LOWER TUOLUMNE RIVER RIPARIAN INFORMATION AND SYNTHESIS STUDY

STUDY REPORT
DON PEDRO PROJECT
FERC NO. 2299



WATER & POWER
Serving Central California since 1887

MID
Modesto Irrigation District

Prepared for:
Turlock Irrigation District – Turlock, California
Modesto Irrigation District – Modesto, California

Prepared by:
Stillwater Sciences

December 2013

Lower Tuolumne River Riparian Information and Synthesis Study
Study Report

TABLE OF CONTENTS

List of Figures

List of Tables

List of Attachments

List of Acronyms

ac ....acres
ACEC..........................Area of Critical Environmental Concern
AF ....acre-feet
ACOE..........................U.S. Army Corps of Engineers
ADA ....Americans with Disabilities Act
ALJ.............................Administrative Law Judge
APE ....Area of Potential Effect
ARMR.........................Archaeological Resource Management Report
BA ....Biological Assessment
BDCP ....Bay-Delta Conservation Plan
BLM............................U.S. Department of the Interior, Bureau of Land Management
BLM-S ....Bureau of Land Management – Sensitive Species
BMI ....Benthic macroinvertebrates
BMP ....Best Management Practices
BO ....Biological Opinion
CalEPPC ....California Exotic Pest Plant Council
CalSPA.......................California Sports Fisherman Association
CAS............................California Academy of Sciences
CCC............................Criterion Continuous Concentrations
CCIC ....Central California Information Center
CCSF..........................City and County of San Francisco
CCVHJV ....California Central Valley Habitat Joint Venture
CD ....Compact Disc
CDBW........................California Department of Boating and Waterways
CDEC ....California Data Exchange Center
CDFA ....California Department of Food and Agriculture
CDFG ....California Department of Fish and Game (as of January 2013, Department of Fish and Wildlife)
CDMG........................California Division of Mines and Geology
CDOF ....California Department of Finance
CDPH ....California Department of Public Health

CDPR........................California Department of Parks and Recreation
CDSOD......................California Division of Safety of Dams
CDWR.......................California Department of Water Resources
CE ....California Endangered Species
CEII............................Critical Energy Infrastructure Information
CEQA.........................California Environmental Quality Act
CESA ....California Endangered Species Act
CFR............................Code of Federal Regulations
cfs...............................cubic feet per second
CGS............................California Geological Survey
CMAP ....California Monitoring and Assessment Program
CMC...........................Criterion Maximum Concentrations
CNDDB......................California Natural Diversity Database
CNPS..........................California Native Plant Society
CORP ....California Outdoor Recreation Plan
CPUE ....Catch Per Unit Effort
CRAM........................California Rapid Assessment Method
CRLF..........................California Red-Legged Frog
CRRF ....California Rivers Restoration Fund
CSAS..........................Central Sierra Audubon Society
CSBP..........................California Stream Bioassessment Procedure
CT ....California Threatened Species
CTR............................California Toxics Rule
CTS ....California Tiger Salamander
CVRWQCB ....Central Valley Regional Water Quality Control Board
CWA ....Clean Water Act
CWHR........................California Wildlife Habitat Relationship
Districts ....Turlock Irrigation District and Modesto Irrigation District
DLA ....Draft License Application
DPRA.........................Don Pedro Recreation Agency
DPS ....Distinct Population Segment
EA ....Environmental Assessment
EC ....Electrical Conductivity

EFH............................Essential Fish Habitat
EIR.............................Environmental Impact Report
EIS..............................Environmental Impact Statement
EPA............................U.S. Environmental Protection Agency
ESA............................Federal Endangered Species Act
ESRCD.......................East Stanislaus Resource Conservation District
ESU............................Evolutionary Significant Unit
EWUA........................Effective Weighted Useable Area
FERC..........................Federal Energy Regulatory Commission
FFS.............................Foothills Fault System
FL...............................Fork length
FMU...........................Fire Management Unit
FOT............................Friends of the Tuolumne
FPC ....Federal Power Commission
ft/mi............................feet per mile
FWCA........................Fish and Wildlife Coordination Act
FYLF..........................Foothill Yellow-Legged Frog
g..................................grams
GIS ....Geographic Information System
GLO ....General Land Office
GPS ....Global Positioning System
HCP............................Habitat Conservation Plan
HHWP........................Hetch Hetchy Water and Power
HORB ....Head of Old River Barrier
HPMP.........................Historic Properties Management Plan
ILP.............................Integrated Licensing Process
ISR ....Initial Study Report
ITA.............................Indian Trust Assets
kV..............................kilovolt
m ....meters
M&I...........................Municipal and Industrial
MCL...........................Maximum Contaminant Level
mg/kg ....milligrams/kilogram

mg/L..........................milligrams per liter
mgd ....million gallons per day
mi ....miles
mi^2 ....square miles
MID...........................Modesto Irrigation District
MOU ....Memorandum of Understanding
MSCS.........................Multi-Species Conservation Strategy
msl.............................mean sea level
MVA ....Megavolt Ampere
MW ....megawatt
MWh ....megawatt hour
mya............................million years ago
NAE ....National Academy of Engineering
NAHC ....Native American Heritage Commission
NAS...........................National Academy of Sciences
NAVD 88..................North American Vertical Datum of 1988
NAWQA ....National Water Quality Assessment
NCCP ....Natural Community Conservation Plan
NEPA ....National Environmental Policy Act
ng/g ....nanograms per gram
NGOs ....Non-Governmental Organizations
NHI ....Natural Heritage Institute
NHPA.........................National Historic Preservation Act
NISC ....National Invasive Species Council
NMFS.........................National Marine Fisheries Service
NOAA ....National Oceanic and Atmospheric Administration
NOI ....Notice of Intent
NPS ............................U.S. Department of the Interior, National Park Service
NRCS ....National Resource Conservation Service
NRHP.........................National Register of Historic Places
NRI............................Nationwide Rivers Inventory
NTU ....Nephelometric Turbidity Unit
NWI...........................National Wetland Inventory

NWIS ....National Water Information System
NWR ....National Wildlife Refuge
NGVD 29...................National Geodetic Vertical Datum of 1929
O&M ....operation and maintenance
OEHHA......................Office of Environmental Health Hazard Assessment
ORV ....Outstanding Remarkable Value
PAD............................Pre-Application Document
PDO............................Pacific Decadal Oscillation
PEIR ....Program Environmental Impact Report
PGA............................Peak Ground Acceleration
PHG............................Public Health Goal
PM&E ....Protection, Mitigation and Enhancement
PMF............................Probable Maximum Flood
POAOR ....Public Opinions and Attitudes in Outdoor Recreation
ppb.............................parts per billion
ppm ....parts per million
PSP.............................Proposed Study Plan
QA..............................Quality Assurance
QC..............................Quality Control
RA ....Recreation Area
RBP ....Rapid Bioassessment Protocol
Reclamation ...............U.S. Department of the Interior, Bureau of Reclamation
RM ....River Mile
RMP ....Resource Management Plan
RP...............................Relicensing Participant
RSP ....Revised Study Plan
RST ....Rotary Screw Trap
RWF ....Resource-Specific Work Groups
RWG ....Resource Work Group
RWQCB ....Regional Water Quality Control Board
SC...............................State candidate for listing under CESA
SCD............................State candidate for delisting under CESA
SCE ....State candidate for listing as endangered under CESA

SCT ....State candidate for listing as threatened under CESA
SD1 ....Scoping Document 1
SD2 ....Scoping Document 2
SE...............................State Endangered Species under the CESA
SFP.............................State Fully Protected Species under CESA
SFPUC ....San Francisco Public Utilities Commission
SHPO ....State Historic Preservation Office
SJRA ....San Joaquin River Agreement
SJRGA ....San Joaquin River Group Authority
SJTA ....San Joaquin River Tributaries Authority
SPD ....Study Plan Determination
SRA............................State Recreation Area
SRMA ....Special Recreation Management Area or Sierra Resource Management Area (as per use)
SRMP.........................Sierra Resource Management Plan
SRP ....Special Run Pools
SSC ....State species of special concern
ST...............................California Threatened Species under the CESA
STORET ....Storage and Retrieval
SWAMP.....................Surface Water Ambient Monitoring Program
SWE ....Snow-Water Equivalent
SWRCB......................State Water Resources Control Board
TAC............................Technical Advisory Committee
TAF ....thousand acre-feet
TCP ....Traditional Cultural Properties
TDS ....Total Dissolved Solids
TID.............................Turlock Irrigation District
TMDL ....Total Maximum Daily Load
TOC............................Total Organic Carbon
TRT ....Tuolumne River Trust
TRTAC ....Tuolumne River Technical Advisory Committee
UC..............................University of California
USDA.........................U.S. Department of Agriculture

USDOC......................U.S. Department of Commerce
USDOI.......................U.S. Department of the Interior
USFS..........................U.S. Department of Agriculture, Forest Service
USFWS......................U.S. Department of the Interior, Fish and Wildlife Service
USGS.........................U.S. Department of the Interior, Geological Survey
USR............................Updated Study Report
UTM...........................Universal Transverse Mercator
VAMP........................Vernalis Adaptive Management Plan
VELB.........................Valley Elderberry Longhorn Beetle
VRM..........................Visual Resource Management
WPT...........................Western Pond Turtle
WSA...........................Wilderness Study Area
WSIP..........................Water System Improvement Program
WWTP.......................Wastewater Treatment Plant
WY............................water year
μS/cm........................microSeimens per centimeter

1.0 INTRODUCTION

1.1 Background

Turlock Irrigation District (TID) and Modesto Irrigation District (MID) (collectively, the Districts) are the co-licensees of the 168-megawatt (MW) Don Pedro Project (Project) located on the Tuolumne River in western Tuolumne County in the Central Valley region of California. The Don Pedro Dam is located at river mile (RM) 54.8 and the Don Pedro Reservoir has a normal maximum water surface elevation of 830 ft above mean sea level (msl; NGVD 29). At elevation 830 ft, the reservoir stores over 2,000,000 acre-feet (AF) of water and has a surface area slightly less than 13,000 acres (ac). The watershed above Don Pedro Dam is approximately 1,533 square miles (mi^2). The Project is designated by the Federal Energy Regulatory Commission (FERC) as project no. 2299.

Both TID and MID are local public agencies authorized under the laws of the State of California to provide water supply for irrigation and municipal and industrial (M&I) uses and to provide retail electric service. The Project serves many purposes including providing water storage for the beneficial use of irrigation of over 200,000 ac of prime Central Valley farmland and for the use of M&I customers in the City of Modesto (population 210,000). Consistent with the requirements of the Raker Act passed by Congress in 1913 and agreements between the Districts and City and County of San Francisco (CCSF), the Project reservoir also includes a “water bank” of up to 570,000 AF of storage. CCSF may use the water bank to more efficiently manage the water supply from its Hetch Hetchy water system while meeting the senior water rights of the Districts. The “water bank” within Don Pedro Reservoir provides significant benefits for CCSF’s 2.6 million customers in the San Francisco Bay Area.

The Project also provides storage for flood management purposes in the Tuolumne and San Joaquin rivers in coordination with the U.S. Army Corps of Engineers (ACOE). Other important uses supported by the Project are recreation, protection of the anadromous fisheries in the lower Tuolumne River, and hydropower generation.

The Project Boundary extends from RM 53.2, which is one mile below the Don Pedro powerhouse, upstream to RM 80.8 at an elevation corresponding to the 845 ft contour (31 FPC 510 [1964]). The Project Boundary encompasses approximately 18,370 ac with 78 percent of the lands owned jointly by the Districts and the remaining 22 percent (approximately 4,000 ac) owned by the United States and managed as a part of the U.S. Bureau of Land Management (BLM) Sierra Resource Management Area.

The primary Project facilities include the 580-foot-high Don Pedro Dam and Reservoir completed in 1971; a four-unit powerhouse situated at the base of the dam; related facilities including the Project spillway, outlet works, and switchyard; four dikes (Gasburg Creek Dike and Dikes A, B, and C); and three developed recreational facilities (Fleming Meadows, Blue Oaks, and Moccasin Point Recreation Areas). The location of the Project and its primary facilities is shown in Figure 1.1-1.

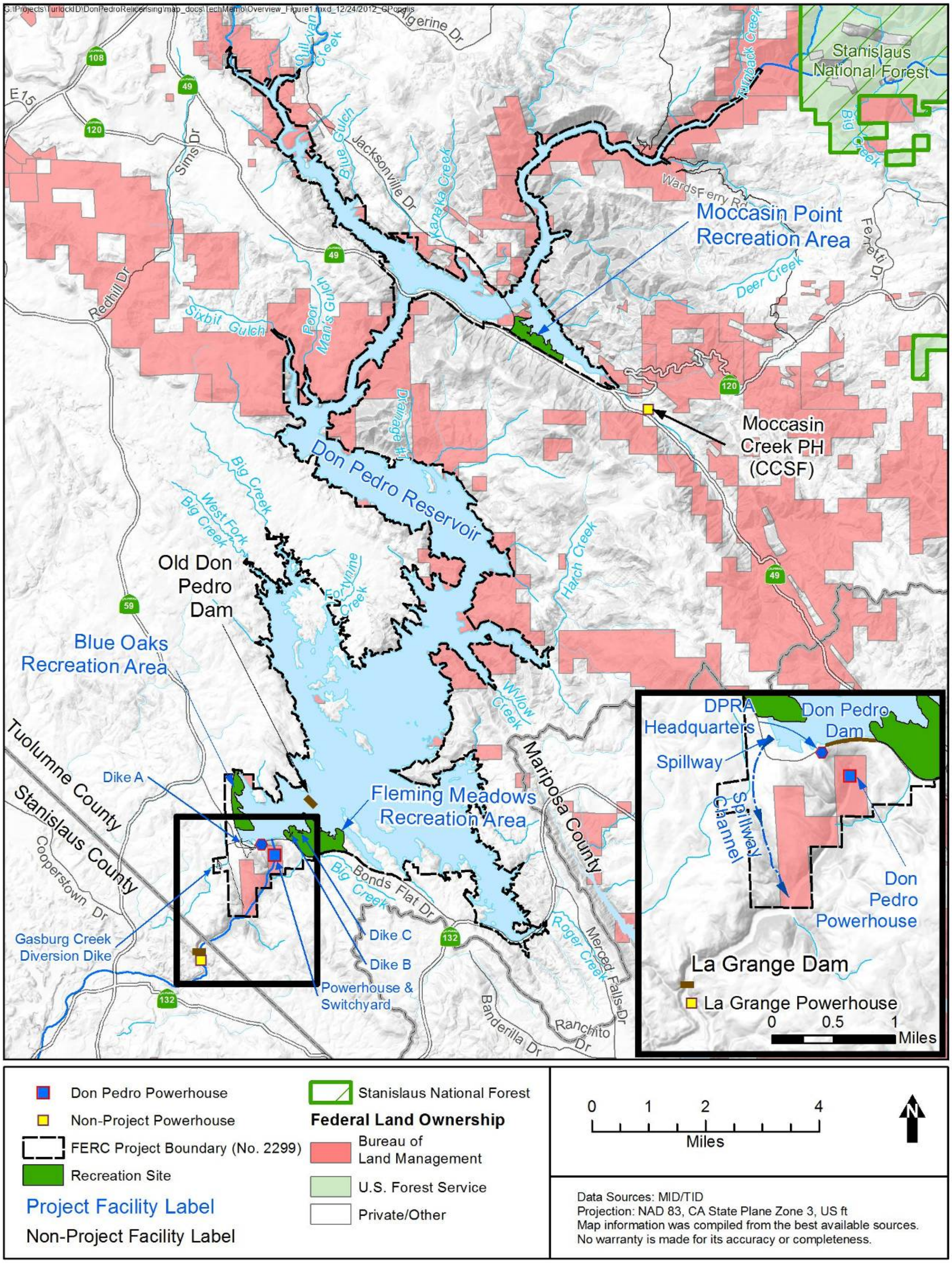

Figure 1.1-1. Don Pedro Project location.

1.2 Relicensing Process

The current FERC license for the Project expires on April 30, 2016, and the Districts will apply for a new license no later than April 30, 2014. The Districts began the relicensing process by filing a Notice of Intent and Pre-Application Document (PAD) with FERC on February 10, 2011, following the regulations governing the Integrated Licensing Process (ILP). The Districts' PAD included descriptions of the Project facilities, operations, license requirements, and Project lands as well as a summary of the extensive existing information available on Project area resources. The PAD also included ten draft study plans describing a subset of the Districts' proposed relicensing studies. The Districts then convened a series of Resource Work Group meetings, engaging agencies and other relicensing participants in a collaborative study plan development process culminating in the Districts' Proposed Study Plan (PSP) and Revised Study Plan (RSP) filings to FERC on July 25, 2011 and November 22, 2011, respectively.

On December 22, 2011, FERC issued its Study Plan Determination (SPD) for the Project, approving, or approving with modifications, 34 studies proposed in the RSP that addressed Cultural and Historical Resources, Recreational Resources, Terrestrial Resources, and Water and Aquatic Resources. In addition, as required by the SPD, the Districts filed three new study plans (W&AR-18, W&AR-19, and W&AR-20) on February 28, 2012 and one modified study plan (W&AR-12) on April 6, 2012. Prior to filing these plans with FERC, the Districts consulted with relicensing participants on drafts of the plans. FERC approved or approved with modifications these four studies on July 25, 2012.

Following the SPD, a total of seven studies (and associated study elements) that were either not adopted in the SPD, or were adopted with modifications, formed the basis of Study Dispute proceedings. In accordance with the ILP, FERC convened a Dispute Resolution Panel on April 17, 2012 and the Panel issued its findings on May 4, 2012. On May 24, 2012, the Director of FERC issued his Formal Study Dispute Determination, with additional clarifications related to the Formal Study Dispute Determination issued on August 17, 2012.

This study report describes the objectives, methods, and results of the Lower Tuolumne River Riparian Information and Synthesis Study (W&AR-19) as implemented by the Districts in accordance with FERC's SPD and subsequent study modifications and clarifications. On January 17, 2013, the Districts filed the Initial Study Report for the Don Pedro Project. In response to comments filed by the U.S. Department of the Interior, Fish and Wildlife Service (USFWS) on March 11, 2013, the Districts modified Section 4.2 of this report to address USFWS concerns. No other changes were made to the report. Documents relating to the Project relicensing are publicly available on the Districts' relicensing website at www.donpedro-relicensing.com.

1.3 Study Plan

FERC's Scoping Document 2 determined that continued operation and maintenance (O&M) of the Don Pedro Project (Project) may contribute to cumulative effects to the distribution, extent, composition, and structure of riparian vegetation along the lower Tuolumne River. FERC's SPD approved with modifications the Districts' Lower Tuolumne River Riparian Information and

Synthesis Study plan as provided in the Districts' RSP filing. In its SPD, FERC directed the Districts to (1) update the riparian vegetation inventory originally developed in 1996-1997 (McBain and Trush 2000); (2) provide a summary and synthesis of literature and other sources to characterize riparian vegetation distribution in the study area; and (3) identify and describe in the final study report riparian vegetation conditions, and linkages between these conditions and factors potentially contributing to cumulative effects to riparian resources in the study area.

The Study Plan was modified in February 2012 to include performing an update to the 1996-1997 riparian vegetation inventory. FERC approved the study plan on July 25, 2012 and directed the Districts to include the USFWS' 1995 and 2001 Final Restoration Plan for Anadromous Fish Restoration Program as one of the literature sources. The Districts completed the Riparian Information and Synthesis study consistent with these directives.

2.0 STUDY GOALS AND OBJECTIVES

2.1 Objectives

The goal of this study is to review, summarize and report information describing the condition of the riparian resources and habitats along the lower Tuolumne River. Study tasks performed to meet this goal include:

- update the 1996-1997 riparian vegetation inventory of the lower Tuolumne River;
- summarize and synthesize literature and other sources to characterize riparian vegetation distribution in the study area; and
- identify and describe factors potentially contributing to cumulative effects on riparian resources in the study area.

2.2 Background

The roughly 150 mi-long Tuolumne River drains a 1,960 mi^2 watershed, ranging in elevation from nearly 11,000 ft in Yosemite National Park, to 35 ft at the confluence with the San Joaquin River in the Central Valley. The Tuolumne is the largest tributary to the San Joaquin River. La Grange Dam is the lowest dam on the river and is located 2.3 mi downstream of Don Pedro Dam. The lower Tuolumne River includes 84 km (52 mi) of river below La Grange Dam that drops gradually from elevation 170 ft to 35 ft above sea level at the San Joaquin confluence. The lower Tuolumne River corridor is part of the Great Valley floristic region and the San Joaquin Valley sub-region (Baldwin et al. 2012). The San Joaquin Valley sub-region includes five large rivers that drain waters from the Sierra Nevada and flow into the San Joaquin to the Delta: the Mokelumne, Stanislaus, Tuolumne, Merced, and San Joaquin rivers. Similar riparian plant communities can be found now, and were found historically, along all of these rivers (Thompson 1961, Warner 1984, Katibah 1984, Vaghti and Greco 2007, Sawyer et al. 2009).

Historically, the lower Tuolumne River supported approximately 13,000 ac of riparian forest (Katibah 1984); however, with European settlement in the mid-to-late 1800s came large changes in land use, water use, and river and riparian area management. The cumulative result of these factors leaves the lower Tuolumne River corridor with roughly 2,200 ac of riparian forest, approximately 17 percent of the pre-European settlement area. Since the Don Pedro Project was completed in 1971, and particularly since the 1995 Don Pedro Project FERC Settlement Agreement, changes in flow regime, as well as ongoing implementation of the Habitat Restoration Plan for the lower Tuolumne River corridor (McBain and Trush 2000), are expected to cause changes in riparian vegetation quality and extent.

The physical processes associated with Central Valley alluvial rivers that control regeneration and survival of riparian vegetation are fairly well understood and include flooding, stream meander, sediment scour, and deposition. Native riparian plant species have evolved with these physical processes and have life history strategies that take advantage of those disturbances (Grime 1977, Scott et al. 1996, Karrenberg et al. 2002, Gurnell et al. 2005, Stella et al. 2006). Examples of such strategies include: seed release timed to catch the high or receding spring snow melt flows to aid in dispersal, seeds adapted for germinating on freshly deposited sand and silt along river margins, vegetative reproduction from parts broken off and carried downstream during high floods, and fast root and shoot growth to enable rapid seedling establishment in a transient environment (Scott et al. 1996, Mahoney and Rood 1998, Karrenberg et al. 2002, Stella et al. 2006, Stillwater Sciences 2006).

In general, riparian plant communities require periodic seedling recruitment and subsequent establishment to replace mature and dying trees to maintain the stand through time, or to reset the process of vegetation succession (Campbell and Green 1968, Johnson 1994, Naiman et al. 2005). In meandering river systems, rejuvenation of riparian plant communities can occur as mature forests located on the outside edge of a migrating river bend collapse into the channel due to bank erosion while new riparian cohorts colonize bare surfaces created on the newly created inside bend point bars (Campbell and Green 1968, Johnson 1994, Naiman et al. 2005). Under such unconstrained conditions, the continuous demise of mature and senescent forests on the outside of meander bends and regeneration of young forests on the inside of these bends results in a relatively consistent age-distribution of dominant riparian tree species (McBain and Trush 2000). In sand-bedded reaches, this process results in frequent disturbance directly adjacent to the channel that can support a mixture of willow and white alder cohorts, while increasingly mature and complex cottonwood and valley oak forest develop on 5- to 20-yr and 20- to 100-yr floodplains, respectively (Katibah 1984, McBain and Trush 2000, Franz and Bazzaz 1977, Auble et al. 1994, Auble and Scott 1998, Friedman et al. 2006).

In contrast, along slightly steeper gravel and cobble-bedded reaches of an unconstrained river, channel migration and floodplain renewal can often be punctuated by episodic disturbances and establishment events (Grant et al. 2003, McBain and Trush 2004a, Polzin and Rood 2006, Stella et al. 2011). The vegetation successional pattern can, therefore, be patchy and dependent upon flood history, site topography, and local variations in physical disturbance (Franz and Bazzaz 1977, Auble and Scott 1998, Polzin and Rood 2006, Friedman et al. 2006, Stella et al. 2011). A second reported result of high annual peak flows observed along western North American alluvial rivers is the scouring of certain riparian species from the active channel, that otherwise can become encroached by native and non-native species (Friedman et al. 1996, Merritt and Cooper 2000, Shafroth et al. 2002, Dewine and Cooper 2007). Decreased annual peak flows on riparian vegetation along alluvial rivers has been reported to potentially result in encroachment, reduced diversity in age, seral status, and species composition, as well as reduced lateral extent and diversity of native riparian habitat (Shafroth et al. 2002, Rood et al. 2005, Naiman et al. 2005).

These relationships between riparian vegetation and the physical environment of an unconstrained river indicate that, if biologically important physical conditions change in a river corridor such that pioneer species are no longer able to establish, the riparian plant community composition will shift from pioneer species to later successional, as well as invasive non-native species, and plant diversity and habitat complexity can become simplified (McBain and Trush 2000, Shafroth et al. 2002, Rood et al. 2005, Naiman et al. 2005).

The quality of riparian vegetation, in terms of being self-sustaining and capable of supporting native plants and wildlife, can also be evaluated based on extent and connectivity, structural and compositional diversity, and indications of natural recruitment. Large intact riparian stands accommodate territories of more species (bird territories can range in size from 0.5 to >25 acres; Seavy et al. 2009). Similarly, connectivity of native riparian stands along the river corridor provides important refuge and transportation corridors for many bird and wildlife species (Gardali et al. 2006, Norris and Stutchbury 2001, Cooper and Walters 2002). Diversity in tree species and age provides structural and therefore habitat diversity along the riparian corridor, and increases the number of different species that are supported (Naiman et al. 2005, RHJV 2004). Finally, channel edge and overhanging vegetation provides local areas of shade and refuge for aquatic species; large trees provide coarse woody debris for in-channel habitat complexity, and channel edge vegetation can stabilize banks to lessen sediment inputs from bank erosion. Vegetation types expected for Central Valley riparian communities include those dominated by valley oak (*Quercus lobata*), Fremont cottonwood, Goodding's black willow, Western sycamore (*Platanus racemosa*), Oregon ash (*Fraxinus latifolia*), California buckeye (*Aesculus californica*), white alder (*Alnus rhombifolia*), box elder (*Acer negundo*), narrow-leaf, arroyo, red and shining willow (*Salix exigua, S. lasiolepis, S. laevigata*, and *S. lucida*) (Vaghti and Greco 2007).

3.0 STUDY AREA

The study area consists of the Tuolumne River from the La Grange Dam (RM 52.2) downstream to its confluence with the San Joaquin River (RM 0). This study uses the reach delineations established by McBain and Trush (2000), which were based on gross differences in geomorphology, land use, and disturbance histories in the study area (Table 3.0-1, also see Figure B-1 in Attachment B).

Table 3.0-1. Summary of reaches along the lower Tuolumne River.

Reach number	River Miles	Landmarks	Dominant channel bottom material
1	0.0 to 10.5	Lower sand-bedded reach	Sand
2	10.5 to 19.3	Urban sand-bedded reach	Sand
3	19.3 to 24.0	Upper sand-bedded reach	Sand
4	24.0 to 34.2	In-channel gravel mining reach	Gravel
5	34.2 to 40.3	Gravel mining reach	Gravel
6	40.3 to 46.6	Dredger tailing reach	Gravel
7	46.6 to 52.1	Dominant spawning reach	Gravel

4.0 METHODOLOGY

4.1 Update Riparian Vegetation Inventory

The extent and distribution of vegetation types (vs. condition and structure) were surveyed and mapped for the lower Tuolumne by McBain and Trush in 1996, just prior to the record flows of January 1997 (McBain and Trush 2000). During the summer of 2012, the 1996 riparian vegetation inventory map was updated in two steps. First, GIS maps of the riparian inventory of the lower Tuolumne River developed in 1996–1997 for the Habitat Restoration Plan for the Tuolumne River (McBain and Trush 2000) were updated using 0.5' color photography orthorectified to the March 2012 LiDAR, and flown on April 6, 2012. Stream flows at the La Grange gage at this time were 317 cfs (provisional data subject to revision from USGS Surface-Water Daily Data for the Nation website for gage number 11289650). The 1996 inventory was updated by first overlaying the April 2012 aerial photography onto the 1996 polygon layer and correcting the polygon extent and shape for visible differences in land use and channel position. The 1996-1997 classification was left unchanged, except when land cover changes were extreme and obvious (e.g., change in vegetation form from herbaceous to woody shrubs or vice versa).

The second step in this process was to perform a field accuracy assessment of the updated vegetation map. The lower Tuolumne River was stratified into 13 three–to–five mile reaches based on accessibility. Four of these ‘accessible reaches’ were randomly selected, and within each of these four ‘accessible reaches’, over ten randomly selected polygons, adding up to 8 percent of the mapped riparian vegetation extent, were ground-truthed during an August 2012 field survey. For each randomly selected polygon, observed vegetation composition and class were recorded in the field. The results were used to assess the accuracy of the updated vegetation map. The minimum mapping unit was 0.5 ac.

Data collected during this field effort was used to assess the accuracy of the updated vegetation map. Mapped vs. observed vegetation types were tabulated side-by-side and accuracy scores were assigned according to mapped vs. ground-truthed vegetation type as follows:

0 = no match;
1 = correct vegetation layer (e.g., tree/shrub/forb-graminoid);
2 = 10-50 percent cover of mapped species was observed in the polygon;
3 = 50-80 percent cover of mapped species was observed in the polygon;
4 = >80 percent cover of mapped species was observed in the polygon.

Summary values of percent accuracy were calculated as percent of potential scores if all polygons had been mapped with 100 percent accuracy (e.g., the vegetation types for all randomly selected polygons perfectly matched what was observed on the ground).

Observations of possible factors contributing to the change in distribution of riparian vegetation types compared to the 1996-1997 mapping were also recorded during the field survey, including human disturbance and development within the riparian corridor, occurrence of non-native invasive plants, condition of active restoration projects, and occurrence of young or multiple age-cohorts of native riparian species within the riparian corridor.

4.2 Summarize and Synthesize Literature and Other Sources

The existing conditions and processes that support and maintain riparian systems along the lower Tuolumne River have been the subject of multiple original research and secondary literature review and analysis efforts in recent years. These include the EIS/EIR for the San Joaquin Flow Objectives Agreement published in 1999, which included a chapter on impacts to riparian and terrestrial vegetation using the lower Tuolumne River as an example (San Joaquin River Group Authority 1998). The Habitat Restoration Plan for the lower Tuolumne River corridor (McBain and Trush 2000) also provides a particularly valuable and comprehensive review of material available up through 1999. Since that time, riparian restoration projects along the lower Tuolumne River, field research projects, and additional relevant scientific journal and "white" papers have been published, notably USFWS (2001), McBain and Trush (2004), Stella et al. (2006), Stillwater Sciences (2006), Null et al. (2010), and Stella et al. (2010).

These and other documents describing current riparian community structure, composition, distribution, and restoration efforts in the study area were compiled. A preliminary list of literature sources was included as Attachment A of the study plan. That list was reviewed and sorted by topic category and relevance to the Tuolumne River watershed; additional references were added during the review process. A final list of literature sources reviewed, with an indication of relevant topics covered by each, is included as Attachment A of this report. Findings from this effort were described in combination with findings from the Update of Riparian Vegetation Inventory.

4.3 Identify and Describe Factors Potentially Contributing to Cumulative Effects

Documents describing recent past and current riparian community structure, composition, and distribution were reviewed along with available information on factors potentially contributing to cumulative effects on vegetation along the lower Tuolumne River. Linkages between the lower Tuolumne River riparian vegetation structure, composition, and vegetation dynamics (seed production and dispersal, seedling germination, survival, and establishment, mortality vs. recruitment, succession), and cumulative factors potentially affecting vegetation (e.g., river hydrology, geomorphology, land use, invasive plant species, flood control, restoration, and mining) were described. Findings from studies in the lower San Joaquin watershed, as well as studies investigating factors affecting similar riparian communities in other alluvial rivers, were also included in this review. The Habitat Restoration Plan for the lower Tuolumne River corridor (McBain and Trush 2000) as well as reports and updates on restoration plans and monitoring along the lower Tuolumne were also reviewed in order to describe potential linkages between the current state of riparian vegetation along the lower Tuolumne and potential factors contributing to ongoing changes (e.g. USFWS 2001). Levees have not been mapped for the lower Tuolumne River. Instead, the FEMA 100-year and 500-year flood maps were used to indicate areas that could be part of the active floodplain, and therefore potentially support riparian vegetation, in the absence of existing levees (Table 5.2-2, Attachment D).

5.0 RESULTS

The results of the vegetation map update and literature review are presented in two sections below. In the first section, 5.1 Riparian Vegetation in the lower Tuolumne River corridor, findings from the update of the 1996 vegetation map are reported, followed by a detailed description of riparian vegetation and restoration projects along each of seven designated reaches of the lower Tuolumne River. Study task 1 (update riparian vegetation inventory) and task 2 (summarize literature to characterize riparian vegetation in the study area) are folded together into this first results section.

In section, 5.2 Factors Contributing to Existing Conditions, important intersections between the natural history of riparian plant species and physical conditions of the riparian corridor are described, followed by descriptions of seven factors contributing to ongoing changes in riparian vegetation along the lower Tuolumne River. These descriptions are based on literature review as well as findings from the vegetation map update.

5.1 Update Riparian Vegetation Inventory and Characterize Riparian Corridor of Lower Tuolumne River

In this section, existing conditions for riparian vegetation in the gravel (RM 24 to RM 52) and sand sections (RM 0 to RM 24) of the lower Tuolumne River are described, including changes underway through many land preservation and restoration actions. A summary of the different riparian vegetation types and their extent as observed in 1996 and then in 2012 is provided below, along with a review of the accuracy assessment of the 2012 vegetation mapping.

5.1.1 **Overview**

Overall, the 1996/2012 updated riparian vegetation type mapping identified 17 native riparian vegetation types, three native upland types, 12 non-native invasive plant dominated types, and one more loosely defined type that could include either native or non-native dominant species (‘emergent vegetation’). Altogether, these areas add up to 2,691 acres, a 419 acre increase (18 percent) over the 1996 mapped riparian vegetation area. The majority of this observed increase was due to several large active restoration efforts.

Along the lower Tuolumne River, the most common vegetation types are valley oak, narrow-leaf willow, Fremont cottonwood, and Goodding’s black willow (Table 5.1-1). The extent of areas dominated by invasive non-native plants decreased by 8 percent compared to 1996, due primarily to the overall increase in native riparian area and to the expansion of native vegetation (mostly narrow-leaf willow) into weedy areas observed in the 1996 survey. Edible fig (*Ficus carica*) and tree of heaven (*Ailanthus altissima*), as subdominant plants, were observed throughout the area during the 2012 field survey and appear to be increasing in extent based on the age of observed plants. Maps of the current vegetation, as classified in 1996 and updated in 2012, are provided in Attachment B.

Table 5.1-1. Total surface area of riparian vegetation types mapped within the lower Tuolumne River corridor (1996 data based on GIS layer developed through McBain and Trush 2000).

Vegetation Series or Land Cover Type		1996 Total Area (acres)	2012 Total Area (acres)	Difference 2012-1996 (acres)	2012 Maximum Patch Size (acres)	2012 Number of Patches (any size)	2012 Number of Patches >5 ac
Native Riparian	Arroyo willow	4.1	4.6	0.5	1.3	9	0
	Goodding's black willow	230.6	391.4	160.8	154	200	8
	Blue elderberry	1.5	1.2	-0.3	0.28	13	0
	Box elder	114.0	105	-9.0	6.45	140	1
	Button bush	3.0	2.2	-0.8	0.55	15	0
	California buckeye	10.1	6.3	-3.8	3.44	6	0
	California grape	0.7	0.4	-0.3	0.17	3	0
	California walnut	13.8	11.4	-2.4	9.84	8	1
	Dusky willow	4.2	2.8	-1.4	1.45	6	0
	Fremont cottonwood	463.3	578.9	115.6	110.29	379	20
	Mixed willow	148.5	154.6	6.1	8.7	135	5
	Narrow-leaf willow	523.90	608.4	84.5	14.5	527	24
	Oregon ash	7.0	7.2	0.20	1.67	20	0
	Shining willow	4.8	4.5	-0.3	1.7	7	0
	Valley oak	626.0	714	88.0	61.44	375	35
	Western sycamore	0.1	0	-0.1	0.05	1	0
	White alder	32.0	31.9	-0.1	2.81	66	0
	Total Native Riparian	**2,187.60**	**2,624.80**	**437.2**	**154**	**1,910**	**94**
Emergent	**Total Emergent**	**40.9**	**26.4**	**-14.5**	**5.18**	**32**	**2**
Exotic Riparian	Black locust	0.1	0.1	0	0.13	1	0
	Disturbed/miscellaneous exotics	6.3	2.4	-3.9	1.24	4	0
	Edible fig	1.5	1.3	-0.2	0.62	3	0
	English walnut	1.9	1.7	-0.2	0.67	6	0
	Eucalyptus	11.7	14.4	2.7	7.03	12	1
	Giant reed	5.3	5.3	0.0	0.7	41	0
	Himalayan berry	3.6	3.0	-0.6	0.59	13	0
	Lamb's quarters	1.0	1.1	0.1	1.09	1	0
	Tamarisk	0.2	0.1	-0.1	0.05	1	0
	Tree of heaven	8.4	8.6	0.2	2.23	17	0
	Tree tobacco	2.7	1.2	-1.5	0.37	5	0
	Weeping willow	0.7	0.6	-0.1	0.22	3	0

Vegetation Series or Land Cover Type		1996 Total Area (acres)	2012 Total Area (acres)	Difference 2012-1996 (acres)	2012 Maximum Patch Size (acres)	2012 Number of Patches (any size)	2012 Number of Patches >5 ac
	Total Exotic Riparian	**43.3**	**39.5**	**-3.6**	**7.03**	**162**	**1**
	TOTAL RIPARIAN	**2,271.90**	**2,691.00**	**419.10**	**154**	**2,104**	**97**
Native Upland	Blue oak	33.9	17.1	-16.8	2.8	20	0
	Bush lupine	6.3	2.2	-4.1	1.82	2	0
	Interior live oak	101.2	140.5	39.3	132.03	10	2
	Total Native Upland	**141.40**	**159.80**	**18.40**	**132.03**	**32**	**2**

With several important exceptions, most remaining riparian forest stands in the sand bedded reaches (RM 0 to 24) are only a few acres in size. In the few areas where some channel migration has occurred within the levee confines, McBain and Trush (2000) report incipient native riparian species colonization on growing point bars and floodplains. However, where banks are armored with rip-rap or concrete rubble, riparian regeneration is sparse. The only native tree species that are naturally regenerating in the sand-bedded reaches under contemporary conditions are Goodding's black willow, narrow-leaf willow, and box elder (McBain and Trush 2000). In the gravel-bedded reaches, patches of remnant riparian vegetation are interspersed with areas that have been heavily altered by gravel mining, aggregate extraction and dredger tailing deposits. More than any other native riparian species, narrow-leaf willow dominates the channel edge in many areas along these reaches.

The accuracy assessment of the 2012 updated 1996 map indicates overall accuracy of 84 percent, which is above the state vegetation mapping minimum accuracy requirement of 80 percent (CDFG 2008, Meidinger et al. 2003). As detailed in Table 5.1-2, of the four most common vegetation types, accuracy was highest for areas mapped as valley oak (93 percent) and lowest for areas mapped as Goodding's willow (71 percent). A variety of other vegetated cover types, including emergent wetland and riparian areas dominated by invasive non-native species[1], also occur along the river corridor. Seven of the native terrestrial vegetation types within the Tuolumne River riparian corridor are listed as state-threatened or very threatened (S2 or S3.2 ranking); narrow-leaf willow and white alder are classified as the least threatened (S4) by the Manual of California Vegetation (Sawyer et al. 2009).

Table 5.1-2. Summary of accuracy assessment for 2012 update of 1996 riparian vegetation map of lower Tuolumne River corridor.

Dominant Vegetation Type	Number Polygons Sampled	Accuracy Score (%)
All Vegetation Types	79	84
Box elder	13	94
Fremont cottonwood	15	77
Goodding's black willow	7	71
Narrow-leaved willow	21	76
Valley oak	19	93

* Accuracy scores were assigned according to mapped vs. ground truthed vegetation type as follows 0= no match; 1 = correct vegetation layer (e.g. tree/shrub/forb-graminoid); 2 = 10-50 percent cover of mapped species; 3. 50-80 percent cover of mapped species; 4. >80 percent cover of mapped species. Percentages calculated as percent of potential scores (e.g., all 4's).

5.1.2 Reach Descriptions of Current Riparian Vegetation

Conditions and progress of restoration and preservation efforts in these seven reaches, as mapped by McBain and Trush (2000) and updated for this document (Summer 2012), are summarized in Table 5.1-3 below and described in more detail in the following sections.

[1] "Invasive non-native plants that threaten wildlands are plants that (1) are not native to, yet can spread into, wildland ecosystems, and that also (2) displace native species, hybridize with native species, alter biological communities, or alter ecosystem processes." (from California Invasive Plant Council definition, published on webpage: http://www.cal-ipc.org/ip/inventory/index.php).

Table 5.1-3. Summary of riparian vegetation per reach in the 2012 update of 1996 riparian vegetation map of lower Tuolumne River corridor.

Reach number	River miles	Total riparian vegetation	Native riparian vegetation/mile	Change since 1996 survey	Non-native dominated vegetation
	miles	acres	acres/mile	acres	acres (%)
1	10.5	657.7	62.6	+261.2	2.4 (0.4)
2	8.8	300.7	34.2	+11.6	8.7 (2.9)
3	4.7	177.4	37.7	+23.6	4.3 (2.4)
4	10.2	350.5	34.4	+23.8	14.3 (4.3)
5	6.1	199.2	32.7	-4.5	1.6 (0.8)
6	6.3	727.8	115.5	+58.2	5.9 (0.8)
7	5.4	279.3	80.3	+42.3	2.3 (0.5)
Total	**52.0**	**2,691.0**	**51.7**	**+419.1**	**40.0 (1.5)**

5.1.2.1 Sand-bedded Reaches (RM 0.0- 24.0)

Reach 1. Lower Sand-bedded Reach (RM 0.0–10.5)

Overall there are approximately 63 acres of riparian vegetation per river mile along this low-gradient, sand-bedded reach (Figure 5.1-1). As detailed below, several restoration projects have been implemented along this reach since the 1996 riparian vegetation mapping, so that the overall extent of riparian vegetation has increased by approximately 261 acres, most of which is dominated by cottonwood and Goodding's black willow. The San Joaquin Wildlife Refuge occupies the downstream end of this reach and represents some of the most intact remaining riparian forests along the lower Tuolumne and in the San Joaquin Basin overall (Figure B-2 in Attachment B; McBain and Trush 2000). Along a tight bend in the river roughly four miles upstream of the San Joaquin confluence, are the 143 ac Grayson River Ranch and 250 ac Big Bend restoration sites. Several other pockets of native riparian vegetation exist between these two sites, including part of a former meander cut-off just downstream of Grayson River Ranch.

The surrounding landscape is in agriculture and the formerly expansive floodplain is frequently constrained by levees that run within approximately 1,000 ft of the channel. In the restoration project areas, the riparian vegetation extends up to 0.5 miles from the channel edge, farther than other reaches in the study area. However, beyond these areas of Reach 1, only a few remnant stands of riparian vegetation exceed five acres in size and extend beyond 150 feet from the stream channel. Thus, the larger restoration areas are tenuously linked by strips of one to two tree-width bands of riparian trees and shrubs.

Banks along several areas of this reach are also stabilized with rip-rap, further limiting the formation of fresh and diverse riparian areas through river meandering. Small pockets of riparian vegetation grow along the banks and within the rip-rap and along the upper edge of the levees. Tree of heaven, an invasive non-native species, was recorded in this reach (Stillwater Sciences 2008) as well as giant reed (*Arundo donax*), tree tobacco (*Nicotiana gluaca*), and eucalyptus (2012 surveys). Since the 1996 vegetation survey, the extent of tree tobacco, giant reed, and tree of heaven decreased slightly while the extent of other non-native species appears to have remained stable.

Figure 5.1-1. Reach 1 supports a very low gradient unshaded channel with eroding, sparsely vegetated banks.

The San Joaquin Wildlife Refuge

USFWS owns and operates this 6,500 ac wildlife refuge which includes riparian woodlands, grasslands, and frequently flooded wetlands at and upstream of the confluence of the Tuolumne with the San Joaquin River. Established in 1987, this refuge has been critical in the recovery of the Aleutian cackling goose and is an important part of the Pacific Flyway (http://www.fws.gov/sanluis/sanjoaquin_info.htm). As part of a wildlife refuge restoration effort, over 400,000 native trees were planted and native wetlands restored across 2,500 ac of river floodplain in 2009, under contract with River Partners, Inc.

Grayson River Ranch

Grayson River Ranch is a perpetual conservation easement on 143 ac of floodplain located approximately four miles upstream from the San Joaquin River confluence (Friends of the Tuolumne 2010). Construction for the restoration project was implemented in 2000 when two sloughs (each connected to the river at the downstream end and extending in an upstream direction into the floodplain) were excavated to provide seasonally inundated floodplain and wetland habitat. Seven thousand woody plants, including four species of willow, cottonwood, box elder, sycamore, Oregon ash, valley oak, as well as creeping wild rye grass, were planted in 2001 and 2003. Post-project fish monitoring was conducted in 2005 (Fuller and Simpson 2005). Anecdotal evidence, including a number of site photos taken during the 2012 survey, indicates that the plantings are healthy and growing; thus the restoration of riparian vegetation on the floodplain and along the newly constructed sloughs appears successful, but no quantitative monitoring assessments are available (Figure 5.1-2).

Figure 5.1-2. Photograph of Grayson Ranch restoration project, showing different ages of plantings in the foreground vs. the background.

Big Bend

The Tuolumne River Trust (Trust) and other partners acquired approximately 250 ac of property on both sides of the Tuolumne River from RM 5.8 to 7.4 ("Big Bend"). The vegetation-related project goals were to enhance existing native riparian vegetation through (1) planting native riparian vegetation, (2) improving natural recruitment processes through increased flood frequency and duration, and (3) removing existing non-native invasive plant species. Restoration implementation began in late summer 2004 and vegetation planting was completed by March 2005. The primary restoration objective of the project was to re-establish the river's access to the floodplain by notching berms along the floodplain within the project reach, resulting in increased floodplain inundation frequency, duration, and sedimentation within the contemporary (post-Don Pedro Project) flow regime. Vegetation monitoring was conducted from spring 2005 through fall 2007. The results suggest that planting to re-establish native woody riparian species was effective, with >70 percent survival of most species during the monitoring period, and that passive restoration via natural recruitment (especially for cottonwoods and willows) might be an effective supplement, particularly during wet years (Stillwater Sciences 2008). Treatment of the invasive tree of heaven achieved >60 percent mortality during the monitoring period, but long-term effectiveness of the implemented weed control efforts is uncertain.

Reach 2. Urban Sand-bedded Reach (RM 10.5–19.3)

Reach 2 runs through the neighboring cities of Ceres and Modesto and under State Highway 99 (Figure B-3 in Attachment B and Figure 5.1-3 below). This reach supports approximately 34 acres of riparian vegetation per river mile, roughly one-half the density observed along Reach 1. The narrow, 20–150 ft band of native riparian vegetation that lines the channel downstream of Modesto is dominated by box elder and narrow-leaf willow; mature stands of valley oak and cottonwood occur along the upper edge of many of the levees (McBain and Trush 2000). Stands are disconnected at several points along the length of the river, interrupted by urban development or disturbed lands. In some areas, particularly in the area near Ceres and Modesto, the riparian corridor narrows to nearly nothing or to several tree widths. Residential and urban development within 250 ft of the river's edge limits possibilities of river meander and of floodplain naturalization along much of this reach, as well as recruitment of young cottonwood and valley oak stands. Dry Creek flows into the Tuolumne River just east of the Highway 99 overpass; the confluence area supports a relatively large patch of mixed willow, valley oak, tree of heaven, and other non-native plants. Several patches of invasive giant reed were also recorded along this reach during the vegetation surveys, along with stands of planted non-native eucalyptus. Edible fig occurs as an understory tree, mixed into cottonwood and mixed willow stands along the south river bank. The extent of this species appears to have increased between the 1996 and 2012 field surveys.

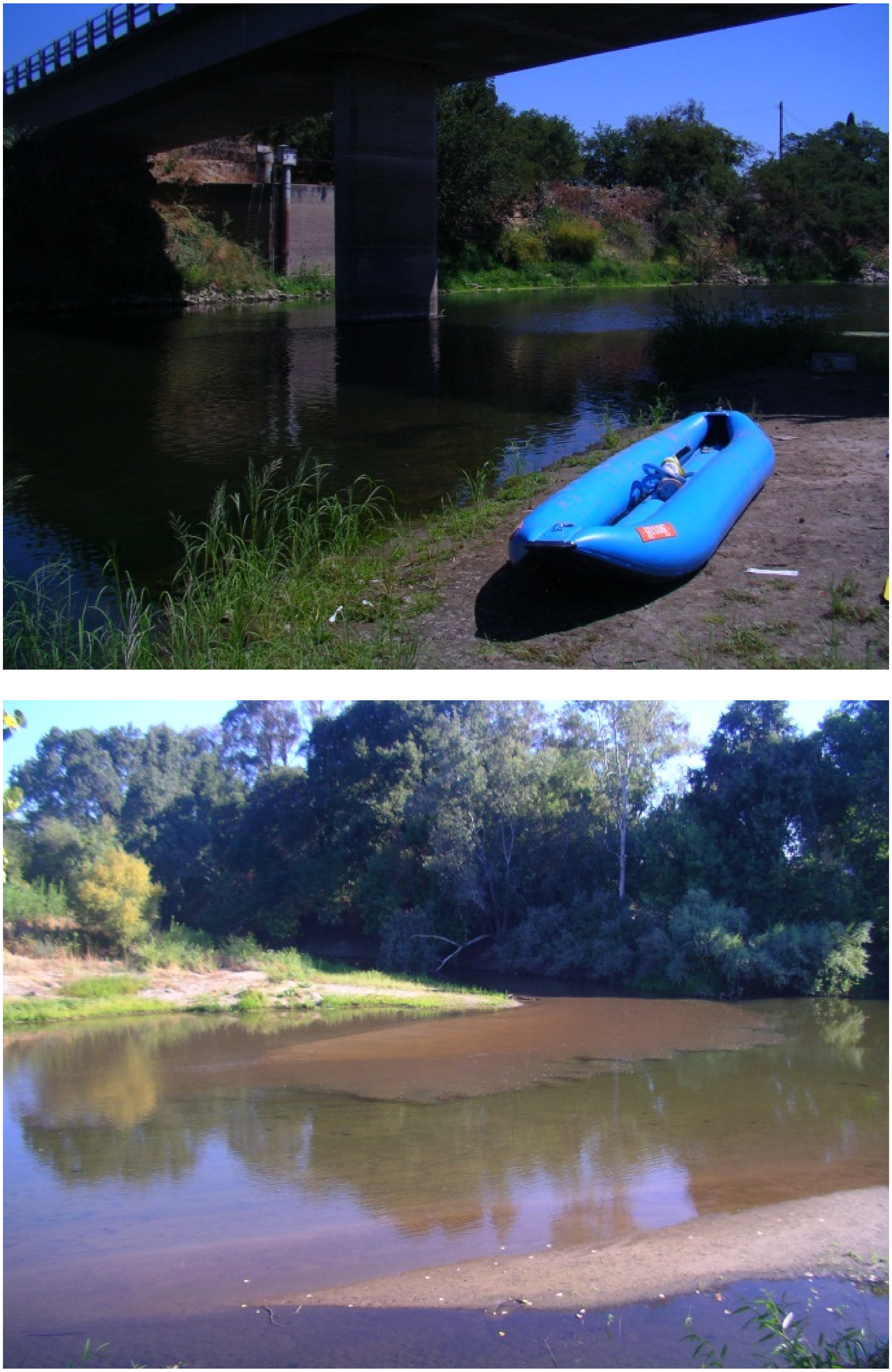

Figure 5.1-3. Views of lower Tuolumne River along Urban Reach 2; (A) Highway 99 underpass, (B) Dry Creek confluence just upstream of Highway 99.

Tuolumne River Regional Park

Tuolumne River Regional Park occupies 500 ac along seven miles of river, and includes five open space areas within the Modesto-Ceres urban boundaries including Legion Park/Airport Area, Gateway Parcel, Mancini Park, Dryden Park Golf Course Area and the Carpenter Road Area. Portions of the park are being restored and expanded with oversight through a joint powers agreement with the City of Modesto, City of Ceres and County of Stanislaus. While the emphasis of these parklands is for recreational use, outdoor education, and enjoyment, some floodplains and low terraces were restored to native riparian communities beginning in 2008 (in particular, the Gateway Parcel) (http://www.modestogov.com/prnd/parks/planning/projects.asp). Plans also include restoration of areas at the confluence of Dry Creek, upstream of the current Tuolumne River Park (http://www.modestogov.com/prnd/parks/planning/docs/050913-Precise%20Plan%20Summary%20Report.pdf). Most areas of the Park include mature valley oaks interspersed with manicured grasses, with no regeneration occurring. Box elder and narrow-leaf willow are the most common native riparian plants dominating river banks along this urban reach. Several stands of tree of heaven, and tree of heaven mixed into other vegetation types, were observed during 2012 field survey of Tuolumne River Regional Park.

Reach 3. Upper Sand-bedded Reach (RM 19.3–24.0)

There are approximately 38 acres of riparian vegetation per river mile along this river reach that runs just upstream of major urban areas. As described for Reach 1, larger parcels of riparian vegetation are linked by narrow (50–100 ft wide) strips of native riparian vegetation. The most common riparian vegetation types along the channel edge are narrow-leaf willow (roughly one-third of the area) and box elder; just above this narrow band are mature stands of valley oak and Fremont cottonwood, often intermixed with residential lawns and gardens. Adjacent suburban areas, along with agricultural lands and pockets of commercial development, constrain the channel width and characterize lands surrounding Reach 3 (Figure B-4 in Attachment B). Several pockets of native riparian vegetation occupy sections of floodplain and adjacent terrace, including valley oak and Fremont cottonwood, although narrow-leaf willow is most common along the water front. Patches of giant reed occur at multiple points along this reach. Between the 1996 and 2012 field surveys, a 24 acre increase in riparian vegetation was observed, including a 16 acre (36 percent) increase in the extent of narrow-leaf willow filling in several formerly open weedy patches observed in the 1996 survey. Edible fig was observed nested within other vegetation types along this reach, as well as along Reach 2. Although the extent of vegetation types *dominated* by non-native species appears to be holding steady along this reach, the amount of non-native *inclusions* within other vegetation types appears to have increased between the 1996 and 2012 surveys.

5.1.2.2 Gravel-bedded Reaches (RM 24.0–52.0)

Most historical riparian floodplain and terrace forests in the gravel-bedded reaches have been replaced by other land uses, including gravel mining and deposits of dredger tailings, rangeland, and cultivated farmland. Small patches of remnant riparian forest exist along with riparian shrubs and wetlands found on floodplains that have been heavily altered by gravel mining, aggregate extraction and dredger tailing deposits. Narrow-leaf willow dominates the channel edge in many areas along these reaches, as it does along the sand-bedded reaches. Recruitment and survival of other native riparian species is less common. Other native species are less common along the channel edge.

Reach 4. In-channel Gravel Mining Reach (RM 24.0–34.2)

This ten mile reach includes a series of gravel pits adjacent to the channel and skirts the southern edge of the community of Waterford (Figure B-5 in Attachment B). Overall, there are 34 acres per river mile mapped along Reach 4, largely dominated by valley oak along the upper terrace and levees, and by narrow-leaf willow along banks and flood prone areas. Smaller amounts of Fremont cottonwood and box elder also occur. Some gravel pit areas have been restored and replanted with native vegetation, resulting in a net decrease in non-native riparian vegetation and an overall increase in native riparian vegetation by approximately 24 ac. The greatest shift since the 1996 mapping was conversion of tree tobacco and open patches to valley oak and narrow-leaf willow. However the percent of the riparian vegetation dominated by non-native species along this reach -- over 4 percent -- is high compared to other parts of the lower Tuolumne corridor.

Except in restored areas, riparian vegetation is constrained to a narrow corridor and typically includes a strip of narrow-leaf willow along the water's edge, backed by stands of mature valley oak along the levee crest. Riparian vegetation rarely extends over 200 feet from the active channel. The first set of in-channel gravel mining pits along this reach, Special Run Pools 9 and 10, were the focus of a 2001 restoration project because they harbored non-native bass, a predator of salmon fry and smolts (McBain and Trush 2000). Tree of heaven, eucalyptus, and giant reed occur in small patches along this reach.

Special Run-Pool 9

The SRP 9 restoration project was among the first high-priority projects selected by the Tuolumne River Technical Advisory Committee (TRTAC) for implementation as part of the Tuolumne River Restoration Program. The project involved constructing a bankfull channel and floodplain where there were two in-channel pits located at RM 25.7 and 25.9 (SRPs 9 and 10), and isolating a terrace mine from the reconstructed channel by repairing a breach in the embankment. River and floodplain habitat reconstruction was completed in fall 2001 and 4.5 ac were planted with native riparian vegetation between November 1 and December 31, 2001. Irrigation and maintenance continued through September 2003. Post-project vegetation monitoring was limited to quantifying planted vegetation survival and to replacing plants as stipulated in the construction contract (TID/MID 2006). Percent cover and growth of planted vegetation was not monitored. Results from a brief survey of tree survival conducted in December 2002 indicate that survival typically exceeded 60 percent for most species one year after planting (but before irrigation ended) (TID/MID 2006). Beaver damage to some trees was noted during this survey. No survival monitoring has been conducted since 2002.

Reach 5. Gravel Mining Reach (RM 34.2–40.3)

The channel along nearly the entire extent of this reach is bounded by gravel pits that have been excavated out of former floodplain (Figure B-6 in Attachment B). Between the existing channel and gravel pits, and along edges of gravel pits and excavated lands, narrow strips of riparian vegetation exist, dominated by valley oak and narrow-leaf willow. Several other native riparian trees, such as Fremont cottonwood and Oregon ash (*Fraxinus latifolia*), also occur in several locations. Active management of these gravel mines has resulted in changes in riparian vegetation cover since the 1996 surveys: a net loss of five acres, mostly classified as Fremont cottonwood, was mapped, as well as a net increase in valley oak cover. The gravel mining areas create a wider, although heavily disturbed, band of riparian habitat along Reach 5, so that overall, this reach supports approximately 33 acres of riparian vegetation per river mile (similar to Reach 4). The vegetated areas are discontinuous both perpendicular to and parallel to the river channel, but extend up to 1,200 feet away from the channel itself at several locations.

Occurrences of vegetation types dominated by non-native species remains a small fraction of the riparian area (<1 percent). These types include tree of heaven, edible fig, and Himalayan blackberry (*Rubus armeniacus*), all of which were recorded during the 1996 and 2012 surveys (McBain and Trush 2000). Gravel bars with sparse vegetation are fairly common along this reach, as well as some rip-rapped and sparsely vegetated channel banks.

7/11 Mining Reach Restoration Project

The 7/11 restoration project is the first phase of the Gravel Mining Reach project, part of the Tuolumne River Restoration Program. The project goals included setting back gravel pit embankments, widening the floodway to 500 ft, constructing a bankfull channel and floodplain within the widened floodway, and establishing native riparian vegetation on 114 ac of newly constructed floodplain along 0.6 mi of Reach 5 (McBain and Trush 2000). In 2003, river and floodplain habitat was restructured and planted, with some follow-up planting in January 2004. Vegetation monitoring extended through 2006 (TID/MID 2006), but was limited to quantifying planted vegetation survival and replacing plants as stipulated in the construction contract. Percent cover, growth rates, and natural recruitment were not monitored.

Reach 6. Dredger Tailing Reach (RM 40.3–46.6)

Gravel mining pits and dredger tailings line the floodplain along this reach, creating off-channel water ways and pockets where native riparian vegetation has taken hold across the 1,000–2,500 ft-wide floodplain (Figure B-7 in Attachment B). The relatively wide, but highly disturbed floodplain supports over 121 acres of riparian vegetation per river mile, more than any of the other six reaches along the lower Tuolumne. Stands of Fremont cottonwood, Goodding's black willow, valley oak, mixed willow and narrow-leaf willow are interspersed by unvegetated mounds of dredger tailings and gravel pits. Since the 1996 surveys, approximately 69 additional acres of riparian vegetation has been mapped along Reach 6, composed of valley oak, narrow-leaf willow, and sparsely vegetated open areas. A large restoration project called 'Bobcat Flat' involved the re-contouring the area to create accessible floodplain where there were mounds of mine tailings and sparsely vegetated lands. The re-contoured lands were actively replanted and now support patches of recently planted cottonwood (2005), valley oak, and mixed willow (Figure 5.1-4). As an unintended consequence of this restoration, excavated ponded areas are also supporting rich populations of the highly invasive aquatic weed, water hyacinth (*Eichhornia crassipes*) (Figure 5.1-5). Areas on the south side of the channel have not been re-contoured and the large ridges of tailings separate portions of the floodplain from the main channel and create local low relative elevation pockets of high moisture colonized by native riparian plants (Figure 5.1-6). Other areas of this reach support a patchwork of riparian vegetation interspersed with open European grasses and weeds and/or sparsely vegetated tailings. This reach includes the only sites where McBain and Trush (2000) reported finding multiple age classes of Fremont cottonwood that were not actively planted, indicating that natural recruitment continues to occur in this area, in contrast to other areas of the lower Tuolumne.

Surrounding land use is rangeland and some crop production. Some native upland vegetation, including live oak (*Quercus wislizeni*), coyote brush (*Baccharis pilularis*), and other upland shrubs provide transition habitat areas between the riparian areas and surrounding agricultural lands.

Figure 5.1-4. Several patches of young Fremont cottonwood occupy areas of low relative elevation along the north side of Reach 6 in the Bobcat Flat restoration area.

Figure 5.1-5. Water hyacinth crowds ponded areas created by depressions in the low elevation portions of Reach 6.

Figure 5.1-6. View looking south, with main channel in back of photographer, from top of mine tailing pile along Reach 6. Valley oaks and mixed willows in foreground have colonized side channel area created by tailings.

Bobcat Flat

In 2001, a land trust called Friends of the Tuolumne, Inc. purchased the 303 acre Bobcat Flat parcel adjacent to 1.6 miles of Tuolumne River. With land acquisitions in 2010, Bobcat Flat now totals 334.09 acres. Since its purchase in 2001, two major restoration efforts have been completed. The first restoration effort (Phase 1) was constructed in 2005, and restored 10.5 acres of floodplain by excavating remnant tailings. Floodplains were then planted with approximately 1,040 trees, 300 shrubs, and 730 herbaceous plants (McBain and Trush 2004b, McBain and Trush 2006). Tailings excavated from the floodplain were sieved and washed, rebuilding riffles and point bars by placing approximately 12,000 yd^3 of clean coarse sediment into 2,000 feet of channel (McBain and Trush 2006). The second project (Phase II) was constructed in 2011, restoring approximately 12 acres of floodplain. Coarse sediment excavated from the floodplain was sieved, and approximately 15,000 yd^3 of coarse sediment was placed into 2,200 feet of mainstem Tuolumne River channel (McBain and Trush 2012). Phase II coarse sediment placement included resupplying the high flow recruitment pile at the upstream end of the Phase I project (McBain and Trush 2011). Monitoring of Bobcat Flat began in 2003 and has continued through 2012. Bobcat Flat monitoring includes: (1) photo point documentation of floodplains and the mainstem channel features; (2) topographic and cross section surveys; (3) marked rock experiments, pebble counts, and bulk samples; (4) groundwater monitoring; and (5) habitat mapping, invertebrate monitoring, and spawning surveys (McBain Trush 2004b, 2006, 2008, 2011, and 2012).

Reach 7. Dominant Spawning Reach (RM 46.6–52.1)

Reach 7 is the most important reach for spawning salmon along the lower Tuolumne River (Figure B-8 in Attachment B). This 5.4 mile reach supports over 80 acres of riparian habitat per river mile, including nearly 50 ac of narrow-leaf and Goodding's black willow that appears to have grown along the channel since the 1996 mapping effort. Narrow-leaf willow covers the greatest area of mapped riparian vegetation in Reach 7, followed by valley oak and Goodding's black willow. As in Reach 6, Reach 7 includes areas that have been subject to gravel mining and swaths of the floodplain that have been re-contoured by mining and include ponds that are disconnected from the channel during low flow periods. Some of the dredger tailings were removed during construction of the Don Pedro Project and the channel was partially reconstructed in 1971 to create a low confinement channel with a broad and frequently flooded floodplain. Some dredger tailings remain and, as in Reach 6, create pits and backwaters that currently support native riparian vegetation (McBain and Trush 2000). Channel banks are occupied by white alder and narrow-leaf willow, while other native riparian trees (Fremont cottonwood, Goodding's black willow, valley oak) grow in patches along the rumpled floodplain surface.

The surrounding uplands are used for rangeland and crop production, and the riparian corridor is confined by levees or bluffs along short sections of the lower and upper ends of the reach, leaving the majority of the channel along this reach 'loosely' confined. Adjacent uplands support California buckeye, blue and interior live oak, (*Quercus douglasii, Q. wislizeni*) in an annual grassland matrix. Directly downstream of La Grange Dam, the valley is confined by bedrock and supports small patches of riparian vegetation (RM 50.5–52.1) (McBain and Trush 2000). A few small patches of giant reed were recorded along this reach but invasive species cover less area in Reach 7 than in most other reaches.

Basso Ecological Reserve Land Purchase

In 2000, two large county-owned parcels were connected through the purchase of a 42-ac 'bridge' parcel called the Basso Ecological Reserve. This land purchase, located between La Grange Bridge and Basso Bridge, was coordinated by CDFG and funded by CALFED. The County parcels are 185 and 350 ac, and the combined protected lands are intended to help protect critical spawning habitat in this reach (McBain and Trush 2000).

5.2 Factors Contributing to Existing Condition of Riparian Vegetation

The lower Tuolumne River has been subject to the cumulative effects of over 100 years of intensive land use and water management. The current condition of the riparian vegetation along the lower Tuolumne River is the result of cumulative ongoing effects associated with European settlement and ongoing changes in the physical conditions along the river. Placer mining and subsequent dredger mining during the Gold Rush affected the channel and associated floodplains (USFWS 2001). Also during this period, steamship transportation along the major rivers was fueled by cordwood harvested from adjacent lands and likely resulted in the first wave of riparian forest clearing in some areas (Rose 2000, as cited in McBain and Trush 2002). This initial phase of settlement was followed by berm and levee construction, land use conversion, and changes in regional hydrology that occurred with pre-1860 dryland farming. Subsequent irrigated cropland production, beginning in the late 1800s, co-occurred with increased stream water withdrawals for irrigation and municipal uses. During the nineteenth century, hydraulic mining, sluicing, and dredging also rearranged large areas of the river and adjacent lands. During the twentieth century, gravel mining along the lower Tuolumne further constrained and altered the riparian floodplain. Wheaton Dam, a small irrigation dam constructed in 1871, was supplemented or replaced by much larger dams along the Tuolumne main stem and tributaries in the twentieth century, affecting downstream flows and coarse and fine sediment transport. Finally, urbanization has accelerated along the lower Tuolumne River riparian corridor and is expected to continue to increase into the future (American Farmland Trust 1995, State of California 2007).

The effects of these changes, excluding initial land clearing, continue to limit the regeneration of native riparian vegetation along the lower Tuolumne River. In the following section, factors contributing to important changes in the riparian physical environment along the lower Tuolumne River are described, along with observations on how those factors could be contributing to the existing condition of riparian vegetation. A list of the dominant factors and their potential cumulative effects on riparian processes and structures is provided in Table 5.2-1 below.

Table 5.2-1. Known and/or hypothesized linkages between cumulative factors affecting current riparian vegetation condition, as well as reaches where effects are evident along the lower Tuolumne River.

Factor Affecting Riparian Resources	Effect on Riparian Structure	Effect on Processes that Support Riparian Vegetation	Reaches Where Effects are Evident
Land use conversion to agriculture	Largely reduced width of riparian vegetation, especially valley oak terraces.	Prevents recruitment and regeneration of native vegetation on former floodplains and terraces. Flood protection requirements not as high as urban areas.	RM 0 to 20
Land use conversion to urban areas	Vegetation removal, isolated and aging remnant riparian vegetation; constrains channel migration; simplifies planform.	Prevents recruitment and regeneration of native vegetation on urbanized former floodplains and terraces; geomorphically and biologically “freezes” surrounding floodplains due to flood protection requirements.	RM 15 to 30
Levees and bank revetment	Greatly constrains channel migration; simplifies planform; reduces bank vegetation	Prevents floodplain inundation which nourishes native riparian plants and delivers propagules; constrains meander; reduces recruitment along banks	RM 0 to 52
Aggregate mining	Leaves large pits in floodplain area - converting floodplain vegetation to open water; levees built to isolate pits from river constrain river.	Precludes regeneration of riparian vegetation (no habitat) and associated levees limit lateral movement of river, reducing amount and diversity of riparian habitat surfaces created.	RM 34 to 50
Dredger tailings	Dredger tailings of unconsolidated sediments on floodplain replace rich soils with depauperate ones, resulting in change in riparian species composition and reduced extent and diversity of riparian vegetation.	Stymied development of native riparian vegetation on spoil piles; reduced riparian habitat connectivity.	RM 38 to 52
Invasive plants	Change in plant species composition, structure and habitat quality.	Reduces and/or precludes native species through competition for water, light and soil nutrients and allelopathic effects; can alter frequency of disturbance associated with bank erosion and fire, favoring plant species that are adapted to less frequent flooding and/or more frequent fire.	RM 0 to 52

Factor Affecting Riparian Resources	Effect on Riparian Structure	Effect on Processes that Support Riparian Vegetation	Reaches Where Effects are Evident
Altered hydrograph	Vegetation encroachment into active channel and lower floodplain; reduced extent of rejuvenating riparian vegetation, reduced diversity and lateral extent of riparian community types; reduced channel migration and simplified planform.	Reduces scour of vegetation within active channel floodplain; reduced frequency of avulsions, channel meander, creation of new recruitment sites for riparian vegetation; distribution of river-transported riparian propagules; survival of native riparian seedlings, and diversity of riparian vegetation types on floodplain; increased competitive advantage for upland and invasive non-native species.	RM 0 to 52
Reduced sediment delivery	Reduced availability of bare mineral soil for recruitment; diminished extent of riparian vegetation; reduced age and structural diversity of riparian vegetation.	Diminished riparian recruitment and establishment of diverse riparian community types.	N/A
Restoration	Increases extent of existing riparian vegetation	Provides seed and propagule sources for downstream recruitment; increases organic material content of soil	RM 0 to 52
Climate change	Uncertain, and dependent on flow regulation response to changes in snow storage and snowmelt patterns as well as changes in user needs; increasing air temperatures may change riparian vegetation structure and composition.	Uncertain effect on flow regulation; potential increase in drought stress and favoring of drier site plant species with increased temperatures; potential changes in seed release timing of cottonwoods and willows with increased air temperatures may result in further decoupling of natural recruitment processes.	RM 0 to 52

5.2.1 Land Use Change, Levees and Flood Control

Following the Gold Rush of the 1840s and 1850s, agriculture activities including crop production and ranching increased rapidly in the Central Valley. During this period, woody vegetation was cleared along the river bottomlands to support crop production in these rich alluvial soils; levees were constructed to protect the new farm lands from flooding in the spring and irrigation canals were constructed to provide irrigation water during the growing season (Thompson 1961, Katibah 1984). Some landowners in the nineteenth century held extensive tracts of land in the Central Valley, and large areas of marshland in the Central Valley were leveed and drained for agricultural uses (Katibah 1984). Clearing riparian forests has the obvious initial effect of simply removing the vegetation, associated habitat, and halting many attendant ecosystem processes (Katibah 1984, Naiman et al. 2005). Grazing and intensive row crop production on these former riparian forest lands suppresses cottonwood sapling survival, as observed on the lower Tuolumne (McBain and Trush 2000) and documented through a research project along the Nacimiento River in coastal central California (Shanfield 1984). Clearing woody plant cover also creates openings within the lower Tuolumne riparian corridor where non-native plant species can secure a foothold and proliferate (McBain and Trush 2000).

The lateral extent of riparian vegetation within the Tuolumne River valley is greatly diminished, in many areas to less than three tree crown widths across or to no riparian vegetation at all. Comparison with historical 1937 aerial photographs revealed that contiguous riparian forests on the southern bank often exceeded 120 ac; these stands were reduced to 30 ac or less by 1993 (McBain and Trush 2000). At a slightly broader scale, land conversion and levee construction constrains the channel migration process, including both the gradual meander bend and meander cutoff/oxbow formation along sand-bedded reaches, and the avulsion process along the gravel-bedded reach (McBain and Trush 2000, Grant et al. 2003). These processes are important for sustaining a diversity of successional community types in the riparian landscape (Scott et al. 1996, Friedman et al. 1998, McBain and Trush 2000, Polzin and Rood 2006, Stella et al. 2011), including the landscape of the lower Tuolumne River.

Natural levees can form alongside rivers as the coarse sediment load suspended during the higher flood flows is deposited during the receding flows (Katibah 1984, Scott 1996). Rivers in the San Joaquin Basin that carried sufficient sediment to their lower reaches to create natural levees include the Tuolumne, as well as the Stanislaus, Merced, Mokelumne, Cosumnes, and northern San Joaquin (Katibah 1984). With land conversion to agriculture and urban uses, these natural levees were augmented to prevent flows from accessing adjacent floodplains, thereby cutting these areas off from seasonal to less frequent inputs of water, sediment, nutrients, and water-borne propagules (Warner 1984, Junk et al. 1989, Tockner et al. 1999). Similarly, man-made levees limit channel migration, narrowing and simplifying the planform, and prevent high flows from scouring vegetation on the land-side of the levee, prohibiting creation of areas for natural riparian vegetation recruitment in these levee protected floodplains. Without these disturbances and deliveries, riparian plant communities behind levees cease to regenerate and become senescent, and vegetation on the water-side of the levees becomes more stable and homogeneous (Stillwater Sciences 1998, McBain and Trush 2000).

While levees have not been mapped along the lower Tuolumne River, the FEMA 100-year flood zone provides an indication of the areas that could be part of the active floodplain, and therefore potentially support riparian vegetation. Although these areas are clearly defined in large part based on the presence of levees, the degree to which areas within the defined 100-year flood zone is occupied by riparian vegetation can be used as a rough indicator of the extent to which levees, as well as other factors, are limiting riparian vegetation (Table 5.2-2, and Attachment D). The comparison of the FEMA 100-year flood zone with the updated map of riparian vegetation illustrates the effect that levees and other land use changes have had on limiting the extent of riparian vegetation, particularly along the lowest reaches of the Tuolumne River (Table 5.2-2, and Attachment D). In Reaches 1 and 3, only 15 percent and 16 percent of the 100-year flood zone supports riparian vegetation, respectively (Table 5.2-2, and Attachment D); the remaining flood zone is not available to support riparian vegetation largely due to levees and land use change to agriculture. Reaches 2 and 4 run through urban areas, and 26 percent and 25 percent of the 100-year flood zone is covered by riparian vegetation, respectively. The conversion of floodplain to urban uses requires more intense flood protection (i.e., higher levees) than conversion to agricultural lands due to the increased risk of costly flood damage and to human life. Thus, where the river runs through or adjacent to Waterford and Modesto, the 100-year flood zone is more constrained by levees, as indicated by the more extensive 500-year flood zone (Attachment D).

The non-urban reaches are less fortified against a 100-year flood and, as a result, there is little to no difference between the extents of the 100-year and 500-year flood zones. Gravel pits and bare soils within active gravel mining areas limit the extent of riparian vegetation within the 100-year flood zone of Reach 5. In Reaches 6 and 7, riparian vegetation extends roughly to the 100-year flood zone limits (Attachment D). Thus, the difference in 100-year flood zone and mapped riparian vegetation is likely due to the combined effects of aggregate extraction, dredger tailings, and to a lesser extent, land use change and associated levees.

Table 5.2-2. Area within the FEMA 100-y flood zone per reach, compared to the existing area of mapped riparian vegetation.

Reach	100 year Flood Zone (acres)	Mapped Riparian Vegetation (acres)	Percent of 100yr FZ Currently Mapped with Riparian Vegetation
1	4,542	658	15
2	1,159	301	26
3	1,107	177	16
4	1,416	350	25
5	1,868	199	11
6	1,737	728	44
7	545	279	52
Overall	**12,374**	**2,691**	**22**

5.2.2 Aggregate Extraction and Dredger Mining

In-channel and floodplain dredging and tailings deposition along the lower Tuolumne converted very large areas of historically diverse riparian habitat to an essentially barren landscape of cobble ridges interlaced with narrow sloughs. The effects are evident along nearly one-third (16 out of the 52 river miles) of the river corridor. The profound impacts of channel and floodplain dredging and gravel mining on riparian vegetation extend from just upstream of Waterford to La Grange (RM 34–50). Several restoration projects, including Special Run Pools 9 and 10, the 7/11 Mining Reach Restoration, and Bobcat Flat have re-contoured these otherwise greatly altered floodplains. Upstream of Turlock Lake State Park (RM 42), some of the dredger tailings area was reclaimed during construction of the Don Pedro Dam. The remaining floodplains along this 16-mile stretch are littered with unconsolidated tailing piles, excavated gravel pits, and frequently scraped and re-surfaced mining areas.

Although dredge mining along the lower Tuolumne ended by 1952, dredger tailing piles extend from river mile 40 to 46 along the lower Tuolumne River. Piles of dredger tailings rise over 20 feet above the channel water surface, excluding any natural recruitment from water born propagules, and have extremely low water holding capacity. Thus, these areas do not offer hospitable habitat for native riparian plant species (Stillwater Sciences 2007, McBain and Trush 2000). Between the tailing deposits are low-lying swales, some of which may be connected to perennial or seasonal groundwater supplies and support a variety of native and non-native riparian and wetlands species (narrow-leaf willow, cattails, and aquatic plants such as duckweeds, water fern, and water hyacinth [*Lemnaceae, Azolla filiculoides, and Eichhornia crassipes*]) (McBain and Trush 2000, Stillwater Sciences 2007).

Aggregate mining continues in localized areas from Hughson to La Grange (RM 24-50). Gravel mining of historic floodplains leaves deep ponds precariously close to the channel, protected from channel capture by levees. Space available for riparian vegetation development is also highly constrained due to the replacement of floodplain surface by gravel pits and, since the top soil has been removed from the active gravel mining operations, few or no native species can become established in the remaining open floodplain areas (Figure 5.2-1). Riparian vegetation along the steep levee banks is cleared and regeneration prevented with the intent of maintaining levee integrity. Gravel pits become filled with ground water and support populations of non-native aquatic plant species, such as water hyacinth. These gravel pits are deep (up to 38 ft deep) and up to 400 ft wide, and by occupying large portions of the floodplain, constrain the channel to a stationary and narrow area (McBain and Trush 2000). Therefore, channel meander is prevented in these reaches, along with associated riparian vegetation development and diversity.

Figure 5.2-1. Active and legacy gravel mining operations can preclude development of riparian vegetation in areas of the historical floodplain that extend from River Mile 24-50 along the lower Tuolumne River.

In summary, the effects of ongoing and historical in-channel and floodplain aggregate extraction and dredger mining continues to alter and limit revegetation of the floodplain with native riparian vegetation along 16 of the 26 gravel-bedded river miles, translating to over 60 percent of the gravel-bedded reach and roughly one-third of the entire river extent along the lower Tuolumne River.

5.2.3 Invasive Plant Species

Invasive non-native species are, by definition, strong biotic competitors for resources such as light and water and can, given the time and space, out-compete existing native riparian plants and alter the composition and structure of the riparian community (Stromberg et al. 2002, Shafroth et al. 1995). Dominance of invasive non-native plants in the riparian corridor interferes with recruitment and survival of native woody plants by occupying the available recruitment sites and by competing for resources with young seedlings (Friedman et al. 2005, Stromberg et al. 2002, Else and Zedler 1996, McBain and Trush 2000, Coffman 2007). The common effect of invasive non-native species is a simplification of the structure and composition of the riparian plant community, in some cases towards monotypic stands (Holt 2002, Dudley 2000, Coffman 2007). Depending on the non-native species characteristics, this often decreases the suitability of the riparian corridor for invertebrates and wildlife, and compromises adjacent aquatic and terrestrial habitat (Bell 1994, Herrera and Dudley 2003). Invasive exotic plant species can affect large alterations on the riparian plant and dependent wildlife community (e.g., Scoggin et al. 2000). Many invasive non-native species can alter ecological processes, such as fire frequency and intensity, litter decomposition, soil richness, and foodweb dynamics (D'Antonio and Hobbie 2005, Brooks et al. 2004, Corbin and D'Antonio 2004, Coffman 2007, Coffman et al. 2010). Such changes in physical conditions or processes that define the riparian habitat make the space less compatible with native species niche requirements and often have no or even a positive effect on the invading species habitat needs (Busch and Smith 1995, Alpert et al. 2000, Coffman 2007, Shafroth et al. 1995).

Non-native species have been introduced to the lower Tuolumne riparian corridor through intentional plantings (e.g., Eucalyptus windrows), as garden and agricultural escapes (e.g., edible fig, tree of heaven, and giant reed), unintentional seeds or vegetative fragments brought in by vehicle or boat, and numerous other ways. The further spread of these introduced species is often facilitated by human activities and alterations, such as vegetation clearing, construction and maintenance of roads and other development, and changes in hydrology and other natural conditions that support non-native over native species.

Overall, non-native dominated vegetation comprise approximately 1.5 percent of the riparian vegetation in the lower Tuolumne River corridor (about 40 ac, or just under one ac per river mile; see Table 5.2-3 below). Since the 1996 mapping effort, the area classified as dominated by non-natives has decreased by 3.8 acres, or 0.4 percent of the total area of mapped riparian vegetation. For most non-native vegetation types, the extent has held steady of time, with minor changes in eucalyptus, Himalayan blackberry, and 'disturbed miscellaneous exotics'. Reaches with the greatest area of riparian vegetation dominated by non-native species are Reach 2 (largely urban area near Modesto, RM 10.5 -19.3) and Reach 4 (in-channel gravel mining reach, RM 24.0 to 34.2).

Table 5.2-3. Acres of non-native dominated riparian vegetation mapped along the lower Tuolumne River in 2012.

Reach	Acres	Acres per River Mile
1	2.40	0.23
2	8.66	0.98
3	4.34	0.92
4	14.28	1.40
5	1.60	0.26
6	5.89	0.93
7	2.30	0.43
Total	**39.50**	**0.77**

Four invasive non-native species, classified as such by the California Invasive Plant Council (CALIPC), make up two-thirds of all mapped non-native dominated vegetation along the lower Tuolumne River: eucalyptus, edible fig, giant reed, and tree of heaven. These species received overall threat ratings of high (giant reed) or moderate (the other three) by CALIPC and are described in more detail in Attachment C. Himalayan blackberry (rated as a high threat by CALIPC) was also frequently observed as an associated understory species during the 2012 field survey.

5.2.4 Changes in the Hydrograph

Like dams on other large tributaries to the San Joaquin River, major dams on the Tuolumne River regulate flow from the upper watershed downstream to the lower Tuolumne River. Overall an average of 60 percent of the river's total flow reaches the San Joaquin confluence 52 mi downstream of La Grange Dam (McBain and Trush 2000). Over the past 120 years, each increment of flow regulation (Wheaton, La Grange, O'Shaughnessy, old Don Pedro, and new Don Pedro dams along the mainstem as well as dams constructed along tributaries above O'Shaughnessy Dam, including Cherry and Eleanor Creeks) has added changes to the lower Tuolumne River flow regime. These changes continue to contribute to the cumulative effects to riparian vegetation along the river corridor. The general mechanisms by which changes in the hydrograph can potentially affect riparian vegetation are summarized in Figure 5.2-2. The two most important hydrologic changes related to riparian vegetation along the lower Tuolumne River are altered annual peak flows and changes in the descending limb of the spring hydrograph.

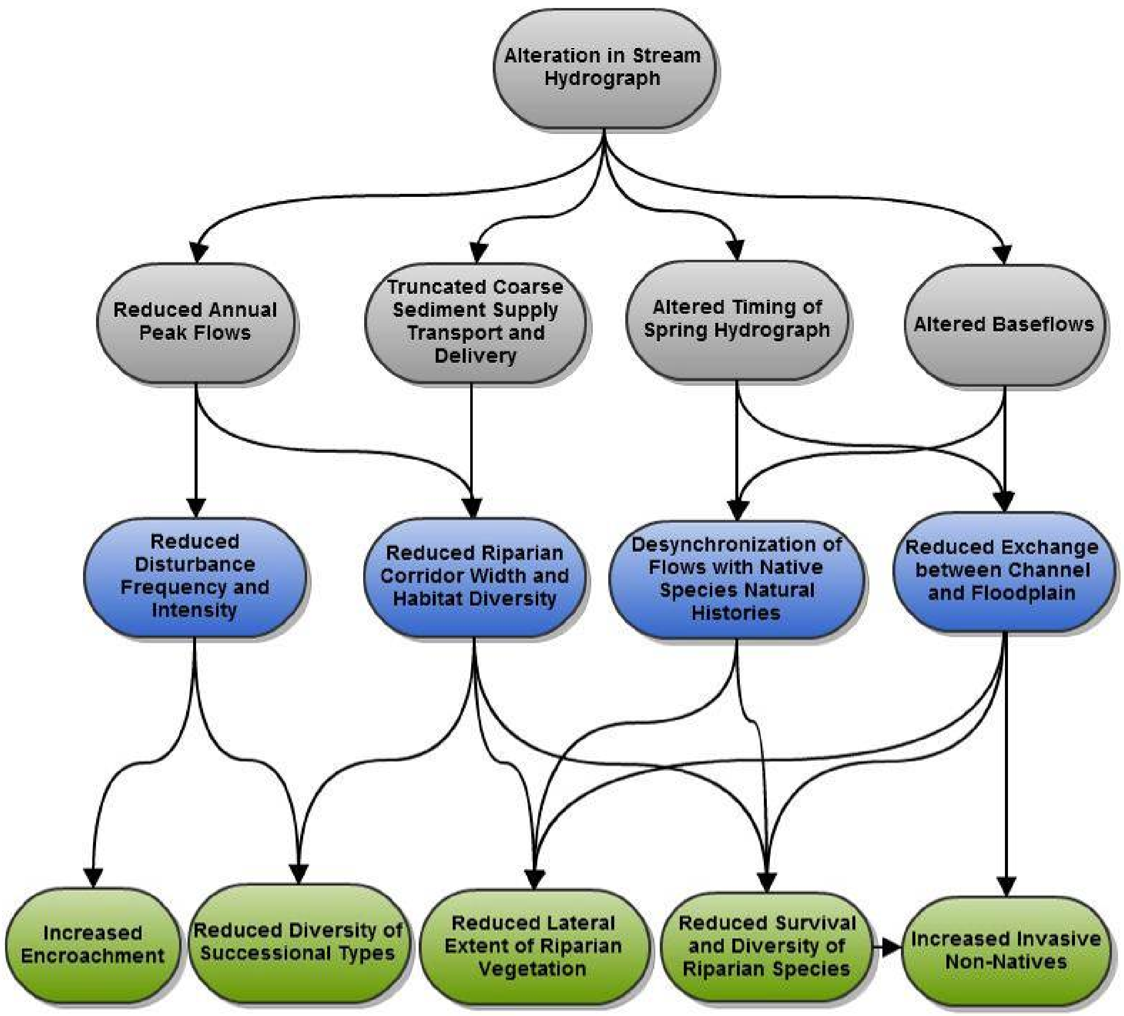

Figure 5.2-2. Flow diagram showing potential linkages between changes in the hydrograph (gray), the physical condition (blue), and vegetation (green) of riparian corridors.

5.2.4.1 Reduced annual peak flows

Evidence of vegetation response to reduced annual peak flows along the lower Tuolumne River has been reported as a frequent line of narrow-leaf willow and/or box elder thickets, located directly along or within the active channel banks (McBain and Trush 2000, see Attachment B maps). Under more frequent high flow conditions, the distribution of these species would be lower compared to other native riparian species because increased mortality would balance with the greater recruitment capacity of these species (McBain and Trush 2000, Stella et al. 2006). Bendix (1999) found that narrow-leaved willow was moderately resistant to high flows, possibly due to its stems and strong roots. For this species, reduced annual peak flow suspends otherwise frequent thinning of cohorts growing adjacent to and into the stream channel. Again, observations of dense and frequent thickets of narrow-leaved willow and box elder along the lower Tuolumne River suggest that reduced annual peak flows make it possible for these thickets to remain in place.

McBain and Trush (2000) inferred that the reduced frequency and magnitude of winter floods along the lower Tuolumne River has reduced scour-mortality of narrow-leaf willow seedlings that recruit along the riverbank, while limiting recruitment of Fremont cottonwood by reducing available bare mineral soil for germination and access to appropriate relative elevation surfaces (McBain and Trush 2000, Stella 2005, Stella et al. 2010). The limited natural recruitment of Fremont cottonwood, Goodding's black willow, and other willow species (excluding narrow-leaf willow, e.g. red and shining willow [*Salix laevigata* and *S. lucida*]) outside of actively replanted restoration areas is evidenced by the lack of young cohorts of these species observed during both the 1996 and 2012 field surveys (McBain and Trush 2000; also see vegetation maps presented in Attachment B). Other tree willows known to have high water demands, such as arroyo and shining willow, were very infrequently observed along the lower Tuolumne River in 1996 surveys, although they are common in other relict riparian stands in the region (e.g., Caswell State Park; Hickson and Keeler-Wolf 2007). In contrast, large areas of new and recent narrow-leaf cohorts were observed along the lower Tuolumne River corridor in the 2012 survey (and by McBain and Trush 2000; also see vegetation maps presented in Attachment B).

5.2.4.2 Truncated sediment supply and delivery

Changes in the availability of fresh sediment deposits, which for many native riparian plant species represent recruitment sites, can affect the extent of riparian vegetation along alluvial rivers (Naiman et al. 2005). The ongoing effect of sediment interception can include sediment-depleted conditions and reduction in riparian recruitment sites, which can be expressed as channel incision or channel widening, downstream if the sediment supply is less than the transport capacity of the downstream channel (Williams and Wolman 1984, Ligon et al. 1995, Kondolf 1997, Grant et al. 2003, McBain and Trush 2004a).

Starting in 1871 with the construction of Wheaton Dam, coarse sediment delivery from the upper to the lower reaches of the Tuolumne River has been intercepted (McBain and Trush 2004a). With construction of Don Pedro Dam, storage capacity was sufficient to withhold both coarse and fine sediment during all but the largest flow events (McBain and Trush 2004a). The primary effect of this change in sediment supply that has been observed on the lower Tuolumne River is the lack of synchrony between recently deposited fine sediment at suitable elevations and the seed release timing of pioneer riparian tree species (Stella et al. 2010) (see next section for additional discussion).

5.2.4.3 Altered timing of spring hydrography

Changes in the spring snowmelt hydrograph away from the historical extent and timing can dampen recruitment of native riparian plants in the floodplain of alluvial rivers, since many of these species have reproduction and survival strategies that are adapted to the timing and shape of the historical spring snowmelt flood hydrograph (Johnson 1994, Karrenberg et al. 2002, Dixon 2003, Lytle and Poff 2004). For example, seed release for Fremont cottonwood and Goodding's black willow is synchronized with the timing of the historical peak or retreating spring snowmelt flood (Merritt and Wohl 2002, Dixon 2003, Stillwater Sciences 2006, Stella et al. 2006, Naiman et al. 2005). Wind- and water-dispersed seeds released by Fremont cottonwood, Goodding's black willow, and other native riparian species are thereby distributed downstream and across the floodplain; as the floodwaters recede, seeds are deposited on moist bare mineral seedbeds (Johnson 1994, Merigliano 1998, Merritt and Wohl 2002, Lytle and Merritt 2004, Stillwater Sciences 2006, Stella et al. 2006). The relative elevation where these seeds land is important, since seeds situated too low are in danger of being scoured by subsequent high winter flows (<2-yr RI), and seeds deposited too high above the summer groundwater table are in danger of desiccation (Mahoney and Rood 1998, Kalischuk et al. 2001, Karrenberg et al. 2002, Johnson 2000, Rood et al. 2003a, Dixon 2003). This optimal position in relation to the declining spring hydrograph and seed release timing has been formalized by Mahoney and Rood (1998) into the 'recruitment box' model.

The slope of the receding limb of the spring hydrograph is also important. Along the sand-bottomed reaches of the lower Tuolumne River, Stella and colleagues (Stella 2005, Stillwater Sciences 2006, Stella et al. 2010) recently demonstrated that the speed at which the saturated soil front descends through the soil column in the spring affects survival of newly germinated Fremont cottonwood and Goodding's black willow seedlings, and is controlled by the slope of the receding limb of the snowmelt hydrograph (also demonstrated for an analogous river corridor in Europe by Guilloy et al. 2011). When the receding limb of snowmelt runoff, or a simulated April to June high flow, occurs too rapidly, the seedling roots are unable to grow downwards at a pace sufficient to access the descending front of saturated soil (Stella et al. 2006). Seedling mortality under such conditions is very high, resulting in greatly reduced recruitment of at least these two critical native riparian species on the floodplain of the lower Tuolumne River (Stella et al. 2006, 2010). Narrow-leaf willow has a longer seed dispersal period than cottonwood, and therefore is able to colonize riverbanks and midstream gravel bars during mid-late summer when agricultural return flows raise and stabilize the summer baseflows, thereby avoiding seedling inundation and drowning associated with increased late spring and early summer flows (Stillwater Sciences 2006, McBain and Trush 2000). Thus, reduced spring flows continue to create conditions that would increase the extent of narrow-leafed willow and decrease the extent of naturally recruited Fremont cottonwood and Goodding's black willow as evidenced by the observed skewed age distribution of these species on the lower Tuolumne River.

5.2.5 Active Riparian Restoration

Active restoration involves 'actively' reshaping the land (e.g. lowering the floodplain surface to ensure a target frequency and duration of flooding) and/or active planting the riparian area with native species. Passive restoration involves only removing a source of stress or a factor that is limiting natural recruitment and survival of native riparian vegetation; for example, notching or setting back a levee to allow for more frequent flooding from the river channel can sometimes be sufficient for restoring a native riparian forest.

As demonstrated during the update of the riparian vegetation inventory, active restoration of riparian vegetation has directly affected the amount, distribution and quality of riparian vegetation along the lower Tuolumne River. The restoration efforts that have been implemented and are directly increasing the extent and quality of native riparian restoration along the lower Tuolumne River are summarized in Table 5.2-4 below. All of these restoration projects have involved active planting of native riparian species.

Table 5.2-4. Restoration efforts implemented along the lower Tuolumne River to-date.

Reach number	River miles	Restoration Name	Acres Actively restored in Study Area
1	0	San Joaquin Wildlife Refuge	0
1	4	Grayson River Ranch	143
1	5.8 to 7.4	Big Bend	250
2	12 to 19	Tuolumne River Regional Park	500
4	25	Special Run Pool 9	4.5
5	--	7/11 Mining Reach Restoration Project	114
6	--	Bobcat Flat	334.09

5.2.6 Climate Change

Changes in snowpack and timing of spring peak flows associated with increasing temperatures have already been observed for many watersheds in the Sierra and in the American west overall, and are implicated as evidence of ongoing climate change (Mote et al. 2005, Stewart et al. 2005, Maurer et al. 2007, Kapnick and Hall 2009). In general, recent (1950 to 1999) flow data for the Sierra Nevada indicate that in snowmelt-dominated rivers, there has been a trend toward earlier spring snowmelt peak flows based on the runoff center of mass timing (e.g., the time when half of the annual runoff has occurred) (Cayan et al. 2001, Knowles and Cayan 2002, Mote et al. 2005, Maurer et al. 2007, Kapnick and Hall 2009).

Young et al. (2009) used a water basin hydrologic model (WEAP21; http://www.weap21.org) to predict that the spring mid-snowmelt runoff period on the Tuolumne will occur approximately 2.2, 4.0 and 5.4 weeks earlier than current conditions by the end of the century under the low (2^{o}C), mid (4^{o}C) and high (6^{o}C) global warming scenarios (Young et al. 2009). Null et al. (2010) extended this research, also using the WEAP21 model, to assess reductions in mean annual flow (MAF) and increased duration of low flow conditions, for the Tuolumne watershed and report minor expected changes in MAF (ranging from 2 to 6 percent for the different warming scenarios), and somewhat more significant increases in expected duration of low flows (ranging from one to three weeks for the low, medium and high warming scenarios (Null et al. 2010).

These potential changes associated with climate change, namely earlier peak snowmelt flows and longer duration summer low flows, could become a factor contributing to future conditions along the lower Tuolumne River riparian corridor. (Naiman et al. 2005, Yarnell et al. 2010). Earlier peak snowmelt, especially shifts that move the flows outside or to the edge of the seed release window for native riparian species, are expected to reduce recruitment of native riparian species such as Fremont cottonwood and Goodding's black willow (Shafroth et al. 1998, Rood et al. 2005, Stella et al. 2006, Stillwater Sciences 2006), and a longer duration and lower summer baseflow would be expected to increase water stress, favor more facultative or mesic site species over moist and wet site plant species, and favor increased channel edge recruitment and encroachment of late seed dispersal species, such as narrow-leaf willow. However, with flow regulation, the effects of climate change are largely masked (Yarnell et al 2010).

6.0 DISCUSSION AND FINDINGS

6.1 Summary of Current Conditions

Native riparian vegetation occupies 2,691 acres along a nearly continuous but variable-width band along the lower Tuolumne River corridor. Overall, the 52 ac average of native riparian vegetation per river mile is slowly changing, with 419 ac increases in net extent of native vegetation between 1996 and 2012 brought about primarily through active restoration projects. Areas with the greatest extent of native riparian vegetation per river mile were mapped along the twelve miles downstream of La Grange Dam in Reaches 6 and 7. Closer to the confluence with the San Joaquin River, several large restoration projects along Reach 1 have also increased the extent of native riparian vegetation.

Areas with the least riparian vegetation and narrowest riparian corridor are along Reach 2 (RM 10.5 to 19.3), which runs through the urban areas of Modesto and Ceres. Reaches 3, 4, and 5 are also confined by gravel mining and other land uses, and include large areas that are sparsely vegetated due to historical mining and dredger tailing deposits. Outside the restored areas, the greatest changes have been in small increases in extent of native narrow-leaf willow and mixed willow dominated vegetation along the channel banks and on several small alluvial surfaces.

Qualitative observations for indicators of riparian condition made during the 2012 field survey and reported by others indicate that outside of actively restored areas, most riparian trees are mature and senescent with very few younger seedlings or pole-sized individuals observed. These observations suggest that there is very limited replacement of mature and senescent plants with younger cohorts outside of restored areas along the lower Tuolumne River corridor. Box elder and narrow-leaf willow dominate much of the channel edge vegetation along the 52-mile corridor.

The areal extent and location of lands dominated by non-native plants has decreased over the past 15 years, with minor mapping changes in tree tobacco and 'disturbed/miscellaneous exotics' (decrease) and eucalyptus (increase). During the 2012 field survey many areas supporting an understory of edible fig and Himalayan blackberry were noted; however, changes in extent of these species were not tracked since vegetation was mapped based only on dominant species type.

6.2 Factors Contributing to Current Conditions

Land clearing and land use change, coupled with levee construction to protect these lands from flooding, has largely limited the lateral extent of potential river influence, and greatly diminished the former extent of both valley oak forests and the mixed riparian cottonwood forests that historically occupied the lower Tuolumne River corridor. Based on the current assessment of the 100- year flood zone, levee constraints on the extent of riparian vegetation are particularly important in the lower reaches. Several restoration efforts in which levees have been notched to increase river access and associated areas actively replanted with native riparian plant species, have been highly successful in supporting restored native vegetation.

In-channel mining, floodplain gravel mining, soil loss, altered topography, and reduced floodplain inundation associated with mining leave a long-lasting legacy that suppresses recolonization of the floodplain areas with native riparian species along the lower Tuolumne River corridor. Several restoration projects, found mostly along reaches 4, 5 and 6 (river miles 24 to 46) have resulted in local improvements, although even these areas are patchworks of native vegetation interspersed with weeds and bare soil. Nevertheless, these restoration sites clearly demonstrate that some of the ecological functions can be returned to reaches that have been degraded by historical floodplain alteration, mining and dredger tailing deposits.

The ongoing differences between the existing hydrograph and a hydrograph that supports native riparian species (e.g. high annual peak flows and slow descending limb during spring and late summer), continues to limit recruitment and survival of important native riparian species expected to dominate Central Valley riparian forests and shrub lands, such as Fremont cottonwood, Goodding’s black willow, shining and red willow. The growth and survival of these species in large, actively replanted restoration sites (e.g. Grayson Ranch and Big Bend) demonstrate that active restoration can be a workable means of bringing these native community types back to the lower Tuolumne River.

In summary, riparian vegetation along the lower Tuolumne has increased by approximately 18 percent since it was last mapped in 1997, in large part due to steady survival of existing vegetation and to active planting on several restoration sites within the riparian corridor. Physical conditions and processes in the lower Tuolumne River are currently supporting some native riparian species, such as narrow-leaf willow and box elder, while not supporting natural recruitment of other native riparian plants, such as Fremont cottonwood. Some of the most important changes in physical conditions causing ongoing limitation of the recruitment and survival of native riparian vegetation are, in rough order of importance on a spatial basis:

(1) Access to the floodplain (land use change, levees along reaches 1 and 2);

(2) Legacy effects of dredger mining and tailing deposits (reaches 4, 5, and 6)

(3) Ongoing gravel mining operations in the floodplain (reaches 3, 4, and 5)

(4) Changes in the hydrograph and sediment delivery (reaches 1–7)

7.0 STUDY VARIANCES AND MODIFICATIONS

This study has been modified to be consistent with the 25 July 2012 FERC approved Study Plan revision, to include an update of the 1996 riparian vegetation inventory originally performed by McBain and Trush (2000). This modification, repeated below, includes alteration to the originally proposed methods, as described below (and detailed in Section 4.3 Riparian Vegetation Inventory Update):

> *Step 3 – Riparian Vegetation Inventory Update. GIS maps of the riparian inventory of the lower Tuolumne River developed in 1996–1997 for the Tuolumne River Restoration Plan (McBain and Trush 2000) will be updated using aerial photo-interpretation of imagery to be collected during spring 2012. Limited on-the-ground validation of vegetation mapping will be conducted in areas where vegetation distribution has changed from previous surveys. Factors contributing to the current distribution of riparian species will be assessed in the final report (Study Plan W&AR-19, revised on February 24, 2012).*

There were no variances to the modified study plan.

8.0 REFERENCES

Alpert, P., E. Bone, and C. Holzapfel. 2000. Invasiveness, invasibility and the role of environmental stress in the spread of non-native plants. Perspectives in Plant Ecology, Evolution and Systematics 3:52–66.

American Farmland Trust. 1995. Alternatives for Future Urban Growth in California's Central Valley: the bottom line for agriculture and taxpayers. Summary Report. October 1995. Published by AFT, Washington, D.C. and Davis, California.

Auble, G.T., J.M. Friedman, and M.L. Scott. 1994. Relating riparian vegetation to present and future streamflows. Ecological Applications 4: 544–554.

Auble, G.T., and M.L. Scott. 1998. Fluvial disturbance patches and cottonwood recruitment along the upper Missouri River, Montana. Wetlands 18: 546–556.

Baldwin, B.G., D.H. Goldman, D.J. Keil, R. Patterson, and T.J. Rosatti, editors. 2012. The Jepson manual: vascular plants of California. Second edition. University of California Press, Berkeley.

Bean, C., and M.J. Russo. 1986. Element stewardship abstract for *Eucalyptus globulus* (Tasmanian blue gum). The Nature Conservancy, Arlington, Virginia. http://members.lycos.co.uk/WoodyPlantEcology/invasive/invasive.htm.

Bell, G.P. 1994. Biology and growth habits of giant reed (*Arundo donax*). Pages 1–6 *in* N. E. Jackson, P. Frandsen, and S. Douthit, editors. *Arundo donax* Workshop Proceedings, November 19, 1993, Ontario, California.

Bell, G.P. 1997. Ecology and management of *Arundo donax*, and approaches to riparian habitat restoration in southern California. Pages 103–113 *in* J. H. Brock, M. Wade, P. Pysek, and D. Green, editors. Plant invasions: studies from North America and Europe. Blackhuys Publishers, Leiden, The Netherlands.

Bendix, J. 1999. Stream power influence on southern California riparian vegetation. Journal of Vegetation Science. 10: 243–252.

Boose, A.B., and J.S. Holt. 1999. Environmental effects on asexual reproduction in *Arundo donax*. Weed Research 39:117–127.

Braatne, J.H., R. Jamieson, K.M. Gill, and S.B. Rood. 2007. Instream flows and the decline of riparian cottonwoods. River Research and Applications 23: 247–267.

Brooks, M.L., C.M. D'Antonio, D.M. Richardson, J.B. Grace, J.E. Keeley, J.M. DiTomaso, R.J. Hobbs, M. Pellant, and D. Pyke. 2004. Effects of invasive alien plants on fire regimes. Bioscience 54: 677–688.

Busch, D.C., and S.D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the southwestern U. S. Ecological Monographs 65: 347–370.

California Department of Fish and Game. 2008. Legislative Analyst's Office Supplemental Report of the 2007 Budget Act: FY 2007-08, Item 3600-001-0001 Department of Fish and Game. Vegetation Mapping Standard for the State of California. 12 pp.

Campbell, C.J., and W. Green. 1968. Perpetual succession of stream-channel vegetation in a semiarid region. Journal of the Arizona Academy of Science 5: 86–95.

Cayan, D.R., S. Kammerdiener, M.D. Dettinger, J.M. Caprio, and D.H. Peterson. 2001. Changes in the onset of spring in the western United States. Bulletin of the American Meteorological Society 82: 399–415.

Coffman, G.C. 2007. Factors influencing invasion of giant reed (*Arundo donax*) in riparian ecosystems of Mediterranean-type climates. Doctoral dissertation, University of California, Los Angeles.

Coffman, G.C., R.F. Ambrose, and P.W. Rundel. 2010. Wildfire promotes giant reed (*Arundo donax*) invasion in riparian ecosystems. Biological Invasions 12: 2,723–2,734.

Cooper, C.B., and J.R. Walters. 2002. Experimental evidence of disrupted dispersal causing decline of an Australian passerine in fragmented habitat. Conservation Biology 16: 471–478.

Corbin, J., and C.M. D'Antonio. 2004. Effects of invasive species on soil nitrogen cycling: implications for restoration. Weed technology 18: 1,464–1,467.

D'Antonio, C.M., and S. Hobbie. 2005. Plant species effects on ecosystem processes: insights from invasive species. *In* D. Sax, J. Stackowich, and S. Gaines, editors. Insights from invasive species. Sinauer, Sunderland, Massachusetts.

DeFeo, V. L. De Martino, E. Quaranta, and C. Pizza. 2003. Isolation of phytotoxic compounds from tree-of-heaven (*Ailanthus altissima* Swingle). Journal of Agricultural and Food Chemistry. 51: 1177-1180.

DeWine, J.M., and D.J. Cooper. 2007. Effects of river regulation on riparian box elder (*Acer negundo*) forests in canyons of the Upper Colorado River Basin, USA. Wetlands 27: 278–289.

DiTomaso J.M., and E.A. Healy. 2007 Weeds of California and Other Western States. Oakland, CA. University of California Division of Agriculture and Natural Resources.

Dixon, M.D. 2003. Effects of flow pattern on riparian seedling recruitment on sandbars in the Wisconsin River, Wisconsin, USA. Wetlands 23: 125–139.

Dudley, T. 2000. *Arundo donax*. *In* C. Bossard, J. Randall, and M. Hoshovsky, editors. Invasive plants of California's wildlands. University of California Press, Berkeley.

Else, J.A. 1996. Post-flood establishment of native woody species and an exotic, *Arundo donax*, in a Southern California riparian system. Master's thesis. San Diego State University, San Diego, California.

Else, J.A., and P. Zedler. 1996. Dynamics of the flood disturbed zone of a riparian system: vegetative establishment and resprouting of woody native species and the exotic, *Arundo donax*. Bulletin of the Ecological Society of America 77: 129.

Franz, E.H., and F.A. Bazzaz. 1977. Simulation of vegetation response to modified hydrologic regimes: a probabilistic model based on niche differentiation in a floodplain forest. Ecology 58: 176–183.

Friedman, J.M., W.R. Osterkamp, and W.M. Lewis, Jr. 1996. Channel narrowing and vegetation development following a Great Plains flood. Ecology 77: 2,167–2,181.

Friedman, J.M., W.R. Osterkamp, M.L. Scott, and G.T. Auble. 1998. Downstream effects of dams on channel geometry and bottomland vegetation: regional patterns in the Great Plains. Wetlands 18: 619–633.

Friedman, J.M., G.T. Auble, P.B. Shafroth, M.L. Scott, M.F. Merigliano, M.D. Freehling, and E.R. Griffin. 2005. Dominance of non-native riparian trees in western USA. Biological Invasions 7: 747–751.

Friedman, J. M., G.T. Auble, E.D. Andrews, G. Kittel, R.F. Madole, E.R. Griffin, and T.M. Allred. 2006. Transverse and longitudinal variation in woody riparian vegetation along a mountane river. Western North American Naturalist 66: 78–91.

Friends of the Tuolumne. 2010. Project details for Bobcat Flat and Grayson River Ranch. Friends of the Tuolumne, Bend, Oregon. http://www.friendsofthetuolumne.org.

Fuller, A.N., and M. Simpson. 2005. Presence, relative abundance, and distribution of fishes at Grayson River Ranch. Draft Report. Prepared for East Stanislaus Resource Conservation District by S. P. Cramer & Associates, Gresham, Oregon.

Furguson L., T.J. Michailides, and H.H. Shorey. 1990. The California fig industry. *In* J. Janick, editor. Horticultural Reviews 12. Timber Press, Portland, Oregon.

Gardali, T., A.L. Holmes, S.L. Small, N. Nur, G.R. Geupel, and G.H. Golet. 2006. Abundance patterns of landbirds in restored and remnant riparian forests on the Sacramento River, California, USA. Restoration Ecology 14: 391–403.

Grant, G.E., J.C. Schmidt, and S.L. Lewis. 2003. A geological framework for interpreting downstream effects of dams on rivers. Pages 209–225 *in* J. E. O'Connor and G. E. Grant, editors. A peculiar river: Geology, geomorphology, and hydrology of the Deschutes River, Oregon. Water Science and Application Series No. 7. American Geophysical Union, Washington, D.C.

Grime, J.P. 1977. Evidence for the existence of three primary strategies in plants and its relevance to ecological and evolutionary theory. The American Naturalist 111: 1,169–1,194.

Guilloy, H., E. González, E. Muller, F.M.R. Hughes, and N. Barsoum. 2011. Abrupt drops in water table level influence the development of *Populus nigra* and *Salix alba* Seedlings of Different Ages. Wetlands. 31: 1,249–1,261.

Gurnell, A.M., K. Tockner, P. Edwards, and G. Petts. 2005. Effects of deposited wood on biocomplexity of river corridors. Frontiers in Ecology and the Environment 3: 377–382.

Heisey R.M. 1996. Identification of an allelopathic compound from *Ailanthus altissima* (Simaroubaceae) and characterization of its herbicidal activity. American Journal of Botany 83: 192–200.

Herrera, A.M., and T.L. Dudley. 2003. Reduction of riparian arthropod abundance and diversity as a consequence of giant reed (*Arundo donax*) invasion. Biological Invasions 5: 167–177.

Hickson D., and T. Keeler-Wolf. 2007. Vegetation and land use classification and map of the Sacramento-San Joaquin River Delta. Prepared by California Department of Fish and Game, Vegetation Classification and Mapping Program for the Bay Delta Region, California Department of Fish and Game.

Holt, J. 2002. Biology and ecology of giant reed. Proceedings of the California Weed Science Society.

Hoshovsky, M. 1999. Element stewardship abstract for tree-of-heaven. The Nature Conservancy.

Johnson, W.C. 1994. Woodland expansion in the Platte River, Nebraska: patterns and causes. Ecological Monographs 64: 45–84.

Johnson, W.C. 2000. Tree recruitment and survival in rivers: influence of hydrologic processes. Hydro Processes 14: 3,051–3,074.

Junk, W.J., P.B. Bayley, and R.E. Sparks. 1989. The flood pulse concept in river-floodplain systems. Pages 110–127 *in* D. P. Dodge, editor. Proceedings of the international large river symposium. Canadian Special Publication of Fisheries and Aquatic Sciences 106.

Kalischuk, A.R., S.B. Rood, and J.M. Mahoney. 2001. Environmental influences on seedling growth of cottonwood species following a major flood. Forest Ecology and Management. 144: 75–89.

Kapnick S., and A. Hall. 2009. Observed changes in the Sierra Nevada snowpack: potential causes and concerns. Prepared for the CEC and Cal/EPA. CEC-500- 2009-016-D.

Karrenberg, S., P.J. Edwards, and J. Kollmann. 2002. The life history of Salicaceae living in the active zone of floodplains. Freshwater Biology 47: 733–748.

Katibah, E.F. 1984. A brief history of riparian forests in the Central Valley of California. Pages 23–29 *in* R. E. Warner and K. M. Hendrix, editors. California riparian systems: ecology, conservation, and productive management. University of California Press, Berkeley.

Kisner, D.A. 2004. The effect of giant reed (*Arundo donax*) on the southern California riparian bird community. Master's thesis, San Diego State University, San Diego, California.

Kjellberg, F., P.H. Gouyon, M. Ibrahim, M. Raymond, and G. Valdeyron. 1987. The stability of the symbiosis between dioecious figs and their pollinators: a study of *Ficus carica* L. and *Blastophaga psenes* International Journal of Organic Evolution 41: 693–704.

Knowles, N., and D. Cayan. 2002. Potential effects of global warming on the Sacramento/San Joaquin watershed and the San Francisco Estuary. Geophysical Research Letters 29.

Kondolf, G.M. 1997. Hungry water: effects of dams and gravel mining on river channels. Environmental Management 21: 533–551.

Kowarik, I. 1995. The clonal growth of *Ailanthus altissima* on a natural site in West Virginia. Journal of Vegetation Science 6: 853–856.

Labinger, Z., and J. Greaves. 2001. Results of 2000 avian surveys and Least Bell's vireo monitoring: restoration phase of the ARCO/Four Corners January 17, 1994 oil spill on the Santa Clara River, California. Prepared for U. S. Fish and Wildlife Service, Ventura, California.

Ligon, F.K., W.E. Dietrich, and W.J. Trush. 1995. Downstream ecological effects of dams: a geomorphic perspective. BioScience 45: 183–192.

Lytle, D.A., and D.M. Merritt. 2004. Hydrologic regimes and riparian forests: a structured population model for cottonwood. Ecology 85: 2,493–2,503.

Lytle, D.A., and N.L. Poff. 2004. Adaptation to natural flow regimes. Trends in Ecology and Evolution 19: 94–100.

Mahoney, J.M., and S.B. Rood. 1998. Streamflow requirements for cottonwood seedling recruitment - an integrative model. Wetlands 18: 634–645.

Maurer, E.P., I.T. Steward, C. Bonfils, P.B. Duffy, and D. Cayan. 2007. Detection, attribution, and sensitivity of trends toward earlier streamflow in the Sierra Nevada. Journal of Geophysical Research: 112 (D11118).

McBain and Trush. 2000. Habitat restoration plan for the lower Tuolumne River corridor. Final report. Prepared for the Tuolumne River Technical Advisory Committee, with assistance from U.S. Fish and Wildlife Service, Anadromous Fish Restoration Program, Sacramento, California. Arcata, California. California.

McBain and Trush, Inc. (eds.), 2002. San Joaquin River Restoration Study Background Report. Prepared for Friant Water Users Authority, Lindsay, California, and Natural Resources Defense Council, San Francisco, California.

McBain and Trush. 2004a. Coarse sediment management plan for the lower Tuolumne River. Revised final report. Prepared by McBain and Trush, Arcata, California for Tuolumne River Technical Advisory Committee, Turlock and Modesto Irrigation Districts, USFWS Anadromous Fish Restoration Program, and California Bay-Delta Authority.

McBain and Trush. 2004b. Bobcat Flat RM 43 Coarse Sediment Introduction Design Document. Prepared for Friends of the Tuolumne, Inc., California.

McBain and Trush. 2006. Bobcat Flat RM 43 – Phase I As-Built Monitoring Final Report. Prepared for Friends of the Tuolumne, Inc. and Turlock Irrigation District.

McBain and Trush. 2008. Monitoring the impacts on the Tuolumne River from Peaslee Creek Erosion and Runoff Events of January 2008. Prepared for the Turlock Irrigation District.

McBain and Trush. 2011. Bobcat Flat RM 43 Phase II Restoration Final Design Document. Prepared for Friends of the Tuolumne, Inc. CA.

McBain and Trush. 2012. Bobcat Flat RM 43 – Phase II As-Built Draft Report. In Progress. Prepared for Friends of the Tuolumne, Inc.

Meidinger, D.V. 2003. Protocol for accuracy assessment of ecosystem maps. Technical Report 011. B.C. Ministry of Forestry, Victoria, British Columbia.

Merigliano, M.F. 1998. Cottonwood and willow demography on a young island, Salmon River, Idaho. Wetlands 18: 571–576.

Merritt, D.M., and N.L. Poff. 2010. Shifting dominance of riparian *Populus* and *Tamarix* along gradients of flow alteration in western North American rivers. Ecological Applications. 20: 135–152.

Merritt, D.M., and E.E. Wohl. 2002. Processes governing hydrochory along rivers: hydraulics, hydrology, and dispersal phenology. Ecological Applications. 12: 1,071–1,087.

Merritt, D.M., and D.J. Cooper. 2000. Riparian vegetation and channel change in response to river regulation: a comparative study of regulated and unregulated streams in the Green River basin, USA. Regulated Rivers: Research and Management 16: 543–564.

Michailides, T.J., D.P. Morgan, and K.V. Subbarao. 1996. Fig endosepsis: an old disease still a dilemma for California growers. Plant Disease 80: 828–841.

Molina, A,M. J. Reigosa, and A. Carballeira. 1991. Release of allelochemical agents from litter, throughfall, and topsoil in plantations of *Eucalyptus globulus* Labill., in Spain. Journal of Chemical Ecology 17: 147–160.

Mote, P.W., A.F. Hamlet, M.P. Clark, and D.P. Lettenmaier. 2005. Declining mountain snowpack in North America. American Meteorological Society January 2005: 39–49.

Naiman, R.J., H. Decamps, and M.E. McClain. 2005. Riparia: ecology, conservation, and management of streamside communities. Academic Press, New York, New York.

Norris, D.R., and B. J.M. Stutchbury. 2001. Extraterritorial movements of a forest songbird in a fragmented landscape. Conservation Biology 15: 729–736.

Null, S.E., J.H. Viers, and F. Mount. 2010. Hydrologic response and watershed sensitivity to climate warming in California's Sierra Nevada. PLos ONE 5(4) e9932. doi:10.1371/journal.pone.0009932.

Polzin, M.L., and S.B. Rood. 2006. Effective disturbance: seedling safe sites and patch recruitment of riparian cottonwoods after a major flood of a mountain river. Wetlands 26: 965–980.

Randall, J.M. 2004. CALIPC Species evaluation form for *Ficus carica* recruitment along the St. Mary River, Alberta, Canada. Rivers 7: 109–125.

RHJV (Riparian Habitat Joint Venture). 2004. Version 2.0. The riparian bird conservation plan: a strategy for reversing the decline of riparian associated birds in California. California Partners in Flight.

Rieger, J.P., and D.A. Kreager. 1989. Giant reed (*Arundo donax*): a climax community of the riparian zone. Pages 222–225 *in* D.L. Abell, editor. Proceeding of the California riparian systems conference: protection, management, and restoration for the 1990s. USDA Forest Service General Technical Report PSW-110, Berkeley, California.

Rood, S.B., J.H. Braatne, and F.M.R. Hughes. 2003a. Ecophysiology of riparian cottonwoods: stream flow dependency, water relations and restoration. Tree Physiology 23: 1,113–1,124.

Rood, S.B., C.R. Gourley, E.M. Ammon, L.G. Heki, J.R. Klotz, M.L. Morrison, D. Mosley, G.G. Scoppettone, S. Swanson, and P.L. Wagner. 2003b. Flows for floodplain forests: a successful riparian restoration. BioScience 53: 647–656.

Rood, S.B., G.M. Samuelson, J.H. Braatne, C.R. Gourley, F.M. R. Hughes, and J.M. Mahoney. 2005. Managing river flows to restore floodplain forests. Frontiers in Ecology and the Environment 3: 193–201.

Rose, G. 2000. The San Joaquin: A River Betrayed. Word Dancer Press, Clovis, CA, 150 pp. *As cited in McBain and Trush (Eds) 2002*.

San Joaquin River Group Authority. 1998. Meeting flow objectives for the San Joaquin River Agreement 1999-2010. Final Environmental Impact Statement and Environmental Impact Report.

Sawyer, J.O., T. Keeler-Wolf, and J.M. Evens. 2009. A manual of California vegetation. Second edition. California Native Plant Society in collaboration with California Department of Fish and Game, Sacramento, California.

Scoggin, S.E., T. Gardali, and G.R. Geupel. 2000. Assessment of songbird response to cape-ivy removal in the Redwood Creek watershed: a progress report to the Golden Gate National Recreation Area. March 2000. Point Reyes Bird Observatory, Stinson Beach, California.

Scott, G. 1994. Fire threat from *Arundo donax*. Pages 17–18 *in* N. E. Jackson, P. Frandsen, and S. Douthit, editors. *Arundo donax* workshop proceedings, Ontario, California.

Scott, M.L., J.M. Friedman, and G.T. Auble. 1996. Fluvial process and the establishment of bottomland trees. Geomorphology 14: 327–339.

Seavy, N.E., J.H. Viers, and J.K. Wood. 2009. Riparian bird response to vegetation structure: a multiscale analysis using LiDAR measurements of canopy height. Ecological Applications 19: 1,848–1,857.

Shafroth, P.B., J.M. Freidman, and L.S. Ischinger. 1995. Effects of salinity on establishment of *Populus fremontii* (cottonwood) and *Tamarix ramosissima* (saltcedar) in southwestern United States. Great Basin Naturalist 55: 58–65.

Shafroth, P.B., G. T. Auble, J.C. Stromberg, and D. Patten. 1998. Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona. Wetlands 18: 577–590.

Shafroth, P.B., J.C. Stromberg, and D.T. Patten. 2002. Riparian vegetation response to altered disturbance and stress regimes. Ecological Applications 12: 107–123.

Shanfield, A.N. 1984. Alder, cottonwood, and sycamore distribution and regeneration along the Nacimiento River, California. *In* R.E. Warner and K.M. Hendrix, editors. California riparian systems: ecology, conservation, and productive management. University of California Press, Berkeley.

State of California. 2007. Department of Finance, Population Projections by Race/Ethnicity for California and Its Counties, 2000-2050.

Stella, J.C. 2005. A field-calibrated model of pioneer riparian tree recruitment for the San Joaquin Basin, CA. Doctoral dissertation. University of California, Berkeley.

Stella, J.C., J.J. Battles, B.K. Orr, and J.R. McBride. 2006. Synchrony of seed dispersal, hydrology, and locate climate in a semi-arid river reach in California. Ecosystems 9: 1,200.

Stella, J.C., J.J. Battles, J.R. McBride, and B.K. Orr. 2010. Riparian seedling mortality from simulated water table recession, and the design of sustainable flow regimes on regulated rivers. Restoration Ecology 18: 284–294.

Stella, J.C., M.K. Hayden, J.J. Battles, H. Piégay, S. Dufour, and A.K. Fremier. 2011. The role of abandoned channels as refugia for sustaining pioneer riparian forest ecosystems. Ecosystems 14: 776–790.

Stewart, I.T., D.R. Cayan, and M.D. Dettinger. 2005. Changes toward earlier streamflow timing across western North America. Journal of Climate 18: 1,136–1,155.

Stillwater Sciences. 1998. Tuolumne River restoration projects: biological resources technical background report. Prepared by Stillwater Ecosystem, Watershed & Riverine Sciences, Berkeley, California for EDAW, San Francisco, California.

Stillwater Sciences. 2006. Restoring recruitment processes for riparian cottonwoods and willows: a field calibrated predictive model for the lower San Joaquin Basin. Brochure and Final Report. Prepared by Stillwater Sciences, Berkeley, California in conjunction with Department of Environmental Science, Policy, and Management, University of California, Berkeley for CALFED Bay-Delta Ecosystem Restoration Program, Sacramento, California.

Stillwater Sciences. 2007. Merced River Ranch revegetation experiment. Prepared for CALFED, Sacramento, California. Berkeley, California.

Stillwater Sciences. 2008. Big Bend restoration project: results of post-project monitoring, 2005–2007. Final Technical Memorandum. Prepared for Tuolumne River Trust, Modesto, California. Berkeley, California.

Stromberg, J. 2001. Restoration of riparian vegetation in the south-western United States: importance of flow regimes and fluvial dynamism. Journal of Arid Environments. 49:17–34.

Stromberg, J., J. Stutz, S. Lite, V. Beauchamp, and G. Katz. 2002. Natural recovery of native riparian tree species to exotic-dominated sites: influence of physical processes and biotic interactions. Project No. NR-02-02. Southwest Center for Environmental Research and Policy, San Diego, California.

Thompson, K. 1961. Riparian forests of the Sacramento Valley, California. Annals of the Association of American Geographers 51: 294–315.

TID/MID (Turlock Irrigation District and Modesto Irrigation District). 2006. 2006 Lower Tuolumne River Annual Report. Special Run Pool 9 and 7/11 Reach: Post-Project Monitoring Synthesis Report. Prepared by McBain & Trush and Stillwater Sciences for TID/MID.

Tockner, K., D. Pennetzdorfer, and J.V. Ward. 1999. Hydrological connectivity, and the exchange of organic matter and nutrients in a dynamic river floodplain system (Danube, Austria). Freshwater Biology 41: 521–536.

USFWS (U.S. Fish and Wildlife Service). 2001. Final Restoration Plan for the Anadromous Fish Restoration Program: a plan to increase natural production of anadromous fish in the Central Valley of California. January 9, 2001.

USFWS. 1995. Working Paper on Restoration Needs. Habitat restoration actions to double natural production of anadromous fish in the Central Valley of California, Volumes 1, 2, 3. May 9, 1995. Stockton CA.

Vaghti, M., and S. Greco 2007. Riparian Vegetation of the Great Valley. Chapter 16 *in* Terrestrial Vegetation of California, 3rd Edition. Edited by M. Barbour, T. Keeler-Wolf, and A. Schoenherr. University of California Press, Berkeley.

Ward, J.V., and J.A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management 11: 105–119.

Warner, P.J. 2004. CALIPC Species evaluation form for *Eucalyptus globulus*.

Warner, R.E. 1984. Structural, floristic, and condition inventory of Central Valley riparian systems. Pages 356–374 *in* R.E. Warner and K.M. Hendrix, editors. California riparian systems: ecology, conservation, and productive management. University of California Press, Berkeley.

Watson, K. 2000. The effect of eucalyptus and oak leaf extracts on California native plants. Environmental Sciences Program – College of Natural Resources, University of California, Berkeley.

Williams, G.P., and M.G. Wolman. 1984. Downstream effects of dams on alluvial rivers. Geological Survey Professional Paper 1286. U.S. Geological Survey, Washington, D.C.

Wijte, A.H.B.M., T. Mizutani, E.R. Motamed, M.L. Merryfield, D.E. Miller, and D.E. Alexander. 2005. Temperature and endogenous factors cause seasonal patterns in rooting by stem fragments of the invasive giant reed, *Arundo donax* (Poaceae). International Journal of Plant Sciences 166: 507–517.

Yarnell, S.M., J. Viers, and J. Mount. 2010. Ecology and management of the spring snowmelt recession. BioScience 60: 114–127.

Young, C.A., M. Escobar, M. Fernandes, B. Joyce, M. Kiparsky, J. Mount, V. Mehta, J. Viers, and D. Yates. 2009. Modeling the hydrology of climate change in California's Sierra Nevada for sub-watershed scale adaptation. Journal of American Water Resources Association 45: 1,409–1,423.

STUDY REPORT W&AR-19
LOWER TUOLUMNE RIVER RIPARIAN INFORMATION AND SYNTHESIS

ATTACHMENT A

LITERATURE REVIEWED

Table A-1. Literature sources reviewed for lower Tuolumne Riparian Information and Synthesis Study.

References	**3.1 Historical Riparian Vegetation**	**3.2 Current Riparian Vegetation**	**4.1 Natural History and Succession in Native Riparian Plant Communities**	**4.2 Land Clearing and Land Use Change**	**4.3 Levees and Flood Control**	**4.4 Aggregate Extraction and Dredger mining**	**4.5 Invasive Plant Species**	**4.6 Changes in the Hydrograph**	**4.7 Changes in Sediment Delivery and Availability of Riparian Surfaces**	**4.8 Climate Change**
Alpert et al. 2000	--	--	--	--	--	--	√	--	--	--
American Farmland Trust 1995	--	--	--	√	--	--	--	--	--	--
Auble et al. 1994	--	--	√	--	--	--	--	--	--	--
Auble and Scott 1998	--	--	√	--	--	--	--	√	√	--
Baldwin et al. 2012	--	√	--	--	--	--	--	--	--	--
Bean and Russo 1986	--	--	--	--	--	--	√	--	--	--
Bell 1994	--	--	--	--	--	--	√	--	--	--
Bell 1997	--	--	--	--	--	--	√	--	--	--
Bendix 1999	--	--	--	--	--	--	--	√	--	--
Boose and Holt 1999	--	--	--	--	--	--	√	--	--	--
Braatne et al. 2007	--	--	--	--	--	--	--	√	--	--
Brooks et al. 2004	--	--	--	--	--	--	√	--	--	--
Busch and Smith 1995	--	--	--	--	--	--	√	--	--	--
Campbell and Green 1968	--	--	√	--	--	--	--	√	--	--
Cayan et al. 2001	--	--	--	--	--	--	--	--	--	√
CDFG 2008	--	√	--	--	--	--	--	--	--	--
Coffman 2007	--	--	--	--	--	--	√	--	--	--
Coffman et al. 2010	--	--	--	--	--	--	√	--	--	--
Cooper and Walters 2002	--	--	√	--	--	--	--	--	--	--
DeWine and Cooper 2007	--	--	√	--	--	--	--	√	--	--
DiTomaso and Healey 2007	--	--	--	--	--	--	√	--	--	--
Dixon 2003	--	--	--	--	--	--	--	√	--	--
Dudley 2000	--	--	--	--	--	--	√	--	--	--
Else 1996	--	--	--	--	--	--	√	--	--	--
Else and Zedler 1996	--	--	--	--	--	--	√	--	--	--
Franz and Bazzaz 1977	--	--	√	--	--	--	--	--	--	--
Friedman et al. 1996	--	--	--	--	--	--	--	√	--	--
Friedman et al. 1998	--	--	--	√	--	--	--	√	--	--
Friedman et al. 2005	--	--	--	--	--	--	√	--	--	--
Friedman et al. 2006	--	--	√	--	--	--	--	--	--	--
Friend of the Tuolumne 2010	--	√	--	--	--	--	--	--	--	--
Fuller and Simpson 2005	--	√	--	--	--	--	--	--	--	--
Furguson et al. 1990	--	--	--	--	--	--	√	--	--	--
Gardali et al. 2006	--	--	√	--	--	--	--	--	--	--
Grant et al. 2003	--	--	√	√	--	--	--	√	√	--
Grime 1977	--	--	√	--	--	--	--	√	--	--
Gurnell et al. 2005	--	--	√	--	--	--	--	--	√	--
Heisey 1996	--	--	--	--	--	--	√	--	--	--
Herrera and Dudley 2003	--	--	--	--	--	--	√	--	--	--

References	3.1 Historical Riparian Vegetation	3.2 Current Riparian Vegetation	4.1 Natural History and Succession in Native Riparian Plant Communities	4.2 Land Clearing and Land Use Change	4.3 Levees and Flood Control	4.4 Aggregate Extraction and Dredger mining	4.5 Invasive Plant Species	4.6 Changes in the Hydrograph	4.7 Changes in Sediment Delivery and Availability of Riparian Surfaces	4.8 Climate Change
Hickson and Keeler-Wolf 2007	--	--	--	√	--	--	--	--	--	--
Holt 2002	--	--	--	--	--	--	√	--	--	--
Hoshovsky 1999	--	--	--	--	--	--	√	--	--	--
Johnson 1994	--	--	√	--	--	--	--	√	√	--
Johnson 2000	--	--	--	--	--	--	--	√	--	--
Junk et al. 1989	--	--	--	--	√	--	--	√	--	--
Kalischuk et al. 2001	--	--	--	--	--	--	--	√	--	--
Kapnick and Hall 2009	--	--	--	--	--	--	--	--	--	√
Karrenberg et al. 2002	--	--	√	--	--	--	--	√	--	--
Katibah 1984	√	√	--	√	√	--	--	--	--	--
Kisner 2004	--	--	--	--	--	--	√	--	--	--
Kjellberg et al. 1987	--	--	--	--	--	--	√	--	--	--
Knowles and Cayan 2002	--	--	--	--	--	--	--	--	--	√
Kondolf 1997	--	--	--	--	--	--	--	√	√	--
Kowarik 1995	--	--	--	--	--	--	√	--	--	--
Labinger and Greaves 2001	--	--	--	--	--	--	√	--	--	--
Ligon et al. 1995	--	--	--	--	--	--	--	√	√	--
Lytle and Merritt 2004	--	--	√	--	--	--	--	√	--	--
Lytle and Poff 2004	--	--	--	--	--	--	--	√	--	--
Mahoney and Rood 1998	--	--	√	--	--	--	--	√	--	--
Maurer et al. 2007	--	--	--	--	--	--	--	--	--	√
McBain and Trush 2000	√	√	√	√	√	√	√	√	√	--
McBain and Trush 2002		√	--	--	--	--	--	--	--	--
McBain and Trush 2004a	√	--	--	--	--	--	--	--	√	--
McBain and Trush 2004b	--	√	--	--	--	--	--	--	--	--
McBain and Trush 2006	--	√	--	--	--	--	--	--	--	--
McBain and Trush 2008	--	√	--	--	--	--	--	--	--	--
McBain and Trush 2011	--	√	--	--	--	--	--	--	--	--
McBain and Trush 2012	--	√	--	--	--	--	--	--	--	--
Meidinger et al. 2003	--	√	--	--	--	--	--	--	--	--
Merigliano 1998	--	--	--	--	--	--	--	√	√	--
Merritt and Poff 2010	--	--	--	--	--	--	√	√	--	--
Merritt and Wohl 2002	--	--	--	--	--	--	--	√	--	--
Merritt and Cooper 2000	--	--	--	--	--	--	--	√	--	--
Michailides et al. 1996	--	--	--	--	--	--	√	--	--	--
Molina et al. 1991	--	--	--	--	--	--	√	--	--	--
Mote et al. 2005	--	--	--	--	--	--	--	--	--	√
Naiman et al. 2005	--	--	√	√	--	--	--	√	--	√
Norris et al. 2001	--	--	√	--	--	--	--	--	--	--
Null et al. 2010	--	--	--	--	--	--	--	--	--	√
Polzin and Rood 2006	--	--	√	√	--	--	--	√	√	--

References	**3.1 Historical Riparian Vegetation**	**3.2 Current Riparian Vegetation**	**4.1 Natural History and Succession in Native Riparian Plant Communities**	**4.2 Land Clearing and Land Use Change**	**4.3 Levees and Flood Control**	**4.4 Aggregate Extraction and Dredger mining**	**4.5 Invasive Plant Species**	**4.6 Changes in the Hydrograph**	**4.7 Changes in Sediment Delivery and Availability of Riparian Surfaces**	**4.8 Climate Change**
Randall 2004	--	--	--	--	--	--	√	--	--	--
Rieger and Kreager 1989	--	--	--	--	--	--	√	--	--	--
Rood et al. 2003b	--	--	--	--	--	--	--	√	√	--
Rood et al. 2003a	--	--	--	--	--	--	--	√	--	--
Rood et al. 2005	--	--	√	--	--	--	--	√	√	√
Rose 2000	√	--	--	√	--	--	--	--	--	--
Sawyer and Keeler-Wolf 2009	--	√	--	--	--	--	--	--	--	--
Scott 1994	--	--	--	--	--	--	√	--	--	--
Scott et al. 1996	--	--	√	√	--	--		√	√	--
Shafroth et al. 1995	--	--	--	--	--	--	√	--	--	--
Shafroth et al. 1998	--	--	--	--	--	--	--	√	--	√
Shafroth et al. 2002	--	--	√	--	--	--	--	√	√	--
Shanfield 1984	--	--	--	√	--	--	--	--	--	--
State of California 2007	--	--	--	√	--	--	--	--	--	--
Stella 2005	--	--	--	--	--	--	--	√	--	--
Stella et al. 2006	--	--	√	--	--	--	--	√	--	√
Stella et al. 2010	--	--	√	√	--	--	--	√	--	--
Stella et al. 2011	--	--	√	√	--	--	--	√	--	--
Stewart et al. 2005	--	--	--	--	--	--	--	--	--	√
Stillwater Sciences 1998	--	--	√	--	√	√	--	√	√	--
Stillwater Sciences 2006	--	--	√	--	--	--	--	√	--	√
Stillwater Sciences 2007	--	--	--	--	--	√	--	--	--	--
Stillwater Sciences 2008	--	√	--	--	--	--	--	--	--	--
Stromberg et al. 2002	--	--	--	--	--	--	√	--	--	--
Thompson 1961	√	--	--	--	--	--	--	--	--	--
TID/MID 2006	--	√	--	--	--	--	--	--	--	--
Tockner et al. 1999	--	--	--	--	√	--	--	√	--	--
USFWS 2001	--	--	--	--	--	√	--	√	--	--
Vaghti and Greco 2007	--	--	--	--	--	--	--	√	--	--
Ward and Stanford 1995	--	--	√	--	--	--	--	√	--	--
Warner 2004	--	--	--	--		--	√	--	--	--
Warner 1984	√	√	--	--	√	--		--	--	--
Watson 2000	--	--	--	--	--	--	√	--	--	--
Williams and Wolman 1984	--	--	--	--	--	--		--	√	--
Wijte et al. 2005	--	--	--	--	--	--	√	--	--	--
Yarnell et al. 2010	--	--	--	--	--	--		√	--	√
Young et al. 2009	--	--	--	--	--	--	--	--	--	√

STUDY REPORT W&AR-19

LOWER TUOLUMNE RIVER RIPARIAN INFORMATION AND SYNTHESIS

ATTACHMENT B

EXISTING RIPARIAN VEGETATION MAPS FOR REACHES 1-7 ALONG THE LOWER TUOLUMNE RIVER

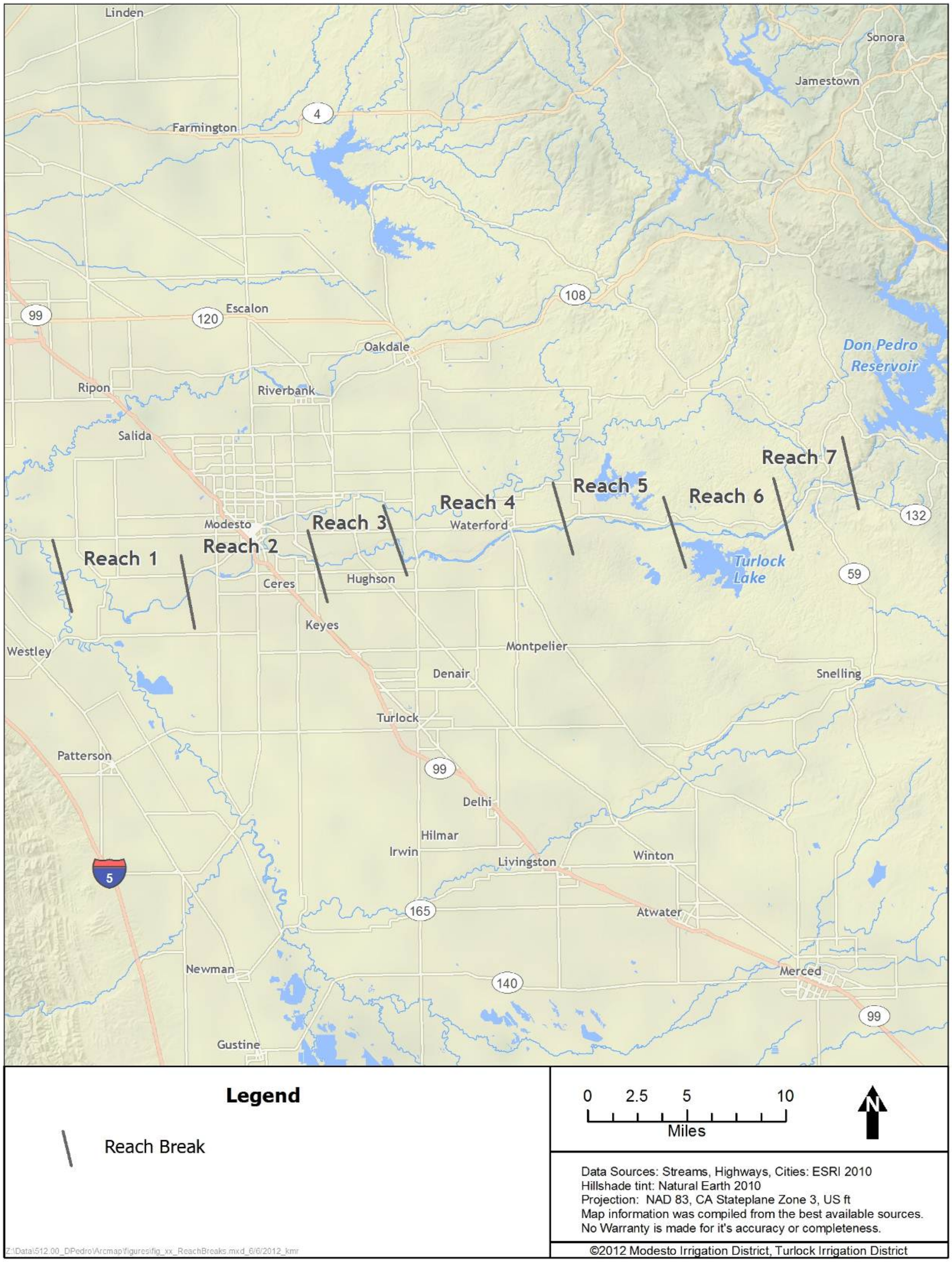

Figure B-1. Reach break locations for Reaches 1-7 along the lower Tuolumne River.

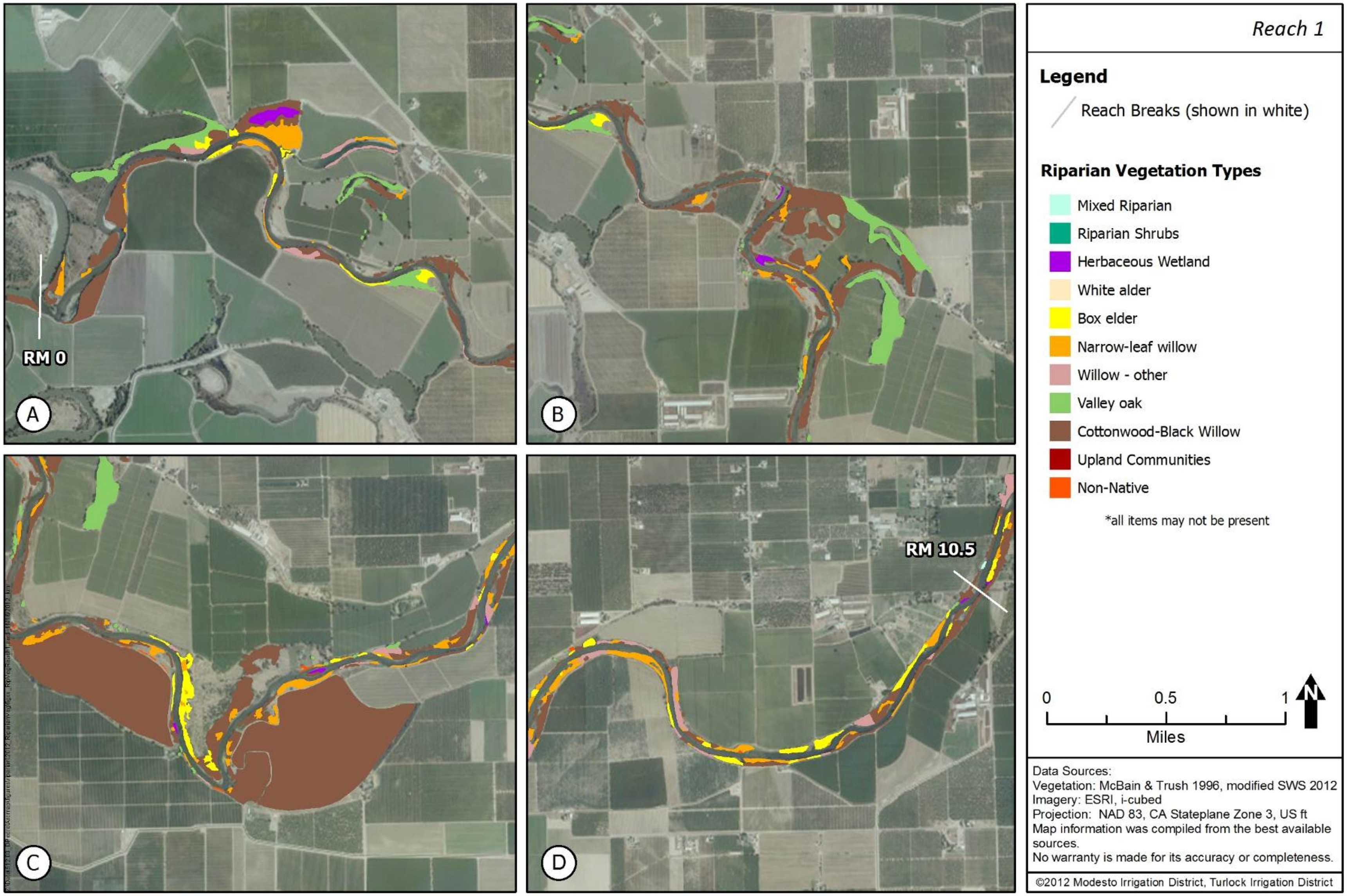

Figure B-2. Existing vegetation mapped along Reach 1 of the lower Tuolumne River.

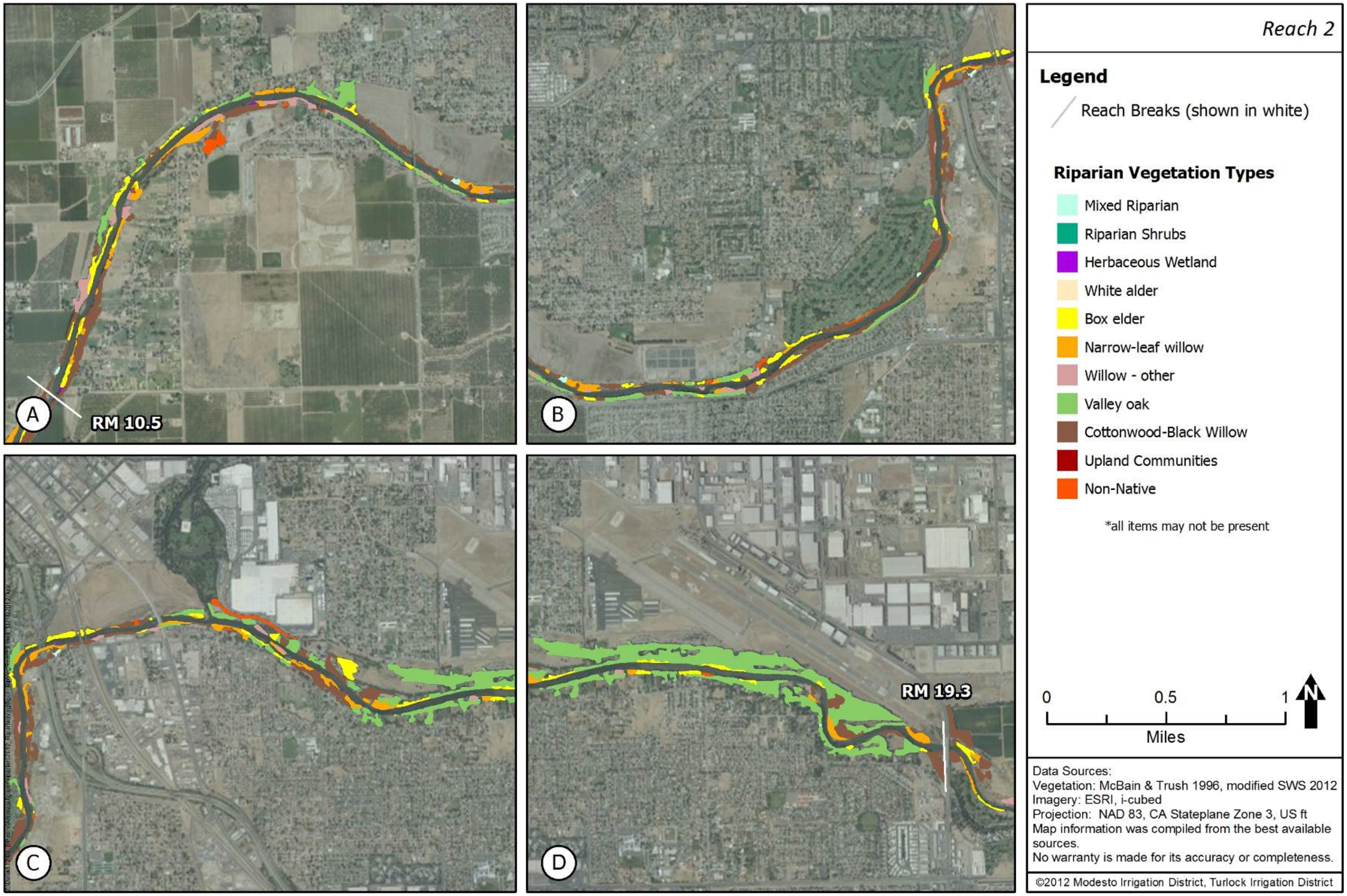

Figure B-3. Existing vegetation mapped along Reach 2 of the lower Tuolumne River.

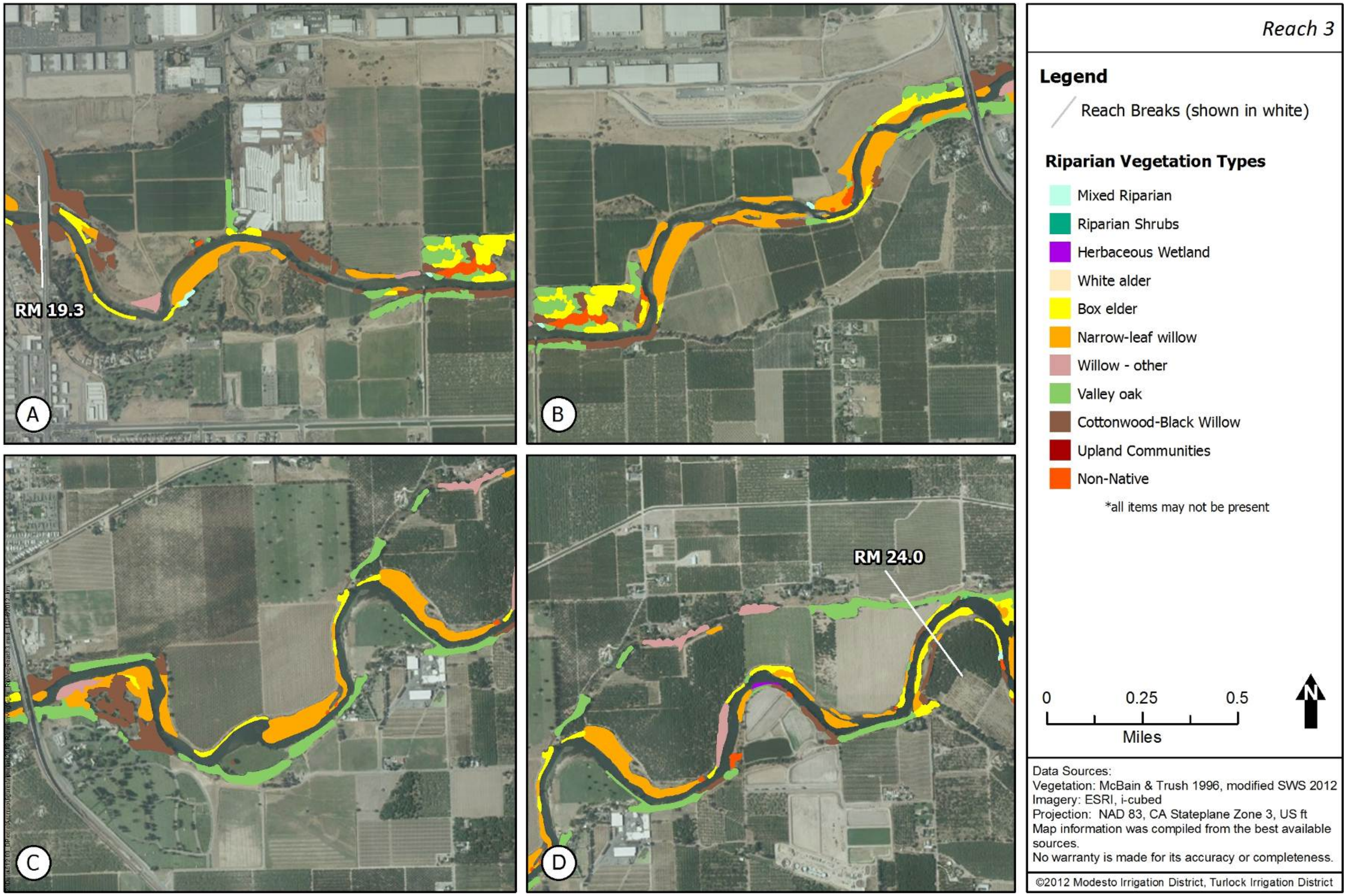

Figure B-4. Existing vegetation mapped along Reach 3 of the lower Tuolumne River.

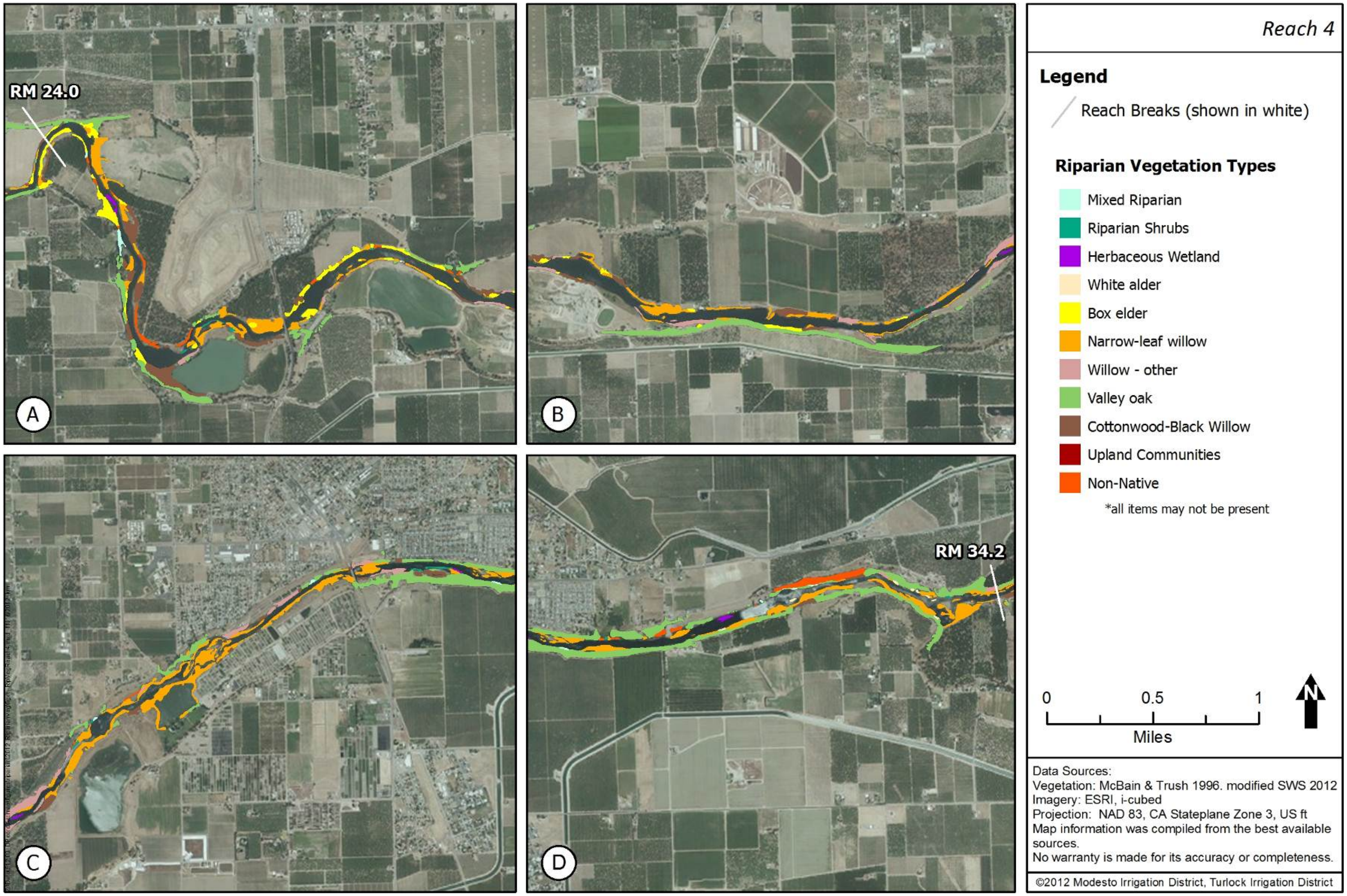

Figure B-5. Existing vegetation mapped along Reach 4 of the lower Tuolumne River.

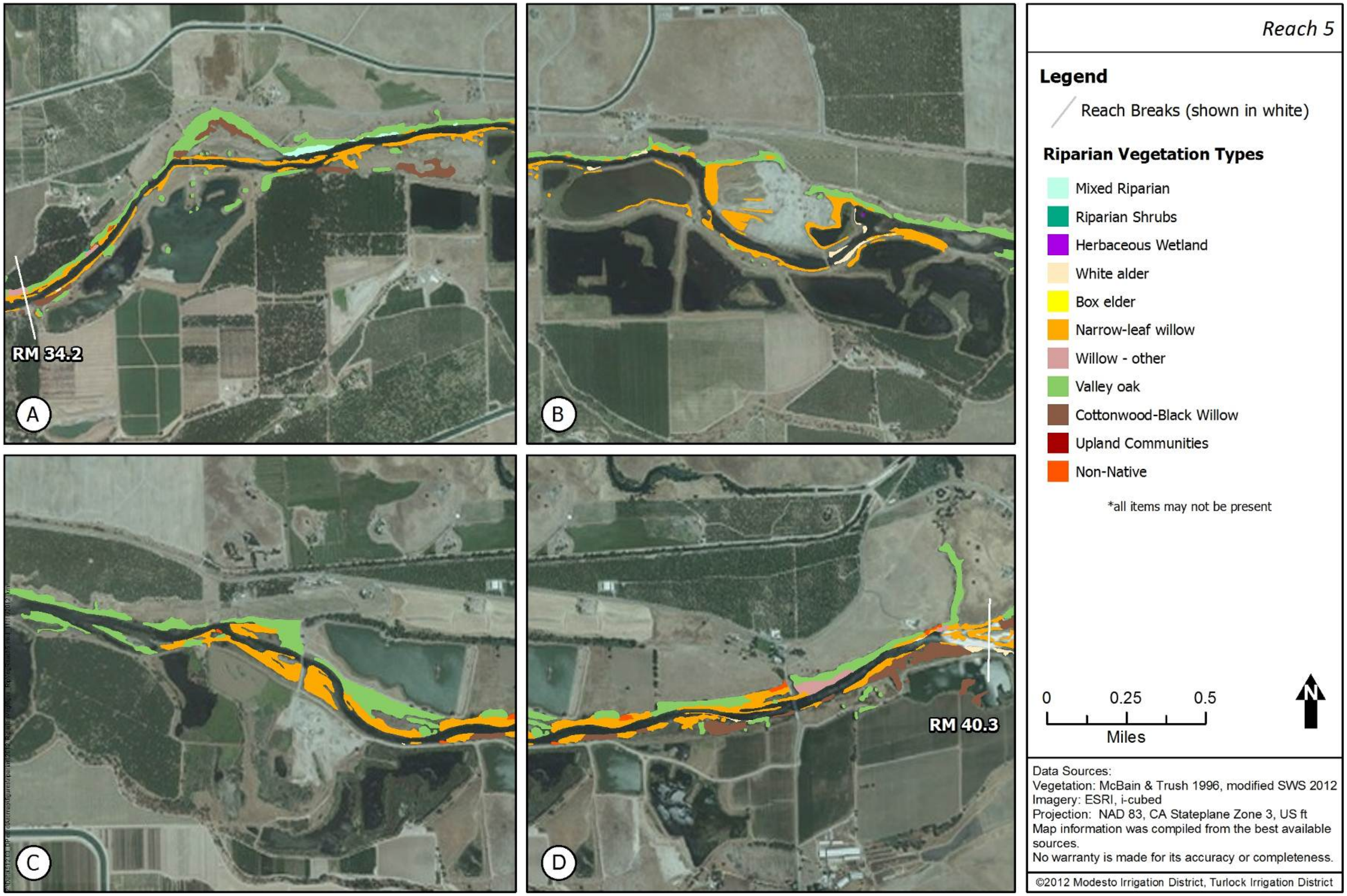

Figure B-6. Existing vegetation mapped along Reach 5 of the lower Tuolumne River.

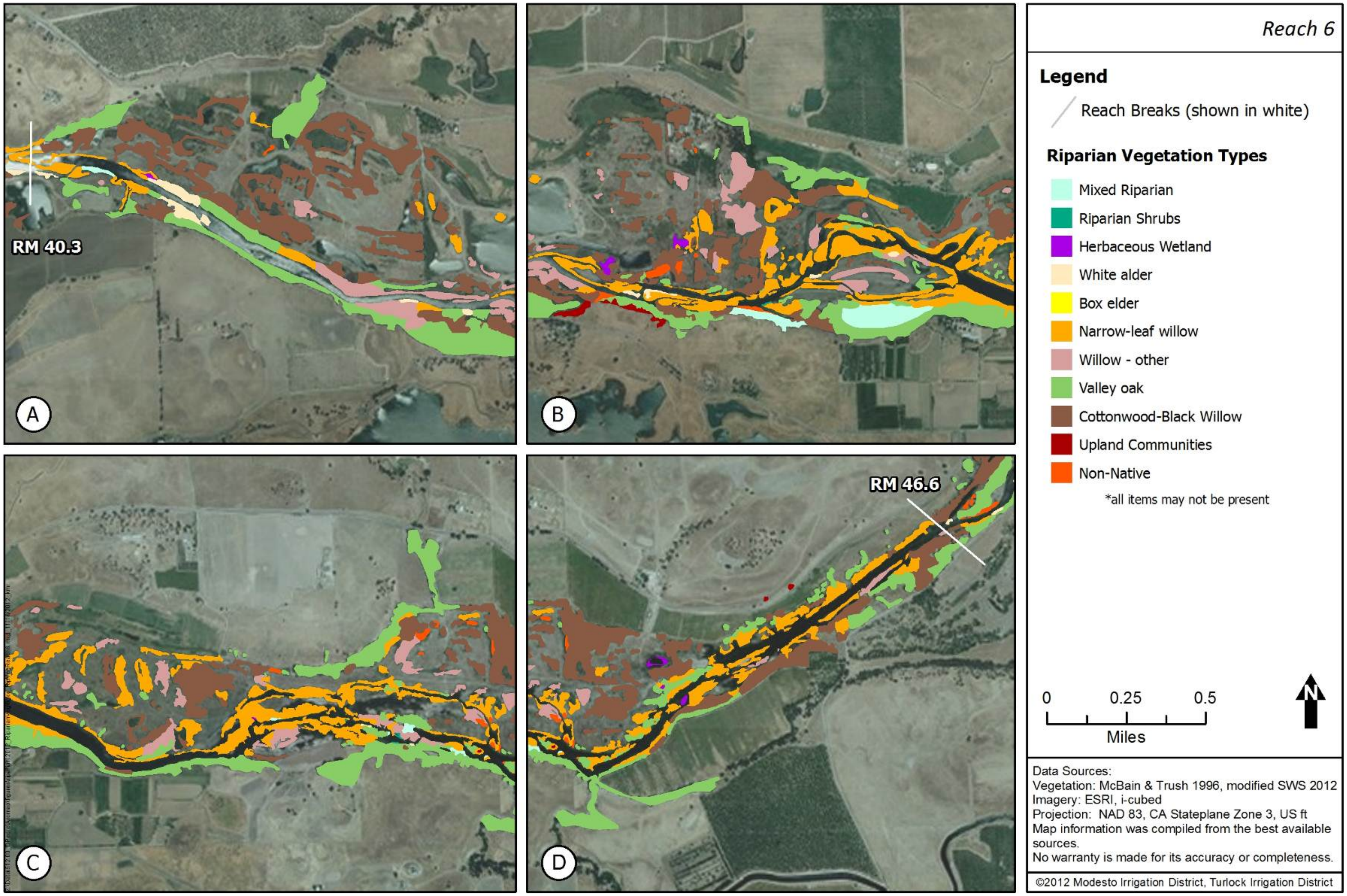

Figure B-7. Existing vegetation mapped along Reach 6 of the lower Tuolumne River

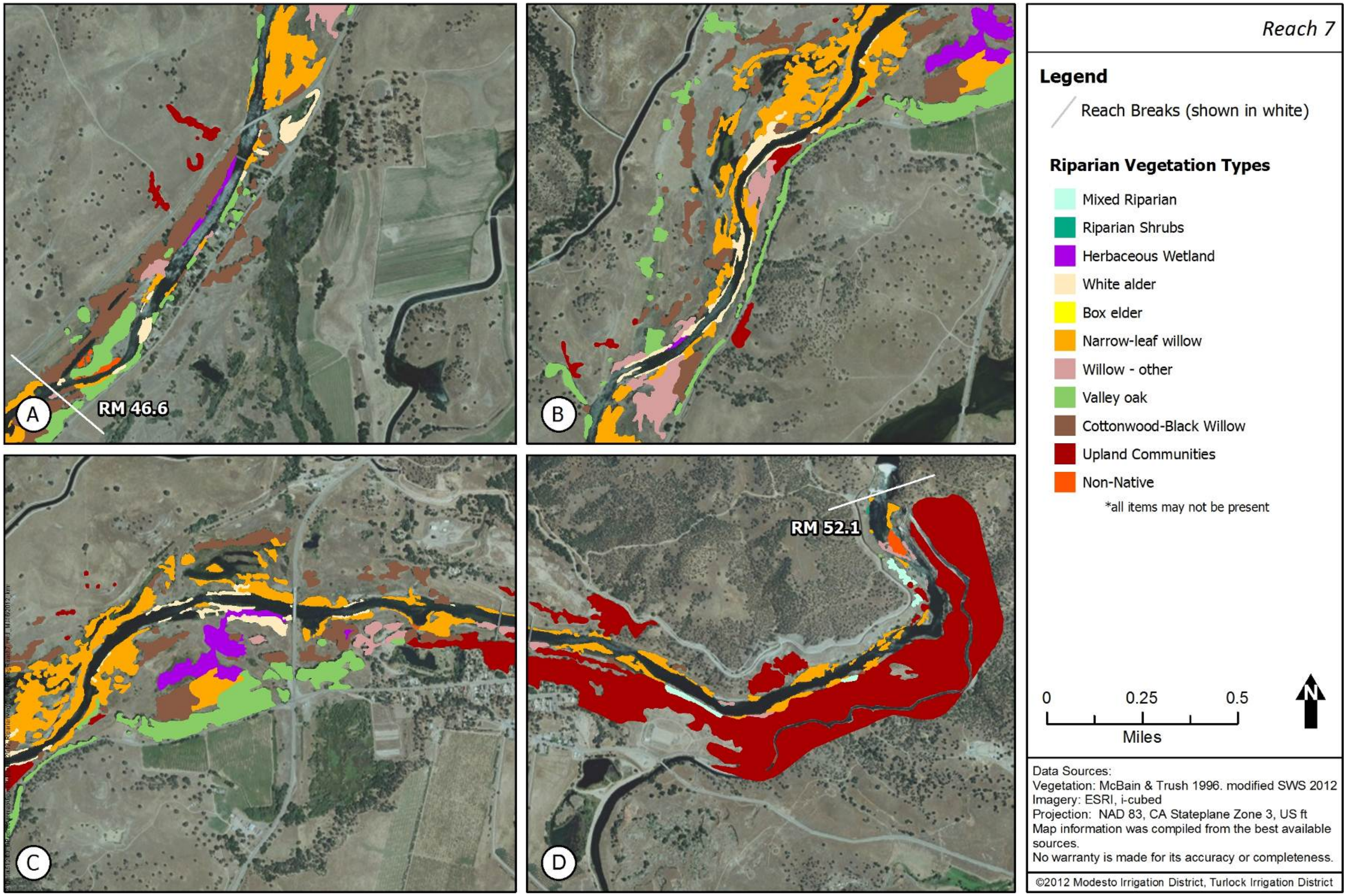

Figure B-8. Existing vegetation mapped along Reach 7 of the lower Tuolumne River.

STUDY REPORT W&AR-19

LOWER TUOLUMNE RIVER RIPARIAN INFORMATION AND SYNTHESIS

ATTACHMENT C

DESCRIPTION OF INVASIVE NON-NATIVE SPECIES IN THE LOWER TUOLUMNE RIVER

<u>Giant Reed (*Arundo donax*)</u>
Overall = High; Impact = severe (A); Invasiveness= Moderate (B); Distribution = Severe (A)

Giant reed is the most invasive non-native observed on the lower Tuolumne River to-date. Due to its clonal growth strategy, efficient use of resources, and high growth rate, *A. donax* is one of the most successful riparian weedy invaders in California (Rieger and Kreager 1989). Once established in an area, it grows into dense and rapidly spreading monotypic stands, spreading vegetatively via rhizomes, and is documented to aggressively out-compete other plants species through both its very high water acquisition rates and very high growth rates, suppressing growth of other neighboring plants through water and light limitation (Holt 2002, Dudley 2000). *Arundo donax* plants are uprooted and dispersed downstream during large, winter flood events characteristic of Mediterranean-type climates (Bell 1994). Portions of the rhizome or culm break off, float downstream, land on a bare, moist substrate as flood waters recede and begin growing. Fragments of the rhizome or culm as small as 0.8 in^2 have been shown to sprout under most soil types, depths and soil moisture conditions (Else 1996, Boose and Holt 1999, Wijte et al. 2005). Growing at an extremely high rate of up to 2.5 in per day under ideal conditions), giant reed quickly establishes on unvegetated or sparsely vegetated soil and grows to a height of greater than 20 ft after only a few months (Rieger and Kreager 1989, Coffman 2007). It then expands outward in area, quickly displacing indigenous shrubs, herbs and grasses, and eventually even trees. It directly competes with Fremont cottonwood and most willow species for riparian habitat (Coffman 2007).

When above ground biomass of giant reed dies back in late summer and fall, riparian areas dominated by this plant become susceptible to fire (Scott 1994). Riparian terraces invaded by giant reed adjacent to shrubland communities are most vulnerable (Coffman 2007). Indigenous riparian trees, shrubs, and other vegetation not as well-adapted to fire are burned along with giant reed and resprout much more slowly (Coffman 2007, Coffman et al. 2010). Giant reed grows back immediately to completely replace the open burned areas originally dominated by indigenous riparian vegetation (Coffman 2007). When natural riparian vegetation types are replaced by thick stands of giant reed, bird species abundance and other native wildlife have been found to decline (Bell 1994, Bell 1997, Herrera and Dudley 2003, Kisner 2004, Labinger and Greaves 2001).

<u>Eucalyptus (*Eucalyptus globulus*)</u>
Overall = Moderate; Impact = Moderate (B); Invasiveness= Moderate (B); Distribution = Moderate (B)

Eucalyptus has been planted in central and coastal California since the mid-1800s as both a wind break and for fuel wood (Warner 2004). It is classified as moderately invasive by Cal-IPC. Reproduction is by large seeds that remain viable for multiple years and germinate best on bare mineral soil (Bean and Russo 1986). Anecdotal reports of rapid reproduction and spread from established stands are common, but not documented in the scientific literature (Warner 2004). The leaves and bark release allelopathic chemicals, suppressing germination and growth of other plants species (Molina et al. 1991, Watson 2000). Eucalyptus stands could spread locally in upper terrace areas of the lower Tuolumne River, but is not a threat to the moister floodplain areas.

Tree of Heaven (*Ailanthus altissima*)
Overall = Moderate; Impact = Moderate (B); Invasiveness= Moderate (B); Distribution = Moderate (B)

Tree of heaven is a deciduous tree that is classified as a Cal-IPC moderate invasive. Native to China, it was introduced by Chinese immigrants during the California Gold Rush as a landscape ornamental, food plant for silk worms, and for medicinal use (DiTomaso and Healy 2007). It is a fast-growing species which spreads rapidly either vegetatively (i.e., with creeping roots), through stump sprouting, or by the copious production of seeds (one tree can produce over 300,000 seeds in a year). Seeds are samara (contained in a "winged" structure that enables the wind to carry the seed further from the parent tree) which can be dispersed by wind or downstream by water. These trees often form dense monocultures (via root sprouts or seed) which preclude native plants by both direct competition for light and water and through allelopathic chemicals leached from the tissue to the soil (De Feo et al. 2003, Heisey 1996). The rapid growth, prolific reproduction and allelopathic effects enable this species to dominate riparian areas in a short amount of time (Kowarik 1995, Hoshovsky 1999).

Edible Fig (*Ficus carica*)
Overall = Moderate; Impact = Moderate (B); Invasiveness= Severe (A); Distribution = Moderate (B)

Edible fig was brought to California as a food crop and ornamental tree and remains an important crop in the state (Randall 2004, Furguson et al. 1990). It is a medium sized broad-leaved tree often found on levees or floodplains. Edible fig can become established in undisturbed riparian areas, but several lands managers suggest that flood disturbance might promote establishment (Randall 2004). Edible fig was observed to spread rapidly at the Cosumnes River Preserve (Randall 2004), but documentation on spread rates is lacking. Reproduction occurs by both seed two to three times a year, through root sprouts, and from branch fragments (Michailides et al. 1996, Furguson et al. 1990, Kjelberg et al. 1987). Seeds can be transported by birds that consume the fruit, and branch fragments, which are easily broken off, can be transferred downstream to new locations (Randall 2004).

STUDY REPORT W&AR-19

LOWER TUOLUMNE RIVER RIPARIAN INFORMATION AND SYNTHESIS

ATTACHMENT D

FEMA FLOOD AREAS ALONG THE LOWER TUOLUMNE

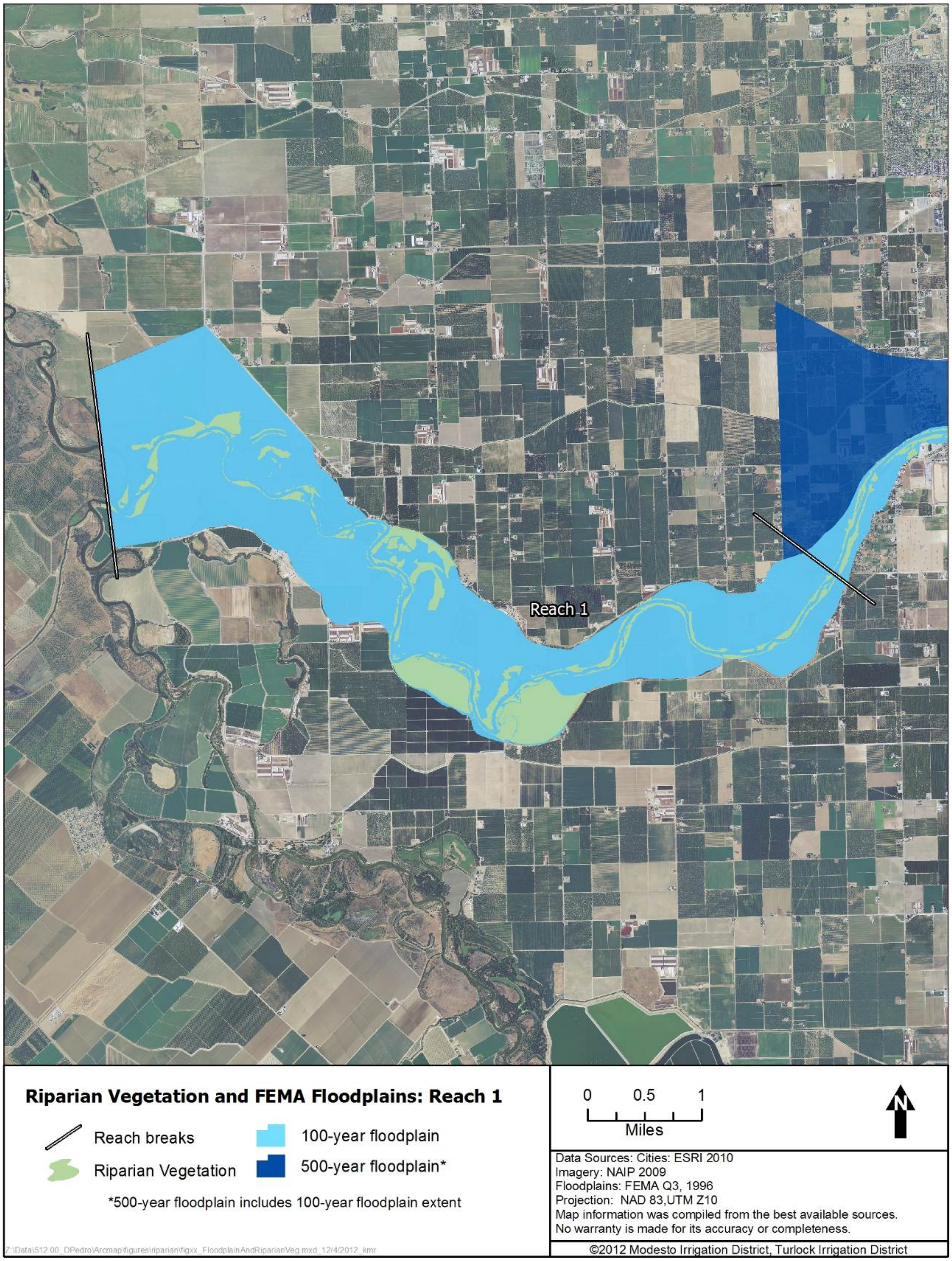

Figure D-1. Riparian vegetation and FEMA floodplains along Reach 1 of the lower Tuolumne River.

Figure D-2. Riparian vegetation and FEMA floodplains along Reach 2 of the lower Tuolumne River.

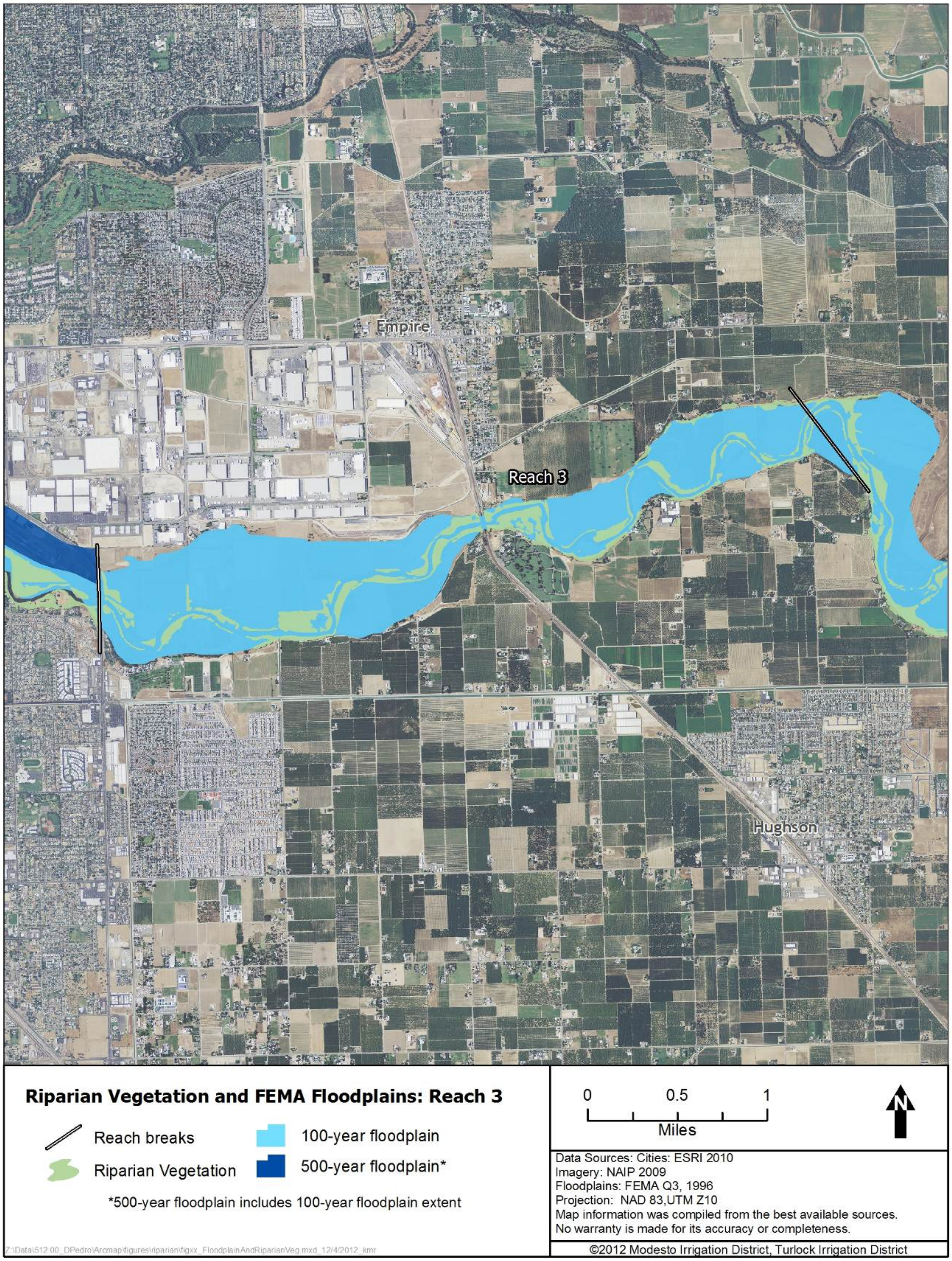

Figure D-3. Riparian vegetation and FEMA floodplains along Reach 3 of the lower Tuolumne River.

Figure D-4. Riparian vegetation and FEMA floodplains along Reach 4 of the lower Tuolumne River.

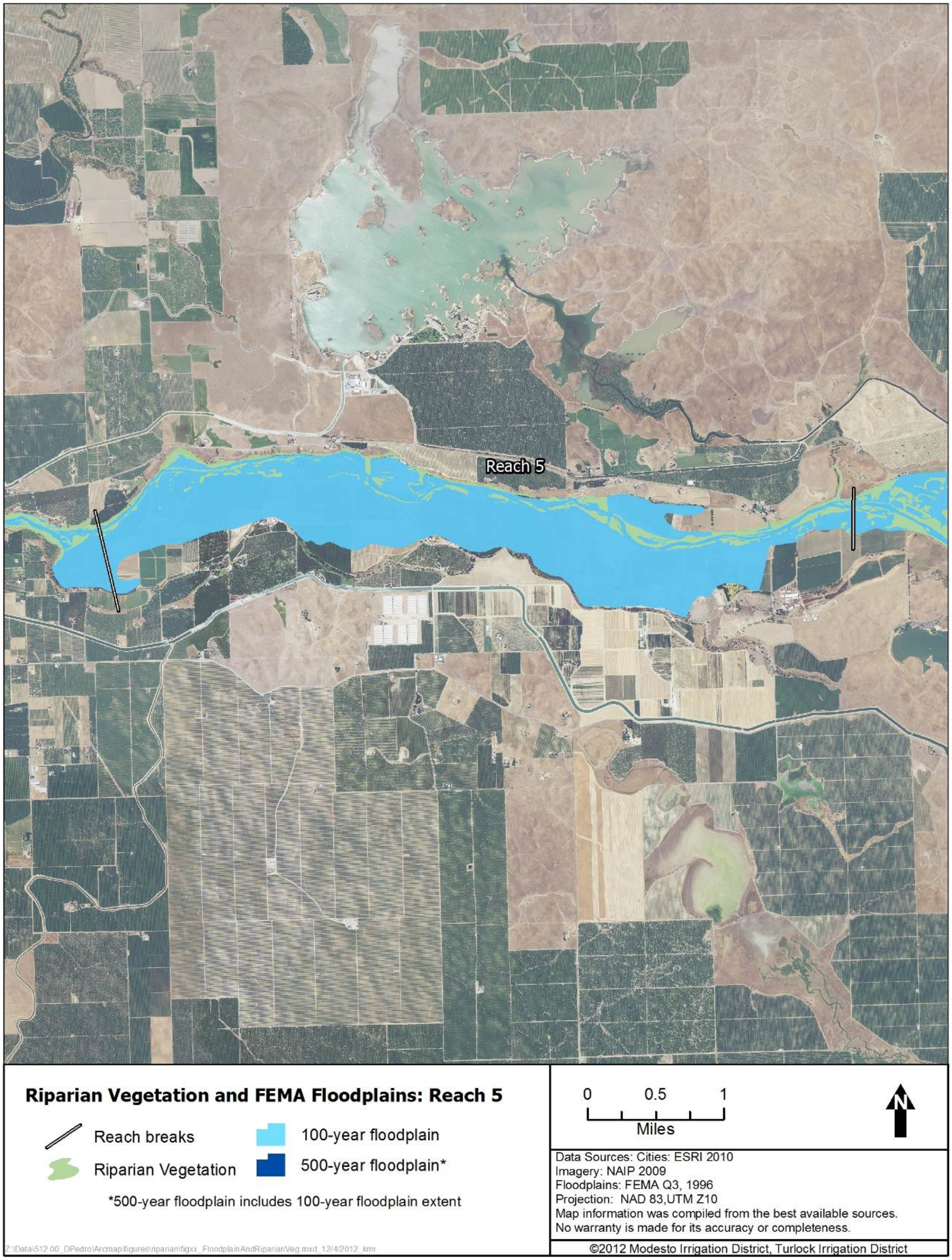

Figure D-5. Riparian vegetation and FEMA floodplains along Reach 5 of the lower Tuolumne River.

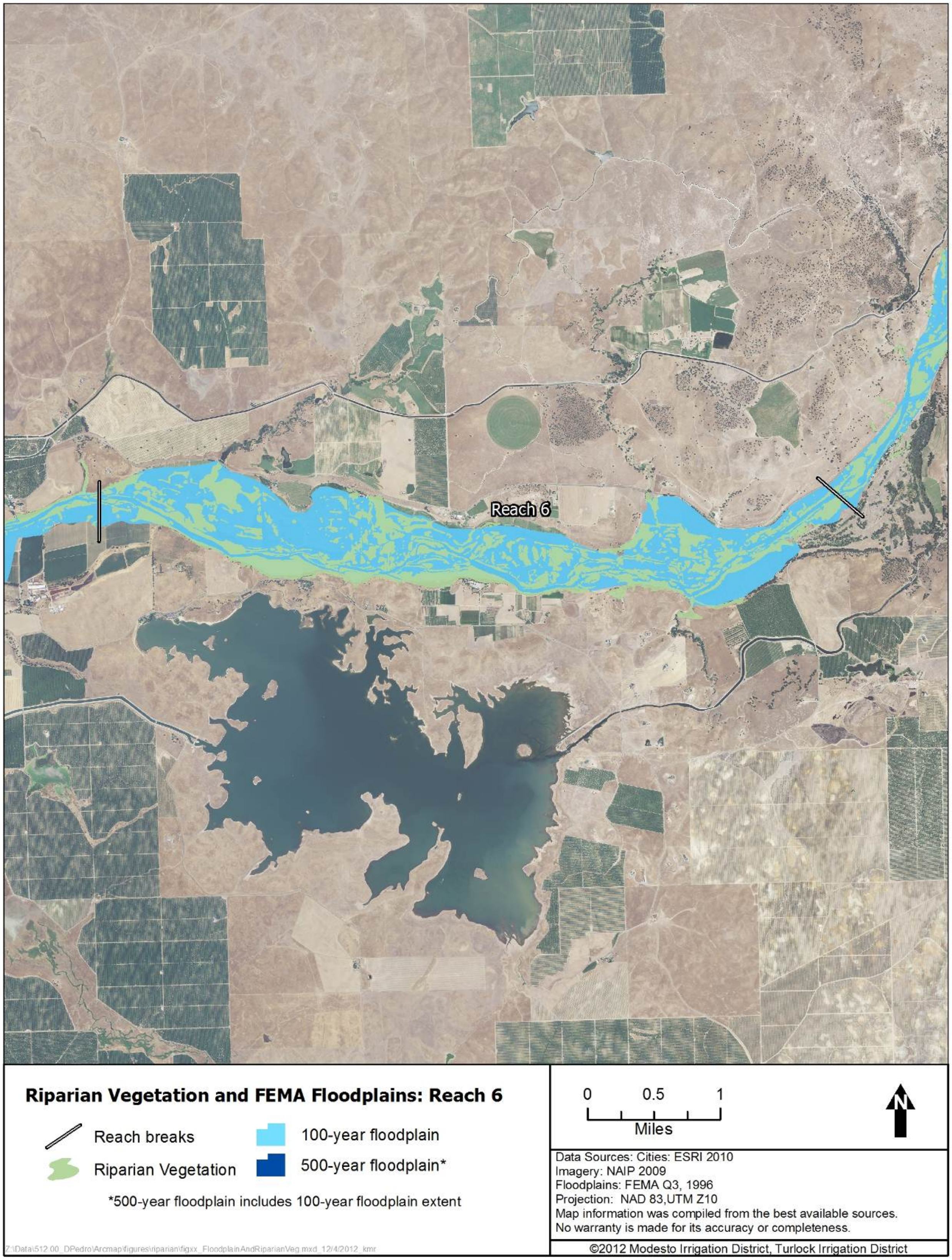

Figure D-6. Riparian vegetation and FEMA floodplains along Reach 6 of the lower Tuolumne River.

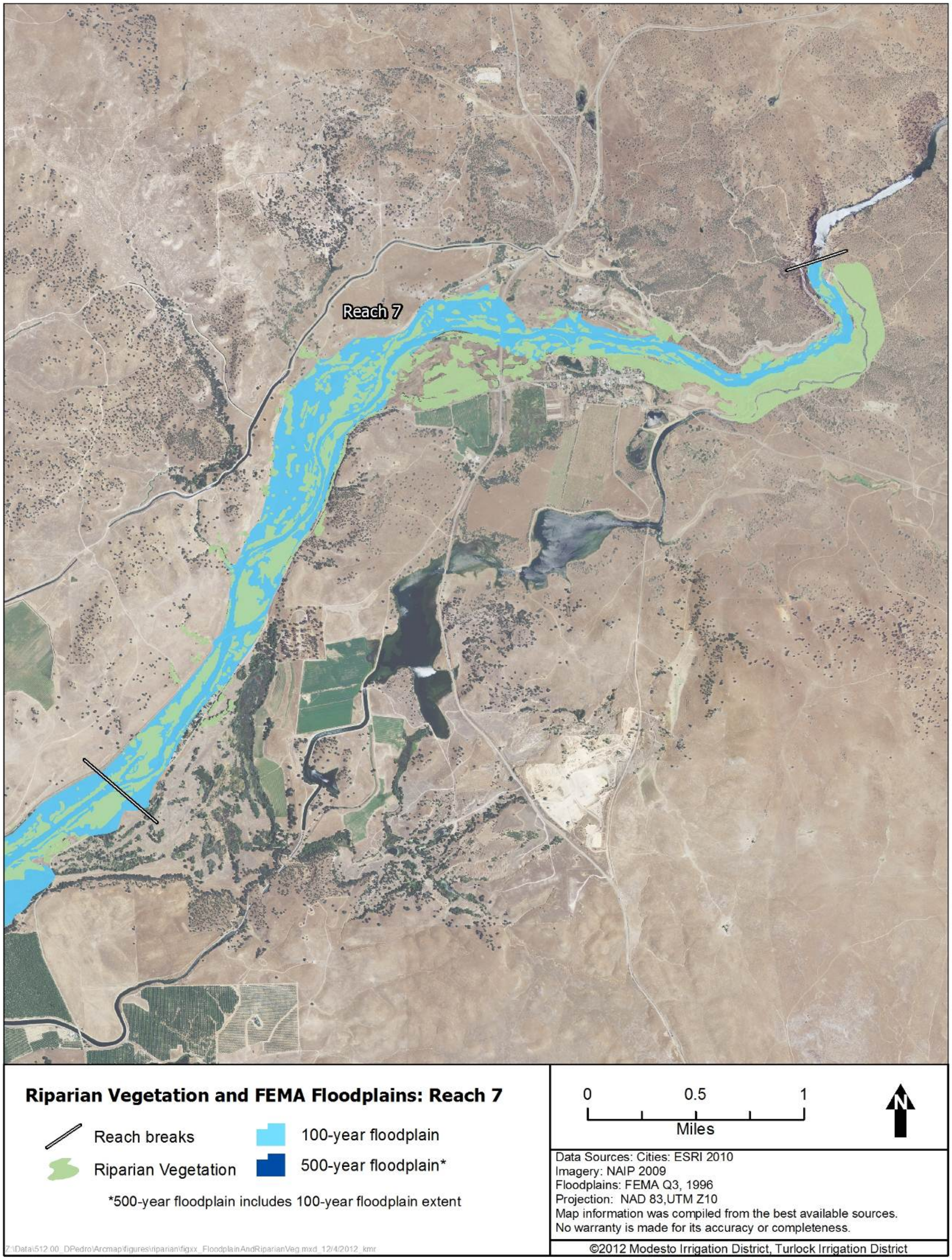

Figure D-7. Riparian vegetation and FEMA floodplains along Reach 7 of the lower Tuolumne River.