riparian stand so as to promote 1) delivery of wood to channels, 2) slope stability, and 3) ground cover	Class III watercourses

[a] Key for Hillslope Goals:

SALMON: Support salmonids throughout their historical range in Elk River

SUPPLY: Support the use of surface water for domestic drinking water and agricultural water supplies

FLOOD: Contain flood flows within the channel bankfull discharge

4.2.3 Application of Water Quality Indicators

The WQIs identified above can be applied in multiple settings. They help to:

- Establish appropriate metrics for ongoing monitoring, whether it is effectiveness monitoring, trend monitoring, or compliance monitoring;
- Determine appropriate control measures to be included in a regulatory mechanism, including specific numeric permit provisions; and
- Establish adaptive management thresholds, appropriate for identifying temporal and spatial conditions for re-evaluation of the applied control measures.

Because NPS restoration is driven by BMPs, evaluating post-implementation monitoring data against these numeric targets can show if the BMPs are adequate to restore and maintain beneficial uses. BMPs prevent sediment from entering waterways and increase the potential that instream numeric targets will be met.

Scientific methods to describe hydrogeomorphic processes are constantly expanding and evolving and, because of this, specific methodologies are intentionally not prescribed for the Instream or Hillslope WQIs. This encourages use of the latest techniques and emerging science to characterize and monitor water quality conditions. The numeric targets can be evaluated and modified through strong science within an adaptive management framework.

Attainment of the numeric targets is intended to be evaluated using a weight-of-evidence approach, because no single WQI applies at all points in the stream system and stream channel conditions are inherently variable. In other words, when considered together, the WQIs are expected to provide good evidence of the condition of the stream and attainment of beneficial uses. It is not necessary to achieve all of the numeric targets in order to meet beneficial uses.

Chapter 5 – Problem Statement

This chapter provides a description of the impairments to the pertinent beneficial uses in the Elk River watershed. It also documents other water quality concerns, such as nuisance flooding. Watershed conditions associated with these watershed impacts are also presented. The Peer Review Draft provides additional detail regarding these topics (Regional Water Board 2013a).

5.1 Watershed Conditions

The impacted reach has been identified as impaired for sediment as a result of three related factors: 1) excess sediment has been deposited on the bed, banks, and floodplain, reducing channel conveyance; 2) sediment delivered from the upper watershed is predominated by very fine particles, which can embed gravel; and 3) deposited material is readily colonized by vegetation, which anchors the material and reduces the potential for remobilization to move sediment out of the system.

There has been a history of significant sediment deposition on the bed, banks, and floodplain of Elk River, including the impacted reach (see Chapter 6.2 for a discussion of sources). This aggradation is a function of sediment volume as well as the composition of the sediment and increased opportunity for vegetation growth, as described above. Overall, this deposition has caused diminished flow conveyance resulting in frequent, extensive flooding. The flooding poses health and safety risks to residents and constitutes a nuisance condition. In addition, the sedimentation impacts salmon habitat and water supply beneficial uses.

In 1998, the Regional Water Board found that it would be too environmentally damaging to remove the sediment deposits and preferred to pursue regulatory requirements for Palco to quantify past waste discharge volumes, treat sites with the potential to discharge, and implement measures designed to prevent new sediment discharges. It was expected that the excess stored sediment would slowly scour over time; particularly as upstream sediment sources were better controlled. This process was effective at reducing sediment loads related to management activities. However, even though sediment sources have been reduced and the watershed has been subject to many large, potentially scouring storms, data indicate that the stream channel, banks, and floodplain continue to aggrade.

Specifically, morphologic changes resulting from deposition of fine sediment is described from observations by residents and staff and corroborated with cross-sectional surveys (Regional Water Board 2013a; Lewis 2013; HRC 2014). The sediment supply in the Elk River has overwhelmed the transport capacity of the river resulting in rapid channel and floodplain aggradation. Deep pools and gravel bars have been filled in and silted over, respectively. The naturally steep stream banks and low terraced floodplains that defined the former bankfull channel have been inundated with repeated deposition of excessive amounts of very fine sand and silt-sized sediment. The broader floodplain is also routinely covered in silty deposits during overbank flooding events. An in-depth analysis and discussion of these issues can be found in the Peer Review Draft (Regional Water Board

2013a). The remainder of this chapter describes various watershed conditions that contribute to the sediment problems in the Upper Elk River watershed. The combination of the environmental setting and management activities has resulted in an increased risk of erosion in the upper reaches and sedimentation in the lower reaches.

5.1.1 Environmental Setting

As described in Chapter 2, the Elk River watershed has steep upland topography, erodible geologic formations, and a restricted, low gradient river mouth. The watershed is also tectonically active, with areas of localized uplift from folds and faults resulting in channel incision. These environmental factors all contribute to the potential for erosion in the upper watershed and subsequent deposition in the lower watershed. This erosion/sedimentation pattern is exacerbated by other factors, including landslides (natural and management-related) and anthropogenic activities. Natural conditions that contribute to erosion and landslides are described in this chapter, while the role of anthropogenic activities is discussed in Chapter 5.1.2. Among these factors are hillside slopes, geology, soils, vegetation, and precipitation:

- **Hillslide Slopes:** The area underlain by the Wildcat Group is characterized by steep and dissected topography sculpted by debris sliding, and is known for high historical erosion rates from such slope failures. Shallow landslides in the Wildcat Group are commonly associated with headwall swales, inner gorges, and hollows. These are areas where weathered soil and colluvium accumulate over the loosely consolidated parent bedrock. The relatively fine-grained nature of the bedrock produces an overall low permeability rate, which increases the risk of slopes becoming saturated with water. The low permeability coupled with the natural orientation of the bedding planes (subparallel to the hillslope) make these areas prone to landsliding (Pacific Watershed Associates [PWA] 1998).
- **Geology:** The argillite-dominated rock units of the Yager terrain are typically deeply weathered and sheared and subject to deep-seated flow failures on moderate slopes (Marshall and Mendes 2005). Deep-seated landslides and earthflows enclosing blocks of component sandstone are common in the Franciscan Complex Central Belt. These blocks commonly create steep slopes and weather to soils that have little strength and are susceptible to debris slides and debris flows (Marshall and Mendes 2005). Shallow landsliding and deep-seated bedding plane failures are common in Hookton terrain (Marshall and Mendes 2005).
- **Soils:** Subsurface erosion of soil via soil pipes appears to be prevalent in Upper Elk River watershed, at least in the Wildcat Group (PWA 2000; Buffleben 2009; Regional Water Board 2013a). Soil pipes are a connection of macropores in the subsurface soils. These macropores run parallel to the soil surface and are a conduit for subsurface runoff. Timber harvesting can modify transpiration and rainfall interception, increasing the amount of subsurface flow generated during storms; and road construction and heavy equipment use can compact soils and disrupt soil pipes (Cafferata and Reid 2013). These alterations to flow through soil pipes can lead to internal erosion of the pipe, which can thus produce daylighted gullies by tunnel collapse (Buffleben 2009; Cafferata and Reid 2013; SHN 2013). The eroded

material can clog soil pipes, causing pore water pressure buildup inside the pipes that can result in landslides, debris flows, embankment failures, or of ephemeral gullies (Fox et al. 2007).

- **Vegetation:** The presence (or the absence of) and density of vegetative cover is directly related to surface and hillslope erosional processes. Increase in both surface erosion and hillslope mass wasting events can occur following alteration of the canopy cover, specifically resulting from changes in rainfall interception, and the effects of root distribution and strength on slope stability. Redwoods have an intricate network of shallow roots that contribute to the stability of steep forested slopes by maintaining the shear strength of soil mantles. Roots add strength to the soil by anchoring through the soil mass into fractures in the bedrock and laterally to root systems of adjacent trees. Root strength contributes to increasing slope stability across zones of weakness or instability (Ziemer and Swanston [1977]; Ziemer [1981], O'Loughlin and Ziemer [1982]). Additionally, roots influence the soil pipe network via providing preferential flow paths and providing stability to protect the capping layer above soil pipes from collapse (Jones 1994).
- **Precipitation:** Storm events with rainfall intensity exceeding 3-4 inches a day are considered capable of initiating landslides (Palco 2004). A 24-hour rainfall total of 4-5 inches in the Eureka area (up to approximately 2,000 feet) has an estimated return interval of 5 years (NOAA Atlas Vol XI Northern California cited in Palco 2004). Rainfall intensities exceeding 5 inches per day are rare and have only occurred 3 times between 1941 and 1998 (water years 1950, 1959, and 1997). The 24-hour rainfall total of 6.8 inches on December 27, 2002 set many records and caused widespread landslide damage and flooding.

These natural factors are documented in the Elk River watershed (Chapter 6.1.3). They are also known to exacerbate erosion and landslides. When evaluated comprehensively, the Elk River watershed has both an increased risk of erosion in the upper watershed and the potential for sedimentation in the lower reaches. These conditions make the watershed prone to sediment impairment and the potential for impairment is further aggravated by anthropogenic or management-related activities.

5.1.2 Historical Management and Land Use Activities

Documenting historical activities and events to establish a timeline provides useful context for the complex technical analyses that are presented in this document. There has been over a century of intensive anthropogenic activity in the Elk River watershed. It is important to consider this activity while simultaneously considering the loads quantified during different time periods (Chapter 6.2). This perspective provides context to evaluate the status of dynamic equilibrium in the impacted reach (Chapter 6.1.1).

From the settling of Elk River in approximately 1850, through the present, Elk River has provided water supplies to residents. Lower Elk River served as the water supply for the growing town of Eureka from 1885–1935, until the construction of Sweasy Dam on the Mad River offered an alternative supply. During that period, Elk River was stocked with fish by CDFW.

The Upper Elk River watershed has been utilized primarily for timber harvesting since the 1850s. Ranching and residential uses have dominated the valley. Between 1850 and 1870, a road was built across Elk River. The bay jetties were constructed between 1880 and 1900. Coast survey maps identify a sand spit at the mouth of Elk River that was constantly changing and an island located approximately half a mile from its mouth. Between 1910 and the mid-1940s, the sand spit grew to the north by 6,200 feet, likely in response to both increased sediment discharges and altered bay hydraulics associated with hardening and deepening.

At various times, Humboldt Bay was deepened to facilitate shipping. By the 1850s, the watershed was becoming a hub for timber production, beginning in Elk River in earnest in the 1860s. Initially, hand harvesting of old-growth redwoods proceeded slowly, yarding[12] the logs to the river by oxen and transporting them down-river in booms or rafts during high flows. Between 1860 and 1885, a log pond operated on South Fork, which would be released during high flows sending logs downstream; high tides would facilitate their transport to the Bay. The sand spit at the mouth of Elk River impeded log transport during high tides from 1880–1900.

From 1880–1935, a mill was operated on South Fork Elk River near McCloud Gulch in the town of Falk. In 1895, a rail line was constructed to Falk, connecting upper Elk River to Humboldt Bay. The primary log transportation was via railroad through the 1930s. Eventually rail lines and mills were built up North Fork, as well. Steam donkeys (steam-powered winches) were used to yard logs until the advent of early tractors in the mid-1920s. Trucks replaced railroads for transportation in the mid-1930s.

Timber operations continued in the upper watershed. In 1986, there was a marked increase in the rate and scale of timber harvesting and road construction activities with an associated increase in sediment discharges. In 1997, increased management controls were implemented in response to several new requirements associated with water quality and endangered species protections. These requirements led to the development and implementation of more robust controls aimed at reducing the land use impacts and have continued to be refined since that time.

Anthropogenic alterations in the Elk River watershed combined with the watershed setting risk factors, have led to alterations in the balance of water and sediment fate and transport. Figure 10 highlights a number of watershed land uses, management activities, and natural events that had a notable impact up through the 1950s; however, there is no sediment source analysis for this period, or stream channel cross-sectional data by which to evaluate the impacts of sediment production from the upper watershed on the downstream reaches. Therefore, Figure 10 primarily illustrates the relative timing of potentially important factors that could have had an impact on historic watershed conditions prior to 1950.

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[12] Yarding is the transport of logs from their hillslope harvest areas.

Figure 10 and Figure 11 provide background on relevant history regarding the timing and magnitude of a number of other watershed factors, which demonstrate the effects of environmental and management-related occurrences on watershed conditions from 1955–2011. Key occurrences in this period are increases in road density and clearcut equivalent acres[13], as well as a series of large storms from 1988–1997. The results of these key activities are represented in the sediment source data and loss of channel capacity (see Chapter 6). There is some indication that implementation of WDRs (including harvest rate limits) and the HCP, coupled with fewer large storms, has helped to reduce the rate of sediment production in the upper watershed from 2001-present. There is also evidence that despite reductions in sediment production, the impacted reach continues to aggrade.

While little historical quantitative data exists prior to the 1950s, the figures below illustrate the approximate timing and relative magnitude of different events and activities that might have relevance to the progression of sediment conditions in Elk River. Within the sediment source assessment (Chapter 6), land use activities in the Upper Elk River watershed allow a comparison over various periods, from 1955–2011 as well as coincident estimates of sediment production and delivery to the stream system (Chapter 6.2).

5.1.3 Water Quality Monitoring

Over the past 15 years, various stakeholder groups have been conducting instream water quality monitoring and channel form evaluations at a number of locations. Monitoring efforts undertaken by industrial landowners, residential landowners, and others such as the fisheries and resident advocacy group, Salmon Forever, have verified the impaired nature of the beneficial uses in the watershed and provided data to support the development of a TMDL for sediment in the Upper Elk River watershed. Information on and results of monitoring can be found in the Peer Review Draft (Regional Water Board 2013a). Some of these data have also been used to develop the sediment source assessment (Chapter 6.2).

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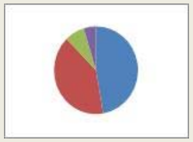
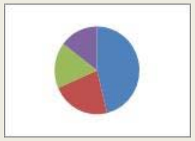
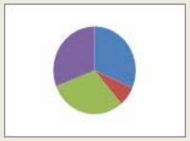
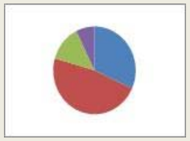
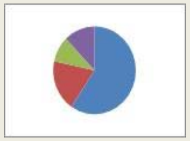
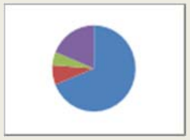
[13] The harvested acreage is normalized to clearcut equivalents based upon weighting coefficients that represent the percentage of canopy removed under the employed silvicultural method.

Figure 10. Illustrated summary of relevant history and related factors for the Elk River watershed 1800 to 2011

TMDL Analysis Period	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
Annual Clear-Cut Equivalent Harvest Rate[1] (% area harvested, acres [ac])	NF: 0.2%, 26 ac SF: 0.2%, 23 ac MS: 0.3%, 4 ac	NF: 0.6%, 81 ac SF: 0.6%, 70 ac MS: 0.9%, 13 ac	NF: 0.2%, 22 ac SF: 0.2%, 19 ac MS: 0.3%, 4 ac	NF: 3.8%, 552 ac SF: 0.5%, 130 ac MS: 2.0%, 28 ac	NF: 1.9%, 264 ac SF: 1.0%, 53 ac MS: 0	NF: 2.3%, 336 ac SF: 1.2%, 152 ac MS: 0	NF: 1.0%, 148 ac SF: 1.5%, 179 ac MS: 0.5%, 7.5 ac
Road Density (mi/mi^2)	NF: 2.2 SF: 1.7 MS: 3.3	NF: 3.3 SF: 2.6 MS: 5.0	NF: 3.8 SF: 2.9 MS: 5.6	NF: 5.9 SF: 4.5 MS: 8.7	NF: 5.9 SF: 4.5 MS: 8.8	NF: 6.3 SF: 4.8 MS: 9.4	No data available for this period.
Total sediment loading to Upper Elk River watershed (yd^3/mi^2/yr) and distribution of loading by source[2] 🟦 In-channel 🟥 Landslides 🟩 Surface erosion 🟪 Management-discharge sites	781 yd^3/mi^2/yr 	563 yd^3/mi^2/yr 	360 yd^3/mi^2/yr 	1,133 yd^3/mi^2/yr 	707 yd^3/mi^2/yr 	563 yd^3/mi^2/yr 	485 yd^3/mi^2/yr 

[1] Harvest history based upon a combination of data from Peer Review draft TMDL (Regional Water Board 2013a), California Department of Forestry and Fire Protection (CalFire), ROWD (2005), Water Quality Timber Harvest staff (2014), and HRC (2014).

[2] yd^3/mi^2/yr = cubic yards per square mile per year
In-channel Sources = Σ (low order channel incision, bank erosion, streamside landslides).
Landslides = Σ (road-related, open slope, deep-seated).
Surface erosion = Σ (harvest surface erosion, road surface erosion).
Management-discharge sites = Σ (management sediment discharge sites, skid trails, post treatment discharge).

Figure 11. Timeline of Upper Elk River land use activities and sediment loading for 1955 to 2011

5.2 Impacts in the Watershed

This chapter describes impacts to the watershed from excess sediment including downstream flooding and impaired recreation, fisheries, and water supplies, which are the basis for listing the Elk River watershed as impaired under Section 303(d) of the CWA. Numerous watershed effects have manifested due to the land use history of the watershed. These include increased peak flows, increased drainage network, altered sediment storage, decreased channel complexity, and altered sediment transport which are discussed in detail in Chapter 6.1. These effects have in turn resulted in increased aggradation, increased turbidity, and decreased summer stream flows. Such effects can be dramatic, such as in the impacted reach where ongoing aggradation and vegetative colonization of fine sediment deposits results in notable and long-lasting impacts such as downstream flooding, impaired recreation, impaired fisheries, and impaired water supplies. These impacts are described below, starting with the beneficial use impairments and followed by nuisance flooding concerns.

5.2.1 Beneficial Use Impairments

Numerous beneficial use impairments have been documented in the Upper Elk River watershed. These impairments include impacts to domestic and agricultural water supplies and impacts to recreational use of the river and degradation or loss of aquatic habitat.

5.2.1.1Domestic and Agricultural Water Supplies

Residents of Upper Elk River, including those along the North Fork, South Fork, and Mainstem, have historically relied on surface water intakes in the river for domestic and agricultural water supplies. The majority of water users in Upper Elk River have relied on an instream pump intake system, usually placed in a relatively deep and stable pool. Specifically, the North Fork has 12 surface domestic supplies, the South Fork has approximately 6-7 impacted surface domestic supplies, and the mainstem has at least 8 documented impacted domestic surface or shallow well water supplies. Many of these sources are also used for localized agriculture for gardens, crops, or small livestock operations. There are also two livestock operations further down in the impacted reach.

The discharge of sediment associated with controllable land use activities has significant adverse impacts in water quality and stream morphology, including filling of pools historically used for domestic and agricultural water supplies. Discharge of sediment has been known to result in conditions that produced tastes and odors in water supplies that were offensive to the senses. Fine sediment provides a medium to promote bacteriological growths, thus reducing the effectiveness of water disinfection for domestic water supplies. Further, elevated turbidity and fine sediment discharges were found to be responsible for limited withdrawal windows between storms and increased frequency of maintenance and replacement of pumps, hot water heaters, and water treatment facilities, as well as damage to agricultural spray equipment and surface water supply intakes.

5.2.1.2Salmon-Related Beneficial Uses

Elk River, a major tributary to Humboldt Bay, provides important freshwater habitat for anadromous salmonids and steelhead. The watershed is home to five fish species listed under the Endangered Species Act (CDFW 2014). Salmonids are identified in North Coast watersheds as the most sensitive of the native cold-water aquatic organisms. They require clear, cold, well-oxygenated water; unimpaired migratory access to spawning grounds; clean, un-embedded gravels for spawning; and food, pools, and places to hide from predators for juvenile rearing.

While there are reaches providing salmonid habitat, in general, current habitat conditions are substantially degraded by fine sediment. Stream substrate is very fine, potential spawning gravels are significantly embedded, pool depths and stream channel depths have been decreased by sediment filling (thus reducing salmonid ability to rear, avoid predators, and migrate during low-flow periods), and high suspended sediment concentrations and durations affect feeding and rearing behavior.

Newcombe and Jensen (1996) developed a *Severity of Ill Effects Index* describing the effects associated with excess suspended sediment. Data analyzed from nine Upper Elk River monitoring stations from 2003 to 2007 indicate the potential for a suite of sublethal effects ranging from 0-90 percent of the time. Sublethal effects include reduction in feeding, increased respiration, and habitat degradation. In addition, the California Department of Fish and Wildlife (CDFW; 2014) points out that pool depths continue to decline and fine sediment targets are still being exceeded 15 years after HCP implementation.

5.2.1.3 Contact and Non-Contact Recreation

As noted in Chapter 4.1.1, recreation uses are adequately protected by the attainment of water supply and salmonid habitat uses. Impacts to recreation uses are described in this section to ensure all impacts in the watershed are thoroughly documented. Contact recreational uses in the Upper Elk River are impaired, in part, due to the lack of deep pools, resulting from sediment deposits and the accumulation of small wood debris and branches and other shrubby vegetation that has encroached on the channel in response to altered geomorphology. The channel bottom is covered with a substantial layer of silt-sized material, rather than sand and gravel sized material, making wading and swimming unpleasant. The anaerobic condition of water during summer months and the presence of colonizing aquatic vegetation, such as sedges and duckweed, also impairs the use of water for contact recreational purposes.

Non-contact recreational uses, including boating and aesthetic enjoyment, is also limited due to the extent of the sediment impairment. Boating is difficult due to lack of stream depth and the accumulation of small vegetative debris, while aesthetic enjoyment is limited due to the degraded stream and riparian conditions and noxious odors arising from shallow, stagnant water and algae growths. Other non-contact recreation such as biking, hiking, and picnicking continues in BLM's Headwaters Forest Reserve.

5.2.2 Nuisance Flooding

In addition to the beneficial use impairments, nuisance flooding is another concern in the watershed. Discharges of sediment and small organic debris to watercourses have aggraded stream channels in the low gradient reaches of the Elk River, significantly reducing channel capacity. Overbank floods now occur at a frequency of four times per year on the North Fork Elk River (Regional Water Board 2005). Therefore, there is flooding of roads, fields, fences, and homes at intervals that are much more frequent than occurred historically (Patenaude 2004). This affects property values and the livelihoods of those who live in the community. South Fork and Mainstem also flood, though their frequency of occurrence is not as quantifiable as on North Fork (Regional Water Board 2005).

The cross-sectional area of the stream channel has been significantly reduced by deposits of fine sediment. Evaluation of cross-section data indicates there are over 280,000 cubic yards (yd^3) of instream stored sediment in the lower North Fork, nearly 100,000 yd^3 in the lower South Fork, and nearly 260,000 yd^3 in the upper mainstem. The fine sediment deposits in the impacted reach of the Upper Elk River watershed have become rooted in place by the encroachment of vegetation, further slowing winter floodwaters, causing streams to spill over their banks at elevated frequency and magnitude.

Potentially serious impacts to health and safety are associated with these flood events, as residents attempt to cross floodwaters, emergency vehicles are limited from accessing homes, and power can be lost to people dependent on health-support machinery and other people for care. Additionally health impacts from contaminated floodwater entering a home include damage to walls, flooring, and furniture and the potential for growth of harmful molds in homes.

Chapter 6 – Sediment Source Assessment

This chapter describes the present level of understanding regarding sediment sources in the Upper Elk River watershed. It discusses past efforts and data available to support the analysis of sediment by source category. The sediment source assessment is intended to determine the predominant sources, locations, and causes of sediment delivery as a way of prioritizing management actions in the watershed (see Figure 12 for an illustration of these factors)**Error! Reference source not found.**.

Chapter 6.1 presents an overall conceptual model of sediment behavior in the Elk River watershed, describing how sediment sources, past and present land use activities, and other natural factors in the basin affect sediment loading and existing sediment conditions in the river. Chapter 6.1 also describes the concept of dynamic equilibrium and provides an explanation of how it fits into the overall conceptual model. Chapter 6.2 presents recent efforts to conduct a quantitative sediment source analysis to support regulatory programs, including current estimates of natural and land use-related sediment loading from the various source categories.

6.1 Factors Controlling Sediment in the Elk River Watershed

Multiple natural and anthropogenic factors influence the behavior of sediment in the Elk River basin. The purpose of this chapter is to describe linkages among those factors and illustrate how they impact sediment delivery and the watershed's responses. Primary *natural* factors include: tectonics, geology, soil characteristics, geomorphology, climate and vegetation. Primary *anthropogenic* factors include: timber harvest, yarding, road building and use, and legacy practices (e.g., pre-Forest Practice Rules) not captured in the other categories (e.g., splash dams, stream channel skidding).

6.1.1 Dynamic Equilibrium and Attainment of Water Quality Standards

A functioning natural system occurs as a result of multiple factors or processes that interact under various environmental conditions, but result in a *dynamic equilibrium*. Dynamic equilibrium can be defined as "the condition of a system in which inflow and outflow are balanced" (Eastlick 1993) and the character of the system remains unchanged[14]. Balanced inflow and outflow is associated with the movement of both water and sediment.

A natural stable channel experiences scour and deposition; however, if over time these processes lead to degradation or aggradation, respectively, then the system is no longer in dynamic equilibrium.

The geomorphic role of rivers is to transport flows and sediment from the watershed while maintaining its dimension, pattern, and profile without aggrading or degrading significantly. A system maintaining this role would be in a state of dynamic equilibrium. The feedback mechanism between sediment input/output is central to the dynamic equilibrium of a river channel (EPA 2012). The relative balance in sediment input/output is also central to the attainment of WQS, including achieving WQOs for sediment, turbidity, suspended sediment, and settleable matter; protection of beneficial uses related to water supplies and aquatic

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[14] http://water.epa.gov/scitech/datait/tools/warsss/rivstab.cfm

habitat; and prevention of nuisance conditions related to flooding, property damage, and loss of free access to and use of property.

The Elk River is aggrading (Chapter 6.2.4); therefore, it is not in dynamic equilibrium. This aggradation has resulted in beneficial use impairments and nuisance flooding and, as described in Chapter 5.2, the Elk River is not attaining WQS. Returning the river to a state of dynamic equilibrium that meets WQS is the ultimate water quality improvement goal for the Elk River.

6.1.2 Anthropogenic Factors

Chapter 5.1.2 provides a detailed description of how the Elk River watershed has been altered by anthropogenic activities over the past 150 years. These alterations have combined with other factors (discussed in Chapter 5.1.1 and below) to result in an alteration in the fate and transport of water and sediment through the watershed. Documenting relevant Elk River watershed history provides a useful context within which to interpret the complex technical analyses associated with sediment source data going back to the 1950s, which is presented in this report (Figure 10).

Though quantitative data do not exist to establish historical loading levels, a firm understanding of the Elk River's relevant history provides a line of evidence in support of the sediment transport and delivery linkages presented below. For the more recent history, Figure 11 illustrates the relative timing of watershed land use and management activities that have had a notable impact on sediment loading through present time. These are connected to the management and land use activities discussed below.

6.1.3 Conceptual Model of Watershed Processes and Ecological Risk Factors

As discussed above, the Elk River has multiple natural watershed setting risk factors that lead to high levels of sediment loading and that make the watershed unusually sensitive to impacts from management activities. A mixed history of management practices has led to increased sediment delivery to the river and degraded hydraulic conditions, which have impacted several of the beneficial uses assigned to the Elk River.

Figure 12 depicts a conceptual model of the linkages among controlling factors, categorizing them by rows. Specifically, the watershed setting (Row A) and land use activities (Row B) interact, resulting in watershed responses (Row C). The combined watershed responses result in physical watershed effects (Row D) and manifest in watershed impacts to beneficial uses and creation of nuisance conditions (Row E).

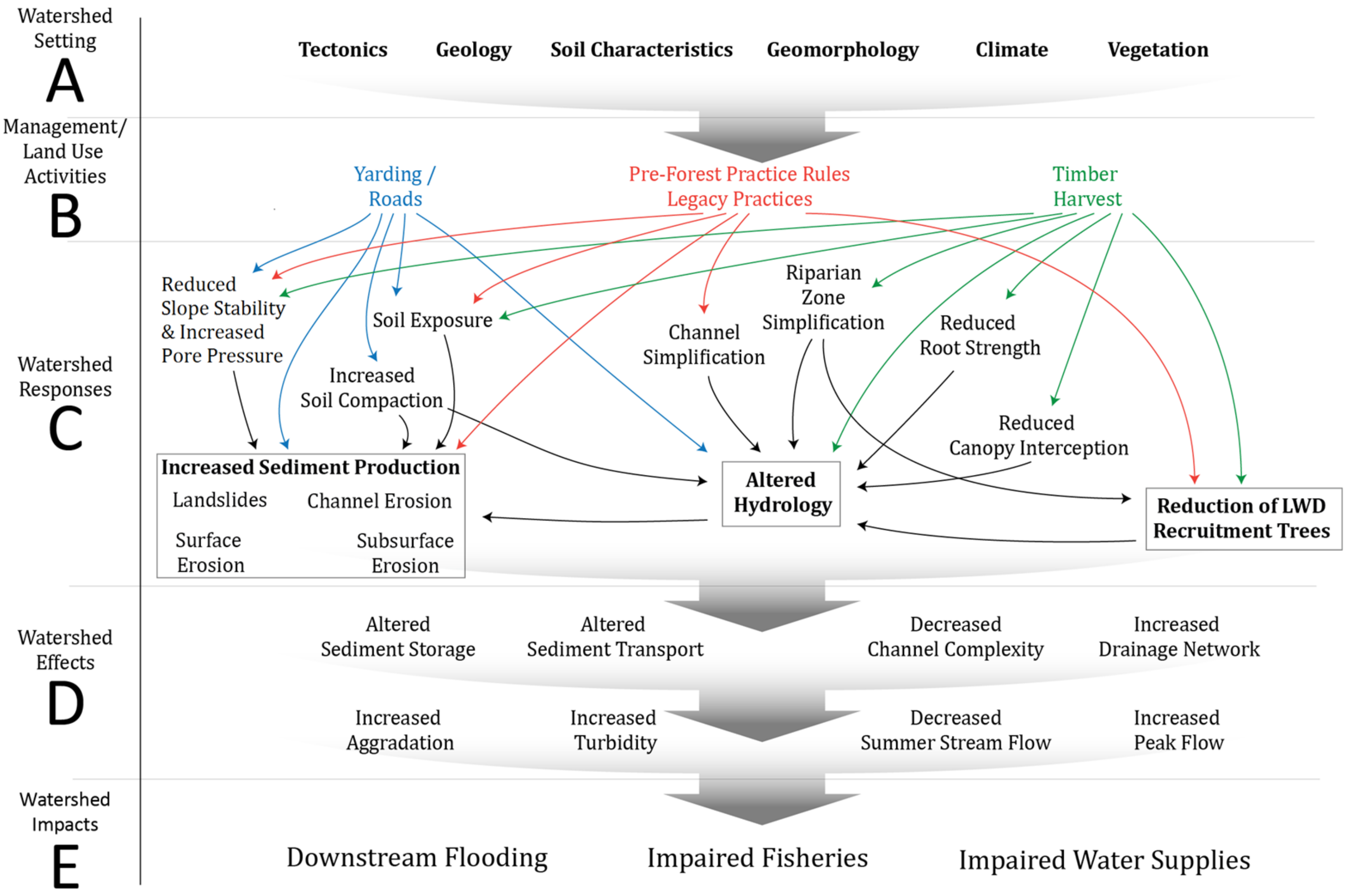

Figure 12. Elk River watershed processes and ecological risk factors conceptual model

The conceptual model of watershed processes and ecological risk factors can be used to identify important elements of a watershed recovery program, as described below:

- **Row A** and **Row B** identify ongoing sources of sediment that could be managed through BMPs to reduce sediment delivery;
- **Row C** represents vulnerabilities in the watershed where control measures could be developed;
- **Row D** identifies metrics that can be measured to track the implementation progress (i.e., decreased aggradation quantifies improvements caused by implementation activities associated with Rows A through C); and
- **Row E** represents the problem to be corrected; reductions in the extent and frequency of these problems demonstrate progress towards attaining WQS.

6.1.3.1 Watershed Setting

Row A in Figure 12 depicts the natural characteristics that determine the Elk River watershed's vulnerability to erosion (e.g., geology, soils, tectonics, etc.). The Upper Elk River watershed is a highly erodible, tectonically active producer of fine-grained sediment that under natural conditions would be reasonably well-anchored on the landscape by the complex, multi-storied tree canopy and ground cover typical of a forest ecosystem. Additional discussion is provided in Chapter 2.

6.1.3.2 Management/Land Use Activities

Row B depicts the varying types of landscape disturbance from Management/Land Use Activities. The Upper Elk River has been managed for industrial timber harvesting since the 1850s. Timber operations, as represented in this figure, are tree harvest activities conducted under the FPR, ranging from single tree selection to clearcuts and burning. Yarding in the watershed has ranged from full suspension cable to tractor yarding in and near watercourses. A significant road network has been built, including low and midslope roads with an increasing emphasis on shifting to a higher slope road system. Prior to the FPR, significant landscape alteration occurred associated with the movement and placement of soil and debris. Splash dams[15] were also used before the FPR to transport logs downstream. Additional discussion on historic activities is provided in Chapter 5.1.2.

6.1.3.3 Watershed Responses

As illustrated in **Row C** of Figure 12, the combination of natural watershed conditions and anthropogenic factors intersect to create *watershed responses*. The most notable responses are increased sediment production, altered hydrology, and reduction of LWD recruitment trees. Watershed response terms identified in the figure are defined below.

Reduced Slope Stability:

- Slope stability is the resistance of a natural or artificial slope or other inclined surface to failure by landsliding.
- Slope stability in forested settings can be reduced by:

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[15] A splash dam is a temporary wooden dam used to raise the water level in streams to float logs downstream; they allowed many more logs to be moved downstream than would be possible using the natural flow of the stream.

  - decreased root strength from timber harvesting;
  - increased pore water pressure inside soils and in soil pipes;
  - road construction on hillslopes utilizing partial bench or full bench construction; and
  - sidecasting from legacy road construction activities, which oversteepens the outboard edge of the road.

Soil Exposure: Removal of overlying duff and organic material leaving bare mineral soil open to the elements. Exposed soil is more prone to runoff and surface erosion.

Increased Soil Compaction: Increased soil compaction reduces rainfall infiltration rates, increasing runoff and surface erosion. Soil compaction can occur from yarding activities and roads in managed areas.

Landslides: A general term covering a wide variety of mass movement landforms and processes involving the downslope transport, under gravitational influence, of soil and rock material en masse.

Watercourse Channel Erosion: Channel erosion in which material is removed by concentrated water flowing in well-defined watercourses and unchanneled swales.

Erosion: The general process or the group of processes whereby the materials of the Earth’s crust are loosened, dissolved, or worn away and simultaneously moved from one place to another by natural agencies including weathering, solution, corrosion (i.e., process of mechanical erosion of the earth's surface caused when materials are transported across it by running water, waves, glaciers, wind or gravitational movement downslope, and transportation but usually excludes mass wasting.

Surface Erosion: Surface erosion is a process that refers to overland transport of eroded material via mechanical processes such as raindrop impact, surface rilling, rutting, and gullying.

Subsurface Erosion: Subsurface erosion is the process by which sediment is mobilized and transported by groundwater through large voids in the hillslopes. Preferential flow through soil pipes results in internal erosion of the pipe, which may produce gullies by tunnel collapse. The eroded material can clog soil pipes, causing pore water pressure buildup inside the pipes that can result in landslides, debris flows, embankment failures, or of ephemeral gullies (Fox et al. 2007).

Channel Simplification: Channel simplification relates to the loss of in-channel complexity because of land use activities. An example of management-related channel simplification is the removal of large woody debris from watercourses. Channel simplification can result in increased flow velocities, reduced sediment storage capacity, and degradation of aquatic habitat.

Riparian Zone Simplification: Management within watercourse riparian zones results in:

- reductions of canopy cover,
- reductions of riparian diversity, and
- changes to the composition and abundance of riparian species.

Pore Pressure: Groundwater held in gaps between in soil and rock particles exerts force known as pore pressure. Pore water pressure is vital in evaluating slope stability. When pore pressure increases, slope stability decreases relative to equilibrium (i.e., stable conditions) with anchoring forces.

Reduced Root Strength: Redwoods have an intricate network of shallow roots that contribute to the stability of steep forested slopes by maintaining the shear strength of soil mantles. Roots add strength to the soil by anchoring through the soil mass into fractures in the bedrock and laterally to root systems of adjacent trees, creating an interconnected root-web matrix. Timber harvest on forested hillslopes results in the reduction of root strength and complexity.

Reduced Canopy Interception: Rainfall is intercepted by the forest canopy, reducing the amount of raindrops that fall to the ground. Increase in timber harvest results in a reduction of canopy and an increased amount of rainfall hitting the ground.

Increased Sediment Production: Excess sediment generated by land use activities within a managed watershed increases the amount of sediment available for transport to the stream channel.

Altered Hydrology: The cumulative impact of increased soil compaction, channel simplification, reduced root strength, reduced rainfall interception, increased drainage density, and riparian zone simplification.

Reduction of LWD Recruitment Trees: Timber harvest focused in riparian areas reduces the overall chance of inputs of large woody debris into the hydrologic system.

6.1.3.4 Watershed Effects

The previous chapter highlighted watershed responses that occur from the combination of inherent erosional risk in the watershed and the history of land use activities (e.g., alterations to erosional, hydrologic, and riparian processes of wood loading). Combined with downstream channel characteristics, these responses have resulted in numerous watershed effects including increased peak flows, increased drainage network, altered sediment storage, decreased channel complexity, and altered sediment transport (see **Row D**). These effects have in turn resulted in increased aggradation, increased turbidity, and decreased summer stream flows. These watershed effects are summarized below.

Increased peak flows: Runoff associated with rainfall events results in increased stream flow. The highest stream flow rate achieved in response to a storm is referred to as peak flows. During storm events, the instantaneous stream peak flows from storm events is a function of antecedent wetness at the onset of the storm, storm intensity and duration, drainage area size and shape, and vegetative cover. Canopy removal associated with timber harvesting and alterations to hillslope drainage associated with roads and compacted areas can alter the magnitude and timing of peak flows. Data from Caspar Creek suggest that the peak flow response for single-tree selection logging may be about 60 percent of that for the equivalent canopy removal by clearcutting (Reid 2012). Additionally, a recent study found that during rainfall events, 30-40 percent more water fell on the ground (effective rainfall) in an opening than under forest cover (Dhakal and Sullivan 2014). When considering this in combination with transpiration, approximately 50 percent more water can be available in forest openings during the wet season (Lewis and Klein 2014).

Increased drainage network: Associated with increased peak flows and compaction is an increase in drainage network. In the Upper Elk River watershed, especially in the Wildcat formation, the combination of tractor and road crossings and hydrologic modification associated with canopy removal in unchanneled swales and their contributing area influenced the collapse of soil pipes, the formation of sink holes, and the headward incision[16] of low order channels, resulting in an estimated three-fold increase in drainage density.

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[16] Scour of low-order channels includes vertical incision and headward migration of the stream channel. Headward migration increases both the channel length and density of the stream network, which increases the drainage network.

Altered sediment storage: Sediment quantity and storage is a function of sediment inputs, sediment transport, and hydraulic controls. When sediment enters the fluvial system from in-channel sediment, surface erosion, or landslides, it is either moved downstream as bedload or carried as suspended load. In the Upper Elk River watershed, the primary sediment component is the suspended load. Conceptually, as sediment is transported downstream, hydraulic controls alter the flow velocity, allowing sediment to drop out of suspension to be stored temporarily until velocities and the resulting shear stresses are large enough again to re-suspend the material. The temporary storage of sediment in the tributary system in this manner prevents the kind of massive sediment deposition as was seen in the impacted reach in the late 1990s (Chapter 6.2.3). Under previous conditions of dynamic equilibrium, the relationship of flow to sediment quantity would be moderated by hydraulic controls such as LWD, changes in gradient, side channels, and floodplains. Sediment would only be mobilized when stream flows were big enough and would be deposited for temporary storage when velocities were reduced. The ability of tributary streams in the watershed to store sediment and meter it slowly over time has been interrupted by many intersecting factors including: an increase in the amount of sediment entering the fluvial system, a decrease in LWD, an increase in the amount of rainfall that enters the fluvial system as surface flow, and an increase in the surface drainage network and associated reduction in subsurface infiltration.

Decreased channel complexity: Channel complexity plays an important role in the fate and transport of sediment through the fluvial system. Channel complexity is highly influenced by the inputs and outputs to and from the stream and has an influence on sediment storage. Riparian areas deliver wood to streams; redwoods take a long time to decay and thus can accumulate and create complexity over time. Complexity in low order streams allows for sorting of coarser sediment, providing important habitat elements for amphibians and aquatic insects that provide food to vertebrates. In steep headwater streams, landslides can be important processes by which wood is delivered to streams. Riparian harvesting reduces these inputs. In the event of a landslide, the absence or reduction in trees that would have stabilized the body and toe of the landslide result in greater volume of sediment delivery. Results from streamside landslide surveys in Upper Elk River and Freshwater Creek clearly identifies increasing delivery volume per slide and increasing frequency of slides associated with decreasing stand age (PWA 2006). These effects, especially when coupled with past practices of yarding logs down and near low order channels, have led to significant alterations in the complexity of channels resulting in greater sediment transport efficiency, reduced sediment storage and metering, higher forces on the banks, and greater bank instability.

Sediment transport is a function of the inherent mobility of the sediment (e.g., grain size) and the transport capacity of the fluvial system. The transport capacity itself is a function of hydrology, gradient, and channel geometry. Therefore, multiple factors influence this process.

The Upper Elk River watershed is dominated by young, fine-grained, erodible geology. When the ground is well covered with duff and vegetation and the soils are reasonably well-anchored by tree roots, both water and eroded fine sediment can be captured and retained on the land prior to entering the fluvial system.

The transport of sediment that does enter the fluvial system is subject to hydraulic controls, such as channel roughness, channel complexity (including LWD), side channels and a functioning floodplain, and stream gradient (among other controls). Such a landscape can be said to be in dynamic equilibrium when the inputs match the outputs over time.

Increased aggradation: During the 1988-1997 period, land use activities in Upper Elk River made the landscape extremely vulnerable to intense rainfall events, resulting in increased discharges of excess sediment from timberlands in the upper watershed. The high flows of the mid-1990s transported fine sediment and deposited it in the bed, on the banks, and across the floodplain, effectively reducing the channel's stream flow capacity and raising water surface elevations. As a result, frequent floods inundated properties adjacent to Elk River. This altered morphology and reduced sediment transport capacity within the impacted reach, coupled with ongoing sediment loading, has led to continued aggradation as indicated by the mass balance in the impacted reach (Chapter 6.2.4.4;) and cross-sectional surveys (Regional Water Board 2013a, 2013b; Lewis 2013; HRC 2014 although it is important to note that quantitative channel survey data were not available during the 1988-1997 time period).

Altered sediment transport: In the case of Upper Elk River, with reduced channel complexity, increased drainage network, and increased peak flows, there has been increased sediment transport from the steep watercourses near the headwaters. At the same time, in the depositional reaches, increased aggradation and encroaching vegetation has led to reduced channel conveyance capacity and increased lateral flooding, thus reducing flow velocities and sediment transport capacity. This results in deposition of sediment in the impacted reach. This is also supported by the pilot Hydrodynamic and Sediment Transport modeling study, which found that over a 2.5 mile reach near the confluence of the North and South forks, the model predicted net sediment deposition on the bed, banks, and floodplain, with greater deposition within riparian forest than pasture areas (NHE and Stillwater 2013).

Increased turbidity: Turbidity is a measure of water clarity and is often used as a surrogate for suspended sediment concentration. As the magnitude and timing of sediment transport is altered, so is the turbidity. The impacts of watershed disturbances include higher peak turbidities during storms, as well as higher turbidities between storms. Turbidity exposure level and duration can impact fish health (Newcomb and MacDonald 1991; Newcomb and Jenson 1996). Low turbidity conditions between storm events can allow important windows of opportunities for fish feeding. Similarly, water supplies can be supported during these between storm times. In the Upper Elk River watershed, turbidity from three sub-basins were compared. This analysis found that the turbidity values from the two managed sub-basins were much greater than 20 percent higher than measurements in the reference sub-basin, indicating exceedance of the turbidity WQO (Regional Water Board 2013b).

Decreased summer stream flows: In surface water-dominated mountainous streams similar to the Elk River, flows decline over the course of the dry summer and fall season. Studies have indicated that timber harvesting can initially increase summer stream flows due to reduced transpiration (Moore and Wondzell 2005; Chamberlin et al. 1991), but decrease below their original levels as harvested areas regrow (Hicks et al. 1991; Perry 2007). Caspar Creek research also found that in the initial 7 years following selection harvest, summer flows increase (Keppeler 1986; Keppeler and Zeimer 1990; Keppeler 1998) and then decline over the next 20 years, compared to expected pre harvest conditions (Reid and Lewis 2011; Reid 2012).

6.1.3.5 Watershed Impacts

As shown in **Row E** of Figure 12, the responses and effects of altered sediment loading has resulted in watershed impacts that include downstream flooding, impaired fisheries, and impaired water supplies. The beneficial use impacts are the basis for listing the Elk River watershed as impaired under Section 303(d) of the CWA. A substantial portion of these impacts can be restored or mitigated and a working landscape can be sustained while maintaining equilibrium conditions to support beneficial uses. A framework to restore conditions and to ensure sustainable land use practices is described within the implementation discussion below (Chapter 8).

6.2 Quantitative Source Analysis

There is an enormous inventory of sediment source and delivery data for the Upper Elk River watershed available from sediment data collection and mapping efforts from a variety of professionals associated with agencies, timber companies, private consultants, and research institutions. These include the following:

- Humboldt Redwood Company
- Pacific Lumber Company
- Green Diamond Resource Company
- Bureau of Land Management
- Pacific Watershed Associates
- Stillwater Sciences
- North Coast Regional Water Board
- Redwood Sciences Laboratory
- California Geologic Survey (CGS)
- Salmon Forever
- Humboldt State University
- Northern Hydrology and Engineering

The volume and variety of data relevant to this watershed are not often available, particularly for management-related sediment delivery, in source analyses for other sediment TMDLs in the North Coast Region. Following is a brief overview of the sediment source analysis work conducted for the Upper Elk River watershed from which the existing source loading estimates have evolved.

6.2.1 History of Upper Elk River Sediment Source Analyses

The Regional Water Board produced a *Preliminary Review Draft Sediment Source Analysis* (Preliminary Review Draft) in 2011. This report was the first effort to estimate sediment loading, in support of a sediment TMDL for the Upper Elk River watershed and relied upon data collected during the 1955-2003 period. Primary sources of data for this report included, Palco watershed analysis (2004), North Fork Elk Sediment Source Inventory (PWA 1998), surveys of natural and managed drainage networks (Regional Water Board 2011b), a BLM inventory, a GDRC inventory, and CAO inventories of management discharge sites. In total, at least 18 data sets were used and they are detailed on page 8 of that document (Regional Water Board 2011b).

The preliminary analysis was revised in 2013 in the Peer Review Draft (Regional Water Board 2013a) in which data analyzed were extended through the period 2004-2011. The analysis included new data related to bank erosion and streamside landslides obtained from HRC Watershed Analysis surveys (HRC 2012a, 2012b), as well as new analyses of road surface erosion. Inclusion of the additional data resulted in updated openslope landslide, road surface erosion, and deposition estimates in the impacted reach relative to the 2011 Preliminary Review Draft.

More recently, Regional Water Board staff evaluated data from HRC's *2014 Watershed Analysis* report (HRC 2014), which included stream survey data for the period 2001-2010 for 26 miles of streams in the Upper Elk River watershed. These data were incorporated into the existing source analysis to update estimates for bank erosion and streamside landslides.

In March of 2015, Regional Water Board staff completed an *Internal Draft Staff Report*, which reflected revisions to the prior sediment source analyses. This analysis included the same total loading estimates from the 2013 results, with changes to the association of streamside landslide estimates to account for the influence of deep seated landslides. This resulted in non-uniform estimates of natural loading temporally and spatially in the watershed. A comparison was also made of the loading rates derived from the sediment source analyses with suspended sediment load data and the sub-basins were ranked according to the magnitude of loading estimates.

The source analysis should not be viewed as static as it can be updated and refined over time to include additional monitoring and research. The rest of this chapter presents the methodology and the most recent estimates of sediment loading for the Upper Elk River watershed. These estimates are based on the most recent data and scientific understanding of natural and land-use related sources.

6.2.2 Sediment Load Estimation Approaches

The following chapters quantify natural and management- or land use-related sediment production and delivery processes in the Upper Elk River watershed based on information available from 1955 to 2011. They include estimates of sediment production from landslides, surface erosion, and channel erosion. Subsurface erosion is noted as a uniquely important, but presently unquantifiable, source of sediment in the watershed and is described narratively.

Sediment conditions in the watershed are greatly influenced by altered hydrology and the reduction of LWD, as well. The routing of the delivered sediment through the fluvial system is not analyzed as part of the source analysis, except to say that increases in peak flows and reduction in LWD have influenced the way in which sediment is routed through the fluvial system, and sediment routing should be an important subject of further sub-basin scale surveys.

The Elk River watershed is stratified into twenty sub-basins for analytical purposes (Stillwater 2007). This analysis focuses on the Upper Elk River watershed, which includes the upper seventeen sub-basins. The primary impairments to beneficial uses and nuisance conditions are found within the impacted reach, located within the Lower Elk River, Lower South Fork Elk River, and Lower North Fork Elk River sub-basins (see Chapter 2.1 for a discussion of the delineated watershed). Figure 13 depicts the sub-basins. Sediment loads are quantified by time period for the upper 17 sub-basins and an overall area-weighted load estimate is provided for this drainage area.

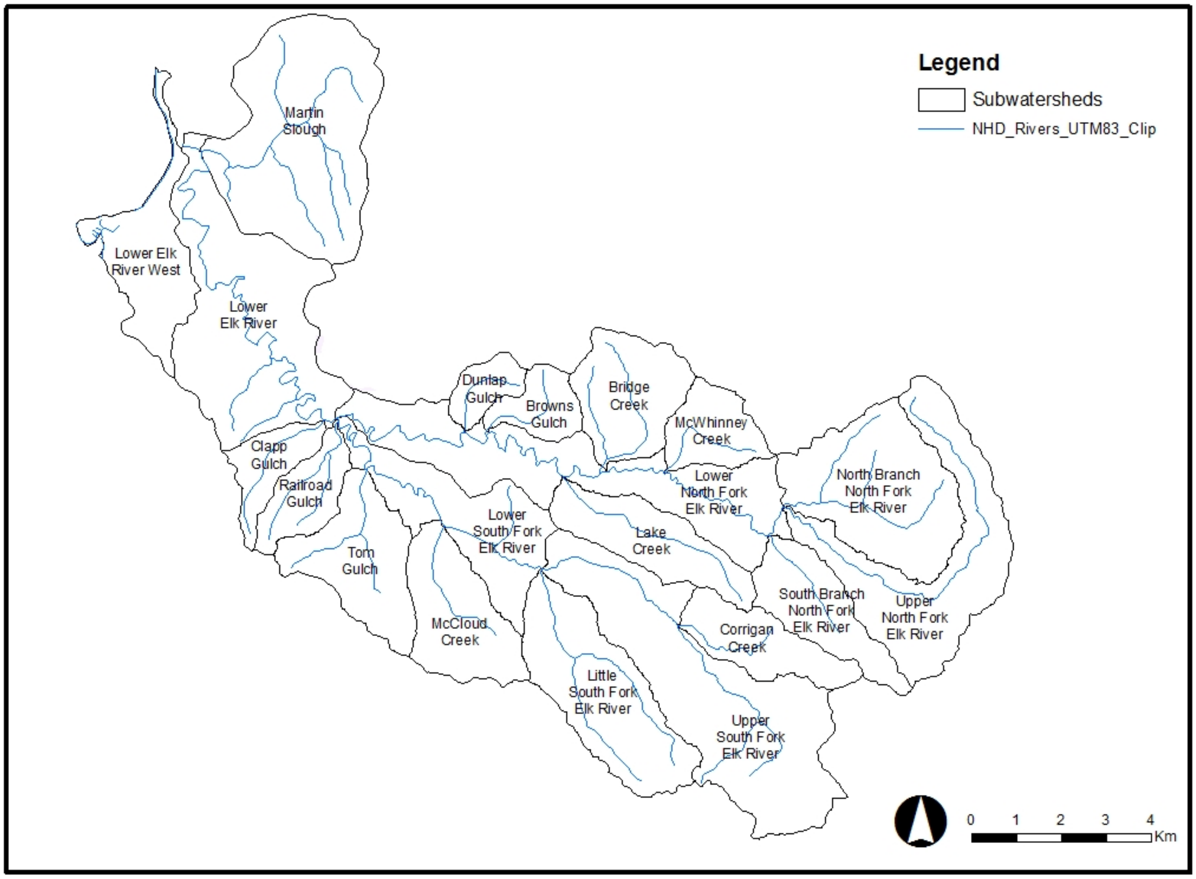

Figure 13. Subbasins in the Elk River watershed

The sediment source inventory is divided by sediment source categories, initiation (i.e., natural or land use-related), and time period (1955-1966, 1967-1975, 1975-1987, 1988-1997, 1998-2000, 2001-2003, and 2004-2011; these ranges correspond with the availability of sequential aerial photos). Table 6 describes the data and approaches used in estimating sediment loading by source category. Specifically, a variety of analytical approaches were used to estimate natural and land use-related sediment loads, including aerial photographs, field surveys, geographic information system (GIS) mapping and modeling, land use history, erosion monitoring, use of study sub-basins[17], and application of erosion models. The text below defines the source category and briefly describes the approach used to quantify sources categories, while the Peer Review Draft (Regional Water Board 2013a) provides a detailed description of available sediment data and how they were used to develop the loading estimates presented below (notable exceptions are identified below).

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[17] Study sub-basins include characterization of reference conditions in Little South Fork Elk River within the Headwaters Forest Reserve and land use influenced conditions in Corrigan Creek, South Branch North Fork Elk River, and nearby Freshwater Creek.

Table 6. Data and Approach Used in Estimating Sediment Loading by Source Category

Sediment Source Category		Data Source(s) and Approach
Natural	Natural Bank Erosion	Field surveys of 1.9 miles of channel in reference sub-basin; natural drainage density estimate
	Natural Streamside Landslides	Field surveys of 2.6 miles of channel in reference sub-basin; natural drainage density estimate
	Shallow Hillslope Landslides	Palco/HRC Reported landslide delivery volumes from Upper Elk River areas not harvested in prior 15 years
	Deep-Seated Landslides	CGS mapped active features (Marshall and Mendes 2005); Palco Elk River Watershed Analysis movement rates (Palco 2004)
	Deep Seated Influences on Bank Erosion and Streamside Landslides	Sub-basin specific bank erosion and streamside landslide surveys Percent drainage network in sub-basin intersecting CGS mapped deep seated landslide (all activity levels) Percent sub-basin with surface roughness associated with deep seated landslides
Land Use	In-Channel: Low Order Channel Incision	Volume of land use-induced channel incision based on measured channel dimensions and field-based estimates of impacted and natural drainage density; assumed 75% occurred in 1950's and 5% in each subsequent decade
	In-Channel: Management-Related Bank Erosion	PWA Field surveys of 3.9 miles of channel in study sub-basins; impacted drainage density estimate; subtracted natural loading
	In-Channel: Management-Related Streamside Landslides	HRC field surveys of 26 miles of channel in Elk River and PWA field surveys of 6.5 miles of channel in impacted sub-basins of Freshwater Creek; applied to natural drainage density and subtracted natural loading. Estimate assumes void features in upper extent of impacted network are accounted for in bank erosion estimates.
	Road-Related Landslides	Sub-basin specific landslide inventory data from Palco Watershed Analysis (2004) and 2005 ROWD
	Open Slope Shallow Landslides	Sub-basin specific landslide inventory data from Palco Watershed Analysis (2004) and 2005 ROWD; non-road-related slides, includes some skid-related slides
	Land Use-Related Sediment Discharge Sites	Sub-basin specific site inventories from Palco Watershed Analysis (2004), HRC CAO reports, GDRC WDR reports, BLM reports
	Post-Treatment Sediment Discharge Sites	Compiled monitoring results from BLM, HRC, and GDRC from sites treated in Elk River
	Skid Trails	Compiled findings from Elk River skid trail-related inventories on BLM and Palco/HRC lands to estimate loading from skid sites not otherwise included in land use discharge site inventories
	Road Surface Erosion	Estimated sub-basin road densities in different road surface and condition categories based on Palco and HRC Watershed Analysis (2004) and 2005 ROWD; unit loading based upon 2005 ROWD
	Harvest Surface Erosion	Estimated harvest history in clear-cut equivalents based upon CalFire, Palco Watershed Analysis (2004), and 2005 ROWD; unit loading based upon Palco Watershed Analysis (2004)

6.2.2.1 Natural Sediment Loading Categories

In the Upper Elk River sediment source analysis, natural sediment sources identified and quantified include:

- bank erosion,
- streamside landslides,
- shallow hillslope slides,
- deep-seated landslides, and
- streamside landslides and bank erosion associated with deep seated landslides.

Natural Bank Erosion and Streamside Landslides

Bank erosion includes lateral incision into stream banks. This category captures sediment production associated with soil creep, a natural process by soil and/or rock debris slowly moves downslope under the influence of gravity. Under equilibrium conditions, sediment supplied to stream banks via soil creep is equal to the bank erosion rate (Reid and Dunne 2003). Soil creep is often estimated in sediment budgets where bank erosion estimates are unavailable; however, as part of the sediment analysis, bank erosion and streamside landslides surveys in the Upper Elk River were conducted. These data were used to provide a more accurate estimate than using literature values of soil creep rates developed in other sediment source analyses.

Streamside landsides are mass wasting landslide features that originate from streamside slopes and are too small to detect on aerial photographs. While the erosional processes are different, the distinction made in the field between bank erosion and streamside landslides is generally based on the size of the resulting void. Bank erosion voids are recognized as smaller than those left by streamside landslides. Long-term estimates of natural bank erosion (9 $yd^3/mi^2/yr$) and streamside landsliding (26 $yd^3/mi^2/yr$) are applied to each of the analysis time periods from 1955-2011.

Shallow Hillslope Landslides

Shallow hillslope landslides (shallow landslides) are landslide features that are typically visible on aerial photographs given their size (greater than 400 square feet [ft^2]). Small landslides with delivery to the fluvial system are accounted for in the small streamside landslide category. Aerial photo inventories include identification of landslide attributes; generally, these inventories have identified if the area was harvested in the 15 to 20 years prior to landslide initiation. If not, it is often assumed that timber harvesting was not a contributing factor. The source analysis estimate of natural landsliding is derived from an inventory of landslides in areas not harvested in the past 15 years, resulting in a long-term sediment delivery rate estimate of 30 $yd^3/mi^2/yr$. Though episodic, this long-term rate was applied uniformly to the Upper Elk River sub-basins.

Deep Seated Landslides

Large storm events can activate debris slides and rotational/translational landslides associated with pre-existing deep-seated landslide features. Deep-seated landslides and their corresponding level of activity are typically identified based on interpretation of topographic signatures and patterns of drainage development in maps and aerial photographs supplemented by field observations. These approaches, however, require substantial effort, are limited by vegetation that obscures relevant features, and require professional judgment based on experience with the local geology and topography; resulting in hazard mapping that is subjective. There can be further uncertainties in the types, boundaries, and activity level of existing deep-seated landslide mapping, especially when mapping was conducted prior to the high resolution topography provided by LiDAR (Sanborn 2005), resulting in uncertainties in the types, boundaries, and activity level of existing deep-seated landslide mapping.

CGS mapped deep seated landslides as part of *Geologic and Geomorphic Features Related to Landsliding in Elk River* (Marshall and Mendes 2005). The CGS map does not identify activity levels or any information from which to determine sediment delivery rates from different mapped features. The Palco (2004) Watershed Analysis included an effort in which Hart Crowser estimated landslide activity levels on mapped features based upon Keaton and Degraff methodology. These activity levels were the best available information on deep seated landslides. For the sediment source analysis, Regional Water Board staff relied upon the Palco (2004) inventory for estimates of the deep seated landslide delivery from "active" features and associated those features with natural loading.

The sediment delivery associated with these features results in an estimated natural deep-seated landslide sediment delivery of 17.2 $yd^3/mi^2/yr$ in the Upper South Fork Elk River and 5.9 $yd^3/mi^2/yr$ in Toms Gulch. The overall deep seated landslide sediment delivery used for the loading calculations was then determined using an area-weighted average loading (resulting in 2.9 $yd^3/mi^2/yr$). The sediment source analysis accounts for sediment delivery from features classified as anything but "active" in other source categories.

Deep Seated Influences on Bank Erosion and Streamside Landslides

The Peer Review Draft (Regional Water Board 2013a) did not tailor the sediment loading estimates of natural bank erosion and streamside landslides based upon concentration of deep seated landslide features and landforms within individual sub-basins. It was concluded that the Peer Review Draft (Regional Water Board 2013a) may not have adequately accounted for the influence of deep features on these in-channel sources (e.g., bank erosion and streamside landslides). Therefore, in response to informal public comments (CalFire 2014; MacDonald 2014), the estimates of natural sediment loading have been adjusted to account for the influence of deep seated landslides on the rate of stream bank erosion. HRC (2014) found that streamside landsliding and bank erosion occurred independent of recent management associations.

The revised estimates were developed based on the proportion of deep seated landforms in the individual sub-basins as identified using the deep seated landslide and earthflow detection model (DSLED) that evaluate surface roughness from the LiDAR and identify features associated with the body of deep seated landslides. The DSLED Rough algorithm modeled surface roughness values ranging from 0.6-0.7, which are generally associated with deep seated landslide features whose activity levels are defined as "historic" or "dormant young" (Stillwater 2007). The revised estimates also were developed using the portion of the existing managed drainage network[18] in each sub-basin that intersects with any CGS-mapped deep seated features. These are the areas where the toes of deep seated features most likely influence bank erosion and streamside landslides.

Two estimates of the proportion of streamside landsliding associated with deep seated features were determined and then averaged for each subbasin. This loading was removed

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[18] The drainage network evaluated was from the channel initiation study (a drainage area of 0.52 hectares) and modeled on the Light Detection and Ranging (LiDAR) DEM.

from the prior management-related estimates and attributed to natural estimates (see table note below). As a result, natural loading varies by period and sub-basin.

Table 7 shows the results for each time period in each sub-basin. The values in the bottom-most table were incorporated into the overall watershed loading estimates (see the table note for additional description on the calculations).

6.2.2.2Management/Land-Use-Related Sediment Loading

This chapter describes the land use influences on sediment production and delivery. Timber harvest is the primary past, current, and probable future land use in the watershed and is therefore the focus of the land use-related sediment source analysis. The sediment source categories affected by land use activities in Upper Elk River watershed that are identified and quantified include:

- In channel sources (low order channel incision, bank erosion, and streamside landslides),
- Road-related landslides,
- Open-slope shallow landslides,
- Land use-related sediment discharge sites,
- Post-treatment discharge sites,
- Skid trails,
- Road surface erosion, and
- Harvest (in unit) surface erosion.

In-channel Sources

The combination of headward channel incision, bank erosion, and streamside landslide features are related and collectively referred to as in-channel sources. Scour of low-order channels includes vertical incision and headward migration of the stream channel. Headward migration increases both the channel length and density of the stream network (thereby increasing the drainage network). Bank erosion and streamside landslide processes are described under natural sources. Generally speaking, channel incision accounts for the initial delivery from expansion of the drainage network length and depth (i.e., gullies) and bank erosion and streamside landslides are erosional processes within the drainage network.

These three categories are identified separately in Table 6, but are grouped into low order channel incision and management-related bank erosion and streamside landslide categories in the loading summaries below. Channel incision estimates were based on measured channel dimensions and field estimates of impacted and natural drainage density (Table 6). Three different survey efforts informed the rates of bank erosion and streamside landsliding in Upper Elk River; the studies corroborated each other very well (Palco 2004; PWA 2006; HRC 2014). The most recent effort was the most extensive (26 miles of stream in Upper Elk River) and was part of the HRC Watershed Analysis Revisit (HRC 2014). These findings were used to estimate loadings associated with land use-related bank erosion and streamside landslides.

Table 7. Summary of Information on Refined Estimates of Natural Streamside Landslide and Bank Erosion Rates Influenced by Deep-Seated Features (all units unless specified are yd³/mi²/yr)

Sub-basin		Area (mi^2)	% area in DSLED Rough 0.6-0.7	Additional natural bank erosion and streamside Landslides based on association with % area in DSLED Rough 0.6-0.7							% channel length intersecting CGS mapped landslide	Additional natural bank erosion and streamside Landslides based on association with % channel length intersecting CGS mapped deep seated landslide						
				1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011		1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
4	Bridge Creek	2.20	5%	12	10	4	15	16	16	16	30%	82	62	24	96	105	105	102
5	Dunlap Gulch	0.66	13%	36	27	11	42	46	46	8	21%	56	43	17	66	72	72	12
6	Browns Gulch	0.89	21%	56	43	17	66	72	72	52	21%	56	43	17	66	72	73	52
7	Upper North Fork Elk River	4.36	22%	56	42	14	66	73	73	11	7%	18	13	5	21	23	23	3
8	McWhinney Creek	1.27	11%	30	23	9	35	38	39	38	8%	22	17	7	26	28	28	28
9	Lower North Fork Elk River	5.02	15%	42	32	13	50	54	54	31	45%	123	93	37	144	158	158	90
10	North Branch North Fork Elk River	4.02	12%	32	24	8	37	41	41	18	57%	149	111	38	175	192	193	83
11	Lower South Fork Elk River	2.90	15%	41	31	12	48	53	53	11	35%	95	72	28	111	122	122	26
12	Railroad Gulch	1.20	22%	61	46	18	72	78	79	64	57%	155	118	46	182	200	200	163
13	Clapp Gulch	1.00	22%	60	46	18	71	78	78	69	68%	184	140	55	216	237	238	210
14	Tom Gulch	2.51	7%	20	15	6	23	25	25	57	52%	141	107	42	166	181	182	410
15	Lake Creek	2.12	11%	31	24	9	37	40	40	33	64%	173	132	52	204	223	224	181
16	McCloud Creek	2.36	25%	67	51	20	79	86	86	55	42%	114	86	34	134	146	147	94
17	Upper South Fork Elk River	6.45	25%	67	51	20	79	86	87	55	56%	153	116	46	179	196	197	126
18	South Branch North Fork Elk River	1.93	23%	63	48	19	74	81	81	65	68%	185	141	55	218	238	239	190
19	Little South Fork Elk River	3.59	20%	53	41	16	63	69	69	44	46%	126	96	38	148	162	163	104
20	Corrigan Creek	1.66	19%	52	39	15	61	67	67	43	72%	195	148	58	229	251	252	161
Total Upper Elk River		**44.13**	**17%**	**47**	**36**	**14**	**55**	**61**	**61**	**37**	**45%**	**121**	**92**	**36**	**142**	**156**	**156**	**114**

Sub-basin		Area (mi^2)	Revised additional natural bank erosion and streamside Landslides based average of associations with DSLED Rough and CGS mapping						
			1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
4	Bridge Creek	2.20	47	36	14	55	61	61	59
5	Dunlap Gulch	0.66	46	35	14	54	59	59	10
6	Browns Gulch	0.89	56	43	17	66	72	72	52
7	Upper North Fork Elk River	4.36	37	28	10	43	48	48	7
8	McWhinney Creek	1.27	26	20	8	30	33	33	33
9	Lower North Fork Elk River	5.02	82	63	25	97	106	106	61
10	North Branch North Fork Elk River	4.02	90	67	23	106	117	117	50
11	Lower South Fork Elk River	2.90	68	51	20	79	87	87	18
12	Railroad Gulch	1.20	108	82	32	127	139	139	113
13	Clapp Gulch	1.00	122	93	37	144	158	158	139
14	Tom Gulch	2.51	80	61	24	94	103	103	234
15	Lake Creek	2.12	102	78	31	120	132	132	107
16	McCloud Creek	2.36	90	69	27	106	116	116	74
17	Upper South Fork Elk River	6.45	110	84	33	129	141	142	90
18	South Branch North Fork Elk River	1.93	124	94	37	146	160	160	127
19	Little South Fork Elk River	3.59	90	68	27	105	115	116	74
20	Corrigan Creek	1.66	123	94	37	145	159	159	102
Total Upper Elk River		**44.13**	**84**	**64**	**25**	**99**	**108**	**108**	**76**

Note: Values in the bottom table were calculated by averaging the two sets of data in the top table. This bottom table was also used to calculate the revised estimates for the deep-seated influence on natural and management-related bank erosion and streamside landslides. Specifically, these values were 1) added to the Peer Review Draft natural loading estimates; and 2) subtracted from the Peer Review Draft total management-related bank erosion and streamside landslide estimates.

Road-related and Open Slope Shallow Landslides

The rate of sediment delivery from management-related open-slope shallow landslides was calculated based on data contained in Palco's landslide inventory databases, including (for most time periods) landslides on lands owned by GDRC and those managed by BLM, as well as HRC lands. Landslides attributable to roads were separated from those attributable to other management activities.

Land Use-Related and Post-Treatment Discharge Sites

Management discharge sites include sites associated with watercourse crossings, roads, skid trails, and gullies. Typically these sites are treated by removing some volume of fill material and then treating the channel and excavated slopes to minimize post-treatment sediment delivery. Significant progress has been made in identifying, prioritizing, treating and monitoring these sites in the Upper Elk River watershed. Sediment delivery rates associated with management discharge sites were estimated for each time period using data submitted by each of the landowners/managers (HRC, GDRC, and BLM), either as part of their own comprehensive ownership analysis or as required by a permit or enforcement order.

Skid Trails

Sediment delivery associated with skid trails is derived from several sources of data, including: a reconnaissance survey of Elk Head Springs conducted by PWA, a database of sediment sites maintained by HRC, Palco's Freshwater Creek Skid Trail Study (Palco 2007), and HRC's Skid Trail Surveys (HRC 2010). The number of sediment sites influenced by skid trails was identified and a past and future rate of sediment delivery estimated to produce a volume of sediment delivered from the areas studied and was applied as uniform rate across the Upper Elk River watershed.

Road Surface Erosion

The road surface erosion source category includes sediment transport and delivery from road surfaces. The material eroded from road surfaces is fine grained in size and discharge can occur during each rain event (a press disturbance), rather than discharging episodically (pulse disturbance) (ISRP 2003). For this reason, road surface erosion has a chronic effect on water quality. The greatest sediment delivery per unit of road length and the greatest road lengths in the Upper Elk River watershed are associated with unsurfaced roads (including stormproofed and non-stormproofed). As a result, un-surfaced roads have the greatest estimated loading from road surface erosion, accounting for approximately 60-75 percent of the estimated sediment loading from recent road surface erosion.

Harvest Surface Erosion

Surface erosion from harvest areas was estimated from harvest history in clear-cut equivalent areas. This information was based on CalFire, the Palco watershed analysis (Palco 2004), and Palco's data.

6.2.3 Summary of Loadings

The load quantification approaches for each source category presented in Chapter 6.2.2 were applied to the Upper Elk River sub-basin areas for each time period evaluated and also rolled up into an overall watershed loading.

6.2.3.1Sub-basin Loading

Table 8 presents a summary of the sediment load by sub-basin. This information is useful to prioritize implementation opportunities (using both sub-basin and source category information) to reduce loads to the stream reaches by prioritizing sub-basin-category combinations with the highest risk of additional sediment delivery.

The source analysis estimated total loads for 2004-2011 were compared with those measured at suspended sediment and streamflow gaging stations as presented by Salmon Forever (Lewis 2013) and HRC (2012b) for similar drainage areas as a check for reasonableness. The annual average loads in the South Fork Elk River reported by Lewis (2013) were 4.6 percent lower and 12.7 percent lower in the North Fork Elk River than the sediment source analysis calculated loads (2004-2011 results in Table 8). The loads presented by HRC (2012b) are approximately 12 percent lower in the North Fork Elk River than those quantified in the sediment source analysis. While these comparisons highlight differences in the gaging results (likely due to limited high flow discharge estimates and turbidity-suspended sediment regression analyses), these comparisons confirm that the loading values estimated by this analysis are reasonable.

Figure 14 ranks sub-basins on a graph, based on the total estimated sediment delivery from each sub-basin during the most recent period (2004-2011). This graph identifies the Toms Gulch sub-basin as a clear outlier with exceptionally high rates of sediment delivery. The relative magnitude of total sediment loading for the 2004-2011 time period is between 400-600 $yd^3/mi^2/yr$ for over half of the sub-basins and several others fall just outside that range, indicating consistency in the spatial pattern of loading throughout the watershed.

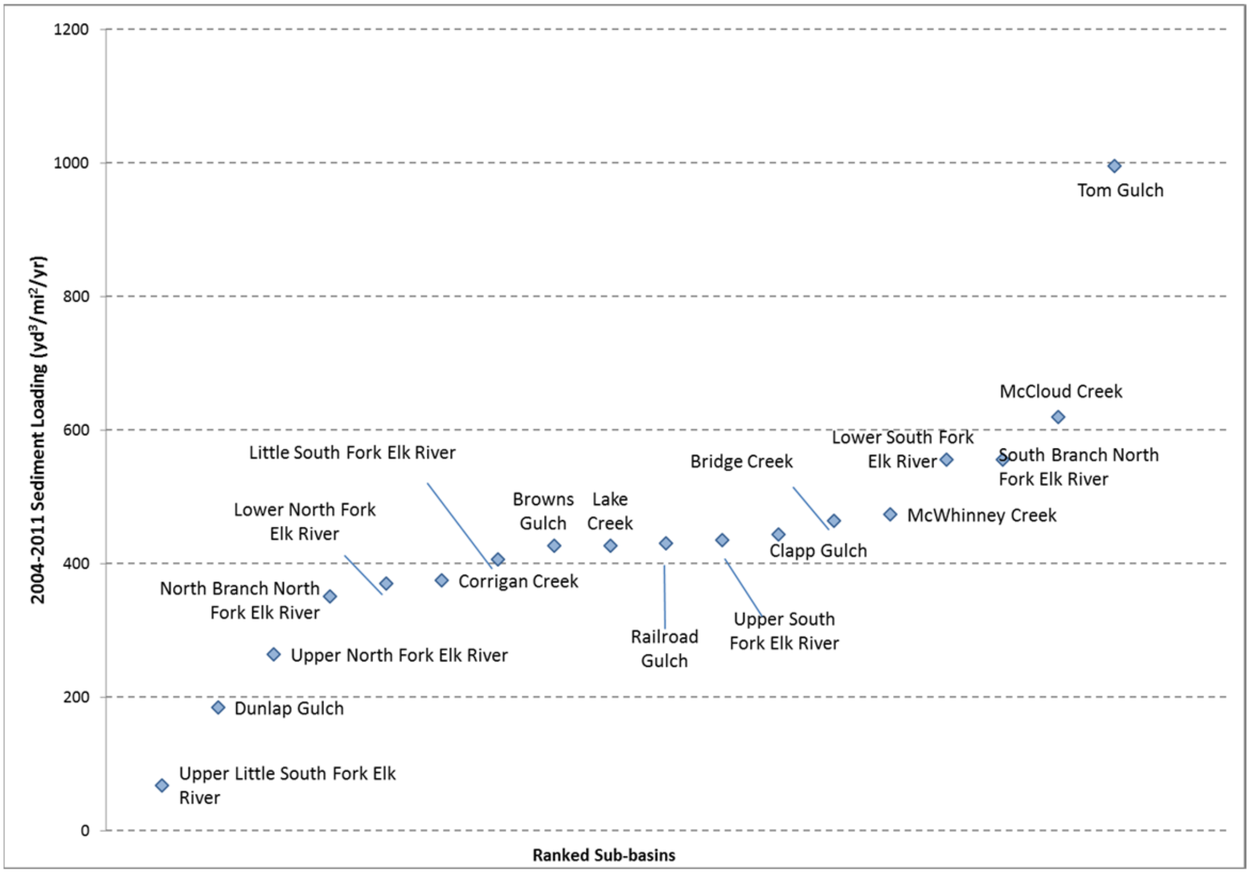

Figure 14. Upper Elk River sub-basin sediment loading for the 2004-2011 analysis time period

Note: The lower-most marker represents the reference sub-basin, Upper Little South Fork Elk River.

During the 1988-1997 time period, open slope landslides and road related landslides were the dominant sources. Specifically, road-related landslides primarily impacted Bridge Creek, Lower North Fork, North Branch North Fork, Railroad Gulch, and Clapp Gulches, while open-slope landslides primarily impacted Lower South Fork, Railroad, Clapp Gulch, Tom Gulch, Lake Creek, and Bridge Creek. All of these sub-basins (with the exception of North Branch North Fork) drain to the impacted reach. The magnitude of discharges during that time period dwarfed other time periods and the location of those large discharges had a direct impact on the impacted reach and the loss of function of the Elk River (see also Regional Water Board 2013b for more discussion of the conditions during this time period).

Table 8. Summary of Sediment Loading to Upper Elk River Sub-basins by Sediment Source Category and Time Period (all units are yd^3/mi^2/yr)

Natural Loading Source Categories

			Natural Source Loads (all years)				Additional natural bank erosion and streamside landslide loads based average of associations with DSLED Rough and CGS mapping (Table 7)							Total Natural*						
Sub-basin		Area (mi^2)	Deep-seated	Bank Erosion	Streamside Landslides	Shallow Landslides	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
4	Bridge Creek	2.20	0.0	9	26	30	47	36	14	55	61	61	59	112	101	79	120	126	126	124
5	Dunlap Gulch	0.66	0.0	9	26	30	46	35	14	54	59	59	10	111	100	79	119	124	124	75
6	Browns Gulch	0.89	0.0	9	26	30	56	43	17	66	72	72	52	121	108	82	131	137	137	117
7	Upper North Fork Elk River	4.36	0.0	9	26	30	37	28	10	43	48	48	7	102	93	75	108	113	113	72
8	McWhinney Creek	1.27	0.0	9	26	30	26	20	8	30	33	33	33	91	85	73	96	98	98	98
9	Lower North Fork Elk River	5.02	0.0	9	26	30	82	63	25	97	106	106	61	148	128	90	162	171	171	126
10	North Branch North Fork Elk River	4.02	0.0	9	26	30	90	67	23	106	117	117	50	156	132	88	171	182	182	116
11	Lower South Fork Elk River	2.90	0.0	9	26	30	68	51	20	79	87	87	18	133	117	85	145	152	152	83
12	Railroad Gulch	1.20	0.0	9	26	30	108	82	32	127	139	139	113	173	147	97	192	204	204	178
13	Clapp Gulch	1.00	0.0	9	26	30	122	93	37	144	158	158	139	187	158	102	209	223	223	204
14	Tom Gulch	2.51	5.9	9	26	30	80	61	24	94	103	103	234	151	132	95	165	174	174	305
15	Lake Creek	2.12	0.0	9	26	30	102	78	31	120	132	132	107	167	143	96	185	197	197	172
16	McCloud Creek	2.36	0.0	9	26	30	90	69	27	106	116	116	74	155	134	92	171	181	181	139
17	Upper South Fork Elk River	6.45	17.2	9	26	30	110	84	33	129	141	142	90	192	166	115	211	224	224	173
18	South Branch North Fork Elk River	1.93	0.0	9	26	30	124	94	37	146	160	160	127	189	159	102	211	225	225	192
19	Little South Fork Elk River	3.59	0.0	9	26	30	90	68	27	105	115	116	74	155	133	92	170	181	181	139
20	Corrigan Creek	1.66	0.0	9	26	30	123	94	37	145	159	159	102	189	159	102	210	224	224	167
Total (area-weighted)		**44.13**	**2.9**	**9**	**26**	**30**	**84**	**64**	**25**	**99**	**108**	**108**	**76**	**152**	**132**	**93**	**167**	**176**	**176**	**144**

*Total natural value for each time period sums the Natural Sources that are consistent for all years as well as the time-variable bank erosion and streamside landslide values.

Management-Related Loading Source Categories

	Low Order Channel Incision							Streamside Landslides and Bank Erosion*							Open Slope Shallow Landslides						
Sub-basin	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
4	74	25	14	23	34	13	15	226	172	67	265	290	291	281	1314	0	10	922	1603	0	0
5	74	25	14	23	34	13	15	227	173	68	267	292	293	50	0	0	0	0	0	0	0
6	74	25	14	23	34	13	15	217	165	65	254	279	279	200	0	0	0	16	0	0	0
7	37	18	10	16	24	9	11	223	166	57	261	287	287	42	334	559	0	63	0	0	0
8	74	25	14	23	34	13	15	247	188	74	290	318	318	310	0	0	0	2	0	248	0
9	74	25	14	23	34	13	15	190	145	57	224	245	245	141	57	0	0	92	0	53	0
10	37	18	10	16	24	9	11	169	126	44	198	218	218	94	261	36	0	0	0	0	0
11	74	25	14	23	34	13	15	205	156	61	241	264	264	56	0	4	0	1414	0	0	0
12	74	25	14	23	34	13	15	165	125	49	193	212	212	173	1118	0	52	318	32	0	0
13	74	25	14	23	34	13	15	150	114	45	177	194	194	171	0	0	0	126	0	0	0
14	74	25	14	23	34	13	15	193	146	58	226	248	248	561	48	0	0	112	0	0	0
15	74	25	14	23	34	13	15	170	130	51	200	219	220	178	183	97	54	525	401	26	0
16	74	25	14	23	34	13	15	182	139	55	214	235	235	150	37	116	0	14	0	0	0
17	74	25	14	23	34	13	15	163	124	49	191	210	210	134	99	82	0	7	103	249	37
18	74	25	14	23	34	13	15	149	113	44	175	191	192	152	0	0	25	0	0	0	0
19	74	25	14	23	34	13	15	183	139	55	215	236	236	151	25	3	0	0	35	0	0
20	74	25	14	23	34	13	15	149	114	45	175	192	192	123	0	0	0	0	0	0	0
Total	**67**	**23**	**14**	**21**	**32**	**12**	**14**	**186**	**141**	**54**	**219**	**240**	**240**	**160**	**189**	**82**	**6**	**201**	**118**	**51**	**5**

*Values are equal to the sum of the Peer Review Draft management-related streamside landslide and bank erosion values minus the loadings associated with natural deep-seated landslides (Table 7).

Management-Related Loading Source Categories (continued)

	Road-related Landslides							Management discharge sites							Skid Trails							Treatment of Management Discharge Sites						
Sub-basin	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1954-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1954-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
4	0	0	7	926	12	13	0	0	0	0	10	8	0	8	2	8	7	8	16	15	15	-	-	-	-	1	0	8
5	0	0	1	12	0	0	0	0	13	22	14	8	0	8	1	2	2	2	5	15	15	-	-	-	-	28	0	5
6	154	0	0	100	0	23	19	25	20	20	46	35	0	35	1	3	3	3	6	15	15	-	-	-	-	17	0	10
7	83	9	3	138	0	7	21	18	21	13	49	39	30	39	4	15	13	15	31	15	15	-	-	-	-	47	10	39
8	0	0	0	3	0	0	0	0	0	3	8	6	0	6	1	4	4	4	9	15	15	-	-	-	-	0	0	18
9	24	1	85	719	0	10	13	34	24	16	29	21	240	21	5	18	15	17	36	15	15	-	-	-	-	22	11	23
10	21	32	7	1245	21	22	3	175	143	88	80	53	5	53	4	14	12	14	29	15	15	-	-	-	-	20	0	31
11	0	14	29	31	0	0	318	17	83	198	82	27	41	27	3	10	9	10	21	15	15	-	-	-	-	0	0	22
12	0	25	3	753	0	13	0	0	6	108	58	20	21	20	1	4	4	4	9	15	15	-	-	-	-	0	0	1
13	0	1	0	773	0	0	0	0	2	12	29	21	0	21	1	4	3	3	7	15	15	-	-	-	-	0	0	0
14	0	0	0	3	0	0	0	4	97	26	24	17	64	17	3	9	8	9	18	15	15	-	-	-	-	0	0	40
15	1696	0	0	141	0	112	2	17	19	25	27	17	86	17	2	7	6	7	15	15	15	-	-	-	-	0	0	1
16	1	58	0	12	0	0	0	19	109	127	266	203	203	203	2	8	7	8	17	15	15	-	-	-	-	0	0	57
17	5	34	10	10	0	4	2	12	77	189	68	17	91	17	7	23	19	22	47	15	15	-	-	-	-	0	0	17
18	4	340	13	7	2	12	0	22	133	142	160	115	0	115	2	7	6	7	14	15	15	-	-	-	-	46	6	35
19	0	0	0	0	0	0	0	28	49	19	55	46	46	46	4	13	11	12	26	15	15	-	-	-	-	9	13	28
20	14	2	6	6	2	229	0	2	66	179	57	10	91	10	2	6	5	6	12	15	15	-	-	-	-	0	0	0
Total	**99**	**29**	**15**	**307**	**3**	**20**	**25**	**30**	**60**	**80**	**65**	**39**	**73**	**39**	**4**	**12**	**11**	**12**	**26**	**15**	**15**	**0**	**0**	**0**	**0**	**13**	**4**	**24**

Management-Related Loading Source Categories (continued)

	Road Surface Erosion							Harvest Surface Erosion							Total of Management-Related Loads						
Sub-basin	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011	1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
4	56	84	94	147	69	71	6	2	6	2	2	11	20	8	1,673	294	200	2,302	2,045	423	341
5	58	88	98	154	72	74	7	2	6	2	4	0	0	11	362	306	207	476	439	395	110
6	53	80	89	140	66	68	12	2	6	2	4	0	12	4	526	299	193	586	437	410	310
7	48	72	81	127	60	61	24	2	6	2	10	1	3	1	749	866	179	680	489	423	192
8	54	81	91	143	67	69	5	2	6	2	7	8	4	7	378	304	188	480	441	667	376
9	57	86	97	152	71	73	17	2	6	2	4	5	8	2	444	304	286	1,259	434	668	245
10	51	77	86	136	64	66	22	2	6	2	4	5	6	7	720	452	249	1,694	434	341	236
11	50	75	84	131	38	40	18	2	6	2	2	0	0	1	351	373	397	1,934	384	373	472
12	75	113	127	199	94	96	24	2	6	2	11	0	0	4	1,435	304	359	1,560	400	370	252
13	87	130	146	229	107	110	18	2	6	2	5	0	0	0	314	282	221	1,364	363	332	240
14	52	79	88	138	40	42	36	2	6	2	0	0	0	8	375	362	195	534	357	381	691
15	58	88	98	154	72	74	27	2	6	2	10	0	6	0	2,203	371	250	1,088	759	552	255
16	37	55	62	97	28	29	29	2	6	2	2	15	0	11	355	515	267	637	532	495	480
17	57	86	97	152	44	46	21	2	6	2	5	23	4	4	419	456	380	478	477	631	262
18	58	88	98	154	72	74	32	2	6	2	11	0	1	0	310	711	344	536	473	313	364
19	16	24	27	43	13	13	13	2	6	2	0	0	0	0	333	259	128	348	398	335	267
20	57	86	97	152	44	46	46	2	6	2	0	0	12	0	300	305	348	419	294	597	208
Total	**52**	**78**	**87**	**137**	**55**	**56**	**22**	**2**	**6**	**2**	**5**	**6**	**5**	**4**	**629**	**431**	**268**	**966**	**531**	**476**	**308**

*Total Sediment Loading = Sum of natural loads and management-related loads

Total Sediment Loading*

Total Sediment Loading						
1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
1,786	395	279	2,423	2,171	549	464
473	406	285	595	563	519	185
647	407	275	718	575	548	427
851	959	254	788	602	536	264
469	389	261	575	540	766	474
592	432	376	1,421	605	840	371
876	585	337	1,865	616	523	351
483	490	482	2,079	536	525	556
1,609	452	457	1,752	604	574	430
501	440	323	1,573	586	555	444
527	494	290	700	531	556	996
2,371	514	346	1,273	956	749	427
510	649	359	808	714	677	620
611	622	495	689	700	855	435
499	871	447	747	698	538	556
487	392	220	518	579	516	406
489	464	450	629	518	821	375
781	**563**	**360**	**1,133**	**707**	**652**	**452**

6.2.3.2 Watershed Loading

Table 9 shows current estimates of loads by source category. These values are derived from the total rows by source from the sub-basin loading summary (Table 8). The loading totals shown in Table 9 for the category *Management-Related Bank Erosion & Streamside Landslides* is reduced relative to 2013 estimates (Regional Water Board 2013a) and loads attributed to natural sources are increased accordingly. As described above, this change was quantified by estimating the potential influence of deep seated landslides on bank erosion and streamside landslides.

Table 9. Summary of Upper Elk River Volumetric Loading (yd^3/mi^2/yr) by Sediment Source Category for Analysis Time Periods

Sediment Source Category		1955-1966	1967-1974	1975-1987	1988-1997	1998-2000	2001-2003	2004-2011
Natural	Natural Bank Erosion	9	9	9	9	9	9	9
	Natural Streamside Landslides	26	26	26	26	26	26	26
	Shallow Hillslope Landslides	30	30	30	30	30	30	30
	Deep seated Landslides	3	3	3	3	3	3	3
	Deep Seated Influence on Bank Erosion and Streamside Landslides	84	64	25	99	108	108	76
	Natural Loading	**152**	**132**	**93**	**167**	**176**	**176**	**144**
Land Use	In-Channel: Low Order Channel Incision	67	23	14	21	32	12	14
	In-Channel: Management-Related Bank Erosion & Streamside Landslides	186	141	54	219	240	240	160
	Road-Related Landslides	99	29	15	307	3	20	25
	Open Slope shallow landslides	189	82	6	201	118	51	5
	Land Use-related Sediment Discharge Sites	30	60	80	65	39	73	39
	Post-Treatment Sediment Discharge Sites	0	0	0	0	13	4	24
	Skid Trails	4	12	11	12	26	15	15
	Road surface erosion	52	78	87	137	55	56	22
	Harvest Surface Erosion	2	6	2	5	6	5	4
	Land Use Loading	**629**	**431**	**268**	**966**	**531**	**476**	**308**
Total	**Total Loading**	**781**	**563**	**360**	**1,133**	**707**	**652**	**452**
	Percent of total attributable to land use activities	*81%*	*77%*	*74%*	*85%*	*75%*	*73%*	*68%*

Figure 15 presents sediment loads by source category and time period (the same values from Table 9). This illustrates the importance of land use-related streamside landslides, open slope shallow landslides, road-related shallow landslides, and road surface erosion as sources of sediment—these sources are largely attributable to timber harvest operations and associated activities. Also notable is the reduction in sediment delivery over time from these specific source categories (except streamside landslides). Sediment delivery attributable to land use activities has reduced over time from a high of 85 percent in the 1988-1997 period to a low of 68 percent in the more recent period (2004-2011).

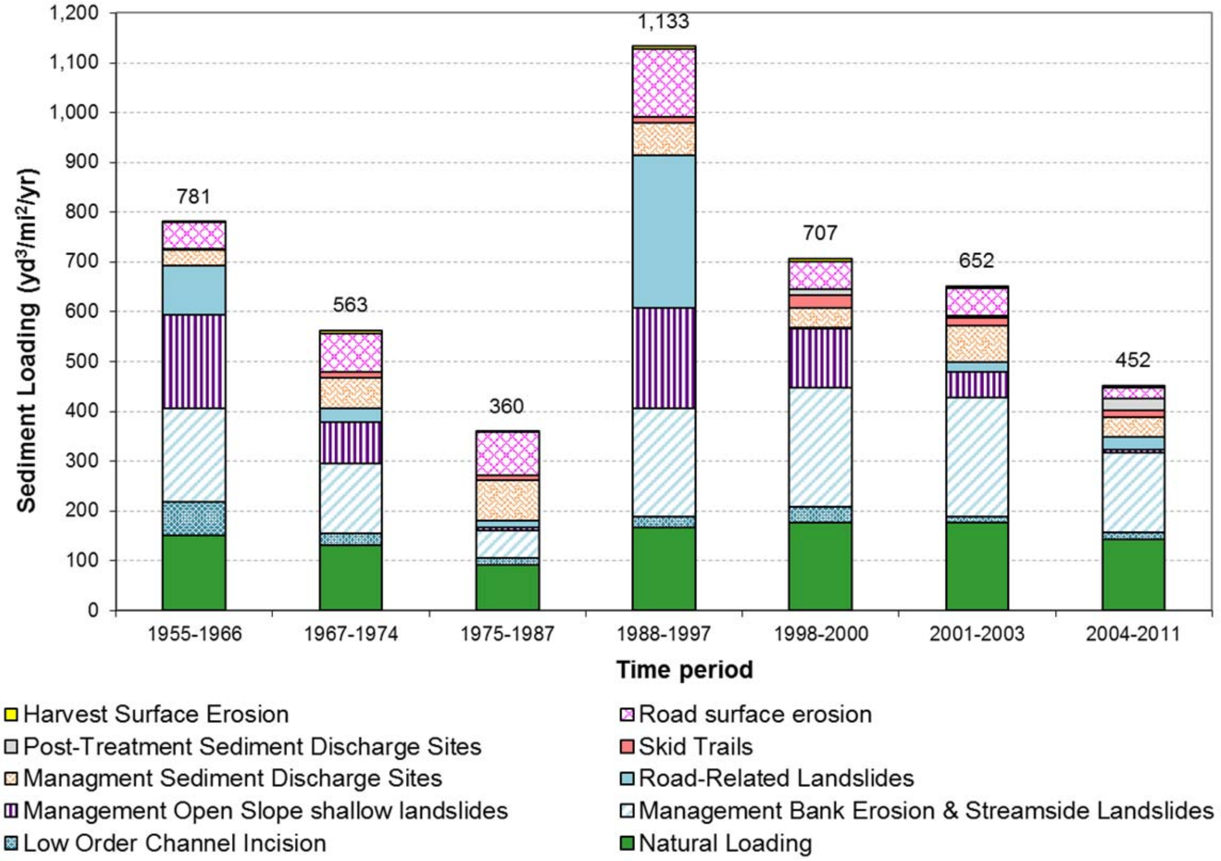

Figure 15. Upper Elk River loading by source category for analysis time periods

The long-term average (1955-2011) land use-related loading is estimated to be 520 yd^3/mi^2/yr (approximately 372 percent of the natural loading). The largest land use-related loading is associated with the 1988-1997 time period, which corresponded with high levels of land disturbance, poor construction and maintenance practices, significant rainfall (1995-1997) and a significant earthquake event (1992) (Regional Water Board 2013b). Natural sediment loading in the same time period is estimated to be approximately 10 percent less than the following six years.

Long-term flow measurements from USGS gage station 11481200 on the Little River near Trinidad, California[19] were evaluated to characterize hydrologic conditions in the area throughout the sediment source analysis time period (Figure 16). These data indicate that the analysis time periods with the wettest years (based on annual water yields) included 1967-1974 and 1998-2000. , The time period with the highest sediment loading rates for the Upper Elk River watershed (Figure 15) was 1988-1997. Therefore, this flow analysis

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[19] Little River offers a long-term gage (61 years of record starting in 1953) in a similar-sized coastal watershed located approximately 20 miles north of the Elk River mouth and provides valuable context for the distribution of discharge events for periods when a gage was not operated on Elk River.

suggests that the high sediment loads estimated for the 1988-1997 period were caused by factors other than significant rainfall.

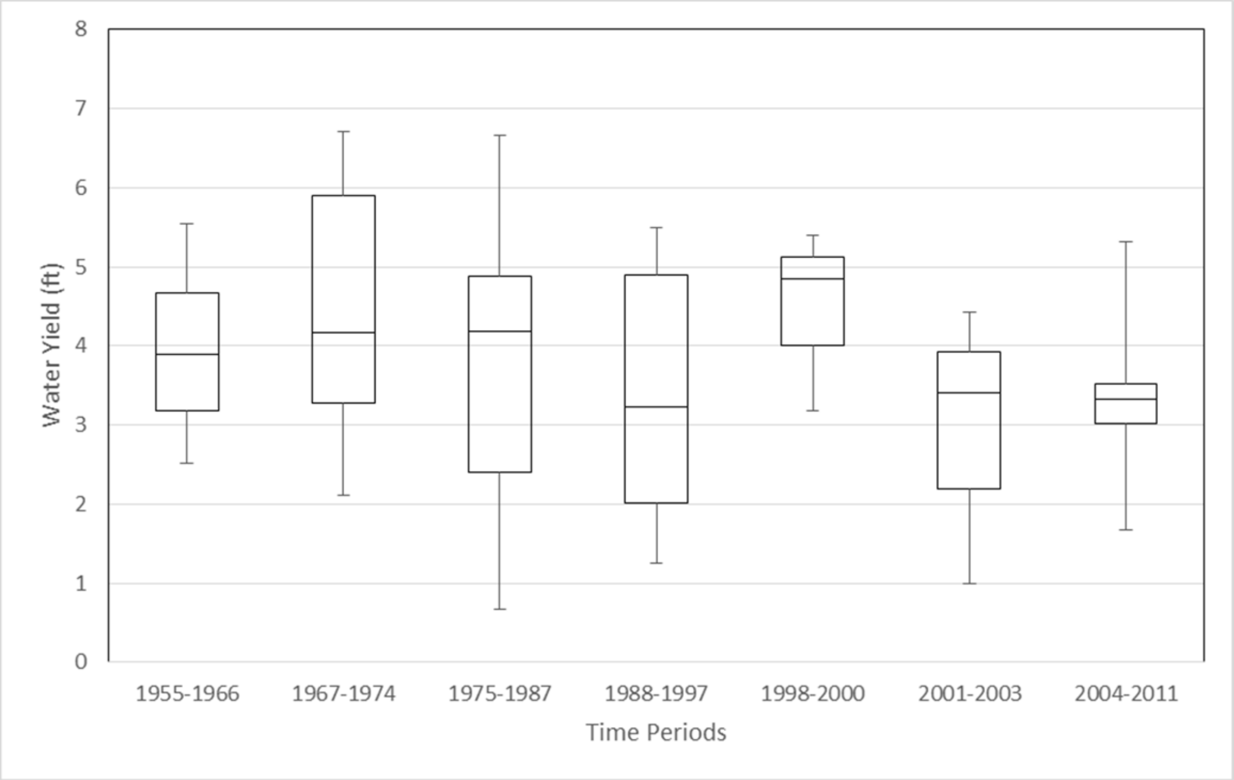

Figure 16. Annual water yields for the Little River near Trinidad, California

Sediment delivery estimates across time periods and source categories have differing levels of uncertainty. Recognizing that uncertainty, loading estimates indicate that in-channel sources of sediment (low order channel incision, bank erosion, and streamside landslides) are the largest controllable source of sediment in the Upper Elk River watershed, and constitute 57 percent of the land use-related sediment delivered to the fluvial system in the most recent period, representing the highest magnitude source though may be the most difficult and currently least controlled. Landslides and management discharge sites represent a medium magnitude source that warrant ongoing control with refinements to the existing programs. Lastly, surface erosion is a chronic, but lower magnitude source that is the most readily controlled.

It should also be noted that different categories of landslides (natural and land use-related) were once identified as a very large component of the total sediment delivered to the Upper Elk River watershed. For example, road-related landslides were the largest single component in the 1988-1997 period (Figure 11). Improvements in land management quality and intensity coincide with a reduction in the proportion of sediment attributable to landslides. This figure illustrates that in-channel sediment sources are the most consistent source of loading to the stream system.

6.2.4 Sediment Transport and Storage

The sediment source analysis describes sediment loading from discrete erosion sources and erosional processes that is available to be delivered to the fluvial system (Chapter 6.2.2 and 6.2.3). Once sediment is delivered to the system, numerous factors influence its transport downstream, including sediment mobility (i.e., grain size) and transport capacity. Conceptually, sediment transport capacity is determined by stream flow, channel characteristics, and roughness features. Land management activities influence these characteristic, as summarized in the Conceptual Model (Chapter 6.1.3), by altering hydrology and reducing LWD recruitment trees. These factors are described below along with a comparison of sediment available in the system and a summary of the sediment deposits in the impacted reach.

6.2.4.1Activities Influencing Sediment Transport Capacity

Large Woody Debris Recruitment Trees

The natural riparian conditions in the watershed created complexity in streams channels, both in the steep upper watershed as well as in the depositional reach (i.e., the impacted reach). Numerous alterations have led to reduced complexity throughout, including reduction in the available recruitable trees within riparian areas. In steep headwater streams, landslides can be important processes by which wood is delivered to streams. Riparian harvesting reduces these inputs. In the event of a landslide, the absence or reduction in trees that may have stabilized the body and toe of the landslide can result in greater volume of sediment delivery. As previously stated, results from streamside landslide surveys in the Upper Elk River and Freshwater Creek indicate increasing delivery volume per slide and increasing frequency of streamside landslides associated with decreasing stand age (PWA 2006). Reduced channel complexity can result in greater sediment transport potential. Large woody debris is critical to restoring natural sediment routing in the Upper Elk River and recruitment of LWD is a critical function of riparian areas.

Altered Hydrology

Within the sediment source analysis period, channel conveyance capacity in the impacted reach was sufficient to contain the majority of high flow events without inundation of the floodplain. Sediment loads associated with the 1988-1997 time period, when combined with downstream channel characteristics and high flows of the mid to late 1990s, resulted in major deposition on the banks and across the floodplain, effectively reducing the stream flow capacity and raising water surface elevations. As a result, frequent floods inundated properties adjacent to the Elk River to unprecedented water surface elevations and lateral flood extents. These events altered the morphology of the river, resulting in a reduction of flow capacity of the channel, effectively reducing the achievable water velocities and the sediment transport capacity of Upper Elk River. This alteration to the hydrologic function in the impacted reaches has made the impacted reach highly sensitive to sediment loads.

6.2.4.2 Sediment within the Stream System

Figure 17 provides a comparison of the total loading as estimated by the void-based sediment source analysis[20] and the suspended sediment load measurements[21]. The comparison of these two datasets, as shown in Figure 17, suggests that there may be some sediment within some of the tributaries that is in addition to the loads delivered from the hillslope. Conceptually, this additional sediment could be sediment stored in the tributary system from past hillslope delivery. It could also include sediment delivered through subsurface erosion. Other possible explanations for the differences are as follows:

1. The void-based estimates amortize sediment loads over a period of years, while the suspended sediment estimates reflect that sediment moves episodically.
2. There are divergent inaccuracies in the estimates of void volume and/or timing and suspended sediment concentration and/or stream flow.
3. There is non-uniformity in the bulk density estimate.

The difference between the two measurements varies across tributaries, but ranges from -60 to 27 percent, with the suspended sediment data generally yielding a higher load estimate (the average difference is 3 percent).

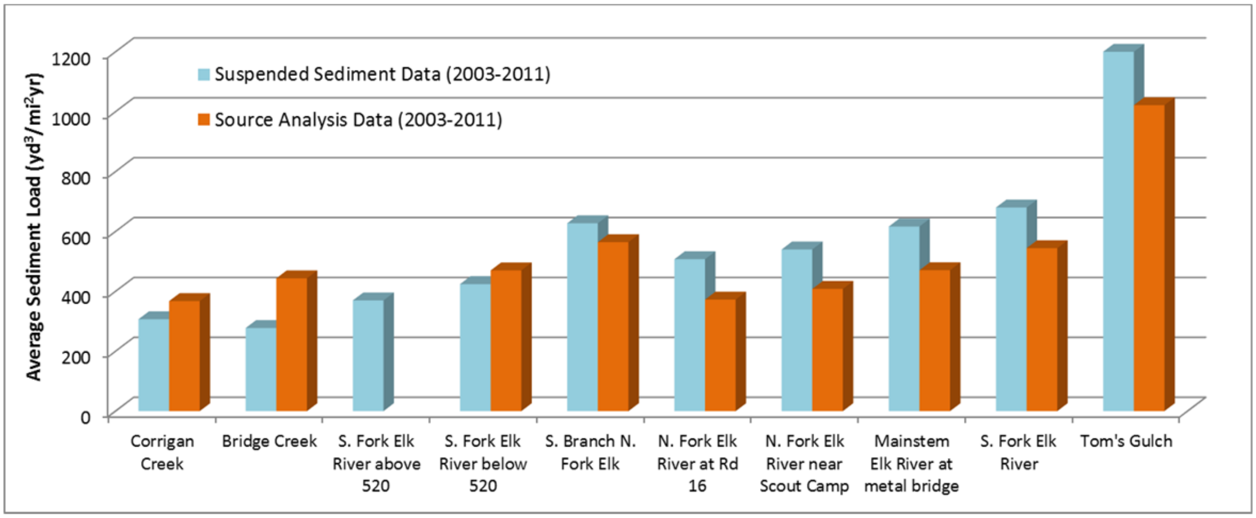

Figure 17. Comparison of average annual sediment loading during the 2003-2011 time period, as estimated by stream flow and suspended sediment data and void-based delivery estimates (source analysis data)

Note: The suspended sediment data were converted using a bulk density of 1.4 tons/yd^3.

In addition to specific land use activities influencing sediment transport capacity, aggradation in the stream influences the altered hydrologic conveyance capacity and the ability of the system to transport sediment downstream.

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[20] The void-based sediment source data represent the rate at which material leaves the hillslope and enters the fluvial system.

[21] The suspended sediment data represents the load of sediment routing through the fluvial system at a given point. These estimates are based on continuous turbidity and stage recording (10-15 minute increments) and empirical stage-discharge and turbidity-suspended sediment concentration relationships.

6.2.4.3 Sediment Deposits in Impacted Reach

The Peer Review Draft identified significant sediment deposits as a primary driver of impaired beneficial uses and nuisance flooding conditions in the impacted reach of the Elk River, which contains the low gradient portions of lower North and South Forks and upper mainstem Elk River (Regional Water Board 2013a). The sediment deposits limit the discharge conveyance capacity, reduce velocities, and limit the stream's ability to pass water and suspended sediment. Table 10 presents estimated volumes of sediment deposits in different segments of the impacted reach, based on calculations of cross-sectional changes identified primarily as of 1993 and described in the Peer Review Draft (Regional Water Board 2013a).

Table 10. Estimated Volume of Instream Sediment Deposits within the Impacted Reach in the Upper Elk River

Reach description (downstream to upstream)	Upstream drainage area (mi^2)	Volume Deposition within Reach (yd^3)	Volume Deposition per Unit Area (yd^3/mi^2)[1]
Upper Mainstem: Shaw Gulch to confluence	45	260,000	6,000
Lower North Fork: confluence to Browns Gulch	22	280,000	13,000
Lower South Fork: confluence to Toms Gulch	19	100,000	5,000
Cumulative excess sediment deposits	**45 (total upstream area)**	**640,000 (sum of upstream reaches)**	**14,000**

[1] Calculated as Volume Deposition divided by Upstream Drainage; rounded to the nearest thousand.

Analysis of cross-section data indicates that recent loading, despite upslope reductions in sediment delivery (Table 9), has nonetheless continued to increase aggradation, including the deposition of sediment in the impacted reach (Lewis 2013; HRC 2012). Table 11 summarizes cross-sectional survey data for several locations in the watershed. These data demonstrate continued deposition at all locations in nearly all years (Regional Water Board 2015).

Figure 18 presents the suspended sediment load data within the impacted reach. Figure 18 illustrates how large flows transport sediment, particularly during 2003 and 2006 when flood heights in the impacted reach were higher than previously observed and significant deposition of sediment was also observed on the bed, banks and floodplain. However, subsequent years also indicated ongoing deposition. The pilot Hydrodynamic and Sediment Transport modeling over a 2.5 mile reach near the confluence of North Fork and South Fork predicted net sediment deposition on the bed, banks, and floodplain (NHE and Stillwater 2013). These results indicate that the majority of the deposition is fine sediment and that deposition has increased since 2003. The surveyed cross-sections within this reach agree with increased deposition (Lewis 2013; HRC 2014; summarized in Table 11 in Regional Water Board 2015).

Table 11. Annual and Cumulative Change in Storage in the Impacted Reach (Regional Water Board 2015).

Year	Mainstem Reach Change in Storage		North Fork Reach Change in Storage		South Fork Reach Change in Storage		Impacted Reach Total Change in Storage	
	Annual (yd^3/yr)	Cumulative (yd^3)	Annual (yd^3/yr)	Cumulative (yd^3)	Annual (yd^3/yr)	Cumulative (yd^3)	Annual (yd^3/yr)	Cumulative (yd^3)
2002	390	390	-3,743	-3,743	-8,678	-8,678	-12,031	-12,031
2003	-4,307	-3,917	-5,428	-9,171	-3,486	-12,164	-13,221	-25,252
2004	791	-3,126	-5,590	-14,761	-3,191	-15,354	-7,989	-33,241
2005	-4,765	-7,891	-6,656	-21,418	-3,717	-19,071	-15,138	-48,379
2006	-7,212	-15,103	-6,087	-27,504	-3,556	-22,627	-16,855	-65,234
2007	-4,833	-19,936	-3,117	-30,622	-3,158	-25,784	-11,108	-76,342
2008	-7,005	-26,941	334	-30,288	-961	-26,746	-7,633	-83,975
2009	-5,314	-32,254	-2,931	-33,219	-1,891	-28,636	-10,136	-94,110
2010	-5,176	-37,430	-3,564	-36,784	-1,339	-29,975	-10,079	-104,189
2011	-3,042	-40,472	-4,414	-41,198	-1,151	-31,126	-8,607	-112,796

Note: Negative numbers indicate deposition in reach and positive numbers indicate scour; yd^3/yr = cubic yards per year.

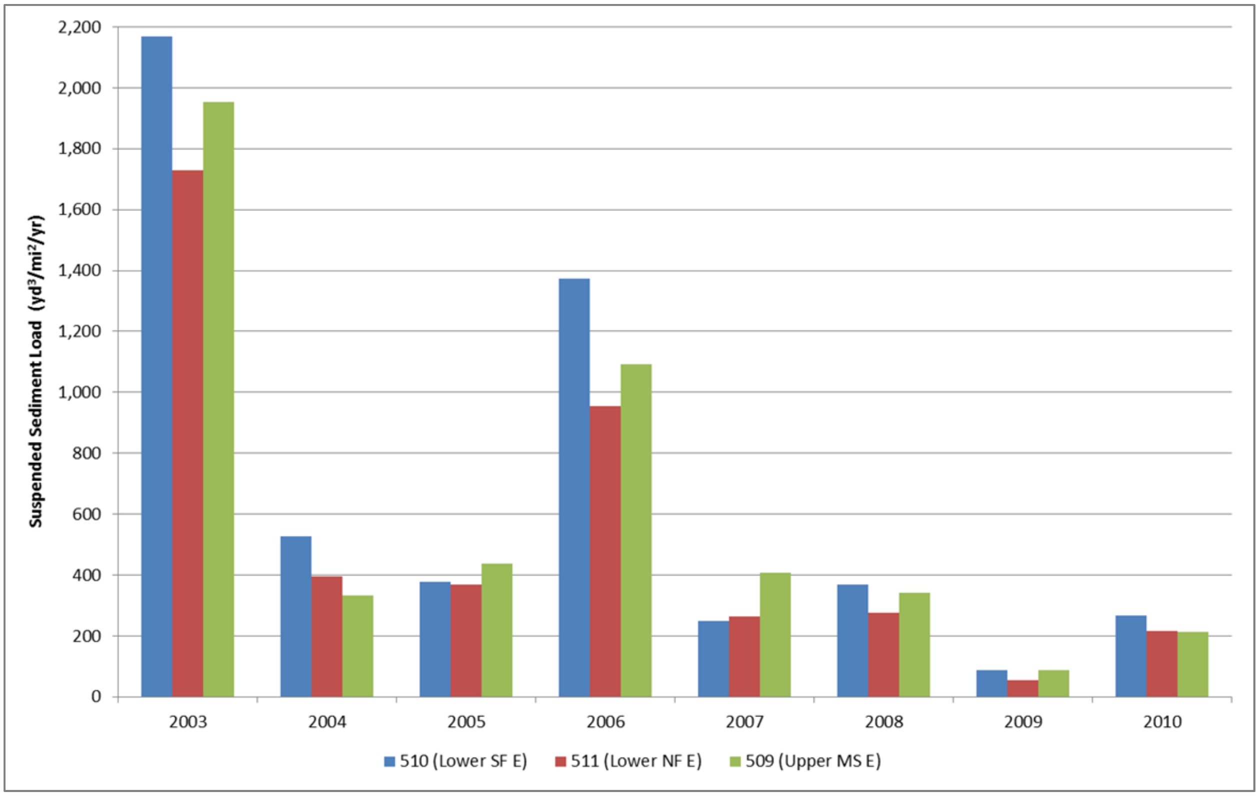

Figure 18. Suspended sediment loads measured near the confluence of South and North Forks of Elk River

6.2.4.4Mass Balance in Impacted reach

It is well established that there is substantial aggradation occurring in the impacted reach of the Upper Elk River. The amount of sediment load entering the impacted reach is also relatively well known based on data collected by HRC and Salmon Forever, among others. In contrast, the data available to establish sediment mass outflow from the impacted reach are limited. The most downstream monitoring station (station 509, mainstem Elk River at Steel Bridge) is in the midst of the impacted reach and does not establish the rate of sediment transport out of the reach.

Ideally, a mass balance could be constructed based upon gage data in the impacted reach. However, gage data are not currently available for the entire impacted reach and entering tributaries. In addition, some data collection and analysis issues have been identified by the Regional Water Board for the available gages, including limitations on capturing the peak discharges at gage sites due to inaccessible locations during floods and inaccuracies in suspended sediment concentrations due to regression techniques and limited depth integrated samples. Efforts are underway to address these issues and should result in a more precise estimate of the sediment mass balance in the impacted reach. Data are, however, already available to accomplish an approximate estimate of the mass balance, as described in the following paragraphs.

One line of evidence is provided by the recently completed pilot hydrodynamic and sediment modeling project (NHE and Stillwater, 2013). The pilot hydrodynamic modeling was calibrated based upon available gage data. NHE and Stillwater compared inflow and outflow from the pilot reach based upon available gage data which indicated that more sediment exits the reach than enters (510, 511, and 509) and more water exits than enters the reach (KRW, SFM, and 509), which was inconsistent with observed aggradation. The pilot modeling ultimately relied on the suspended sediment concentrations from KRW and SFM as upstream inputs and adjusted the discharge estimates to match observed water surface elevations. The pilot modeling results offered reasonable estimates of water surface elevations, scour, and fill as compared to observed conditions during the simulation period. Station 509 is internal to the model grid and thus the model estimates may be compared with the gage estimates of sediment flux.

The pilot model does not extend to the top of the impacted reach on either North Fork or South Fork, nor does it extend to the bottom of the impacted reach. The estimated upstream inputs likely don't change too much on the upper end of the model, although there may be a reduction in the suspended sediment load due to deposition between the top of the impacted reach and the top of the pilot reach. The pilot model extends downstream past station 509, but also does not extend to the downstream end of the impacted reach, ending at Berta Road. Over the simulation period of 2003-2008, the hydrodynamic sediment modeling predicts that 18 percent of the sediment entering the pilot model study area is stored within the channel and floodplain prior to reaching the downstream end of the hydrodynamic model area. Additional storage likely occurs between the end of the geographic extent of the hydrodynamic model and the downstream end of the impacted reach based on the low gradient and observed aggradation of cross sections in this area.

The pilot hydrodynamic modeling in its current preliminary state of calibration does not provide a firm basis for completing the mass balance over the entire impacted reach. First and foremost, the pilot modeling does not cover the downstream extent of the impacted reach. In addition, modeling results appear to be potentially biased relative to suspended sediment monitoring data at station 509: For the period of WY 2004-2008 the model predicts a mean concentration of 349 milligrams per liter (mg/L), whereas the measured mean is 490 mg/L, a difference of -34 percent. However, reliance solely on the gage data indicates that there is net export from the reach bracketed by stations 511 on North Fork, 510 on South Fork, and 509 and on the mainstem.

Observed suspended sediment concentration data are not available at the downstream end of the impacted reach, so a full mass balance cannot be constructed from water column monitoring data. The best currently available evidence for total sediment retention within the impacted reach is provided by analysis of cross-section data over time.[22] This analysis (Regional Water Board 2015) suggests that sediment retention in the impacted reach averages to 8,624 cubic meters per year (m^3/yr), equivalent to 11,280 yd^3/yr, over the period of 2002-2011 (the years for which cross sections throughout the impacted reach are available) and 9,167 m^3/yr, equivalent to 11,990 yd^3/yr, for 2003-2008 (the period covered by the pilot hydrodynamic modeling), with the caveats that there is uncertainty in extending results from a limited number (11) of cross section locations to the entire 6.8 km length of the impacted reach, that not all cross-sections were measured annually, and that this does not include floodplain deposition. Analyses of sediment deposits in the impacted reach (NHE and Stillwater 2013) suggest that the average dry bulk density of these deposits is 0.847 metric tons per cubic meter (mT/m^3)[23], so the estimated mass retention rate (for 2002-2011) is equivalent to approximately 7,300 metric tons per year (mT/yr).

Sediment retention for the 2003-2008 pilot hydrodynamic modeling period based on cross-section data is equivalent to approximately 7,800 mT/yr over the entire impacted reach. The inflow sediment load to the impacted reach from the North Fork, South Fork, Clapp Gulch, and Railroad Gulch for this period is assumed to be approximately the same as the sediment load estimated as influent to the pilot model of 30,100 mT/yr (NHE and Stillwater 2013). On this basis, the fraction of influent sediment stored within the entire impacted reach for this period is estimated at about 26 percent, with the remainder being transported to the Lower Elk River. As would be expected, the sediment load fraction stored in the longer impacted reach is somewhat greater than that estimated for the pilot model area of 18 percent.

The approximate sediment mass balance within the impacted reach for 2003-2008 is summarized in Figure 19. The outflow load is calculated as the difference between the

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[22] If more recent LiDAR or detailed topographic survey data become available, they can be compared with the 2005 LiDAR to estimate change in storage.

[23] The bulk density is extremely low thus making the material particularly difficult to transport with the velocities present in the impacted reach since the material goes into suspension and then quickly settles rather than being transported downstream.

estimated inflow load and the retained load as flow and suspended sediment monitoring are not available at that location. As mentioned above, the total sediment load entering the impacted reach may be larger than the upstream load estimated for the pilot modeling study, in which case the estimated downstream load would also be greater and the percentage retained would be smaller.

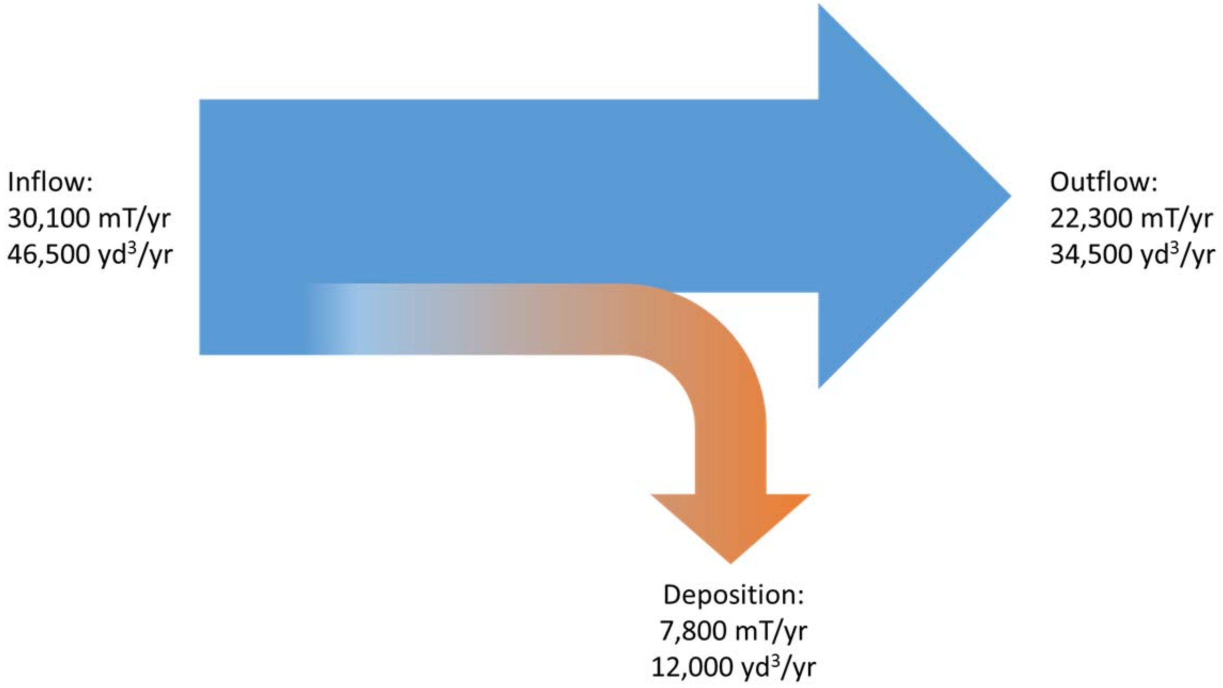

Figure 19. Approximate mass balance within the impacted reach for 2003 – 2008

A majority of the sediment load that enters the impacted reach is passed through to the Lower Elk River. The portion (~26 percent) that is retained is sufficiently large to cause ongoing reduction in channel capacity (e.g., continued aggradation) that induces increased flooding, filling of pools, and other problems. Impairments associated with excess fine sediment in spawning gravels are related to net deposition in the impacted reach, although not linearly. Impairments associated with increased turbidity are more closely tied to the total influent sediment load than to the retention rate within the impacted reach and reducing aggradation rates in the impacted reach may not be sufficient to achieve WQOs associated with those endpoints.

Under current conditions, sediment deposition within the impacted reach is excessive and there is no available assimilative capacity for additional loads (see Chapter 7.2 below). The loading capacity relative to aggradation is not zero, but rather represents a condition in which inflow and outflow loads for the impacted reach are in approximate balance or dynamic equilibrium over time (see Chapter 7.3 below). The mass balance analysis suggests that the river is still capable of moving a sizeable mass of sediment downstream, although less than the recent rate of inflow. The relationship may, however, be non-linear as the pilot hydrodynamic and sediment modeling suggests that, under current conditions, 81 percent of the influent sediment load is transported out of the pilot project reach, whereas under conditions in which the upstream influent load is reduced by 75 percent, 86 percent of the influent load would be transported out of the pilot reach. Because significant retention of sediment is predicted even under reduced upstream loads, it appears to be necessary to consider implementation actions that increase sediment transport capacity within the impacted reach. This is further discussed in Chapter 7 and Chapter 8 below.

Efforts are underway to improve the approach for data collection and analysis to better track changes in sediment deposition and transport. This could inform updates to the mass balance described above. A better understanding of the mass balance could also result from the hydrodynamic modeling currently underway to support remediation and restoration of the impacted reach (Elk River Recovery Assessment). Such refinements could inform a reevaluation of the loading capacity, particularly at the time that sediment remediation and channel restoration are complete. In addition to informing remediation strategies, the Elk River Recovery Assessment could provide information describing sediment transport characteristics, such as the range of particle sizes transported for a given flow in different stream reaches, and the bulk densities of those sediments, thereby allowing for refinement to the mass balance.

Chapter 7 – Sediment Loading Capacity and Load Allocations

The amount of sediment (or any pollutant) a waterbody can assimilate, while maintaining overall waterbody health and experiencing no harmful effects is known as the waterbody's assimilative capacity. The loading capacity of the Upper Elk River is defined as the total sediment load (natural and management-related) that can be discharged into the Upper Elk River and its tributaries without impacting beneficial uses of water, causing an exceedance of WQOs, or creating a nuisance condition.

The balance of sediment input/output may not be achieved every year, but if too little sediment is output (or too much is input) consistently (indicating that the waterbody is not in a state of dynamic equilibrium), then WQS may become impaired. Achieving a state of dynamic equilibrium that meets WQS is the water quality goal for the Elk River. It is anticipated that meeting the loading capacity described in this chapter will achieve this goal.

During development of the loading capacity and subsequent implementation, it is important to consider the relationship between the rate of sediment inflow and outflow, which may be non-linear. Significant retention of sediment is expected even when upstream loads are reduced; therefore, it may be necessary for implementation to include measures that increase sediment transport capacity within the impacted reach (Chapter 6.2.4.4). In light of these technical considerations, this document focuses on three key factors influencing attainment of beneficial uses and elimination of nuisance conditions:

a. Sediment remediation and channel restoration in the impacted reach to better achieve equilibrium conditions associated with sediment output at the bottom of the impacted reach (i.e., improving sediment transport capacity);
b. Control of sediment production and tributary routing as the mechanism to better achieve equilibrium conditions associated with sediment input at the top of the impacted reach; and
c. Document and/or quantify changes in storage to better address the sediment flux within the impacted reach.

Chapter 8 (Framework for Implementation, Monitoring, and Adaptive Management) describes the implementation framework proposed to restore Elk River's assimilative capacity and meet WQS. Implementation is proposed to occur in two phases. The first phase is defined by a zero available assimilative capacity for sediment within the impacted reach. The second phase is expected to be defined once the impacted reach assimilative capacity for additional sediment has been recovered (after which the sediment loading capacity can be recalculated). Discussion of the sediment loading capacity in this chapter mirrors these two phases.

7.1 Total Maximum Daily Load (TMDL)

As described in 40 CFR Part 130.79(c)(1), TMDLs must be established at levels necessary to attain and maintain the applicable narrative and numeric WQS with seasonal variations and a margin of safety (MOS), which takes into account any lack of knowledge concerning the relationship between effluent quality and the resulting influence on ambient water quality conditions. A TMDL is a calculation of the maximum daily amount of a pollutant that can be discharged to a waterbody and still ensure attainment of WQS, taking into account critical conditions of stream flow, loading, and water quality parameters. It is equivalent to the loading capacity of the waterbody for the pollutant in question.

TMDLs attribute pollutant load allocations (LAs) to natural sources and nonpoint sources[24] (e.g., natural background, non-National Pollutant Discharge Elimination System [NPDES][25] permitted discharges) and wasteload allocations (WLAs) to point sources (i.e., NPDES permitted discharges). In addition, the TMDL must include either an explicit or implicit MOS to account for uncertainties in the TMDL development process. The TMDL is represented by the following equation:

$$\textit{TMDL} = \textit{Loading Capacity} = \sum \textit{WLAs} + \sum \textit{LAs} + \textit{MOS}$$

TMDLs can be implemented in phases, allowing for a longer-term perspective with a documented point for reassessment to consider new information. The Regional Water Board is considering a phased TMDL in which the TMDL of the first phase is calculated based on existing conditions and the second phase is calculated based on a future condition in which the impacted reach is remediated and restored.

7.2 Phase I—Current Loading Capacity and Load Allocations

The data suggest that sediment supply exceeds sediment transport capacity in the current condition of the impacted reach. This has resulted in a portion of the sediment load stored in the channel, on its banks, and on the floodplain. The volume of this stored sediment is estimated as the largest sediment source contributing to impairment of beneficial uses and nuisance conditions. As discussed in Chapter 6.2.4.3, an estimated 640,000 yd^3 of excess sediment has been deposited in the impacted reach over approximately the past three decades. Changes in historical cross-sectional area suggest that the channel was relatively stable near the Elk River gaging station in the period from 1955-1965, even given the enormity of the 1964 floods that dramatically impacted most other watersheds in the North Coast Region (Regional Water Board 2013b). For example, in this period, the cross-sectional area at the Elk River gaging station changed no more than 2 percent, but from 1965 to 2003, the cross-sectional area at this location lost nearly 35 percent, clearly

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[24] NPS pollution, also known as polluted runoff, is unlike pollution from distinct, identifiable sources. NPS pollution comes from many diffuse sources. It is caused by rainfall, snowmelt, or irrigation water that moves over and through the ground. As the runoff moves, it picks up and carries away natural and human-made pollutants and deposits them into lakes, rivers, wetlands, ground water, and other inland and coastal waters. Common sources of NPS pollution include runoff from agricultural activities, including feedlots, grazing and dairies; runoff from urban areas; and erosion from timber harvesting, construction sites, and roads.

[25] The NPDES program is a federal program, which has been delegated to the State of California for implementation. NPDES permits, also referred to as Waste Discharge Requirements, are issued to regulate the discharge of municipal wastewater or industrial process, cleaning, or cooling, wastewaters, commercial wastewater, treated groundwater from cleanup projects, or other wastes to surface waters only. If the waste discharge consists only of non-process storm water, it may be regulated under the NPDES Stormwater program. The discharge of waste to the ground surface or to groundwater is regulated under the Non-Chapter 15 Permitting, Surveillance, and Enforcement Program.

impacting assimilative capacity at this location. This quantifies aggradation at a single point in the watershed; however, similar conditions have been observed at other locations in the watershed (Regional Water Board 2013a, 2013b; Lewis 2013; NHE and Stillwater 2013; HRC 2014).

Because of sediment aggradation, there is currently no apparent loading capacity for additional sediment within the impacted reach. This observation is based on (1) sediment inflows to the impacted reach that exceed outflows, (2) continued aggradation in the impacted reach, (3) continued exceedances of sediment-related WQS, and (4) a delay before sediment remediation and channel restoration can be accomplished in the impacted reach, estimated by the Regional Water Board as 10-15 years.

Without apparent capacity for additional sediment, the impacted reach of the Upper Elk River watershed has a current conceptual and regulatory sediment <u>loading capacity of zero</u>. This is conceptual, since using current technology and techniques, there is no amount of land use restriction and channel restoration that can physically result in zero loading of sediment (i.e., the control of all sediment discharge from the tributary system). This *regulatory* loading capacity cap should be maintained until the impacted reach's physical assimilative capacity has been expanded through sediment remediation and channel restoration during Phase I implementation[26].

There are no point source discharges of sediment in the Upper Elk River watershed. All land use-related sediment delivered to the stream channel is considered a nonpoint source discharge. NPS loads are attributed LAs. The LA encompasses nonpoint source sediment discharges from existing sources (see Chapter 6) and new sources, which could occur as a result of new management activities.

The LA also contains sediment from natural background conditions. There are multiple ways of defining the sediment loads associated with natural background conditions, including:

- Measuring sediment loads within a reference basin that is natural or minimally disturbed (as described in Regional Water Board 2013a);
- Estimating sediment loads during a period of time that represents natural or minimally disturbed conditions; and
- Modeling sediment loads from a theoretical landscape that represents natural or minimally disturbed conditions.

As presented previously, there is zero assimilative capacity for additional sediment in the impacted reach and

The loading capacity is defined as zero because:

- Nuisance conditions exist and require remediation to abate.
- Sediment inflow exceeds outflow.
- Channel in the impacted reach is aggrading.
- During high flows (when sediment deposits would be scoured in a functioning system), incoming water and sediment overtops the channel bank and flows across the floodplain. This slows velocities and causes sediment to fall out of suspension.
- Vegetation readily colonizes newly deposited sediment. This slows down flow due to resistance, causing additional sediment deposition.

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[26] A mechanism needs to be developed by which to implement the zero load allocation. The Regional Water Board is intending to develop WDRs, which translate the zero load allocation into permit conditions.

therefore the loading capacity is zero. A zero sediment loading capacity is equivalent to a zero sediment LA. The zero LA is attributed to each nonpoint source of sediment. This approach incorporates a conservative, implicit MOS.

In sum, Phase I of the TMDL is proposed to include a current sediment loading capacity of zero to prevent and minimize sediment delivery to the impacted reach. As described below in Chapter 8, revised or new WDR(s) could be developed to control existing and new sources of sediment in a manner consistent with a zero LA. Phase I would also include remediation and restoration within the impacted reach to reestablish the hydraulic function of the system.

7.3 Phase II – Expanded Sediment Loading Capacity

A second phase of the TMDL (Phase II) could subsequently be considered, as described below. In Phase II the sediment loading capacity of the impacted reach could be recalculated and allocations redistributed. It is important to note that this recalculation could occur at any time since nothing precludes the Regional Water Board from refining the loading capacity in the proposed adaptive management framework. The Phase II updated calculations would quantify the allowable loading to the system that is functioning in dynamic equilibrium (after Phase I efforts are complete).

Once sediment remediation and channel restoration of the impacted reach is accomplished, a process that is anticipated to be informed by the Elk River Recovery Assessment and supported by the stewardship group (Chapter 8), sediment delivery associated with land management and source control activities in the upper watershed might be sufficient to balance sediment input with sediment output through the impacted reach (to minimize changes in storage). The goal of proposed remediation and channel restoration is to restore a dynamic equilibrium in which WQS are attained in the Upper Elk River watershed. This is expected to expand the sediment loading capacity and restore hydrologic function, bringing into balance the sediment output from the impacted reach with the sediment input, thereby justifying the recalculation of the loading capacity in Phase II.

Completion of the sediment and hydrodynamic modeling described in the Elk River Recovery Assessment could help determine this future sediment loading capacity. The revised sediment loading capacity and associated sediment load allocations can then be applied through the chosen regulatory mechanism(s) and restoration of beneficial uses can also be evaluated.

Chapter 8 – Framework for Implementation, Monitoring, and Adaptive Management

The Regional Water Board has identified an implementation framework for the Upper Elk River watershed. They have identified a combination of regulatory and non-regulatory implementation actions that they believe will lead to recovery of beneficial uses and prevention of nuisance conditions in the Upper Elk River:

1. Revise applicable regulatory programs to reduce sediment loads from new and existing sources toward the load allocation,
2. Develop and implement an instream and channel remediation and restoration program to improve hydraulic and sediment transport in the impacted reaches of Upper Elk River,
3. Establish a watershed Stewardship Program to serve as an umbrella in support of beneficial use enhancement, prevention of nuisance, and a trajectory of watershed recovery.

These actions are described below and they are expected to be implemented and monitored as part of an adaptive management framework.

The conceptual model presented in Chapter 6 identifies eight watershed effects that should be managed to restore beneficial uses and prevent nuisance conditions. If executed, the proposed implementation framework is expected to successfully reduce these effects. The lists below generally characterize the expected linkage between the watershed effects and implementation actions (although it is important to note that each watershed effect may be influenced by more than one implementation action).

- Sediment Load Reduction is expected to control:
  - Increased peak flows
  - Increased drainage network
  - Decreased channel complexity
  - Increased turbidity
  - Decreased summer stream flows

- Instream Remediation and Restoration is expected to control:
  - Altered sediment storage
  - Altered sediment transport
  - Increased aggradation

These anticipated improvements should be quantified through monitoring. In addition, the watershed stewardship process is expected to provide an important mechanism for adaptive management to adjust and refine the regulatory and non-regulatory actions, as determined necessary.

8.1 Sediment Load Reduction

WDR(s) is the primary regulatory mechanism utilized by the Regional Water Board to control the nonpoint source pollution resulting from past and ongoing timber harvesting activities, the primary land use in Upper Elk River watershed. Revision of the WDRs for the timberland owners are anticipated as the primary regulatory action needed to implement water quality improvements. Specifically, WDR revisions ensure that sediment load reductions from new and existing sources of sediment are consistent with a zero load allocation, through the application of a comprehensive prevention and minimization program, in combination with beneficial use enhancement projects. The prevention and minimization measures are informed by more than a decade of BMP implementation and sediment source tracking via ownership management plans, HCPs, CAOs, and ownership-wide WDRs. The updated WDRs are expected to be informed by the sediment source assessment, the hillslope WQIs, and technical reports from landowners and watershed partners. Through the WDR, together with regulated stakeholders, the Regional Water Board can enforce measures to prevent and minimize new sediment discharges, reduce existing sources of sediment loading, and restore watershed functions.

8.2 Instream Remediation and Restoration

In addition to sediment load reduction via a strong regulatory and enforcement program, instream sediment remediation and channel restoration is determined necessary to improve the hydrologic and sediment transport capacity of the impacted reach, thus improving the assimilative capacity for sediment and abating nuisance conditions. Potential recovery actions may include dredging, new channel construction, off-channel sediment detention basins, levee construction or modification, vegetation management, infrastructure improvements, creation of inset floodplains, high flow channels, and placement of in-stream LWD.

Such an undertaking requires the participation, coordination, and support of multiple landowners, scientists, permitting agencies, and funders. As such, the Regional Water Board has opted to pursue primarily non-regulatory means of accomplishing sediment remediation and channel restoration to improve conditions in the impacted reach of the Upper Elk River. The Regional Water Board has initiated a sequence of efforts toward this, including:

1. A pilot feasibility study completed in 2012 which tested the use of hydrodynamic and sediment transport models in predicting system response to sediment loading (NHE and Stillwater 2012). The effort was funded by a State Water Board Proposition 50 Grant to RCAA.
2. The Elk River Recovery Assessment is a full scale feasibility study based upon data collection and modeling of current conditions and predication of system response to a combination of generalized sediment loading and remediation actions. The effort began in 2014 and is expected to result in the technical foundation for an implementation framework to remediate instream stored sediment originating from historic land use activities, contain annual winter flows within the historic stream channel and prevent nuisance flooding conditions, and help lead to recovery of ecosystem functions and beneficial uses in the Elk River. The effort is funded by the State Water Board under a contract with California Trout in coordination with a technical team and in consultation with a technical advisory committee.
3. Pilot remediation permitting and implementation projects are planned for 2016-2018. The goals of the pilot projects are to demonstrate implementation capacity and inform the Recovery Assessment of sediment remediation effectiveness, implementation costs, and logistics (e.g., sediment re-use), and environmental compliance procedures.
4. Full-scale remediation permitting and implementation is anticipated to allow for construction to begin in approximately 2020.
5. Monitoring and maintenance is anticipated for an extended period (e.g., ten to twenty years) following completion of remediation efforts.

8.3 Watershed Stewardship

A key, and overarching, component of implementation is to convene a participatory program that engages community members, residents, scientists, land managers, and regulatory agencies in developing a collaborative planning process that seeks to enhance conditions in the Elk River watershed. The Elk River Watershed Stewardship Program will include the entire Elk River watershed and will work to accomplish the following goals:

1. Promote shared understanding and seek agreements among diverse participants.
2. Identify strategies and solutions to:
   a. Improve the hydrologic, water quality, and habitat functions of Elk River;
   b. Reduce nuisance flooding of private properties and improve public transportation routes during high water conditions; and
   c. Improve domestic and agricultural water supplies.
3. Promote coordinated monitoring and adaptive management.

The Stewardship Program will interface with and augment the other implementation elements. The Stewardship Program will create opportunities for partnerships and projects to improve conditions in the entire watershed. By providing an open, transparent, and primarily non-regulatory process that is sensitive to diverse needs and interests, the program will cultivate the relationships and strategies needed to renew the health and function of the watershed, effect changes in infrastructure and access, and sustain a vibrant working landscape.

Beginning in 2015, a steering committee to provide facilitation and capacity to the Elk River Watershed Stewardship Program convened and is comprised of Humboldt County, University of California Cooperative Extension, Natural Resources Conservations Services, California Trout, and the Regional Water Board. Initial program funding is provided by 319(h) grant funds from the EPA and will support the stewardship efforts through 2017. The Regional Water Board anticipates that the stewardship efforts will be active throughout the watershed recovery process.

8.4 Monitoring and Adaptive Management

A key component of implementation is monitoring and adaptive management. The Regional Water Board has identified four primary goals for near and long-term monitoring in the Elk River:

- Evaluate compliance with WDR requirements and verify that the provisions of the WDRs are being implemented as designed and permitted.
- Evaluate the effectiveness of management measures and management modifications aimed at reducing sediment loads to the impacted reach via the WDR, and remediation efforts aimed at increasing conditions in the impacted reach.
- Track whether conditions are trending toward numeric targets, WQOs, and beneficial use support.
- Inform when and how to reevaluate the loading capacity.

A combination of monitoring resources are anticipate to achieve these goals, including the Elk River stewardship program, monitoring and reporting requirements associated with the WDRs, monitoring associated with evaluating the effectiveness of sediment remediation and channel restoration projects, ongoing ownership specific monitoring for management plans, and habitat and population monitoring. All of these efforts will contribute to tracking improvements in water quality and beneficial use support, reduction in instream storage, increased hydrologic conveyance and sediment transport, and abatement of nuisance conditions.

Chapter 9 – References

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