Draft
Existing Conditions and Assessment Report and Stream Corridor Management Plan for Arcade Creek, Sacramento County, California

Prepared for
City of Sacramento
Department of Utilities
1395 35th Avenue
Sacramento, CA 95822
Contact: Patrick Sanger, Public Outreach Coordinator
psanger@cityofsacramento.org
916/808-1726

In Coordination with
State Water Resources Control Board
11020 Sun Center Drive, Suite 200
Rancho Cordova, CA 95670
Contact: Lori Webber, Environmental Scientist
lwebber@waterboards.ca.gov
916/464-4745

Prepared by
Jones & Stokes
2600 V Street
Sacramento, CA 95818
Contact: Karen Leone, Project Director
kleone@jsanet.com
916/737-3000

October 2007

Arcade Creek
Watershed

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Contents

Page

Chapter 1 Introduction....1-1
1.1 Introduction....1-1
  1.1.1 Phase I....1-1
  1.1.2 Phase II....1-2
1.2 Project Location....1-3
1.3 Document Purpose and Scope....1-3
1.4 Document Organization....1-4

Chapter 2 Background....2-1
2.1 Introduction....2-1
  2.1.1 Location and Description....2-1
2.2 Physical Natural Resources....2-2
  2.2.1 Topography....2-2
  2.2.2 Geology/Soils....2-2
  2.2.3 Geomorphology....2-4
  2.2.4 Hydrology....2-5
  2.2.5 Water Quality....2-7
  2.2.6 Vegetation and Wetlands....2-12
2.3 Vegetation Characteristics....2-12
  2.3.1 Land Cover Types....2-12
  2.3.2 Nonnative Plant Species....2-15
  2.3.3 Fish....2-17
  2.3.4 Land Use....2-18

Chapter 3 Methods....3-1
3.1 Literature and Data Reviewed....3-1
3.2 Development of Assessment Protocols....3-2
3.3 Data Collection....3-3
  3.3.1 Segment and Reach Identification....3-5
  3.3.2 Geomorphic Assessment....3-6
  3.3.3 Aquatic Survey Assessment....3-10
  3.3.4 Vegetative Assessment....3-10
  3.3.5 Wildlife Surveys....3-11
  3.3.6 Restoration Opportunities....3-11

Chapter 4 **Results** **4-1**
4.1 Introduction 4-1
4.2 Segment and Reach Descriptions 4-1
  4.2.1 Segments 4-1
  4.2.2 Reaches 4-1
4.3 Geomorphic Channel Characteristics 4-2
4.4 Aquatic Habitat Conditions 4-7
4.5 Vegetation Characteristics 4-7
  4.5.1 Land Cover Types 4-7
  4.5.2 Nonnative Plant Species 4-10
  4.5.3 Land Cover Types and Nonnative Plant Species by Project Reach 4-12
4.6 Wildlife and Fish Resources 4-19
  4.6.1 Wildlife 4-19
  4.6.2 Fish 4-19
  4.6.3 Benthic Macroinvertebrates 4-20

Chapter 5 **Restoration Opportunities** **5-1**
5.1 Stream Corridor Management Plan 5-1
5.2 Restoration Opportunities 5-2
  5.2.1 Prioritization of Restoration Opportunities 5-4
  5.2.2 Summary of Restoration Opportunities 5-5
5.3 High Priority Restoration Opportunities 5-40
  5.3.1 Restoration Opportunities 5-40
  5.3.2 Restoration Sites 5-43
5.4 Data Gaps and Future Studies 5-43

Chapter 6 **References** **6-1**
6.1 Printed References 6-1
6.2 Personal Communications 6-5

Appendix A Arcade Creek Stream Corridor: Representative Digital Images, by Reach [Included on CD]

Appendix B Arcade Creek Stream Corridor: Existing Conditions and Restoration Opportunities Maps (2007) [Included on CD]

Appendix C Public Involvement Plan [To Come]

Appendix D Invasive Species Plan [To Come]

Appendix E Environmental Permit Requirements

Appendix F Common and Scientific Species Names

Tables

On Page

2-1 Hydrologic and Erosional Characteristics of Soil....................................2-4

2-2 Major Land Cover Types and Associated Dominant Species Observed in the Arcade Creek Stream Corridor, by Reach..follows 2-14

2-3 Invasive Nonnative Plant Species Observed in the Arcade Creek Stream Corridor, by Reach ....follows 2-16

3-1 Channel Characterization Methodology...3-7

3-2 Terms Used to Describe Bank Stability Conditions 3-9

4-1 Geomorphic Characteristics of the Arcade Creek Stream Corridor, by Segment...4-2

4-2 Summary of Geomorphic Channel Conditions in Lower Segment 4-3

4-3 Summary of Geomorphic Channel Conditions in Middle Segment 4-4

4-4 Summary of Geomorphic Channel Conditions in Upper Segment 4-5

4-5 Summary of Geomorphic Channel Conditions in Cripple Creek Segment..4-6

5-1 Project Goals Addressed by Restoration Opportunities 5-3

5-2 Restoration Opportunities in Arcade Creek Stream Corridor, by Reach...follows 5-6

Figures

Follows Page

1-1 Project Vicinity 1-4

3-1 Arcade Creek Corridor Geomorphic Field Data Collection Form 3-6

3-2 Existing Conditions Data Collection Form 3-10

3-3 Arcade Creek Corridor Invasive Plant Species Data Collection Form..3-10

4-1 Arcade Creek Stream Corridor: Segment and Reach Boundaries..4-2

4-2 Longitudinal Profiles of Arcade Creek and Cripple Creek 4-2

Acronyms and Abbreviations

Project	Arcade Creek Stream Corridor Management project
City	City of Sacramento
EPA	U.S. Environmental Protection Agency
DWR	California Department of Water Resources
CBDA	California Bay-Delta Authority
State Water Board	State Water Resources Control Board
PIP	Public Involvement Plan
ECAR/Corridor Management Plan	Existing Conditions Assessment Report/Stream Corridor Management Plan
Invasive Species Plan	Invasive Species Control and Management Plan
cfs	cubic feet per second
USGS	U.S. Geological Survey
SRWP	Sacramento River Watershed Program
NAWQA	National Water Quality Assessment Program
CCC	Criterion Continuous Concentration
OPP	Office of Pesticide Programs
CMC	Criterion Maximum Concentration
TMDL	total maximum daily load
RWQCB	Regional Water Quality Control Board
TDS	total dissolved solids
TOC	total organic carbon
THMs	trihalomethanes
MPN	Most Probable Number
ESA	federal Endangered Species Act
BMI	benthic macroinvertebrate
NAWQA	National Water-Quality Assessment
SRWP	Sacramento River Watershed Program
GPS	global positioning system

Chapter 1
Introduction

1.1 Introduction

The Arcade Creek Stream Corridor Management project (Project) is a multi-phase project. The first phase was initiated in 2002 by the City of Sacramento (City), with support from a U.S. Environmental Protection Agency (EPA) grant. Building on the successes and lessons learned from the first phase, the second phase was initiated in 2006, again by the City, with continued support from the EPA and additional support from a California Department of Water Resources (DWR) Urban Stream Restoration Grant and California Bay-Delta Authority (CBDA) Proposition 50 funds. The CBDA Proposition 50 funds for the Project are being administered by the State Water Resources Control Board (State Water Board).

1.1.1 Phase I

During the first phase of Project implementation, from 2002 to 2003, the following major efforts were accomplished:

- ■ The stream corridor **Project goals** were developed and include:
  - ❑ Improve water quality,
  - ❑ Reduce flood damage,
  - ❑ Restore/enhance wildlife and plant habitat, and
  - ❑ Increase recreational opportunities, including public education of watershed issues.
- ■ The **Arcade Creek Watershed Group** was formed to provide a forum for stakeholders to discuss past, ongoing, and future stream corridor restoration projects in the Arcade Creek stream corridor, consistent with stream corridor project goals.
- ■ The **Arcade Creek Feasibility Study** (Phase I Feasibility Study; Foothill Associates 2002) was completed and included an assessment of the Arcade Creek stream corridor from Marysville Road to the Sacramento City limits (4.5 miles of stream); specifically, the objectives of the study were to identify

factors negatively affecting water quality; identify opportunities and constraints for flood control; evaluate the quality of riparian and aquatic habitat; and identify recreational opportunities.

- The **Arcade Creek Watershed Plan** (Phase I Watershed Plan; Foothill Associates 2003) was completed and included an assessment of the Arcade Creek watershed and landscape-level projects that might address issues identified in the feasibility study.

1.1.2 Phase II

A major theme of the second phase of the stream corridor project is to move from planning efforts to on-the-ground implementation of actual stream corridor restoration projects consistent with stream corridor project goals.

During the currently underway second phase of implementation, from 2004 to 2009, the following major efforts are planned:

- **Preparation of a Public Involvement Plan** (PIP) that presents strategies to increase public education, stewardship, and participation in the watershed group, with magnitude of costs associated for each of the strategies. Some of the strategies presented in the PIP include **creating a project website and brochure** that supports public involvement efforts.
- **Reinitiate the Arcade Creek Watershed Group** to continue to serve as a forum for stakeholders (focusing primarily on property owners and community members in the watershed), to discuss ongoing and future stream corridor restoration projects in the Arcade Creek stream corridor, consistent with stream corridor project goals.
- **Preparation of a combined Existing Conditions Assessment Report/Stream Corridor Management Plan** (ECAR/Corridor Management Plan) that 1) updates Phase I Watershed Plan watershed assessment with newly available data and a 2007 full-census field survey of the Arcade Creek stream corridor; 2) presents a 20-year action plan for project-level stream corridor restoration projects; and 3) a prioritization of the project-level restoration projects.
- **Preparation of an Invasive Species Control and Management Plan** (Invasive Species Plan) that presents an implementation plan for invasive species removal and management.
- **Construction of the Del Paso Regional Park Detention and Filtration Wetland Project** in Del Paso Park, removal of invasive species and revegetation with native species, and other stream corridor restoration projects.
- **Monitoring and documentation for all on-the-ground activities**, including Del Paso Regional Park detention and filtration basin and invasive plant species removal and revegetation with native riparian plant species.

- **Final Project Report** that describes how the stream corridor project achieves CBDA Watershed Program priorities.

1.2 Project Location

Arcade Creek is the major creek in the Arcade Creek watershed, a 38-square-mile area of land that covers sections of the cities of Sacramento and Citrus Heights, Sacramento County, California. Arcade Creek's main stem is approximately 16 miles in length and is fed by eight major tributaries, including Cripple Creek, Mariposa Creek, South Branch Arcade Creek, San Juan Creek, Brooktree Creek, Coyle Creek, Kohler Creek, and Verde Cruz Creek. Of these, Cripple Creek is the largest tributary. (Figure 1-1.)

1.3 Document Purpose and Scope

This document is a combined ECAR/Corridor Management Plan for Arcade Creek. This ECAR/Corridor Management Plan should be viewed as an outgrowth and further extension of the Phase I Feasibility Study and Watershed Management Plan. As part of Phase I, much planning occurred in support of the Project at the watershed level and to a lesser degree at the stream corridor level (from Marysville Boulevard to Sacramento City limits, about 4.5 miles of the total 16 miles of Arcade Creek).

Moving forward with Phase II, the City will be shifting gears from planning to implementation of actual on-the-ground site-specific projects along the entire length of the Arcade Creek stream corridor. The site-specific projects will address water quality concerns as well as other project goals.

Although there is some background information from the Phase I Feasibility Study and Watershed Plan included in this ECAR/Corridor Management Plan, efforts were made to limit redundancy between the Phase I and the Phase II documents.

The ECAR/Corridor Management Plan updates existing conditions in the watershed/stream corridor based on a full-census assessment conducted in May, June, and August 2007 of the entire length of Arcade Creek and its' major tributary Cripple Creek. Restoration opportunities have been identified based on the existing conditions assessment. These opportunities are described generally and then by specific-sites. The level-of-detail regarding restoration opportunities was specifically developed to be used as important baseline information for regulatory compliance and detailed design and implementation.

For the purposes of this document, the Arcade Creek stream corridor is defined as Arcade Creek itself, Cripple Creek tributary, seasonal side channels, and the terrestrial zone adjacent to the creek that has ecological interactions with the creek. It is also the portion of the creek and its floodplain that is in a relatively natural condition (i.e., vegetated and non-urbanized). The Arcade Creek stream corridor width ranges from 150 to 300 feet.

1.4 Document Organization

This combined ECAR/Corridor Management Plan is organized into the following chapters.

Chapter 1, "Introduction," provides context for this ECAR/Corridor Management Plan through discussion of previous work efforts done under Phase I of the Project.

Chapter 2, "Background," updates existing conditions in the Arcade Creek watershed/stream corridor initially presented in the Phase I Watershed Plan and focuses the discussion to the stream corridor where possible.

Chapter 3, "Methods," presented the methods used in the 2007 full census field surveys of the Arcade Creek stream corridor.

Chapter 4, "Results," presents the results from the 2007 field survey that focused on characterization of channel geomorphology, aquatic habitat conditions, and vegetation. The results are presented by reach for each component surveyed. Tables are used throughout the chapter to summarize results to facilitate review and analyses of the data.

Chapter 5, "Restoration Opportunities," presents restoration opportunities for the Arcade Creek stream corridor and should be viewed primarily as the stream corridor management plan for the Project. This chapter expands on information and data presented in Phase I planning studies for the Project, especially the Phase I Feasibility Study (Foothill Associates 2002) and the Phase I Watershed Plan (Foothill Associates 2003). This chapter also relies heavily on full census field surveys conducted in May, June, and August 2007, in support of Phase II efforts.

Chapter 6, "References," lists references and personal communications cited in the ECAR/Corridor Management Plan.

Appendix A, "Arcade Creek Stream Corridor: Representative Digital Images, by Reach," presents ground-level digital images taken during 2007 field surveys that provide a good representation of each reach. These digital images are provided electronically in the CD pocket at the back of this document.

Appendix B, "Arcade Creek Stream Corridor: Existing Conditions and Restoration Opportunities Maps (2007)," presents the results of the 2007 field surveys—both existing conditions and restoration opportunities—as mapped on 1-foot resolution color aerial photographs from 2004. These digital images are provided electronically in the CD pocket at the back of this document.

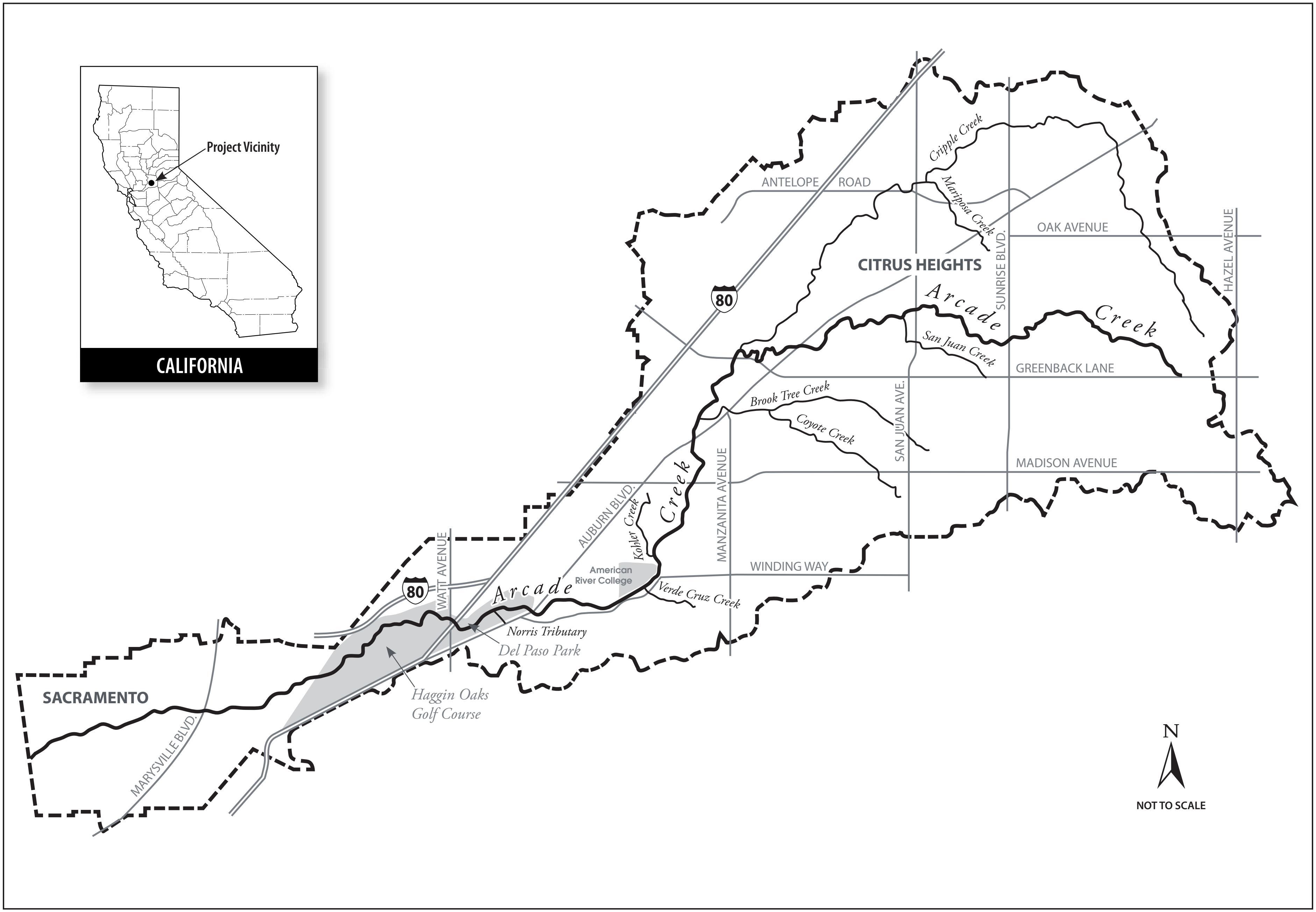

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Figure 1-1
Project Vicinity

Appendix C, “Public Involvement Plan,” attaches the aforementioned.

Appendix D, “Invasive Species Plan,” attaches the aforementioned.

Appendix E, “Environmental Permit Requirements,” presents common environmental permits that may be applicable to the restoration opportunities described in Chapter 5. Examples of project triggers that necessitate compliance with each permit are also provided.

Appendix F, “Common and Scientific Species Names,” provides the common and scientific names of plants (native and nonnative) and wildlife discussed in the ECAR/Corridor Management Plan.

Chapter 2
Background

2.1 Introduction

This chapter provides a summary of the natural resources of the Arcade Creek watershed and stream corridor based on a review of existing data from Phase I efforts and other references plus recently conducted field surveys (i.e., June, July, and August 2007) performed in support of Phase II efforts.

This chapter is primarily tiered off the Phase I Watershed Plan, Chapter 4, “Watershed Resource Assessment” (Foothill Associates 2003a), unless otherwise noted. Information from the Phase I Watershed Plan has been summarized, updated, and augmented to provide context for existing conditions and restoration opportunities, asdecribed under Phase II efforts.

The natural resources of the Arcade Creek stream corridor that are described in this report include physical and biological natural resources. Physical natural resources consists of topography, geology and soils, geomorphology, hydrology, and water quality. Biological natural resources consist of vegetation and wildlife. For the most part, this chapter focuses on and presents natural resources information related to Arcade Creek’s stream corridor. In some instances, natural resources information is presented for the entire Arcade Creek watershed to fully characterize particular natural resources.

Refer to Appendix F, “Common and Scientific Species Names,” for common and scientific names of species mentioned in this chapter.

2.1.1 Location and Description

The 16-mile long Arcade Creek flows through the cities of Sacramento and Citrus Heights, California. Arcade Creek’s headwaters are located near Greenback Lane in Orangevale and the mouth is located at the confluence with Steelhead Creek. Arcade Creek drains a 38-square mile watershed. (Figure 1-1.)

The Arcade Creek watershed is highly urbanized and supports primarily residential, commercial, and transportation land uses. Some open space areas remain along the stream corridor, but the habitat quality of these areas has generally been degraded by the adjacent urban land uses.

Prior to urbanization, Arcade Creek watershed supported a stream corridor with much more physical and biological diversity and a wider, better functioning floodplain than current conditions. Urbanization of the watershed has resulted in floodplain encroachment, increased water runoff rates, and related flood control efforts. These factors have affected the physical natural resources of the Arcade Creek stream corridor by altering the creek and its' tributaries' geomorphology and the biological natural resources of the stream corridor by displacing many habitat types and plant communities and the wildlife that rely on these areas.

2.2 Physical Natural Resources

2.2.1 Topography

Topography in the Arcade Creek watershed, as well as the stream corridor is generally flat. The elevation of Arcade Creek at its headwaters is approximately 200 feet, and at its mouth is approximately 20 feet. This change occurs over approximately 16 linear miles of stream length.

Topography is typically used to determine watershed boundaries. This convention is only partially useful for the highly urbanized Arcade Creek watershed because local streets and the storm drainage system carries surface flow from outside the topographic watershed boundary to the creek channels inside the watershed. As such, the actual boundaries of the watershed probably extend out to include these areas. Conversely, there may be some areas within the watershed where surface drainage is being conveyed out of the watershed by this same mechanism. (Foothill Associates 2003a.)

2.2.2 Geology/Soils

2.2.2.1 Geology

From west to east (downstream to upstream), the thick alluvial deposits of the Arcade Creek stream corridor consist of basin deposits (alluvium); levee and channel deposits with the alluvium of the Riverbank formation on both sides of the floodplain; and sand, silt, and levee and channel deposits with the gravel of the Turlock Formation on both sides of the floodplain (Helley and Harwood 1985; Wagner et al. 1987). The boundaries of the basin deposits extend from the confluence with Steelhead Creek to approximately Norwood Avenue; the boundaries of levee and channel deposits with the alluvium of the Riverbank formation on both sides of the floodplain extend from approximately Norwood Avenue to Watt Avenue; and the boundaries of levee and channel deposits with the gravel of the Turlock Formation on both sides of the floodplain extend from Watt Avenue to the headwaters of Arcade Creek.

Most of the Arcade Creek watershed outside of the stream corridor is covered by the large alluvial fans of the Riverbank Formation that appear to bury older alluvial fans of the Turlock Lake Formation (Helley and Harwood 1985). The channel and floodplain of Arcade Creek and its tributaries are mainly Holocene alluvial deposits.

2.2.2.2 Soils

There are approximately 25 individual soil map units that have been mapped in the Arcade Creek watershed (Rogers 1980; Tugel 1993). These soils are predominantly Fiddyment, San Joaquin, Urban Land, and Xerarents, or combinations of these soils types. Smaller areas of the watershed have Bruella, Cosumnes, Dierssen, Jacktone, Kaseberg, Liveoak, Orangevale, Ramona, Redding, or Reiff soils.

For the purposes of this description, the soil units found in the Arcade Creek watershed have been placed into 10 groups of one or more units (Table 2-1):

Table 2-1. Hydrologic and Erosional Characteristics of Soils in the Arcade Creek Watershed

Soil Group	Hydrologic Group*	Flooding Frequency	Hydric Soils	Erosion Potential
Bruella	B	None	No	Slight or none
Cosumnes	C	Rare	Yes	Slight
Dierssen	D	Rare	Yes	Slight or none
Fiddyment/Kaseberg/Urban Land	D	None	No	Slight or moderate
Jacktone	D	Rare	Yes	Slight or none
Liveoak	B	Occasional/rare	Inclusions	Slight
Orangevale	B	None	No	Moderate
Ramona	B	None	Inclusions	Slight
Redding	D	None	Inclusions	Slight or moderate
Reiff	B	Occasional	No	Slight
San Joaquin/Urban Land	D	None	Inclusions	Slight
Urban Land	NA	NA	NA	NA
Xerarents	NA	NA	NA	NA

* The hydrologic groups are defined as:

- A—High infiltration rates, deep soils, well to excessively drained.
- B—Moderate infiltration rates.
- C—Slow infiltration rates.
- D—Very slow infiltration rates.

Urban Land and Xerarents are areas that have been modified by human activities and no longer posses the attributes of the underlying soil units. Therefore, they are not given the same representation in Table 2-1; information pertaining to these groups is provided below.

- **Urban Land:** modified by human activities and no longer posses the attributes of the underlying soil units. Urban Land consists of areas covered by impervious surfaces or structures, such as roads, driveways, sidewalks, buildings, and parking lots. As a practical matter, Urban Land has a very low infiltration rate, may flood where urban development has encroached on the floodplain, does not have hydric soils, and has a very low rate of erosion.
- **Xerarents:** modified by human activities and no longer posses the attributes of the underlying soil units. Xerarents consist of moderately deep to very deep, well drained, altered soils that commonly have a buried soil. These soils are in filled areas on hills, low terraces, and high terraces. They formed in fill material mixed by grading, excavation, and leveling activities. Xerarents have a moderate to very slow infiltration rate, are unlikely to flood, generally lack hydric soils, and have a slight erosion hazard.

2.2.3 Geomorphology

The major characteristic of channel geomorphology in the Arcade Creek stream corridor is heavy channel incision. Channel incision ranges from a few feet in the upper watershed to more than 14 feet deep in the vicinity of the American River College campus. Channel incision has negetative effects for Arcade Creek. First, incision has led to a deepened channel. This deepening limits channel-floodplain interaction, thereby increasing such variables as unit stream power (Brizga and Finlayson 1990). The increase in unit stream power further increases the instability of stream banks, as all the energy of the flow is contained within the bed and banks of the channel and does not have the opportunity to dissipate onto the floodplain. Limited channel-floodplain interaction also restricts ecological interactions between the channel and the floodplain (Doyle et al. 2000). Second, incised channels further increase the flashy response of channels like Arcade Creek, where relatively infrequent winter precipitation events dominate geomorphic effectiveness (Wolman 1988). Third, channel habitat units, such as pool-riffle sequences, are rare in incised channels, and those that do exist do so for only limited time intervals (Shields et al. 1998). Fourth, the increased depth of flow associated with incision, coupled with an increased flashy regime, results in bed armoring and a decreased frequency of bed mobilization (Doyle et al. 2000). Fifth and last, eroded material from unstable stream banks is added to the channel bed of the creek (often in the form of sandy, lateral bars), decreasing channel capacity and exacerbating flooding. In brief, channel incision has the potential to decrease the diversity of ecosystems as well as to disrupt the morphological structure of the entire channel.

In the lower segment of Arcade Creek between Marysville Boulevard and Roseville Road, sections of the stream banks have been armored with gunnite and riprap. This area is immediately upstream of the levees that were installed below Marysville Blvd to the confluence with Steelhead Creek to protect the property in the lower part of the stream corridor from flooding. The need for the constructed bank protection is a response to both the increased velocity of flows due to urban runoff, the narrowing of the floodplain that constrains the ability of the creek to move laterally, and the subsequent incision. The armoring is an attempt to stabilize the oversteepened banks but precludes the development of riparian vegetation and thus adversely impacts habitat value, aesthetics, and water quality.

The potential to restore or enhance portions of Arcade Creek to a more natural configuration is limited mostly by the degree of encroachment on the floodplain by adjacent urban land uses. There are relatively few locations along the Arcade Creek corridor where adequate undeveloped floodplain remains to allow widening of the channel or establishment of side channels and meanders. In some areas, it may be possible to lay back the creek banks to establish secondary terraces that would increase channel capacity while also improving vegetative structural diversity and habitat opportunities.

2.2.4 Hydrology

2.2.4.1 Effects of Climate

Because of low elevations and Mediterranean climate, there is no snow pack in the Arcade Creek watershed to augment base flows. The rainfall that falls tends to be concentrated in the winter months and is often associated with short, intense storm events.

2.2.4.2 Surface Water

Urbanization of the Arcade Creek watershed has changed the hydrology dramatically over the past 150 years. As impervious surfaces, such as roads, buildings, and parking lots, were constructed, peak flows increased in volume. The creation of storm drainage systems, including paved gutters, drop inlets, and culverts and outfalls, has resulted in a decrease in the time it takes for flows to reach the channel. Grading, paving, and the loss of wetlands and other land use practices have decreased the volume of depressional storage in the watershed. This combination of increased flow volumes and an increase in the rate of flows has resulted in higher peak flows and higher scour capacity.

Historically, Arcade Creek was a seasonal stream that conveyed flows during the winter and spring. Urbanization caused the stream to flow perennially, perhaps beginning about 45 years ago. Under current conditions, landscape irrigation runoff, car washing, and industrial and other non-stormwater discharges augment low flows, and Arcade Creek is now a perennial stream. The interception of shallow groundwater may also augment low flows.

Under current conditions, low flows during the drier summer months may be as little as 2 cubic feet per second (cfs). Between 1964 and 2000, the mean annual flows ranged widely, from 5.96 cfs to 37.3 cfs (U.S. Geological Survey 2007). Typical flows (i.e., base flows) are in the range of 15 to 20 cfs. Peak flows during intense but infrequent storm events range as high as 2,800 cfs or higher (Stopher 1992). The ratio of peak flows to base flows is in the range of 150:1 or higher, and indicates a very "flashy" system in terms of its hydrology. This is a reasonable conclusion, given the high rate of runoff generated by the soils in the watershed, the large amount of impervious surfaces, the small size of the watershed, and the Mediterranean climate.

Currently there are several flood management concerns in the Arcade Creek watershed. Flood hazards occur throughout the stream corridor but may be greatest in the lower portion of the stream corridor. The City of Sacramanto has stoem event trouble call data (i.e., flood report calls) from residents within their jurisdictionm from 1986, 1990, 1995, and 2005. These data show that the majority of trouble calls for the flooding alonbg the Arcade Creek steam corridor occur in the lower portion. This is confirmed by field observations of the constricted nature of the channel, narroweing of the floodplain due to encroachment, and the relatively large number of pipe outfalls draining into the creek.

Additonal flood management concerns occur within the City of Citrus Heights, where private properties back onto Aracde Creek . Homeowners' property and structures are then threatened during high water events and subject to erosion and/or bank failure. To complicate matters, the practices used by some homeowners to maintain their property may impact the channels' flood function by either stripping away vegetation that stabilizes the banks, or by encouraging invasive non-native species that choke the channel and reduce conveyance capacity.

While Citrus Heights is for the most part a fully developed community, there are still a number of neighborhoods served by roads that do not have curbs and gutters to direct surface runoff. In these areas, open vegetated roadside swales intercept and convey surface runoff. These swales actually provide some off-channel detention. However, in some neighborhoods, homeowners are requesting to replace the open swales with buried pipes so the filled areas can be used for additional parking or other uses. The City has discouraged such requests due to the complexity of trying to provide adequate inlets and connections for these pipes to the existing storm sewer system. Another concern is the potential for this approach to deliver storm flows in greater quantity and more quickly and putting additional stress on the storm sewer system.

The changing hydrologic regime of the Arcade Creek watershed and stream corridor has implications for channel geomorphology, flood damage, native vegetation, and aesthetics. Arcade Creek reaches flood stage and overtops its banks more quickly and more frequently than it did prior to development. Water surface elevations rise and fall more rapidly since a high percentage of the watershed has been urbanized.

Flood-related damage occurs from scour and erosion in addition to inundation. This damage may be in the form of streambank instability, habitat loss, damage to bridges and roads, damage to the storm drain system, water quality impacts, damage to residential and recreational structures, and other infrastructure in the watershed, such as utilities.

2.2.4.3 Ground Water

Most of the Arcade Creek channel is deeply incised. This lower creek bed may intercept shallow groundwater, which would also augment low flows. In those areas of Liveoak soils, the shallow groundwater would be expected to be at 6 or 7 feet in depth. Typically, the channel has incised to a depth of 8 to 15 feet, more than deep enough to intercept these flows. This loss of shallow groundwater in riparian zones may negatively affect vegetation.

2.2.5 Water Quality

2.2.5.1 Surface Water

Watersheds with more than 25% impervious area are likely to have significantly degraded water quality (Schueler 1994). The water quality issues in the Arcade Creek system are consistent with this finding. The surface water that flows into Arcade Creek is largely urban runoff. Urban runoff typically contains a range of conventional and toxic pollutants, including nutrients from fertilizers and manure, bacteria and other microbes from a variety of sources, heavy metals from industrial and vehicular sources, and pesticides from residential gardens, recreational areas, and road right-of-ways. Soap, grease, fats, oil, and other hydrocarbons flow into the creek from vehicles, gas stations, car washing, and incidental spills. The surface water in Arcade Creek is also impacted by the presence of litter and other solid wastes and by atmospheric deposition. Rainfall in urban environments will typically contain higher levels of phosphorus and mercury and have a lower pH than precipitation in a pristine environment.

This ECAR/Corridor Management Plan is concerned with the assessment and amelioration of all sources of water quality impacts in the watershed, including both “point sources” and “non-point sources.” Point sources are discharges from a discrete location or facility such as an outfall, pipe, or similar structure. Non-point sources are diffuse by nature, and include atmospheric deposition, runoff from mining, construction and agriculture, and urban runoff from roads and parking lots. When urban runoff is collected in a storm drain system and discharged through an outfall into the receiving body, it is still considered a non-point source because the pollutants are generated from the landscape or other diffuse sources. Non-point source water pollution is a very significant issue in the Arcade Creek watershed because over half of the watershed is in residential use, and nearly half of the watershed is covered by impervious surfaces.

Surface Water Quality Monitoring

Within the past 15 years a number of agencies have monitored various aspects of water quality in Arcade Creek. These include the monitoring conducted by the U.S. Geological Survey (USGS) and by the Sacramento River Watershed Program (SRWP).

The most far-reaching monitoring has been done by the USGS, which selected Arcade Creek as a trend-tracking site as part of its National Water Quality Assessment Program (NAWQA). Continuous monthly data are available for 1996-1998 for a variety of water quality parameters including major element chemistry, nutrients, dissolved organic carbon, pH, alkalinity, dissolved oxygen, pesticides, and volatile organic chemicals. Beginning in 2000, the monitoring protocol was revised to include only pesticides, nutrients, major inorganic constituents, and some basic ecological assessments in order to develop trend data. Beginning in October 2004 the NAWQA program initiated an intensive ground and surface water sampling at a number of sites throughout the Sacramento River basin for a four-year period. Arcade Creek near Del Paso Heights is one of two surface water sites to be monitored as part of the Status and Trends portion of the NAWQA Program (U.S. Geological Survey 2007). During the time period of October 1, 2007 through September 30, 2008, the Arcade Creek site will be sampled 25 times, and will include storm event sampling. The samples will be analyzed for nutrients, pesticides, suspended sediment, pH, alkalinity, dissolved oxygen, specific conductance, chloride, and sulfate (Domagalski pers comm.)

The SRWP produces an annual monitoring report on a number of creeks and rivers in the Sacramento Valley. This report compares data from different waterways characterized by a variety of land uses. Arcade Creek is the designated representative urban creek site and it is sampled at Norwood Avenue. The SRWP monitoring report incorporates data from many sources including the USGS NAWQA program, Sacramento River Coordinated Monitoring Program, pesticide studies from the Department of Pesticide Regulation, and the Sacramento Stormwater Program’s annual report.

Mercury and Methylmercury

Results from the most recent SRWP monitoring study (2003–2004) reveal that total mercury concentrations in Arcade Creek were substantially higher than all Sacramento River mainstem sites sampled (Sacramento River Watershed Program 2005). Methylmercury concentrations in water column samples exceeded the Great Lakes human health-based criterion of 0.24 ng/L most frequently in samples from Arcade Creek (55% of samples). Additionally, Arcade Creek methylmercury concentrations exceeded the Great Lakes wildlife-based criterion of 0.05 ng/L (Sacramento River Watershed Program 2005).

Dissolved Metals

The last SRWP monitoring study to assess trace metals in the Sacramento River watershed was the 1999–2000 study (Larry Walker Associates 2001). Copper, cadmium, lead, zinc, selenium and silver are primarily of concern due to potential toxic impacts on aquatic life. In Arcade Creek, copper, zinc, and arsenic appear to be the metals of primary concern due to elevated concentrations. At this time, Arcade Creek had the highest median concentration of dissolved copper (4.0 µg/L) and the fourth highest median concentration of total copper (4.29 µg/L) relative to all other sampling sites. This is likely indicative of the influence of two potentially significant copper sources: urban runoff and agricultural use of copper-based pesticides (e.g., triazines) (Larry Walker Associates 2001). The median concentration of dissolved zinc was also highest in Arcade Creek. Arcade Creek ranked third in median dissolved arsenic concentrations (2.0 µg/L), which was more than twice that of the Sacramento River mainstem. (Larry Walker Associates 2001.)

Pesticides

Most of pesticide monitoring of surface waters of the Sacramento River watershed has focused on pesticides used in rice cultivation and orchard dormant spray applications, and on pesticides commonly found in urban runoff (Sacramento River Watershed Program 2005). The SRWP annual monitoring program has focused primarily on organophosphate and carbamate pesticides, with triazine pesticides also monitored at selected locations (including Arcade Creek).

Two triazine herbicides, prometon and simazine, and three organophosphates, diazinon, malathion, and chlorpyrifos, were detected in Arcade Creek during SRWP's 2003–2004 monitoring (Sacramento River Watershed Program 2005). Sampling took place four times during the year (i.e., January, February, June, and July), and each of the detected pesticides was detected only once. Water quality criteria were exceeded for chlorpyrifos and diazinon. Chlorpyrifos was detected at greater than DFG's recommended Criterion Continuous Concentration (CCC) of 0.014 µg/L in two field replicates from Arcade Creek that were qualified as estimated based on high variability between the replicates. The concentrations reported for both of these samples (0.65 µg/L and 0.041 µg/L) also exceeded the lowest toxic threshold reported in EPA's Office of Pesticide Programs (OPP) Ecotoxicity Database (0.028 µg/L, LC50 for crustacean species) and the recommended Criterion Maximum Concentration (CMC) of 0.02 µg/L. Diazinon concentrations in Arcade Creek (0.64 µg/L) also exceeded CDFG's CCC. Furthermore, of all the waterways sampled as part of the SRWP 2003–2004 monitoring, the highest diazinon concentration observed was reported for Arcade Creek. Arcade Creek diazinon concentrations also exceeded the lowest LC50 (0.2 µg/L, for crustacea) reported in the EPA's OPP Ecotoxicity Database. It should be noted that many other organic compounds were detected but do not quality standards (Cooke et al. 1998).

The well-documented effects on water quality from diazinon and chlorpyrifos for urban use (exemplified by Arcade Creek) are being addressed through several regulatory programs. Historically, Arcade Creek has been 303(d) listed for the organophosphates diazinon and chlorpyrifos; as of 2006, copper was the only 303(d) listed pollutant/stressor for Arcade Creek (State Water Resources Control Board 2006). The potential impacts on beneficial uses from diazinon and chlorpyrifos in drainages dominated by agricultural runoff are now being addressed through the Water Quality Management Strategy developed by the Organophosphate Pesticide Focus Group, by the total maximum daily load

(TMDL) developed by the Central Valley Regional Water Quality Control Board (RWQCB), and by proposed amendments of the Central Valley Basin Plan to add the DFG recommended criteria for diazinon (and other provisions related to diazinon) (Sacramento River Watershed Program 2005).

Drinking Water

The Sacramento River and its tributaries, including Arcade Creek, are the primary source of flow to the Sacramento-San Joaquin Delta and the source of drinking water for 20 million people in the Bay Area, Central Coast, and Southern California. Drinking water parameters of concern included in the SRWP monitoring program include total dissolved solids (TDS), organic carbon, minerals, nutrients, pathogens, turbidity, and minerals.

Total Dissolved Solids and Organic Carbon. Of the 21 waterways sampled in the SRWP’s 2003–2004 monitoring program, Arcade Creek was one of four waterways with the highest TDS concentration, but this did not exceed the California Department of Health Services and EPA’s Secondary Drinking Water Standard maximum contaminant level of 500 mg/L. TDS can have an important effect on the taste and palatability of drinking water, and at very high levels, may cause health problems in sensitive individuals. Total organic carbon (TOC) thresholds were exceeded in Arcade Creek (range=7.2 to 11 mg/L). Organic carbon is of concern primarily due to its role in the creation of carcinogenic trihalomethanes (THMs) and other disinfection by-products during disinfection of source water. EPA’s Stage 1 Disinfectants/Disinfection By-products Rule (TOC treatment thresholds of 2 mg/L and 4 mg/L) was designed to limit precursors to disinfection byproducts such as THMs. In cases where the running annual average TOC in source water (measured at water treatment plant intakes) is 2.0–4.0 mg/L, water utilities may be required to remove up to 35% of the TOC (depending on source water alkalinity) unless they meet other specific quality or treatment technology requirements; if running average source water TOC exceeds 4 mg/L, water utilities may be required to remove up to 45% of the TOC in their influent (U.S. Environmental Protection Agency 1998b).

Minerals. Arcade Creek had elevated levels of almost all minerals sampled. In the USGS sampling from February 1996 to April 1998, most minerals were measured at higher concentrations in the summer and lower concentrations during winter months. This was a general trend that did not always apply. According to the SRMP 1998–1999 monitoring report, when mineral concentrations were last assessed by SRWP, concentrations in Arcade Creek were all higher than the Sacramento River. Sodium, calcium, potassium, manganese and iron concentrations were all elevated in Arcade Creek relative to most of the other sites sampled in the Sacramento River watershed (Sacramento River Watershed Program 2000).

Nutrients. Elevated nutrient concentrations may promote excessive algal growth and consequently contribute to taste and odor problems associated with some species of algae. According to the 2000 SRWP report, Arcade Creek had among the highest nutrient concentrations of any sampled waterway. Arcade Creek had the highest levels of nitrite (0.51 mg/L). Two separate surveys recorded Arcade Creek as having the highest nitrate level at 0.04 mg/L, while most other waters had <0.01 mg/L. The Sacramento River had a higher concentration of ammonia nitrogen (0.11 mg/L) but Arcade Creek had the highest concentration of any of its tributaries at 0.07 mg/L, compared to most others with <0.01 mg/L. Arcade Creek also had the highest organic nitrogen concentration (0.76 mg/L) and dissolved orthophosphate, 0.123 mg/L, compared to the next highest at 0.09 mg/L. Analyses of samples for total phosphorous revealed one other sample equaled the concentrations found in Arcade Creek at 0.24 mg/L, while the lowest concentration recorded was 0.01 mg/L.

Pathogens. Pathogens are disease-producing organisms (protozoa, bacteria, and viruses) that adversely affect drinking water qulaity and/or may pose human health risks for water contact recreation. Coliform bacteria are monitored primarily as indicators of fecal contamination and the possible presence of enteric pathogens such as *Cryptosporidium* and *Giardia* because these pathogens are difficult to monitor effectively (Sacramento River Watershed Program 2005). The EPA recommends monitoring *Escherischia coli* (*E. coli*) and *Enterococci* as the preferred indicators of pathogen organisms. In SRWP's 2003–2004 monitoring, fecal coliform bacteria numbers were evaluated in comparison to the Central Valley Basin Plan water quality objective of 200 Most Probable Number (MPN) per 100 as a geometric mean value and a maximum value of 400 MPN/100 ml. Fecal coliform in Arcade Creek exceeded the maximum water quality objective 4-fold during one sampling event. The recommended limits for *E. coli* are 126 MPN/100 mL as a 5-sample 30-day geometric mean and 235 MPN/100 mL as a single sample maximum. The single sample limit for *E. coli* was exceeded at nearly every site sampled in the Sacramento River watershed, including Arcade Creek (Sacramento River Watershed Program 2005).

Aquatic Toxicity

Aquatic toxicity monitoring in the mainstem Sacramento River and its tributaries (including Arcade Creek) was undertaken by the SRWP (2005) to characterize the spatial and temporal distribution of toxicity in surface waters of the watershed, and to identify potential sources and causes of toxicity. Laboratory toxicity tests were performed using standard EPA procedures with the freshwater test species *Ceriodaphnia dubia* (water flea), *Pimephales promelas* (fathead minnow), and *Selenastrum capricornutum* (single-cell green algae) to assess water quality. In contrast to previous years, samples collected from Arcade Creek at Norwood Avenue did not exhibit a higher frequency or severity of toxicity relative to other tributaries and mainstem Sacramento River sites. One of the four samples collected in 2003–2004 from Arcade Creek caused significant mortality to *Ceriodaphnia*, with one additional sample causing reproductive toxicity. Toxicity to *Pimephales* was less frequently observed in samples collected from the major tributaries (25%), agricultural drains (25%), or Arcade Creek (25%).

Groundwater

There are no known groundwater contamination problems in the Arcade Creek watershed. Monitoring conducted by the USGS did not reveal any toxicants at elevated levels (U.S. Geological Survey 2002). This may be due to the depth of groundwater and the partially confined nature of the aquifer. Shallow groundwater, found above the impermeable or slowly permeable layers in the subsoils, is at a greater risk of contamination.

2.2.6 Vegetation and Wetlands

This section describes the land cover types and the nonnative plant species that occur in the Arcade Creek stream corridor. The study area comprises all of the land area within and adjacent to Arcade Creek and Cripple Creek. The width of the study area corridor varied within each study reach but generally extended up to, and sometimes included, residential, commercial, or City property landscapes and parks.

2.3 Vegetation Characteristics

This section describes the land cover types and the nonnative plant species that occur in the Arcade Creek stream corridor. This section also provides a brief description of the land cover types and most common nonnative plant species that occur in the Arcade Creek stream corridor, by reach.

2.3.1 Land Cover Types

A land cover type represents the dominant features of the land surface and can be defined by natural vegetation, water, or human uses (e.g., parks). Although land cover types were not specifically mapped, 12 major land cover types were identified during the 2007 field surveys. Because land cover type surveys were not specifically performed, additional land cover types may be present in the Arcade Creek stream corridor. Table 2-2 identifies the major land cover types and the dominant species, by reach.

A jurisdictional wetland delineation was not performed for the stream corridor during the 2007 field surveys; however emergent wetlands and other waters of the United States were observed. The Phase I Watershed Management Plan also identified remnant vernal pools in the vicinity of Del Paso Regional Park (Foothill Associates 2003a).

- emergent wetland,
- other waters of the United States,
- valley oak riparian forest,
- mixed oak forest,
- riparian forest,
- riparian scrub,
- annual grassland,

- ornamental landscape (residential and commercial),
- park,
- agricultural land,
- disturbed area, and
- developed area.

2.3.1.1 Emergent Wetland

The emergent wetland land cover type occurs throughout the stream corridor both within and along stream margins. Emergent wetlands are dominated by erect, rooted, herbaceous hydrophytes that may occur in large patches, such as Reach 1, but more typically occur in narrow bands along the low-flow channel, such as Reach 3. The species composition of this land cover type varies by reach. Emergent wetlands support a variety of herbaceous wetland plant species, including common tule, cattail, and water smartweed.

2.3.1.2 Other Waters of the United States

Arcade Creek, Cripple Creek, and associated tributaries are considered other waters of the United States. General information on the characteristics of creeks and tributaries are described in Section 4.3, “Geomorphic Channel Characterization.”

2.3.1.3 Valley Oak Forest

The valley oak forest land cover type is common in the Arcade Creek stream corridor, occurring in upland areas adjacent to Arcade Creek and Cripple Creek. Although valley oak forest occurs on the floodplain, it is typically located on higher terraces or on the outer limits of the floodplain and away from the creeks and drainages. Valley oak is the dominant overstory species and the understory is typically dominated by annual grasses and ruderal forbs. In many reaches nonnative species, including Himalayan blackberry, vinca, and fruit trees are dominant understory species.

2.3.1.4 Mixed Oak Forest

The mixed oak forest land cover type is common in the Arcade Creek stream corridor, occurring in upland areas adjacent to Arcade Creek and Cripple Creek and at similar landscape positions as valley oak forest. The species composition of the mixed oak land cover type varies by reach and may include valley oak, blue oak, and interior live oak. The dominant understory species are typically dominated by annual grasses, ruderal forbs and poison oak. In many reaches nonnative species, including Himalayan blackberry, vinca, and fruit trees, are dominant understory species.

2.3.1.5 Riparian Forest

The riparian forest land cover type is common in the Arcade Creek stream corridor, occurring along the banks of Arcade Creek and Cripple Creek and associated drainages. Valley oak is the dominant overstory species in many reaches. Other native overstory species include Fremont’s cottonwood, Goodding’s willow, Oregon ash, and box elder. Nonnative tree species observed with the riparian forest land cover type include catalpa, black locust, acacia, Japanese privet, and tree-of-heaven.

Depending on location, the understory may consist of tree and shrub seedlings or native and nonnative herbaceous vegetation. In many reaches, nonnative species such as Himalayan blackberry, vinca, English ivy, fruit trees, and fig are dominant midstory and understory species.

2.3.1.6 Riparian Scrub

The riparian scrub land cover occurs along the banks of the Arcade Creek stream corridor and associated drainages. Riparian scrub typically consists of small trees and seedlings of riparian tree and shrub species and nonnative species and in some cases may be early successional stages of riparian forest.

2.3.1.7 Annual Grassland

Annual grassland is dominated by a mixture of annual grasses and herbaceous nonnative species. Annual grassland generally occurs on levee and channel banks and in disturbed areas, such as edges of fields and roads, in the Arcade Creek stream corridor. The species in this land cover type are generally native and nonnative annual grasses and forbs.

2.3.1.8 Ornamental Landscape

The Arcade Creek stream corridor is located within an urbanized watershed. As a result, residential and commercial ornamental landscapes occur almost continuously along the creek corridor and in some cases extend all the way to the creek banks. Ornamental landscapes are dominated by nonnative species, some of which occur in native land cover types throughout the watershed. Ornamental species include, but are not limited to those species identified in Table 2-3.

Table 2-2. Major Land Cover Types and Associated Dominant Species Observed in the Arcade Creek Stream Corridor, by Reach

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
ARCADE CREEK														
1			X	X	X	X	X				X	Valley oak Gooding's willow	Box elder Narrow-leaved willow	Italian ryegrass Bermuda grass
2			X	X	X	X	X				X	Valley oak Gooding's willow Box elder	Box elder Narrow-leaved willow	Annual grasses Cocklebur Tule
3			X	X	X	X	X				X	Valley oak		Annual grasses
4			X	X	X	X	X	X			X	Gooding's willow Valley oak Blue oak Interior live oak Cottonwood Gooding's willow	Arroyo willow Box elder Oregon ash Narrow-leaved willow Black walnut	Cocklebur Annual grasses Wild radish Bedstraw
5			X	X	X	X	X			X	X	Valley oak Blue oak Box elder	Arroyo willow Gooding's willow Narrow-leaved willow	Annual grasses Mugwort Santa Barbara sedge
6	X	X	X	X		X	X		X		X	Valley oak Interior live oak		Santa Barbara sedge Annual grasses

Table 2-2. Continued

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
												Gooding's willow		
7	X	X	X	X		X	X		X		X	Valley oak Blue oak Interior live oak Oregon ash	Oregon ash	Annual grasses Santa Barbara sedge Mugwort Poison oak
8	X	X	X	X	X	X	X		X		X	Valley oak Blue oak Interior live oak Gooding's willow	Oregon ash Box elder Gooding's willow	Annual grasses Santa Barbara sedge Mugwort Poison oak
9	X	X	X	X		X	X	X			X	Valley oak Blue oak Interior live oak	Gooding's willow Oregon ash Buckeye	Annual grasses Mugwort
10	X	X	X	X		X		X	X		X	Valley oak Interior live oak Blue oak Oregon ash	Oregon ash Valley oak Yellow willow Elderberry Toyon Buckeye	Annual grasses Mugwort Santa Barbara sedge

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
11	X		X	X		X		X	X		X	Interior live oak Valley oak Oregon ash Cottonwood Box elder Gooding's willow	Box elder Red willow	Annual grasses
12	X		X	X	X	X		X			X	Valley oak Interior live oak Gooding's willow Oregon ash	Box elder Black walnut Elderberry	Annual grasses Himalayan blackberry Poison oak Santa Barbara sedge
13	X	X			X	X	X	X			X	Valley oak Interior live oak Blue oak Oregon ash Gooding's willow	Black walnut Box elder Oregon ash Arroyo willow	Annual grasses Santa Barbara sedge
14	X	X	X		X	X		X		X		Valley oak Blue oak Interior live oak	Valley oak Blue oak Interior live oak	Annual grasses Mugwort Santa Barbara sedge

Table 2-2. Continued

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
													Black walnut Box elder Elderberry	Poison oak
15	X	X	X	X	X	X		X	X		X	Valley oak Blue oak Interior live oak	Valley oak Blue oak Interior live oak	Annual grasses Santa Barbara sedge Mugwort Poison oak Himalayan blackberry
16	X	X	X	X	X	X				X	X	Valley oak Blue oak Interior live oak	Valley oak Blue oak Interior live oak Cottonwood Toyon	Annual grasses Poison oak Santa Barbara sedge
17	X	X	X	X	X	X		X			X	Valley oak Blue oak Interior live oak	Buckeye Elderberry Black walnut Toyon Gooding's willow	Annual grasses Santa Barbara sedge Mugwort

Table 2-2. Continued

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
18	X	X	X	X	X	X		X	X		X	Valley oak Blue oak Interior live oak Cottonwood Black walnut	Gooding's willow Valley oak Blue oak Interior live oak Coyote brush Black walnut Buckeye	Annual grasses Himalayan blackberry
19	X	X	X	X	X	X		X			X	Valley oak Interior live oak Blue oak		Annual grasses
20	X	X			X	X		X				Blue oak Interior live oak Gooding's willow Cottonwood	Buckeye Box elder	Annual grasses Himalayan blackberry
21	X	X	X	X	X	X		X			X	Blue oak Interior live oak	Blue oak Interior live oak	Annual grasses Himalayan blackberry

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
CRIPPLE CREEK														
22	X	X	X	X		X	X	X			X	Blue oak Interior live oak Valley oak	Oregon ash Valley oak Elderberry	Himalayan blackberry Annual grasses
23	X	X	X	X		X	X	X	X		X	Interior Live Oak Valley oak	Fruit trees Valley oak Oregon ash	Himalayan blackberry Annual grasses Vinca
24	X	X	X	X	X	X	X		X	X	X	Valley oak Interior live oak Blue oak	Tree of heaven Valley oak Black walnut	Vinca Himalayan blackberry Bermuda grass Annual grasses
25	X	X	X	X		X	X		X	X	X	Valley oak Interior live oak Blue oak	Valley oak Fig Black walnut Black willow Privet	English ivy Himalayan blackberry Vinca Annual grasses
26	X	X					X	X	X	X	X	Valley oak Interior live oak	Valley oak Chinese pistache	Himalayan blackberry Annual grasses

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
												Plane tree Redwood	Catalpa Box elder	Vinca
27	X	X	X	X			X	X		X	X	Valley oak Interior Live oak Black walnut	Valley oak Mulberry Privet	Himalayan blackberry Annual grasses Vinca
28	X		X	X			X	X		X	X	Valley oak Black walnut	Mulberry Tree of heaven Privet Valley oak	Annual grasses Himalayan blackberry Giant reed
29	X	X		X	X	X	X	X	X		X	Valley oak Black walnut Interior live oak	Tree of heaven Black willow Valley oak Mulberry	Himalayan blackberry Poison oak Annaul grasses English Ivy
30	X			X	X		X	X		X	X	Valley oak Eucalyptus	Valley oak Chinese pistache Tree of heaven Mulberry Fig	Himalayan blackberry English ivy

Creek	Valley Oak Forest	Mixed Oak Forest	Riparian Forest	Riparian Scrub	Emergent Wetland	Other Waters of the United States	Annual Grassland	Ornamental Landscapes (Residential or Commercial)	Parks	Disturbed Areas	Developed Areas	Dominant Overstory Species	Dominant Midstory Species	Dominant Understory Species
31	X	X		X	X		X	X		X	X	Valley oak Interior Live oak	Valley oak Silk tree Fig Tree of Heaven Mulberry	Himalayan blackberry Annual grasses English ivy
32				X	X		X	X		X	X	Valley oak Elm London Plane tree	Mulberry Fig Misc. landscaping trees Valley oak	Himalayan blackberry Annual grasses

2.3.1.9 Park Land

There are several parks that occur along the Arcade Creek stream corridor. These parks typically include maintained turf grasses and scattered native and nonnative trees and shrubs. Some ornamental species that occur in parks also occur in native land cover types throughout the stream corridor although the presence of these nonnative species cannot be attributed to park plantings.

Parks located adjacent to or near the Arcade Creek stream corridor include the following (listed based on downstream to upstream location in stream corridor):

- Hagginwood Park,
- Haggin Oaks Golf Course,
- Del Paso Regional Park,
- American River College,
- Arcade Creek Park,
- Crosswoods Park,
- Tempo Park,
- Sunrise Golf Course, and
- Rusch Regional Park.

2.3.1.10 Developed Land

Developed lands in Arcade Creek stream corridor varies by reach and may include levee and other access roads; high, medium, and low density residential areas; commercial developments; and streets and bridges.

2.3.2 Nonnative Plant Species

This section describes invasive, nonnative plant species that occur in the Arcade Creek stream corridor. This section does not focus on the characteristics of individual nonnative species but instead groups nonnative species with like physical characteristics (e.g., vines and groundcovers), reproductive characteristics (e.g., fruit bearing trees), or by its level of invasiveness. Additional descriptions of nonnative species are provided in the Invasive Species Plan (Appendix D).

Nonnative plant species along the Arcade Creek stream corridor include escaped ornamental landscape tree, shrub, and vine species. The nonnative species in the stream corridor are common riparian weed species along many urban streams. The original point source for most of these nonnative species is unknown but is assumed to residential or commercial landscapes. Many of the nonnative species in the stream corridor are now self-sustaining and promoting the further expansion of nonnative species. Many invasive species form monocultures that outcompete native species and reduce wildlife habitat values.

Although some nonnative species may be the dominant weed species in a given reach, most nonnative species were observed in many of the reaches (Table 2-2). Nonnative species occurrences ranged from mature stands or mature individual nonnative trees, shrubs or vines, to isolated occurrences of nonnative seedlings that are just beginning to colonize an area.

2.3.2.1 Vines and Groundcovers

Nonnative vines and groundcovers include species that form dense monocultures along creek banks or in the understory of adjacent woodlands. The most common species in the study area include Himalayan blackberry, ivy, vinca, and cultivated grapes. Himalayan blackberry forms dense stands of interwoven vines that are impenetrable once established. This plant species spreads vegetatively and by seed dispersal. Ivy and vinca spread vegetatively and are typically found in locations were they have escaped from adjacent landscaped areas. Ivy may also occur in the riparian tree canopy.

2.3.2.2 Giant Reed and Pampas Grass

Giant reed and pampas grass typically occur in isolated, dense stands throughout the Arcade Creek stream corridor. Giant reed spreads vegetatively and may become established through the dispersal of root segments dislodged by high flow events. Pampas grass spreads by seed dispersal.

2.3.2.3 Red Sesbania

Red sesbania is an extremely invasive nonnative shrub that occurs in isolated occurrences throughout the Arcade Creek stream corridor. Seedlings and small trees typically occur along the lower portion of the bank or on sandbars. This species was most often observed where there was no overhead riparian cover or where there were openings within the canopy. This species is a prolific seeder and establishes quickly in disturbed areas along stream corridors.

2.3.2.4 Cultivated Fruit and Nut Trees

Common cultivated fruit and nut trees in the study area include plum, apple, almond, mulberry, English walnut, edible fig, and Mexican fan palm. These species escaped from adjacent landscapes or gardens and are typically spread by seed dispersal. Cultivated plums form dense stands in the understory of oak and riparian woodlands in several reaches.

Table 2-3. Invasive Nonnative Plant Species Observed in the Arcade Creek Stream Corridor, by Reach

Page 1 of 2

Reach	Acacia	Ash	Black locust	Catalpa	Chinese pistache	Elm	English ivy	Eucalyptus	Fig	Giant reed	Himalayan blackberry	Japanese privet	Liquidambar	Maple	Mulberry	Oleander	Plum/fruit trees	Red sesbania	Redwood/pine	Silk tree	Tree of Heaven	Vinca	Washington palm	Other
ARCADE CREEK																								
1		X				X												X			X			
2		X	X	X		X								X	X						X			
3			X	X		X				X								X			X			
4		X		X					X	X	X				X	X	X	X			X			English walnut, Wisteria
5	X	X		X		X	X		X	X	X				X			X					X	White alder
6		X		X		X		X		X	X	X			X		X	X					X	Beefwood
7		X	X	X		X				X	X										X			
8	X			X		X			X		X	X		X				X			X	X	X	Almond
9	X		X	X		X	X			X	X			X	X		X				X	X		English walnut, Buckthorn
10	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	Olive
11	X	X	X	X					X			X			X		X	X				X		Pampas grass, Camphor
12	X		X	X			X	X	X	X	X	X	X		X		X	X			X	X	X	
13	X		X	X							X	X		X	X		X	X			X			Pampas grass, Redbud
14	X		X				X		X	X		X		X	X		X					X		
15	X		X	X			X		X		X			X	X		X				X	X		
16	X	X	X	X						X	X				X		X				X	X		
17	X	X	X	X			X		X	X	X	X			X		X					X	X	Olive
18	X			X	X		X			X	X	X	X	X	X		X				X			Camphor

Table 2-3. Continued

Page 2 of 2

Reach	Acacia	Ash	Black locust	Catalpa	Chinese pistache	Elm	English ivy	Eucalyptus	Fig	Giant reed	Himalayan blackberry	Japanese privet	Liquidambar	Maple	Mulberry	Oleander	Plum/fruit trees	Red sesbania	Redwood/pine	Silk tree	Tree of Heaven	Vinca	Washington palm	Other
19	X						X		X	X	X	X			X		X						X	Pampas grass
20	X						X		X		X	X					X							
21	X								X		X	X		X			X				X		X	Weeping willow
CRIPPLE CREEK																								
22		X	X	X			X		X		X	X	X	X	X	X	X	X	X	X	X	X	X	
23	X	X		X			X				X	X			X		X	X		X	X	X		
24		X		X			X			X	X	X					X				X	X		Bamboo
25		X					X	X	X	X	X	X		X		X	X	X	X		X			
26				X	X		X		X	X	X			X			X	X		X		X	X	
27		X	X	X	X	X	X		X	X	X	X		X	X	X	X	X				X		
28		X		X					X	X	X	X		X	X						X	X		
29	X		X	X	X		X				X	X	X	X	X			X			X	X		
30		X	X	X			X	X	X		X	X			X	X	X	X		X		X	X	Beefwood
31				X			X				X				X									

2.3.2.5 Other Species

There are numerous other nonnative woody species that occur in the Arcade Creek stream corridor. These include non-cultivated fruit- and seed-bearing trees and shrubs, and other nonnative tree and shrub species. Some of the more common nonnative species in the study area include Japanese privet, black locust, catalpa, tree-of-heaven, and elm. Additional species observed in the Arcade Creek stream corridor are listed in Table 2-3. Many of these species, including Japanese privet, black locust, and catalpa, are prolific seeders and have quickly expanded their range in the stream corridor.

2.3.2.6 Wildlife

The Arcade Creek stream corridor provides habitat for a variety of small mammals, birds, amphibians, fish, and reptiles. Incidental wildlife observations made during the 2007 field surveys were recorded and the results are presented in Appendix F (Table F-2). Wildlife observations included visual observation, songs or calls, tracks, scat, or other signs of species presence (e.g., feathers).

2.3.3 Fish

Chinook salmon and steelhead trout have not been reported in Arcade Creek in over 20 years. Due to the lack of suitable rearing and spawning habitat and summer low flows, it is not likely that these species would return in the foreseeable future (Healy pers comm. 2007). However, these species do occur in the Sacramento River system and could potentially be affected by the water quality of Arcade Creek. Both of these species have been documented in recent years in Miners Ravine and Secret Ravine, tributaries of the Dry Creek watershed immediately to the north. While the Dry Creek watershed is not as heavily urbanized as the Arcade Creek watershed, the potential exists for these species to return to the Arcade Creek system if habitat conditions improve. Steelhead in the Central Valley are listed as threatened under the federal Endangered Species Act.

Other native fish species that are likely to occur in Arcade Creek include tule perch, Sacramento sucker, and several minnow species (Foothill Associates 2002).

Introduced fish species expected to occur in Arcade Creek are similar to those that are found in nearby Dry Creek. These include catfish, bluegill, and mosquito fish. Green sunfish may also be present, and both carp and largemouth bass were reported in 1977 (Stopher 1992).

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Benthic Macroinvertebrate

Benthic macroinvertebrate (BMI) survey data was received from the Arcade Creek Project (Arcade Creek Project 2007a) team at Mira Loma High School in Sacramento, California. Students from the Mira Loma High School International Baccalaureate Program collected BMI samples from Arcade Creek from 2000 through 2007. Samples were generally collected from up to six sites during spring and fall of each calendar year; however, the actual number of samples collected each season varied from six samples to zero samples. Sampling was conducted following the California Stream Bioassessment Procedure for Point-Source Sampling (Arcade Creek Project 2007b). Invertebrate identifications were generally made to the Standard Level 2 Taxonomic Effort for Citizen Monitors.

2.3.4 Land Use

Land use in the Arcade Creek watershed is predominantly residential, commercial, and transportation infrastructure (i.e., roads, parking lots, and railroads). The area of impervious surfaces and the generation of pollutants are directly related to land uses within the watershed. Nearly half (45%) of the

Arcade Creek watershed is covered with impervious surfaces that prevent infiltration of precipitation, exacerbate urban runoff, and preclude habitat availability.

Chapter 3
Methods

3.1 Literature and Data Reviewed

Current, applicable literature and data with relevance to the Arcade Creek stream corridor and watershed were identified and reviewed as part of Phase II efforts to prepare the ECAR/Corridor Management Plan and Invasive Species Plan. The following sources were reviewed:

- Arcade Creek Feasibility Study (Foothill Associates 2002);
- Arcade Creek Watershed Plan (Foothill Associates 2003a);
- Biological Assessment and Essential Fish Habitat Assessment, Central Valley Steelhead and Central Valley Fall-Run Chinook salmon: Bridge Road Bridge Replacement Project (Jones & Stokes 2003);
- Management Plan and Grant Implementation Report, American River College Nature Area (Stopher 1992);
- National Water Quality Assessment, Groundwater Data: Sacramento Urban Land-Use Study (U.S. Geological Survey 2002);
- Roseville Creek and Riparian Management and Restoration Plan—Existing Conditions and Assessment Report (Foothill Associates 2003b);
- Sacramento River Basin National Water-Quality Assessment (NAWQA) Program (U.S. Geological Survey 2007);
- Sacramento River Watershed Program (SRWP) Annual Monitoring Report 1999-2000 (Larry Walker Associates 2001);
- Soil Survey of Sacramento County, California. USDA Soil Conservation Service in cooperation with the University of California Agricultural Experiment Station (Tugel 1993);
- SRWP Annual Monitoring Report 2000–2001 (Sacramento River Watershed Program 2002); and
- SRWP Annual Monitoring Report 2003–2004 (Sacramento River Watershed Program 2005).

The potential to restore or enhance portions of Arcade Creek to a more natural condition is limited primarily by the high degree of encroachment on the floodplain by adjacent urban land uses. There are relatively few locations along the Arcade Creek stream corridor where adequate undeveloped floodplain remains to allow widening of the channel or establishment of side channels and meanders. In some areas, it may is possible to reduce the grade of stream banks to establish secondary terraces that would increase channel capacity while also improving vegetative structural diversity and habitat opportunities. The Phase I Feasibility Study (Foothill Associates 2002) identified locations along the Arcade Creek stream corridor where these landscape-level projects might be sited. This ECAR/Corridor Management Plan expands upon the Phase I Feasibility Study and identifies additional locations for such projects.

Accordingly, some of the methods identified in the Phase I Feasibility Study (Foothill Associates 2002) are used in this ECAR/Corridor Management Plan to classify reaches and determine potential restoration sites. However, this ECAR/Corridor Management Plan encompasses the entire length of Arcade Creek stream corridor. As such, data collection is more generalized and reach-based.

3.2 Development of Assessment Protocols

The two main purposes of this ECAR/Corridor Management Plan are to 1) identify the existing geomorphic and vegetative conditions along the Arcade Creek corridor; and 2) determine appropriate potential restoration opportunities to meet Project goals. The methods used to complete these objectives were therefore based on two strategies:

- Qualitative and quantitative description of the geomorphic and vegetative characteristics of each reach; and
- Site-specific, global positioning system (GPS)-based inventory of potential restoration sites

In order to assess the geomorphic and vegetative characteristics in the Arcade Creek stream corridor, the following sources were used in development of the protocols for this study:

- California Stream Bioassessment Procedure (California Department of Fish and Game 1994);
- California Watershed Assessment Guide (Shilling et al. 2004);
- Method Manual for the Large Woody Debris Survey (Schuett-Hames et al. 1994); and
- Methods in Stream Ecology (Hauer and Lamberti 1996);
- R1/R4 (Northern/Intermountain Regional) fish and fish habitat standard inventory procedures handbook (Overton et al. 1997);
- Stream Channel Reference Sites: An illustrated Guide to Field Technique (Harrelson et al. 1994);

- Stream Habitat Classification and Inventory Procedures for Northern California (McCain et al. 1990);
- Stream Visual Assessment Protocol (U.S. Department of Agriculture 1998);
- Timber-Fish-Wildlife Ambient Monitoring Program Manual;
- Watershed Analysis Manual, v. 4.0 (Washington State Forest Practices Board 1997).

The protocol includes qualitative and quantitative assessments in the following areas:

- stream channel morphology and aquatic habitat indicators
  - width of corridor,
  - channel pattern,
  - large woody material influence, and
  - streambed material composition.
- water quality indicators
  - number of pipe outfalls, and
  - number of debris jams.
- land cover type mapping
  - vegetation communities, and
  - occurrence and frequency of invasive species.
- wildlife occurrences
- restoration opportunities

3.3 Data Collection

The survey team consisted of a fluvial geomorphologist and a biologist, both with expertise in riverine restoration. An initial field reconnaissance survey to delineate segments and reaches was conducted on April 2, 2007. Field surveys were conducted on Arcade Creek between May 23 and June 13, 2007. Field surveys were conducted on Cripple Creek between August 13 and 15, 2007. Channel geomorphology, aquatic habitat conditions, and vegetation conditions were mapped for the north forks of Arcade and Cripple Creeks. Qualitative assessments were performed at road crossings for the south fork of Cripple Creek; no mapping occurred on the south fork of Cripple Creek.

Surveys on the north forks of Arcade and Cripple Creeks included:

- walking the entire length of the stream corridor,
- performing qualitative and quantitative surveys,

- identifying and recording the geomorphic and vegetative characteristics of each reach,
- identifying restoration opportunities, and
- recording digital photographs at key locations.

Pertinent site features were mapped on 1-foot scale resolution color aerial photographs (2004) that identified the stream corridor, floodplain, and surrounding landscape, including road crossings and developed areas. The maps were used to record, among other information, the following:

- the location of reach start and endpoints,
- tributary locations,
- unstable banks,
- pipe outfalls,
- parking lots or other hardscaped areas with runoff issues,
- local areas with bank hardening,
- recreational trails,
- areas of structural constriction/encroachment,
- grade control structures,
- vegetation communities,
- significant stands of nonnative vegetation, and
- restoration opportunities

A handheld GPS was used to record the information above to the greatest resolution possible (based on GPS receiver reception). These coordinates were used in the creation of Appendix B, “Arcade Creek Stream Corridor: Existing Conditions and Restoration Opportunities Maps (2007).”

Characterization for a reach occurred at the end of the reach. Protocol data was collected and organized based upon left and right bank location. As a general rule in stream assessment, and for the purposes of this study, left bank is defined as the bank on the left when facing downstream.

3.3.1 Segment and Reach Identification

3.3.1.1 Segments

Channel morphology varies moving downstream in the Arcade Creek stream corridor. Because of this variation and for classification and descriptive purposes, the stream corridor was divided into segments and channel reaches. Segments are distinctive sections of the channel network that possess geomorphic properties and hydrologic transport characteristics that distinguish them from adjacent reaches (Bisson and Montgomery 1996). Segments were identified and separated based on six anthropogenic and morphological characteristics partly after Schumm (1977) and Montgomery and Buffington (1993).

Segments within the Arcade Creek stream corridor were identified based on the following criteria:

- presence of levees and/or other bank hardening;
- form (confined, moderately confined, or unconfined floodplain);
- width (defined as width of former/current floodplain between areas of encroachment);
- gradient;
- channel form/pattern (straight, meandering, braided, and branching); and
- sinuosity (ratio of actual channel distance between identified points compared to straight/down-valley distance).

3.3.1.2 Reaches

A segment usually has one or more reaches. Reaches are usually at least half a mile in length (Montgomery and Buffington 1993). Reaches consist of relatively homogeneous associations of topographic features and channel geomorphic units that distinguish them from adjoining reaches (Bisson and Montgomery 1996).

The extent of the reaches was determined by the team members in the field. Reaches were defined by changes in the morphology of the creek environment and based on the following criteria:

- channel form/pattern (straight, meandering, braided, and branching);
- channel gradient (e.g., uniform run to a pool/riffle sequence);
- channel width;
- changes in bank material and stability;
- degree of hardscaping;
- changes in the surrounding vegetation;
- changes in surrounding land use (e.g., road crossings or a transition from parkland to a residential neighborhood); and
- sediment characteristics.

3.3.2 Geomorphic Assessment

Draft data sheets were developed from the existing protocols to record observations of the indicators noted above. These data sheets were refined during the first day of field surveys into the geomorphic field form shown in Figure 3-1.

The following paragraphs describe the methods by which the geomorphic conditions of the Arcade Creek stream corridor were evaluated. The Arcade Creek stream corridor was evaluated both qualitatively and quantitatively.

3.3.2.1 Segment/Creek/Reach Identification

Other types of information (besides segment and reach identification) that were collected in the creek/reach identification portion of the geomorphic field form (Figure 3-1) include the reach type (i.e., pool-riffle, regime, plane-bed), description of the starting and ending points for each reach, number of tributaries on each bank, and key to all digital photographs that were taken.

3.3.2.2 Channel Characterization

Stream channel was characterized based upon average statistics within each reach. Table 3-1 lists the geomorphic characteristics that were collected, provides a brief synopsis of the methodology used to collect data on the characteristics, and the level of resolution of data that were collected.

Segment/Creek/Reach Identification

Segment
lower middle upper

Date:
Personnel:
Photo ID #s:

Creek Name:
Reach ID:
Reach Type:

Reach Start:
Reach End:

Tributaries LB:
Tributaries RB:

Channel Characterization

Single or Mutliple Channel
single multiple

Sinuosity
straight slighty sinuous sinuous meandering braided

Natural floodplain width:
Average bankfull width:
Mean bankfull depth:
Low-flow width:
Low-flow depth:

Reach Dominated by:

~ # Pools:
~ # Riffles:
~ # Runs:

Grade control structures:

Large Woody Material Influence
low moderate high

degree of incision
low moderate high

Dominant Streambed Material
silt/clay sand gravel cobble/boulder

degree of encroachment
low moderate high

Dominant Streambank Material
silt/clay sand gravel cobble/boulder

overall bank stability
low moderate high

Water Quality Indicators
# of pipe outfalls:
debris jams:
other:

RESTORATION OPPORTUNITES / LIST OF ITEMS TO GPS and MAP ON AERIAL PHOTOS

** start reach (START REACH)*
** end reach (END REACH)*
** tributaries (TRIB) (LB or RB)*

* severely eroding banks (ERO BANK)

* pipe outfalls (PIPE)

* debris jam (DEBRIS)

* parking lots with significant runoff issues (PARKING)

* localized bank harderning areas (HARD BANK) (flood walls, gabions, riprap, other)

* trails (TRAILS)

* removal of stuctures/areas of structural constriction/encroachment (ENCROACHMENT)

* grade control structures (GRADE)

* other specific restoration opportunities (REST)

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Figure 3-1
Arcade Creek Corridor Geomorphic Field Data Collection Form

Table 3-1. Channel Characterization Methodology

Geomorphic Characteristic	Methodology	Level of Resolution
Single or multiple channel	Visual determination from walking survey	Reach length
Sinuosity	Aerial photograph interpretation to determine if channel is straight, slightly sinuous, sinuous, meandering, or braided; straight (1); slightly sinuous (1.1-1.3); sinuous (1.4-1.7); meandering (1.8 and above); Sinuosity defined as ratio of actual channel distance between identified points compared to straight/down-valley distance	Reach length
Number of pools, riffles, and runs	Visual determination from walking survey*	Reach length
Dominant habitat unit	Visual determination from walking survey (pool, riffles, or run-dominated)	Reach average
Large woody material influence	Visual determination from walking survey (low, moderate, or high influence); influence based on channel morphology as a result of woody material (overhanging banks, alcoves, etc.) and not shade provision**	Reach average
Dominant streambed material	Visual determination from walking survey (silt/clay, sand, gravel, or cobble/boulder); Silt/clay (0 – 0.062 mm), sand (0.062 – 2 mm), gravel (2 – 64 mm), cobble/boulder (> 64 mm)	Reach average
Dominant streambank material	Visual determination from walking survey (silt/clay, sand, gravel, or cobble/boulder); Silt/clay (0 – 0.062 mm), sand (0.062 – 2 mm), gravel (2 – 64 mm), cobble/boulder (> 64 mm)	Reach average
Number of pipe outfalls	Running tally; all pipe outfalls included	Reach length
Number of debris jams	Running tally; debris jam includes large woody material that noticeably constricts channel	Reach length
Natural floodplain width	Aerial photograph interpretation; natural floodplain width defined as width of current floodplain between areas of encroachment	Reach minimum, maximum, and average
Average bankfull width	Measured at various locations within reach; Average bankfull width defined as geomorphic bankfull or effective surface where stream water just begins to overflow into the active floodplain***	Reach average
Mean bankfull depth	Measured at various locations within reach; Mean bankfull depth defined as depth below geomorphic bankfull or effective surface where stream water just begins to overflow into the active floodplain to thalweg***	Reach average
Low-flow width	Measured at various locations within reach; low-flow width defined as width of wetted channel at time of survey	Reach average
Low-flow depth	Measured at various locations within reach; Low-flow width depth defined as average depth of wetted channel at time of survey	Reach average
Grade control structures	Running tally; formal grade control structures included concrete channel bed and/or artificial riffles that detained sediment and	Reach length

Geomorphic Characteristic	Methodology	Level of Resolution
	backed up flow	
Degree of incision	See discussion under "Degree of Incision" (located below)	Reach average
Degree of encroachment	Visual determination from walking survey (low, moderate, or high encroachment); Partly determined natural floodplain width	Reach average
Overall bank stability	See discussion under "Overall Bank Stability" (located below)	Reach average

* Methodology based on Overton et al. 1997 and McCain et al. 1990.

** Methodology partly based on Schuett-Hames et al. 1999, and Washington State Forest Practices Board 1997.

*** Methodology based on Harrelson et al. 1994 and Hauer and Lamberti 1996.

Degree of Incision

The degree to which the channel in a particular reach was incised was recorded. Degree of incision was qualitatively analyzed using the following criteria:

- Identification of any quaternary landforms on the floodplain (e.g., terraces, low floodplain, fan, etc.). Terraces typically have steep streambanks and the channel may not necessarily be incised. Steep, unstable streambanks adjacent to a low floodplain surfaces, however, typically indicate incision.
- Identification of bedforms downstream of the site where noted and if the channel was less incised. Bed and streambank material from incised channels will typically be deposited downstream in somewhat uncharacteristically large deposits on the channel bed (downstream aggradation).
- Recognition of base level changes downstream. Grade control structures and other barriers can create upstream changes in channel bed elevation (i.e., headward migration of incision).
- Visual survey of channel bed in the reach. Channel or habitat sequences, such as pool-riffle sequences, are rare in incised channels. Additionally, the increased depth of flow associated with incision, coupled with an increased flashy regime, results in bed armoring and a decreased frequency of bed mobilization.
- Determination of the health of the riparian and floodplain plant species. Plants that are found in similar, non-incised reaches are usually not present in incised reaches. No vegetation is an indicator of no hydrologic interaction between the floodplain and the channel and therefore incision.
- Identification of recent evidence of overbank deposition of fine sediment, plant debris, or other organic matter. A channel that floods its' banks frequently will typically have splay (i.e., sand) deposits and vegetation with a smoothed, flooded appearance in the downstream direction. Natural levee development is also an indication of frequent flooding.

- Degree of incision was recorded as negligible, low, moderate, or high.

Overall Bank Stability

Bank instability refers to streambanks that either are actively eroding or have the potential to erode in the near future. Bank instability was qualitatively assessed in all surveyed (i.e., walked) areas. The purpose of assessing this indicator was to identify fluvial erosion (erosion associated with flowing water) and bank failure (erosion associated with gravitational forces and weakening processes[1]).

Bank stability is defined as the natural streambank that has stable ground cover. Stable ground cover includes rooted trees, shrubs, herbaceous plants, and naturally occurring rocky substrates. The terms defined in Table 3-2 were used to describe observed bank stability conditions. Only potentially unstable and currently unstable streambanks were recorded.

Table 3-2. Terms Used to Describe Bank Stability Conditions [a]

Category	Term	Definition
Streambanks	Stable streambank	Has 75% or more cover of live plants and/or other stability elements that are not easily eroded and has no instability elements.
	Potentially unstable streambank	Has 75% or more cover but has 1 or more instability element(s)[b]
	Unstable streambank	Has less than 75% cover of live plants and/or other stability elements and/or 1 or more instability element(s) (unstable streambanks are often bare or nearly bare streambanks composed of noncohesive soil that is susceptible to fluvial erosion; particle size may vary depending on streambank material).
Stability elements	Live plants	Perennial herbaceous species, such as grasses, sedges, rushes; woody shrubs, such as willows; broadleaf trees, such as cottonwood and alder; conifer trees; and plant roots that are on or near the surface of the streambank and provide substantial binding strength to the streambank material.
	Rock	Boulders, bedrock, and cobble/boulder aggregates that are combined to form a stable mass.
	Downed wood	Logs firmly embedded in streambanks.
	Erosion-resistant soil	Hardened conglomerate or cohesive clay/silt streambanks.
Instability elements	Bank height	Moderately high to high bank height relative to surrounding streambanks.
	Fracturing, blocking, or slumping	Cracks near the top of the streambank, slumping streambanks, and blocks of soil/plant material that have fallen off or slid down the streambank.

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[1] Weakening processes are any bank or near-bank processes that act to erode or prepare streambanks for further erosion (Lawler 1992).

Category	Term	Definition
	Mass movement	Bank failure from landslides and gravity erosion of oversteepened streambank slopes.
	Undercutting	Frequent or continuous scour; significant to severe undercutting.

[a] Based on definitions of streambank conditions in the U.S. Forest Service Region 5 Stream Condition Inventory Guidebook.

[b] Exception: Streambank is classified as stable if bank height is the only instability element present.

3.3.3 Aquatic Survey Assessment

As discussed in Chapter 2, “Background,” due to the low probability that Arcade Creek stream corridor supports Chinook salmon and steelhead, as documented by resource agency personnel, and the low presence of BMI, a limited aquatic survey was performed. Information collected for geomorphic and vegetative indicators has also been used to inform aquatic habitat conditions.

3.3.4 Vegetative Assessment

Quantitative and qualitative vegetation surveys were performed for the Arcade Creek steam corridor. Each reach was walked in its entirety which the exception of a few portions of some reaches were dense vegetation precluded access. Surveys were performed primarily while walking along the floodplain terrace to ensure a relatively clear view of all vegetation within the floodplain. The surveys were performed from either the left or right side of the creek with the side from which the surveys were performed determined based on access.

Data sheets were developed to record observations of the key field indicators related to vegetation assessment. The locations of prominent stands of nonnative plant species and other pertinent site features related to vegetation or restoration opportunities were mapped on aerial photographs. One of the data sheets recorded information related to existing conditions (Figure 3-2). The other data sheet was used to record occurrences of invasive nonnative species (Figure 3-3).

The existing conditions data sheet recorded information related to dominant land cover type, dominant canopy layer species, wildlife species or activity observed, and the presence of existing formal or informal trails. The nonnative species data sheet was used to record information related to nonnative tree, shrub, and vine species observed, their location along the creek (e.g., left bank or right bank), and the type of occurrence (e.g., individual plants or a cluster of less than five individuals; large clusters).

Reach	Street Crossings	Date	Personnel
Dominant Land Cover Types			
Dominant Overstory Species			
Dominant Midstory Species			
Dominant Understory Species			
Overhead Cover (N = 0%, L= 1- 25%, M = 26% - 75%, H = 76% - 100%)			
Bird Species Observed			
Wildlife Species Observed		Beaver Activity	
Invasive Species			
Trail (Formal/Informal [F/I], Type, Condition)			
Comments			

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Figure 3-2
Existing Conditions Data Collection Form

Date	Personnel:		Streets Crossings:	
Segment	Reach			
	Occurrences of Invasive (LB)		Occurrences of Invasive (RB)	
Invasive Species	Individuals/Small Clusters (<5 plants)	Large Clusters (>5 plants)	Individuals/Small Clusters (<5 plants)	Large Clusters (>5 plants)
Giant reed				
Red sesbania				
Locust				
Acacia				
Maple				
Ash				
Catalpa				
English ivy				
Vinca				
Plum/fruit trees				
Privet				
Tree-of-heaven				
Blackberry				
Palm				
Elm				
Fig				
Liquidambar				
Redwood/pine				
Oleander				
Mulberry				
Pistache				
Eucalyptus				
Need/Description of Potential Restoration:				
Access (Y/N)				
Restoration/Management Options				

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Figure 3-3

Arcade Creek Corridor Invasive Plant Species Data Collection Form

3.3.5 Wildlife Surveys

Qualitative wildlife surveys were performed for the Arcade Creek stream corridor. Wildlife surveys included recording all wildlife species observed (i.e., birds, mammals, amphibians, and reptiles) or signs or their presence (e.g., tracks, feathers).

3.3.6 Restoration Opportunities

Potential restoration opportunities were identified and mapped on aerial photographs through the use of GPS for the Arcade Creek stream corridor. The data collection protocol identified the following restoration opportunity categories: control runoff from parking lots, improve floodplain function, improve pipe outfalls, reconfigure channel, remove concrete-line channel, remove debris jams and other flow obstructions, remove invasive nonnative vegetation, remove sediment and vegetation from creek crossings, stabilize banks, and stabilize swales.

Restoration opportunities are discussed in detail in Chapter 5, “Restoration Opportunities.”

Chapter 4

Results

4.1 Introduction

This chapter describes the results of the 2007 full census survey to characterize channel geomorphology, aquatic habitat conditions, and vegetation along the entire Arcade Creek stream corridor.

4.2 Segment and Reach Descriptions

4.2.1 Segments

Four separate segments within the Arcade Creek stream corridor were identified (Figure 4-1) based on the criteria described in Chapter 3, “Methodology”: lower, middle, and upper segments of Arcade Creek; and the Cripple Creek segment.

Data collection also revealed that the segments differ in terms of surrounding channel geology, bank and channel sediment types, bank vegetation, floodplain and valley floor vegetation, and dominant bank erosion processes.

Table 4-1 summarizes the characteristics between the different segments in the Arcade Creek stream corridor.

4.2.2 Reaches

Based on the criteria described in Chapter 3, 21 separate reaches along Arcade Creek and 10 reaches along Cripple Creek were identified (Figure 4-1).

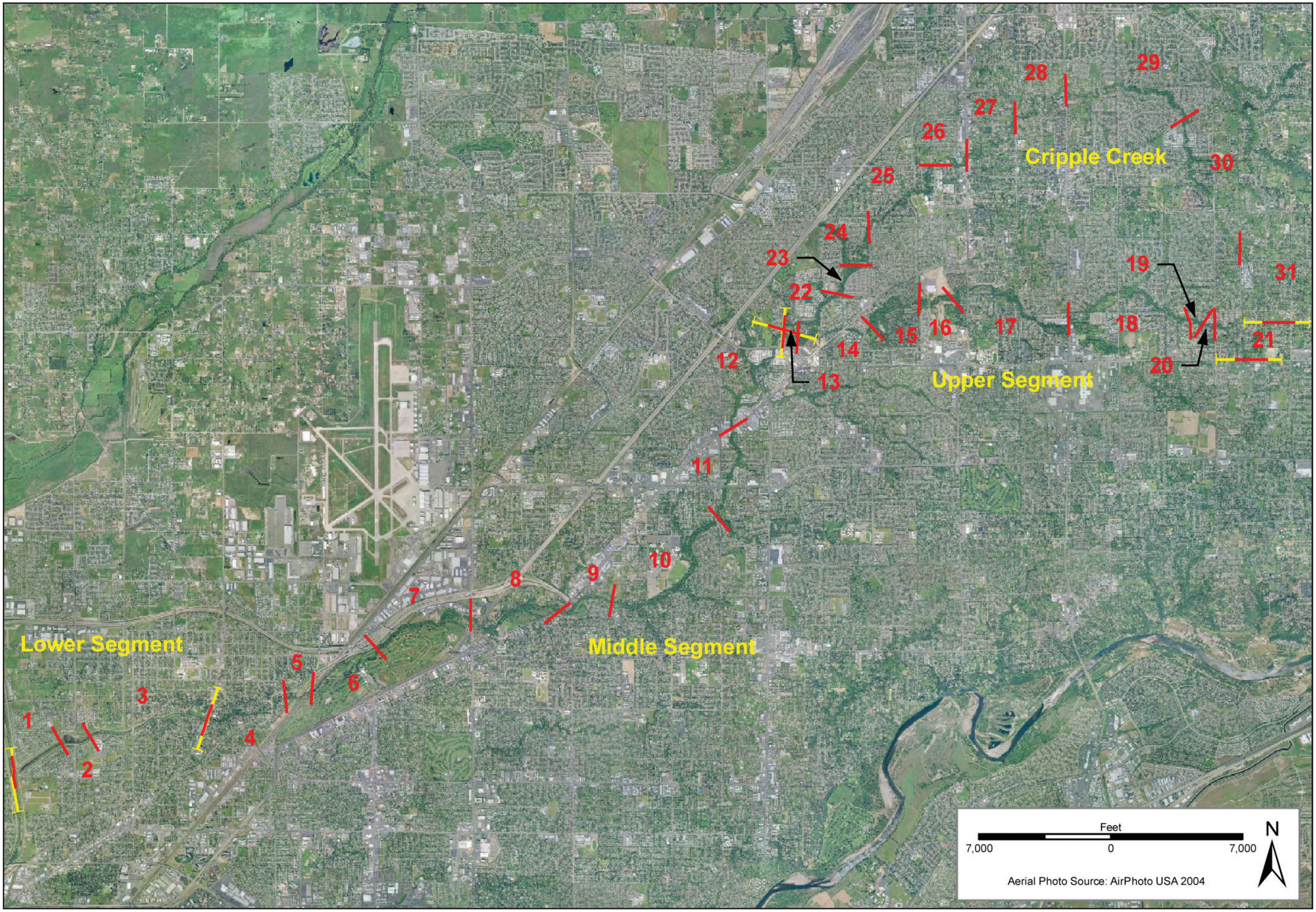
Figure 4-2 shows a generalized longitudinal profile of Arcade Creek and Cripple Creek with the segment boundaries.

4.3 Geomorphic Channel Characteristics

The following tables (Tables 4-1 through 4-5) summarize geomorphic channel characteristics within the Arcade Creek stream corridor. Representative digital images are presented in Appendix A.

Table 4-1. Geomorphic Characteristics of the Arcade Creek Stream Corridor, by Segment

Segment	Segment Boundaries	Presence of Levees and/or Other Bank Hardening	Form	Average Width (feet)	Gradient	Channel Form/Pattern (i.e., Sinuosity)
Lower Segment	Confluence with Steelhead Creek to Marysville Boulevard	Levees on both banks	Confined	300	0.0002	Slightly sinuous (1.1)
Middle Segment	Marysville Boulevard to confluence with Cripple Creek	Local bank hardening (gunnite, riprap, gabions, and cribwalls)	Moderately confined	200	0.0004	Slightly sinuous (1.2)
Upper Segment	Confluence with Cripple Creek to headwaters	Local bank hardening (gunnite, riprap, gabions, and cribwalls)	Moderately confined to unconfined	150	0.0010	Sinuous (1.5)
Cripple Creek Segment	Confluence with Arcade Creek to headwaters	Local bank hardening (riprap and cribwalls)	Moderately confined to unconfined (mostly unconfined)	300	0.0008	Slightly sinuous (1.3)



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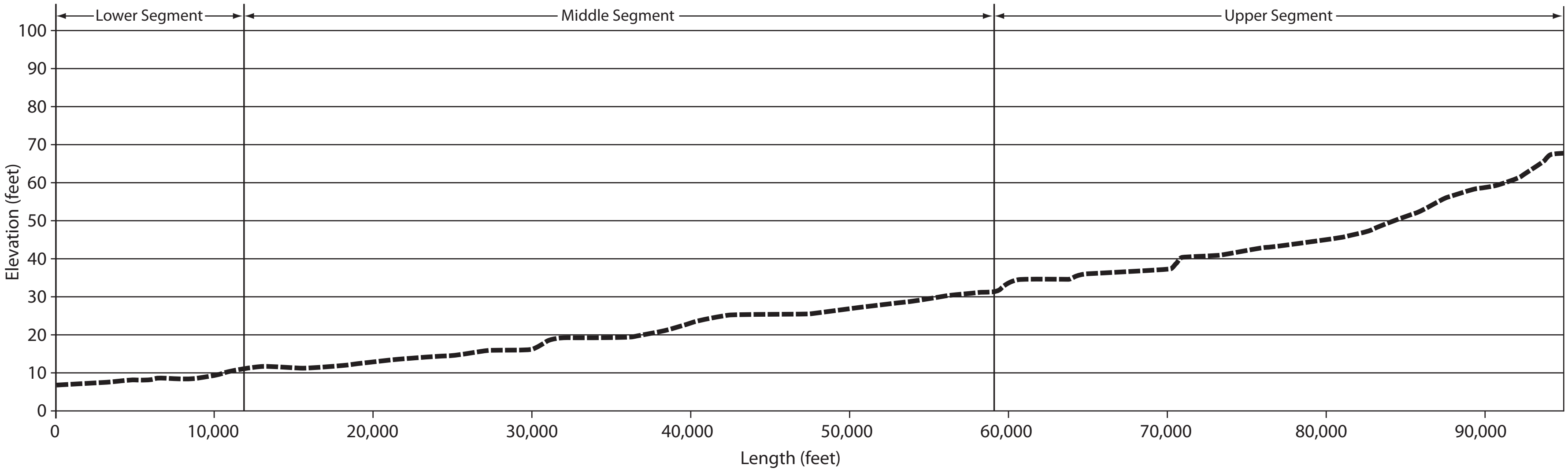
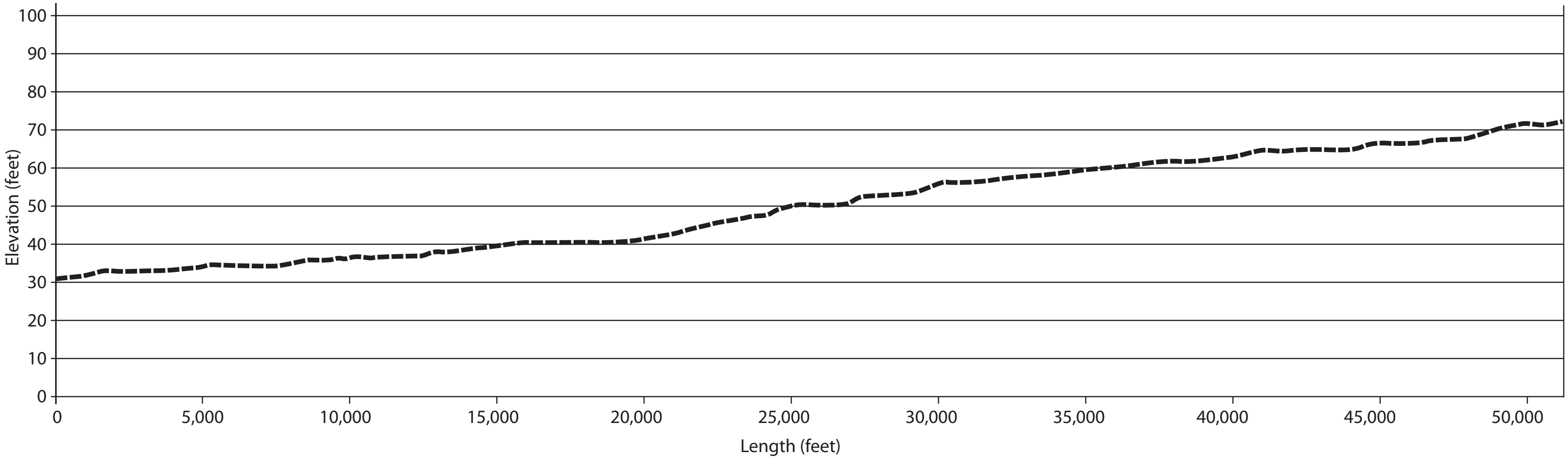
Jones & Stokes

Figure 4-1
Arcade Creek Stream Corridor: Segment and Reach Boundaries



ARCADE CREEK



CRIPPLE CREEK

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Jones & Stokes

Figure 4-2
Longitudinal Profiles of Arcade Creek and Cripple Creek

Table 4-2. Summary of Geomorphic Channel Conditions in Lower Segment

Geomorphic Characteristic	Results	Comments
Channel type	Single channel	Some islands and side channels exist in lower depositional reaches (Reaches 1 and 2); islands and side channels are a function of beaver activity and avulsion around vegetated clay islands
Sinuosity	Slightly sinuous	Channel is generally straight with meanders in only a few places
Dominant habitat unit	Run-dominated	Some pools; very few riffles
Large woody material influence	Low influence	Most in-channel large woody material has been cleared; downed wood is present on the floodplain in Reaches 1 and 2, but does not interact with low-flow channel
Dominant streambed material	Silt, clay, and sand	Reaches 1 and 2 are dominated by silt and clay; Reach 3 is dominated by sand
Dominant stream bank material	Sand	Some interbedded clay lenses, but mostly sand
Number of pipe outfalls	11	Most pipe outfalls associated with levee system
Number of debris jams	3	2 small isolated debris jams; 1 large debris jam under Norwood Ave.
Natural floodplain width	Minimum: 150’; maximum: 600’; average 300’	Confined by levees
Average bankfull width	150’–200’ in Reaches 1 and 2; 30’–40’ in Reach 3	Reach 3 is where ponding effect of confluence with Steelhead Creek ends and channel narrows
Mean bankfull depth	Unable to determine in Reaches 1 and 2; 5’–10’ in Reach 3	
Low-flow width	100’ in Reaches 1 and 2; 30’ in Reach 3	Reach 3 is where ponding effect of confluence with Steelhead Creek ends and channel narrows
Low-flow depth	Difficult to determine in Reaches 1 and 2; 1.5’–2’ in Reach 3	In Reaches 1 and 2, depth is a function of beaver dams and is spatially variable
Grade control structures	0	Hardscape associated with bridges functions as grade control
Degree of incision	Moderate	Difficult to distinguish due to presence of levees, but evidence of incision becomes more apparent in most upstream reach of segment (Reach 3)
Degree of encroachment	Moderate	Confined by levees, but average width is approximately 300’ so encroachment noted as moderate
Overall bank stability	High	Levee slopes are generally stable

Table 4-3. Summary of Geomorphic Channel Conditions in Middle Segment

Geomorphic Characteristic	Results	Notes
Channel type	Single channel	Many secondary, higher elevation channels on floodplains of creek in vicinity of Del Paso Park
Sinuosity	Slightly sinuous	Channel is generally straight, but starts to meander more so than in lower segment
Dominant habitat unit	Run-dominated	Some pools; few riffles; habitat unit diversity starts to increase in upstream direction (pools get deeper, and dense clay lenses trap gravels and act as riffles)
Large woody material influence	Low influence	Some downed wood is present in channel, but it usually extends from middle or top of bank and does not provide direct interaction with channel
Dominant streambed material	Sand	Mostly sand-dominated channel bed, but clay lenses are present too
Dominant stream bank material	Sand	Some interbedded clay lenses, but mostly sand
Number of pipe outfalls	74	Occurrences are random, but usually associated with bridge crossings
Number of debris jams	32	Highest concentration of debris jams found between Watt Ave. and Auburn Blvd. (Reach 8)
Natural floodplain width	Minimum: 100’; maximum: 300’; average: 200’	Unconfined in vicinity of Haggin Oaks Municipal Golf Course, Del Paso Park, and Arcade Creek Park
Average bankfull width	25’–30’	When no sand bars are present within the channel, average bankfull width is very similar to low-flow width because of steep vertical banks
Mean bankfull depth	5’–7’	
Low-flow width	20’–25’	When no sand bars are present within the channel, average bankfull width is very similar to low-flow width because of steep vertical banks
Low-flow depth	0.5’–2’	Low-flow depth varies as a function of the habitat unit
Grade control structures	2 formal structures	Hardscape associated with bridges functions as grade control; dense, not easily-eroded clay lenses sometimes act as grade control
Degree of incision	High	Channel is generally highly incised
Degree of encroachment	Moderate	Unconfined in vicinity of Haggin Oaks Municipal Golf Course, Del Paso Park, and Arcade Creek Park
Overall bank stability	Low	Stream banks are generally unstable

Table 4-4. Summary of Geomorphic Channel Conditions in Upper Segment

Geomorphic Characteristic	Results	Notes
Channel type	Single channel	Some secondary, higher elevation channels on floodplains of creek in less constricted areas
Sinuosity	Sinuous	Channel meanders to a significant degree
Dominant habitat unit	Run-dominated	Greatest habitat unit diversity along Arcade Creek (greatest abundance of pool/riffle sequences, although riffles are limited in linear direction and lack suitable gravels)
Large woody material influence	Low influence	Some downed wood is present in channel, but it usually extends from middle or top of bank and does not provide direct interaction with channel
Dominant streambed material	Sand and clay	Mostly sand-dominated channel bed, but clay is present as well
Dominant stream bank material	Sand and clay	Clay content of banks increases in upstream direction
Number of pipe outfalls	55	Occurrences are random, some associated with bridge crossings
Number of debris jams	28	Highest concentration of debris jams found between confluence with San Juan Creek and Sunrise Blvd. (Reach 17)
Natural floodplain width	Minimum: 100’; maximum: 300’; average: 150’	Unconfined between confluence of unnamed tributary near Van Maren Lane and confluence with San Juan Creek
Average bankfull width	15’–20’	Average bankfull width decreases in upstream direction
Mean bankfull depth	5’–7’	
Low-flow width	5’–10’	Low-flow width decreases in upstream direction
Low-flow depth	0.5’–2’	Low-flow depth varies as a function of the habitat unit
Grade control structures	6 formal structures	Hardscape associated with bridges functions as grade control; dense, not easily-eroded clay lenses sometimes act as grade control
Degree of incision	Moderate	Channel is generally highly incised in lower portion of segment, but incision lessens with distance upstream as channel becomes smaller
Degree of encroachment	Moderate	Unconfined between confluence of unnamed tributary near Van Maren Lane and confluence with San Juan Creek
Overall bank stability	Low to moderate	Stream banks are generally unstable in lower portion of segment, but become more stable with distance upstream as channel becomes smaller and clay banks dominate

Table 4-5. Summary of Geomorphic Channel Conditions in Cripple Creek Segment

Geomorphic Characteristic	Results	Notes
Channel type	Single channel	Some secondary, higher elevation channels on floodplains of creek in less constricted areas
Sinuosity	Slightly sinuous	Channel meanders to a moderate degree
Dominant habitat unit	Run- and riffle-dominated	Greatest habitat unit diversity in Arcade Creek watershed (greatest abundance of pool/riffle sequences and highest occurrence of riffles)
Large woody material influence	Low influence	Some downed wood is present in channel, but it usually extends from middle or top of bank and does not provide direct interaction with channel
Dominant streambed material	Sand and clay	Mostly sand-dominated channel bed, but clay is present as well (especially upstream)
Dominant stream bank material	Sand and clay	Clay content of banks increases in upstream direction
Number of pipe outfalls	98	Highest concentration of pipe outfalls found anywhere in Arcade Creek watershed
Number of debris jams	14	Relatively few debris jams
Natural floodplain width	Minimum: 100’; maximum: 500’; average: 300’	Unconfined in various locations
Average bankfull width	15’–20’	Average bankfull width decreases in upstream direction
Mean bankfull depth	5’–7’	
Low-flow width	5’–10’	Low-flow width decreases in upstream direction
Low-flow depth	0.5’–2’	Low-flow depth varies as a function of the habitat unit
Grade control structures	10 formal structures	Hardscape associated with bridges functions as grade control; dense, not easily-eroded clay lenses sometimes act as grade control
Degree of incision	Moderate	Channel is generally highly incised in lower portion of segment, but incision lessens with distance upstream as channel becomes smaller
Degree of encroachment	Moderate	Unconfined in various locations
Overall bank stability	Low to moderate	Stream banks are generally unstable in lower portion of segment, but become more stable with distance upstream as channel becomes smaller and clay banks dominate

4.4 Aquatic Habitat Conditions

The general incised nature of the Arcade Creek system, as well as a low gradient, limits diversity in channel habitat units, such as pool-riffle sequences. Those that do exist do so for only a limited time (Shields et al. 1998). In all segments, very few riffles exist, substrate quality for spawning is poor (excessive fine material), and large woody material influence (for establishing habitat niches) is generally low. These observations, coupled with the general knowledge of water quality in the Arcade Creek corridor, suggest that aquatic habitat conditions are poor.

4.5 Vegetation Characteristics

This section describes the land cover types and the nonnative plant species that occur in the Arcade Creek stream corridor. This section also provides a brief description of the land cover types and most common nonnative plant species that occur in the Arcade Creek stream corridor, by reach.

4.5.1 Land Cover Types

A land cover type represents the dominant features of the land surface and can be defined by natural vegetation, water, or human uses (e.g., parks). Although land cover types were not specifically mapped, 12 major land cover types were identified during the 2007 field surveys. Because land cover type surveys were not specifically performed, additional land cover types may be present in the Arcade Creek stream corridor. Table 2-2 identifies the major land cover types and the dominant species, by reach.

A jurisdictional wetland delineation was not performed for the stream corridor during the 2007 field surveys; however emergent wetlands and other waters of the United States were observed. The Phase I Watershed Management Plan also identified remnant vernal pools in the vicinity of Del Paso Regional Park (Foothill Associates 2003a).

- emergent wetland,
- other waters of the United States,
- valley oak riparian forest,
- mixed oak forest,
- riparian forest,
- riparian scrub,
- annual grassland,
- ornamental landscape (residential and commercial),
- park,

- agricultural land,
- disturbed area, and
- developed area.

4.5.1.1 Emergent Wetland

The emergent wetland land cover type occurs throughout the stream corridor both within and along stream margins. Emergent wetlands are dominated by erect, rooted, herbaceous hydrophytes that may occur in large patches, such as Reach 1, but more typically occur in narrow bands along the low-flow channel, such as Reach 3. The species composition of this land cover type varies by reach. Emergent wetlands support a variety of herbaceous wetland plant species, including common tule, cattail, and water smartweed.

4.5.1.2 Other Waters of the United States

Arcade Creek, Cripple Creek and associated tributaries are considered other waters of the United States. General information on the characteristics of creeks and tributaries are described in Section 4.3, “Geomorphic Channel Characterization.”

4.5.1.3 Valley Oak Forest

The valley oak forest land cover type is common in the Arcade Creek stream corridor, occurring in upland areas adjacent to Arcade Creek and Cripple Creek. Although valley oak forest occurs on the floodplain, it is typically located on higher terraces or on the outer limits of the floodplain and away from the creeks and drainages. Valley oak is the dominant overstory species and the understory is typically dominated by annual grasses and ruderal forbs. In many reaches nonnative species, including Himalayan blackberry, vinca, and fruit trees are dominant understory species.

4.5.1.4 Mixed Oak Forest

The mixed oak forest land cover type is common in the Arcade Creek stream corridor, occurring in upland areas adjacent to Arcade Creek and Cripple Creek and at similar landscape positions as valley oak forest. The species composition of the mixed oak land cover type varies by reach and may include valley oak, blue oak, and interior live oak. The dominant understory species are typically dominated by annual grasses, ruderal forbs and poison oak. In many reaches nonnative species, including Himalayan blackberry, vinca, and fruit trees, are dominant understory species.

4.5.1.5 Riparian Forest

The riparian forest land cover type is common in the Arcade Creek stream corridor, occurring along the banks of Arcade Creek and Cripple Creek and associated drainages. Valley oak is the dominant overstory species in many reaches. Other native overstory species include Fremont’s cottonwood, Goodding’s willow, Oregon ash, and box elder. Nonnative tree species observed with the riparian forest land cover type include catalpa, black locust, acacia, Japanese privet, and tree-of-heaven.

Depending on location, the understory may consist of tree and shrub seedlings or native and nonnative herbaceous vegetation. In many reaches, nonnative species such as Himalayan blackberry, vinca, English ivy, fruit trees, and fig are dominant midstory and understory species.

4.5.1.6 Riparian Scrub

The riparian scrub land cover occurs along the banks of the Arcade Creek stream corridor and associated drainages. Riparian scrub typically consists of small trees and seedlings of riparian tree and shrub species and nonnative species and in some cases may be early successional stages of riparian forest.

4.5.1.7 Annual Grassland

Annual grassland is dominated by a mixture of annual grasses and herbaceous nonnative species. Annual grassland generally occurs on levee and channel banks and in disturbed areas, such as edges of fields and roads, in the Arcade Creek stream corridor. The species in this land cover type are generally native and nonnative annual grasses and forbs.

4.5.1.8 Ornamental Landscape

The Arcade Creek stream corridor is located within an urbanized watershed. As a result, residential and commercial ornamental landscapes occur almost continuously along the creek corridor and in some cases extend all the way to the creek banks. Ornamental landscapes are dominated by nonnative species, some of which occur in native land cover types throughout the watershed. Ornamental species include, but are not limited to those species identified in Table 2-3.

4.5.1.9 Park Land

There are several parks that occur along the Arcade Creek stream corridor. These parks typically include maintained turf grasses and scattered native and nonnative trees and shrubs. Some ornamental species that occur in parks also occur in native land cover types throughout the stream corridor although the presence of these nonnative species cannot be attributed to park plantings.

Parks located adjacent to or near the Arcade Creek stream corridor include the following (listed based on downstream to upstream location in stream corridor):

- Hagginwood Park,
- Haggin Oaks Golf Course,
- Del Paso Regional Park,
- American River College,
- Arcade Creek Park,
- Crosswoods Park,
- Tempo Park,
- Sunrise Golf Course, and
- Rusch Regional Park.

4.5.1.10 Developed Land

Developed lands in Arcade Creek stream corridor varies by reach and may include levee and other access roads; high, medium, and low density residential areas; commercial developments; and streets and bridges.

4.5.2 Nonnative Plant Species

This section describes invasive, nonnative plant species that occur in the Arcade Creek stream corridor. This section does not focus on the characteristics of individual nonnative species but instead groups nonnative species with like physical characteristics (e.g., vines and groundcovers), reproductive characteristics (e.g., fruit bearing trees), or by its level of invasiveness. Additional descriptions of nonnative species are provided in the Invasive Species Plan (Appendix D).

Nonnative plant species along the Arcade Creek stream corridor include escaped ornamental landscape tree, shrub, and vine species. The nonnative species in the stream corridor are common riparian weed species along many urban streams. The original point source for most of these nonnative species is unknown but is assumed to residential or commercial landscapes. Many of the nonnative species in the stream corridor are now self-sustaining and promoting the further expansion of nonnative species. Many invasive species form monocultures that outcompete native species and reduce wildlife habitat values.

Although some nonnative species may be the dominant weed species in a given reach, most nonnative species were observed in many of the reaches (Table 2-2).

Nonnative species occurrences ranged from mature stands or mature individual nonnative trees, shrubs or vines, to isolated occurrences of nonnative seedlings that are just beginning to colonize an area.

4.5.2.1 Vines and Groundcovers

Nonnative vines and groundcovers include species that form dense monocultures along creek banks or in the understory of adjacent woodlands. The most common species in the study area include Himalayan blackberry, ivy, vinca, and cultivated grapes. Himalayan blackberry forms dense stands of interwoven vines that are impenetrable once established. This plant species spreads vegetatively and by seed dispersal. Ivy and vinca spread vegetatively and are typically found in locations were they have escaped from adjacent landscaped areas. Ivy may also occur in the riparian tree canopy.

4.5.2.2 Giant Reed and Pampas Grass

Giant reed and pampas grass typically occur in isolated, dense stands throughout the Arcade Creek stream corridor. Giant reed spreads vegetatively and may become established through the dispersal of root segments dislodged by high flow events. Pampas grass spreads by seed dispersal.

4.5.2.3 Red Sesbania

Red sesbania is an extremely invasive nonnative shrub that occurs in isolated occurrences throughout the Arcade Creek stream corridor. Seedlings and small trees typically occur along the lower portion of the bank or on sandbars. This species was most often observed where there was no overhead riparian cover or where there were openings within the canopy. This species is a prolific seeder and establishes quickly in disturbed areas along stream corridors.

4.5.2.4 Cultivated Fruit and Nut Trees

Common cultivated fruit and nut trees in the study area include plum, apple, almond, mulberry, English walnut, edible fig, and Mexican fan palm. These species escaped from adjacent landscapes or gardens and are typically spread by seed dispersal. Cultivated plums form dense stands in the understory of oak and riparian woodlands in several reaches.

4.5.2.5 Other Species

There are numerous other nonnative woody species that occur in the Arcade Creek stream corridor. These include non-cultivated fruit- and seed-bearing trees and shrubs, and other nonnative tree and shrub species. Some of the more common nonnative species in the study area include Japanese privet, black locust, catalpa, tree-of-heaven, and elm. Additional species observed in the Arcade Creek stream corridor are listed in Table 2-3. Many of these species, including Japanese privet, black locust, and catalpa, are prolific seeders and have quickly expanded their range in the stream corridor.

4.5.3 Land Cover Types and Nonnative Plant Species by Project Reach

The following sections provide a brief summary of the land cover types and non-native species that occur in the Arcade Creek stream corridor, by reach. Tables 2-2 and 2-3 identify the all the land cover types and nonnative species, respectively, observed in the stream corridor. Appendix B provides maps of all reaches.

4.5.3.1 Arcade Creek

Reach 1

Reach 1 is a channelized, leveed reach that is maintained to provide flood conveyance. The levee slopes are maintained as annual grassland. A narrow band of riparian vegetation occurs on the left bank and riparian revegetation occurs on the right bank. The channel invert is wide and dominated by emergent wetland vegetation. Nonnative trees and shrubs occur at isolated locations throughout the reach.

Reach 2

Reach 2 is a channelized, leveed reach that is maintained to provide flood conveyance. The levee slopes are maintained as annual grassland. The portion of Reach 2 downstream of Norwood Avenue has been widened and is dominated by emergent wetland vegetation. The portion of Reach 2 upstream of Norwood Avenue is narrower but still supports a dense stand of emergent wetland vegetation. A narrow band of riparian vegetation occurs along both banks of the channel. Nonnative trees and shrubs occur at isolated locations throughout the reach.

Reach 3

Reach 3 is a channelized, leveed reach that extends from Norwood Avenue to Marysville Boulevard and is maintained to provide flood conveyance. The low-flow channel in Reach 3 is better defined than in Reaches 1 and 2 and does not support dense stands of emergent wetland. Emergent wetland vegetation is typically limited to narrow bands along the low flow channel and may be absent in some locations. The portion of Reach between Norwood Avenue and the bike trail supports a wide band of riparian vegetation comprised of native and nonnative trees. Riparian vegetation upstream of the bike trail consists of isolated trees or small clusters of trees. The levee slopes are maintained as annual grassland. Nonnative trees and shrubs occur at isolated locations throughout the reach with a high concentration of nonnative maples.

Reach 4

Reach 4 is a channelized, narrow, unleveed reach that extends from Marysville Boulevard to Verano Street. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel but may be absent in some locations. Riparian vegetation occurs along both banks of the creek with oaks occurring on the upper banks and riparian forest and scrub species occurring on the lower banks adjacent to the low-flow channel. Nonnative trees and shrubs occur throughout the reach with densities varying by location.

Reach 5

Reach 5 is a channelized, narrow, unleveed reach extends from Verano Street to Roseville Road. Riparian vegetation occurs along both banks of the creek with oaks occurring on the upper banks and riparian forest and scrub species occurring along the lower banks adjacent to the low-flow channel. The channel banks in the upstream portion of this reach, between the railroad bridge and Roseville Road appear to have been disturbed and riparian vegetation is less dense than in the downstream portion of the reach. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel but may be absent in some locations. Nonnative trees and shrubs, including giant reed and red sesbania, occur throughout the reach with densities varying by location.

Reach 6

Reach 6 is a relatively wide and meandering reach located on the western portion of the Haggin Oaks Golf Course between Roseville Road and approximately 1,200 lf upstream of the club house. Riparian vegetation occurs in varying densities in this reach with little to no riparian vegetation at fairway crossings or other area of visual interest on the golf course. The fairway crossings are typically dominated by emergent wetland vegetation within the stream channel and turf grasses on the channel banks. Numerous nonnative seedlings are also observed in these locations. The land cover types along the undisturbed portions of the creek consist of mixed oak woodland occurring on the upper banks and floodplain surfaces and riparian forest and scrub species occurring along the lower banks adjacent to the low-flow channel.

Reach 7

Reach 7 is a relatively wide and meandering reach located on the eastern portion of the Haggin Oaks Golf Course up to Watt Avenue. The stream corridor in this reach is adjacent to, but is not crossed by, fairways. As a result, the stream corridor is lined with dense stands of oak and riparian vegetation. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel, primarily at openings in the canopy, but may be absent in some locations. Nonnative trees and shrubs, including black locust, occur throughout the reach with densities varying by location. Black locust planted on the fairways may have been the primary point source for black locust trees and seedlings occurring in the riparian and oak woodland habitat.

Reach 8

Reach 8 is a relatively wide and meandering reach that extends from Watt Avenue to Auburn Boulevard and includes the Del Paso Regional Park. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel, primarily at openings in the canopy, and may be absent in some locations. Nonnative trees and shrubs occur throughout the reach with densities varying by location.

Reach 9

Reach 9 is a relatively wide and meandering reach that extends from Auburn Boulevard to Pasadena Avenue. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel, primarily at openings in the canopy, but may be absent in some locations. Dense stands of ivy, vinca, black locust, and fruit trees occur in this reach. Other nonnative trees, shrubs, and vines are also present with densities varying by location

Reach 10

Reach 10 is a relatively wide and meandering reach that extends from Pasadena Avenue to Garfield Avenue and includes the areas adjacent to American River College. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel, primarily at openings in the canopy, but may be absent in some locations. Dense stands of Himalayan blackberry and vinca occur in this reach. Other nonnative trees, shrubs, and vines are also present with densities varying by location.

Reach 11

Reach 11 is a relatively narrow and meandering reach that extends from Garfield Avenue to Auburn Boulevard. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel, primarily at openings in the canopy, but may be absent in some locations. Dense stands of fruit trees, Himalayan blackberry, vinca, and Japanese privet occur on the left bank between Arcade Creek Park and Madison Avenue. Urban runoff from the high floodplain appears to be supporting some of this vegetation. Dense stands of ivy, Himalayan blackberry, vinca, fruit trees, and other nonnative species occur between Madison Avenue and Auburn Boulevard.

Reach 12

Reach 12 is a relatively wide and meandering reach that extends from Auburn Boulevard to Greenback Lane. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Emergent wetland vegetation is typically limited to narrow bands along the low-flow channel, primarily at openings in the canopy, but may be absent in some locations. Dense stands of fruit trees, ivy, Himalayan blackberry, vinca, and other nonnative species occur in this reach.

Reach 13

Reach 13 is a relatively narrow and meandering reach that extends from Greenback Lane to approximately 500 lf upstream of the Cripple Creek confluence. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Dense stands of fruit trees and several other nonnative species occur in this reach.

Reach 14

Reach 14 is a relatively wide and meandering reach that extends from approximately 500 lf upstream of the Cripple Creek confluence to upstream of Van Maren Lane. This reach becomes narrow in the vicinity of Auburn Boulevard. Oak forest occurs along most of the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Dense stands of fruit trees and ivy and several other nonnative species occur in this reach.

Reach 15

Reach 15 is a relatively wide and meandering reach that extends from upstream of Van Maren Lane to a pedestrian bridge crossing. Oak forest occurs along most of the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Dense stands of fruit trees, Himalayan blackberry and vinca and several other nonnative species occur in this reach.

Reach 16

Reach 16 is a relatively narrow and meandering reach that extends from a pedestrian bridge crossing to an unnamed tributary west of Sylvan Lane. Oak forest occurs along most of the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Several nonnative species occur in this reach.

Reach 17

Reach 17 is a relatively narrow and meandering reach that extends from a an unnamed tributary west of Sylvan Lane to Sunrise Boulevard. Oak forest occurs along most of the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Himalayan blackberry and ivy occur in dense stands that extend the width of the floodplain making pedestrian and wildlife access difficult. Several other nonnative species also occur in this reach.

Reach 18

Reach 18 is a relatively narrow and meandering reach that extends from Sunrise Boulevard to Trajan Drive. Oak forest occurs along most of the upper banks and floodplain and riparian forest and scrub species occurs along the lower banks adjacent to the low-flow channel. Dense stands of Japanese privet and fruit trees and several other nonnative species occur in this reach. Himalayan blackberry extends the width of the floodplain in several locations making pedestrian and wildlife access difficult.

Reach 19

Reach 19 consists of a concrete-lined channel upstream of Trajan Drive. Oak forest occurs along most of the upper banks and floodplain. Riparian vegetation is absent because of the concrete-lined channel. Nonnative vegetation primarily consists of isolated occurrences of several species.

Reach 20

Reach 20 is a relatively narrow and meandering reach that extends from the upstream limit of the concrete-lined channel to Kenneth Avenue. Residential buildings (e.g., sheds), ornamental landscapes, and turf grasses extend to the edge of the channel. Livestock pens extend across the channel immediately downstream of Kenneth Avenue.

Reach 21

Reach 21 is a relatively narrow and meandering reach that extends from Kenneth Avenue to Greenback Lane, which represents the terminus of Arcade Creek. Residential buildings (e.g., homes, garages, sheds), ornamental landscapes, and turf grasses extend to the edge of the channel in some locations. Oak forest occurs along some portions of the floodplain. Dense stands of Japanese privet and Himalayan blackberry occur in this reach as well as several other nonnative species.

4.5.3.2 Cripple Creek

Reach 22

Reach 22 is a relatively narrow and meandering reach that extends from the Cripple Creek confluence to Oak Lakes Lane. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry and vinca as well as several other nonnative species occur in this reach.

Reach 23

Reach 23 is a relatively short, narrow and meandering reach that extends from Oak Lakes Lane to Misty Woods Way. Oak forest occurs on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of privet, fruit trees, and Himalayan blackberry, as well as several other nonnative species occur in this reach.

Reach 24

Reach 24 is a relatively narrow and meandering reach that extends from Misty Woods Way to Van Maren Lane. Oak forest occurs and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of

Japanese privet, fruit trees, and Himalayan blackberry as well as several other nonnative species occur in this reach.

Reach 25

Reach 25 is a relatively narrow and meandering reach that extends from Van Maren Lane to Antelope Road. The creek flows primarily through residential lots. Relatively sparse oak forest and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry and vinca, as well as several other nonnative species occur in this reach.

Reach 26

Reach 26 is a relatively narrow and meandering reach that extends from Antelope Road to Auburn Boulevard. The creek flows primarily through residential lots. This reach is relatively sparsely vegetated with isolated trees or small clusters of trees and annual grassland occurring on the upper banks and floodplain and riparian forest and scrub species occurring along the lower banks adjacent to the low-flow channel. Small stands of nonnative species occur in this reach.

Reach 27

Reach 27 is a relatively narrow and meandering reach that extends from Auburn Boulevard to Mariposa Avenue. The creek flows primarily through private residential lots. Relatively sparse oak forest and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry and vinca, as well as several other nonnative species occur in this reach.

Reach 28

Reach 28 is a relatively narrow and meandering reach that extends from Mariposa Avenue to Sunrise Boulevard. The creek flows primarily through residential lots. Relatively sparse oak forest and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry as well as several other nonnative species occur in this reach.

Reach 29

Reach 29 is a relatively narrow and meandering reach that extends from Sunrise Boulevard to Old Auburn Boulevard. The creek flows primarily through residential lots. Relatively sparse oak forest and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry as well as several other nonnative species occur in this reach.

Reach 30

Reach 30 is a relatively narrow and meandering reach that extends from Old Auburn Boulevard to Almond Avenue. Oak forest and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry as well as several other nonnative species occur in this reach.

Reach 31

Reach 31 is a narrow and meandering reach that extends from Almond Avenue to Central Avenue. The creek flows primarily through residential lots. Oak forest and annual grassland occur on the upper banks and floodplain and riparian forest and scrub species occur along the lower banks adjacent to the low-flow channel. Dense stands of Himalayan blackberry as well as several other nonnative species occur in this reach.

4.6 Wildlife and Fish Resources

4.6.1 Wildlife

The Arcade Creek stream corridor provides habitat for a variety of small mammals, birds, amphibians, fish, and reptiles. Incidental wildlife observations made during the 2007 field surveys were recorded and the results are presented in Appendix F (Table F-2). Wildlife observations included visual observation, songs or calls, tracks, scat, or other signs of species presence (e.g., feathers).

4.6.2 Fish

Chinook salmon and steelhead trout have not been reported in Arcade Creek in over 20 years. Due to the lack of suitable rearing and spawning habitat and summer low flows, it is not likely that these species would return in the foreseeable future (Healy pers comm. 2007). However, these species do occur in the Sacramento River system and could potentially be affected by the water quality of Arcade Creek. Both of these species have been documented in recent years in Miners Ravine and Secret Ravine, tributaries of the Dry Creek watershed immediately to the north. While the Dry Creek watershed is not as heavily urbanized as the Arcade Creek watershed, the potential exists for these species to return to the Arcade Creek system if habitat conditions improve. Steelhead in the Central Valley are listed as threatened under the ESA.

Other native fish species that are likely to occur in Arcade Creek include tule perch, Sacramento sucker, and several minnow species (Foothill Associates 2002).

Introduced fish species expected to occur in Arcade Creek are similar to those that are found in nearby Dry Creek. These include catfish, bluegill, and mosquito fish. Green sunfish may also be present, and both carp and largemouth bass were reported in 1977 (Stopher 1992).

4.6.3 Benthic Macroinvertebrates

Benthic macroinvertebrate samples collected from Arcade Creek appear to be dominated by taxonomic groups that are relatively tolerant of human influences. Asian clams (*Corbicula fluminea*), non-biting midges (Diptera, Chironomidae), and aquatic worms (Oligochaeta) are the most abundant groups observed in the samples. Each of these opportunistic groups is common to urban streams in California and each is an indicator of poor stream health when observed in high abundance relative to other, less tolerant taxonomic groups. Conversely, aquatic insects in the mayfly, stonefly, and caddis fly orders (Ephemeroptera, Plecoptera, and Trichoptera, respectively) are generally considered to be intolerant of human influences and are indicators of good stream health when found in relatively high abundance. The relative abundance of mayflies, stoneflies, and caddisflies in Arcade Creek samples has been consistently low and when present they have most commonly been from generalist families (i.e., Baetidae and Hydropsychidae).

Chapter 5

Restoration Opportunities

5.1 Stream Corridor Management Plan

This chapter of the ECAR/Corridor Management Plan should be viewed primarily as the stream corridor management plan for the Project. This chapter expands on information and data presented in Phase I planning studies for the Project, especially the Phase I Feasibility Study (Foothill Associates 2002) and the Phase I Watershed Plan (Foothill Associates 2003).

This chapter also relies heavily on full census field surveys conducted in May, June, and August 2007, in support of Phase II efforts (the entire stream corridor, both the channel and banks, was surveyed on foot by a team trained in geomorphology, plant ecology, and wildlife biology, with applied skills in riverine assessment and restoration). As discussed in Chapter 4, “Results,” data was collected for a variety of environmental indicators related to geomorphology; aquatic and terrestrial habitats; and wildlife. During the course of the 2007 field surveys, specific data was collected on the following items that are responsible for stream degradation and create system stressors:

- Unstable banks—eighty-eight individual sites in the Arcade Creek stream corridor are considered unstable or potentially unstable banks that affect water quality, habitat quality, and flood damage reduction.
- Poor channel configuration—two areas were identified in the Arcade Creek stream corridor (Reach 17 between Sylvan Road and Mariposa Avenue and Reach 18 between Sunrise Boulevard and Fair Oaks Boulevard) where channel reconfiguration could be used to improve flood damage reduction and habitat quality.
- Uncontrolled runoff from parking lots—five parking lots or other large paved areas were identified where runoff drains directly into the creek, rather than being “polished” by vegetated swales or other permeable materials. Uncontrolled runoff affects water and habitat quality.
- Poor floodplain function—general improvements to floodplain function include secondary channel enhancement/creation; tributary confluence enhancement; and terrace creation. Thirty-two areas where floodplain improvements could be made were identified throughout the Arcade Creek

stream corridor. Poor floodplain function affects water quality, flood damage reduction, habitat quality, and recreational opportunities.

- Invasive plant species infestations—invasive plant species were identified throughput the Arcade Creek stream corridor (approximately 50 different species were mapped). No one invasive species stood out as more problematic then others; rather, depending on the situation or location, a particular species could be identified as most problematic. Invasive species affect flood damage reduction, habitat quality, and recreational opportunities.
- Accumulation of excess vegetation and sediment in creek crossings—sixteen creek crossings were identified where sedimentation and vegetation are reducing the channel's capacity and creating localized flooding. Creek crossings with reduced capacity affect flood damage reduction.
- Loss of natural channel—approximately 700 feet of concrete-lined channel were identified in the upper segment of the Arcade Creek stream corridor (this does not include the concrete-lined channels in the lower segment that are part of the flood control project from Marysville Road to Steelhead Creek). This hardscaped section could be removed and restored to a natural channel. Removal of hardscape from natural channels affected flood damage reduction, habitat quality, and recreational opportunities.
- Debris jams and other flow obstructions—eighty-five debris jams (consisting of natural materials) or other flow obstructions (consisting of abandoned structures and trash) were identified throughout the Arcade Creek stream corridor. These debris jams and flow obstructions affect water quality, flood damage reduction, habitat quality, and recreational opportunities.
- Aging pipe outfalls—as part of 2007 field surveys, all pipe outfalls were mapped and GPS coordinates were collected. Approximately 238 pipe outfalls were identified with 20 in need of repair. Poorly situated or aging pipe outfalls can affect water quality, flood damage reduction, habitat quality, and recreational opportunities.
- Unstable swales—three unstable swales were identified that were threatening bank stability, infrastructure and property, and floodplain function. Unstable swales affect water quality, habitat quality, and recreational opportunities.

5.2 Restoration Opportunities

This chapter has been designed to address the major theme of Phase II efforts—to ensure that progress occurs on the ground with site-specific projects. To this end, ten restoration opportunities have been identified in response to the stream degradation and system stressors noted above and their connection to the stream corridor project goals. Of the ten restoration opportunities, 8 focus on remedial actions and 2 focus on maintenance requirements. Each individual restoration opportunity and its relationship to specific stream corridor project goals are summarized in Table 5-1, below

Table 5-1. Project Goals Addressed by Restoration Opportunities

	Primary Goal(s)				Secondary Goal(s)			
Restoration Opportunity	Improve Water Quality	Reduce Flood Damage	Restore/Enhance Wildlife and Plant Habitat	Increase Recreational Opportunities Including Public Education	Improve Water Quality	Reduce Flood Damage	Restore/Enhance Wildlife and Plant Habitat	Increase Recreational Opportunities Including Public Education
Remedial Actions								
Control runoff from parking lots	X	X					X	
Improve floodplain function		X	X					X
Improve pipe outfalls	X	X						
Reconfigure channel		X	X					
Remove concrete-lined channel		X	X		X			X
Remove invasive nonnative vegetation			X			X		X
Stabilize banks	X	X	X					
Stabilize swales	X	X	X					
Maintenance Requirements								
Remove debris jams and flow obstructions		X	X		X			X
Remove sediment and vegetation at creek crossings		X					X	

For each restoration opportunity, an action plan with the following components is presented:

1. Problem/need Statement—why is a particular remedial action or maintenance requirement considered a system stressor?
2. Desired Condition—how will the item function/appear after remedial action(s) or maintenance requirement is implemented (representative digital images or figures are provided)?
3. Construction Methods—what changes to the item need to be made to remove it as a system stressor?
4. Estimated Magnitude of Construction Cost—what is the unit construction cost for each restoration opportunity in comparison to other restoration opportunities?

5. Construction Schedule—when can construction commence and when does it need to end, based on calendar year?
6. Phasing Schedule—during the Project's 20-year implementation schedule, at what point does the item fit into the timeframe?
7. Recommended Personnel—will construction effort require professionals or can volunteers (unskilled, age appropriate) conduct the work? The City's Parks and Recreation Department has developed a volunteer program as part of the Robla Creek Stewardship Plan (City of Sacramento Parks and Recreation Department 2007) and has designated a volunteer coordinator to run this program. The determination as to skill level required to complete the site-specific restoration projects may free up Project funds for other restoration projects that require advanced or professional skills.

Due to the variability of the restoration opportunity and the area that may be disturbed by construction (e.g., stream banks, stream channel, floodplain, Clean Water Act Section 404 jurisdictional habitat [i.e., wetlands and waters of the United States], and special-status species habitats), it is difficult to identify permit requirements for each restoration opportunity. Appendix E presents common regulatory compliance permits and examples of triggers for each permit.

5.2.1 Prioritization of Restoration Opportunities

The corridor management plan is anticipated to have a 20-year implementation schedule and presents restoration opportunities that have been prioritized for implementation over this schedule. To determine prioritization, restoration opportunities were presented to the watershed group in August 2007 with a request that the group provide feedback on what they viewed as priorities, either by opportunity category (e.g., stabilize banks) or by specific site (e.g., bank erosion adjacent to a specific bridge).

Based on historic and recent feedback from the group (gauging support for one recommendation over another by vocal support), a preliminary priority list has been identified:

- Flooding, primarily localized flooding but also stream corridor/watershed flooding.
- Safety, as related to the Del Paso Regional Park detention and filtration wetland (primarily in regard to illicit activity and health concerns). Arcade Creek watershed has been one of the most active for infected mosquitoes carrying West Nile virus in the Sacramento-Yolo Vector and Mosquito Control District's area of service (J. Buettner pers. comm.).
- Habitat improvement and open space preservation.
- Compliance with stream corridor project goals (improve water quality, reduce flood damage, restore/enhance wildlife and plant habitat, and increase recreational opportunities (including public education about watershed issues).

- Synergy, as related to combining site-specific restoration opportunities to create a major affect at a cumulative level. Not many large-scale restoration opportunities (e.g., channel reconfiguration and floodplain improvements) are possible in the stream corridor except at public parks and open space areas (which are, in themselves, limited). Large-scale restoration opportunities are limited because the Arcade Creek watershed is almost completely built-out and minimal open space area remains available or in public ownership that can be used for these large projects.
- Cost, as budget limitations from year-to-year partially guide the order in which restoration projects can be implemented.
- Funding sources. As part of Phase II funding, money is available to conduct invasive plant species removal and revegetation with native riparian plant species. Future funding may also direct the priority in which restoration opportunities will be funded.
- Threats to infrastructure or property, due to unstable banks.
- Ease of construction. In some locations along the stream corridor, especially where invasive plant species or flow obstruction removal is being considered, it may be difficult to get hand crews and/or machinery to the site and then remove cleared debris from the site due to access issues.

The priority list quickly disperses after these concerns with no one remaining concern taking precedence over another.

Based on the above priority list, a ranking of low, medium, and high priority was given to each restoration activity by specific site (Table 5-2).

5.2.2 Summary of Restoration Opportunities

Restoration opportunities are presented below, divided into opportunities that focus on remedial actions (Sections 5.2.2.1 through 5.2.2.8) and opportunities that focus on maintenance requirements (Sections 5.2.2.9 to 5.2.2.10). Table 5-2, “Restoration Opportunities in Arcade Creek Stream Corridor, by Reach,” lists all restoration opportunities by specific site. Appendix B, “Arcade Creek Stream Corridor: Existing Conditions and Restoration Opportunities Maps (2007),” includes maps that locate each restoration opportunity by a specific site.

5.2.2.1 Control Runoff from Parking Lots

Problem/Need Statement
The Arcade Creek watershed has been greatly modified from its natural condition. A large percentage of the watershed is influenced by development and many areas are impervious. The lack of permeability in the watershed contributes to an increase in the hydrologic response, reflected in short duration, high peak discharges during storm flow runoff. The storm flow runoff also carries high concentrations of pollutants from impervious surfaces to the receiving waters,

reducing water quality in the watershed. In addition, the high peak discharges increase the potential for erosion of the stream banks, further reducing water quality.

Riparian corridors can serve as buffers (i.e., areas where floodplain development is excluded) and have been identified as a viable method to reduce the effects of increased runoff from surrounding development and therefore limit the amount of precipitation a storm can deliver to the creek and its tributaries. However, most of the Arcade Creek stream corridor lacks a riparian corridor along its length with development often extending to the top of stream banks.

Desired Condition

The digital image below illustrates an example of current conditions. The five other figures below illustrate desired conditions.

Table 5-2. Restoration Opportunities in Arcade Creek Stream Corridor, by Reach

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
ARCADE CREEK—LOWER SEGMENT				
Reach 1	R1-Rest-001	Remove invasive nonnative vegetation	Low	Elm, Tree of Heaven, red sesbania
	R1-Rest-002	Remove invasive nonnative vegetation	Low	Elm, Tree of Heaven, red sesbania
Reach 2	R2-Rest-001	Remove invasive nonnative vegetation	Low	Elm, Tree of Heaven, mulberry, catalpa, maple
	R2-Rest-002	Remove invasive nonnative vegetation	Low	Elm, ash, locust, maple, red sesbania, catalpa
	R2-Rest-003	Remove invasive nonnative vegetation	Low	Elm, ash, maple, locust, Tree of Heaven, catalpa
	R2-Rest-004	Remove debris jam and flow obstructions	High*	Debris jam under Norwood Avenue creating a flood hazard
	R2-Rest-005	Remove invasive nonnative vegetation	Low	Elm, ash, maple, locust, Tree of Heaven, catalpa
	R2-Rest-006	Remove invasive nonnative vegetation	Low	Elm, ash, maple, locust, Tree of Heaven, catalpa
Reach 3	R3-Rest-001	Remove invasive nonnative vegetation	Moderate	Maple, catalpa, red sesbania, elm, giant reed, Tree of Heaven
	R3-Rest-002	Stabilize banks	Moderate	
	R3-Rest-003	Stabilize banks	High	
	R3-Rest-004	Remove debris jam and flow obstructions	High	
	R3-Rest-005	Remove debris jam and flow obstructions	High*	Debris jam under Marysville Boulevard creating a flood hazard (at Reach 3 and Reach 4 boundary)
ARCADE CREEK-—MIDDLE SEGMENT				
Reach 4	R4-Rest-001	Remove debris jam and flow obstructions	High*	Debris jam under Marysville Boulevard creating a flood hazard (at Reach 3 and Reach 4 boundary)
	R4-Rest-002	Stabilize banks	High*	Eminent property damage on right bank
	R4-Rest-003	Remove invasive nonnative vegetation	High	Giant reed, Tree of Heaven
	R4-Rest-004	Stabilize banks	High*	Eminent property damage on right bank
	R4-Rest-005	Remove invasive nonnative vegetation	High	Himalayan blackberry
	R4-Rest-006	Remove invasive nonnative vegetation	High	Japanese privet, acacia, Himalayan blackberry, ivy, catalpa, fig, red sesbania

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R4-Rest-007	Remove invasive nonnative vegetation	Moderate	Ivy
	R4-Rest-008	Remove invasive nonnative vegetation	High	Ivy, Japanese privet
	R4-Rest-009	Remove invasive nonnative vegetation	Moderate	Giant reed
	R4-Rest-010	Remove invasive nonnative vegetation	Moderate	Giant reed
	R4-Rest-011	Remove invasive nonnative vegetation	Moderate	Giant reed
	R4-Rest-012	Remove invasive nonnative vegetation	Low	Tree of Heaven, black locust, ivy, English walnut, Himalayan blackberry
	R4-Rest-013	Remove invasive nonnative vegetation	Moderate	Giant reed, Himalayan blackberry, red sesbania
Reach 5	R5-Rest-001	Remove invasive nonnative vegetation	Moderate	Giant reed, Himalayan blackberry
	R5-Rest-002	Remove invasive nonnative vegetation	High	Red sesbania
	R5-Rest-003	Stabilize banks	High	
	R5-Rest-004	Stabilize banks	High	
	R5-Rest-005	Stabilize banks	High	
	R5-Rest-006	Remove invasive nonnative vegetation	Moderate	Giant reed, red sesbania
	R5-Rest-007	Remove invasive nonnative vegetation	Moderate	Giant reed, red sesbania
Reach 6	R6-Rest-001	Stabilize banks	High*	Hardscape failing in vicinity of bridge
	R6-Rest-002	Remove invasive nonnative vegetation	Low	Fruit trees, black locust, beefwood
	R6-Rest-003	Remove invasive nonnative vegetation	Low	Fruit trees
	R6-Rest-004	Improve pipe outfall	High	
	R6-Rest-005	Remove debris jam and flow obstructions	High*	Flow obstruction increasing local flooding hazard
	R6-Rest-006	Remove debris jam and flow obstructions	High	
	R6-Rest-007	Improve pipe outfall	High	
	R6-Rest-008	Remove invasive nonnative vegetation	Moderate	Fruit trees, elm, fruit trees, mulberry, Himalayan blackberry, Japanese privet, acacia, Tree of Heaven

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
Reach 7	R7-Rest-001	Remove debris jam and flow obstructions	High*	Flow obstruction increasing local flooding hazard
	R7-Rest-002	Remove debris jam and flow obstructions	High	
	R7-Rest-003	Remove invasive nonnative vegetation	Moderate	Black locust
	R7-Rest-004	Stabilize banks	Low	
	R7-Rest-005	Remove invasive nonnative vegetation	High	Black locust
	R7-Rest-006	Remove debris jam and flow obstructions	High	
	R7-Rest-007	Remove debris jam and flow obstructions	High	
	R7-Rest-008	Remove invasive nonnative vegetation	High	Black locust, Himalayan blackberry
	R7-Rest-009	Remove debris jam and flow obstructions	High	
	R7-Rest-010	Stabilize banks	High	
	R7-Rest-011	Stabilize banks	High	
	R7-Rest-012	Remove debris jam and flow obstructions	High*	Flow obstruction increasing local flooding hazard and contributing to local bank instability
	R7-Rest-013	Stabilize banks	Low	
	R7-Rest-014	Remove debris jam and flow obstructions	High	
Reach 8	R8-Rest-001	Restore recreational trail	High	
	R8-Rest-002	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-003	Remove invasive nonnative vegetation	High*	Himalayan blackberry, Tree of Heaven, fig, catalpa, acacia, Japanese privet, vinca, sugar maple, fruit trees. Cull nonnatives to improve visibility and safety around Discovery Museum.
	R8-Rest-004	Improve floodplain function	High	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R8-Rest-005	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-006	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-007	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-008	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-009	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-010	Remove invasive nonnative vegetation	Moderate	Mature black locust in park provide seed source
	R8-Rest-011	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-012	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R8-Rest-013	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-014	Remove invasive nonnative vegetation	Low	Giant reed
	R8-Rest-015	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-016	Restore recreational trail	High	
	R8-Rest-017	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-018	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-019	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-020	Remove invasive nonnative vegetation	Moderate	Black locust
	R8-Rest-021	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)
	R8-Rest-022	Remove debris jam and flow obstructions	High*	All 15 debris jams in Reach 8 (Watt Avenue to Auburn Boulevard) are creating a significant local flooding hazard; debris jams typically consist of items that can pose a threat to public safety (e.g., hypodermic needles)

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
Reach 9	R9-Rest-001	Remove invasive nonnative vegetation	High	Giant reed
	R9-Rest-002	Remove debris jam and flow obstructions	High	
	R9-Rest-003	Remove invasive nonnative vegetation	Low	Himalayan blackberry, black locust, vinca, fruit trees
	R9-Rest-004	Remove debris jam and flow obstructions	High*	Flow obstruction increasing local flooding hazard
	R9-Rest-005	Restore recreational trail	High	Ivy, vinca
Reach 10	R10-Rest-001	Stabilize banks	Moderate	
	R10-Rest-002	Remove invasive nonnative vegetation	High	Giant reed
	R10-Rest-003	Remove invasive nonnative vegetation	High	Giant reed
	R10-Rest-004	Stabilize banks	Moderate	
	R10-Rest-005	Stabilize banks	Moderate	
	R10-Rest-006	Remove invasive nonnative vegetation	Moderate	Ivy, vinca, red sesbania, acacia, Japanese privet, giant reed, fruit trees, Himalayan blackberry, Tree of Heaven
	R10-Rest-007	Remove debris jam and flow obstructions	High	
	R10-Rest-008	Stabilize banks	Moderate	
	R10-Rest-009	Remove invasive nonnative vegetation	Moderate	Black locust, Himalayan blackberry, vinca, tamarisk, red sesbania
	R10-Rest-010	Remove debris jam and flow obstructions	High*	Debris jam perched on a structure – both are creating local flooding hazard
	R10-Rest-011	Remove debris jam and flow obstructions	High*	Debris jam perched on a structure – both are creating local flooding hazard
	R10-Rest-012	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-013	Stabilize banks	Moderate	
	R10-Rest-014	Stabilize banks	Moderate	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R10-Rest-015	Stabilize banks	Moderate	
	R10-Rest-016	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-017	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-018	Improve floodplain function	Low	
	R10-Rest-019	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-020	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-021	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel thereby decreasing channel capacity
	R10-Rest-022	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-023	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-024	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R10-Rest-025	Remove debris jam and flow obstructions	High*	Flow obstruction increasing local flooding hazard and contributing to local bank instability
	R10-Rest-026	Stabilize banks	Moderate	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R10-Rest-027	Stabilize banks	Moderate	
	R10-Rest-028	Remove invasive nonnative vegetation	Moderate	Japanese privet, fruit trees, black locust, red sesbania, mulberry, Tree of Heaven, catalpa, maple
	R10-Rest-029	Stabilize banks	Moderate	
	R10-Rest-030	Remove debris jam and flow obstructions	High	
Reach 11	R11-Rest-001	Improve floodplain function	High	
	R11-Rest-002	Improve floodplain function	Low	
	R11-Rest-003	Remove invasive nonnative vegetation	High*	Black locust, privet, fruit trees, Himalayan blackberry, vinca. Cull nonnatives to improve visibility and safety
	R11-Rest-004	Improve floodplain function	High	
	R11-Rest-005	Remove debris jam and flow obstructions	High	
	R11-Rest-006	Stabilize banks	High	
	R11-Rest-007	Remove debris jam and flow obstructions	High*	Debris jam under Madison Avenue creating a flood hazard
	R11-Rest-008	Remove invasive nonnative vegetation	High	Japanese privet, mulberry, ivy, catalpa, red sesbania
	R11-Rest-009	Stabilize banks	High*	Eminent property damage on left bank
	R11-Rest-010	Control runoff from parking lot	High	
	R11-Rest-011	Remove invasive nonnative vegetation	Moderate	Japanese privet, fruit trees, ivy, vinca, Himalayan blackberry
	R11-Rest-012	Improve pipe outfall	Moderate	
	R11-Rest-013	Remove invasive nonnative vegetation	High	Japanese privet, fruit trees, ivy, vinca, Himalayan blackberry, giant reed, pyracantha
	R11-Rest-014	Stabilize banks	Moderate	
Reach 12	R12-Rest-001	Improve floodplain function	Moderate	
	R12-Rest-002	Stabilize banks	High	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R12-Rest-003	Improve pipe outfall	High*	Eroding pipe outfall causing left bank instability upstream and downstream of pipe
	R12-Rest-004	Remove invasive nonnative vegetation	High	Fruit trees, privet, fig, giant reed, Himalayan blackberry
	R12-Rest-005	Remove invasive nonnative vegetation	Moderate	Fruit trees, privet, fig, giant reed, Himalayan blackberry, red sesbania
	R12-Rest-006	Improve floodplain function	Moderate	
	R12-Rest-007	Remove debris jam and flow obstructions	High	
	R12-Rest-008	Stabilize banks	Moderate	
	R12-Rest-009	Improve floodplain function and stabilize banks	High	
	R12-Rest-010	Improve floodplain function	Moderate	
	R12-Rest-011	Stabilize banks	High	
	R12-Rest-012	Improve pipe outfall	High*	Eroding pipe outfall causing left bank instability upstream and downstream of pipe
	R12-Rest-013	Remove invasive nonnative vegetation	Low	Ivy, vinca, fig, Japanese privet
	R12-Rest-014	Improve floodplain function and stabilize banks	Moderate	
	R12-Rest-015	Stabilize banks	High	
	R12-Rest-016	Stabilize banks	High	
	R12-Rest-017	Stabilize banks	High	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
ARCADE CREEK—UPPER SEGMENT				
Reach 13	R13-Rest-001	Remove invasive nonnative vegetation	High	Fruit trees, Japanese privet, eucalyptus, black locust, Tree of Heaven, catalpa, vinca, Himalayan blackberry, pampas grass, mulberry
	R13-Rest-002	Stabilize banks	High*	Bank located adjacent to road and is contributing a significant amount of sediment to channel and decreasing channel capacity
	R13-Rest-003	Improve floodplain function and stabilize banks	High	
	R13-Rest-004	Improve pipe outfall	High*	Eroding pipe outfall causing left bank instability upstream and downstream of pipe
	R13-Rest-005	Remove debris jam and flow obstructions	High	
	R13-Rest-006	Remove debris jam and flow obstructions	High	
	R13-Rest-007	Remove debris jam and flow obstructions	High	
	R13-Rest-008	Stabilize banks	High	
	R13-Rest-009	Stabilize banks	High	
Reach 14	R14-Rest-001	Remove invasive nonnative vegetation	High	Fruit trees, Japanese privet, eucalyptus, black locust, Tree of Heaven, catalpa, vinca, Himalayan blackberry, pampas grass, mulberry
	R14-Rest-002	Stabilize banks	High	Eminent property damage on left bank; right bank contributing significant sediment to channel and decreasing channel capacity
	R14-Rest-003	Stabilize banks	High	
	R14-Rest-004	Improve pipe outfall	High*	Eroding pipe outfall causing right bank instability upstream and downstream of pipe
	R14-Rest-005	Stabilize banks	High	
	R14-Rest-006	Stabilize banks	High	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R14-Rest-007	Remove debris jam and flow obstructions	High*	Flow obstruction increasing local flooding hazard and contributing to local bank instability
	R14-Rest-008	Improve floodplain function	Low	
	R14-Rest-009	Remove debris jam and flow obstructions	High	
	R14-Rest-010	Remove debris jam and flow obstructions	High	
	R14-Rest-011	Remove debris jam and flow obstructions	High	
	R14-Rest-012	Stabilize swale	High	
	R14-Rest-013	Stabilize banks	High	
	R14-Rest-014	Remove invasive nonnative vegetation	Low	Giant reed, Japanese privet, ivy, mulberry
	R14-Rest-015	Remove invasive nonnative vegetation	Moderate	Ivy, purple leaf plum, black locust, Japanese privet, giant reed
	R14-Rest-016	Stabilize swale	High	
	R14-Rest-017	Improve floodplain function	Low	
	R14-Rest-018	Remove debris jam and flow obstructions	High	
	R14-Rest-019	Improve floodplain function	Moderate	
	R14-Rest-020	Remove debris jam and flow obstructions	High	
	R14-Rest-021	Remove invasive nonnative vegetation	Low	Fruit trees, ornamental in landscape
	R14-Rest-022	Remove invasive nonnative vegetation	Low	Fruit trees, fig, catalpa
	R14-Rest-023	Remove debris jam and flow obstructions	High	
	R14-Rest-024	Improve pipe outfall	High*	Eroding pipe outfall causing instability of swale upslope
	R14-Rest-025	Remove invasive nonnative vegetation	Low	English ivy, giant reed, fig
Reach 15	R15-Rest-001	Stabilize banks	High	
	R15-Rest-002	Remove invasive nonnative vegetation	Moderate	Fruit trees, Russian olive, vinca, Himalayan blackberry, catalpa, acacia
	R15-Rest-003	Improve floodplain function	Low	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R15-Rest-004	Stabilize banks	High	
	R15-Rest-005	Improve floodplain function	Low	
	R15-Rest-006	Improve floodplain function	Low	
	R15-Rest-007	Stabilize swale	High	
	R15-Rest-008	Remove debris jam and flow obstructions	High	
	R15-Rest-009	Remove debris jam and flow obstructions	High	
	R15-Rest-010	Improve pipe outfall	High*	Eroding pipe outfall causing instability of swale upslope
	R15-Rest-011	Improve floodplain function and stabilize banks	Low	
	R15-Rest-012	Stabilize banks	High	
	R15-Rest-013	Remove invasive nonnative vegetation	High	Sweet gum, catalpa, fruit trees, vinca, Himalayan blackberry, privet, weeping willow, fig, mulberry
	R15-Rest-014	Remove debris jam and flow obstructions	High	
Reach 16	R16-Rest-001	Remove invasive nonnative vegetation	High	Catalpa, fruit trees, Himalayan blackberry
	R16-Rest-002	Stabilize banks	Low	
	R16-Rest-003	Stabilize banks	High*	Severe bank erosion along pedestrian bridge
	R16-Rest-004	Improve floodplain function and stabilize banks	Moderate	
	R16-Rest-005	Remove invasive nonnative vegetation	High	Scotch broom, Russian olive, Himalayan blackberry
	R16-Rest-006	Remove invasive nonnative vegetation	Low	Himalayan blackberry, vinca, catalpa, mulberry
	R16-Rest-007	Remove debris jam and flow obstructions	High	
Reach 17	R17-Rest-001	Remove invasive nonnative vegetation	Low	Himalayan blackberry, vinca, ivy, catalpa
	R17-Rest-002	Remove invasive nonnative vegetation	Moderate	Privet, mulberry, Russian olive, acacia, catalpa, vinca, fruit trees, Himalayan blackberry

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R17-Rest-003	Improve floodplain function	High	
	R17-Rest-004	Stabilize banks	High*	Eminent property damage on left bank
	R17-Rest-005	Improve pipe outfall	High*	Eroding pipe outfall causing left bank instability upstream and downstream of pipe
	R17-Rest-006	Stabilize banks	Moderate	
	R17-Rest-007	Improve floodplain function	Moderate	
	R17-Rest-008	Remove debris jam and flow obstructions	High	
	R17-Rest-009	Remove invasive nonnative vegetation	High	Privet, fruit trees, Himalayan blackberry, vinca, ivy
	R17-Rest-010	Remove debris jam and flow obstructions	High	
	R17-Rest-011	Reconfigure channel	High	
	R17-Rest-012	Remove debris jam and flow obstructions	High	
	R17-Rest-013	Remove invasive nonnative vegetation	High	Catalpa, palm, mulberry, acacia, maple, privet, vinca, Himalayan blackberry
	R17-Rest-014	Remove debris jam and flow obstructions	High	
	R17-Rest-015	Remove debris jam and flow obstructions	High	
	R17-Rest-016	Remove debris jam and flow obstructions	High	
	R17-Rest-017	Remove debris jam and flow obstructions	High*	Series of debris jams creating local flooding hazard and contributing to localized bank instability
	R17-Rest-018	Stabilize banks	Moderate	
	R17-Rest-019	Remove debris jam and flow obstructions	High	
	R17-Rest-020	Improve pipe outfall	High	
	R17-Rest-021	Stabilize banks	Moderate	
	R17-Rest-022	Stabilize banks	Low	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R17-Rest-023	Remove debris jam and flow obstructions	High*	Series of debris jams creating local flooding hazard and contributing to localized bank instability
	R17-Rest-024	Improve floodplain function	High	
	R17-Rest-025	Remove invasive nonnative vegetation	High	Catalpa, fruit trees, mulberry, privet, vinca, Himalayan blackberry, eucalyptus
	R17-Rest-026	Stabilize banks	High	
	R17-Rest-027	Improve floodplain function	Low	
	R17-Rest-028	Improve pipe outfall	High	
	R17-Rest-029	Remove debris jam and flow obstructions	High	
	R17-Rest-030	Improve pipe outfall	High	
	R17-Rest-031	Remove invasive nonnative vegetation	Low	Eucalyptus
Reach 18	R18-Rest-001	Remove debris jam and flow obstructions	High	
	R18-Rest-002	Stabilize banks	High*	Eminent property damage on right bank
	R18-Rest-003	Improve floodplain function and reconfigure channel	High	
	R18-Rest-004	Remove invasive nonnative vegetation	Low	Himalayan blackberry, privet
	R18-Rest-005	Remove invasive nonnative vegetation	Moderate	Privet, Himalayan blackberry, ivy
	R18-Rest-006	Remove sediment and vegetation at creek crossings	Moderate	
	R18-Rest-007	Stabilize banks	Moderate	
	R18-Rest-008	Stabilize banks	Low	
	R18-Rest-009	Remove debris jam and flow obstructions	High	
	R18-Rest-010	Remove invasive nonnative vegetation	High	Himalayan blackberry, fruit trees, privet
	R18-Rest-011	Stabilize banks	High	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R18-Rest-012	Improve pipe outfall	High*	Eroding pipe outfall causing left bank instability upstream and downstream of pipe
	R18-Rest-013	Stabilize banks	High*	Eminent property damage on left bank
	R18-Rest-014	Stabilize banks	High*	Eminent property damage on right bank
	R18-Rest-015	Improve floodplain function	High	
	R18-Rest-016	Remove debris jam and flow obstructions	High	
	R18-Rest-017	Stabilize banks	High	
	R18-Rest-018	Improve pipe outfall	High*	Eroding pipe outfall causing right bank instability upstream and downstream of pipe
	R18-Rest-019	Stabilize banks	Moderate	
	R18-Rest-020	Remove debris jam and flow obstructions	High	
Reach 19	R19-Rest-001	Remove concrete-lined channel	Low	
Reach 20				(No proposed restoration sites)
Reach 21	R21-Rest-001	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, privet
	R21-Rest-002	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, privet
	R21-Rest-002	Remove sediment and vegetation at creek crossings	Moderate	
CRIPPLE CREEK—UPPER SEGMENT				
Reach 22	R22-Rest-001	Remove invasive nonnative vegetation	Low	Vinca, ivy, Himalayan blackberry
	R22-Rest-002	Improve floodplain function	Low	
	R22-Rest-003	Stabilize banks	High*	Eminent property damage on right bank
	R22-Rest-004	Remove debris jam and flow obstructions	High	
	R22-Rest-005	Stabilize banks	High*	Bank instability on left bank compromising bridge
	R22-Rest-006	Remove invasive nonnative vegetation	Low	Vinca, ivy, Himalayan blackberry

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R22-Rest-007	Stabilize banks	High*	Toe of right bank needs to be stabilized
	R22-Rest-008	Stabilize banks	High*	Eminent property damage on right bank
	R22-Rest-009	Remove invasive nonnative vegetation	High	Vinca
	R22-Rest-010	Improve pipe outfall	High	
	R22-Rest-011	Improve pipe outfall	High	
	R22-Rest-012	Remove invasive nonnative vegetation	High	Vinca
	R22-Rest-013	Remove debris jam and flow obstructions	High	
	R22-Rest-014	Remove invasive nonnative vegetation	High	Vinca, Himalayan blackberry
	R22-Rest-015	Remove debris jam and flow obstructions	High	
Reach 23	R23-Rest-001	Remove invasive nonnative vegetation	Moderate	English ivy, vinca, privet
	R23-Rest-002	Remove invasive nonnative vegetation	High	Red sesbania, Tree of Heaven, mulberry
	R23-Rest-003	Remove invasive nonnative vegetation	Moderate	Red sesbania, Tree of Heaven, privet
	R23-Rest-004	Remove invasive nonnative vegetation	High	Fruit trees, privet, Himalayan blackberry, catalpa
	R23-Rest-005	Improve pipe outfall	High*	Eroding pipe outfall causing instability of swale upslope
Reach 24	R24-Rest-001	Remove invasive nonnative vegetation	Low	Himalayan blackberry
	R24-Rest-002	Remove invasive nonnative vegetation	Low	Himalayan blackberry, catalpa
	R24-Rest-003	Remove invasive nonnative vegetation	Moderate	Giant reed
	R24-Rest-004	Remove invasive nonnative vegetation	High	Unvegetated banks, plant with native vegetation
	R24-Rest-005	Remove invasive nonnative vegetation	High	Ivy, fruit trees, vinca, Himalayan blackberry
	R24-Rest-006	Remove invasive nonnative vegetation	Moderate	Fruit trees, vinca
	R24-Rest-007	Remove invasive nonnative vegetation	Low	Vinca, Tree of Heaven, Himalayan blackberry, catalpa
	R24-Rest-008	Remove debris jam and flow obstructions	High	

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R24-Rest-009	Remove sediment and vegetation at creek crossings	High	
Reach 25	R25-Rest-001	Remove invasive nonnative vegetation	High	Tree of Heaven, Himalayan blackberry, catalpa
	R25-Rest-002	Stabilize banks	High*	Eminent property damage on left bank
	R25-Rest-003	Remove invasive nonnative vegetation	High	Himalayan blackberry, ivy, giant reed
	R25-Rest-004	Remove invasive nonnative vegetation	High	Ivy, Himalayan blackberry
	R25-Rest-005	Remove invasive nonnative vegetation	High	Himalayan blackberry, privet
	R25-Rest-006	Remove invasive nonnative vegetation	High	Himalayan blackberry, vinca, giant reed
	R25-Rest-007	Remove invasive nonnative vegetation	High	Tree of Heaven, Himalayan blackberry, ivy, vinca
	R25-Rest-008	Stabilize banks	Moderate	
	R25-Rest-009	Stabilize banks	High*	Eminent property damage on right bank
	R25-Rest-010	Remove invasive nonnative vegetation	High	Tree of Heaven, Himalayan blackberry, ivy, vinca
	R25-Rest-011	Remove debris jam and flow obstructions	High	
	R25-Rest-012	Stabilize banks	High*	Eminent property damage on right bank
	R25-Rest-013	Stabilize banks	Moderate	
	R25-Rest-014	Remove invasive nonnative vegetation	Moderate	Ivy, privet, giant reed, fruit trees
	R25-Rest-015	Remove invasive nonnative vegetation	High	Himalayan blackberry, privet
	R25-Rest-016	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry
	R25-Rest-017	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry
	R25-Rest-018	Stabilize banks	Low	
	R25-Rest-019	Remove sediment and vegetation at creek crossings	High	
	R25-Rest-020	Remove invasive nonnative vegetation	Low	Himalayan blackberry
	R25-Rest-021	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, eucalyptus, fruit trees

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R25-Rest-022	Control runoff from parking lot	High	
	R25-Rest-023	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, eucalyptus, fruit trees
	R25-Rest-024	Remove debris jam and flow obstructions	High	
	R25-Rest-025	Remove invasive nonnative vegetation	Low	Giant reed
	R25-Rest-026	Remove invasive nonnative vegetation	Low	Blackberry, elderberry
	R25-Rest-027	Improve floodplain function	High	
	R25-Rest-028	Remove invasive nonnative vegetation	Moderate	Blackberry, vinca, ash
	R25-Rest-029	Control runoff from parking lot	High	
Reach 26	R26-Rest-001	Stabilize banks	Low	
	R26-Rest-002	Improve floodplain function	Low	
	R26-Rest-003	Improve floodplain function	Low	
	R26-Rest-004	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, ivy, privet, catalpa
	R26-Rest-005	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry
	R26-Rest-006	Remove sediment and vegetation at creek crossings and remove debris jam and flow obstructions	High	
	R26-Rest-007	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, vinca, fruit trees
	R26-Rest-008	Remove sediment and vegetation at creek crossings	High	
	R26-Rest-009	Improve pipe outfall	High	
	R26-Rest-010	Improve pipe outfall	High	
	R26-Rest-011	Stabilize banks	High*	Eroding right bank site in Rusch Regional Park – right bank is collapsing and presenting a danger to visitors in park
	R26-Rest-012	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, ivy, catalpa, vinca, privet

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R26-Rest-013	Remove invasive nonnative vegetation	Low	Giant reed, blackberry, vinca, fig
	R26-Rest-014	Remove sediment and vegetation at creek crossings	Moderate	
	R26-Rest-015	Improve floodplain function	Moderate	
	R26-Rest-016	Remove invasive nonnative vegetation	Low	Vinca, catalpa, mulberry, Himalayan blackberry
	R26-Rest-017	Remove sediment and vegetation at creek crossings	High	
	R26-Rest-018	Control runoff from parking lot	High	
	R26-Rest-019	Control runoff from parking lot	High	
Reach 27	R27-Rest-001	Remove invasive nonnative vegetation	Moderate	Giant reed, vinca, Himalayan blackberry
	R27-Rest-002	Remove invasive nonnative vegetation	High	Fig, mulberry, vinca, Himalayan blackberry, privet
	R27-Rest-003	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, fig, privet, vinca
	R27-Rest-004	Remove invasive nonnative vegetation	Moderate	Giant reed, catalpa, Himalayan blackberry, mulberry, vinca
	R27-Rest-005	Remove invasive nonnative vegetation	Low	Himalayan blackberry, catalpa, fig
	R27-Rest-006	Remove invasive nonnative vegetation	Moderate	Fig, catalpa, mulberry, Himalayan blackberry, Chinese pistache
	R27-Rest-007	Stabilize banks	High*	Eminent property damage on left bank
	R27-Rest-008	Remove invasive nonnative vegetation	High	Himalayan blackberry, catalpa, vinca, Chinese pistache
	R27-Rest-009	Remove debris jam and flow obstructions	High	
	R27-Rest-010	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, vinca
	R27-Rest-011	Remove invasive nonnative vegetation	High	Elm, privet, Himalayan blackberry, vinca
	R27-Rest-012	Stabilize banks	High*	Eminent property damage on left bank
	R27-Rest-013	Remove debris jam and flow obstructions	High	
	R27-Rest-014	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry

Table 5-2. Continued

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R27-Rest-015	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, Chinese pistache, mulberry
	R27-Rest-016	Remove debris jam and flow obstructions	High	
Reach 28	R28-Rest-001	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, catalpa, vinca
	R28-Rest-002	Remove debris jam and flow obstructions	High*	Series of debris jams creating local flooding hazard and contributing to localized bank instability
	R28-Rest-003	Remove invasive nonnative vegetation	Low	Himalayan blackberry
	R28-Rest-004	Remove debris jam and flow obstructions	High	
	R28-Rest-005	Remove debris jam and flow obstructions	High	
	R28-Rest-006	Remove invasive nonnative vegetation	Moderate	Tree of Heaven, Himalayan blackberry
	R28-Rest-007	Remove invasive nonnative vegetation	Moderate	Giant reed, Himalayan blackberry, mulberry, privet
	R28-Rest-008	Remove debris jam and flow obstructions	High	
	R28-Rest-009	Remove invasive nonnative vegetation	Moderate	Vinca
	R28-Rest-010	Remove invasive nonnative vegetation	Low	Himalayan blackberry, mulberry
	R28-Rest-011	Remove invasive nonnative vegetation	High*	Giant reed, mulberry, Himalayan blackberry. Giant reed stand occurs within the bed and banks of the creek and impedes flood flows.
	R28-Rest-012	Remove debris jam and flow obstructions	High	
	R28-Rest-013	Remove sediment and vegetation at creek crossings	High	
Reach 29	R29-Rest-001	Remove invasive nonnative vegetation	Low	Himalayan blackberry
	R29-Rest-002	Remove sediment and vegetation at creek crossings	Low	
	R29-Rest-003	Remove invasive nonnative vegetation	High	Himalayan blackberry, Tree of Heaven
	R29-Rest-004	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, mulberry
	R29-Rest-005	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, Tree of Heaven, vinca

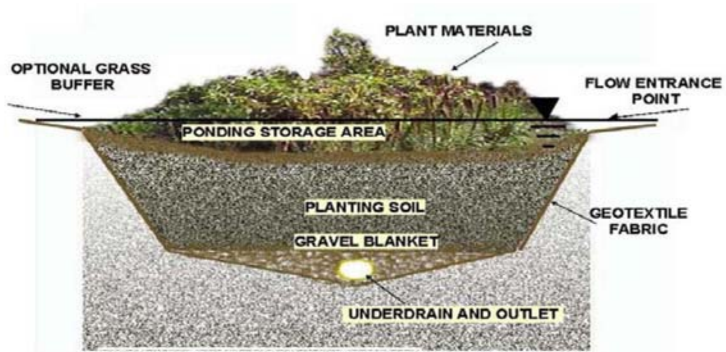
Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R29-Rest-006	Remove sediment and vegetation at creek crossings	Moderate	
	R29-Rest-007	Remove invasive nonnative vegetation	Low	Himalayan blackberry, Tree of Heaven, privet
	R29-Rest-008	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, mulberry, vinca
	R29-Rest-009	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry
	R29-Rest-010	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry
	R29-Rest-011	Remove sediment and vegetation at creek crossings	Moderate	
	R29-Rest-012	Remove invasive nonnative vegetation	High	Himalayan blackberry, Tree of Heaven
	R29-Rest-013	Remove sediment and vegetation at creek crossings	Moderate	
	R29-Rest-014	Remove debris jam and flow obstructions	High*	Series of debris jams creating local flooding hazard and contributing to localized bank instability
	R29-Rest-015	Remove sediment and vegetation at creek crossings	Moderate	
	R29-Rest-016	Remove invasive nonnative vegetation	High	Himalayan blackberry, ivy
Reach 30	R30-Rest-001	Remove invasive nonnative vegetation	High	Tree of Heaven, Himalayan blackberry
	R30-Rest-002	Remove debris jam and flow obstructions	High	
	R30-Rest-003	Remove invasive nonnative vegetation	Low	Himalayan blackberry
	R30-Rest-004	Remove sediment and vegetation at creek crossings and improve floodplain function	Low	
	R30-Rest-005	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, silk tree, ivy
	R30-Rest-006	Remove invasive nonnative vegetation	Low	Eucalyptus, Himalayan blackberry, privet, Chinese pistache
	R30-Rest-007	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, privet, Tree of Heaven

Reach Designation	Identification Number	Type of Restoration Activity	Priority Level*	Target Species/Notes
	R30-Rest-008	Remove sediment and vegetation at creek crossings	Moderate	
	R30-Rest-009	Remove invasive nonnative vegetation	Low	Beefwood, silk tree, privet, Himalayan blackberry
	R30-Rest-010	Improve floodplain function	Low	
	R30-Rest-011	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry, silk tree, fig
	R30-Rest-012	Remove debris jam and flow obstructions	High	
	R30-Rest-013	Remove invasive nonnative vegetation	Low	Himalayan blackberry, Tree of Heaven
	R30-Rest-014	Stabilize banks	Low	
	R30-Rest-015	Remove sediment and vegetation at creek crossings	High	
	R30-Rest-016	Remove invasive nonnative vegetation	Moderate	Himalayan blackberry
	R30-Rest-017	Remove debris jam and flow obstructions	High	
	R30-Rest-018	Remove invasive nonnative vegetation	Low	Privet, Himalayan blackberry
	R30-Rest-019	Stabilize banks	Low	
	R30-Rest-020	Remove sediment and vegetation at creek crossings	High	
	R30-Rest-021	Remove invasive nonnative vegetation	Moderate	Privet, Himalayan blackberry
Reach 31	R31-Rest-001	Remove invasive nonnative vegetation	Low	Pampas grass, Himalayan blackberry

* = Restoration opportunity given highest priority per Section 5.3.2

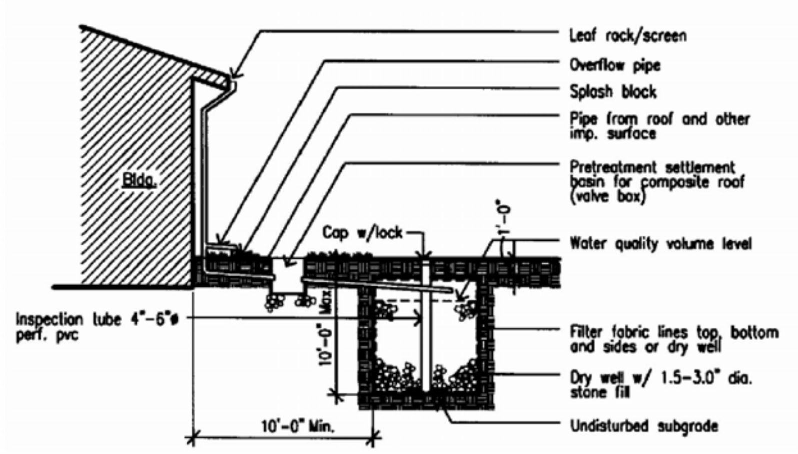
Paved Swale on Left Bank Terrace (Reach 11)

Desired Conditions (1 of 5)



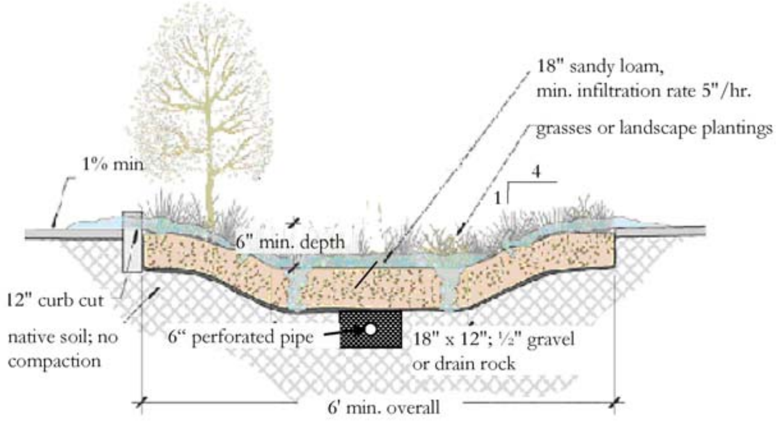
Bioretention Area
(Prince George's County 1993)

Desired Conditions (2 of 5)



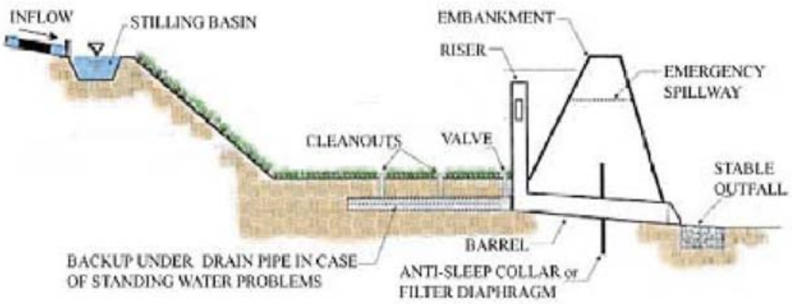
Dry Well
Bay Area Stormwater Management Agencies Association

Desired Conditions (3 of 5)



Vegetated or Grassy (Dry) Swale
Adapted from City of Portland 2004 Stormwater Manual

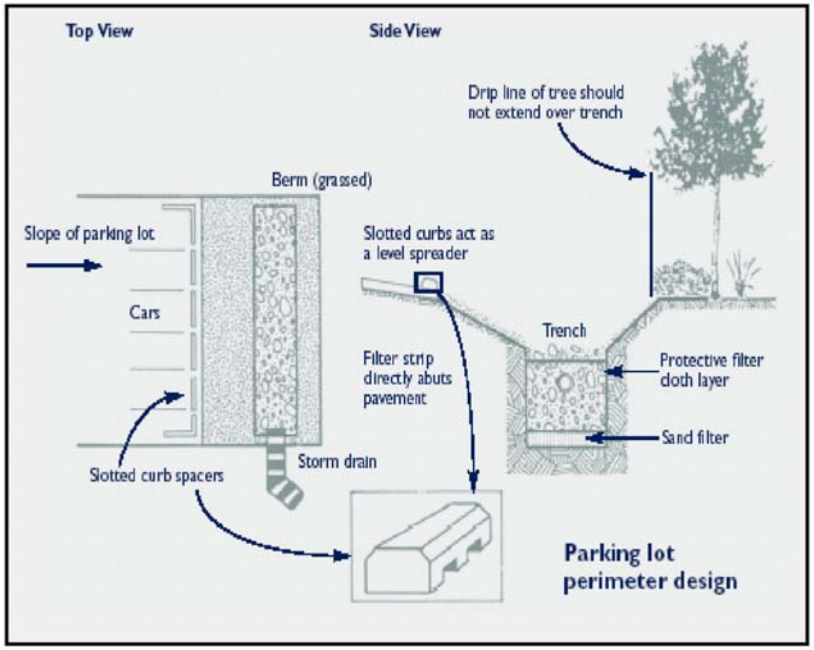
Desired Conditions (4 of 5)



Infiltration Basin

PDEP 2004

Desired Conditions (5 of 5)



Infiltration Trench

Young et al. 1996

Construction Methods

Construction methods for controlling runoff from parking lots generally involve capturing the runoff before it enters the stream. Options that could work well in the Arcade Creek stream corridor include:

- bioretention areas,
- vegetated or grassy ("dry") swales,
- infiltration basins,
- dry wells, and
- infiltration trenches.[1]

Bioretention areas remove stormwater pollutants through a combination of overland flow through vegetated swales, surface detention, and filtration through soil. Surface detention area is typically sized at 0.04 times the surface area of the swale/surface area of tributary impervious area. If soils are clayey or when infiltration is not desired, a perforated pipe underdrain can be installed. Beneath the surface detention area, a layer of drain rock or pea gravel, up to 4' deep, stores treated runoff before it seeps into the soil or underdrain. Plant species installed at bioretention areas should be suitable to well-drained soils and occasional inundation.

In a "dry" swale, pollutants are removed as runoff seeps through a layer of imported engineered soil. Treated runoff then infiltrates into the underlying native soil. A perforated pipe underdrain is incorporated into the design where native soils are clayey or when infiltration is not desired. The underdrain must be piped to a storm drain or other discharge point. Because the main mode of treatment is by filtration through the imported soil—not by settling and contact with vegetation—required detention times are minimal (approximately 10 minutes). Multiple inlets may be located along the length of the swale. Treatment-only swales typically must have a sizing factor (surface area of swale/surface area of tributary impervious area) of at least 0.04. Swales may be planted with turf grass or with plants and trees. If grass is used, the design should include gentle slope transitions and access for mowing equipment. Plantings should be selected for viability in a well-drained soil with occasional inundation. Irrigation is typically required to maintain plant viability.

Infiltration basins are shallow impoundments, typically without no outlet, designed to temporarily store and infiltrate stormwater. Suitable sites—flat, vegetated open spaces with highly permeable soils and sufficient depth to groundwater—are relatively frequent in the Arcade Creek stream corridor. The low cost of construction make infiltration basins an attractive option where they are feasible. The required minimum basin area for a designated basin depth needs to be determined. For treatment-only, the resulting volume is equal to the minimum water-quality volume; for treatment-plus-flow control, the area is the minimum necessary to ensure runoff does not exceed pre-project rates and

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[1] All methods and details described and presented below are derived from Contra Costa Clean Water Program's *Stormwater C.3 Guidebook* (Contra Costa Clean Water Program 2006).

durations. The side slopes and bottom of the basin should be vegetated with a dense turf or other water-tolerant grass immediately after construction. The root systems of healthy vegetation will help keep soil pores open and maintain infiltration rates. An underdrain system is a valuable backup to ensure the basin can be drained even as soils begin to clog.

Dry wells are typically a prefabricated structure, such as an unlined or open-bottomed vault or box, placed in an excavation or boring and filled with open-graded rock. Runoff is stored in the rock voids and allowed to infiltrate into the subsurface soil. The required minimum area for a designated dry well depth needs to be determined. For treatment-only, the resulting volume is equal to the minimum water-quality volume; for treatment-plus-flow control, the area is the minimum necessary to ensure runoff does not exceed pre-project rates and durations. A simple observation well should be included and can be fashioned from a footplate, perforated PVC pipe, and a locking cover. An overflow should be provided to handle large runoff flows. Dry wells should be inspected following storms to ensure water drains within 72 hours. Movement of water into the drain rock can sometimes be restored by removing and replacing the surface sand filter and filter fabric.

An infiltration trench is typically long, narrow, and filled with gravel or other permeable material. The trench stores runoff and infiltrates it through the bottom and sides into the subsurface soil. In a variation of this method, perforated drain pipes may convey runoff to gravel-filled trenches and into the native soil. The required minimum area for a designated dry well depth needs to be determined. For treatment-only, the resulting volume is equal to the minimum water-quality volume; for treatment-plus-flow control, the area is the minimum necessary to ensure runoff does not exceed pre-project rates and durations. Following excavation, the trench is lined with a Geotextile filter fabric. A sand layer is placed on the bottom, and the trench is backfilled with clean, open-graded gravel or rock. A horizontal layer of filter fabric is placed over the gravel or rock before a final surface layer of topsoil, sand or pea gravel. A simple observation well can be fashioned from a footplate, perforated PVC pipe, and a locking cover.

Estimated Magnitude of Construction Cost

Cost associated with controlling runoff from parking lots is approximately $5.00 per square foot. However, cost varies depending upon the specific methods of construction.

Construction Schedule

Runoff control activities should occur during the summer and fall when rainfall levels are at their lowest.

Phasing Schedule

Treatment of impervious areas is a low-cost restoration action that yields high returns for water quality improvement. This restoration action should be considered within the first few years of the Project’s implementation schedule.

Recommended Personnel

Runoff control activities should be performed by professionals with expertise in erosion control. A team of specialists, including engineers, hydrologists, and erosion control specialists should be involved in the design process.

5.2.2.2 Improve Floodplain Function

Problem/Need Statement

Floodplain encroachment from development has decreased the area and width of Arcade Creek's historic floodplain and reduced its ability to store flood flows, slow flow velocities, and manage sediment loads. Floodplain functional characteristics consist of three variables: the manner in which the stream channel is hydrologically connected to the floodplain (i.e., the degree of channel incision), the presence and stability of secondary channels, and the stability of tributary confluences with the main channel.

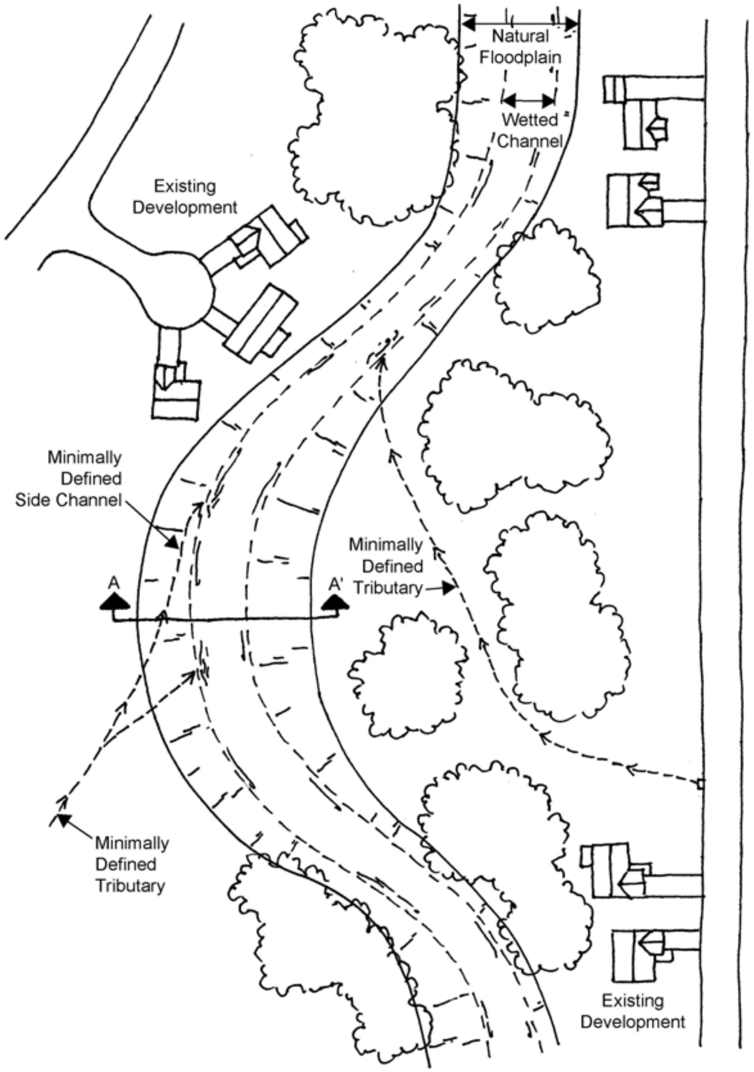
Many portions of the Arcade Creek channel have bankfull channels that are too narrow and not properly sized to convey flows of larger magnitudes, because of the incised nature of the creek. This incision promotes lateral bank instability as flood flows are contained within the bankfull channel and do not have the opportunity to dissipate their energy onto the floodplain. Furthermore, the incised nature of the creek precludes alternating point bar development, an indicator of channel habitat unit complexity.

Most tributaries and secondary channels in the Arcade Creek stream corridor (including the upper fork of Arcade Creek and Cripple Creek) are similar in geomorphic, vegetative, and aquatic characteristics to the creek itself. Channel incision, excessive erosion, and dense non-native vegetation are common. Most tributary confluences within the stream corridor are unstable; the tributary itself has unstable banks and the main channel has unstable banks upstream and downstream of the confluence point. Secondary channels are limited in number and those that do exist are overgrown and difficult to distinguish.

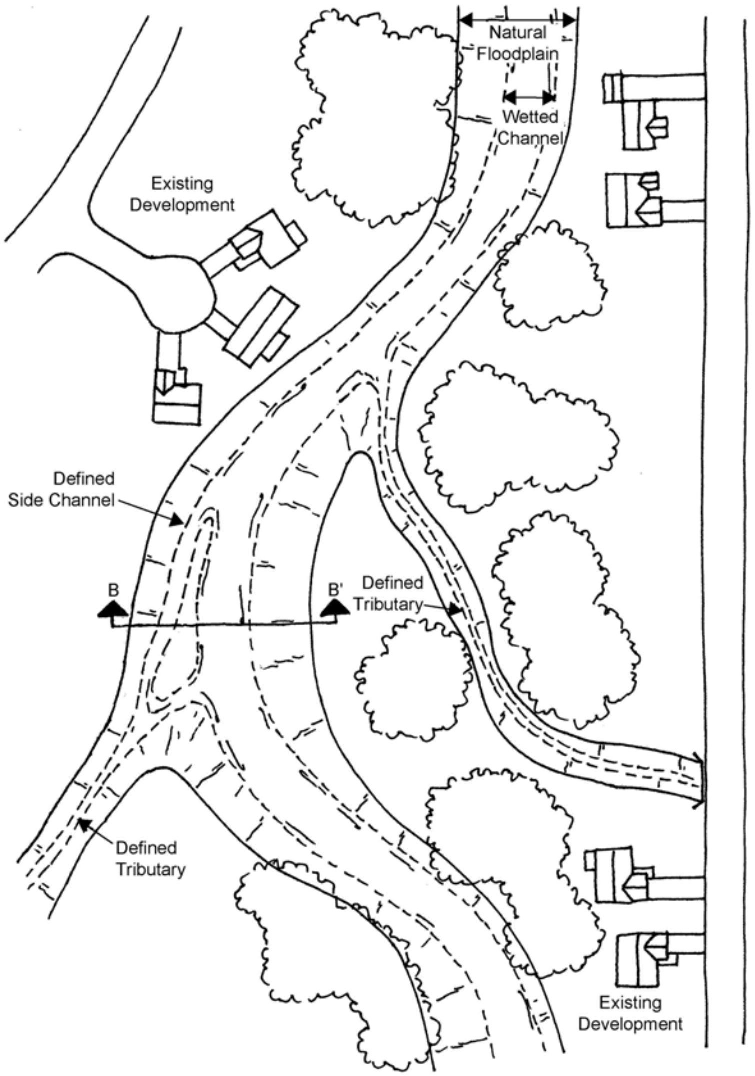
Desired Condition

The figures below illustrate current and desired conditions for improving floodplain function.

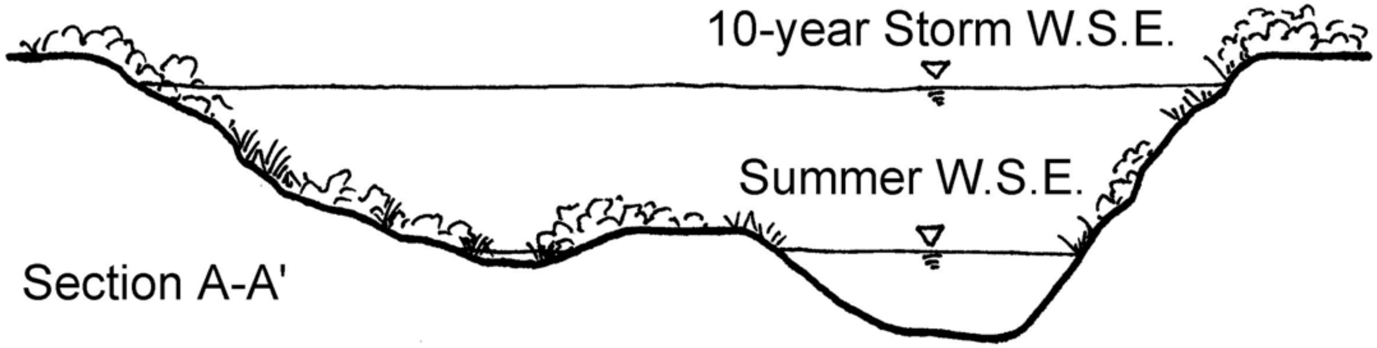
Current Floodplain Scenario



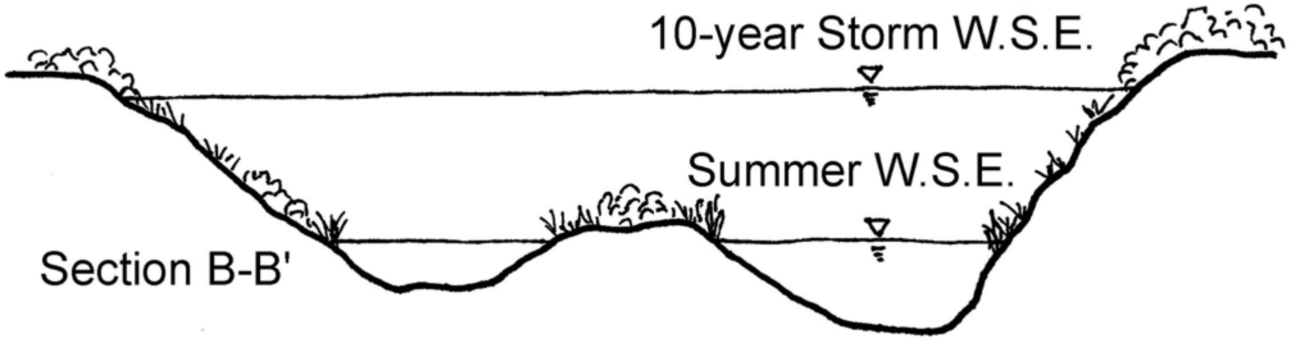
Desired Floodplain Scenario



Current Channel Capacity



Desired Channel Capacity



Construction Methods

Regarding the manner in which the stream channel is hydrologically connected to the floodplain (i.e., the degree of channel incision), grading back (i.e., decreasing the slope of) cutbanks and creating point bars and terraces opposite of the cutbanks would allow for better hydraulic connectivity between the channel and the floodplain, promote channel stability, and improve ecological functions. For secondary channel creation and/or enhancement, vegetation removal and excavation would be the primary associated activities. A primary path for the secondary channel would need to be defined, then cleared accordingly. For tributary confluences, bank stabilization activities would be necessary.

Estimated Magnitude of Construction Cost

Cost associated with grading back cutbanks and creating point bars and terraces opposite of the cutbanks is approximately $500.00 per linear foot. Cost associated with secondary channel creation and/or enhancement is approximately $300.00 per linear foot. Cost associated with bank stabilization is approximately $500.00 per linear foot. However, cost for all of these activities varies because of accessibility issues, the type of material encountered during construction, and the specific methods of treatment.

Construction Schedule

Floodplain enhancement activities should occur during the summer and fall when water levels in the creek are at their lowest, as the creek will most likely need to be diverted during construction.

Phasing Schedule

Improving floodplain function may require a combination of construction methods that are typically implemented over the course of one to two years. In between construction cycles, all exposed areas susceptible to erosion need to be fully stabilized using BMPs. Revegetation is then necessary during successive years as the floodplain is again connected the channel and exposed to more frequent inundation. This restoration action should be considered after the first 10 years of the Project’s implementation schedule.

Recommended Personnel

This restoration activity should be performed by professionals with expertise in stream restoration. A team of specialists, including engineers, hydrologists, geomorphologists, landscape architects, fish biologists, botanists, and ecologists, should be involved in the design process.

5.2.2.3 Improve Pipe Outfalls

Problem/Need Statement

Twenty pipe outfalls are in poor condition in the Arcade Creek stream corridor. Many protrude from stream banks and discharge water at an elevation above the water surface. Localized erosion of the stream banks in the vicinity of pipe outfalls is common. Pipe outfalls often promote scour along stream banks in both the upstream and downstream direction as flow interacts with the structure.

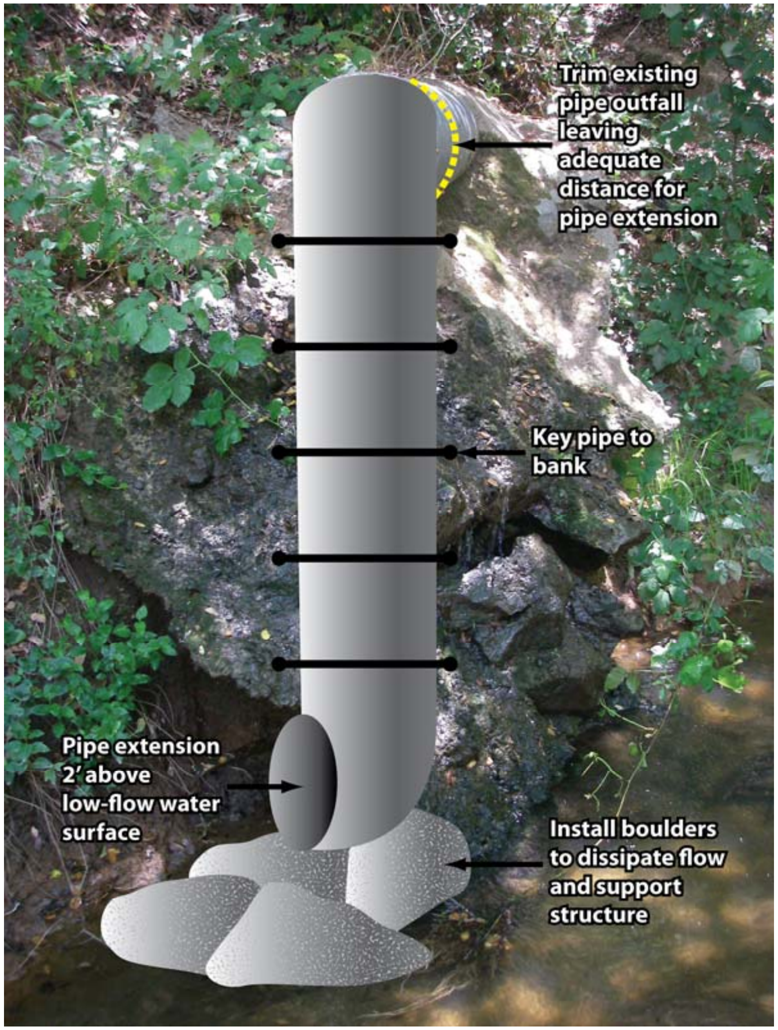
Furthermore, they sometimes trap debris and trash thereby impacting the water quality. Some pipe outfalls may be able to be removed without creating significant floodplain ponding. Removal of pipe outfalls would decrease the amount of water entering the creek during storm events and allow for natural floodplain retention in those areas.

Desired Condition

The digital images below illustrate current and desired conditions for the two dominant examples of eroding pipe outfalls.

Eroding Pipe on Right Bank (Reach 15)

Proposed Improvement



Eroding Pipe on Right Bank (Reach 12)

Proposed Improvement

Construction Methods

The existing pipe outfall would be trimmed back to either allow for an extension of the pipe outfall in the downward direction (if the pipe outfall exceeds more than a few feet in height) or to lay flush with the bank. In both cases, boulders would be installed in the channel bed against the bank to dissipate the energy of the water exiting the pipe outfall. If the pipe extension method were used, then the extension would need to be properly secured to the bank with the outlet located approximately 2 feet above the low-flow water surface. The outlet would also be supported by the boulders placed in the channel bed.

Estimated Magnitude of Construction Cost

Cost associated with improving pipe outfalls is approximately $5,000.00 per each site-specific project.

Construction Schedule

Improvement of pipe outfalls should occur during the summer and fall when water levels in the creek are at their lowest to allow for the easiest access.

Phasing Schedule

Improvement of pipe outfalls could potentially occur over the course of the first year. Monitoring of the pipe extension (if built) and the placed boulders is recommended on an annual basis. This restoration action should be considered within the first years of the Project’s implementation schedule.

Recommended Personnel

This restoration activity should be performed by contractors with expertise in pipe outfall installation. Consultation with a civil engineer and/or a geomorphologist is also suggested.

5.2.2.4 Reconfigure Channel

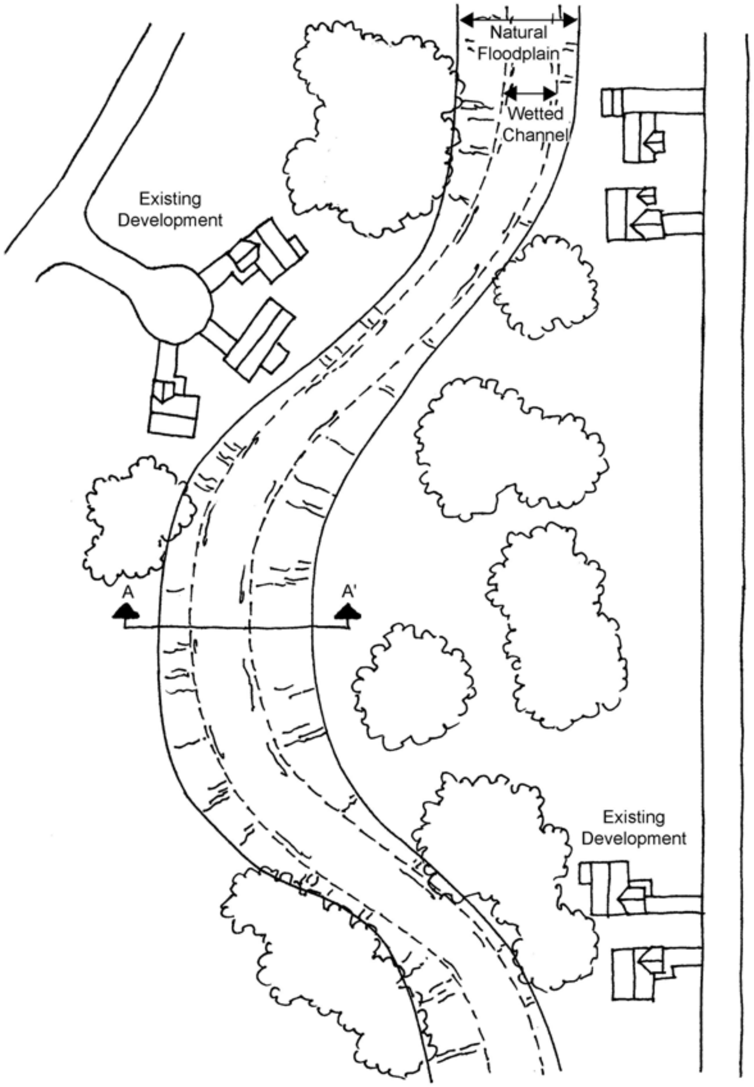
Problem/Need Statement

Historical channel straightening has significantly influenced the planform, geomorphic processes, and habitat structure of the Arcade Creek stream corridor. Channel complexity and variability have been reduced as development has encroached onto the floodplain and the creek has been confined. In the lower reaches of Arcade Creek, levees have further channelized and straightened the creek. As a result, flood flow velocities and associated erosion processes in the stream corridor have increased, reducing the overall natural function of the channel. This restoration opportunity is proposed for two sites located in Reach 17 (R17-Rest-011) and Reach 18 (R18-Rest-003) (Table 5-2; Appendix B).

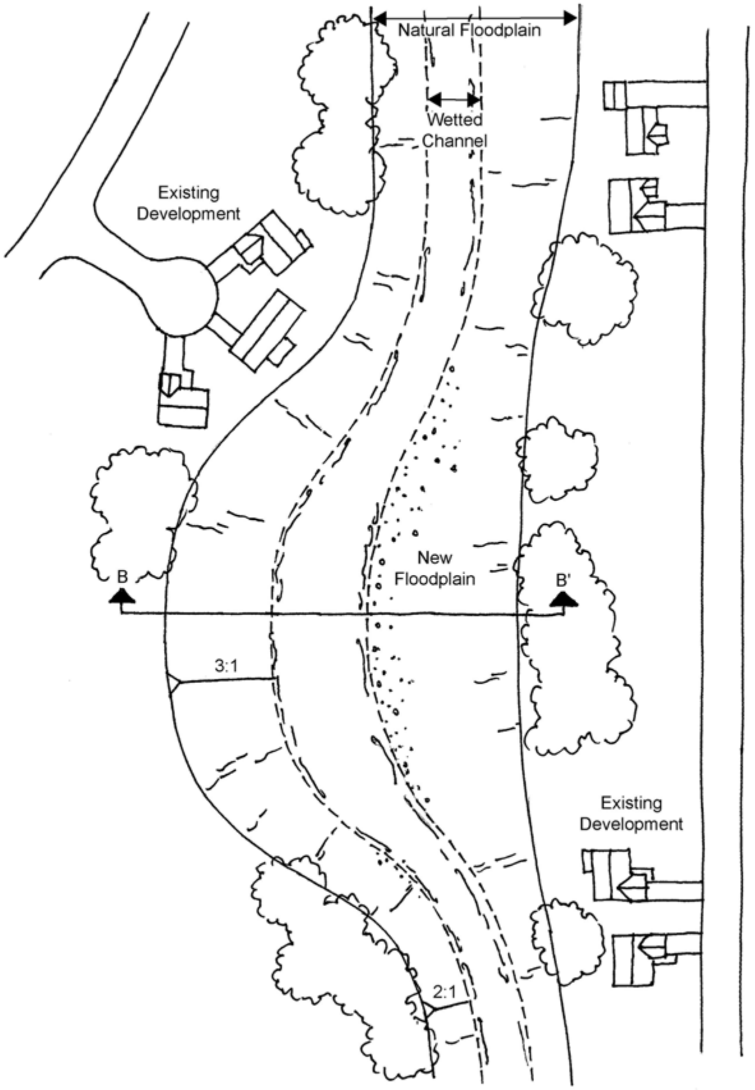
Desired Condition

The figures below illustrate current and desired conditions for channel reconfiguration in Reach 17 and Reach 18.

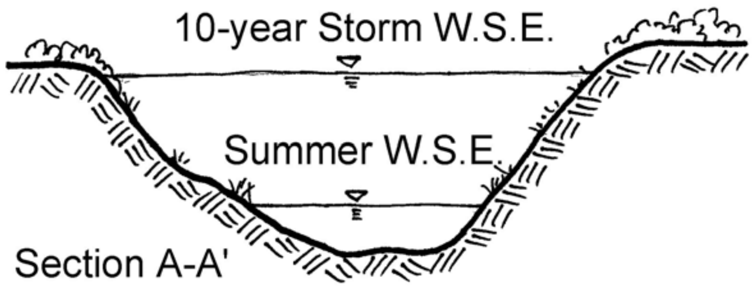
Current Channel Configuration



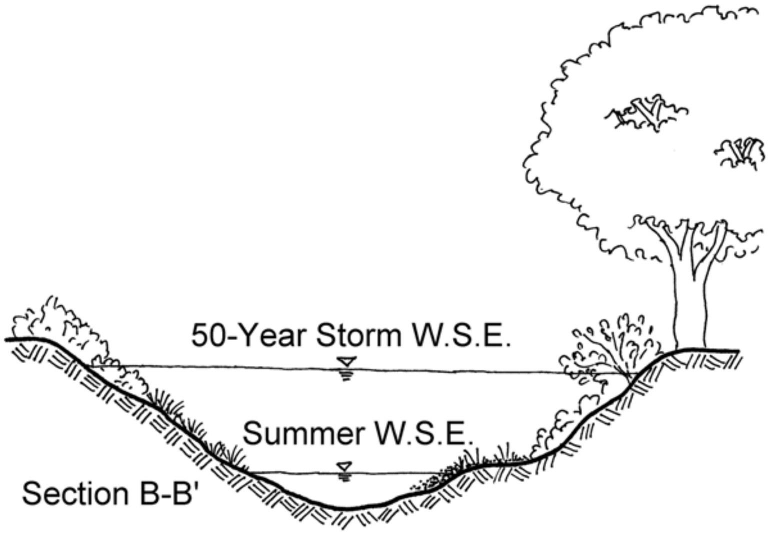
Desired Channel Reconfiguration



Current Channel Capacity



Desired Channel Capacity



Construction Methods

In general, reconfiguring the channel involves physically redirecting part or all of the channel from its' current path. The planform of the channel changes and stream banks and the floodplain are affected. By increasing planform sinuosity (constructing more meanders) and creating point bars and terraces, the conveyance capacity of the channel increases and the erosive energy of flow decreases. Furthermore, decreasing the slope of the surrounding banks, as well as increasing the distance between the channel, its banks, and surrounding structures protects property and infrastructure from flooding and associated erosion.

This restoration opportunity is the most complex in the corridor management plan. Other restoration opportunities would most likely be implemented simultaneously with channel reconfiguration. These may include at a minimum stabilize banks, improve floodplain function, and remove invasive non-native vegetation.

Estimated Magnitude of Construction Cost

Cost associated with reconfigure channel is approximately $300.00 per linear foot. However, cost varies significantly because of accessibility, type of material encountered during channel reconfiguration, and the specific methods of construction.

Construction Schedule

Channel reconfiguration activities should occur during the summer and fall when water levels in the creek are at their lowest, as the creek will most likely need to be diverted during construction.

Phasing Schedule

Channel reconfiguration activities are typically implemented over the course of several years. A new channel alignment is usually initiated, followed by burial and/or redesign of the former channel alignment. In between construction cycles, all exposed areas susceptible to erosion need to be fully stabilized using BMPs. Revegetation is then necessary during successive years after the channel has been reconfigured. This restoration action should be considered 15 years into the Project's implementation schedule.

Recommended Personnel

Channel reconfiguration activities should be performed by professionals with expertise in stream restoration. Of all the restoration activities described in the stream corridor plan, channel reconfiguration would involve the most planning and effort. A team of specialists, including engineers, hydrologists, geomorphologists, landscape architects, fish biologists, botanists, and ecologists, should be involved in the design process.

5.2.2.5 Remove Concrete-Lined Channel

Problem/Need Statement

One section of channel (i.e., channel bottom and most of the adjacent bank) in the upper segment of the Arcade Creek stream corridor[2] has been concrete-lined for flood control purposes (R19-Rest-001). Concrete lining improves hydraulic efficiency, allowing more rapid transit of storm flows to be conveyed by the channel. Development that has occurred since these concrete-lined channel sections were installed has further increased the volume of each storm flow that the creek conveys. While the concrete-lined sections may still have capacity to convey these flows, the downstream receiving reach may not and the potential for erosion and flooding can be increased. Additionally, vegetation, natural substrate, and aquatic organisms are constantly disturbed downstream of concrete-lined channels due to the flushing action of upstream flows.

Removal of each concrete-lined channel sections will require a channel conveyance analysis related to the current level of development as current flood protection must be maintained. This may require increasing the current creek bankfull geometry (top of bank to top of bank) and likely be developed in conjunction with upstream reduction of storm runoff (storm conveyance retrofit projects).

Desired Condition

The digital images below illustrate current and desired conditions for removal of concrete-lined channels.

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[2] The lower reaches of Arcade Creek also have sections of concrete-lined channels. However, these sections are small and spatially variable.

Concrete-Lined Channel (Reach 19)

Stable Channel Section (Reach 11)

Construction Methods

To remove a concrete-lined channel, the concrete needs to be manually removed and properly disposed of. The channel then needs to be restored to a natural condition and stabilized. Natural fill for both the channel bed and the bank needs to be imported. Specific habitat units (e.g., pools, riffles, and runs) need to be properly excavated and stabilized, often with grade control structures. Clean gravels (i.e., gravels with a low fine sediment matrix) may need to be incorporated for riffle habitat, if desirable. Grade control structures may need to be incorporated into the overall channel design in order to lessen the likelihood of incision. Revegetation efforts need to occur on the banks, and the connection to the floodplain needs to be constructed properly. BMPs to limit erosion after the initial restoration of the reach need to be implemented and monitored on a regular basis.

Estimated Magnitude of Construction Cost

Cost associated with the removal of the concrete-lined channel is approximately $1,000.00 per linear foot. The high cost is related to the need to remove and dispose of concrete, restore and stabilize the channel, and to possibly construct upstream facilities to maintain flood control.

Construction Schedule

Removal of the concrete-lined channel should occur during the summer and fall when water levels in the creek are at their lowest, as the creek will most likely need to be diverted during construction.

Phasing Schedule

Concrete-lined channel removal activities are typically implemented over the course of a few years. After the concrete has been removed, a new channel alignment is usually initiated, followed by burial and/or redesign of the former channel alignment. In between construction cycles, all exposed areas susceptible to erosion need to be fully stabilized using BMPs. Revegetation is then necessary during successive years. This restoration action should be considered with the first few years of the Project’s implementation schedule.

Recommended Personnel

This restoration activity should be performed by professionals with expertise in stream restoration. A team of specialists, including engineers, hydrologists, geomorphologists, landscape architects, fish biologists, botanists, and ecologists, should be involved in the design process.

5.2.2.6 Remove Invasive Nonnative Vegetation

Problem/Need Statement

Invasive nonnative plant species occur throughout the Arcade Creek stream corridor and include ornamental landscape tree, shrub and vine species. Invasive nonnative species occurrences ranged from mature stands or mature individual nonnative trees and shrubs to isolated occurrences of invasive nonnative seedlings just beginning to colonize an area. Many invasive nonnative species form monocultures that out-compete native plant species and reduce wildlife habitat values.

As stated above, invasive nonnative species occur throughout the Arcade Creek stream corridor; therefore it is not practical to remove all occurrences. Table 5-2 identifies all of the concentrations of invasive nonnative species in the Arcade Creek stream corridor, identifies the dominant invasive nonnative species observed and prioritizes the stands to be controlled based on the following criteria:

- **Provides a point source for invasive nonnative species**—Invasive nonnative species are very successful at establishing because they have developed effective reproductive strategies. Some invasive species disperse vegetatively so controlling the spread by treating individual occurrences may be effective. Other species disperse by seed so removing these species from upstream sections of the stream corridor to eliminate seeds being transported downstream by flows or wind may be necessary.
- **Restricts flood conveyance**—Dense stands of invasive nonnative vegetation, particularly Himalayan blackberry, can restrict flood conveyance and result in local flooding and promote the establishment of debris jams and flow obstructions. Removal or management of this invasive nonnative vegetation may improve local flood conveyance; however, prior to removal of vegetation in any location the potential for increased flooding downstream due to increase in flow needs to be determined.
- **Impedes public access**—Although there are no formal maintained trails in the stream corridor, dense stands of invasive nonnative vegetation can impede informal access in some locations.
- **Threatens public safety**—Dense stands of invasive nonnative vegetation may pose a threat to public safety when the stands impedes visual access along informal trails and other public and private access areas. These areas may also support homeless encampments. Examples of where this situation occurs include the area behind the Discovery Museum on Auburn Boulevard and the area upstream of Arcade Creek Park.
- **Reduces habitat value and restricts the establishment of native species**—Dense stands of invasive nonnative vegetation, particularly vines and groundcover, reduce habitat values and restrict the establishment of native species. This situation occurs in several locations in the upper Segment of the Arcade Creek stream corridor where Himalayan blackberry, ivy, and vinca form dense stands or mats over the ground surface.
- **Feasibility and method of removal possible based on site access**—Most of the land along the Arcade Creek stream corridor is privately owned. Landowner approval may be required to access invasive nonnative vegetation sites, remove the vegetation from the site, and discard vegetation from the stream corridor.

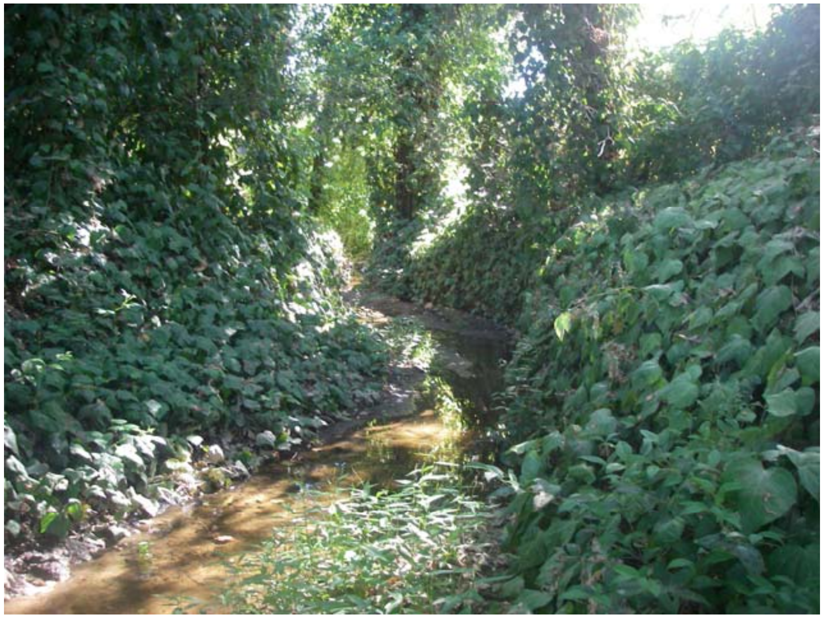
Desired Conditions

The digital images below show high quality habitat (minimal coverage by invasive nonnative vegetation) and low quality habitat (almost total coverage by invasive nonnative vegetation).

Oak Forest Habitat along Arcade Creek

Riparian Forest and Scrub Habitat along Arcade Creek

English Ivy Dominating Channel



Large Giant Reed Stand on Cripple Creek near Sunrise Boulevard

Construction Methods

Before removing invasive nonnative species, particularly dense monoculture stands of vines and groundcover, it should be determined if the removal of the vegetation would result in channel or floodplain instability. Revegetation with native species following initial removal efforts of invasive nonnative species could be performed at all of the removal sites to promote the establishment of native species before nonnative species can reestablish. The establishment of native species will require the purchase, installation, and maintenance of plant material. Specific revegetation and maintenance plans would be developed.

Construction methods will vary on a site-by-site basis based on site access (e.g., equipment access) and the preferred control method for particular invasive nonnative species. Additional information related to the opportunities and constraints of vegetation control methods are provided in the Invasives Species Plan (Appendix D).

Estimated Magnitude of Construction Cost

Cost associated with invasive nonnative species removal stabilization is approximately $150.00 per linear foot. However, cost varies significantly because of accessibility, the species (and age class) being removed, and the specific methods of removal.

Construction Schedule

Depending on the targeted invasive nonnative species (and age class), removal activities are best performed in the late summer or alternatively in the late spring after storm waters recede.

Phasing Schedule

This restoration action should be considered during years 1 and 2 of the Project’s implementation schedule.

Recommended Personnel

Depending on removal method (manual or equipment), this restoration activity could be performed by supervised volunteers if access is not problematic.

5.2.2.7 Stabilize Banks

Problem/need Statement

Lawler (1992) groups unstable banks into three categories: weakening, fluvial erosion, and mass-failure processes. Weakening processes erode or prepare banks for further erosion (e.g., storm events that dislodge individual particles on the banks and trail establishment). Fluvial erosion processes (i.e., erosion by water) are related to the energy of flow (i.e., boundary shear stress). Mass-failure processes cause gravitational collapse of all or part of the bank. Weakening, fluvial, and mass-failure processes act separately and/or together on banks at various locations along the Arcade Creek stream corridor. Accordingly, there are different ways to minimize bank instability.

Approximately 170,000 linear feet of the Arcade Creek stream corridor supports natural banks. Many of these natural banks consist of non-cohesive sands, silt, and clays and lack suitable vegetative cover. These banks, which are usually very steep, are typically prone to both fluvial erosion during high flow events (which are common in flashy, incised streams such as Arcade Creek), and mass failure after flows have subsided. When natural banks are unstable, they can deliver large amounts of sediment into the stream, decreasing channel capacity and habitat value while increasing the potential for flooding.

Bank instability is a natural process that occurs in all river systems. Stabilizing all areas of stream bank in the Arcade Creek stream corridor is neither practical nor ecologically sound. Accordingly, only bank instability areas that are considered to be “critical” have been identified and recommended as a restoration opportunity. Criteria to list a bank instability area as critical includes:

- Areas where reduction of excessive sedimentation of the channel could be prevented;
- Areas where reduction of risk to public safety and infrastructure could be prevented or lessened; and
- Areas adjacent to or part of other potential restoration actions.

Desired Condition

The digital images below illustrate current and desired conditions for unstable banks in the Arcade Creek stream corridor.

Severe Bank Erosion on Left Bank Adjacent to Pedestrian Bridge (Reach 16)

Eroding Bank near Bridge in Rusch Regional Park (Reach 26)

Stable Banks between Norwood Avenue to Marysville Boulevard (Reach 3)

Construction Methods

In general, bank stabilization can be divided into two main categories: biotechnical stabilization and hardscaping. Biotechnical stabilization involves the use of natural materials (e.g., vegetation, large woody material, etc.) to stabilize banks. Often, these natural materials are placed on the unstable bank once the bank has been re-graded to a less steep slope that will decrease the likelihood of erosion due to mass failure. Hardscaping involves the use of rip-rap, concrete, gabions, and other hard methods for stabilizing banks. These methods are not as environmentally sensitive as biotechnical stabilization methods and typically are only used when the latter approach is not feasible.

Construction methods for bank stabilization are site-specific. Methods may include:

- revegetation of the stream bank (biotechnical)
- re-grading of the stream bank followed by revegetation (biotechnical)
- stabilizing the bottom (i.e., toe) of the stream bank with natural materials (biotechnical) or hardscaping (hardscaping)
- stabilizing the entire stream bank with hardscape (hardscaping)

The particular method used depends on the longitudinal position of the bank within the channel (i.e., whether the bank is located in a straight channel section or a meandering channel section), bank height, and bank material. Additionally, the proximity of the bank to crucial structures such as property or infrastructure is a factor in determining the methods used to stabilize banks.

Estimated Magnitude of Construction Cost

Cost associated with bank stabilization is approximately $500.00 per linear foot. However, cost varies significantly because of accessibility, the type of bank material, and the specific methods of construction.

Construction Schedule

Bank stabilization activities should occur during the summer and fall when water levels in the creek are at their lowest.

Phasing Schedule

Bank stabilization activities (e.g., grading, excavation, revegetation, and/or hardscaping) should be implemented during the first few years of the Project's implementation schedule.

Recommended Personnel

Bank stabilization activities often include earthwork (i.e., grading). In this instance, the activity should be performed by professionals with expertise in stream restoration. A team of specialists, including engineers, hydrologists, geomorphologists, landscape architects, fish biologists, botanists, and ecologists, should be involved in the design process. If bank stabilization activities include only revegetation, then supervised volunteers could help perform this activity if access is not problematic.

5.2.2.8 Stabilize Swales

Problem/need Statement

Three swales (i.e., smaller depressional channels that convey water) adjacent to the creek have been identified as actively headcutting (Table 5-2). Some past remediation methods such as rock-stabilized areas to curtail headcutting have worked well in other swales that are not listed in Table 5-2. However, the three identified eroding swales in Table 5-2 are either actively headcutting above rock-stabilized areas, or are in poor condition throughout the entire length of the swale. These swales will continue to erode over time, continuing to increase sediment delivery into the creek.

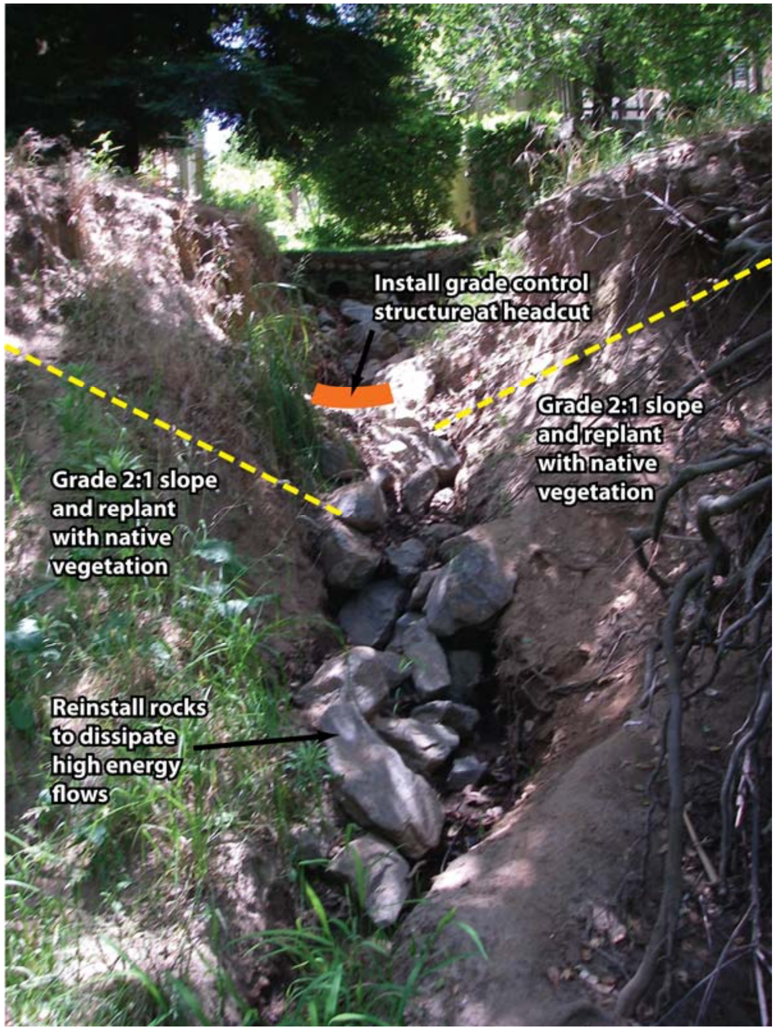
These swales have been identified as super-critical eroding sites. Excessive sedimentation from channel headcutting, danger to public safety, and areas where other restoration opportunities would occur concurrently with this restoration opportunity all define a super-critical eroding site.

Desired Condition

The digital images below illustrate current and desired conditions for eroding swales.

Eroding Swale (Reach 15)

Proposed Improvement



Construction Methods

The banks of the swale would be graded to a stable slope (e.g., 2:1). Installation of a grade control structure at the headcut in the swale is the second step in the construction process. New boulders would be placed on the channel bed of the swale. Lastly, revegetation of the banks would occur.

Estimated Magnitude of Construction Cost

Cost associated with stabilizing swales is approximately $100.00 per linear foot.

Construction Schedule

Stabilization of swales should occur during the summer and fall when water levels in the creek and the swales are at their lowest to allow for the easiest access.

Phasing Schedule

Stabilization of swales could potentially occur over the course of one year. This restoration action should be considered 10 years into the Project's implementation schedule.

Recommended Personnel

This restoration activity should be performed by contractors with expertise in erosion control. Consultation with a civil engineer and/or a geomorphologist is also recommended, though not required.

5.2.2.9 Remove Debris Jams and Flow Obstructions

Problem/Need Statement

Debris jams from both natural (e.g., fallen trees) and nonnatural materials (e.g., trash and abandoned structures [small bridges and abutments associated with old road crossings]), add unwanted material to the channel and decrease channel capacity so that local flooding increases. Debris jams also promote scour along stream banks as flow is directed outwards and away from the flow obstruction. Lastly, trash in the channel can also affect water quality (e.g., discarded industrial drums and chemical containers).

Desired Condition

The digital images below illustrate current conditions for a typical debris jam and a typical flow obstruction.

Debris Jam (Reach 11)

Flow Obstruction on Left Bank (Reach 11)

Construction Methods

Methods for removal of debris jams and flow obstructions are straightforward. Personnel need access to the creek and need to employ the necessary tools and equipment to fully remove the debris jam or flow obstruction. In some cases, debris jams can be removed by hand labor to minimize disturbance to the surrounding area. Based on the field survey, many of the debris jams and all flow obstructions will need to be removed using equipment.

Estimated Magnitude of Construction Cost

Cost associated with the removal of debris jams is approximately $2,500.00 per each debris jam. Cost associated with the removal of flow obstructions is approximately $5,000.00 per each flow obstruction.

Maintenance Schedule

Removal of debris jams and flow obstructions should be performed at least once a year, preferably after winter and spring storms have subsided so that significant transport rates have declined and water levels have decreased to expose the debris jam or flow obstruction as much as possible.

Phasing Schedule

This restoration action should be considered in years' 1 and 2 of the Project's implementation schedule to address the many flow obstructions and then revisited each year to keep such obstructions to a level where flood hazard is minimal.

Recommended Personnel

It is recommended that professionals with experience in debris removal, vegetation removal, and sediment excavation conduct debris jams and flow obstruction removal. Consultation with a geomorphologist and a vegetation specialist is also suggested.

5.2.2.10 Remove Sediment and Vegetation at Creek Crossings

Problem/Need Statement

Sixteen areas in the upper portion of the Arcade Creek stream corridor have excessive vegetation and sediment that decrease channel capacity (Table 5-2). As a result, the low-flow channel is too narrow and not properly sized to convey flows of larger magnitudes. There are some areas where vegetation is minimal and only excavation of sediment is necessary. Many of these areas occur at creek crossings, where excessive vegetation and sediment are responsible for backing up (and increasing the surface level) of water during flood events.

Desired Condition

The digital images below illustrate current and desired conditions for sediment and vegetation removal at creek crossings.

Sediment and Vegetation Upstream and Downstream of Creek Crossing (Reach 21)

Proposed Improvement

Construction Methods

Removal of sediment and vegetation at creek crossings requires manual excavation (by hand and/or with machinery). Once proper access is determined, this activity is relatively easy to implement. It is recommended that all non-native vegetation be fully removed within at least 20 feet of the creek crossing (in both the upstream and downstream directions), and that the sediment be excavated and removed to a depth that resembles the average of the channel bottom elevation 50 feet upstream and downstream of the creek crossing.

Estimated Magnitude of Construction Cost

Cost associated with the removal of sediment and vegetation at creek crossings is approximately $15 per cubic yard to haul away material; $6.00 per cubic yard to excavate material; and $30.00 per cubic yard for refuse fees. Cost decreases the further upstream the material that needs to be removed is located (i.e., where the creek has a smaller width).

Maintenance Schedule

Removal of sediment and vegetation at creek crossings should be performed at least one time a year, preferably after winter and spring storms have subsided so that significant sediment transport rates have declined and so that water levels have decreased to expose the channel bed as much as possible.

Phasing Schedule

This restoration action should be considered in years’ 1 and 2 of the Project’s implementation schedule to address sediment and vegetation at creek crossings and then revisited each year to keep such obstructions to a level where flood hazard is minimal.

Recommended Personnel

It is recommended that professionals with experience in vegetation removal and sediment excavation conduct sediment and vegetation removal. Consultation with a geomorphologist and a vegetation specialist is also suggested.

5.3 High Priority Restoration Opportunities

5.3.1 Restoration Opportunities

Of all described restoration opportunities, the following are considered to be high priority:

- Improve Pipe Outfalls
- Stabilize Banks
- Remove Invasive Nonnative Vegetation
- Remove Debris Jams and Flow Obstructions

5.3.1.1 Improve Pipe Outfalls

Twenty pipe outfalls are in poor condition in the Arcade Creek stream corridor. Many protrude from stream banks and discharge water at an elevation above the water surface. Local erosion of the stream banks in the vicinity of pipe outfalls is common. Pipe outfalls can promote scour along stream banks in both the upstream and downstream direction as flow interacts with the structure. Furthermore, pipe outfalls can trap debris and trash and impacting water quality. Improvement of pipe outfalls is associated with the following negative effects to steam corridors:

- Flooding. Dissipation of energy at the base of restored pipe outfalls will help minimize the erosive capability of water entering from point-source pipe outfalls in the Arcade Creek stream corridor.
- Habitat degradation. Localized areas of bank instability are often associated with eroding pipe outfalls. Restored pipe outfall areas will also improve habitat.
- Threats to infrastructure or property. In some cases, gullying (upslope downcutting of bank material) associated with eroding pipe outfalls is compromising infrastructure or property on the top of banks.

5.3.1.2 Stabilize Banks

Bank stabilization is a high priority because eminent property or infrastructure damage is likely at several locations in the Arcade Creek steam corridor. Bank instability is associated with the following negative effects to steam corridors:

- Flooding. Excessive sedimentation from bank instability fills the channel bed with sediment, thereby decreasing local channel capacity and increasing the flood hazard, as well as affecting water quality.
- Habitat degradation. Excessive sedimentation from bank instability fills the channel bed with sediment, burying gravels and degrading aquatic habitat. Filling of the channel also reduces water quality by creating more shallow channels that can be a factor in water temperature increases.
- Infrastructure or property risk. Unstable banks threaten nearby infrastructure and property as the banks erode and sediment is deposited into the channel.

It is important to note that without stream corridor-wide implementation of all restoration opportunities discussed above in Section 5.2.2, the general instability of stream banks in the corridor will most likely remain similar or worsen in the future.

5.3.1.3 Remove Debris Jams and Flow Obstructions

Removal of debris jams and flow obstructions will have the most immediate benefit to the Arcade Creek stream corridor. Debris jams and flow obstructions add unwanted material to the channel and decrease channel capacity so that local flooding increases. Debris jams also promote scour along stream banks as flow is directed outwards and away from the flow obstruction. Lastly, trash in the channel can also affect water quality (e.g., discarded industrial drums and chemical containers). Removal of debris jams and flow obstructions is associated with the following negative effects to steam corridors:

- Flooding. Excessive material can fill the channel and reduce channel capacity and increase flood hazard.
- Habitat degradation. Debris jams and flow obstructions divert flows into banks and can undermine banks and indirectly cause a loss of shaded riverine aquatic (SRA) cover habitat as trees and shrubs fall into the creek. The loss of SRA cover to the channel has benefit (e.g., instream cover) but also a negative effect as shade that helps cool water temperatures is lost.
- Infrastructure or property risk. Debris jams and flow obstructions can lead to bank instability due to flow diversion around the obstruction. Nearby infrastructure and property can be threatened as the banks erode and sediment is deposited into the channel.

5.3.1.4 Remove Invasive Nonnative Vegetation

Invasive nonnative vegetation occurs throughout the Arcade Creek stream corridor, with species and density of nonnative species varying greatly. Removal of all invasive nonnative species populations in the Arcade Creek stream corridor is not feasible; however, select populations or locations are be identified and should be cleared. Invasive nonnative vegetation has the following negative effects to steam corridors:

- Key point source. Established stands of invasive nonnative species provide the seed source or other reproductive strategy for colonization of nearby areas along the stream corridor.
- Flooding. Dense stands of invasive nonnative vegetation, particularly Himalayan blackberry, can restrict flood conveyance and result in localized flooding and promote the establishment of debris jams and flow obstructions.
- Access limited. Although there are no formal maintained trails in the stream corridor, dense stands of invasive nonnative vegetation can impede informal access in some locations.
- Public safety threat. Dense stands of invasive nonnative vegetation may pose a threat to public safety when the stands impede visual access along trails and other public and private access areas.

- Habitat degradation. Dense stands of invasive nonnative vegetation, particularly vines and groundcover, reduce habitat values and restrict the establishment of native species.
- Feasibility and site access. Most of the land along the Arcade Creek stream corridor is privately owned. Landowner approval may be required to access invasive nonnative vegetation sites, remove the vegetation from the site, and discard vegetation from the stream corridor.

5.3.2 Restoration Sites

The following are considered to be high priority restoration sites:

- Bank stabilization sites
- Debris jams and flow obstructions
- Invasive nonnative vegetation sites
- Pipe outfalls

Priority status is given to these types of sites because restoration actions at these sites can immediately address many of the priority items listed in Section 5.2.1. Table 5-2 identifies specific sites with high priority. With respect to invasive nonnative vegetation sites, it should be noted that all populations of invasive nonnative vegetation could be identified as a high priority removal site because any population could produce propagules to expand their population and cover more area in the stream corridor. However, three sites have been identified as high priority removal sites: Site R8-Rest-003 is located behind the Discovery Children’s Museum and Site R11-Rest-003 is located north of Arcade Creek Park—both sites have been identified because of potential threats to public safety. Site R28-Rest-011 (on Cripple Creek near Sunrise Boulevard) has been identified because a giant reed stand occurs within the bed and banks of the creek and impedes flood flows.

5.4 Data Gaps and Future Studies

It is recommended that future studies pertaining to the establishment of a formal recreational trail spanning the entire length of the Arcade Creek stream corridor be conducted. Currently, there are many informal trails used primarily by equestrians that cover sections of the stream corridor. Most of these trail sections have been identified and mapped accordingly (see Table 5-2, “Restoration Opportunities in Arcade Creek Stream Corridor, by Reach”; and Appendix B, “Arcade Creek Stream Corridor: Existing Conditions and Restoration Opportunities Maps [2007]”).

Connecting these informal trails and improving them should be done in conjunction with restoration opportunities so that one does not preclude the other.

Issues to study include public support (several Arcade Creek Watershed Group members have described historical conditions were equestrians could access most of Arcade Creek via trails), access (connecting trails through private property and narrow creek sections), construction costs, maintenance responsibility, etc.

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Appendix A

Arcade Creek Stream Corridor: Representative Digital Images, by Reach

[Included on CD]

Appendix B

Arcade Creek Stream Corridor: Existing Conditions and Restoration Opportunities Maps (2007)

[Included on CD]

Appendix C

Public Involvement Plan

[To Come]

Appendix D

Invasive Species Plan

[To Come]

Appendix E

Environmental Permit Requirements

Appendix E
Regulatory Compliance Permits

E.1 Introduction

This appendix summarizes federal, state, and local regulatory compliance permits that are often required to implement restoration projects.

E.2 Common Environmental Regulations Affecting Restoration

- Endangered Species Act (state and federal, CESA and ESA, respectively)
- Clean Water Act (CWA) and California Porter-Cologne Act
- National Historic Preservation Act (NHPA)
- National Environmental Policy Act (NEPA)
- California Environmental Quality Act (CEQA)
- California Fish and Game Code
- Local/municipal/regional policies and regulations

E.2.1 Endangered Species Act

- **Purpose**
  - ☐ Protect plant and animal species listed as endangered and threatened
  - ☐ Protect habitat of these species
- **Administration**
  - ☐ U.S. Fish and Wildlife Service (USFWS) (federal)
  - ☐ National Marine Fisheries Service (NMFS) (federal)
  - ☐ California Department of Fish and Game (DFG) (state)

- **Example**
    - Seasonal wetlands restoration in an upper floodplain with elderberry shrubs
    - Elderberry shrubs are host plant of Valley Elderberry Longhorn Beetle
    - Valley Elderberry Longhorn Beetle is federally listed species
- **Issues**
    - Regulated by programmatic guidelines
    - Possible taking of habitat, need to coordinate with USFWS

E.2.2 Clean Water Act Section 404

- **Purpose**: Regulate the discharge of dredged or fill material into waters of the U.S., that may include wetlands
- **Administration**: U.S. Army Corps of Engineers (Corps), Environmental Protection Agency oversight
- **Example**
    - Native perennial prairie restoration in freshwater marsh complex
    - Freshwater marshes are wetlands under Corps jurisdiction
- **Issues**
    - Need wetland delineation
    - Triggers ESA, CWA Section 401, and NHPA

E.2.3 National Historic Prevention Act

- **Purpose**: Protect cultural resources
- **Administration**: State Historic Preservation Officer (SHPO), Advisory Council on Historic Preservation
- **Example**
    - Riparian forest restoration in old irrigation ditch
    - Ditch is 50 years old and eligible for National Register of Historic Places
- **Issues**
    - If federal agency is involved, need to consult SHPO for determination of significance, effects, and mitigation
    - If CWA Section 404 permit is required, Corps has responsibility as Lead Agency to consult with SHPO

E.2.4 National Environmental Policy Act and California Environmental Quality Act

- **Purpose**: Ensure due process for determining environmental effects of discretionary actions
- **Administration**: Federal and state or local lead agency (no governing body)
- **Example**
  - ❑ A restoration project involves public land and state and federal funding
  - ❑ Action to approve project land use and funding requires environmental review
- **Issues**
  - ❑ Environmental analysis must be conducted and documented in a NEPA and CEQA document for public review, such as an EA or EIS (NEPA) and an IS or EIR (CEQA)
  - ❑ State and federal compliance are often combined in single document

E.2.5 California Fish and Game Code

- **Purpose**: Protect fish and wildlife resources
- **Administration**: California Department of Fish and Game (DFG)
- **Example**
  - ❑ Salmon spawning bed restoration project that alters a river channel bottom
  - ❑ Projects in river channels are subject to Sections 1600-1607 of the Fish and Game Code
- **Issue:** A Section 1601 or 1603 Streambed Alteration Agreement will need to be developed with DFG

E.2.6 Local and Municipal Codes

- **Purpose**: Protect locally important environmental resources
- **Administration**: City and county governments
- **Example**
  - ❑ A bridge-widening project will necessitate removal of native oak trees
  - ❑ Oak trees are protected by a county ordinance
- **Issues**

- Tree removal triggers an arborist survey, application for removal, and mitigation plan
- Mitigation may be onsite planting or restoration of an offsite degraded woodland

Appendix F

Common and Scientific Species Names

Table F-1. Native and Nonnative Plant Species Observed in the Arcade Creek Stream Corridor during 2007 Field Surveys

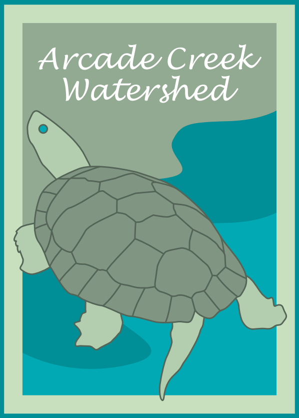
Common Name	Scientific Name
Native	
Alder	*Alnus rhombifolia*
Bedstraw	*Galium aparine*
Black walnut	*Juglans californica* var. *hindsii*
Blue elderberry	*Sambucus mexicana*
Blue oak	*Quercus douglasii*
Box elder	*Acer negundo* var. *californicum*
California bay	*Umbellularia californica*
California buckeye	*Aesculus californica*
Cattail	*Typha* sp.
Common tule	*Scripus acutus*
Coyote brush	*Baccharis pilularis*
Fremont’s cottonwood	*Populus fremontii*
Goodding’s willow	*Salix gooddingii*
Interior live oak	*Quercus wislizenii*
Lupine	*Lupinus* spp.
Mugwort	*Artemisia douglasiana*
Narrowleaf cattail	*Typha angustifolia*
Oregon ash	*Fraxinus latifolia*
Poison oak	*Toxicodendron diversilobum*
Redbud	*Cercis occidentalis*
Santa Barbara sedge	*Carex barbarae*
Shining willow	*Salix lucida*
Valley oak	*Quercus lobata*
Water smartweed	*Polygonum* sp.
White alder	*Alnus rhombifolia*
Nonnative/Horticultural Species	
Acacia	*Acacia* spp.
Almond	*Prunus* spp.
American elm	*Ulmus americana*
Apple	*Malus* spp.
Ash	*Fraxinus* spp.
Bamboo	*Phyllostachys* spp.
Beefwood	*Grevillea* spp.
Black locust	*Robinia pseudoacacia*
Black walnut	*Julgans californica* var. *hindsii*
Camphor tree	*Cinnamomum camphora*
Catalpa	*Catalpa bignonioides*

Common Name	Scientific Name
Chinese pistache	*Pistacia chinensis*
Chinese tallow tree	*Sapium sebiferum*
Elm	*Ulmus* spp.
English ivy	*Hedera helix*
English walnut	*Juglans regia*
Eucalyptus	*Eucalyptus* spp.
Fig (edible)	*Ficus carica*
Fire thorn	*Pyracantha augustofolia*
Giant reed	*Arundo donax*
Grape (cultivated)	*Vitis* spp.
Hackberry	*Celtis* spp.
Himalayan blackberry	*Rubus discolor*
Ivy	*Hedera* spp.
Japanese privet	*Ligustrum japonicum*
Liquidambar	*Liquidambar styraciflua*
Mexican fan palm	*Washingtonia robusta*
Mock orange	*Pittosporum tobira*
Mulberry	*Morus* spp.
Narrow-leaved willow	*Salix exigua*
Oleander	*Nerium oleander*
Pampas grass	*Cortaderia selloana*
Pine	*Pinus* spp.
Plum	*Prunus* spp.
Red sesbania	*Sesbania punicea*
Redwood	*Sequoia sempervirens* (nonnative to the stream corridor)
Russian olive	*Elaeagnus angustifolius*
Scotch broom	*Cytisus scoparius*
Silk tree	*Albizia julibrissin*
Silver poplar	*Populus alba*
Smartweed	*Polygonum* spp.
Toyon	*Heteromeles arbutifola*
Tree of Heaven	*Ailanthus altissima*
Vinca	*Vinca major*
Weeping willow	*Salix babylonica*
Wild radish	*Raphanus aphanistrum*
Yellow starthistle	*Centaurea solstitialis*

Table F-2. Wildlife Species Observed in the Arcade Creek Stream Corridor during Spring and Summer 2007 Field Surveys

Common Name	Scientific Name
Birds	
Acorn woodpecker	*Melanerpes formicivorus*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Carduelis tristis*
American robin	*Turdus migratorius*
Anna’s hummingbird	*Calypte anna*
Ash-throated flycatcher	*Myiarchus cinerascens*
Barn swallow	*Hirundo rustica*
Belted kingfisher	*Megaceryle alcyon*
Black-crowned nigh heron	*Nycticorax nycticorax*
Black phoebe	*Sayornis saya*
Bushtit	*Psaltriparus minimus*
California towhee	*Pipilo crissalis*
Cliff swallow	*Petrochelidon pyrrhonota*
Cooper’s hawk	*Accipiter cooperii*
European starling	*Sturnus vulgaris*
Great blue heron	*Ardea herodias*
Great egret	*Ardea alba*
Green heron	*Butorides virescens*
House finch	*Carpodacus mexicanus*
House sparrow	*Passer domesticus*
House wren	*Troglodytes aedon*
Lark sparrow	*Chondestes grammacus*
Lesser goldfinch	*Carduelis psaltria*
Mallard	*Anas platyrhynchos*
Moorhen	*Gallinula chloropus*
Mourning dove	*Zenaida macroura*
Northern mockingbird	*Mimus polyglottos*
Northern rough-winged swallow	*Stelgidopteryx serripennis*
Nuttall’s woodpecker	*Picoides nuttallii*
Oak titmouse	*Baeolophus inornatus*
Pie-billed grebe	*Podilymbus podiceps*
Ring-necked pheasant	*Phasianus colchicus*
Red-shouldered hawk	*Buteo lineatus*
Red-winged blackbird	*Agelaius phoeniceus*
Scrub-jay	*Aphelocoma californica*
Snowy egret	*Egretta thula*
Tree swallow	*Tachycineta bicolor*

Common Name	Scientific Name
Turkey vulture	*Cathartes aura*
Western bluebird	*Sialia mexicana*
Wild turkey	*Meleagris gallopavo*
Wood duck	*Aix sponsa*
Yellow-billed magpie	*Pica nuttalli*
Mammals	
Beaver	*Castor canadensis*
Eastern fox squirrel	*Sciurus niger*
Feral cat	*Felis catus*
Mule deer	*Odocoileus hemionus*
Raccoon	*Procyon lotor*
Striped skunk	*Mephitis mephitis*
Western gray squirrel	*Sciurus griseus*
Reptiles and Amphibians	
Bullfrog	*Rana catesbeiana*
Northwestern pond turtle	*Clemmys marmorata marmorata*
Red-eared slider	*Trachemys scripta elegans*



Help Preserve Arcade Creek
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