A Joint Effort

The Arkansas River Watershed Invasive Plants Plan (ARKWIPP) was prepared with the input of a multitude of partners from over thirty organizations in southeastern Colorado representing state and federal agencies, local communities, private landowners, industry, and non-governmental organizations. Five river systems comprising the bulk of the Arkansas River's eastern Colorado headwaters are included in this comprehensive plan; the Arkansas River, the Purgatoire River, the Huerfano River, the Apishapa River and Fountain Creek.

This partnership was led by Southeastern Colorado Water Conservancy District and Bent County with the Tamarisk Coalition providing valuable technical assistance. Funding to develop the Plan was provided through the Colorado Department of Local Affairs, Colorado Water Conservation Board, Bent County, Prowers County, Crowley County, Otero County, Purgatoire Water Conservancy District, Southeastern Colorado Water Conservancy District, West Otero-Timpas Conservation District, and Arkansas River Conservation District. Endorsement of this plan by the ARKWIPP partners in no way limits any government's, agency's, industry's, landowner's, or organization's existing legal authority or responsibilities.

The Plan is provided in two parts – the body of the ARKWIPP Plan contained herein and the comprehensive tamarisk inventory and mapping Data-DVDs located in the back of the Plan.

For more information on the ARKWIPP Plan, contact Southeastern Colorado Water Conservancy District at 719-948-2400 or jean@secwcd.com

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ARKANSAS RIVER WATERSHED INVASIVE PLANTS PLAN ARKWIPP

Executive Summary

In August 2007, a partnership formed to develop a strategic plan for Colorado's Arkansas River riparian areas impacted by non-native invasive trees, principally tamarisk (Tamarix spp., aka salt cedar) and Russian olive (Elaeagnus angustifolia). This partnership, known as the Arkansas River Watershed Invasive Plants Plan (ARKWIPP), was initiated in Bent County through the leadership of the Southeastern Colorado Water Conservancy District (SECWCD). Many state and federal agencies, local communities, private landowners, and non-governmental organizations have cooperated to draft this plan.

The shared vision is an overall Arkansas River watershed restored as a thriving and diverse riparian ecosystem containing minimal infestations of non-native invasive species in order to protect water resources, protect native riparian species and habitat, protect communities from wildfire and flooding, to enhance agricultural productivity and improve recreational opportunities.

The ARKWIPP plan was developed to geographically focus on the entire Arkansas River basin in Colorado. The Arkansas River basin, at 28,286 square miles (more than 18 million acres), is the largest basin in Colorado and it extends from the continental divide near Leadville to the Kansas state line. The plan represents the fundamental backbone for riparian restoration throughout southeastern Colorado.

The ARKWIPP plan is structured around a set of Guiding Principles focusing on ecological, social-cultural, economic, education, and research considerations. In summary, the Guiding Principles recognize that successful riparian restoration must include: 1) all restoration components – planning and design, control, revegetation, biomass reduction, monitoring, and long-term maintenance; 2) respect for private property rights, state water rights, existing infrastructure, and endangered species; 3) education to gain public support and funding; 4) research to identify the most effective and efficient techniques for restoration through the practice of "adaptive management"; and 5) partnerships to optimize and leverage existing and future funding.

The ARKWIPP plan is a collaborative document to assist in the development and implementation of future, objectives-driven restoration designs for each area within the watershed impacted by tamarisk and Russian olive. ***The ARKWIPP plan is not a site-specific design for restoration.*** Rather, the ARKWIPP plan functions as the backbone for future riparian restoration.

The **Goals** of ARKWIPP Plan are to:

- Provide a mechanism for communication and coordination among diverse parties and land managers throughout the watershed to bring about the ideas set forth in the vision statement.
- Develop a strategy pairing timely and cost effective riparian restoration with well designed monitoring and maintenance processes.

The long-term **Objectives** of the ARKWIPP Plan are to:

- Control tamarisk and Russian olive infestation while reestablishing sustainable native plants and habitat.
- Maintain informational databases of partnerships, funding opportunities, intellectual and private industry resources, infestation levels, volunteer efforts, on-the-ground project areas, and control, restoration, monitoring, and maintenance actions.
- Support basin-wide coordination from strong "grass-roots" leadership and initiatives to successfully realize the vision.

In 2005 and 2006, the Colorado Water Conservation Board (CWCB) contracted with the Tamarisk Coalition to perform an initial inventory of tamarisk infestations on the main-stem of the Arkansas River east of Pueblo Reservoir Dam, the main-stems of the Purgatoire River, Huerfano River, Fountain Creek, Big Sandy Creek, Buffalo Creek, Lake Meredith, Adobe Creek Reservoir, Neeskah Reservoir, Neenoshe Reservoir and Sheridan Lake.

In 2007, funding was provided by ARKWIPP participants and a grant from the Colorado Department of Local Affairs to complete a supplementary inventory of tamarisk to include the entire Arkansas watershed. The starting point for the Arkansas River mapping project was the upper main-stem area near the Town of Salida, and for the Purgatoire River it was Trinidad Reservoir Dam.

In total, the Tamarisk Coalition's mapping efforts inventoried over 1,633 miles and included infested tributaries, reservoirs, wetlands, canals, ephemeral streams, and upland stands in the entire Arkansas watershed. This type of information is invaluable in determining the total acres of infestation and average density, estimate of current and future water losses, as well as the costs associated with control, restoration and long-term management.

The ARKWIPP Mapping and Inventory Report (Report) (Appendix A) indicate the Arkansas watershed contains over 67,059 acres of land infested with tamarisk and it harbors sixty nine percent (69%) of the tamarisk in the state of Colorado. The majority of tamarisk infestation is located below 65,000 feel in elevation in Pueblo, Huerfano, Fremont, El Paso, Las Animas, Otero, Crowley, Bent, and Prowers counties. Russian olive occupies a similar range although both species occur in isolated pockets at higher elevations. Tamarisk is the invasive species that predominates in most riparian habitats.

The Report determined that current water losses are based on the amount of water tamarisk is using under observed densities minus the water that would be used by native plants. The significant water losses occur as tamarisk occupies upland areas within the floodplain that would normally have xeric vegetation such as grasses, sage, rabbit brush, etc. These uplands xeric areas of the Arkansas and Purgatoire Rivers and their tributaries typically exceed fifty percent (50%) of the tamarisk infested areas. Based on these conditions, the estimates of current water losses in the Arkansas watershed, above and beyond what native vegetation would use, is 77,036 acre feet.

If no action is taken, these water losses and other ecosystem degradations have the potential of expanding significantly in the future. The Report determined that future water losses in the Arkansas River watershed assume an infilling of the existing infested areas that will likely occur over the next several decades is based on similar conditions observed by other states (New Mexico, Utah, and Nevada). Future water losses from infilling only (no expansion from existing infested areas) are estimated to be 199,591 acre feet.

The Report and the economic algorithms developed by the Tamarisk Coalition identify a range of costs for tamarisk and Russian olive control and restoration. Combining the attribute information gathered for each area of infestation (acres, percent cover, accessibility, and width) with the economic algorithms found on the supplementary data-DVD, provides a "planning-level" range of costs based on an *Integrated Pest Management* approach for each individual area. This detailed information is presented in the supplementary data-DVD.

The cost information is considered to be appropriate for planning purposes to understand the basic range of costs one could expect. To account for unsurveyed sites an extra twenty percent (20%) contingency should be added.

Based on the estimates developed, the overall costs for planning, design, control, revegetation, monitoring, and maintenance activities:

Arkansas River main-stem	$45,000,000 (±$10,000,000)
Arkansas River tributaries and reservoirs	$20,000,000 (±2,000,000)
Purgatoire River main-stem	$8,000,000 (±$1,000,000)
Purgatoire River tributaries	$600,000 (±$80,000)
Entire Arkansas River watershed	~ $70,000,000

Control of tamarisk and Russian olive in the watershed will utilize a full suite of techniques ranging from hand control to mechanical treatment. A promising method for tamarisk control is biological control using the tamarisk leaf beetle, *Diorhabda elongata*, from Asia. This insect species has been tested extensively in quarantine and field releases to ensure safety with respect to non-target species impacts. These insects have been approved for open release in Colorado and are being closely monitored by the Colorado Department of Agriculture's Palisade Insectary and entomologists at Colorado State University. Recent results from the Moab, Utah area indicate that tamarisk biological control could be successful on a large-scale in the Arkansas watershed. Among many benefits, biological control provides a cost advantage and greatly reduces herbicide use. Expected conditions following tamarisk and Russian olive control and restoration projects in the Arkansas River watershed include improved aquatic, riparian, and floodplain habitat. This will result in increased and improved habitat for fish and wildlife. The watershed supports several Colorado state endangered and threatened fish as well.

The ARKWIPP plan lays out a specific "path forward" for implementing the Plan, including a specific set of five actions to facilitate success.

The five actions include:

1. **Develop Ways to Work with Landowners**
2. **Develop and Provide Education, Outreach, and Volunteerism Programs**
3. **Determine Research Needs**
4. **Determine and Develop Long-Term Funding Mechanisms**
5. **Determine and Develop a Long-Term Sustainability Program**

Develop Ways to Work with Landowners

To successfully implement these restoration actions, the property rights of each landowner must be respected to ensure that 1) efforts coordinate with the landowner's specific objectives for the land and that 2) the landowner is included in restoration decision-making. Landownership includes public (federal, state, county, and local communities), legal subdivisions of the state (e.g., sanitation districts, drainage districts), private landowners, non-profits (e.g., The Nature Conservancy), commercial, and industry (e.g., Railroad and utility easements).

Action #1

The ARKWIPP Technical Advisory Team and county weed managers along with the Colorado Association of Conservation Districts, USDA Natural Resource Conservation Service (NRCS), local Resource Conservation and Development (RC&D) representatives, Colorado State University (CSU) Extension, Colorado Division of Wildlife, United States Bureau of Reclamation (USBR), major federal and state landowners, The Nature Conservancy and the Tamarisk Coalition should develop the following:

1. Develop a GIS dataset of landownership for the riparian corridor impacted by the target invasive species.
2. Develop a communication system that informs county weed managers of all projects being conducted.
3. Post the ARKWIPP mapping project on the www.arkwipp.org website to assist landowners with identifying their tamarisk infestation levels.
4. Develop an interactive database for landowners that will determine proper control and revegetation methods for restoration. Because control and restoration methods are very site specific a contact list of agencies that would provide on-site analysis for landowners will be developed.

A concern of the ARKWIPP partners is that without coordination between all these entities, there will be undue competition for the same funds; entities will not be aware of all of the funding resources available; and/or there will be inefficiency in using funds that are acquired. To resolve this concern, the following is recommended:

5. Establish a simple clearinghouse system to inform all parties of grant opportunities. A list of grant opportunities (Appendix K) will be placed on the www.arkwipp.org and Tamarisk Coalition, www.tamariskcoalition.org websites in the summer of 2008.
6. Create a prioritization system that could be used to screen grants and appropriate locations for restoration work. An example is provided in Appendix J, Example of Prioritization System.

Develop and Provide an Education, Outreach, and Volunteerism Programs

Gaining public support requires providing factual information that describes the problem and the solutions being initiated. Important information for the public understanding includes all aspects of the tamarisk and Russian olive problem; control approaches that will be used with significant emphasis on the biological control component; how things will look differently over the next ten years; revegetation, biomass removal, monitoring, and long-term maintenance. ***The overarching theme is RESTORATION not just tamarisk or Russian olive control.***

Action #2

Outreach expertise from counties, private landowners, major State and Federal landowners, Colorado State Forest Service, National Park Service, Colorado State Parks, The Nature Conservancy, CSU Extension, Denver Botanic Garden, USDA NRCS, Tamarisk Coalition and the ARKWIPP Technical Advisory Team should be used to develop materials appropriate for community and visitors to the areas.

1. The education and resource materials will be housed on the www.arkwipp.org website and will be accessible for reproduction by ARKWIPP partners as well as any interested entities. The website will be utilized as a resource tool for landowners and managers and it will enable others the ability to track the progress of the Plan as it is implemented. Key elements of the website may include:
   A. The Problem: Why Tamarisk is a Problem, No-action Alternatives, and Frequently Asked Questions.
   B. Problem Solutions: Control Methods, Biological Control, Biomass Potential, Riparian Restoration, Long-Term Management, and Success Stories.
   C. Strategic Plans: Colorado and Other States.
   D. Resource Materials and Links.
   E. Funding: List of Funding Agencies and Organizations.
   F. Manage Your Problem: Landowners database for sorting individual land use and infestation levels to determine proper control and restoration methods.
   G. Tamarisk Maps
      a. ARKWIPP mapping project.
      b. Federal Emergency Management Agency Flood Plain Map of the

Arkansas Basin.
c. Colorado State Forest Service Wild Land Fire Map of Arkansas Basin.
d. USDA Natural Resource Conservation Service Soil Survey Map of the Arkansas Basin.

H. Tamarisk and Russian Olive Research.
I. Current Events.
J. Volunteer Opportunities and Programs.
K. Who We Are and Contact Information.

2. Develop brochures for distribution through the visitor centers, Colorado State Parks, Division of Wildlife, wildlife refuges, USDA Natural Resource Conservation Service, Colorado State University Extension etc.
   A. A “frequently asked questions” brochure that will help locals and visitors understand the following:
      a. What tamarisk is, where it came from, why it is a problem, and tamarisk control methods.
      b. How biological control works, what to expect, monitoring of changes, etc..
      c. What will replace the tamarisk, how the process will affect wildlife.
      d. Who will implement these projects and how will they be funded.
   B. Fact sheets on tamarisk ecology, biological, control, herbicide usage and safety, etc.
3. Display boards with historical photos can be utilized to compare present day conditions to the past to give a perspective on the problem.
4. River guide training on the issue and provision of education cards similar to "Leave No Trace" laminated waterproof cards.
5. Information booths at local events, festivals, etc.
6. Presentations to service groups such as Lions, Rotary, and Chamber of Commerce, as well as schools and other organizations.
7. Demonstration sites that can be used for tours.

[Note: The Tamarisk Coalition is developing many of these components with support from others. This information will be available in summer 2008.]

Volunteer Program - An important aspect of education is gaining public support for tamarisk and Russian olive control and restoration to improve the ecosystem of the ARKWIPP study area. One way of achieving this is through volunteer programs. By participating in these programs, people gain first-hand experience and an appreciation of ecosystem restoration. The volunteer education effort would include information concerning how and where to get involved as an individual or as an organization.

8. The groups identified above should work together to:
   A. Develop a volunteer "lessons learned" pamphlet that can be used by others to develop their own volunteer program (a starter "cookbook").
   B. Identify good volunteer projects.

C. Pool resources for volunteer projects.

Determine Research Needs

There are a number of research activities that can improve the success, effectiveness, and efficiency of restoration for the Arkansas River watershed. The unique nature of the watershed also offers special opportunities to better understand tamarisk and Russian olive impacts to water resources and wildlife habitat as well as restoration responses. By intertwining restoration with research there is greater appeal to some funding sources to provide grants (e.g., federal legislation under P.L. 109-320, the Salt Cedar and Russian Olive Demonstration Act).

Action #3

The Southeastern Colorado Water Conservancy District has agreed to initiate the facilitation of a working group to establish collaborative partnership with educational institutions to identify specific research needs for the area, to utilize their research skills, and to ensure information sharing within the watershed.

The working group may include, but not be limited to representatives from: ARKWIPP Technical Advisory Team, Pueblo Community College, Otero Junior College, Lamar Community College, Trinidad State Junior College, Colorado State University in Pueblo and Fort Collins, University of Denver, Colorado College, University of Colorado – Colorado Springs, Pikes Peak Community College, county weed management departments, CSU Extension, major federal and state landowners, Colorado State Parks, National Park Service, Colorado State Forest Service, USDA NRCS, Colorado Division of Wildlife, The Nature Conservancy, Arkansas Valley Audubon Society, Upper Arkansas Weed Management Cooperative, Denver Botanic Garden, Colorado Association of Conservation Districts, USBR, US Fish and Wildlife, Environmental Protection Agency (EPA), Colorado State Department of Agriculture, United States Corps of Engineers (USACE), and the Tamarisk Coalition.

Determine and Develop Long-Term Funding Mechanisms

The partners in ARKWIPP should work together to continue to support and leverage existing projects to gain additional funding resources. An example would be funding derived from federal legislation PL 109-320. The key to successful implementation on any of the proposed restoration strategies, education, research, outreach, etc., is funding to sustain the activity.

Action #4

An active Grants and Projects Committee will be established to focus on developing grant opportunities and to communicate progress for active projects. A list of grant opportunities (Appendix K) available for tamarisk related issues will be available on the www.arkwipp.org and the Tamarisk Coalition www.tamariskcoalition.org websites. For further information the reader is encouraged to visit the funding sources website and contact the funding source directly.

Suggested participating entities should include: The ARKWIPP Technical Advisory Team and county weed managers along with the Colorado Association of Conservation Districts, USDA NRCS, local Resource Conservation and Development representatives, major federal and state landowners, Tamarisk Coalition, CSU Extension, USBR, Colorado Water Conservation Board, EPA, USACE, Colorado Department of Local Affairs, and The Nature Conservancy.

Determine and Develop Long-Term Sustainability Program

Long-term sustainability of the restored riparian lands is a function of a good monitoring and maintenance program. The purpose of monitoring is to provide information for making informed decisions to ensure maintenance efforts will remain, remediate, and improve the ecological processes of the watershed.

It is clear that if resources are spent only on control and revegetation with no cohesive approach to long-term monitoring and maintenance, the potential for successful riparian restorations are limited. Therefore, the following recommendation is made to establish a workable long-term monitoring and maintenance program:

Action #5

1. The Southeastern Colorado Water Conservancy District has agreed to initiate the facilitation of a working group to formulate a set of solutions and policies for long-term monitoring and maintenance for the entire Arkansas River watershed. It is recommended that the working group be co-chaired by the Colorado Department of Agriculture and the Colorado Department of Natural Resources. These two agencies are appropriate to lead this effort because their main responsibilities are to protect Colorado's natural resources and work closely with the agricultural community.
2. The working group may include, but not be limited to, representatives from: county weed management departments (the areas within the watershed with most of the infestations), State representatives to the House and Senate, CSU Cooperative Extension, Bureau of Land Management, Colorado State Parks, National Park Service, US Forest Service, Colorado State Forest Service, canal and ditch companies, USDA Natural Resource Conservation Service, Colorado Department of Local Affairs, Colorado Water Conservation Board, Pueblo Community College, Otero Junior College, Lamar Community College, Colorado State University in Pueblo and Fort Collins, University of Denver, Colorado College, University of Colorado – Colorado Springs, Pikes Peak Community College Colorado Division of Wildlife, The Nature Conservancy, Arkansas Valley Audubon Society, Colorado Association of Conservation Districts, the Southeastern Colorado Water Conservancy District, Purgatoire River Water Conservancy District, Lower Arkansas Valley Water Conservancy District, Upper Arkansas Water Conservancy District, USACE, USBR, and the Tamarisk Coalition.

3. Within 12 months a consensus plan should be produced to implement a long-term monitoring and maintenance program describing the technical, political, and

financial steps for tamarisk control implementation and responsible entities.

This will not be an easy task, but it is a critical element for successful riparian restoration and should be dealt with seriously. When a workable long-term monitoring and maintenance program for the Arkansas River watershed is successfully formulated, this will signify a landmark effort.

Introduction

Arkansas River Watershed Invasive Plant Plan

In August 2007, a partnership formed to develop a strategic plan for the Arkansas River's riparian areas impacted by non-native invasive trees, principally tamarisk (Tamarix spp., aka salt cedar) and Russian olive (Elaeagnus angustifolia). This partnership, known as the Arkansas River Watershed Invasive Plant Plan (ARKWIPP), was initiated in Bent County through the leadership of the Southeastern Colorado Water Conservancy District. Many state and federal agencies, local communities, private landowners, and non-governmental organizations have cooperated to draft this plan.

The vision is an overall Arkansas River watershed restored as a thriving and diverse riparian ecosystem containing minimal infestations of non-native invasive species in order to protect water resources, protect native riparian species and habitat, protect communities from wildfire and flooding, to enhance agricultural productivity, and improve recreational opportunities.

These combined efforts have involved state and federal agencies, local communities, private landowners, industry, and non-governmental organizations (NGO). The Southeastern Colorado Water Conservancy District provided the staff to assemble the plan.

The planning effort includes a comprehensive tamarisk inventory/mapping component that was finalized in February 2008 and will guide restoration work for approximately 67,000 acres of infested lands within the Arkansas River watershed. The ARKWIPPP project area is an ideal large-scale demonstration project as it encompasses several critical watersheds, has diverse landscape characteristics, has a significant cooperative conservation effort, provides unique opportunities for field research and will provide education and outreach efforts to communities within the entire Arkansas River Watershed.

The **Goals** of ARKWIPPP are to:
(1) Provide a mechanism for communication and coordination among diverse parties and land managers throughout the watershed to bring about the ideas set forth in the vision statement.
(2) Develop a strategy pairing timely and cost effective riparian restoration with well designed monitoring and maintenance processes.

The long-term **Objectives** of ARKWIPPP are:
(1) To control tamarisk and Russian olive infestations while reestablishing sustainable native plants and habitat.
(2) Maintain informational databases of partnerships, funding opportunities, intellectual and private industry resources, infestation levels, volunteer efforts, on-the-ground project areas, and control, restoration, monitoring, and maintenance actions.
(3) Support basin-wide coordination from strong “grass-roots” leadership and initiatives to successfully realize the vision.

The ARKWIPP plan is a collaborative document to assist in the development and implementation of future, objectives driven restoration designs for each area within the watershed impacted by tamarisk and Russian olive. While not the only non-native invasive species present or the only problems impacting riparian areas, tamarisk and Russian olive serve as the "poster children" for gaining public support.

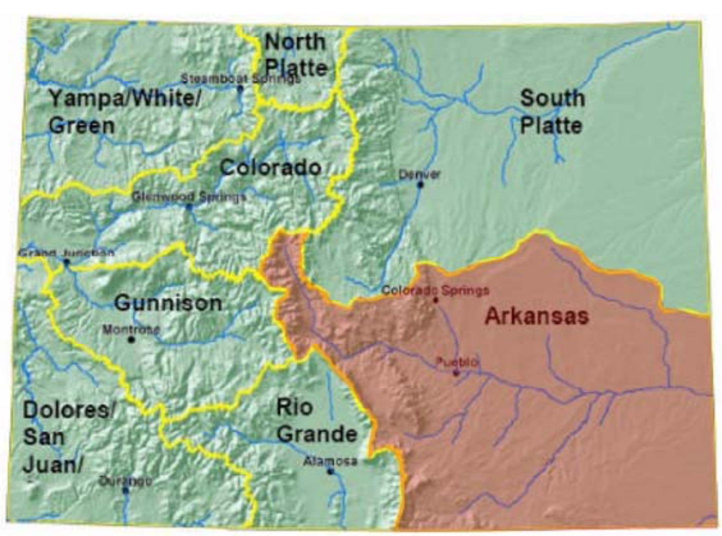
The ARKWIPP plan is divided into two distinct parts: The background describing the nature of the problem with recommendations for solutions and an implementation approach with specific actions.

Section 1 – Background

ARKWIPP and How It Fits With Other Planning Efforts

Effective watershed management and invasive species control efforts rely on a coordinated approach that transcends artificial boundaries such as political jurisdictions. However, to get one's "arms around the problem" planning efforts are organized within the confines of political jurisdictions or at least reasonable land masses. The ARKWIPP planning area was developed geographically to focus on the Arkansas River main-stem and tributaries from the Continental Divide to the Kansas state line.

Figure 1: Colorado River Basins



Partners

- Tamarisk Coalition
- Southeastern Colorado Water Conservancy District
- Natural Resource Conservation Service
- Southeast Land and Environment
- Bent County
- Crowley County
- Otero County
- Colorado State University Extension
- Colorado State Forest Service
- State of Kansas Water Office
- Senator Ken Salazar's Regional Office
- West Otero-Timpas Conservation District
- The Nature Conservancy
- Southeast Colorado Resource Conservation and Development
- Make Mine Magic, Inc.
- Prowers County
- Lincoln County
- Pueblo County
- Fremont County
- Colorado State Parks
- Purgatoire River Water Conservancy District
- Arkansas River Conservation District
- Arkansas Valley Audubon Society
- U.S. Army Corps of Engineers

Guiding Principles

The guiding principles will be a living document to provide the foundation which can direct ecological restoration efforts into the future. They will reflect a broad agreement between partner organizations, agencies, communities, and individuals that are cooperating to develop this management plan.

The guiding principles will also reflect the priorities of many stakeholders in adjoining watersheds in both Colorado and Kansas. These principles will adjust and change as additional information becomes available.

The effort recognizes that non-native invasive plants cause economic and environmental harm, negatively affect public health and welfare, and require active long-term management programs with sustainable funding. Thus, the partners subscribe to the following guiding principles:

- **Ecological –** Promoting ecological integrity, natural processes, and long-term resiliency is important for success.
  - Where appropriate, non-native invasive vegetation will be replaced with sustainable native plant species.

- Restoration will take into account the overall condition of the system, including presence of native species, species diversity, hydrologic regime, water quality, streambank integrity and wildlife habitat.
- Best management practices utilizing Integrated Pest Management techniques will be used and, as research and experience dictates, updated through adaptive management.
- Changes to hydrologic conditions can support native plant restoration efforts and will be considered, where possible, within the constraints of state and federal water law and the Arkansas/Kansas Compact.
- Efforts will be made to understand the historical, present, and future role of fire and flood in riparian areas.
- The removal of tamarisk and Russian olive over-story may promote the growth of other invasive plants. Management strategies will be developed to avoid or address additional noxious plant infestations.
- Restoration and maintenance efforts will be monitored and evaluated on an ongoing basis to ensure effectiveness.
- In certain circumstances, the protection of threatened and endangered species can be enhanced through well planned efforts to establish native riparian communities and restore natural processes. In areas of concern, threatened and endangered species surveys will be encouraged.
- If no action is taken, tamarisk and associated non-native invasive plants will continue to spread and increase the environmental damage throughout the Arkansas River watershed.

- **Sociocultural –** The values of the diverse human communities in the Arkansas River watershed will be supported and sustained by ecological restoration.
  - A comprehensive strategic approach throughout the watershed is important for success. However, the Arkansas River watershed is a mix of publicly managed lands, industry owned lands, and private property. Federal land management policy will be adhered to and private property rights, local customs, and local uses will be respected.
  - The Arkansas River watershed has been altered by human actions to improve their capability to store and supply water for beneficial use. Tamarisk and Russian olive control and restoration can be performed without impeding these systems or uses. Effective control should result in preservation of water resources for human and environmental uses.

- **Economic –** Economic productivity is dependent on healthy ecosystems and will be leveraged to full potential in support of long-term ecological health.
  - Existing frameworks of funding, technical assistance, and expertise will be identified, used, and publicized to optimize resources and maximize local effectiveness.
  - Partnerships will be developed to leverage existing and future funding.
  - Improvements to agricultural production will be supported by increasing grazing areas and accessibility to water for livestock, as well as enhancing water resources for irrigation.

- Tourism and outdoor recreation are vital economic components of the Arkansas watershed. Visitors come from all over the state and country to experience these recreational activities. Enhancing the visitor's experience and promoting a safe recreational experience is important.
- Private sector involvement in restoration efforts can lead to employment and economic benefits to the local communities of the Arkansas River watershed area. Efforts will be made to encourage the use of local resources.

- **Education –** Public education and outreach efforts will increase the understanding of the impacts from non-native invasive plants, safe methods for control, benefits of restoration, and the need for appropriate levels of funding to effectively manage the problem.
  - Educational materials will be developed on all aspects of the restoration process. This is especially important and critical for highly visible treatment areas.
  - Community outreach and volunteer efforts will be used to aid the public and landowners in gaining first-hand knowledge of the problem and establishing ownership of the solution.
  - Appropriate outreach will also be used to communicate successes and failures to other regions and the scientific community.

Figure 2: Lake Pueblo State Park Tamarisk Control Tour Participants

- **Research/Monitoring –** Research and monitoring can provide mechanisms to improve the effectiveness and efficiency of restoration actions and will be evaluated on an ongoing basis to ensure effectiveness.
  - Universities, federal, and state agencies, and private industry will be encouraged to use riparian restoration efforts within the Arkansas River watershed as "living laboratories" to monitor changes and provide scientific support to enhance success.

- To improve management decisions, data from inventories, monitoring, and control actions will be comparable (standardized and consistent) and shared at all levels.
- Performance measures for all phases of the restoration effort will include quantifiable units (e.g., acres treated and restored, fuel reduction) leading to the long-term recovery of healthy, productive ecosystems.

Relevant Legislation and Government Actions

Colorado: Colorado's federal and state legislators recognize that tamarisk, Russian olive, and other non-native plants are severely impacting the health of Colorado's river systems. These impacts degrade water resources, agricultural value, recreational use, and wildlife habitat.

The State of Colorado had developed a "10-Year Strategic Plan on Removal of Tamarisk and Restoration of Native Riparian Ecosystems" (Appendix B). The 10-Year Plan represents a strategic approach to solving the non-native phreatophyte tree problem and describes specific measures to take that will support the formulation and implementation of watershed level solutions for control within the state. It is composed of the ten components that include both actions and responsibilities. The components are: Organizational structure, inventory of the non-native, invasive species problem, education, research, funding, roll of non-profits, role of local communities, role of state agencies, role of federal agencies, and role of the Governor and State Legislature.

1. **Organizational Structure** has three components: watershed, state, and advisory. The formulation and implementation of control and revegetation plans is best done at the local watershed level with coordinating support from the state through a small team of two-four existing employees (Tamarisk Support Team). A volunteer advisory panel of experts would provide technical assistance to watershed partnerships of communities, agencies, and organizations, and to the Tamarisk Support Team.

2. **Inventory of the Tamarisk Problem** is the crucial element in the development of a control plan at watershed and state-wide scales. In 2004, it was estimated that 55,000 acres of infestation existed in the state. A more accurate inventory is needed to provide the basis for project planning (e.g., cost estimates, resource allocation, and priority setting) and tracking the long-term success of control efforts.

3. **Education** is needed to provide the public with an understanding of the problem and means of implementing solutions.

Political leaders have taken positive steps to help solve this problem with legislation to fund control and revegetation efforts. The Colorado Water Conservation Board (CWCB) has included a provision in its 2008 "Projects Bill" to allocate $1,000,000 from the severance tax trust fund operational account to the Board's Construction Fund to be used in implementing a Cost-Sharing Grant Program for Tamarisk Control. CWCB's intent for the funds is:

- Tamarisk and Russian olive control, revegetation and monitoring to ensure successful restoration of riparian lands.
- Local match of a minimum of one half of the costs of restoration as non-state cost-sharing, which may consist of a combination of in-kind and cash match.
- Grants available to communities, conservation districts, non-profits, and other eligible entities through a competitive process with input from the Colorado Department of Agriculture.
- A portion of the appropriated fund, not to exceed ten percent, will be used for grant program administration, scientific research, and monitoring to better target projects and assess their effectiveness. The supervisory financial management role shall remain with the CWCB.
- Use the Cost-Sharing Grant Program as seed funds to take full advantage of other grant programs from federal sources such as EPA, Corps of Engineers, and USDA: and from private foundations.

It is the intent of the CWCB that upon demonstration of the grant program's success, the CWCB will request additional funding in future fiscal years.

Kansas: In January 2005, the Kansas Water Office initiated development of a long-term strategic plan for addressing tamarisk and other non-native phreatophytes throughout Kansas. The Kansas Tamarisk 10-Year Plan (Appendix C) represents a strategic approach to addressing the tamarisk problem and describes specific measures to take that will support the formulation and implementation of watershed level solutions for controlling tamarisk within the state.

More than 25 agencies, organizations, and communities participated in the development of the Kansas Tamarisk 10-Year Plan. These stakeholders ranged from local basin advisory committee members and county weed managers to the U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service. The Tamarisk 10-Year Plan Committee was organized into five subcommittees: State Agencies, Federal Agencies, Local Communities, Universities and Non-Profit Organizations, and Governor and Legislature. A representative from each subcommittee served as chairperson and was charged with defining their role in tamarisk research, funding, and education. Information gathered during the subcommittee meetings was used to develop the overall statewide tamarisk plan. A working draft of the plan was presented to the public through local basin advisory committee meetings and was posted to the Kansas Water Office website in the fall of 2005. In November 2005, the working draft was presented to the Kansas Water Authority and the Governor's Natural Resources Subcabinet for approval. In December 2005, Governor Kathleen Sebelius signed the final plan, approving of the findings, guiding principles, and recommendations described in the plan. She also strongly encouraged the agencies, organizations, and communities involved in developing the plan to work towards full implementation of the actions recommended.

Federal Legislation: After four years of diligent work by the House and Senate, the *Salt*

Cedar and Russian Olive Control Demonstration Act was signed into law by the President on October 11, 2006. It is referenced as HR 2720 or Public Law 109-320 (Appendix D). Colorado's congressional delegation was instrumental in its passage. Senator Wayne Allard, Senator Ken Salazar, Congressman John Salazar, Congressman Mark Udall, and former Congressman Scott McInnis were all involved as co-sponsors to make this law a reality. The principal components of the Act include:

- Authorization to fund $80 million for large-scale demonstrations and associated research over a five year period.
- Assessment of the tamarisk and Russian olive problem during the first year.
- Assessment of biomass reduction and utilization.
- Demonstration projects for control and revegetation that serve as research platforms to assess restoration effectiveness, water savings, wildfire potential, wildlife habitat, biomass removal, and economics of restoration.
- Project funding will be seventy five percent (75%) federal and twenty five percent (25%) local (cash and/or in-kind) with up to $7,000,000 per project for the federal share. Demonstration projects on federal lands and research will be funded at one hundred percent (100%).
- Development of long-term management and funding strategies.
- Department of Interior will be the lead and will work with the USDA through a Memorandum of Understanding to administer the Act.

The next step in providing funding at the local level is the inclusion of appropriations to fully fund the Act in 2009. Several organizations and states are currently working with the Department of Interior and Congress on this measure.

Arkansas River Environmental Setting

The Arkansas River originates high in the center of Colorado near Mt. Elbert (14,433 feet), the highest point in the state. Here the waters of alpine snowmelt and mountain storms coalesce to form the headwaters of the river that eventually runs out of Colorado into Kansas, pushing downstream toward its meeting with the Mississippi River. The river follows a steep gradient through several canyons, the last and largest of which is the Royal Gorge, a 1,000 ft deep rock chasm. The canyon areas, including the Gorge, are well known for their recreation opportunities, and are famous for their fishing and whitewater rafting. Upon exiting the Gorge, the river takes on a much gentler gradient. Downstream of the City of Canon City, most of the river’s main-stem is wide and meandering across a broad floodplain.

In-Stream Structures and Tributaries: Many canals and irrigation structures intersect the river in this section. Two major reservoirs exist in the main-stem of the Arkansas River. Pueblo Reservoir is just upstream of the city of Pueblo, and John Martin Reservoir is located downstream below the city of Las Animas. As the Arkansas River runs from west to east, numerous tributaries enter from both the north and the south. In general, the southern tributaries drain a higher and larger watershed area from the Spanish Peaks and the Sangre de Cristo mountains. Therefore, they are more numerous and contain more water. Several of these tributaries flow through incised canyon areas, such as the Huerfano, Cucharas, and Purgatoire Rivers. These canyons present a unique ecosystem on the southern Great Plains and are home to several rare plant, fish and bird species. (*See Purgatoire River Environmental Setting Page 19*)

Landownership: Many of the lands adjacent to the Arkansas River from Pueblo to the Kansas state line are dominated by agricultural use. Crops such as alfalfa, melons, corn, onions, winter wheat, and dry beans are examples of the many agricultural products from the area. Additionally, numerous State Wildlife Areas exist primarily in riparian zones, and provide wildlife habitat and hunting opportunities.

A majority of the land in the Arkansas watershed downstream from the City of Canon City is privately owned. Military installations within the watershed include: Fort Carson, Piñon Canyon Maneuver Site, the Transportation Technology Center, and Pueblo Chemical Depot.

Vegetation: As the river's morphology changes character, as it moves downstream, so does its riparian vegetation composition. The Arkansas River's riparian plant communities are threatened by the invasion of aggressive, non-native, woody plants including tamarisk, Russian olive and Siberian elm. Tamarisk has choked the river and transformed riparian areas. In many cases these areas have been altered from healthy, viable habitat with mixed plant communities supporting ninety percent (90%) of the area's wildlife, into crowded monoculture forests with little biodiversity value. Tamarisk infestations in some areas have drastically reduced the river's channel capacity, thus limiting stream-flows, impairing wildlife habitat, and increasing flood danger. The riparian zones associated with the Arkansas River main-stem and its tributaries are traditionally dominated by cottonwood and willow. Upland areas are dominated by both grasslands and piñon and juniper forests, but can also be invaded by tamarisk.
Climate: **Precipitation in the watershed ranges from 35 inches a year in the headwaters to 10 inches per year on the lower plains. Precipitation levels fluctuate widely each year. Average annual temperatures for the entire watershed vary from 35 degrees F to 54 degrees F. Soils in the watershed range from very shallow to very deep, and are generally well drained.**

Fish and Wildlife: The Arkansas River watershed is home to a plethora of fish and wildlife species. Antelope, mule deer, jackrabbit, badger, turkey and pheasant are all common species. Many birds of prey including red tail hawks, prairie falcons, and osprey are found in upland and riparian zones. In the fresh water, Arkansas darter, plains minnow, channel catfish, walleye and crappie are some of the many fish species present.

Special Status Wildlife Habitat: The Arkansas River basin is home to three state endangered fish species; the southern redbelly dace (*Phoxinus erythrogaster*), the suckermouth minnow (Phenacobius mirabilis), and the plains minnow (*Hybognathus placitus*). In addition, the Arkansas darter (*Etheostoma cragini*), which is a state threatened fish, and the flathead chub (*Platygobio gracilis*), a state species of concern, also occupy the lower Arkansas basin.

Inhabiting the Arkansas River riparian area there are five (5) State Species of Concern - Reptiles/Amphibians including the triploid checkered whiptail, plains leopard frog, yellow mud turtle, roundtail horned lizard, and Texas horned lizard. The Colorado

Division of Wildlife and U.S. Fish and Wildlife Service have identified at-risk species of birds found along the riparian area including; least tern (federally and state endangered), piping plover, bald eagle (both federally and state threatened), western yellow-billed cuckoo, greater sandhill crane, western snowy plover and long-billed curlew (all state species of concern). Several threatened and endangered plant species occur in the plan area as well.

This Arkansas River system provides dispersal corridors for woodland birds across otherwise treeless terrain. Riparian systems occupy only a small proportion of Colorado's area. However, the lowland riparian ecosystem typically supports more species of native birds than surrounding grassland or shrubland ecosystems. Riparian ecosystems are considered to be important repositories for biodiversity throughout western United States.

Tamarisk: In the broad floodplain adjacent to the river channel, large, mature tamarisk infestations generally become more prevalent as the river progresses downstream. Tamarisk infestations occur primarily in the riparian zone habitat stretching to the extent of the 100 year floodplain. The infestations begin in earnest in El Paso, Fremont and Huerfano Counties, generally below 6,500 feet in elevation. There are isolated pockets at higher elevations, such as areas in the nearby foothills, but at these elevations tamarisk is less competitive with native species.

The tamarisk infestation increases dramatically as the river enters John Martin Reservoir. Beyond the reservoir, tamarisk continues to be the dominant woody plant species along the riparian corridor as the river eventually enters Kansas. Side canyons, perennial and ephemeral streams, springs, and tributaries support isolated stands of tamarisk. Upland tamarisk infestations outside of the floodplain also occur in fallow fields and around cattle tanks but are typically not as common or dense.

There are isolated pockets of Russian olive trees at higher elevations such as around the town of Texas Creek. At these elevations more precipitation occurs and thus, tamarisk tends to be less competitive with native species. The majority of tamarisk infestations can be found within the riparian corridor stretching to the extent of the 100 year floodplain. Side canyons, perennial and ephemeral streams, and tributaries support stands of tamarisk. Upland tamarisk infestations outside of the floodplain also occur in occur in fallow fields, naturally occurring low areas, or stock ponds but are typically not as common or dense.

Ongoing Removal Projects: Many tamarisk removal projects are planned or have been completed in areas of the watershed. See Appendix E for a list of projects that are ongoing or have been completed as of June 2008. The ARKWIPP coalition will continue to monitor these efforts and update this information on the www.arkwipp.org website periodically.

Purgatoire River Environmental Setting

The Purgatoire River flows east from Culebra Peak, a 14,069 foot mountain in the Sangre de Cristo mountain range, to its confluence with the Arkansas River in southeastern Colorado. As the Purgatoire River exits the Sangre de Cristo Mountains and their foothills, the river takes on a more gentle gradient and begins to meander downstream of Trinidad. This area consists mostly of prairie grasslands divided into small parcels under private ownership. The riparian zone found here contains many large, dense cottonwood galleries lining the river main-stem. Near the Purgatoire River confluence with San Francisco Creek, the river changes character as it enters a more incised canyon geological formation. For approximately the next 50 miles, the canyon becomes more remote and has very few vehicle access points. This canyon geologic configuration persists downstream until Nine-Mile Bottom, where the canyon opens into a broader floodplain hosting a wide swath of mature tamarisk infestation. Downstream of Nine-Mile Bottom, the river again changes back to a meandering, broad floodplain. This configuration is consistent until the Purgatoire River bends northeast to the City of Las Animas where it enters the Arkansas River at the west end of John Martin Reservoir. The river main-stem in this area is characterized by extensive agricultural irrigation and infrastructure, as well as significantly greater vehicle access than the upstream canyon reaches.

On both the northwest and southeast sides of the Purgatoire River main-stem, many tributaries enter the canyon. In general, tributaries from the north are shallower, broad washes and arroyos (i.e. entering from Piñon Canyon Military Reservation and Comanche National Grassland, while those approaching from the south are more narrow, incised canyons.

Tributaries of the Purgatoire River have created lush side canyons that sustain several rare plant species including leafy goldenweed (*Oonopsis foliosa var. foliosa*) and Sandhill Goosefoot (*Chenopodium cycloids*). Above the canyons lie shale outcrops, piñon /juniper woodlands, and extensive prairie uplands that support native grasses and shrubs, creating a diverse prairie mosaic. The riparian zones associated with the Purgatoire River main-stem and its tributaries are traditionally dominated by cottonwood and willow.

The Purgatoire's globally rare riparian plant communities are threatened by the invasion of aggressive, non-native, woody plants including tamarisk, Russian olive and Siberian elm. Tamarisk has choked the river and transformed the plains riparian areas. Some of these areas have been altered from healthy, viable habitat with mixed plant communities supporting ninety percent (90%) of the area's wildlife, into crowded monoculture forests with little biodiversity value.

The site supports one of the best native fisheries in the Central Shortgrass Prairie east of the Rocky Mountains. The habitat that the Purgatoire River provides for fisheries is unique; the following species all occur together within the Purgatoire River: Black bullhead, central stoneroller, longnose sucker, white sucker, brook stickleback, red shiner, Arkansas darter, plains killfish, plains minnow, channel catfish, green sunfish, orange spotted sunfish, speckled chub, sand shiner, flathead chub, longnose dace, and creek chub.

Referencing the Prairie and Wetlands Focus Area Strategic Plan (Rocky Mountain Bird Observatory), birds that will benefit from tamarisk control include: Wilson's snipe, spotted sandpiper, Mississippi kite, Lewis's woodpecker, and red-headed woodpecker. Amphibians that will benefit from an increase in the availability of water for wet meadow habitat include: Northern leopard frog, canyon tree frog, Great Plains narrowmouth toad, and plains leopard frog. Waterfowl and some water birds will also benefit from an increase in wet meadow habitat.

Mean annual average precipitation in the watershed varies from 8 to 14 inches per year, depending on location. Nearly 75 percent of the precipitation falls during the growing season, lasting from mid-April to late-September. Temperatures in the watershed can range from as low as -35 degrees F up to 108 degrees F. Powerful storms may occasionally generate winds in excess of 60 miles per hour.

Tamarisk: Tamarisk infestations occur primarily in the riparian zone habitat stretching to the extent of the 100 year floodplain. The infestations begin in earnest at Trinidad Lake, or generally below 6,500 feet in elevation. There are isolated pockets at higher elevations, such as areas in the nearby foothills, but at these elevations more precipitation occurs and, thus, tamarisk is less competitive with native species. Side canyons, perennial and ephemeral streams, springs, and tributaries support isolated stands of tamarisk. Upland tamarisk infestations outside of the floodplain also occur in fallow fields, naturally occurring low areas, or stock ponds but are typically not as common or dense.

Several tamarisk removal projects are planned or have been completed in areas of the watershed ranging from Trinidad Lake to the confluence with the Arkansas River near John Martin Reservoir. In 2006 and 2007, Trinidad Lake State Park removed tamarisk around the lake and in a few of the nearby tributaries. Several landowners and ranchers in the watershed have undertaken similar projects. At the lower end of the watershed, both the Comanche National Grassland and the Army Corps of Engineers at John Martin Reservoir completed tamarisk control projects on their lands.

Attributes of Tamarisk and Russian Olive Species

The Arkansas River and its associated tributaries are renowned for their ecological, recreational, aesthetic, cultural, and vital economical value for water supply, livestock, and, agriculture production. Riparian lands are especially integral and fragile aspects of western ecosystems due to their role in maintaining water quality and quantity, providing ground water recharge, controlling erosion, and dissipating stream energy during flood events (NRST 1997). Unfortunately, many of these water systems and associated riparian lands have been severely degraded over the past 150 years by anthropogenic activities (damming, road building, irrigation, etc.) and invasive plant species, resulting in reduced water quality, altered river regimes and reduced ecological systems and habitats.

Tamarisk *(Tamarix* spp.) and Russian olive *(Elaeagnus angustifolia)* are invasive species of particular interest due to their high profile status and negative environmental impacts.

Tamarisk ecology and impacts - Tamarisk is a deciduous shrub or small tree that was introduced to the western U.S. in the early nineteenth century for use as an ornamental, in windbreaks, and for erosion control. Originating in central Asia and the Mediterranean, tamarisk is a facultative phreatophyte with an extensive root system well suited to the hot, arid climates and alkaline soils common in the western United States. These adaptations have allowed it to effectively exploit many of the degraded conditions in southeastern river systems today (e.g., interrupted flow regimes, increased flooding and fire). By the mid-twentieth century, tamarisk stands dominated many low elevation (under 6,500 feet) river, lake, and stream banks from Mexico to Canada and into the plains states. Tamarisk cover estimates range from 1 to 1.5 million acres of land in the western U.S. and may be as high as 2 million acres (Zimmerman 1997).

Figure 3: Tamarisk Tree

The exact date of introduction is unknown; however, it is generally understood that tamarisk became a problem in western riparian zones in the mid 1900's (Robinson 1965, Howe and Knopf 1991). Genetic analysis suggests that tamarisk species invading the U.S. include *Tamarix chinensis, T. ramosissima, T. parviflora, T. gallica,* and *T. aphylla* (Gaskin 2002, Gaskin and Schaal 2002). A hybrid of the first two species appears to be the most successful intruder. There are several ornamental varieties of tamarisk still marketed in the western United States. While these species are noninvasive they do contribute genetic diversity to invasive populations.

Tamarisk reproduces primarily through wind and water-borne seeds, but a stand may also spread through vegetative reproduction from broken or buried stems. Seeds are viable for approximately six weeks (Carpenter 1998) and require a wet, open habitat to germinate. In the presence of established native vegetation or sprouts, tamarisk seedlings are not strongly competitive (Sher, Marshall and Gilbert, 2000; Sher, Marshall and Taylor, 2002; Sher and Marshall, 2003). Therefore, if native plant communities are intact or conditions favor native plant establishment or growth, tamarisk invasion by seed is not likely to occur. However, the following several conditions coinciding with the removal of the native canopy due to natural or anthropogenic causes will allow new infestations to occur: 1) Late flooding - Tamarisk seed production generally has a longer season than native vegetation, and therefore is able to take advantage of over-bank flooding at times of the year when native vegetation is not dispersing seed. 2) Suppression of native vegetation - Herbivory (e.g., cows will eat native saplings), drought, fire, lack of seed, or other disruptive processes can prevent native plants from establishing, and thus allow tamarisk to invade. Once tamarisk seedlings are established (as great as 1,000 indivduals/m^2 initially), thick stands are very competitive, excluding natives (Busch and Smith 1995, Taylor *et al.* 1999). Any disruption of the riparian ecosystem appears to make invasion more likely, especially alterations of hydrology (Lonsdale 1993, Decamps P1anty-Tabacchi and Tabacchi 1995, Busch and Smith 1995, Springuel *et al.* 1997, Shafroth et *al.* 1998). However, there are also numerous documented cases of tamarisk stands where no known disruptions have occurred.

Once a tamarisk stand is mature, it will remain the dominant feature of an ecosystem unless removed by human means. Tamarisk has a higher tolerance of fire, drought, and salinity than native species (Horton *et al.* 1960, Busch *et al.* 1992, Busch and Smith 1993 and 1995, Shafroth *et al.* 1995, Cleverly *et al.* 1997, Smith et *al.* 1998, Shafroth *et al. 1998).* Tamarisk can increase fire frequency and intensity, drought (Graf 1978), and salinity (Taylor *et al.* 1999) of a site. Hence, a strong initial infestation will promote a positive feedback mechanism that will lead to more tamarisk invasion.

In addition to affecting abiotic processes, tamarisk dominance dramatically changes vegetation structure (Busch and Smith 1995) and animal species diversity (Ellis 1995). High invertebrate and bird diversity has been recorded in some tamarisk-dominated areas and tamarisk is valued highly by the bee industry for its abundant flower production. Although some forms of tamarisk (primarily younger, highly branching stands) are favored by cup nesting bird species many endemic species are completely excluded by it, including raptors such as eagles (Ellis 1995). Because of its potential usefulness to some species, stands of tamarisk mixed with native vegetation were found to have high ecological value in Arizona study sites (Stromberg 1998). In contrast, mature monocultures of tamarisk have a much lower ecosystem value.

In general, the following is an assessment of tamarisk and its impacts on riparian systems throughout the West (Carpenter 1998, McDaniel *et al. 2004).*

- Tamarisk populations develop in dense thickets, with as many as 3,000 plants per acre that can prevent the establishment of native vegetation (e.g., cottonwoods *(Populus spp),* willows *(Salix spp),* sage, grasses, and forbs).

- As a phreatophyte, tamarisk invades riparian areas, potentially leading to extensive degradation of habitat and loss of biodiversity in the stream corridor.

- Due to the depths of their extensive root systems tamarisk draw excess salts from the groundwater. These are excreted through leaf glands and deposited on the ground with the 1eaf litter. This increases surface soil salinity to levels that can prevent the germination of many native plants.

- Tamarisk seeds and leaves lack nutrients and are of little value to most wildlife and livestock.

- Tamarisk increases the frequency and intensity of wildfires which kill native cottonwood and willows but stimulate tamarisk growth.

- Dense tamarisk stands on stream banks accumulate sediment in their thick root systems, gradually narrowing stream channels and increasing flooding. These changes in stream morphology can impact critical habitat for endangered fish.

- Dense stands affect agricultural production by decreasing grazing areas and accessibility to water for livestock, and by using precious water resources that could be used for crop irrigation.

- Aesthetic values of the stream corridor are degraded, and access to streams for recreation (e.g., boating, fishing, hunting, bird watching) is lost.

- Tamarisk has a reputation for using significantly more water than the native vegetation that it displaces. This non-beneficial user of the West's limited water resources has been reported to dry up springs, wetlands, and riparian areas by lowering water tables (Carpenter 1998, DeLoach 1997, Weeks *et al. 1987).*

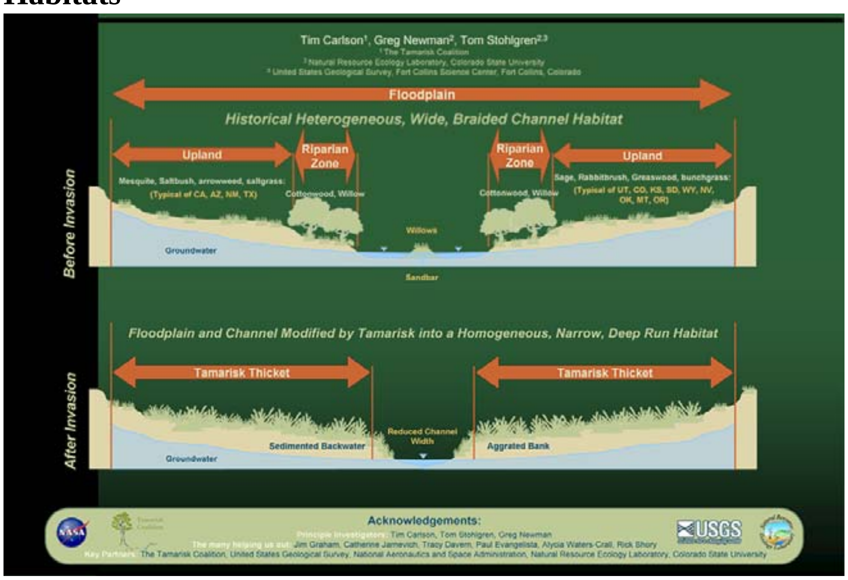
What are the local impacts? - The most critical impacts for the ARKWIPP study area are aesthetics, wildlife habitat loss, fire, flooding, and water usage. Aesthetics are highly valued due to the tourism industry, a major economic driver for the area. Wildlife habitat loss and altered fire regimes are important from the ecological standpoint, while flooding and wildland fire are a safety concern to communities. Tamarisk changes the natural fire regimes of the native riparian areas; it increases fire frequency and intensity. It also changes the way in which flooding occurs. So fire and flood is two-fold—affecting the ecology as well as the safety of communities. Water loss, however, is considered the most critical issue. The following section provides a brief explanation of how this water loss occurs.

How much water is lost? - Limited evidence indicates that water usage per leaf area of tamarisk and the native cottonwood/willow riparian communities is very similar. However, because tamarisk grows in extremely dense thickets, the leaf area per acre may actually be much greater than native stands; thus, water consumption could be greater on a per acre basis (Kolb 2001). Another aspect of tamarisk water consumption is its deep root system. Tamarisk roots can extend down to 100 feet, much farther than healthy cottonwoods and willows stands which reach a depth of only a few meters (Baum 1978, USDI - BOR 1995). This allows tamarisk to grow further back from the river, occupy a larger area, and use more water across the floodplain than native phreatophytes. This is significant because the upper floodplain terraces adjacent to the riparian corridor typically occupy an area several times larger than the riparian zone itself. In these areas, mesic and xeric plants (such as bunch grasses, sagebrush, rabbit brush, four-wing salt bush, and skunk bush) can be replaced by tamarisk resulting in overall water consumption several times the ecosystem's natural rate (DeLoach *et al.* 2002).

Water consumption estimates vary a great deal depending on location, maturity, density of infestation, water quality, and groundwater depth. In 27 research plots, tamarisk had an average annual water usage of 4.2 acre-feet/acre (ninety five percent (95%) confidence interval = 3.85 to 4.86) (NISC 2006). This agrees strongly with the most sophisticated evapotranspiration studies using eddy-covalence measurements performed for the Bureau of Reclamation (King and Bawazir 2000) of 4.35 feet per year. Water use by Russian olive was found to be approximately the same. In many situations this water consumption is equivalent to that of cottonwood and willow vegetation at a similar density. For dry-land vegetation such as grasses/sage/rabbit brush communities, which are shallow-rooted and get their water primarily from precipitation, the difference in water use is a function of the precipitation received for the area. In the ARKWIPP study area's riparian lands that tamarisk occupies annual precipitation ranges from a low of eight inches to approximately fifteen inches per year at the higher elevations where tamarisk exists (6,500 feet). For areas that could support native phreatophytes, it is estimated that only approximately twenty five percent (25%) would actually be occupied by these species based on a number of factors. Water loss calculations are based on these findings. Future water losses assume complete infilling of tamarisk with no expansion of range.

Figure 4 represents the differences in vegetative cover with and without tamarisk. Figure 4 illustrates that tamarisk occupation of an area is much greater than the riparian zone which typically would support phreatophytes. Significant water losses may occur as tamarisk occupy upland areas within the floodplain that would normally support only upland mesic and xeric vegetation such as grasses, sage, rabbit brush, etc.

Figure 4: Tamarisk Induced Changes in Channel Structure and Associated Habitats



Russian olive ecology and impacts - Russian olive *(Elaeagnus angustifolia)* was introduced to the United States in the late nineteenth century as an ornamental shrub or small tree and has since spread from cultivation (Ebinger and Lehnen 1981, Sternberg 1996). Originating in southern Europe and central and eastern Asia (Hansen 1901, Shishkin 1949, Little 1961), Russian olives are long-lived and resilient plants. They are adapted to survive in a variety of soil types and moisture conditions, grow between sea level and 8,000 feet, can grow up to 6 feet in one year (Tu 2003), are shade tolerant (Shafroth et al. 1995), and can germinate over a longer time interval than native species (Howe and Knopf 1991).

Until the 1990's several state and federal agencies promoted the distribution of Russian olives for windbreaks and horticulture plantings in the western U.S. (Tu 2003, Olson and Knopf 1986, Haber 1999). The seedlings were touted for their use in controlling erosion (Katz and Shafroth 2003), providing wildlife habitat (Borell 1962), and serving as a nectar source for bees (Hayes 1976). As a result, Russian olives were widely distributed and continue to spread through natural sexual and vegetative reproduction (Tu 2003).

Russian olives begin producing seeds 3 to 5 years after establishment (Tu 2003). Seeds are encased in a fleshy fruit providing an attractive food source for wildlife, especially avian species. As the outer layer of the seed is impervious to digestive fluids (Tesky 1992), seed predators are a significant factor in Russian olive recruitment. Plant establishment has been documented following seed consumption by birds (USDA 1974, Shafroth et al. 1995, Lesica and Miles 1999, Muzika and Swearingen 1998). Coyotes, deer, and raccoons have also consume and distribute the seeds (USDA 2002). The seeds are dispersed in a dormant state during the fall and winter. They prefer an after-ripening period of moist conditions lasting roughly 90 days to successfully germinate (Hogue and LaCroix 1970, Belcher and Karrfalt 1979). In average conditions, seeds are viable for up to 3 years (USDA 2002). This lengthy seed viability allows Russian olive more time to utilize optimal germination conditions than most native plants giving Russian olive another competitive edge (Howe and Knopf 1991, Shafroth et al 1995).

Russian olive seeds can germinate on undisturbed soils, are not highly dependent on the flood disturbances that sustain native species (Shafroth et al. 1995, Lesica and Miles 1999, Katz 2001) and are able to exploit the degraded conditions of southwestern rivers today (e.g., interrupted flow regimes, reduced flooding, increased fire, etc.). Russian olives grow and compete with native plants in dry, upland soils (Laursen and Hunter 1986) and in wet-saline soils. However, non-saline, hydric soils and soils with elevated sodium levels favor native species and the invasive plant tamarisk recruitment *(Tamarix spp.)* over Russian olive respectively (Carman and Brotherson 1982).

Figure 5: Russian Olive Trees along the main-stem of the upper Arkansas River

shade tolerant seedlings are able to germinate and thrive in the understory of native trees. As the native trees die, Russian olive becomes the upper canopy of the system, shading out native tree recruits (Shafroth et al.1995).

In general, the following is an assessment of Russian olives and their impacts on riparian systems throughout the West (Tu 2003):

- Russian olives form dense, monotypic stands that affect vegetative structure, nutrient cycling, and ecosystem hydrology.
- Presence of Russian olive can modify plant succession in a system.
- Russian olive results in lower native plant and animal diversity.
- Wide spreading throughout woodlands connects riparian forests with upland areas stabilizing floodbanks, increasing overbank deposition, and limiting cottonwood regeneration sites.
- The evapotranspiration rates of Russian olives are higher than native species, thus they consume more water resources (Carman and Brotherson 1982).
- The invasives can convert riparian areas to relative drylands with Russian olive as the climax species (Olson and Knopf 1986).
- Dense stands of Russian olives increase fuel loads leading to more frequent and intense wildfires that kill native plants (Caplan 2002).
- Russian olive trees provide inferior habitat to native vegetation and reduce abundance and diversity of wildlife (Knopf and Olson 1984, Brown 1990).

The difficulty of controlling or removing mature stands of Russian olive makes it almost impossible to eradicate from a watershed once it is established. Thus, it is important to detect new infestations of Russian olive early on and to rapidly respond to remove them. There are methods available to control Russian olives on a small scale, but the cost and intense labor demands of the work can be expensive. Techniques used include mowing, cutting, and girdling combined with herbicide application; basal bark herbicide application; and burning, excavating, and bulldozing with no herbicide application (Tu 2003).

In general, Table 1 provides an overview of adverse characteristics and potential impacts widely attributed to tamarisk (T) and Russian olive (RO). For more detailed information the reader is referred to Carpenter 1998 and Tu 2003.

It should be noted that various other non-native invasives are intermixed with tamarisk and Russian olive such as Russian knapweed, whitetop, Russian thistle, and purple loosestrife and should be considered throughout the planning and implementation of restoration actions.

Table 1: Characteristics of Tamarisk (T) and Russian Olive (RO)

Characteristics		**Description**
Origin	T	Central Asia/Mediterranean
	RO	Europe/Western Asia
Estimated Cover	T	1 to 1.5 million acres in the western United States
	RO	Unknown
Elevation	T	Sea Level to 6,500 feet
	RO	Sea Level to 8,000 feet
Habitat/Range	T	Western U.S. along rivers, springs, drainages
	RO	Throughout U.S. - most dense in western states
Tolerant	T	Floods, droughts, close shearing, and burning
	RO	Floods, droughts, close shearing, burning in dormancy, seedlings and saplings are shade tolerant
Intolerant	T	Shade
	RO	Acidic conditions (pH<6.0)
Reproduction/Distribution	T	Sexual and vegetative; seeds need moist soils/water and wind
	RO	Sexual and vegetative; seeds can propagate in
Growth patterns	T	Dense monotypic stands, clumps or stringers
	RO	Dense monotypic stands or scattered occurrences
Soils	T	Seedling require moist soils; ranges widely as adult; highly tolerant of and actually increases surface salinity
	RO	Can tolerate bare mineral or nitrogen poor soils, prefers sandy floodplains and open, moist riparian habitats, tolerant of prolonged inundation
Vegetation Impacts	T	Once established, grows densely and excludes natives
	RO	Shade tolerant, allowing it to out compete natives through succession and exclusion

Characteristics		Description
Water Use	T	Equivalent evapotranspiration to riparian native phreatophytes such as willows and cottonwoods, but deep roots systems uses water even in drought, high leaf area index and tendency to grow in dense thickets can result in more water usage per acre than natives, and grows in mesic and xeric areas due to deep root depths
	RO	High rates of evapotranspiration similar to other phreatophytes, but uses more water than native upland mesic and xeric vegetation
Wildlife Impacts	T	Reduced insect prey and habitat structure negatively impacts most bird species with some exception, and poor habitat for raptors such as bald eagles; channelization of streams reduced native riparian recruitment and reduces backwaters and spawning areas for endangered fish
	RO	Provides inferior habitat in the long-term resulting in loss of species richness
Wildfire	T	Increase frequency and intensity, extremely fire tolerant
	RO	Increases fuel load; fire tolerant
Management	T	Difficult and expensive for mature stands
	RO	Difficult and expensive for mature stands
Forage	T	Poor nutrition
	RO	Poor nutrition, birds and other wildlife can feed on fruit
Livestock	T	Reduces forage area, surface water, and impedes access to flowing water
	RO	Reduces forage area, surface water, and impedes access to flowing water
Stream/River Morphology	T	Dense stands stabilize river banks, change stream structure by narrowing and deepening channels, and decreasing number and size of backwaters needed to sustain a properly functioning ecosystem with native riparian communities and wildlife habitats. Reduced carrying capacity of river channels can increase flood damage
	RO	Stabilizes river banks, increasing overbank deposition, and limit native cottonwood regeneration

Characteristics		Description
Recreation	T	Can be aesthetically pleasing though generally degrades aesthetic value, obstructs access to streams/rivers, reduces native ecosystems and diversity
	RO	Can be aromatically, aesthetically pleasing, obstructs river access, reduces native ecosystems and diversity

Extent of the Problem

Inventory Background and Objectives – In 2007, the Tamarisk Coalition completed an inventory of tamarisk infestations in the Arkansas River watershed and its main tributaries. The purpose of this work was to establish and implement an inventory protocol that would be economical to perform and would provide a clear understanding of the extent of the tamarisk problem. The inventory mapping protocols proved to be successful and have been used to identify tamarisk infestations throughout the remainder of the state. This discussion of the extent of the problem is focused on tamarisk because it is the indicator species in the Arkansas watershed that best describes areas that have serious riparian degradation.

Inventory Approach - Inventory and mapping were performed during the summer and fall of 2006. This effort mapped the watershed along the main-stem of the Arkansas River from Pueblo Reservoir Dam east to the Kansas state line. Fountain Creek, portions of the Purgatoire River, the Huerfano River and several of the large reservoirs in southeastern Colorado were mapped as well.

A second mapping project was initiated in the fall of 2007. This project inventoried the main-stem and tributaries west of Pueblo Reservoir Dam to Texas Creek, and included the tributaries, reservoirs, lakes, canals, ephemeral streams in the watershed that had not been mapped.

Figure 6: Arkansas Watershed Mapping Project Field Equipment

The mapping efforts were coordinated with the U.S. Geological Survey's (USGS) efforts to establish a national on-line database which would conform to the weed mapping standards developed by the North American Weed Management Association. The basic approach (see Appendix E for mapping protocols) uses existing aerial photography, satellite imagery, and local knowledge available from counties, river districts, soil and water conservation districts, state agencies, Army Corps of Engineers, National Resources Conservation Service, USGS, Colorado State University (CSU), and The Nature Conservancy. This information was then "ground-truthed" by a two-man team to confirm infestation density, maturity, accessibility, presence of native species, and several other site characteristics. GPS data and digital photo records were taken and shape files were developed utilizing GIS capabilities.

Nearly 1,633 miles on the Arkansas River and the major tributaries were surveyed using this approach. This information, in the form of shapefiles and characteristics data, has been transformed into a digital GIS database which is available on the USGS National Institute of Invasive Species Science website, www.niiss.org, on the ARKWIPP website, www.arkwipp.org, and on the supplementary data-DVD.

The www.arkwipp.org website will become a valuable resource tool for landowners and managers. The website will house the mapping project. A landowner will be able to determine the amount of tamarisk on his/her property by clicking on his property.

Findings - The inventory for the Arkansas River and the major tributaries are presented in the ARKWIPP Mapping and Inventory Summary Report (Appendix A). The report represent a summary of the detailed information collected which is found on the supplementary data-DVD. Tables 2, 3, and 4 exemplify the tamarisk infestations in Arkansas River watershed. The tables illustrate the most current assessment of acreage of tamarisk and its impacts on water resources and the associated costs. Note that the average density within each major division is calculated by dividing the canopy cover acreage by total acreage. The total average is based on individual weighted acreages and may very slightly when calculated on a parcel by parcel basis.

Table 2: Tamarisk Infestations in Arkansas River Watershed

Arkansas River Main Stem	Cum-ulative River Miles	Average Density	Total Acreage	Current Water Loss (acre feet/year)	Future Water Loss (acre-feet/year)	Cost Estimates for Control and Restoration
Prowers County	49	59%	6,088	10,422	17,579	$10,054,330
Bent County	91	68%	9,714	19,711	29,040	$18,220,239
Otero County	145	49%	6,177	8,956	18,331	$8,573,169
Pueblo County to Pueblo Dam	197	36%	7,026	7,542	20,825	$7,276,000
Pueblo Dam to Texas Creek	281	19%	2,297	1,317	6,857	$1,316,613

Arkansas River Main Stem	Cum-ulative River Miles	Average Density	Total Acreage	Current Water Loss (acre feet/year)	Future Water Loss (acre-feet/year)	Cost Estimates for Control and Restoration
Totals for the Arkansas River Main Stem	**281**	**52%**	**31,302**	**47,948**	**92,632**	**$45,440,351**
Arkansas Related Waterways	**River Miles**	**Average Density**	**Total Acreage**	**Current Water Loss acre-feet/year**	**Future Water Loss acre-feet/year**	**Cost Estimates for Control and Restoration**
Apishapa River	122	24%	1,954	1,393	5,749	$1,435,016
Fountain Creek	22	26%	1,953	1,397	5,309	$1,502,806
Horse Creek	126	23%	1.065	775	3,402	$692,060
Huerfano/ Cucharas Rivers	164	25%	5,910	4,590	18,080	$4,685,094
Pueblo Washes	40	30%	602	564	1,879	$511,559
Rule Creek	62	28%	95	84	298	$77,141
Rush Creek	101	20%	466	291	1,481	$259,763
St. Charles/ Greenhorn Rivers	70	24%	1,945	1,383	5,726	$1,326,193
South La Junta Drainages	60	49%	373	526	1,081	$564,600
Timpas Creek	77	36%	361	410	1,138	$378,694
Two Buttes Creek	117	20%	171	112	558	$96,799
Arkansas Reservoirs*	N/A	28%	9,790	8,127	29,404	$7,825,675
Arkansas Tributaries**	40	27%	1,058	895	3,338	$930,687
Related Waterways Totals	**1,001**	**27%**	**25,744**	**20,547**	**77,442**	**$20,286,087**
*Arkansas Reservoirs include: Lake Meredith, Adobe Creek, Neeskah, Neenoshe, and Sheridan Lake **Arkansas Tributaries include: Big Sandy and Buffalo Creek						

Table 3: Tamarisk Infestation in the Purgatoire River Watershed

Purgatoire River Main Stem	Cum-ulative River Miles	Average Density	Total Acreage	Current Water Loss (acre feet/year)	Future Water Loss (acre-feet/year)	Cost Estimates for Control and Restoration
Bent/Otero County Line/Confluence	38	34%	3,023	3,075	8,926	$2,926,850
Otero County / Las Animas County Line	60	33%	2,072	2,049	6,289	$1,900,062
Trinidad Lake Dam	179	23%	4,155	2,841	12,099	$3,213,320
Totals	**179**	**30%**	**9,250**	**7,966**	**27,314**	**$8,040,233**
Purgatoire Related Waterways	**River Miles**	**Average Density**	**Total Acreage**	**Current Water Loss (acre feet/year)**	**Future Water Loss (acre-feet/year)**	**Cost Estimates for Control and Restoration**
Powell Arroyo	6	11%	12	4	39	$3,511
Raton Creek	3	5%	9	1	24	$1,422
Chicosa Arroyo	15	26%	140	103	393	$102,740
Frijole Creek	19	35%	52	52	149	$50,559
San Francisco Creek	13	49%	9	12	26	$14,286
San Isidro Creek	21	25%	182	134	535	$128,416
Trinchera Creek	7	20%	17	10	50	$9,834
Luning Arroya	30	45%	56	74	165	$84,958
Van Bremer Arroyo	24	23%	45	31	133	$37,131
Chacuaco Creek	24	22%	227	145	648	$178,612
Bent Canyon	10	20%	14	8	40	$7,734
Totals	**172**	**26%**	**763**	**575**	**2,203**	**$619,204**

Table 4: Total Tamarisk Infestation in the Entire Arkansas River Watershed

Totals for Entire Arkansas River Watershed	**1,633**	**33.5%**	**67,059**	**77,036**	**199,591**	**$74,385,875**

The inventory process focused on an efficient economical mapping/inventory protocols to identify eighty five (85%) to ninety percent (90%) of tamarisk within the watersheds. The remaining percentage represents small pockets of infestations that are scattered throughout the region and would be proportionately very expensive to map. Thus, the inventory and water loss calculations are somewhat conservative.

Current water losses are based on the amount of water tamarisk is currently using under observed densities minus the water that would be used by native plants. Figure 4 illustrates the differences in vegetative cover with and without tamarisk and shows that tamarisk is able to occupy a much greater area than the riparian zone that supports cottonwoods and willows, also phreatophytes. The significant water losses occur as tamarisk occupies terrace areas within the floodplain that would normally have dryland xeric vegetation such as grasses, saltbush, rabbit brush, etc. Based on these conditions, the estimates of current water losses above and beyond what native vegetation would use are approximately 76,600 acre feet per year.

Future water losses assume an infilling of the existing infestation areas will likely occur over the next several decades based on similar conditions observed in other states (NM, UT, and NV). Future water losses from infilling only (with no expansion from existing infested areas) are estimated to be approximately 198,000 acre feet per year.

If tamarisk control and revegetation occurs on any of these river or tributary sections, the water normally lost to the atmosphere through evapotranspiration will be conserved and will remain within the groundwater and/or surface water regimes.

Throughout these watersheds it is common to have Russian olive coexist with tamarisk especially in the urban corridor where Russian olive has escaped from landscape plantings and at higher elevations.

Expected Ecosystem Changes to Riparian Areas - Expected conditions following tamarisk and Russian olive control projects in the Arkansas watershed include enhanced aquatic, riparian, and floodplain habitat. The quantity and quality of these habitats would be improved, resulting in increased habitat for fish and wildlife including endangered fish species. Opportunities for environmental education, improved aesthetics, recreation and agricultural use, reduction of wildfire hazards and improved management of flood flows would exist in project areas. Significant conservation of water resource would also result from tamarisk and Russian olive control in the watershed. These expected changes will occur only if all aspects of restoration are part of the solution; i.e., site specific planning and design, control, revegetation, biomass reduction, monitoring, and long-term maintenance.

Beneficial impacts of restoration also include increased resilience to future stresses such as fire, drought, climate change, or other invasive plants; creating a more self-sustaining ecosystem; providing the benefits of improved water resources; and reducing future riparian management costs.

Control, Biomass Reduction, Revegetation, Monitoring, and Long-Term Maintenance

Management of non-native phreatophytes generally consists of five components; planning with inventory/mapping, control and biomass reduction, revegetation, monitoring, and maintenance. Without all five components it is unlikely that tamarisk and Russian olive control projects will be successful over time. Successful management also depends on flexible approaches open to experimental learning and new technologies. This is referred to as "adaptive management."

For the discussion on the control component of management, the focus is on tamarisk because it is the principal non-native phreatophyte in the Arkansas watershed. In general, the following discussion also applies to Russian olive but may be slightly different for each (e.g., type of herbicide used). A detailed comparison of major control technologies implemented throughout the West can be found in Appendix F. It describes in more detail effectiveness, impacts, applicability, cost algorithms, and time distribution of costs.

Templates and Protocols, (Appendix H) provides a suggested approach to select appropriate techniques for control and biomass reduction, revegetation, monitoring, and long-term maintenance. Biomass reduction and revegetation approaches are not always needed because in many situations natural revegetation can occur and biomass reduction may not be needed. For the purposes of this Plan the term *template* defines what actions should be taken, and the term *protocol* defines how the actions could be performed. These templates and protocols are intended as suggested guidance and criteria for decision making while carrying out the activities associated with various aspects of tamarisk and Russian olive control and biomass reduction, revegetation, monitoring, and long-term management. Thus, the intent is to ensure that selected approaches are effective and efficient, and decisions are well documented.

The ARKWIPP Technical Advisory Team has developed an interactive database to assist private landowners in determining the proper control and revegetation methods for restoration. The templates and protocols were used as the foundation for the database and are housed on the www.arkwipp.org website.

Control

Tamarisk can be controlled using a variety of weed management techniques, including chemical, mechanical, and biological techniques. All of the following tamarisk control techniques are appropriate, but each must be selected based on local conditions; i.e., "Integrated Pest Management."

- **Hand cutting with herbicide application** - This method is referred to as the "cut stump" approach in which the tree is cut or scored with chainsaws, handsaws, or axes, and the stump is treated with a herbicide within a few minutes of cutting.

    - This approach is considered to be very appropriate in the ARKWIPP study area for difficult to access areas; areas of special concern; areas in close proximity to valuable native vegetation, historic and archeological sites; campgrounds; and efforts involving volunteer support.

- **Hand removal by extraction** - This method uses simple hand tools such as the Weed Wrench, tripod/hand winch, and shovels and saws to dig out the root system and cut below the root crown. These techniques have been perfected at the Dinosaur National Monument and utilize volunteer groups because of their high labor requirements. No herbicides are used with these approaches. These approaches are most appropriate for the ARKWIPP study area in sensitive areas where volunteer labor can be used to effectively remove tamarisk. This approach may not work on larger trees.

- **Mechanical removal** - This approach uses heavy equipment to physically remove tamarisk. This is accomplished in one of two ways - root crown removal or mulching.
    - **Root crown removal** is the extraction of the root crown by either root plowing accompanied by root raking to remove the root crown from the soil or by extraction of the entire plant. These approaches do not use herbicide.
    - **Root plowing and raking** is extremely disruptive to the soil, native plants are destroyed, and the intense soil disturbance would support weed viability. It essentially removes all vegetation in a manner that would be similar to preparing land for intense agricultural production. For this reason and because areas may not be accessible for large equipment (Cat D-7 or larger), using root plowing and raking will depend on the site location and the type of mechanical equipment that will be utilized.
    - **Extraction** approaches using a large tracked excavator (Cat 325 or larger) is appropriate for some areas, especially those areas that have steep banks such as ditches and river banks and along roadway embankments. This approach results in high levels of soil disturbance and thus may require significant revegetation efforts. The removed biomass may also require disposal or additional treatment such as mulching.
    - **Mulching** uses newly developed, specialized equipment followed by herbicide application to the cut stumps. The most commonly used pieces of equipment are the Timber Ax, the Hydro Ax, and the Bull Hog. The resulting mulched materials can reduce soil disturbance, and provide a good seed bed for native plant recruitment if the mulched materials are not too thick while discouraging establishment of noxious weeds. Tracked mulching equipment provides a lighter footprint pressure than those with wheels and thus causes less soil disturbance. ARKWIPP areas suitable for this approach are limited to wide or somewhat level floodplains or terraces in scattered locations along the Arkansas River. A few larger tributaries could also be treated by mulching.

Figure 7: Mechanical Tamarisk Control

- **Aerial herbicide application** - In larger infestation areas helicopter and fixed wing aircraft have been used to apply foliar herbicide where monotypic stands of tamarisk exist. This approach will likely be used in the ARKWIPP area because: 1) monotypic infestations in this region are typically broad enough to make this approach economically feasible, 2) significant native vegetation is not present within the tamarisk infestations and aerial spraying would not cause mortality among these species, and 3) preliminary biological control results for this region look promising.

Figure 8: Helicopter Herbicide Application on Tamarisk

- **Ground application of foliar and basal bark herbicides** - Herbicides can be effectively applied by hand, from horseback, or by motorized equipment in some cases where other methods are impractical or expensive. It is recommended that this approach be used in isolated areas where other methods would unlikely be used such as scattered infestations in sparse or remote locations, upland areas, isolated stock tanks, etc.

Biological Control

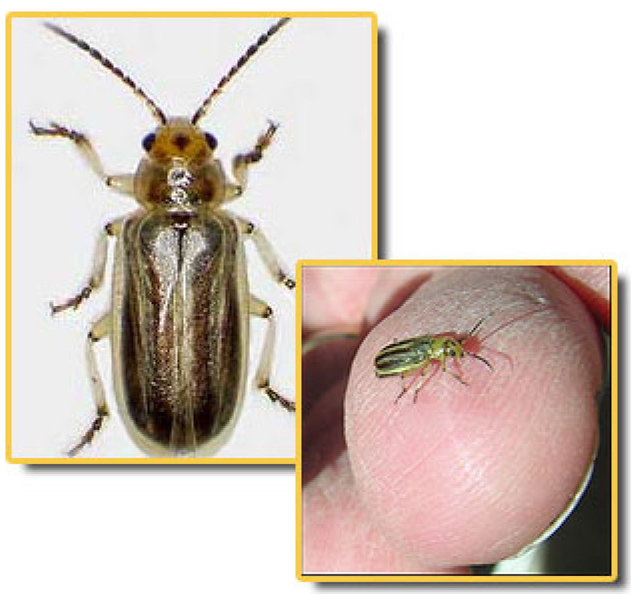
This method for invasive plant control uses specific organisms to control an undesirable organism. Two biological control agents have been identified for tamarisk - goats and a tamarisk leaf-eating beetle. Both organisms work to control tamarisk by repeated defoliation of the plant over several years.

- **Goats** will feed on tamarisk shrubs if fencing is provided to limit other food sources. Typically, a guard dog, herding dog, goat herder, and/or electric fencing pens are required. Several private goat herds are available throughout the region. For some areas this approach may be favored, especially if other noxious weeds such as knapweed are in abundance and herbicide use is restricted.

Figure 9: Goat Herd Devouring Tamarisk

- ***Diorhabda elongata,* tamarisk leaf-eating beetle,** has been tested extensively in quarantine and field releases to ensure safety with respect to non-target impacts. These insects (see Figure 10) are native to Asia and are currently approved for open release in Colorado. These releases are being closely monitored by the Colorado Department of Agriculture's Palisade Insectary and entomologists from CSU. Russian olive will not be controlled through this biological control agent. The use of these insects is seen as an important issue and a promising approach for tamarisk control for the main river corridor.
-

Figure 10: *Diorhabda elongata* Adult Beetle, actual size - 3/16 inch.



Controlled test sites show that three to five years of sequential defoliation are required to achieve tamarisk mortality of 70 percent; however, it is unknown how many seasons of defoliation will be required to kill tamarisk in southeastern Colorado's natural setting. The most promising characteristic of the tamarisk beetle is that it inflicts no damage to native plant populations. Preliminary evidence of effectiveness shows great potential and if biological control continues to progress it could be used as one of the main mechanisms for tamarisk control and maintenance. If this is the case, the advantages over other approaches will be significant; i.e., limited use of herbicides and a cost effective long-term solution.

Another point of interest is that lightly infested areas some distance from the main tamarisk infestations may support beetle activity and may experience defoliation. However, overtime, these small stands may simply provide an insufficient food source to sustain a growing population of insects. Thus, alternative methods should be considered for these areas.

1.

Using biological control as the primary tamarisk control technology requires several considerations to ensure that the approach garners successful results. Monitoring will be instrumental in determining rate of spread, native plant recruitment, other weed infestations to be addressed, biomass accumulation, and dead biomass removal approaches. The expertise of the Palisade Insectary and Colorado State University will be critically important for identifying the most appropriate protocols for disbursement, monitoring, and follow-up actions within the Arkansas River Watershed.

Figure 11: Beetle Defoliated Tamarisk at Lake Pueblo State Park

Although biological agents are being investigated for Russian olive, these invasive trees will still require traditional methods of control.

Biomass Reduction

Removal of dead tamarisk tree skeletons may be important after mechanical root crown removal, biological control, or foliar herbicide control if densities are moderate to heavy. Biomass reduction under these conditions assists planned revegetation efforts, restores aesthetic values, and reduces the wildfire potential of decomposing litter in moderately to highly infested areas. The removal of dead trees can be accomplished using mechanical mulching equipment or fire.

Mechanical mulching, by its nature manages the dead material by transforming it into mulch. However, if a large amount of biomass is mechanically mulched and piled the thickness of the layer produced may actually impede or prevent revegetation. Reducing biomass with fire may require the construction of adequate fire breaks in sensitive riparian areas to safely burn the invasive plants. In addition, air quality may be a concern for large-scale burns as carbon sequestered in the tamarisk will be released instantly. **Fire is an option that must be carefully coordinated with land managers and county air quality personnel. It should only be used for biomass reduction on dead plants, because live tamarisk will flourish after fire.** As shown in Figure 12 fire breaks and professional fire fighting staff are critical because of the intensity that tamarisk fires exhibit.

Figure 12: Removal of Tamarisk Slash Piles Using Controlled Fire at Bent's Fort

For many areas with light to moderate infestations, the dead biomass can be left standing without any actual physical biomass reduction actions. Standing dead biomass in these situations probably does not significantly impede natural or planned revegetation, affect aesthetics, or support high wildfire potential. After plant mortality, it will take an additional two to four years for root decay to occur before the dead skeletons will naturally fall over. Over the next few years the remaining biomass will decompose to a level that may not present any significant problems. These time estimates are based on site observations of tamarisk killed by herbicide in the area.

Revegetation

Successful revegetation is an enormously complex undertaking with few straightforward guidelines and no universal solutions. As a result, implementing revegetation projects following the removal of invasive species is an inherently site-specific task that does not easily translate into a large scale plan. For the ARKWIPP planning area it is recommended that local revegetation specialists, CSU Cooperative Extension, NRCS, and comprehensive revegetation and restoration texts be used to develop a course of action for individual projects. The University of Denver is currently preparing a "Best Management Practices" handbook for revegetation that will be available in 2008. There is an extensive list of excellent educational resources presently available on various methods of revegetation on the http://arkwipp.org/riparian-restoration.asp. While the specifics of revegetation are difficult to comprehensively determine, some general information corresponding to the ARKWIPP planning area is provided.

Figure 13: Cottonwood Pole Planting

One of the most interesting aspects of local experience with tamarisk control is the abundance of native plants present in the tamarisk understory. Non-native weeds such as Russian knapweed and whitetop were also found and could become a problem if left unattended. Annual weeds, while a short term concern, generally find a balance that does not preclude native plant establishment (with some exceptions). A plant list from the Native Plant Revegetation Guide for Colorado, prepared by the Colorado Natural Areas Program, Colorado State Parks, and Colorado Department of Natural Resources, is included in Appendix H. The entire guide can be accessed through the http://arkwipp.org/riparian-restoration.asp website. The plant list provides a starting point for revegetation planning, keeping in mind the importance of knowing specific site characteristics before choosing plants for revegetation purposes.

Revegetation is critical to successful long-term tamarisk and Russian olive control. Revegetation efforts may require labor, seed, plant materials, fertilizer, equipment rental, weed control, and water. Requirements for revegetation have a direct relationship to density of infestation and width of infestation. For narrow widths (less than 50 feet) natural revegetation may occur more easily because of close proximity to native plant/seed sources. However, these areas may still incur minor to moderate costs because of soil disturbance and the need for weed control. For broader widths (greater than 50 feet) costs will shift to the higher side because less native plant/seed will be available for reintroduction to the interior areas of the infestation. Other site conditions also influence revegetation such as surface and ground water dynamics, soil chemistry and texture, density of propagules of desired revegetation species, etc.

When there are many natives interspersed within the tamarisk stand (which is often difficult to determine until removal begins) removal of invasives must be executed in a manner that protects native seed sources for natural revegetation on-site and within the basin. Manual control, root extraction and Timber Ax mowing/mulching are methods capable of sparing interspersed natives, even one-inch caliper saplings.

In broader areas of infestation, it may be important to plan a biomass removal pace that allows and encourages natural native plant regeneration rather than seeding and planting. However, in such large dense stands of tamarisk it may be advisable to create vegetative islands and paths within the tamarisk to help speed the native regeneration process, and provide fire breaks.

In some higher value areas such as wildlife habitats or high profile/high human use areas pole plantings, shrub tubing plantings, and seeding may be desirable to aid in the regeneration process. However, these kinds of revegetation projects are extremely expensive and require long-term maintenance commitments.

Figure 14: After Tamarisk Control and Restoration Measures at Bent's Fort

Monitoring

For riparian restoration activities, "monitoring" is the act of observing changes that are occurring or expected to occur with, or without, remediation actions. The purpose of monitoring is to provide information in response to objectives, to make informed decisions to initiate, continue, modify, or terminate specific actions, remediation activities or programs - better known as "adaptive management."

Two considerations important to the ARKWIPP monitoring efforts to gauge ecological changes are scale and ownership. In general there are two divisions in each of these elements: large-scale versus small-scale projects; and public ownership versus private ownership. For the purposes of this discussion it will be assumed that parcel sizes large enough to support large-scale projects are usually located on public lands and that small scale projects will be located primarily on private lands. Coordination between private landowners and public land managers is essential to gain access to private lands, create a standard monitoring protocol, and to develop and execute training in monitoring methods. Depending on the large-scale monitoring on public lands allows policy makers, land managers, and the public to evaluate the potential impacts of remediation on water resources, vegetation, wildlife habitat, biodiversity, economic health, society, and culture. These are essential considerations for determining what level of funding should be committed to the control efforts by the local, state, and/or federal agencies. Pre-restoration monitoring is important to establish baseline data to determine if goals and objectives are being achieved on the landscape scale.

Small-scale monitoring on private lands provides useful information on the effectiveness of control and remediation activities. This information allows for modifications, if necessary, to achieve the remediation goals. In general, small-scale monitoring criteria should consist of simple and inexpensive monitoring techniques based on the needs of the management objectives. The objectives of each restoration site, varying combinations of monitoring approaches, may be designed based on intensity of restoration, site specifics, or capability of collaborators.

Long-Term Maintenance

Long-term maintenance is a dynamic management process, carried out over years to decades to achieve social, economic, and ecological goals associated with a watershed. The process of management encompasses the strategic implementation of actions to identify, maintain, remediate, improve, and monitor the ecological processes of the watershed. Actions, and the tools required to accomplish them, are chosen because they are consistent with and likely to achieve the watershed goals, and because they address the results of monitoring.

Monitoring is related to maintenance; in that it is the act of observing changes that are occurring with, or without, remediation actions. Monitoring provides information for making informed decisions to ensure "maintenance" will continue to remediate or improve the ecological processes of the watershed. For tamarisk and Russian olive restoration these measures are important for effective control on a long-term basis and that the desired outcomes of revegetation and prevention of other noxious weed infestations are successful.

Research shows that if resources are spent only on control with no cohesive approach to long-term revegetation, monitoring, and maintenance, the potential for successful riparian restoration is limited.

Proposed Strategies for Control, Biomass Reduction, Revegetation, Monitoring, and Long-term Maintenance of Watershed Sections

Mapping and inventory work completed by the Tamarisk Coalition (Appendix A), in coordination with county weed managers and the economic algorithms developed by the Tamarisk Coalition (Appendix G) identify a range of costs for tamarisk and Russian olive control and restoration. The cost algorithms were developed to provide a "planning-level" range of costs for tamarisk control along each river segment.
They employ tamarisk infestation information for each segment (acres infested, percent cover, accessibility, and width) to estimate costs based on which control strategies would be appropriate for the area, and how much these strategies would cost for the given acreage. Therefore, the cost algorithm data tables can be manipulated to reflect decisions concerning which tamarisk control strategies will be used, and to what extent, on a given river segment. As a result, the percentage that each control strategy will likely be used on a section can be continually adjusted using the algorithms to find more accurate, or updated, cost estimates. This detailed information is presented in the supplementary data-DVD.

The following discussions articulate the proposed strategies for tamarisk control, biomass reduction, and revegetation for specific geographic settings in the Arkansas River watershed. These strategies were developed in coordination with county weed managers and land managers throughout the region.

The restoration recommendation for areas not specifically addressed below is as follows: Biological control using the tamarisk leaf beetle, *Diorhabda elongata*, coupled with natural biomass decomposition for light infestations, biomass reduction for moderate to heavy infestations, and revegetation for areas where biomass is reduced.

Biological control should be considered the priority approach for the Arkansas River watershed. However, at present, it is uncertain how effectively the tamarisk leaf beetle will achieve large scale tamarisk mortality. Until that efficiency is known the methods described below should be used on high priority areas to ensure success regardless of the bio-control’s effectiveness. If bio-control is unsuccessful as a large-scale approach the methods described below would be appropriate to control tamarisk throughout the watershed.

In general, biomass reduction should not be needed for light infestations and some moderate infestations but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries in many of these areas as well as native shrubs.

Revegetation will likely occur naturally for lightly infested sites with some minor weed control. For moderate infestations, some reseeding will be necessary while heavy infestations will require substantial revegetation efforts. Any revegetation efforts will be very site specific, and will vary, depending on local conditions such as soil type, intended land use and mesic versus xeric sites. Site specific revegetation plans will be developed for sites requiring revegetation. In general, revegetation efforts for all areas, when required, may consist of:

1. Pole cuttings for cottonwoods and willows in areas with shallow groundwater (less than 10 feet).

2. Longstem planting using tall pot techniques to revegetate upper terrace sites that have deeper groundwater and lack overbank flooding. This approach is very useful for some trees and shrubs such as currants and skunkbush. For more information see the revegetation section contained earlier in the plan.

3. Broadcast or seed drilling for grasses and forbs such as salt grass, alkali sacaton, sand dropseed, alkali muhley, and indian ricegrass, among many others depending on the local site conditions.

Weed control following tamarisk and Russian olive control and during revegetation efforts is necessary to prevent the establishment of noxious weeds such as Russian knapweed, perennial pepperweed, cheatgrass, hoary cress (whitetop), Canada thistle, etc. In general, weed control for all areas, when required, may utilize herbicide, mechanical and biological control, and preventive measures associated with successful revegetation approaches. The need for weed control will increase proportionately with the degree of infestation.

Arkansas River Watershed Strategies

Arkansas River Main-stem: John Martin Reservoir Dam to Kansas State Line
This information can be found on the data-DVD: Drawings A1-A17 and Photo Log No. 2-16, 18-26, 28, 52-63
Estimated Acres Infested with Tamarisk **– 8,346**
Estimated Average Tamarisk Density **– 59%**

This area constitutes the lands adjacent to the Arkansas River east of John Martin Reservoir Dam and extending to the Kansas state line. Significant irrigation and infrastructure are characteristic of this area. Consequently, vehicle access to the river and tributaries are generally good. Landownership in this region consists of smaller private parcels and ranches, as well as substantial croplands. Mike Higbee State Wildlife Area is adjacent to the Arkansas River near Lamar.

This river segment consists of dense, wide and monotypic stands of tamarisk typical of those found on the Arkansas River main-stem downstream of Pueblo Reservoir. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Along Hwy 50, mechanical removal with cut-stump herbicide application or extraction should be used to assure highway safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application.

Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and willow communities in many of these areas, as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction (not possible for Russian olive) or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Along Highway 50: Control: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk. Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit. Revegetation: Native shrubs and grass seed mixes.

Arkansas River Main-stem: John Martin Reservoir
This information can be found on the data-DVD: Drawings A17-A20, AW148, AW155, AW163-AW165
Estimated Acres Infested with Tamarisk – **4,876**
Estimated Average Tamarisk Density – **73%**

This area is comprised of the lands surrounding John Martin Reservoir and upstream of the dam that creates the reservoir. Significant irrigation and infrastructure are characteristic of this area. Additionally, the reservoir's use as a recreation and wildlife area necessitates many roads, and vehicle access to the reservoir and tributaries in this area is generally good. Landownership consists almost entirely of both John Martin Reservoir State Park and John Martin Reservoir State Wildlife Area.

This area consists of more dense, wide and monotypic stands of tamarisk than any other on the Arkansas River system. The perimeter of the reservoir has a "bathtub ring" of immature tamarisk most likely caused by the recession of the reservoir waters in recent drought years. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Along Hwy 50, mechanical removal with cut-stump herbicide application or extraction should be used to assure highway safety. No herbicide should be needed for resprouts if biological control is active in the area.

Russian olive, although less abundant than tamarisk, has a moderate presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application as the primary approach in all areas.
Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and willow communities in many of these areas, as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, & Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake.

<ins>Biomass</ins>: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. <ins>Revegetation</ins>: Pole plantings of cottonwood & willow & tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
<ins>Light to Moderate Infestations in the Floodplain:</ins> <ins>Control</ins>: Hand cut-stump control, mechanical extraction (not possible for Russian olive) or grab & cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. <ins>Biomass</ins>: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. <ins>Revegetation</ins>: Pole plantings of cottonwood & willow & tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
<ins>Along Highway 50:</ins> <ins>Control</ins>: Mechanical removal with grab & cut-stump or extraction. Bio-control (if active) for remaining tamarisk. <ins>Biomass</ins>: Mulching for revegetation. Stack and burn slash piles when conditions permit. <ins>Revegetation</ins>: Native shrubs and grass seed mixes.

Arkansas River Main-Stem: Pueblo Reservoir Dam to John Martin Reservoir
This information can be found on the data-DVD: Drawings A20-A50, AW137, AW146, AW148 and Photo Log No. 31, 33, 35, 36, 63-68, 69, 70, 93, 96-99, 100-106, 108, 109, 110, 111, 113, 115-130, 137, 142, 143
Estimated Acres Infested with Tamarisk **– 16,000**
Estimated Average Tamarisk Density **– 44%**

This area constitutes the lands adjacent to the Arkansas River east of Pueblo Reservoir Dam and extending to the upstream end of John Martin Reservoir. Significant irrigation and infrastructure are characteristic of this area. Consequently, vehicle access to the river and tributaries is generally good. Landownership in this region consists of smaller private parcels and ranches, as well as substantial croplands. Several State Wildlife Areas are also adjacent to the Arkansas River. Additionally, the river passes through or near several towns and the City of Pueblo in this section.

This area consists of more dense, wide and monotypic stands of tamarisk than any other on the Arkansas River system. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking are appropriate for lands designated for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Along Highway 50 and in significantly populated areas, mechanical removal with cut-stump herbicide application or extraction should be used to ensure public safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application.

Biomass reduction is unnecessary for light infestations and some moderate infestations. Moderate densities in or around high value areas and all high density infestations will require biomass reduction to reduce the fuel load and flood debris potential in riparian areas. Examples of high value areas include campsites, road ways, and native vegetation stands such as cottonwood galleries, willow communities, sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods of biomass reduction are recommended though some hand work may be required in difficult to access areas. When conditions permit, biomass slash piles can be stacked and burned.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and/or rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction (not possible for Russian olive), or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Along Highway 50 and in cities/towns: Control: Mechanical removal with grab and cut-stump or extraction (not possible for Russian olive). Bio-control (if active) for remaining tamarisk. Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit. Revegetation: Native shrubs and grass seed mixes.

Arkansas River Main-stem: Texas Creek to Pueblo Reservoir
This information can be found on the data-DVD: Drawings AW1-AW4, AW7, AW8, AW13, AW14, AW15, AW18, AW20, AW21, AW26, AW27 and Photo Log No. 2121, 2129, 2137, 2138, 2139, 2142
Estimated Acres Infested with Tamarisk – **1,603**
Estimated Average Tamarisk Density – **15%**

This area constitutes the lands adjacent to the Arkansas River west of the Texas Creek confluence and extending to the upstream end of Pueblo Reservoir. Vehicle access to the river and tributaries is generally good. Landownership consists of small private parcels and ranches, including some agricultural use downstream of Cañon City. Additionally, the river passes through Cañon City, Florence, and Lake Pueblo State Park. Upstream of Pueblo Reservoir, the Arkansas River main-stem moves from the flat, broad floodplains east of Pueblo, to a shallow valley between Florence and Pueblo Reservoir. The area surrounding Cañon City and Florence returns to an open floodplain briefly, then dramatically changes as the foothills rise and the river pours out of the 1,000 foot deep Royal Gorge. The entrance to this gorge is the upstream extent of nearly all major tamarisk infestations on the Arkansas River. Spotty stands of tamarisk exist further upstream, but are drastically limited by topography and increasing elevation.

The tamarisk infestations occupying the majority of this river segment will be controlled with combinations of mechanical removal, herbicide application, and some hand cut-stump work. Light, broad infestations would best be removed with mechanical extractors and grab and cut-stump equipment. Biomass will then be stacked for wildlife habitat or mulched for revegetation purposes depending on the desires of the landowner. Additionally, biomass can be piled and burned when conditions permit. Moderate to heavy, broad infestations where biomass reduction is a high priority should be mechanically mulched. Due to the high costs of hand cut-stump control work, this method should only be used around valuable vegetation and in areas inaccessible to mechanical equipment. Only areas that are very heavily infested and broad should be considered for aerial spraying, such a section is represented in drawing AW21 and AW26. Along Highway 50 and in significantly populated areas, mechanical removal with cut-stump herbicide application or extraction should be used to ensure public safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will correspond with tamarisk removal methods in most areas, with the exception of mechanical extraction which is inappropriate for Russian olive removal. In such instances mechanical grab and cut-stump removal should be used instead. The primary approach for controlling those Russian olive stands that do not occur near tamarisk infestations will be either hand or mechanical cut-stump removal with herbicide application.

Biomass reduction is unnecessary for light infestations and some moderate infestations. Moderate densities in or around high value areas and all high density infestations will require biomass reduction to reduce the fuel load and flood debris potential in riparian areas. Examples of high value areas include campsites, road ways, and native vegetation stands such as cottonwood galleries, willow communities, sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods of biomass reduction are recommended though some hand work may be required in difficult to access areas. When conditions permit, biomass slash piles can be stacked and burned.

Areas necessitating biomass reduction will require revegetation. For mechanical methods, native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. In aerial spraying locations, revegetation is critical in all cases due to the inherent loss of surrounding vegetation. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction, or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Along Highway 50 and in cities/towns: Control: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk. Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit. Revegetation: Native shrubs and grass seed mixes.

Arkansas River Main-stem: Headwaters to Texas Creek
Drawings N/A
Photo Log No. N/A
Estimated Acres Infested with Tamarisk – **N/A**
Estimated Average Tamarisk Density – **N/A**

Tamarisk infestations in this area consist of isolated stands near the Arkansas River main-stem and its major tributaries. In many cases, the Bureau of Land Management (BLM) has taken control measures for tamarisk in this reach of the river. For remaining spotty infestations, hand cut-stump control with herbicide application should be used. In infested areas already controlled by the BLM, monitoring and controlling tamarisk resprouts will be important in preventing future infestations. Revegetation in most areas should occur naturally from surrounding native plants, but should be considered in the absence of other plant species.

Fremont and Pueblo Counties Dry Washes
This information can be found on the data-DVD: Drawings AW4-AW6, AW8-AW19, AW21-AW27, AW30-AW35, AW54-AW58 and Photo Log No. 2122, 2123, 2124, 2126, 2127, 2128, 2132, 2133, 2134, 2135, 2136, 2140, 2141, 2669, 2671, 2672, 2673, 2675
Estimated Acres Infested with Tamarisk – **1,295**
Estimated Average Tamarisk Density – **24%**

This area consists of many ephemeral washes and arroyos surrounding the Pueblo and Cañon City areas. Generally the washes and arroyos in this section are characterized by shallow, broad stream morphology. Exceptions to this generalization are some of the deeper canyons entering Pueblo Reservoir from the north and south. These washes are more incised and narrow, with steep canyon walls and very limited vehicle access. Shallow washes offer better vehicle access, except near their terminus as they enter the Arkansas River. Here they are deeply incised and are more difficult access. West, east, and north of Pueblo are several shallow arroyos with steep walls and spotty tamarisk infestations. The edges of these arroyos can be accessed easily, though reaching the streambed for mechanized removal methods may be difficult.

These washes and arroyos typically support heavier tamarisk infestations at their juncture with the Arkansas River that lessen farther upstream. Tamarisk infestation within these washes is generally light, and is confined to either standing water or ephemeral streambanks. Cover from other riparian species in this area is typically light, with native grasses and forbs constituting the majority of upland cover. Small stands of cottonwood and willow do exist in isolated areas, and should be adjusted for accordingly.

Hand cut-stump control should be used in each of these areas starting at the upper extent of infestations and working down to the continuous, dense infestations near the tributaries' confluences with the Arkansas River. Biological control may be active along the main-stem of the Arkansas River and could adequately control these heavy infestations. Some hand cut-stump work should be used in these areas around stands of valuable vegetation. Biomass for the upper portions of the washes where hand control is performed will be stacked for wildlife habitat. Biomass reduction may be necessary in the lower, denser infestations around valuable vegetation by the Arkansas River following beetle defoliation. Natural revegetation with native grasses, fourwing saltbush, and other shrubs and forbs may occur in some areas.

The areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

Moderate to Heavy Infestations: Control: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching or stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light, Spotty Infestations along the Tributaries: Control: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active). Biomass: Stacking for wildlife. Revegetation: Natural revegetation.

Apishapa River: Headwaters to County Road 707
This information can be found on the data-DVD: Drawings AW102-AW107, AW108-AW119b and Photo Log No. 2250-2253, 2255, 2256, 2260
Estimated Acres Infested with Tamarisk – **718**
Estimated Average Tamarisk Density – **24%**

This river section and its tributaries are characterized by shallow canyons with generally poor vehicle access. Tamarisk infestations on the Apishapa River in this area are mostly light to moderate, with little other major riparian vegetation except some pockets of willow. This area contains the Apishapa State Wildlife Area, but is mostly held by private landowners.

Mostly hand work should be performed along the main-stem and spottily infested tributaries in this section. In areas that permit mechanized access, mechanical removal methods may be applied. Biomass should be stacked for wildlife and some natural revegetation is expected to occur. Additionally, biomass can also be piled and burned when conditions permit. As with other sites, natural biomass decomposition, reduction, and revegetation should occur after biological control has caused significant mortality in tamarisk.

The areas necessitating biomass reduction will require revegetation. For mechanical methods, native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit.

<u>Revegetation</u>: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
<u>Moderate to Heavy Infestations:</u> <u>Control</u>: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. <u>Biomass</u>: Mulching or stack and burn slash piles when conditions permit. <u>Revegetation</u>: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
<u>Light, Spotty Infestations along the Tributaries</u>: <u>Control</u>: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active). <u>Biomass</u>: Stacking for wildlife. <u>Revegetation</u>: Natural revegetation.

Apishapa River: County Road 707 to Arkansas River Confluence
This information can be found on the data-DVD: Drawings AW89-AW102 and Photo Log No. 2198, 2199, 2204, 2205, 2206
Estimated Acres Infested with Tamarisk **– 1,237**
Estimated Average Tamarisk Density **– 22%**

In this area, the Apishapa River topography opens and the channel returns to a meandering, wide floodplain morphology. The level of agricultural use on the lands surrounding this reach increases somewhat toward the Arkansas River. Several springs are present near the Apishapa main-stem. Additionally, moderate irrigation and infrastructure are characteristic of this area. Consequently, vehicle access to the river and tributaries is generally good. Landownership consists of small private parcels.

This area consists of some dense, wide and monotypic stands of tamarisk. The primary management method should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Near Highway10, mechanical removal with cut-stump herbicide application or extraction should be used to assure highway safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application.

Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and willow communities in many of these areas, as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction, or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Along Highway 10: Control: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk. Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit. Revegetation: Native shrubs and grass seed mixes.

Fountain Creek: Headwaters to Arkansas River Confluence
This information can be found on the data-DVD: Drawings F1-F9 and Photo Log No. 146, 147, 149-152, 156-164

Estimated Acres Infested with Tamarisk **– 1953**
Estimated Average Tamarisk Density **– 25%**

Fountain Creek runs from the Colorado Springs area southward toward Pueblo where it meets the Arkansas River. From north to south, the creek runs nearly parallel to Interstate 25. Subsequently vehicle access to the Arkansas main-stem and tributaries in this area are generally good. Native vegetation in the riparian zone includes cottonwood and willow communities.

The broad tamarisk infestations occupying the majority of this section will be controlled with combinations of mechanical removal, herbicide application, and some hand cut-stump work. Light, broad infestations would best be removed with mechanical extractors and grab and cut-stump equipment. Biomass will then be stacked for wildlife habitat or mulched for revegetation purposes depending on the desires of the landowner. Additionally, biomass can be piled and burned when conditions permit. Moderate to heavy, broad infestations where biomass reduction is a high priority should be mechanically mulched. Due to the high costs of hand cut-stump control work, this method should only be used around valuable vegetation and in areas inaccessible to mechanical equipment.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Mostly hand work should be performed along the spottily infested areas in this section. Biomass should be stacked for wildlife and natural revegetation is expected to occur. Additionally, biomass can also be piled and burned when conditions permit. As with other sites, natural biomass decomposition, reduction, and revegetation should occur after biological control has caused a significant mortality in tamarisk.

Russian olive, although less abundant than tamarisk, has a significant presence as Fountain Creek nears Pueblo. Control will correspond with tamarisk removal methods in most areas with the exception of mechanical extraction which is inappropriate for Russian olive removal. In such instances mechanical grab and cut-stump removal should be used instead. The primary approach for controlling those Russian olive stands that do not occur near tamarisk infestations will be either hand or mechanical cut-stump removal with herbicide application.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations along the Main-stem: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Moderate to Heavy Infestations along the Main-stem: Control: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching or stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

<u>**Light, Spotty Infestations along the Tributaries**</u>:
<u>Control</u>: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active).
<u>Biomass</u>: Stacking for wildlife.
<u>Revegetation</u>: Natural revegetation.
<u>**Along Interstate-25:**</u>
<u>Control</u>: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk.
<u>Biomass</u>: Mulching for revegetation. Stack and burn slash piles when conditions permit.
<u>Revegetation</u>: Native shrubs and grass seed mixes.

Huerfano/Cucharas Rivers: Headwaters to Huerfano/Cucharas Ditch
This information can be found on the data-DVD: Drawings AW60-AW88 and Photo Log No. 2154, 2155, 2156, 2157, 2158, 2160, 2162, 2163, 2164, 2166, 2168, 2173-2179
Estimated Acres Infested with Tamarisk **– 3,771**
Estimated Average Tamarisk Density **– 27%**

This area contains the main-stem canyons of the Huerfano and Cucharas Rivers. It also includes a significant perimeter infestation of tamarisk around Cucharas Reservoir (AW79-AW81). The narrow canyon section greatly restricts access to the river until it broadens slightly as it moves northeast toward the Arkansas River. If active in the area biological control should be considered the main approach for this section. In the narrow canyon of the main-stems, hand cut-stump control methods should be used to protect areas of valuable vegetation. In these locations biomass should be stacked for wildlife habitat and some low maintenance revegetation (i.e. pole plantings of willow and/or cottonwood) may be appropriate. Light, broad infestations in the wider section approaching the floodplain would best be removed with mechanical extractors and grab and cut-stump equipment. Biomass will then be stacked for wildlife habitat or mulched for revegetation purposes depending on the desires of the landowner. Moderate to heavy, broad infestations where biomass reduction is a high priority should be mechanically mulched.

The areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.
Most of the canyon sections are characterized by deeply incised, narrow waterways, and have little or no vehicle access. The canyons are very remote and are home to several rare plant, animal and fish species including leafy goldenweed (*Oonopsis foliosa var. foliosa*), swift fox, mountain plover, and Arkansas darter. Efforts will be made to clear tamarisk infestations in close proximity to these species and to avoid disturbing them during control work.

Hand cut-stump control should be used in each of these tributaries starting at the upper extent of infestations and working down to the continuous, dense infestations near the tributaries' confluences with the Huerfano/Cucharas Rivers. Biological control may be active along the main-stem of the rivers and could adequately control these heavy infestations. Some hand cut-stump work should be used in these areas around stands of valuable vegetation. Biomass for the upper portions of the washes where hand control is performed will be stacked for wildlife habitat. Biomass reduction may be necessary in the lower, denser infestations around valuable vegetation next to the river following beetle defoliation. Natural revegetation with native grasses, fourwing saltbush, and other shrubs and forbs will likely occur in most areas; however, some revegetation and some weed control will be required.

Control, Biomass Reduction, & Revegetation Approach
Mainstem – Narrow Canyon: Control: Hand cut-stump control work around areas of valuable vegetation with bio-control (if active) for remaining tamarisk. Biomass: Stack for wildlife where hand cut-stump control is used. Leave standing where bio-control (if active) is used. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas in areas where hand control is used. Natural revegetation following bio-control (if active).
Mainstem – Light Infestations, Broader Floodplain: Control: Mechanical extraction or grab & cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Mainstem – Moderate Infestations, Broader Floodplain (including Cucharas Reservoir): Control: Mechanical mulching for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Tributaries - Upper Extent of Light Infestations: Control: Hand cut-stump control work with bio-control (if active) for remaining tamarisk. Biomass: Stack for wildlife where hand cut-stump control is used. Leave standing where bio-control (if active) is used. Revegetation: Natural revegetation.

Huerfano/Cucharas Rivers: Huerfano/Cucharas Ditch to Arkansas River Confluence
This information can be found on the data-DVD: Drawings H1-H7, AW59 and Photo Log No. 104-107, 109-113, 115, 116
Estimated Acres Infested with Tamarisk – **2,437**
Estimated Average Tamarisk Density – **24%**

In this area the Huerfano River topography opens and returns to meandering, wide floodplain morphology. The level of agricultural use on the lands along and surrounding this reach of the Huerfano River increases somewhat towards the Arkansas River. Moderate irrigation and infrastructure are characteristic of this area. Consequently, vehicle access to the river and tributaries in this area is generally good. Landownership in this region consists of smaller private parcels and limited agricultural use.

This area consists of some dense, wide and monotypic stands of tamarisk. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application as the primary approach in all areas.

Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and willow communities in many of these areas, as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction, or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

St. Charles River and Greenhorn Creek: Headwaters to St.Charles/Greenhorn Confluence
This information can be found on the data-DVD: Drawings AW44-AW53 and Photo Log No. 2148-2152
Estimated Acres Infested with Tamarisk **– 668**
Estimated Average Tamarisk Density **– 27%**

This river section and its tributaries are characterized by shallow canyons with generally good vehicle access. Tamarisk infestations on the St. Charles River and Greenhorn Creek in this area are mostly light to moderate, with most other riparian vegetation consisting of cottonwood and willow. This area contains some parcels of state land, but is mostly held by private landowners.

Mostly hand work should be performed along the main-stem and spottily infested tributaries in this section. In areas that permit mechanized access, mechanical removal methods may be applied. Biomass should be stacked for wildlife and some natural revegetation is expected to occur. Additionally, biomass can also be piled and burned when conditions permit. As with other sites, natural biomass decomposition, reduction, and revegetation should occur after biological control has caused a significant mortality in tamarisk.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will correspond with tamarisk removal methods in most areas with the exception of mechanical extraction which is inappropriate for Russian olive removal. In such instances mechanical grab and cut-stump removal should be used instead. The primary approach for controlling those Russian olive stands that do not occur near tamarisk infestations will be either hand or mechanical cut-stump removal with herbicide application.

The areas necessitating biomass reduction will require revegetation. For mechanical methods, native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

<u>Moderate to Heavy Infestations:</u> <u>Control</u>: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. <u>Biomass</u>: Mulching or stack and burn slash piles when conditions permit. <u>Revegetation</u>: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
<u>Light, Spotty Infestations along the Tributaries</u>: <u>Control</u>: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active). <u>Biomass</u>: Stacking for wildlife. <u>Revegetation</u>: Natural revegetation.

St. Charles River: St.Charles/Greenhorn Confluence to Arkansas River Confluence
This information can be found on the data-DVD: Drawings AW36-AW44 and Photo Log No. 2143-2147
Estimated Acres Infested with Tamarisk **– 1,277**
Estimated Average Tamarisk Density **– 30%**

In this area the St. Charles River topography opens and returns to meandering, wide floodplain morphology. The level of agricultural use on the lands along and surrounding this reach of the Apishapa River increases somewhat towards the Arkansas River. Moderate irrigation and infrastructure are characteristic of this area. Consequently, vehicle access to the river and tributaries in this area is generally good. Landownership in this region consists of smaller private parcels and several large sections of state land .

This area consists of some dense, wide and monotypic stands of tamarisk. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Near Interstate - 25, mechanical removal with cut-stump herbicide application or extraction should be used to assure highway safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will correspond with tamarisk removal methods in most areas with the exception of mechanical extraction which is inappropriate for Russian olive removal. In such instances mechanical grab and cut-stump removal should be used instead. The primary approach for controlling those Russian olive stands that do not occur near tamarisk infestations will be either hand or mechanical cut-stump removal with herbicide application.

Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and willow communities in many of these areas, as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction, or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Along Interstate-25: Control: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk. Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit. Revegetation: Native shrubs and grass seed mixes.

Timpas Creek: Tributaries south of La Junta
This information can be found on the data-DVD: Drawings AW120-AW133 and Photo Log No. 2183-2186, 2189, 2190-2192, 2195-2197
Estimated Acres Infested with Tamarisk – **427**
Estimated Average Tamarisk Density – **35%**

This area contains many ephemeral washes and arroyos south of the La Junta area. The area also encompasses the Timpas Creek drainage. Generally the washes and arroyos in this section are characterized by shallow, broad stream morphology. The shallow washes in this area possess generally good vehicle access. The edges of some of these arroyos can be accessed easily, though reaching the streambed for mechanized removal methods may be difficult. Most landownership in this area consists of small parcels and residential parcels, although further upstream (southwest) Timpas Creek flows through the Comanche National Grassland (US Forest Service).

These washes and arroyos typically have heavier tamarisk infestations at their juncture with the Arkansas River and become sparse farther upstream. Tamarisk infestation within these washes is generally light, with pockets of infestation confined to either standing water or ephemeral streambanks. Small stands of cottonwood and willow do exist in some areas, and should be adjusted for accordingly.

Hand cut-stump control should be used in each of these areas starting at the upper extent of infestations and working down to the continuous, dense infestations near the tributaries' confluences with the Arkansas River. Biological control may be active along the main-stem of the Arkansas River and could adequately control these heavy infestations. Some hand cut-stump work should be used in these areas around stands of valuable vegetation. Biomass for the upper portions of the washes where hand control is performed will be stacked for wildlife habitat. Biomass reduction may be necessary in the lower, denser infestations around valuable vegetation by the Arkansas River following beetle defoliation. Natural revegetation with native grasses, fourwing saltbush, and other shrubs and forbs may occur in some areas.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application as the primary approach in all areas.

The areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Moderate to Heavy Infestations: Control: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching or stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

<u>**Light, Spotty Infestations along the Tributaries**</u>:
<u>Control</u>: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active).
<u>Biomass</u>: Stacking for wildlife.
<u>Revegetation</u>: Natural revegetation.

Arkansas River Watershed Reservoirs: Lake Meredith, Adobe Creek Reservoir, Neenoshe Reservoir, Sheridan Lake, Two Buttes Reservoir
This information can be found on the data-DVD: Drawings AR1-AR3, AW173 and Photo Log No. 1-8, 2249, 2269
Estimated Acres Infested with Tamarisk **– 9,895**
Estimated Average Tamarisk Density **– 21%**

This area is comprised of the lands surrounding several reservoirs near the Arkansas River. Significant irrigation and infrastructure are characteristic of this area. Additionally, the use of these reservoirs as prime recreation and wildlife areas necessitate many roads; thus, vehicle access to the reservoirs and tributaries in these areas is generally good. Landownership in this region consists of both private and state lands including Lake Henry State Wildlife Area (SWA), Meredith Reservoir SWA, Adobe Creek Reservoir SWA, Two Buttes Reservoir SWA, Queens SWA, Thurston Reservoir SWA, and Blue Lake State Trust Land.

This area consists of dense, wide and monotypic stands of tamarisk. Additionally, the perimeters of some reservoirs have a "bathtub ring" of immature and mature tamarisk most likely caused by the recession of the reservoir waters in recent drought years. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Along nearby highways, mechanical removal with cut-stump herbicide application or extraction should be used to assure highway safety.

Russian olive, although less abundant than tamarisk, has a moderate presence throughout much of these areas. Control will require either hand or mechanical cut-stump approaches with herbicide application as the primary approach in all areas.

Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries and willow communities in many of these areas, as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction, or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Along Highways: Control: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk. Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit. Revegetation: Native shrubs and grass seed mixes.

Arkansas River Tributaries: Big Sandy Creek, Buffalo Creek, Rule Creek, Rush Creek, Horse Creek, Fort Lyon Canal
This information can be found on the data-DVD: Drawings AT1-AT16, AW134-AW136, AW138, AW156-AW162, AW166-AW172 and Photo Log No. 9-16, 2260, 2262-2264, 2270, 2273-2277, 2280-2282, 2284
Estimated Acres Infested with Tamarisk – **2,685**
Estimated Average Tamarisk Density – **27%**

These areas consist of ephemeral washes, arroyos, and creeks north and south of the Arkansas River near Lamar. Generally the washes and arroyos in this section are characterized by shallow, broad stream morphology. The shallow washes in this area possess generally good vehicle access. The edges of some of these arroyos can be accessed easily though reaching the streambed for mechanized removal methods may be difficult. Most landownership in these areas consists of private and agricultural parcels.

These washes and arroyos typically have heavier tamarisk infestations at their juncture with the Arkansas River and become sparse farther upstream. Tamarisk infestation within these washes is generally light, with pockets of infestation confined to either standing water or ephemeral streambanks. Significant stands of cottonwood and willow do exist in some areas (i.e. Big Sandy Creek), and should be adjusted for accordingly.

Hand cut-stump control or mechanical removal should be used in each of these areas starting at the upper extent of infestations and working down to the continuous, dense infestations near the tributaries' confluences with the Arkansas River. Biological control may be active along the main-stem of the Arkansas River and could adequately control these heavy infestations. Some hand cut-stump work should be used in these areas around stands of valuable vegetation. Biomass for the upper portions of the washes where hand control is performed will be stacked for wildlife habitat. Biomass reduction may be necessary in the lower, denser infestations around valuable vegetation by the Arkansas River following beetle defoliation. Natural revegetation with native grasses, fourwing saltbush, and other shrubs and forbs may occur in some areas.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application as the primary approach in all areas.

The areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Moderate to Heavy Infestations: Control: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching or stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light, Spotty Infestations along the Tributaries: Control: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active). Biomass: Stacking for wildlife. Revegetation: Natural revegetation.

Purgatoire River Watershed Strategies

Purgatoire River, Trinidad Lake to San Francisco Creek confluence (including tributaries: Raton Creek, Powell Arroyo, Chicosa Arroyo, Frijole Creek, San Francisco Creek and San Isidro Creek)
This information can be found on the data-DVD: Drawings P35 to P44, RC1 to RC2, PA1, CA1 to CA4, FC1 to FC5, SFC1 to SFC3, and SIC1 to SIC6 and Photo Log No. 50, 53, 56, 58, 59, 61, 64, 74 – 78; 41 – 43; 51 – 52; 63, 66, 67, 68, 72, 80 – 82; 83, 86, 87, 90 - 93
Estimated Acres Infested with Tamarisk – **2,748 acres**
Estimated Average Tamarisk Density – **30%**

This area is located north, south and east of Trinidad and consists mostly of prairie grasslands with blue grama, western wheatgrass, prairie sandreed, and fourwing saltbush as some of the dominant vegetation in this zone. Native vegetation in the riparian zone includes cottonwood and willow communities, with large cottonwood galleries present in the areas near the San Francisco Creek confluence. Additionally, heavy infestations of Russian olive exist in the riparian areas near Trinidad, in some cases they are the dominant plant species near the river main-stem. Some agricultural areas exist in this area; subsequently vehicle access to the main-stem and tributaries in this area is generally good.

The broad tamarisk infestations occupying the majority of this section of the Purgatoire's main-stem will be controlled with combinations of mechanical removal, herbicide application, and some hand cut-stump work. Light, broad infestations would best be removed with mechanical extractors and grab and cut-stump equipment. Biomass will then be stacked for wildlife habitat or mulched for revegetation purposes depending on the desires of the landowner. Additionally, biomass can be piled and burned when conditions permit. Moderate to heavy, broad infestations where biomass reduction is a high priority should be mechanically mulched. Due to the high costs of hand cut-stump control work, this method should only be used around valuable vegetation and in areas inaccessible to mechanical equipment. Only areas that are very heavily infested and broad should be considered for aerial spraying, such a section is represented in drawing P40-P41.

The areas necessitating biomass reduction will require revegetation. For mechanical methods, native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. In aerial spraying locations, revegetation is critical in all cases due to the inherent loss of surrounding vegetation. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Mostly hand work should be performed along the spottily infested tributaries in this section. Biomass should be stacked for wildlife and natural revegetation is expected to occur. Additionally, biomass can also be piled and burned when conditions permit. As with other sites, natural biomass decomposition, reduction, and revegetation should occur after biological control has caused a significant mortality in tamarisk.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will correspond with tamarisk removal methods in most areas with the exception of mechanical extraction, which is inappropriate for Russian olive removal. In such instances mechanical grab and cut-stump removal should be used instead. The primary approach for controlling those Russian olive stands that do not occur near tamarisk infestations will be either hand or mechanical cut-stump removal with herbicide application.

Control, Biomass Reduction, and Revegetation Approach
Light Infestations along the Main-stem: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Moderate to Heavy Infestations along the Main-stem: Control: Mechanical mulching for high priority areas. Hand cut-stump control work around valuable vegetation and in inaccessible areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching or stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow along channel edges and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light, Spotty Infestations along the Tributaries: Control: Hand cut-stump removal where appropriate around valuable vegetation. Bio-control for remaining tamarisk (if active). Biomass: Stacking for wildlife. Revegetation: Natural revegetation.

Purgatoire River northern tributaries, from San Francisco Creek to Nine-Mile Bottom (Hwy 109 intersection) – including tributaries: Luning Arroyo, Van Bremer Arroyo, Bent Canyon, and various washes/arroyos contained in Pinon Canyon Military Reservation and Comanche National Grasslands
This information can be found on the data-DVD: Drawings LA1 to LA6, VBA1 to VBA5, and BC1 to BC2
Estimated Acres Infested with Tamarisk **– 98 acres**
Estimated Average Tamarisk Density **– 30%**

This area is partially contained within the Pinon Canyon Maneuver Site (PCMS) and the Comanche National Grasslands. Generally the washes and arroyos in this section are characterized by shallow, broad stream morphology. Two exceptions to this generalization are Luning and Lockwood Arroyos. These two waterways are more incised and narrow, with steep canyon walls and very limited vehicle access. Lockwood

Arroyo is contained within the boundaries of PCMS. The shallow washes in this area possess better vehicle access, except near their terminus as they enter the Purgatoire River canyon. Here they demonstrate a deeper incision and more difficult access.

These washes and arroyos typically have heavier tamarisk infestations at their juncture with the Purgatoire River and become sparse farther upstream. Tamarisk infestation within these washes is generally light, with pockets of infestation confined to either standing water or ephemeral streambanks. Cover from other riparian species in this area is typically light, with native grasses and forbs constituting the majority of upland cover. Small stands of cottonwood and willow do exist in isolated areas, and should be adjusted for accordingly.

Hand cut-stump control should be used in each of these areas starting at the upper extent of infestations and working down to the continuous, dense infestations near the tributaries' confluences with the Purgatoire River. Biological control may be active along the main-stem of the Purgatoire River and could adequately control these heavy infestations. Some hand cut-stump work should be used in these areas around stands of valuable vegetation. Biomass for the upper portions of the washes where hand control is performed will be stacked for wildlife habitat. Biomass reduction may be necessary in the lower, denser infestations around valuable vegetation by the Purgatoire River following beetle defoliation. Natural revegetation with native grasses, fourwing saltbush, and other shrubs and forbs may occur in some areas.

The areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
<u>Upper Extent of Light Infestations</u>: <u>Control</u>: Hand cut-stump control work with bio-control (if active) for remaining tamarisk. <u>Biomass</u>: Stack for wildlife where hand cut-stump control is used. Leave standing where bio-control (if active) is used. Stack and burn slash piles when conditions permit. <u>Revegetation</u>: Natural revegetation.
<u>Lower, Heavy Infestations at Tributaries' Confluence with the Purgatoire River:</u> <u>Control</u>: Mostly bio-control for tamarisk control with some hand cut-stump work around stands of valuable vegetation. <u>Biomass</u>: Stack for wildlife where hand cut-stump work is performed. Leave standing following bio-control (if active). Stack and burn slash piles when conditions permit. <u>Revegetation</u>: Pole plantings of cottonwood and willow and tall-pot, deep plantings of native shrubs and grass seed mixes for upland areas.

Purgatoire River main-stem and southern tributaries, San Francisco Creek to Nine-Mile Bottom (Hwy 109 intersection) – including tributaries: Trinchera Creek, Chacuaco Creek, and Bachicha Creek

This information can be found on the data-DVD: Drawings P13 to P35, TrC1 to TrC2, and ChCr1 to ChCr4 and Photo Log No. 11, 12, 13, 14, 15, 98, 100, 25, 28
Estimated Acres Infested with Tamarisk **– 3,157 acres**
Estimated Average Tamarisk Density **– 30%**

This area contains the main-stem canyon of the Purgatoire River (P35 to P16). Large ranches constitute the majority of landownership in this section. This narrow canyon section greatly restricts access to the river until it broadens slightly as it moves east toward Nine-Mile Bottom (P15 to P13). If active in the area biological control should be considered the main control approach for this section. In the narrow canyon of the main-stem, hand cut-stump control methods should be used to protect areas of valuable vegetation. In these locations biomass should be stacked for wildlife habitat and some low maintenance revegetation (i.e. pole plantings of willow and/or cottonwood) may be appropriate. Light, broad infestations in the wider section approaching the floodplain would best be removed with mechanical extractors and grab and cut-stump equipment. Biomass will then be stacked for wildlife habitat or mulched for revegetation purposes depending on the desires of the landowner. Moderate to heavy, broad infestations where biomass reduction is a high priority should be mechanically mulched.

The areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Most of the southern, tributary canyons are characterized by deeply incised, narrow waterways, have little or no vehicle access, and fall within several very large ranches on the southeast side of the Purgatoire River. The canyons are very remote and are home to several rare plant, animal and fish species including leafy goldenweed (*Oonopsis foliosa var. foliosa*), swift fox, mountain plover, and Arkansas darter.

Hand cut-stump control should be used in each of these tributaries starting at the upper extent of infestations and working down to the continuous, dense infestations near the tributaries' confluences with the Purgatoire River. Biological control may be active along the main-stem of the Purgatoire River and could adequately control these heavy infestations. Some hand cut-stump work should be used in these areas around stands of valuable vegetation. Biomass for the upper portions of the washes where hand control is performed will be stacked for wildlife habitat. Biomass reduction may be necessary in the lower, denser infestations around valuable vegetation by the Purgatoire River following beetle defoliation. Natural revegetation with native grasses, fourwing saltbush, and other shrubs and forbs will likely occur in most areas; however, some revegetation and some weed control will be required.

Control, Biomass Reduction, and Revegetation Approach
Main-stem – Narrow Canyon: Control: Hand cut-stump control work around areas of valuable vegetation with bio-control (if active) for remaining tamarisk. Biomass: Stack for wildlife where hand cut-stump control is used. Leave standing where bio-control (if active) is used. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas in areas where hand control is used. Natural revegetation following bio-control (if active).
Main-stem – Light Infestations, Broader Floodplain: Control: Mechanical extraction or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Main-stem – Moderate Infestations, Broader Floodplain: Control: Mechanical mulching for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulching. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Tributaries - Upper Extent of Light Infestations: Control: Hand cut-stump control work with bio-control (if active) for remaining tamarisk. Biomass: Stack for wildlife where hand cut-stump control is used. Leave standing where bio-control (if active) is used. Revegetation: Natural revegetation.
Tributaries - Lower, Heavy Infestations at Tributaries' Confluence with the Purgatoire River: Control: Mostly bio-control (if active) for tamarisk control with some hand cut-stump work around stands of valuable vegetation. Biomass: Stack for wildlife where hand cut-stump work is performed. Leave standing following bio-control (if active). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

Purgatoire River and Smith Canyon, Nine-Mile Bottom to Arkansas Confluence
This information can be found on the data-DVD: Drawings P1 to P13 and AW150 to AW154 and Photo Log No. 2187, 2188, 2, 3, 5, 6, 7, 9, 10
Estimated Acres Infested with Tamarisk **– 4,254 acres**
Estimated Average Tamarisk Density **– 25%**

This area constitutes the opening of the Purgatoire River canyon and its return to meandering, wide floodplain morphology. The level of agricultural use on the lands along and surrounding this reach of the Purgatoire River increases significantly as they approach the Arkansas River. Significant irrigation and infrastructure are characteristic of this area. Consequently, vehicle access to the river and tributaries in this area is generally good. Landownership in this region consists of smaller private parcels than those of the large ranches upstream.

This area consists of more dense, wide and monotypic stands of tamarisk than any other on the Purgatoire River system. The primary management method for these areas should be biological control (if possible) and/or aerial foliar herbicide spraying. Root plowing and raking would be appropriate for lands needed for agricultural use. No herbicide should be needed for resprouts if biological control is active in the area. Mechanical or hand cut-stump removal should be used in some areas to protect valuable vegetation and to form fire breaks and reduce wildfire damage. Along Highways 109 and 101, mechanical removal with cut-stump herbicide application or extraction should be used to assure highway safety.

Russian olive, although less abundant than tamarisk, has a significant presence throughout much of this river section. Control will require either hand or mechanical cut-stump approaches with herbicide application as the primary approach in all areas.

Biomass reduction should not be needed for light infestations and some moderate infestations, but should be performed for all other situations to reduce the fuel load in riparian areas. This is especially important to protect the valuable cottonwood galleries in many of these areas as well as native shrubs such as sand sagebrush, fourwing saltbush, and western sandcherry. Mechanical methods are recommended with some hand work required in difficult to access areas. As with other sites, natural biomass decomposition and reduction should occur after biological control has caused a significant mortality in tamarisk.

Areas necessitating biomass reduction will require revegetation. Native planting requirements will increase proportionately with the density of infestation and extent of ground disturbance. Weed control will be critical for much of this river section to prevent other noxious weeds from filling the void left by tamarisk and Russian olive removal.

Control, Biomass Reduction, and Revegetation Approach
Heavy Infestations in the Floodplain: Control: Aerial herbicide, bio-control (if active), and root plow and rake. Biomass: Mulch, controlled burn, or stack for wildlife (if land is to be used for agriculture). Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.
Light to Moderate Infestations in the Floodplain: Control: Hand cut-stump control, mechanical extraction, or grab and cut-stump control for high priority areas. Bio-control (if active) for remaining tamarisk. Biomass: Mulch for revegetation or stack for wildlife. Stack and burn slash piles when conditions permit. Revegetation: Pole plantings of cottonwood and willow and tall-pot, deep planting of native shrubs and grass seed mixes for upland areas.

Along Highways 109 and 101:
Control: Mechanical removal with grab and cut-stump or extraction. Bio-control (if active) for remaining tamarisk.
Biomass: Mulching for revegetation. Stack and burn slash piles when conditions permit.
Revegetation: Native shrubs and grass seed mixes.

Section 2 – Implementation

The ARKWIPP plan up to this point (Section 1 - Background) has outlined the background of the ARKWIPP planning process, the general nature of the problem, important governmental actions, the site-specific problem in the study area, the natural resource impacts to water and wildlife habitat, recommended restoration approaches, and costs associated with those control and revegetation actions.

Section 2 – Implementation lays out a specific "path forward" for implementing the Plan, including a specific set of five actions to facilitate success.

The five actions include:

1. **Develop Ways to Work with Landowners**
2. **Develop and Provide Education, Outreach, and Volunteerism Programs**
3. **Determine Research Needs**
4. **Determine and Develop Long-Term Funding Mechanisms**
5. **Determine and Develop a Long-Term Sustainability Program**

Develop Ways to Work with Landowners

ARKWIPP's main objective is to restore riparian lands within the Arkansas watershed that have been degraded by woody invasive plants, principally tamarisk and Russian olive. To successfully implement these restoration actions, the property rights of each landowner must be respected to ensure that 1) efforts coordinate with the landowner's specific objectives for the land and that 2) the landowner is included in restoration decision-making. Landownership includes public (federal, state, county, and local communities), legal subdivisions of the state (e.g., sanitation districts, drainage districts), private landowners, non-profits (e.g., The Nature Conservancy), commercial, and industry (e.g., Railroad and utility easements).

Because noxious weed control and riparian restoration are not normal components of most of these landowner activities, assistance is often needed to identify funding opportunities, apply for grants, and to administer grants. There is not precedence for who should be the lead for each situation; however, the following provides some general guidance for the ARKWWIPP partners.

- For private agricultural producers, the soil and water conservation districts are the most appropriate organizations to manage many of these grants, especially those grants from the USDA. The USDA Natural Resource Conservation Service (NRCS) and the Colorado Association of Conservation Districts website, www.ag.state.co.us/ccdd, is a good resource to assist these local districts in becoming significant partners with landowners and restoration activities.
- Counties and non-profits (e.g., The Nature Conservancy) can assist in acquiring grants for all entities, even for work on federal lands through some grant programs (e.g., National Fish and Wildlife Foundation).
- Each entity can pursue its own grant opportunities for the land that it manages.

Action #1

The ARKWIPP Technical Advisory Team and county weed managers along with the Colorado Association of Conservation Districts, USDA Natural Resource Conservation Service (NRCS), local Resource Conservation and Development (RC&D) representatives, Colorado State University (CSU) Extension, Colorado Division of Wildlife, United States Bureau of Reclamation (USBR), major federal and state landowners, The Nature Conservancy and the Tamarisk Coalition should develop the following:

1. Develop a GIS dataset of landownership for the riparian corridor impacted by the target invasive species.
2. Develop a communication system that informs county weed managers of all projects being conducted in their vicinity.
3. Post the ARKWIPP mapping project on the www.arkwipp.org website to assist landowners with identifying their tamarisk infestation levels.
4. Develop an interactive database for landowners that will determine proper control and revegetation methods for restoration. Because control and restoration methods are very site specific a contact list of agencies that would provide on-site analysis for landowners will be developed.

A concern of the ARKWIPP partners is that without coordination between all these entities, there will be undue competition for the same funds; entities will not be aware of all of the funding resources available; and/or there will be inefficiency in using funds that are acquired. To resolve this concern, the following is recommended:

5. Establish a simple clearinghouse system to inform all parties of grant opportunities. A list of grant opportunities (Appendix K) will be placed on the www.arkwipp.org and Tamarisk Coalition website, www.tamariskcoalition.org in the summer of 2008.
6. Create a prioritization system that could be used to screen grants and appropriate locations for restoration work. An example is provided in Appendix J, Example of a project prioritization system.

Develop and Provide Education, Outreach, and Volunteerism Programs

Gaining public support requires providing factual information that describes the problem and the solutions being initiated. Important information for the public understanding includes all aspects of the tamarisk and Russian olive problem; control approaches that will be used with significant emphasis on the biological control component; how things will look differently over the next ten years; revegetation, biomass removal, monitoring, and long-term maintenance. ***The overarching theme is RESTORATION not just tamarisk or Russian olive control.***

Action #2

Outreach expertise from counties, private landowners, major State and Federal landowners, Colorado State Forest Service, National Park Service, Colorado State Parks, The Nature Conservancy, CSU Extension, Denver Botanic Garden, USDA NRCS, Tamarisk Coalition and the ARKWIPP Technical Advisory Team should be used to develop materials appropriate for community and visitors to the areas.

1. The developed education and resource materials will be housed on the www.arkwipp.org website and will be accessible for reproduction by ARKWIPP partners as well as any interested entities. The website will be utilized as a resource tool for landowners and managers and it will enable others the ability to track the progress of the Plan as it is implemented. Key elements of the website may include:
   A. The Problem: Why Tamarisk is a Problem, No-action Alternatives, and Frequently Asked Questions.
   B. Problem Solutions: Control Methods, Biological Control, Biomass Potential, Riparian Restoration, Long-Term Management, and Success Stories.
   C. Strategic Plans: Colorado and Other States.
   D. Resource Materials and Links.
   E. Funding: List of Funding Agencies and Organizations.
   F. Manage Your Problem: Landowners database for sorting individual land use and infestation levels to determine proper control and restoration methods and resources for land managers on developing Weed Management Plans.
   G. Tamarisk Maps
      a. ARKWIPP mapping project.
      b. Federal Emergency Management Agency Flood Plain Map of the Arkansas Basin.
      c. Colorado State Forest Service Wild Land Fire Map of Arkansas Basin.
      d. USDA NRCS Soil Survey Map of the Arkansas Basin.
   H. Tamarisk and Russian Olive Research.
   I. Education resources.
      a. Brochures
      b. Fact Sheets
      c. Templates for a visual display
   J. Forum to ask questions and share information
   K. Current Events.
   L. Volunteer Opportunities and Programs.
   M. Who We Are and Contact Information.
2. Develop brochures for distribution through the visitor centers, Colorado State Parks, Division of Wildlife, wildlife refuges, USDA NRCS, Colorado State University Extension, etc.
   A. A “Frequently Asked Questions” brochure that will help locals and visitors understand the following:
      a. What tamarisk is, where it came from, why it is a problem, and tamarisk control methods.
      b. How biological control works, what to expect, monitoring of changes, etc..
      c. What will replace the tamarisk, how the process will affect

wildlife.
   d. Who will implement these projects and how will they be funded.
   B. Fact sheets on tamarisk ecology, biological, control, herbicide usage and safety, etc.
3. Display boards with historical photos can be utilized to compare present day conditions to the past to give a perspective on the problem.
4. River guide training on the issue and provision of education cards similar to "Leave No Trace" laminated waterproof cards.
5. Information booths at local events, festivals, etc.
6. Presentations to service groups such as Lions, Rotary, and Chamber of Commerce, schools and other organizations.
7. Demonstration sites that can be used for tours.

[Note: The ARKWIPP Technical Advisory Team and the Tamarisk Coalition are developing many of these components with support from others. This information will be available in summer 2008.]

Volunteer Program - An important aspect of education is gaining public support for tamarisk and Russian olive control and restoration to improve the ecosystem of the ARKWIPP study area. One way of achieving this is through volunteer programs. A number of groups within the area have done some excellent work using volunteers for riparian restoration. These include: Colorado Volunteer Day, Colorado Range Riders, Volunteers for Outdoor Colorado, The Nature Conservancy, Colorado State Parks, and Colorado State Forest Service. By participating in these programs, people gain first-hand experience and an appreciation of ecosystem restoration. The volunteer education effort would include information concerning how and where to get involved as an individual or as an organization.

8. The groups identified above should work together to:
   A. Develop a volunteer "lessons learned" pamphlet that can be used by others to develop their own volunteer program (a starter "cookbook").
   B. Identify good volunteer projects.
   C. Pool resources for volunteer projects.

Determine Research Needs

There are a number of research activities that can improve the success, effectiveness, and efficiency of restoration for the Arkansas River watershed. The unique nature of the watershed also offers special opportunities to better understand tamarisk and Russian olive impacts to water resources and wildlife habitat as well as restoration responses. By intertwining restoration with research there is greater appeal to some funding sources to provide grants (e.g., federal legislation under P.L. 109-320, the Salt Cedar and Russian Olive Demonstration Act). The following are current research interests at the university and federal research levels.

- The University of Denver (DU) has developed a “Best Management Practices” handbook for tamarisk control and will complete a similar handbook for revegetation in the summer of 2008.
- DU has an active riparian restoration program for undergraduate and graduate students that includes field work to develop practical solutions.
- Colorado State University is devoting time and funding for tamarisk research efforts and have a number of active research projects in the ARKWIPP project area.
- Bureau of Reclamation scientists in Denver are developing more effective measures to improve revegetation success.

Action #3

The Southeastern Colorado Water Conservancy District has agreed to initiate the facilitation of a working group to establish collaborative partnership with educational institutions to identify specific research needs for the area, to utilize their research skills, and to ensure information sharing within the watershed.

The working group may include, but not be limited to representatives from: ARKWIPP Technical Advisory Team, Pueblo Community College, Otero Junior College, Lamar Community College, Trinidad State Junior College, Colorado State University in Pueblo and Fort Collins, University of Denver, Colorado College, University of Colorado – Colorado Springs, Pikes Peak Community College, county weed management departments, CSU Extension, major federal and state landowners, Colorado State Parks, National Park Service, Colorado State Forest Service, USDA NRCS, Colorado Division of Wildlife, The Nature Conservancy, Arkansas Valley Audubon Society, Upper Arkansas Weed Management Cooperative, Denver Botanic Garden, Colorado Association of Conservation Districts, USBR, US Fish and Wildlife, Environmental Protection Agency (EPA), Colorado State Department of Agriculture, United States Corps of Engineers (USACE), and the Tamarisk Coalition.

Determine and Develop Long-Term Funding Mechanisms

The partners in ARKWIPP should work together to continue to support and leverage existing projects to gain additional funding resources. An example would be funding derived from federal legislation PL 109-320. The key to successful implementation on any of the proposed restoration strategies, education, research, outreach, etc., is funding to sustain the activity.

Action #4

An active Grants and Projects Committee will be established to focus on grant opportunities and to communicate progress for active projects. A list of grant opportunities (Appendix K) that are available for tamarisk related issues is available on the www.arkwipp.org and Tamarisk Coalition www.tamariskcoalition.org websites. For further information the reader is encouraged to visit the funding sources website and contact the funding source directly.

Suggested participating entities should include: The ARKWIPP Technical Advisory

Team and county weed managers along with the Colorado Association of Conservation Districts, USDA NRCS, local Resource Conservation and Development representatives, major federal and state landowners, Tamarisk Coalition, CSU Extension, USBR, Colorado Water Conservation Board, EPA, USACE, Colorado Department of Local Affairs, and The Nature Conservancy.

Determine and Develop a Long-Term Sustainability Program

Long-term sustainability of the restored riparian lands is a function of a good monitoring and maintenance program. To reiterate from previous discussions, “monitoring” is the act of observing changes that are occurring with, or without, remediation actions. The purpose of monitoring is to provide information for making informed decisions to ensure maintenance efforts will remain, remediate, and improve the ecological processes of the watershed. For tamarisk and Russian olive restoration these measures are important for effective control on a long-term basis and to ensure that the desired outcomes of revegetation and prevention of other noxious weed infestations are successful.

The questions that must be addressed for the entire Arkansas River watershed is: ***Who should perform monitoring and maintenance? Do they have the legal responsibility for these actions? Do they have the necessary funding to carry out these responsibilities?***

Action #5

It is clear that if resources are spent only on control and revegetation with no cohesive approach to long-term monitoring and maintenance, the potential for successful riparian restorations are limited. Therefore, the following recommendation is made to establish a workable long-term monitoring and maintenance program:

1. The Southeastern Colorado Water Conservancy District has agreed to initiate the facilitation of a working group to formulate a set of solutions and policies for long-term monitoring and maintenance for the entire Arkansas River watershed. It is recommended that the working group be co-chaired by the Colorado Department of Agriculture and the Colorado Department of Natural Resources. These two agencies are appropriate to lead this effort because their main responsibilities are to protect Colorado’s natural resources and work closely with the agricultural community.
2. The working group may include, but not be limited to, representatives from: county weed management departments (the areas within the watershed with most of the infestations), State representatives to the House and Senate, CSU Cooperative Extension, Bureau of Land Management, Colorado State Parks, National Park Service, US Forest Service, Colorado State Forest Service, canal and ditch companies, USDA Natural Resource Conservation Service, Colorado Department of Local Affairs, Colorado Water Conservation Board, Pueblo Community College, Otero Junior College, Lamar Community College, Colorado State University in Pueblo and Fort Collins, University of Denver, Colorado College, University of Colorado – Colorado Springs, Pikes Peak Community College Colorado Division of Wildlife, The Nature Conservancy,

Arkansas Valley Audubon Society, Colorado Association of Conservation Districts, the Southeastern Colorado Water Conservancy District, Purgatoire River Water Conservancy District, Lower Arkansas Valley Water Conservancy District, Upper Arkansas Water Conservancy District, USACE, USBR, and the Tamarisk Coalition.

3. Within 12 months a consensus plan should be produced to implement a long-term monitoring and maintenance program describing the technical, political, and financial steps for tamarisk control implementation and responsible entities.

This will not be an easy task, but it is a critical element for successful riparian restoration and should be dealt with seriously. When a workable long-term monitoring and maintenance program for the Arkansas River watershed is successfully formulated, this will signify a landmark effort.

Table 5 provides a summary of all the action items that have been developed, responsibilities for carrying out the action or organizing a working group to complete the action, and a schedule for accomplishing the action.

Table 5: Actions, Lead Responsibility, and Time Line

Action	Lead Responsibility	Time-Line
#1 Working with Landowners	The ARKWIPP Technical Advisory Team, county weed managers, USDA Natural Resource Conservation Service, and major federal and state landowners.	July – December 2008
#2 Education, Outreach and Volunteerism	Outreach expertise from counties, Tamarisk Coalition and the ARKWIPP Technical Advisory Team.	July 2008 – July 2009
#3 Research Needs	The Southeastern Colorado Water Conservancy District has agreed to initiate the facilitation of a working group.	July – December 2008
#4 Long-Term Funding Mechanisms	The ARKWIPP Technical Advisory Team, Sangre de Cristo RC&D and Southeast Colorado RC&D to organize Grants and Projects Committee.	July – December 2008
#5 Long-term Sustainability	The Southeastern Colorado Water Conservancy District has agreed to initiate the facilitation of a working group.	July 2008 – July 2009

Definitions

Adaptive management is a natural resources management process under which planning, implementation, monitoring, research, evaluation, and incorporation of new knowledge are combined into a management approach that 1) is based on scientific findings and the needs of society, 2) treats management actions as experiments, 3) acknowledges the complexity of these systems and scientific uncertainty, and 4) uses the resulting new knowledge to modify future management methods and policy.

Basal bark herbicide application refers to the application of herbicide to the smooth bark at the base of non-native phreatophytes usually through a spray.

Biodiversity refers to biological diversity in an environment as indicated by numbers of different species of plants and animals.

Collaboration means involving all affected stakeholders in a set of decisions that guide how ecological rehabilitation and maintenance is undertaken, supported, and evaluated.

Coordination means making sure that those involved are aware of what other related activity is taking place. Coordination helps to maximize the efficient use of resources, promote consistency in process and standards where appropriate, and sequence efforts to achieve the greatest impact.

Disturbance regimes are the range of events, natural to an ecosystem, that temporarily change the structure and function of the systems, such as wildfire, drought, floods and insect or disease outbreak, to which the system is adapted.

Ecological processes refer to the natural cycles, disturbances and interactions of all parts of an ecosystem, such as nutrient and mineral cycles, fire or flood incidence, and species interactions.

Ecological restoration refers to a broad framework of activities for returning ecosystems to healthy functioning conditions. Ecological restoration activities are based on specific landscapes and objectives, and should incorporate past experience as a guide to sustainable futures. These activities include, but are not limited to: reducing overly-dense wood vegetation, re-establishing native vegetation, repairing erosion and soil condition, restoring hydrological function, and monitoring all these activities for effective long-term maintenance.

Ecosystem is the complex of a community of organisms interacting with one another and with the chemical and physical factors of their environment. In Colorado, the pinyon-juniper forest is an example of an ecosystem.

Economies in Colorado take many forms, and include those that are amenity-based, such as tourism, recreation, real estate, and others like industries; product-based, which refer to forest products, mining, and other extractive industries; as well as those that are agriculturally based such as farming and ranching.

Ephemeral streams are streams that flow only during or immediately after periods of precipitation.

Evapotranspiration is the combined diffusion of water vapor into the atmosphere from transpiration from plants and evaporation from soil and water surfaces.

Floodplain terrace are the lands outside the riparian zone that supports native phreatophytes but still within the floodplain. Terraces are generally supportive of xeric and mesic types of vegetation.

Foliar herbicide application refers to the application of herbicide to the leaves of a plant usually through a spray.

Forb is a small, herbaceous (non-woody), broad-leaved vascular plant (excluding grasses, rushes, sedges, etc.). For example, wild flowers are a type of forb.

Health refers to a condition where the system's parts and functions are sustained over time and where the capacity for ecological self-repair is maintained within a natural range of variability, allowing goals for sustainable uses, values, and services to be met.

Hydrologic cycle describes the continuum of the transfer of water from precipitation to surface water and ground water, to storage and runoff, and to the eventual return to the atmosphere by transpiration and evaporation.

Hydrologic processes refer to that part of the hydrologic cycle that includes the amount and timing of streamflow, which in turn influences ecological functions in the stream corridor.

Implementation refers to the development of teams and specific action items to address the recommendations of this Plan as well as efforts to initiate "on-the-ground efforts."

Integration means considering the other initiatives taking place as well as the impacts of these on the larger ecosystem over the long-term, and having this consideration inform the effort.

Landscape means a spatial mosaic of several ecosystems, landforms, watersheds and plant communities that are repeated in similar form across a defined area irrespective of ownership or other artificial boundaries.

Mesic vegetation is plants that utilize soil moisture that is more readily available than would be present in upland drier soils.

Partners are considered to be any state, federal, local, non-governmental, individuals, industry, or private entities that cooperate in ARKWIPP.

Phreatophyte refers to a deep-rooted plant that obtains its water from the water table or the layer of soil just above it.

Restoration is the reestablishment of the structure and function of ecosystems. It involves the recovery of ecosystem functions and processes in a degraded habitat. The restoration process reestablishes the general structure, function, and dynamic but self-sustaining behavior as closely as possible to pre-disturbance conditions and functions while respecting private property rights, state water law, existing infrastructure, and endangered species considerations.

Riparian is the geographically delineated areas with distinct resource values that occur adjacent to rivers, streams, lakes, ponds, wetlands, and other water bodies. Typical vegetation in the ARKWIPP areas includes grasses, cottonwood, willows and forbs.

State refers to Colorado state government and its agencies.

Stream Morphology refers to the study of the channel pattern and the channel geometry at several points along a river channel, including the network of tributaries within the drainage basin.

Sustainable refers to a level of human use of a natural resource that can continue through time without diminishing the resource's productivity or resilience.

Watershed refers to a region or land area that is drained by a single stream, river or drainage network, and includes all of the land within the entire drainage area. The Arkansas River is an example of a large watershed. Example of smaller watershed within the larger watershed is the Fountain Creek drainage.

Xeric vegetation represents plants that are adapted to a dry environment.

References

Baum, B. R. 1978. The Genus Tamarix. Israel Academy of Sciences and Humanities, Jerusalem. 209 pp.

Bawazir, A.S., New Mexico State University, Personal communication, April 2003·

Bean, D. Director Palisade Insectary, Personal communication, March, 2007

Belcher, E. W. and R. P. Karrrfalt. 1979. Improved methods for testing the viability of Russian olive seed. Journal of Seed Technology 4:57-64.

Belsky, A.J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the Western United States. Journal of Soil and Water Conservation.

Borell, A. E. 1962. Russian-olive for wildlife and other conservation uses. U.S. Department of Agriculture, Washington, DC, USA. Leafet No. 517.

Brown, C.R. 1990. Avian use of native and exotic riparian habitats on the Snake River, Idaho. M.S. Thesis. Colorado State Univ., Fort Collins, CO. pp. 60.

Busch, D. E., and S. D. Smith. 1993. Effects of fire on water and salinity relations of riparian woody taxa. *Oecologia 94:186-194.*

Busch, D. E., and S. D. Smith. 1995. Mechanisms associated with decline of woody species in riparian ecosystems of the Southwestern us. *Ecological Monographs 65:* 347-37°·

Busch, D. E., N. L. Ingraham, and S. D. Smith. 1992. Water-uptake in woody riparian phreatophytes of the southwestern United States: a stable isotope study. *Ecological Applications* 2: 450-459.

Caplan, T. 2002. Controlling Russian olives within cottonwood gallery forests along the Middle Rio Grande floodplain (New Mexico). Ecological Restoration 20(2): 138-139.

Carman, J.G., and J.D. Brotherson. 1982. Comparison of sites infested and not infested with saltceder *(Tamarix pentandra)* and Russian-olive *(Elaeagnus angustifolia).* Weed Sci. 10:360-364.

Carpenter, A. 1998. Element Stewardship Abstract for *Tamarix ramosissima* Lebedour, *Tamarix pentandra* Pallas, *Tamarix chinensis* Loureiro, and *Tamarix parviflora* De Candolle. The Nature Conservancy, Arlington, Virginia.

Chaney, E., W. Elmore, and W.S. Platts. 1990. Livestock grazing on western riparian areas. Northwest Resources Information Center, Inc. Eagle Idaho.

Horton, J. S., F. C. Mounts, and J. M. Kraft. 1960. Seed germination and seedling establishment of phreatophyte species. U.S. Department of Agriculture, Rocky

Mountain Forest and Range Experiment Station, Fort Collins, Colorado. Paper No. 48. 26pp.

Hogue, E. J. and L. J. LaCroix. 1970. Seed dormancy of Russian olive *(Elaeagnus angustifolia* L.). Journal of the American Society of Horticultural Science 95:449-452.

Howe, W.H. and F.L. Knopf. 1991. On the imminent decline of Rio Grande cottonwoods in central New Mexico. The Southwestern Naturalist 36:218-224.

Katz, G. L. 2001. Fluvial Disturbance, flood control, and biological invasion in Great Plains riparian forests. Ph.D. Dissertation. University of Colorado, Boulder, CO, USA.

Katz, G.L., and P.B. Shafroth. 2003. Biology, ecology and management of Elaeagnus angustifolia L. (Russian olive) in western North America. Wetlands 23(4): 763-777.

King, J.P. and Bawazir, S.A. 2000. Riparian Evaporation Studies of the Middle Rio Grande. Technical Completion report, U.S. Bureau of Reclamation.

Kolb, Thomas E. 2001 "Water Use of Tamarisk and Native Riparian Trees." Proceedings of the Tamarisk Symposium, September 26 - 27, 2001, Grand Junction, Colorado.

Knopf, F.L., and T.E. Olson. 1984. Naturalization of Russian-olive; implications to Rocky Mountain wildlife. Wildl. Soc. Bul. 12: 289-298.

Lesica, P. and S. Miles 1999. Russian olive invasion into cottonwood forests along a regulated river in north-central Montana. Canadian Journal of Botany 77: 1077-1083.

Little, E. L. 1961. Sixty trees from foreign lands. U. S. Department of Agriculture, Washington, DC, USA. Agricultural Handbook No. 212.

Lonsdale, W. M. 1993. Rates of spread of an invading species *Mimosa pigra* in northern Australia. J. of Ecology 81:513-521.

McDaniel, K.C., DiTomaso, J.M., Duncan, C.A. 2004. *Tamarisk or Saltcedar (Tamarix spp.)* Galley proof for Allen Press.

Muzika, R.-M. and J.M. Swearingen. 1998. Russian-olive *(Elaeagnus angustifolia L.).* PCAAlien Plant Working Group. (http://www.nps.gov/plants/alien/fact/elan1.htm).

National Invasive Species Council, Tamarisk Economics Impact Study, in progress January 2006.

Ohmart, R.D. 1996. Historical and present impacts of livestock grazing on fish and wildlife resources in western riparian habitats. Pages 245-279 In: Krausman, P.R. (ed.).

Stromberg, J. 1998. Dynamics of Fremont cottonwood *(Populus fremontii)* and salt cedar *(Tamarix chinensis)* populations along the San Pedro River, Arizona. *Journal of*

Arid Environments 40: 133-155.

Stromberg, J. C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: The San Pedro, Arizona. *Ecological Applications 6:113-131*.

Taylor, J. P, D. B. Wester, and L.M. Smith. 1999. Soil disturbance, flood management, and riparian woody plant establishment in the Rio Grande floodplain. *Wetlands 19:372*-382.

Tesky, J.L. 1992. *Elaeagnus angustifolia. In:* USDA, Forest Service, Rocky Mountain Res. Sta., Fire Sci Lab. (2001, July). Fire Effects Information System, [Online]. Available: http://www.fs.fed.us/database/feis/.

Tu, M. 2003. Element Stewardship Abstract for *Elaeagnus angustifolia* L., Russian olive, oleaster. The Nature Conservancy. (http://tncweeds. ucdavis.edu/ esadocs/ documnts/ elaeang.html).

US Department of Energy, 2005. "Remediation of the Moab Uranium Mill Tailings, Grand and San Juan Counties, Utah, Final Environmental Impact Statement." July 2005·

USDI-BOR 1995. "Vegetation Management Study: Lower Colorado River, Phase II." U.S. Department of Interior, Bureau of Reclamation, Lower Colorado River, Draft Report, Boulder City, Nevada.

USDA. 1974. Seeds of wood plants in the United States. USDA Agr. Handbook No. 450.

USDA. 2002. Technical Notes: Plant Materials No. 47. History, Biology, Ecology, Suppression and Revegetation of Russian-Olive Sites *(Elaeagnus angustifolia* L.). Available: http://www.usgs.nau.edu/SWEPIC/factsheets/ELAN.APRS.pdf.

US Fish and Wildlife Service, 2005. "Designation of Critical Habitat for the Southwestern Willow Flycatcher *(Empidonax trailli extimus);* Final Rule", Federal Register (50 CFR Part 17), October 19, 2005.

Weeks, E., H. Weaver, G. Campbell and B. Tanner, 1987. Water use by saltcedar and by replacement vegetation in the Pecos River floodplain between Acme and Artesia, New Mexico. U.S. Geological Survey, Reston, Virginia.

Zimmerman, J. 1997. Ecology and Distribution of *Tamarix chinensis* Lour and *T. parvijlora* D.C., *Tamariccea.* Southwest Exotic Plant Mapping Program, U.S. Geological Survey.