# Findings, Determinations and Recommendations Regarding Five Charges in Subsection (n) of Section 1.26A of the Edwards Aquifer Authority Act

Report to the Steering Committee and Stakeholders
of the
Edwards Aquifer Recovery Implementation Program

By the
Recharge Facility Feasibility Subcommittee
For the Edwards Aquifer Recovery Implementation Program

November 23, 2009

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**To:** The Steering Committee and Stakeholders of the Edwards Aquifer Recovery Implementation Program

**From:** The Recharge Facility Feasibility Subcommittee For the Edwards Aquifer Recovery Implementation Program

Attached please find a final report titled *Findings, Determinations and Recommendations Regarding Five Charges in Subsection (n) of Section1.26A of the Edwards Aquifer Authority Act*. This report meets the requirements of Article 12, Senate Bill 3, Regular Session, $80^{th}$ Texas Legislature, Section 1.26A(n), and the requirements of your charges to us. On November 23, 2009, the Recharge Facility Feasibility Subcommittee met to consider the final report. A quorum of the voting membership was present. The Subcommittee adopted this report by consensus.

If you have any questions regarding this report, please contact Mr. Steven J. Raabe, P.E, with the San Antonio River Authority and Chair of the Recharge Facility Feasibility Subcommittee.

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## INTRODUCTION

**A. Compliance with Senate Bill 3**. This Report of the Recharge Facility Feasibility Subcommittee (Subcommittee) of the Edwards Aquifer Recovery Implementation Program (EARIP) has been prepared in compliance with the requirements of Article 12 of Senate Bill 3, 80th Texas Legislature (2007). Article 12 amends the Edwards Aquifer Authority Act by adding new Section 1.26A (hereafter referred to as Sec. 1.26A or the Act.) Section 1.26A requires Edwards Aquifer stakeholders to participate in an EARIP, overseen by a Steering Committee and managed by a Program Director, for the purpose of developing recommendations to the Edwards Aquifer Authority (Authority) for the protection of Aquifer-related endangered species. Subsection (n) of Section 1.26A requires the EARIP stakeholders to establish a Recharge Facilities Feasibility Subcommittee to review the feasibility of aquifer recharge facilities, and to prepare and submit to the RIP Steering Committee and other RIP stakeholders a report of its findings, determinations, and recommendations not later than December 31, 2009, responding to the five charges stated in paragraph B.

**B. Charges.** Section 1.26A directs the Subcommittee to address the following five charges:

1. assess the need for the Authority or any other entity to own, finance, design, construct, operate, or maintain recharge facilities;

2. formulate plans to allow the Authority or any other entity to own, finance, design, construct, operate, or maintain recharge facilities;

3. make recommendations to the Steering Committee as to how to calculate the amount of additional water that is made available for use from a recharge project including during times of critical period reductions;

4. maximize available federal funding for the Authority or any other entity to own, finance, design, construct, operate, or maintain recharge facilities;

5. evaluate the financing of recharge facilities, including the use of management fees or special fees to be used for purchasing or operating the facilities.

**C. Subcommittee Chair, Vice-Chair, and Members.** The Steering Committee appointed 18 EARIP participants as voting members of the Subcommittee. The members include representatives of environmental groups, land stewardship organizations, river authorities, water purveyors, general stakeholders, business interests, state agencies, and stakeholders from the Edwards Aquifer recharge and contributing zones. The Subcommittee also includes six non-voting members representing state and federal agencies. The Subcommittee elected Steve Raabe, a representative of the San Antonio River Authority and member of the Steering Committee, as Chair of the

Subcommittee and Kirk Patterson, a representative of Regional Clean Air and Water and also a member of the Steering Committee, as Vice-Chair. The names of the persons who served on the Subcommittee are listed on the membership roster attached to this Report as ***Appendix 1.***

**D. Subcommittee Meetings.** The Subcommittee held regular monthly meetings from August 2008 through November 2009. The Subcommittee received informational presentations at the meetings held from September 2008 through February 2009. The Subcommittee considered and made findings and recommendations relating to the five statutory charges during the meetings held from March 2009 through November 2009.

The Subcommittee limited its initial work to responding to the five statutory charges. Subcommittee members recognize and acknowledge that there are other important issues related to the subject of aquifer recharge facilities feasibility that is not addressed in this report.

Copies of the Subcommittee meeting agenda, the Subcommittee reports to Steering Committee, and handouts to Subcommittee members are included in ***Appendix 2***.

**E. Initial Report.** This initial report sets forth the findings and recommendations of the Subcommittee. The findings and recommendations are intended to be supplemented as aquifer stakeholders continue to study the feasibility of recharge facilities.

## SUBCOMMITTEE'S RESPONSES TO STATUTORY CHARGES

**1. Charge 1 – Assess the need for the Authority or any other entity to own, finance, design, construct, operate, or maintain recharge facilities.**

*The Subcommittee's Response.*

**1.1.** The climate of the Edwards Aquifer region alternates between periods of drought and heavy rainfall causing flooding. The Texas Legislature, in 1993, adopted comprehensive aquifer management legislation (Edwards Aquifer Authority Act or Act), which was implemented in 1996. The Act changed the recognition of groundwater withdrawal rights in the region from the common law "rule of capture" to a system of permits issued by the Authority in amounts based on the historic usage of permit holders. The Act guaranteed permits to qualified historic users and capped the total amount of permits that could be issued. The 450,000 acre-foot cap set in the 1993 legislation was raised by the Legislature in 2007 to 572,000 acre feet, provided in Article 12 of Senate Bill 3, to correspond to the total of guaranteed permits that the Authority was required to issue. The Authority manages the aquifer by monitoring compliance with the withdrawal permits and enforcing pumping reductions when aquifer index wells or springflows are below certain levels under the statutory demand management critical period management (DM/CPM) limitations.

The Authority's multiple statutory objectives, which include aquifer "optimization" and springflow protections for endangered species, create a need for increasing aquifer recharge to increase the amount of available water and the need for facilities to cause or permit the increase. The Subcommittee acknowledges, and this Report recognizes, that facilities which can increase recharge to the aquifer include not only structures that facilitate recharge but also land management practices that facilitate recharge.

**1.2.** Recognizing both the challenges and opportunities of the climate of the Edwards region, the Subcommittee has identified needs for and benefits from recharge enhancement. They include:

(a) Increased springflow for the benefit of endangered species;

(b) Increased water available for withdrawal permits;

(c) Increased reliability for withdrawal permits. (Edwards Aquifer groundwater withdrawal permits are subject to Drought Management/Critical Period Management (DM/CPM) restrictions. One incentive to the development of enhanced recharge might be the improvement in regional index well levels and springflows that trigger the DM/CPM restrictions. If the index well levels and springflows can be improved, permit holders would receive a benefit of reduced DM/CPM.) ;

(d) Increased Edwards Aquifer water levels.

**1.3.** The entities and interest groups who have a need to own, finance, design, construct, operate, or maintain recharge facilities include:

(a) the Authority

(b) aquifer permitholders

(c) land stewardship interests

(d) private interests

(e) governmental interests

(f) springflow interests

**2. Charge 2 – Formulate plans to allow the Authority or any other entity to own, finance, design, construct, operate, or maintain recharge facilities.**

*The Subcommittee's Response.*

**2.1.** The issues to be addressed in a plan to allow the Authority or other entities to own, finance, design, construct, operate, or maintain recharge facilities include:

(a) identify interested parties;

(b) determine purpose of recharge facility – purpose purely intended to support springflow, water supply, or mixed purpose (an example of which could be a recharge facility coupled with other purposes such as flood control);

(c) evaluate legal authority;

(d) develop project partnerships;

(e) determine feasibility;

(f) determine and Allocate benefits and costs;

(g) acquire applicable federal, state and local permits and authorizations;

(h) evaluate financing alternatives – heavily predicated on success of implementing advice from Charges 4 and 5.

**2.2.** The Subcommittee recognizes that planning for any proposed recharge facility will include additional factors related to the type of facility.

**3. Charge 3 – Make recommendations to the Steering Committee as to how to calculate the amount of additional water that is made available for use from a recharge project including during times of critical period reductions.**

*The Subcommittee's Response.*

**3.1.** There are four techniques by which recharge to the Edwards Aquifer might be enhanced. They are: (1) direct injection, 2) recharge structures, (3) land stewardship and (4) recharge and recirculation. The subcommittee recognized that determining the amount of additional water that is made available for use from a recharge facility has to be accomplished in two steps.

The first step is to calculate the enhanced recharge to the aquifer for the particular recharge enhancement technique employed. The second step is to determine or allocate the amount of enhanced recharge that is available for a particular purpose.

## 3.2. Step One – Calculating Enhanced Recharge

**3.2.1. Enhanced Recharge by means of Direct injection –** (a technique per the Texas Water **Code**) implies an "injection well," which is an excavation or artificial opening. The Code recognizes five classes of injections wells, designated (I-V). All classifications are regulated either by Texas Commission on Environmental Quality (TCEQ) or the Railroad Commission of Texas (RRC). The Subcommittee understands, based on the information in the TCEQ guidance texts that "direct injection" wells for recharge purposes would most likely be assigned a Class V designation, which would be regulated by TCEQ. Class V wells include those releasing a liquid or liquids into or above a drinking water source.

The **calculation** of recharge by means of an injection well requires devices and strategies, including the following:

(a) Flow meter – device for measuring fluid movement. Variations of mechanical, pressure, electromagnetic/ultrasonic devices exist and an appropriate device installed to manufacturer's specifications would measure flow contribution within a prescribed accuracy. A flow meter in the case of direct injection would be installed to measure amount of recharge.

(b) Location and timing – currently a product of the conceptual understanding of the aquifer and its modeling. All direct injection is predicated on a conceptual understanding of the aquifer system based on conceptual geologic information and modeling based on coarse observations. More detailed site-specific observations would be required to validate or refine this limited understanding.

(c) Confirmation that water is reaching aquifer (well log) – a properly constructed well for injection to the aquifer would provide the most direct route to deliver volumes of water for recharge to a target zone. A well log and construction records would substantiate the confirmation.

(d) Water quality limitations (dependent on proximity to springs for species requirements, TCEQ standards for direct injection) – The unique application of direct injection in the context of any recharge contemplated by the EARIP program may require matching the ambient conditions of natural surface waters recharging the targeted injection zone. A bracketed range may be biologically sufficient for the sentinel endangered species of focus, depending on the water quality parameter(s) of most concern.

(e) Source water and injection permit – Having regulatory rights and access to both the water and approval to implement the technology.

(f) Environmental review.

### 3.2.2. Enhanced recharge by means of recharge structures

**Major Recharge dams** are major structures or dams located on the larger streams that traverse the Edwards Aquifer recharge zone and contributing zone. These structures have historically been studied and classified as 1) Type 1 – projects located on the Edwards Aquifer contributing zone that collect and store runoff for long periods of time and release it at a rate so that the flow enters the Edwards Aquifer as it flows across the recharge zone; 2) Type 2 – projects located on the Edwards Aquifer recharge zone on streams that are often dry. These structures impound water for only a few days or weeks following storm events and recharge water very quickly to the aquifer.

**Minor recharge dams** are small structures or dams on ephemeral waterways to capture runoff and hold it for seepage into the aquifer. This strategy can be implemented by individual landowners, but would probably need cost sharing by organized groups who depend upon the aquifer or through federal, state and local programs that provide technical and financial assistance.

**The measurement of** enhanced **recharge by recharge structures requires:**

(a) direct measurement (such as stream gauges, synoptic flow measurements, groundwater monitoring wells);

(b) indirect estimation (surface water-groundwater models, analytical calculations);

(c) confirmation that water is reaching aquifer (geologic assessment of recharge feature, recharge capacity);

(d) location and timing;

(e) water quality limitations (recharge meets ambient source stream water quality);

(f) O&M to preserve recharge rate;

(g) source water appropriation permit; and

(h) environmental review.

Permitting of any recharge facility will be subject to all federal, state, and local laws and restrictions. The Subcommittee recognizes the following section of the Edwards Aquifer Authority's Act that reads as follows:

> Section 1.45 Recharge Dams
>
> (a) The authority may own, finance, design, construct, operate, and maintain recharge dams and associated facilities, structures, or works in the contributing or recharge area of the aquifer if the recharge is made to increase the yield of the aquifer, the recharge project does not impair senior water rights or vested riparian rights, and the recharge project is not designed to recirculate water at Comal or San Marcos Springs.
>
> (b) The commission shall determine the historic yield of the floodwater to the Nueces River basin. The historic yield is equal to the lesser of:
>
> (1) the average annual yield for the period from 1950 to 1987; or
> (2) the annual yield for 1987.
>
> (c) Only the amount of floodwater in excess of the historic yield as determined by the commission may be impounded by a recharge dam built or operated under this section (emphasis added).

The Subcommittee suggests that this Section is vague and complicates the process of developing recharge facilities over the Edwards Aquifer so long as "the historic yield of the floodwater to the Nueces basin" remains undefined and the "amount of floodwater in excess of the historic yield" remains undetermined.

**3.2.3. Enhanced recharge by means of Land Stewardship.** Private ranches and rangelands comprise the bulk of lands over the Edwards Aquifer, and keeping watersheds (or more appropriately, water catchments) in open space is critical for water infiltration and recharge in the recharge and contributing zones of the Edwards Aquifer. The precipitation that falls on Texas rangelands is the major source of surface flow and aquifer recharge, and the condition and management of these rangelands has major impacts on the water available for recharge and river flows. Healthy rangelands provide clean, high quality drinking water, promote recharge, conserve soil, filter and slow overland flow of water, provide forage for livestock, and provide wildlife habitat (Hays *et al* 1998). Over the last century, encroachment of woody species (particularly Ashe juniper – commonly known as cedar) across much of Texas' open rangelands has degraded many of these services, and research demonstrates juniper has affected recharge and streamflow. Rangeland restoration programs reverse this trend through the use of sound management practices to control woody species, and with proper follow-up management practices healthy rangelands can be restored. Such restoration may benefit spring dependent species affected by the Edwards Aquifer as well as downstream organisms and communities dependent on reliable stream flows.

Research indicates rangeland restoration and management increases water quantity, as well as quality, for surface water run-off and aquifer recharge. The proper site and geology are critical specific to aquifer recharge, but most central Texas areas within the recharge zone and contributing zone can be enhanced for increased spring, seep and surface water flow. Woody plant invasion can be reversed through rangeland restoration. Initial costs, however, are generally more than a landowner can justify when considering livestock production alone. Costs are more for established, mature stands of unwanted brush and lower for younger aged, non-resprouting species. Under certain circumstances, additional water yield results from rangeland restoration. As is suggested by several studies, there may be opportunities for creating incentive-based programs that lead to additional water yield through rangeland restoration. An additional acre-foot can be gained for every 5 to 8 acres of brush converted to native rangeland in the Edwards Plateau.

Assuming rangeland restoration practices are effective for at least 10 years, the cost to produce an additional acre-foot of water in the Edwards Plateau would be $40 to $180 depending on the method. (Connor *et al* 2008) These surface waters flows are also slowed and cleaned with good range management, releasing water more slowly over time rather than in a singular muddy rush in a huge flood event, allowing for these waters to slowly percolate and released over time and/or to flow over increased periods of time into aquifer recharge structures. There is still uncertainty as to exactly how much additional water actually enters the aquifer. Additional research is underway and reporting is expected soon.

Vegetation management (brush management, prescribed burning, grassland restoration, grazing management, riparian management) is used to capture rainfall, increase soil infiltration, reduce runoff, and enhance water quality and quantity. The goal of vegetation management is to reduce Ashe juniper canopies in appropriate areas while enhancing and then maintaining healthy mid and tall grasses with vigorous root systems that can reduce erosion from rainfall impact on bare ground, increase infiltration into the root zone and beyond, and reduce rapid runoff that prevents the slow, continuous natural recharge in creeks and riparian areas.

Other conservation practices (such as terracing, soil aeration) can also be used to increase soil infiltration and slow or reduce runoff

### 3.2.4. The measurement of enhanced recharge by rangeland management requires:

(a) Several studies measuring evapo-transpiration have calculated an average increase in water yield (streamflow and recharge) of approximately 1.75 inches/year (45mm/year) under average or above average annual precipitation. (Wright 1996, Dugas *et al* 1998, and Huang *et al* 2006) However, there is still some uncertainty as to what fraction of additional water goes toward recharge. Interception losses to the canopy and litter are significant depending upon species of woody plant and species composition of woody/herbaceous cover. (Thurow and Hester, 1997)

(b) Direct measurement (such as stream gauges, synoptic flow measurements, groundwater monitoring wells, synoptic water level measurements, lysimeters, evapo-transpiration monitoring). Two separate demonstrations in the Seco Creek project point to water quantity increases to the Edwards Aquifer through selective woody plant management that increases water yield from rangeland watersheds. The two demonstrations show an increase of 35,000 to 55,000 gallons of water per acre per year following the selective removal of certain woody species. (http://wmc.ar.nrcs.usda.gov/news/secocreek.html)

(c) Indirect estimation (surface water-groundwater models, analytical calculations) Keese *et al* 2005 modeled recharge dynamics for the entire state of Texas taking into account the influence of climate, soils, and vegetation. For the Edwards Plateau region, their simulations suggest that recharge would be approximately 0.1-0.4 inches/ year (5-10 mm/year).

(d) Confirmation that water is reaching aquifer (geologic assessment of recharge zone, recharge capacity). There is still uncertainty as to exactly how much additional water actually enters the aquifer. There are several studies proposed that would research this but none have been funded at this point.

(e) Location and timing of vegetation management is important to achieve the desired vegetative state in areas identified to contribute to aquifer recharge particularly as they impact watersheds (water catchments) above critical spring areas and increased flows in rivers related to downstream species of interest.

(f) Enhancement and maintenance management practices to preserve desired vegetative state in targeted areas include planned/managed grazing (including deferment), prescribed fire, brush management, reseeding grasses and forbs with native plants as necessary, wildlife and habitat management planning, riparian management and restoration, erosion management and springs and creek-banks protection strategies, conserving and maintaining specific recharge features, increasing native biodiversity, conservation of rare species, managing exotics (flora and fauna) as necessary, appropriate estate planning (to limit fragmentation), conservation easements, local community and neighbor efforts to prioritize abilities of landowners to maintain open space broadly conserving spring sites, aquifer recharge areas and upstream contributing areas through conservation programs including federal, state and local community efforts such as PDRs, 2008 Farm Bill programs (such as CRP, CTA, CPGL, GRP, EQIP, WRP, CStP, FRPP) state programs (such as Landowner Incentive Program), local programs (Proposition 4) See Appendix 4.

(g) Environmental review for compliance with federal and state laws

**3.2.5. Enhanced recharge by means of Recharge and Recirculation -** Recharge and Recirculation is a combination of strategies for adding water to the aquifer by a number of methods that are inclusive of enhanced recharge structures, surface water sources (including both available stream flows and water from surface storage units) and groundwater sources (including pumping both regular permits and recharge withdrawal permits from the Edwards Aquifer). The purposes of a Recharge and Recirculation strategy is to provide springflow and/or additional firm yield water supply through aquifer management techniques, when compared to baseline conditions such as maximum allowed pumping under the regime established under S.B. 3, Article 12 .

Recharge and Recirculation source waters can include:

(i) unused regular withdrawal permits (Edwards);
(ii) unused recharge withdrawal permits (Edwards);
(iii) enhanced recharge structures over Recharge Zone (Type 2s);
(iv) enhanced recharge structures over Contributing Zone (Type 1s);
(v) diversions from rivers and lakes (surface water);
(vi) diversions from groundwater projects such as ASR projects;
(vii) diversions from additional surface water storage (quarries);
(viii) enhanced recharge from land stewardship projects.

Recirculation is a source of enhanced recharge that using previously created recharge withdrawal rights or regular rights to add water to the Aquifer at locations and times that can increase the amount and duration of stored waters in the Aquifer

**3.2.6. Methods of measuring the amount of enhanced recharge to the aquifer include both direct and indirect measurements**:

(a) “Direct measurements,” which include gauges above and below contributing streams or recharge structures, and flow meters on pipelines and water wells diversion facilities from storage units to recharge structures or injection wells.

(b) “Indirect measurements,”which include use of groundwater models and surface water models, and analytical calculations such as those used by TCEQ in Surface Water Availability Models (WAMs), Region L, Trans-Texas, HDR Engineering, and Todd Engineers.

**3.2.7. Methods of calculating the amount of recharge that may be withdrawn from enhanced recharge projects include:**

(a) Use of groundwater models such as the GAM models (Groundwater Availability Models) (MODFLOW or GWSIMIV) to calculate the duration of aquifer storage from a recharge project, adjusting over time for increased understanding of site specific characteristics and hydrologic behavior through adaptive management.

(b) Groundwater models may also be used to provide “safety factors” and to calculate “optimizations” required in calculating withdrawals, including these conditions on recharge withdrawals required by the EAA Statute and EAA Rules. The optimizations and safety factors are described as follows:

(i) *Optimization:* The recharge project is sited and designed to “optimize” the beneficial use of groundwater available for withdrawal from the Aquifer. EAA Rules, Sec. 711.264(15)

(ii) *Safety Factor***:** The proposed withdrawal of groundwater under the recharge recovery permit would not unreasonably negatively affect other permittees, including permitees holding initial regular permits. EAA Rules, Sec. 711.264(11), Sec. 711.264(14)

(iii) *Safety Factor:* Continuous minimum springflows of the Comal Springs and San Marcos Springs necessary to protect endangered and threatened species to the extent required by federal law, will not be negatively impacted when compared to springflow conditions if the project did not exist. EAA Rules, Sec. 711.264(16).

(iv) *Safety Factors:* Only the enhanced recharge with the project over base conditions of recharge without the project can be included in water available for withdrawal, less:

- additional waters discharged through springs due to the stored water;
- artificial recharge attributable and permitted to another Aquifer recharge storage and recovery project;
- loss of stored water; and
- an amount of groundwater not to be recovered to compensate the EAA in lieu of aquifer management fees as may be determined by the EAA Board.

Withdrawals may be reduced by an additional safety factor to account for uncertainties in the above calculations.

[EAA Statute, Sec. 1.44(b); EAA Rules, Sec. 711.261]

(c) Withdrawals of enhanced recharge, after being subjected to optimization and safety factors, are not subject to the maximum total permitted withdrawals provided by Sec. 1.14 of the EAA Act [Sec. 1.44(d) EAA Act]; and recharge withdrawal rights are not subject to EAA Critical Period Reductions under the present rules of the EAA [Sec. 711.255 (f) and (g), EAA Rules].

(d) Water remaining in Aquifer storage must be considered. In order to assess how much water remains in the Edwards Aquifer for pumping or recirculation or to assess how much of the enhanced recharge has gone to increase springflows or has otherwise left Edwards Aquifer storage, groundwater models such as the accepted Groundwater Availability Models used in state water planning can be used for evaluation purposes, given the location and timing and quantity of both the enhanced recharge and the location and timing and quantity of the enhanced pumping from enhanced recharge withdrawal permits.

(e) In order to confirm that water is reaching the Edwards Aquifer, local assessments of geological features at recharge sites may be made and any losses due to pipeline losses carrying water to the recharge site can be estimated or metering can occur as the water enters the recharge feature.

(f) Water quality limitations on recharge entering the aquifer in natural recharge features from surface water sources are identified in the EAA Rules, both for artificial injection into the Aquifer and for natural infiltration. [EAA Rules, Sec. 711.254 (b)(1) & (2)].

(g) The EAA may not approve an application for an aquifer recharge and storage permit unless protection of the water quality of the Aquifer is demonstrated in the application.

(h) Operation and Maintenance (O&M) Costs: There are varying amounts of O&M costs involved in preserving recharge rates for Recharge and Recirculation projects, depending on whether the project uses dam structures that need to be maintained, pipelines and diversion facilities that need to be maintained or well fields that need to be maintained.

(i) Source water appropriation permits include the surface water and groundwater permits for withdrawing or diverting water from surface water streams and groundwater sources. These include both state and federal permits, as well as permits from the Edwards Aquifer Authority.

(j) The projects for Recharge and Recirculation are subject to environmental review under both state and federal laws and regulations, as well as the reviews provided for under the rules of the Edwards Aquifer Authority.

## 3.3 Step Two – Allocate Enhanced Recharge

The Subcommittee identified several purposes for water recharged to the Aquifer as well as techniques that may be used to evaluate the effectiveness of a recharge project. These techniques may be used to design a project and to predict project performance, or they may be used to evaluate performance after a project is operating.

### 3.3.1. Purpose: Increased spring flow for benefit of endangered species

Evaluation techniques include:

(a) GAM Numerical models of Edwards Aquifer (such as MODFLOW[1], GWSIMIV[2]);

(b) biological studies to determine effects on the aquatic species;

(c) analytical tools (such as Darcy equation); and

(d) field measurements (such as synoptic[3] water level measurements, tracer studies).

### 3.3.2. Purpose: Increased water available for permits

Evaluation techniques include:

(a) GAM Numerical models of Edwards Aquifer (MODFLOW, GWSIMIV);

(b) consideration of the biological need to contribute to the recovery of species which are the focus of the EARIP;

(c) analytical tools (such as Darcy equation); and

(d) field measurements (such as synoptic water level measurements, tracer studies).

### 3.3.3. Purpose: Increased reliability for permits

Evaluation techniques include:

(a) GAM Numerical models of Edwards Aquifer (such as MODFLOW, GWSIMIV);

(b) consideration of the biological need to contribute to the recovery of species which are the focus of the EARIP;

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[1] U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model, see USGS 1996.

[2] Texas Water Development Board Edwards Aquifer model, see TWDB 1999.

[3] Synoptic water level measurements are measurements that are taken at approximately the same time (over a period of several days).

(c) analytical tools (such as Darcy equation); and

(d) field measurements (such as synoptic water level measurements, tracer studies).

### 3.3.4. Purpose: Increased water levels

Evaluation techniques will rely on a number of tools, including:

(a) GAM Numerical models of Edwards Aquifer (such as MODFLOW, GWSIMIV);

(b) biological studies to determine effects on the aquatic species;

(c) analytical tools (such as Darcy equation); and

(d) field measurements (such as synoptic water level measurements, tracer studies)

## 3.4. Technical evaluations.

Technical evaluations will be required for all recharge projects. The level of detail and specificity required in the technical evaluation will depend on the project's purpose. Highly detailed evaluations will be required if the purpose of the project is to increase the amount of water that may be pumped from the Aquifer (i.e., projects seeking recharge credits), whether for water supply or springflow. Less detail may be required if the sole purpose of a project is to increase springflow, and recharge credits are not being sought.

The permitting agency may develop default evaluation procedures for small projects that will not necessitate the expense associated with a detailed evaluation.

Technical evaluations should answer fundamental questions regarding the fate of recharged water, and the evaluations should show how the fate would change over time. All technical evaluations should answer the following questions.

(a) How much water would be recharged by the project?

(b) How much recharge would occur in the absence of the project?

(c) How much of the recharged water would discharge to springs?

(d) How much of the recharged water would be pumped from the Aquifer?

(e) What are the impacts to the downstream water rights and environmental flows?

(f) If there is evidence that the downstream water rights and/or environmental flows are adversely impacted, how would they be mitigated?

**3.5. Additional questions.**

Depending on the nature of the project, additional questions may have to be answered. One such question concerns the amount of the recharged water would discharge to streams and adjacent aquifers.

(a) "Safety factors" and "Optimization factors" may be applied to enhanced recharge projects to ensure that the water pumped by the operators of a recharge project does not exceed the amount of recharged water remaining in the Aquifer, to protect regular permit holders and minimum springflows required for endangered species by federal law, and to "optimize the benefits" of waters withdrawn from the Aquifer for recharge projects.

(b) In an application for a recharge withdrawal permit for a recharge project that adds enhanced recharge to Aquifer storage, the amount of the enhanced recharge that may be withdrawn over time may be determined by an application of the GAM models to the particular recharge project (MODFLOW model of the EAA; GWSIM4 model of the TWDB).

(c) To ensure that the permittee does not withdraw water that is not remaining in Aquifer storage, the Authority may require Monthly Reporting by the permittee [EAA Rules, Sec. 711.270], Operations Report by the permittee [EAA Rules, Sec. 711.271] and may consider the application of a safety factor to account for uncertainties, and shall review the permit every five years or on a more frequent schedule established by the Authority [EAA Rules, Sec. 711.272], which may result in an increase, decrease or no change in the calculation of water remaining in Aquifer storage that is subject to withdrawal over time.

**4. Charge 4 - Maximize available federal funding for the authority or any other entity to own, finance, design, construct, operate, or maintain recharge facilities.**

*The Subcommittee's Response.*

The Subcommittee has identified federal agencies and programs within federal agencies which are potential sources of federal funding. The Subcommittee recognizes that potential sources are subject to change as programs are modified and additional programs are made available. Budget considerations will affect whether funds are available and the amounts of available funds.

The federal agencies currently identified are listed below in this Section 4.

**4.1. United States Department of Agriculture (USDA)**

a) all USDA programs require cost share between landowner/USDA; and

b) additional assistance/partners to help fund landowner share of costs could increase participation in these programs.

**4.1.1. The Conservation Reserve Program (CRP)** provides technical and financial assistance to eligible farmers and ranchers to address soil, water, and related natural resource concerns on their lands in an environmentally beneficial and cost-effective manner. The program provides assistance to farmers and ranchers in complying with Federal, State, and tribal environmental laws, and encourages environmental enhancement. The program is funded through the Commodity Credit Corporation (CCC). CRP is administered by the Farm Service Agency, with NRCS providing technical land eligibility determinations, conservation planning and practice implementation. The Conservation Reserve Program reduces soil erosion, protects the Nation's ability to produce food and fiber, reduces sedimentation in streams and lakes, improves water quality, establishes wildlife habitat, and enhances forest and wetland resources. It encourages farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover, such as tame or native grasses, wildlife plantings, trees, filter strips, or riparian buffers. Farmers receive an annual rental payment for the term of the multi-year contract. Cost sharing is provided to establish the vegetative cover practices.

**4.1.2. The Environmental Quality Incentives Program (EQIP)** is a voluntary conservation program that promotes agricultural production and environmental quality as compatible National goals. Through EQIP, farmers and ranchers may receive financial and technical help to install or implement structural and management conservation practices on eligible agricultural land. EQIP was reauthorized in the Food, Energy and Conservation Act of 2008 (Farm Bill). The Natural Resources Conservation Service (NRCS) administers EQIP. Funding for EQIP comes from the Commodity Credit Corporation.

**4.1.3. The Agricultural Water Enhancement Program (AWEP)** is a voluntary conservation initiative that provides financial and technical assistance to farmers and ranchers to improve water conditions on their agricultural land.

**4.1.4. The Conservation Innovation Grant program (CIG)** is a voluntary program intended to stimulate the development and adoption of innovative conservation approaches and technologies while leveraging Federal investment in environmental enhancement and protection, in conjunction with agricultural production. Under CIG, Environmental Quality Incentives Program (EQIP) funds are used to award competitive grants to non-Federal governmental or non-governmental organizations, Tribes, or individuals. CIG enables NRCS to work with other public and private entities to accelerate technology transfer and adoption of promising technologies and approaches to address some of the Nation's most pressing natural resource concerns. CIG will benefit agricultural producers by providing more options for environmental enhancement and compliance with Federal, State, and local regulations. The Natural Resources Conservation Service (NRCS) administers CIG. The CIG requires a 50-50 match between the agency and the applicant. The CIG has two funding components - national and state.

**4.1.5.** **The Cooperative Conservation Partnership Initiative (CCPI)** is a voluntary conservation initiative that enables the use of certain conservation programs with resources of eligible partners to provide financial and technical assistance to owners and operators of agricultural and nonindustrial private forest lands.

**4.1.6.** **The Wildlife Habitat Incentives Program (WHIP)** provides financial incentives to develop habitat for fish and wildlife on private lands. Participants agree to implement a wildlife habitat development plan and NRCS agrees to provide cost-share assistance for the initial implementation of wildlife habitat development practices. NRCS and program participants enter into a cost-share agreement for wildlife habitat development. Cost-sharing is available for 50 percent of the average cost of practice establishment. The cost-share agreement typically is for a minimum of 5 years from the date that the contract is signed.

**4.1.7.** **The Wetlands Reserve Program (WRP)** is a voluntary program offering landowners the opportunity to protect, restore, and enhance wetlands on their property. The USDA Natural Resources Conservation Service (NRCS) provides technical and financial support to help landowners with their wetland restoration efforts.

**4.1.8.** **The Grassland Reserve Program (GRP)** is a voluntary program that helps landowners and operators restore and protect grassland, including rangeland and pastureland, and certain other lands, while maintaining the areas as grazing lands. Emphasis for enrollment into the program is on support for grazing operations, plant and animal biodiversity, and grasslands under the greatest threat of conversion.

**4.1.9.** **The Farm and Ranch Lands Protection Program (FRPP)**, formerly the Farmland Protection Program, is a voluntary conservation program that helps farmers and ranchers keep their land in agriculture. This program provides funds to help purchase development rights to keep productive farmland in agricultural uses. Working through existing programs, the USDA Natural Resources Conservation Service (NRCS) joins state, tribal, or local governments and non-governmental organizations to acquire conservation easements. The NRCS provides up to 50 percent of the appraised fair market easement value.

**4.1.10 The Conservation Stewardship Program (CSP)** is a voluntary conservation program that encourages producers to address resource concerns in a comprehensive manner by undertaking additional conservation activities and improving, maintaining, and managing existing conservation activities. CSP is available on tribal and private agricultural lands and non-industrial private forest land in all 50 States and the Caribbean and Pacific Islands Areas. The program provides equitable access to all producers, regardless of operation size, crops produced, or geographic location. The resource concerns that have overarching priority in Texas are water quantity**,** soil erosion and plant health and condition**.**

**4.1.11 Texas Watershed Program** - In the mid-1930s, Congress began looking at ways to complement the downstream flood control program of the Corps of Engineers. It passed flood control acts in 1936, 1944, and 1954 and assigned responsibility of the Watershed Protection and Flood Prevention Program to the USDA Soil Conservation Service, now the Natural Resources Conservation Service (NRCS).

Since that time, NRCS has assisted watershed sponsors in construction of nearly 2,000 floodwater retarding structures in 145 watershed projects across Texas. In addition, NRCS has assisted watershed sponsors in installation of land treatment practices, channel improvements, and dikes for watershed protection.

(a) Conservation Technical Assistance – planning and implementation assistance provided to landowners by NRCS staff

**4.1.12 Conservation Technical Assistance Program –** Conservation technical assistance is the help NRCS and its partners provide to land users to address opportunities, concerns, and problems related to the use of natural resources and to help land users make sound natural resource management decisions on private, tribal, and other non-federal lands.

The technical assistance can help land users:

(a) maintain and improve private lands and their management;

(b) implement better land management technologies;

(c) protect and improve water quality and quantity;

(d) maintain and improve wildlife and fish habitat;

(e) enhance recreational opportunities on their land;

(f) maintain and improve the aesthetic character of private land;

(g) explore opportunities to diversify agricultural operations; and

(h) develop and apply sustainable agricultural systems.

The assistance may be in the form of resource assessment, practice design, resource monitoring, or follow-up of installed practices.

Although the CTA program does not include financial or cost-share assistance, clients may develop conservation plans, which may serve as a springboard for those interested in participating in USDA financial assistance programs. CTA planning can also serve as a door to financial assistance and easement conservation programs provided by other Federal, State, and local programs.

**4.1.13 Conservation of Private Grazinglands Program -** The NRCS Conservation of Private Grazing Land (CPGL) initiative will ensure that technical, educational, and related assistance is provided to those who own private grazing lands. It is not a cost share program. This technical assistance will offer opportunities for: better grazing land management; protecting soil from erosive wind and water; using more energy-efficient ways to produce food and fiber; conserving water; providing habitat for wildlife; sustaining forage and grazing plants; using plants to sequester greenhouse gases and increase soil organic matter; and using grazing lands as a source of biomass energy and raw materials for industrial products.

Conservation of Private Grazing Land Program was authorized by the conservation provisions of the Federal Agricultural Improvement and Reform Act (1996 Farm Bill). The intent of this provision is to provide accelerated technical assistance to owners and managers of grazing land. The purpose is to provide a coordinated technical program to conserve and enhance grazing land resources and provide related benefits to all citizens of the United States. Currently, funds have not been appropriated for this program.

## 4.2 United States Fish and Wildlife Service (USFWS)

### 4.2.1. Partners for Fish and Wildlife

(a) Partners for Fish and Wildlife is a voluntary program that provides technical and financial assistance to private landowners to restore or enhance fish and wildlife habitats for Federal trust species (e.g. migratory birds, threatened, endangered, and candidates species and other declining species).

(b) A fact sheet about the Partners for Fish and Wildlife program is included in Appendix 6.

### 4.2.2 Endangered Species Habitat (Section 6)

(a) Section 6 of the Endangered Species Act, also called the "Cooperative Endangered Species Conservation Fund," establishes a grant program to the

States that provides funds for voluntary conservation projects for candidate, proposed and listed species.

(b) Section 6 grants are available in two categories: Traditional and Nontraditional grants.

*Traditional* grants are provided for conservation actions for candidate, proposed and listed species. Funds for this program are provided to the states based on a formula and grants are selected by Texas Parks and Wildlife Department (TPWD) in cooperation with the Service. It's called "Traditional" because this part of the program has been around since the 1980s.

*Nontraditional (or "Competitive") grants* fund only one of three specific activities: Recovery Land Acquisition, Habitat Conservation Planning Assistance, and Habitat Conservation Plan (HCP) Land Acquisition. Proposed projects are submitted by TPWD for competition and awarded by the Service. The grants are called "Nontraditional" because this part of the program began around 2001.

(c) A fact sheet about the Section 6 grant program is included in Appendix 6.

### 4.2.3. Federal Aid in Wildlife Restoration

(a) Since 1937, the Federal Aid in Wildlife Restoration Program has provided funds to state fish and wildlife agencies for the restoration, conservation, management, and enhancement of wild birds and mammals, and the provision for public use of and benefits from these natural resources. Federal Aid is a major funding source for Texas Parks and Wildlife Department, including habitat restoration and management and assistance to private landowners.

(b) Funds are also used for the education of hunters and archers in the skills, knowledge, and attitudes necessary to be responsible, competent sportsmen and women.

(c) A federal excise tax is collected from manufacturers of firearms, ammunition, and archery equipment. This tax is passed on to the hunter and shooter, who benefit from the recreational and educational opportunities created with the funds; users pay, and users benefit.

## 4.3. Environmental Protection Agency (EPA)

(a) 319(h) funding;

(b) Project must be water quality based.

## 4.4. United States Army Corps of Engineers (USACE)

(a) The USACE can participate in projects in conjunction with local sponsoring governments. Projects are initiated and funded through one of three mechanisms: 1) traditional feasibility study, design and construction process, 2) Continuing Authorities Program, or 3) non-traditional process.

(b) Regardless of which mechanism is employed to initiate a project, the project must progress through four main phases:

(i) Reconnaissance Phase
(ii) Feasibility Phase
(iii) Preconstruction, Engineering and Design Phase
(iv) Construction Phase

(c) Traditional Feasibility Study, Design and Construction Process

(i) Reconnaissance Phase does not need project specific authorization and is 100 percent funded by the USACE up to $100,000.
(ii) A project has to be authorized by an act of Congress and funds appropriated by Congress in order for USACE to participate in a feasibility study. The costs for the feasibility study are shared equally between the USACE and local sponsor.
(iii) The costs for the preconstruction, engineering, design phase and construction phase are typically shared 65 percent federal and 35 percent local sponsor; however, with certain projects the federal cost share can be as high as 75 percent. These phases require a separate appropriation of funds by Congress in order to proceed.
(iv) Office of Management and Budget (OMB) applies its decision criteria, which can be different from the USACE criteria, to projects that have a federal interest determination and are vying for construction funding. Projects need OMB support in order to get into the President's budget. Otherwise congressional delegation has to insert funding for the project in budget committee negotiations.

(d) Continuing Authorities Program

(i) Projects follow the same phases as in the traditional process
(ii) The Continuing Authorities Program is pre-authorized and appropriated so projects do not need individual authorizations and appropriations directly from Congress
(iii) Total federal participation in projects initiated through this program is limited to $5 million.
(iv) New project starts are subject to the availability of federal funds.

(e) Nontraditional Project Processes include:

(i) Local sponsor conducts reconnaissance and feasibility studies in conformance with USACE requirements and standards.

(ii) Local sponsor works with its congressional delegation to write authorization and appropriation language in a bill to direct the USACE to build project plan developed by the local sponsor.

(iii) Must conform to the National Environmental Policy Act (NEPA).

(iv) Projects are subject to "earmark" scrutiny and prohibitions.

A Nontraditional Project must be consistent with one of the USACE authorized purposes. The two USACE authorized purposes that are most applicable to recharge are:

(i) Flood control; and

(ii) Ecosystem restoration (recharge supports spring flow that supports endangered species or bay and estuary inflow)

(f) As of November 2009 there are five currently authorized USACE projects that have the potential to enhance recharge to the Edwards Aquifer:

(i) *Nueces Watershed study:* Project includes multi-purpose flood risk management; ecosystem restoration; recharge; and recreation;

*(ii) Guadalupe-San Antonio Basin Study;*

(iii) *Cibolo Creek Feasibility Project*: Project includes multi-purpose flood risk management; ecosystem restoration; recharge; recreation;

(iv) *Leon Creek Feasibility Study:* Project includes primarily flood risk management; ecosystem restoration can be added and if there is detention, the project has recharge potential; and

(v) *Lower San Antonio Feasibility Study:* Project will not affect Edwards recharge zone

(g) Annual appropriations, or lack thereof, typically restrict or lengthen the amount of time needed to complete any study.

(h) Requires executing a cost share agreement between local sponsors and USACE.

(i) Studies can be modified or terminated at any time by local sponsor.

(j) USACE can only fund projects that meet the requirements of a federal interest (favorable cost/benefit ratio, for a federal authorized purpose).

(k) The USACE cannot fund mitigation projects but can fund recovery projects

**4.5 Other Federal Agencies –**to explore opportunities of additional federal funding.

**4.5.1. United States Geological Survey (USGS)**

**4.5.2. Department of Defense (DOD)**

**4.5.3. United States Bureau of Reclamation (USBR)**

**4.6. Other state and local funding sources –** to be used as match for federal funds or to be used independently of federal funds

**4.7 Landowner Associations**

**4.7.1** Wildlife **Management** Associations

(a) Wildlife management associations are landowner-driven organizations formed by groups of neighboring landowners for the purpose of improving wildlife habitat and associated wildlife populations and to achieve shared wildlife management goals.

(b) These associations are often 501(c) 3 not for profit organizations with the ability to receive and administer funding for habitat and watershed improvement practices on lands operated by the members.

**4.7.2** Prescribed Burn Associations

(a) Prescribed burn associations facilitate prescribed burns among members by providing equipment, training and manpower. They don't receive any funding other than some grants to purchase equipment.

(b) The presence of a local prescribed burn association would facilitate prescribed burning as a land stewardship tool and might provide a opportunity for equipment to be obtained through grants.

**4.8** Conservation Easements and Land Trusts

**4.9** Local tax revenue funding programs

(a) City of San Antonio Propositions 1 and 3; and

(b) City of Austin Proposition 2.

## 5. Charge 5 - Evaluate the financing of recharge facilities, including the use of management fees or special fees to be used for purchasing or operating the facilities

*The Subcommittee's Response:*

This Report lists below the options for financing recharge facilities and describes the main potential sources of funding. Funding sources are subject to change from time to time, and thus the list is not all-inclusive . Further, each agency's budget is subject to appropriation. The Subcommittee will provide more detail and evaluation of the available alternatives for financing of recharge facilities upon receiving guidance from the Steering Committee.

**5.1.** Evaluation of other financing options:

(a) General Obligation bonds issued by cities, counties;

(b) General tax revenues issued by cities, counties;

(c) Revenue bonds/contracts issued by cities, utilities, river authorities, water districts, private entities, port authorities;

(d) Voluntary contributions by private entities, individuals, NGOs; and

(e) Dedicated revenues from special marketing items (*E.g.*, License plate fees, use fees, bottled water).

**5.2.** Evaluation of the use of management fees or special fees to be used for purchasing or operating facilities:

(a) EAA, TCEQ (surface water permit holders): A Special fee for recharge programs would be applied all permit holders so all aquifer beneficiaries participate in funding.

(b) Impact/development fees assessed by a regulatory authority

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# APPENDIX 1

# MEMBERSHIP

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Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Roster

Voting Members

Environmental Groups
- George Rice, AGUA
- Tyson Broad, Sierra Club

Land Stewardship Groups
- Kirby Brown, Texas Wildlife Association
- Mike McMurry, Texas Department of Agriculture
- Gene Richardson, Texas Farm Bureau
- Linda Campbell, Texas Parks and Wildlife

Regional/River Authorities
- Steve Raabe, San Antonio River Authority
- Con Mims, Nueces River Authority

Water Purveyors
- Humberto Ramos, Bexar Met
- Jerry James, City of Victoria
- Darren Thompson, replaced by Patrick Shriver, SAWS
- Gus Gonzales, City of Corpus Christi

General Stakeholders
- Dan Laroe, Guadalupe Basin Coalition
- Kirk Patterson, Regional Clean Air and Water

Contributing Zone
- Ronald Fieseler, GMA 9

Recharge Zone
- Vic Hilderbran, Uvalde County Underground Water Conservation District
- Robert Rothe, Medina County Groundwater Conservation District

Business Interests
- Mary Kelly, Greater San Antonio Chamber of Commerce

Non-Voting Members
- Cary Betz, Texas Commission on Environmental Quality
- George Ozuna, US Geological Survey
- Mark Mosely, Natural Resources Conservation Service
- Will Amy, replaced by Kevin Connally, US Fish and Wildlife Service
- Marcia Hackett, US Army Corps of Engineers
- Roberto Anaya, Texas Water Development Board

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# APPENDIX 2

## Meeting Agenda and Reports to Steering Committee

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Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
August 14, 2008 meeting

The subcommittee elected Steve Raabe, San Antonio River Authority, chair.

Reviewed the five (n) charges for the subcommittee.

Discussed completing the subcommittee's work by January 2010 with a report to the Science Subcommittee in July 2009.

Recommended adding the following agencies as non-voting members of the subcommittee:

- Texas Commission on Environmental Quality
- Texas Water Development Board
- Edwards Aquifer Authority
- United States Geological Survey
- United States Army Corps of Engineers
- United States Fish and Wildlife Service
- Natural Resources Conservation Service

The subcommittee agreed to meet at 8:30 am the morning of the monthly Steering Committee meetings.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

September 25, 2008
9:00 am
Edwards Aquifer Authority Boardroom

1. Call to Order
2. Election of Vice-Chair
3. Review and Prioritization of Subcommittee Charges
4. Schedule/Timelines
5. Alternates/Committee Rules
6. Subcommittee Webpage Content
7. Bibliography on Recharge/Land Stewardship
8. Status of Research
9. Subcommittee Reporting
10. Agenda Items for Next Meeting

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
September 25, 2008 meeting
Held at the Edwards Aquifer Authority

The meeting was called to order at 9:15 am, however a quorum was not present.

Discussion was held on the organization and content of the subcommittee webpage and regarding a bibliography on land stewardship prepared by Tyson Broad.

At the completion of those discussions a quorum was achieved.

The subcommittee elected Kirk Patterson, Regional Clean Air and Water, Vice-chair.

Steve Raabe laid out a proposed process by which the subcommittee would review, prioritize and address the five subcommittee charges including a schedule. After some adjustments to the schedule, Humberto Ramos moved and Cary Dupuy seconded to adopt the process as presented and the schedule as modified. The motion passed unanimously. The adopted process and schedule are attached.

The subcommittee discussed the need for alternates and modifications to the quorum requirements. There are 18 voting members on the subcommittee of which 16 members (85%) constitute a quorum for meetings at which the subcommittee will make a decision on a recommendation to the Steering Committee. The subcommittee recommended changing the quorum requirement to 50% for meetings where no recommendation decisions are made. The subcommittee noted that the appointments to the subcommittee were on an entity or organization basis. Con Mims moved and Robert Rothe seconded to have subcommittee members designate an alternate if they will be absent provided they notify the chair of their designation of an alternate prior to the meeting. The motion passed unanimously.

The meeting adjourned at 10:30 am.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Process

Review Subcommittee Charges

- The five charges direct the subcommittee to make recommendations on who should do recharge projects, how to calculate and allocate enhanced recharge and how should recharge projects be funded.
- The charges do not direct the subcommittee to recommend specific recharge projects for implementation.
- Recommend that selection of specific recharge projects for implementation be done by the Steering Committee starting January 2010 as part of "Task 5 – Develop Water Management Plan" of EARIP implementation schedule prepared by Dr. Gulley.

Prioritize Subcommittee Charges

- Charge #3 directs the subcommittee to make a recommendation to the Steering Committee on how to calculate the amount of enhanced recharge due to recharge projects and how that water could be made available for support of springflow and for Edwards permit holders.
- Charges #1, #2, # 4 and #5 deal with which entity should do recharge projects and how could they be funded.
- Charges #1, #2, # 4 and #5 are not particularly relevant unless recharge can be calculated and allocated which is the focus of Charge #3.
- Work on Charge #3 first followed by Charges #1, #2, # 4 and #5.

Subcommittee Schedule

- Have presentations on the various recharge projects and land stewardship to get subcommittee familiar with the various ways recharge can be enhanced. (October 2008 through January 2009)
- Next work on Charge #3. Complete this work by July 1, 2009 so subcommittee recommendation is available to Science Subcommittee to consider in their recommendation. (February 2009 through June 2009)
- Next work on Charges #1, #2, # 4 and #5 and have subcommittee recommendation to Steering Committee by January 2010 (July 2009 through December 2009)

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Schedule/Timeline

| | | |
|---|---|---|
| September 25, 2008 | - | Agree on Charges, Activities and Schedule |
| October 16, 2008 | - | Presentation on Previous Recharge Project Studies |
| November 13, 2008 | - | Presentation on Barton Springs Recharge project |
| Nov./early Dec. | - | Workshop on Cibolo/Nueces Corps of Engineers Studies and Land Stewardship |
| December 11, 2008 | - | Topic to be determined |
| January 8, 2009 | - | Presentation on EAA Recharge Rules |
| January 27 or 28, 2009 | - | Presentation on Recharge and Recirculation |
| February 2009 – June 2009 | - | Work on Charge # 3. Meet 2 times per month if needed. |
| July 2009 – December 2009 | - | Work on Charges #1,2,4,5 |
| January 2010 | - | Report to Steering Committee |

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

October 16, 2008
8:30 am
Dunbar Recreation Center
San Marcos, Texas

1. Call to Order

2. Presentation on Previous Recharge Studies for the Edwards Underground Water District, Trans-Texas Water Program and Region L Planning Group – Sam Vaugh, HDR Engineering, Inc.

3. Subcommittee Reporting

4. Agenda Items for Next Meeting

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
October 16, 2008 meeting
Held at the Dunbar Recreation Center, San Marcos, Texas

The meeting was called to order at 8:30 am, however a quorum was not present at the beginning of the meeting but was achieved during the presentation.

Sam Vaugh/HDR Engineering made a presentation on previous recharge studies conducted by the Edwards Underground Water District, Trans-Texas Water program, Region L and the US Geological Survey.

Chair Steve Raabe reminded the subcommittee that the next meeting is to be November 13, 2008 at Trinity University.  There will be a presentation on the Antioch Cave Recharge project by Ron Fieseler/Blanco-Perdenales Groundwater District and Brian Smith/Barton Springs Edwards Groundwater District.

The meeting adjourned at 9:45 am.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

November 13, 2008
8:30 am
Trinity University
San Antonio, Texas

1. Call to Order

2. History and Operation of the Antioch Cave Recharge Facility on Onion Creek, Hays County, Texas – Ron Fieseler, Blanco-Perdernales Groundwater District and Brian Smith, Barton Springs Edwards Aquifer Conservation District

3. Report on Workshop

4. Discussion regarding comments to the Program Operating Rules Work Group

5. Subcommittee Reporting

6. Agenda Items for Next Meeting

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
November 13, 2008 meeting
Held at the Fiesta Room, Trinity University, San Antonio, Texas

The meeting was called to order at 8:30 am, however a quorum was not present.

Ron Fieseler/Blanco-Perdenales Groundwater District and Brian Smith/Barton Springs Edwards Groundwater District made a presentation on the Antioch Cave Recharge project.

Chair Steve Raabe reminded the subcommittee that the Recharge Facility Feasibility Subcommittee Workshop will be held on December 4 from 9:00 to 3:00 at the EAA boardroom.

Discussed comments regarding the Program Operating Rules.

The meeting adjourned at 9:45 am.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

December 4, 2008
9:00 am to 3:00 pm
Edwards Aquifer Authority Boardroom
San Antonio, Texas

1. Call to Order

2. Corps of Engineers Nueces and Cibolo Studies – Marcia Hackett, USACOE

3. Rangeland Restoration to Enhance Recharge to the Edwards Aquifer – Summary of Research/Region L Study – Brad Wilcox/Todd Snelgrove, TAMU

4. Recovery Credit System – Concept and Case Study - Fort Hood – Susan Baggett, NRCS

5. Rangeland Restoration for Enhancing Recharge to the Edwards Aquifer – Implementation Scenario – Neil Wilkins, TAMU IRNR

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
December 4 2008 meeting
Held at the Edwards Aquifer Authority Boardroom, San Antonio, Texas

The meeting was called to order at 9:00 am, however a quorum was not present.

Marcia Hackett/US Army Corps of Engineers made a presentation on the Nueces Feasibility Study and Rob Newman/US Army Corps of Engineers presented on the Cibolo Creek Feasibility Study. Both of these studies are evaluating enhancing recharge to the Edwards Aquifer for ecosystem restoration benefits.

Dr. Brad Wilcox/Ecosystem Science and Management Department, Texas A&M University presented on the state of research regarding water yield from rangeland restoration using brush management.

Todd Snelgrove/Institute for Renewable Natural Resources, Texas A&M University presented on geospatial techniques available to identify and evaluate candidate areas suitable for rangeland restoration using brush management to enhance recharge.

Susan Baggett/USDA Natural Resources Conservation Service presented on recovery credits as a method to value endangered species habitat in a recovery program.

Dr. Neal Wilkins/ Institute for Renewable Natural Resources, Texas A&M University presented a conceptual implementation scenario using recovery credits for enhancing recharge to the Edwards Aquifer.

Chair Steve Raabe announced that the Recharge Facility Feasibility Subcommittee meeting on December 11, 2008 was cancelled since the EARIP Steering committee meeting was cancelled. The next meeting of the Recharge Facility Feasibility Subcommittee will be held on January 8, 2009 from 8:30 to 10:00.

Steve Raabe also stated that the Recharge and Recirculation presentation to the Recharge Facility Feasibility Subcommittee will have to be moved to early February. It was agreed to schedule that presentation for February 11, 2009 pending confirmation from the Edwards Aquifer Authority.

The meeting adjourned at 2:50 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

January 8, 2009
8:30 am
San Antonio Water System
San Antonio, Texas

1. Call to Order

2. Presentation on Edwards Aquifer Authority Recharge Rules

3. Subcommittee Reporting

4. Schedule and Agenda Items for Next Meeting

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
January 8, 2009 meeting
Held at the San Antonio Water System, San Antonio, Texas

The meeting was called to order at 8:35 am, however a quorum was not present. A quorum was achieved during the next agenda item.

Darcy Frownfelter with Kemp Smith, LLP, Edwards Aquifer Authority legal counsel, made a presentation on the Edwards Aquifer authority recharge rules.

Chair Steve Raabe reminded the subcommittee that the next meeting of the subcommittee will be held on February 11, 2009 to hear a presentation on the Edwards Aquifer Authority's study regarding recharge and recirculation. The location and time will be announced when they are determined.

The meeting adjourned at 9:45 am.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
February 11, 2009 meeting
Held at the Great Hall in the Chapman Center at Trinity University in San Antonio, Texas

The meeting was called to order at 1:00 pm, however a quorum was not present.

Phyllis Stanin, Todd Engineers, made a presentation of the results of the Phase III/IV Report on Recharge and Recirculation. The study was funded by the Edwards Aquifer Authority and the San Antonio Water System. Also present were the remaining members of the consultant team, Dr. Bob Brandes with TRC/Brandes, and Bill Norris and Mike Irlbeck with NRS Engineering.

Chair Steve Raabe stated that this meeting concluded the informational phase of the Subcommittee's work. The agenda for the next meeting will include a discussion of the process to develop the committee's recommendations and consideration of changing the meeting day and times for the subcommittee.

Chairman Raabe reminded the subcommittee that the next meeting of the Subcommittee will be held on March 12, 2009 at 8:30 am at GBRA.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

March 12, 2009
8:30 am
Guadalupe-Blanco River Authority
River Annex
Seguin, Texas

1. Call to Order

2. Discuss Process for Development of Subcommittee Work Products
    a. Short Term Objectives
    b. Long Term Role

3. Consider Changing Meeting Times and Location

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
March 12, 2009 meeting
Held at the Guadalupe-Blanco River Authority River Annex in Seguin, Texas

The meeting was called to order at 8:30 am, however a quorum was not present.

The subcommittee discussed the process for development of the subcommittee's work products. It was noted that the subcommittee was not given a statutory deadline to complete its work on the five (n) charges. A two step process was discussed to get more direction from the Steering Committee and to allow the EARIP process to mature. The process is listed below:

- Short Term Objectives to be completed by December 31, 2009
    - Layout key concepts and information relating to Charges 1-5
    - Work on information that is most useful to the EARIP Steering committee at this point in the process
    - Prepare a "Fact Book" that includes the information developed above
- Long Term Role for the Subcommittee after December 31, 2009
    - Activity of subcommittee will have better focus as the Steering Committee and stakeholders layout objectives for the Edwards Aquifer and species
    - Subcommittee will flesh out Charges 1-5 as the Steering Committee discussions/negotiations progress

The subcommittee changed its regular meeting time to the fourth Monday of the month at 1:00 pm. The next meeting will be held on March 23, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

Chair Steve Raabe asked for volunteers for the Steering Committee to consider for appointment of a working group to visit with the US Army Corps of Engineers regarding the Corps role in implementation of strategies developed by the EARIP. Steve Raabe, Kirk Patterson, Patrick Schriver, Dan Laroe and Rick Illgner volunteered.

The meeting was adjourned at 9:35 am.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

March 23, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Review Process for Development of Subcommittee Work Products
   a. Short Term Objectives
   b. Long Term Role

3. General Discussion Regarding Charges 1-5

4. Detailed Discussion Regarding Charge 3
   a. Methods of recharge enhancement to specifically accommodate
   b. Identify types of benefit of recharge enhancement
   c. Identify required parameters for each method of recharge enhancement

5. Set Location and Agenda for next meeting

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
March 23, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm, however a quorum was not present.

The subcommittee reviewed the short term objectives and long term role of the Recharge Facility Subcommittee. The subcommittee also reviewed the (n) charges 1-5.

There was an extended discussion on the draft outline and contents of the Subcommittee Report (Fact Book). The subcommittee identified key points in each charge that should be addressed.

The agenda for the April 27th meeting would address Charges 1 and 2. Charge 3 would be discussed if time allows.

The next meeting will be held on April 27, 2009 at 1:00 pm at the San Antonio River Authority boardroom. The May 25th meeting was moved to June 1st because of Memorial Day falling on May 25th.

The meeting was adjourned at 4:00 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

April 27, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Discussion Regarding Charges 1-2

3. Discussion Regarding Charge 3

4. Set Location and Agenda for next meeting
    a. June 1, 2009, 1:00 pm
    b. Location

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
April 27, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:00 pm, however a quorum was not present.

The subcommittee worked on developing the contents of the Subcommittee Report (Fact Book). The subcommittee addressed Charges 1 and 2. Charge 3 was not discussed and will be the topic of the June 1, 2009 meeting.

The next meeting will be held on April 27, 2009 at 1:00 pm at the San Antonio River Authority boardroom. The May $25^{th}$ meeting was moved to June $1^{st}$ because of Memorial Day falling on May $25^{th}$.

The meeting was adjourned at 4:00 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

June 1, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Discussion Regarding Charge 3

3. Set Agenda for next meeting
    a. June 22, 2009, 1:00 pm

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
June 1, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm. A quorum was not present at the start of the meeting but a quorum was established during Agenda Item No 2.

George Rice explained the draft document he developed regarding availability of recharged water which included a simplified water balance. Future refinements would include revising the water balance as a time series and adding an example of how the water balance equation could be applied.

The subcommittee had an extended discussion regarding how to calculate enhanced recharge for each type of recharge technique and how to allocate enhanced recharge for each purpose or use of recharge.

Charge 3 was not discussed in any great detail and will be the topic of the June 22, 2009 meeting.

The next meeting will be held on June 22, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

The meeting was adjourned at 3:20 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

June 22, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Discussion Regarding Charge 3

3. Set Agenda for next meeting
    a. July 27, 2009, 1:00 pm

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
June 22, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm.  A quorum was not present at the meeting.

The subcommittee identified potential parameters and methods to calculate enhanced recharge for direct injection, recharge structures, land stewardship and recharge and recirculation.

Discussed the schedule and topics for the remaining subcommittee meetings in 2009 as follows:

July 27 – Complete Charge 3, discuss water balance
August 24 – Work on Charges 4 and 5
September – November – complete subcommittee report

The next meeting will be held on July 27, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

The meeting was adjourned at 3:40 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

July 27, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Discussion Regarding Charge 3
    a. Review purposes of recharge
    b. Develop remaining Charge 3 items

3. Review Water Balance

4. Set Agenda for next meeting
    a. August 24, 2009, 1:00 pm

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
July 27, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm. A 51 percent quorum was present. An 85 percent quorum was not present at the meeting.

Robert Gulley asked Calvin Finch/SAWS to brief the subcommittee on a potential study being considered by the Additional Studies Workgroup. The potential study would evaluate recharge to 1) support springflow, 2) reduce the frequency of Stages 3 & 4 Critical Period pumping reductions, 3) prepare preliminary cost-benefit analyses and 4) consider all potential sources of recharge water, components and methods used to increase recharge. The preliminary budget is approximately $150,000. The scope of the study will be developed by the Additional Studies Workgroup for potential action by the EARIP Steering Committee at the September 10th meeting. The Recharge Facilitiy Feasibiltiy Subcommittee members offered comments on the study and were requested to submit any remaining comments to Dr. Finch or Dr. Gulley.

The subcommittee identified potential parameters and methods to allocate enhanced recharge for 1) increased spring flow for benefit of endangered species, 2) increased water available for permits, 3) increased reliability for permits and 4) increased aquifer water levels.

The subcommittee also reviewed the water balance prepared by George Rice.

The next meeting will be held on August 24, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

The meeting was adjourned at 3:50 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

August 24, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Discussion Regarding Charge 4

3. Discussion Regarding Charge 5

4. Review Charge 3

5. Set Agenda for next meeting
    a. September 28, 2009, 1:00 pm

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
August 24, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm. A 51 percent quorum was present. An 85 percent quorum was not present at the meeting.

The subcommittee discussed Charge 4 – How to maximize federal funding for recharge facilities. Mark Moseley – USDA NRCS, Marcia Hackett – USACOE and Linda Campbell – TPWD provided information on relevant federal funding opportunities.

The subcommittee discussed Charge 5 – Evaluate the financing of recharge facilities including the use of management or special fees to be used for the purchasing or operating recharge facilities.

Chair Steve Raabe asked for volunteers to start writing text for the subcommittee report. The following volunteered: Steve Raabe, George Rice, Patrick Schriver, Kirk Patterson, Linda Campbell and Kirby Brown.

The next meeting will be held on September 28, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

The meeting was adjourned at 4:00 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Agenda

September 28, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

1. Call to Order

2. Review Draft Report

3. Set Agenda for next meeting
    a. October 26, 2009, 1:00 pm

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
September 28, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm. A 51 percent quorum was present. An 85 percent quorum was not present at the meeting.

The subcommittee discussed the draft committee report. The subcommittee established the following schedule to complete the report:

- October 9 - RFS comments, additions and modifications to text submitted to Steve Raabe
- October 19 – revised text emailed out to RFS
- October 26, 1:00 – Review meeting report and make final drafting assignments
- November 6 – final comments submitted to Steve Raabe
- November 16 – final report draft emailed out to RFS
- November 23, 1:00 – final RFS meeting to consider adoption of report. **Need 85% quorum at this meeting (16 out of 18 members)**

The next meeting will be held on October 26, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

The meeting was adjourned at 3:00 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

# Agenda

October 26, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

11. Call to Order

12. Review Draft Report

13. Set Agenda for next meeting
    a. November 23, 2009, 1:00 pm

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
October 26, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:05 pm. A 51 percent quorum was present. An 85 percent quorum was not present at the meeting.

The subcommittee discussed the draft committee report. Several drafting assignments were made. It was requested that the formatting of the report be improved to increase the visual and content clarity. Mary Kelly, although not at the meeting, had previously volunteered to accomplish the reteve formatting. The subcommittee established the following schedule to complete the report:s

- October 30 – final drafting work submitted to Steve Raabe
- November 2 – revised draft emailed to RFS
- November 6 – final comments submitted to Steve Raabe
- November 16 – final report draft emailed out to RFS
- November 23, 1:00 – final RFS meeting to consider adoption of report. **Need 85% quorum at this meeting (16 out of 18 members)**

The next meeting will be held on November 23, 2009 at 1:00 pm at the San Antonio River Authority boardroom.

The meeting was adjourned at 3:30 pm.

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

# Agenda

November 23, 2009
1:00 – 4:00 pm
San Antonio River Authority
Boardroom
San Antonio, Texas

14. Call to Order

15. Review Draft Report

16. Consideration of Adoption of Report

Edwards Aquifer Recovery Implementation Program

Recharge Facility Feasibility Subcommittee

Subcommittee Report
Of
November 23, 2009 meeting
Held at the San Antonio River Authority River Boardroom in San Antonio, Texas

The meeting was called to order at 1:10 pm. An 85 percent quorum was present at the meeting.

The Subcommittee discussed the draft committee report and made several minor revisions. The Subcommittee directed the Chair to make several final formatting changes subsequent to the meeting. Kirk Patterson moved to adopt the report substantially in the form as presented and revised at the meeting. Kirby Brown seconded the motion. The motion passed by consensus.

Dr. Robert Gulley briefed the Subcommittee on a potential study regarding the feasibility of certain recharge options to protect springflow at the Comal and San Marcos Springs. If approved by the EARIP Steering Committee, the consultant would make several presentations regarding the progress of the study to the Subcommittee to receive comments.

The meeting was adjourned at 2:45 pm.

# APPENDIX 3

## Land Stewardship Publications

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# LAND-BASED WATER CONSERVATION & WATER YIELD PRACTICES IN REGION L: MONITORING STRATEGIES

SUBMITTED TO
REGION L
SOUTH CENTRAL TEXAS REGIONAL WATER PLANNING GROUP
BY

TEXAS A&M Institute of Renewable Natural Resources

&

GRAZINGLAND MANAGEMENT SYSTEMS, INC.

STUDY SPONSORED BY
TEXAS WILDLIFE ASSOCIATION FOUNDATION

San Antonio, Texas
May 1, 2008

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**ABSTRACT**

The goal of the monitoring program is to determine the amount, if any, of additional recharge and/or streamflow results from managing woody plants. An effective monitoring program would need to include multiple measurements at several different scales. Monitoring approaches include remote sensing, watershed comparisons, small catchment studies, micrometeorological towers and soil moisture measurements. For the Region L area we recommend the following: (1) incorporate and apply the large scale remote sensing technology across the Region L area; (2) in each of the target areas have a network of evaptranspiration (ET) towers in treated and untreated locations; (3) in the Carrizo-Wilcox area, complement ET tower measurements with detailed monitoring of soil moisture in treated and untreated areas: and (4) in the Guadalupe Watershed monitor spring flow in as many locations in treated and untreated areas (ET towers would be in the same areas).

## LAND-BASED WATER CONSERVATION & WATER YIELD PRACTICES IN REGION L: MONITORING STRATEGIES

We have determined that there are three distinct areas within Region L that offer the most potential for increased streamflow through management of woody plants. These include (1) the Carrizo-Wilcox aquifer recharge zone with special emphasis in Dimmit and Zavala Counties (2) the Edwards aquifer recharge zone in Uvalde, Medina, Bexar, Comal and Hays Counties, and (3) the Guadalupe River watershed above Canyon Lake including Comal and Kendall counties. Each of the areas are different and have a distinct regional hydrology that must be taken into account in developing monitoring protocols that are aimed at evaluating the hydrological effect of brush control.

There are two major recharge zones within the Region L Area—the Carrizo-Wilcox and the Edwards Aquifer. As noted above the recharge zones and the aquifers that they supply are very different in character. The Edwards Aquifer is a karst system and as such is very dynamic and capable of very rapid recharge as well as discharge. It is a renewable groundwater resource meaning that recharge is roughly equivalent to discharge, including groundwater pumping. Recharge occurs largely within stream channels that traverse the recharge zone. There is likely some distributed recharge outside of the stream channels but as of yet there have been no reliable estimates of how important distributed recharge may be.

The Carrizo-Wilcox aquifer, by contrast, is not a renewable aquifer and recharge is lower than ground water pumping, with the result being that groundwater levels are declining. Recharge occurs where the Carrizo Sands and Wilcox formation are exposed at the surface. Soils are quite sandy and infiltration rates are high (little runoff). Water that moves beyond the rooting zone is available for recharge.

The third area that we have identified as having a potential for augmenting water supply through brush control is the area of the Guadalupe Watershed above Canyon Lake. The presence of Canyon Lake affords the opportunity for storing any additional water that may result from land management activities.

The goal of this report to lay out some potential strategies and techniques that may be employed for determining the extent to which, if any, water supply is augmented through brush management. Because each area is so distinct, a different suite of monitoring protocols will be required for each.

### POTENTIAL MONITORING STRATEGIES

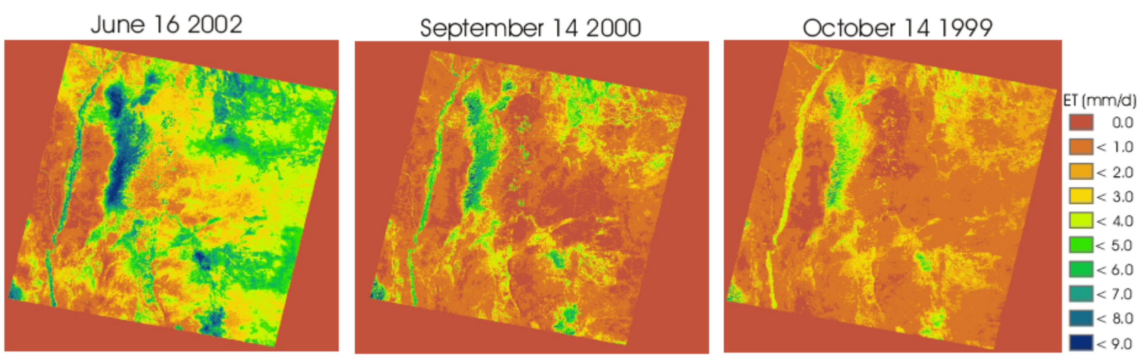
The fundamental challenge posed is that of determining how much, if any, additional water has resulted from particular land management practices. This requires determining both how much recharge (or streamflow) occurs AND whether or not it is higher than would have been in the absence of the land management practice. The variability of climate often makes this a difficult and time consuming proposition. In addition, in order to determine if there is a difference we have to be able to make a comparison of different treatments either in time or space.

***Regional scale***

*Remote sensing*

Emerging technology now exits for estimating evapotranspiration using remote sensing imagery. This is relatively new technology but there is the potential to map evapotranspiration across very large areas within Region L and relating evapotranspiration rates to vegetation cover (the presence or absence of woody plant cover). This approach could potentially allow for a comprehensive evaluation of the potential for releasing more groundwater recharge through shrub control. Specifically, tracking evapotranspiration rates across several years could answer specific questions such as (1) can shrub clearing lead to enhanced recharge (2) where would shrub clearing be most effective (3) would the effect be the same or different for wet and dry years.

The technique has been successfully applied in New Mexico. An example from the Rio Grande Valley in New Mexico is presented below (Hong and Hendrickx, 2006). This example provides a nice illustration of the spatial and temporal resolution that is possible.




*Challenge:* This technique is still experimental and would require implementation and evaluation by remote sensing experts

*Application Area:* This technique could be effectively applied in each of the three target areas

***Intermediate scale (100-10000 km²)***

*Large Watershed Studies*

Watershed experiments in which streamflow is continuously monitored in one or more watersheds offer the potential of assessing land management practices. These kinds of experiments have been conducted in many settings, with considerable success(Bosch and Hewlett, 1982; Stednick, 1996). However, there are significant challenges in successfully completing such experiments. A typical approach is using a pair of watersheds where one is treated and the other is not. For these kinds of experiments to work, considerable time is required (years), both to insure that the watersheds are comparable and also having sufficient time after implementation of the treatment. Another approach is that of using a single watershed and implementing the treatment after several years of monitoring. The effectiveness of the North Concho shrub control project has recently been evaluated using this kind of approach (Wilcox et al. 2008). Similarly, Trimble et al. (1987) used long term streamflow records to demonstrate that streamflows in Tennessee have been diminished because of expanding forests.

*Challenge:* Time and expense. Large watershed studies require significant time and resources to be successfully implemented

*Application Area:* Guadalupe River above Canyon Lake.

***Field Scale***

At smaller scales more detailed measurements of water fluxes can be measured and several approaches are available, both of which have advantages and disadvantages

*Evapotranspiration Micrometeorology Towers*

The technology is now available to directly measure evapotranspiration over areas the size of a football field using instrumentation that is mounted on towers. The most common approach for doing this relies on the Eddy Covariance technique. Similarly, the Bowen Ratio approach has been applied with some success. Direct measurements of evapotranspiration at the field scale can provide estimates of water savings resulting from vegetation management. These techniques have been used with good success for assessing the effects of vegetation on the water cycle (Dugas *et al.*, 1998; Dugas and Mayeux, 1991; Scott *et al.*, 2003) and for best results these measurements should be complemented by field measurements of surface runoff.

*Challenge:* Operation of evapotranspiration towers require skilled technicians and good data management systems.

*Application Area:* All areas

*Small catchments experiments*

Monitoring runoff and springflow at the scale of a few acres can provide insight as to the effects of vegetation manipulation. The same logic ideas and constraints apply as for the very large watershed scale studies discussed above. Small catchment studies have been done with some success in the Edwards Plateau in evaluating the effect of vegetation management (Huang *et al.*, 2006; Wilcox *et al.*, 2005).

*Challenge:* As with the large watershed studies, catchment experiments required many years of observation. In addition, it can be very difficult to find suitable catchments for paired experiments.
*Application Area:* Guadalupe River above Canyon Lake.

***Plot Scale***

*Monitoring water in the vadose zone*

One of the best ways of determining the influence of plants on recharge is that of making detailed measurements soil water both within and below the plant root zone. Ideally measurements would be made repeatedly in both time and space. The technology is available for continuous monitoring of soils moisture and a variety of techniques and approaches are available. This approach has been used with great success including several studies in South Texas (Weltz and Blackburn, 1995; Moore *et al.*, 2008)

*Challenge:* Soil monitoring is difficult if not impossible in the Edwards Plateau region because of shallow, rocky soils.

*Application Area:* Carrizo-Wilcox recharge zone.

*Plant level measurements of transpiration and interception*

Woody plants affect the water cycle because they transpire water and they also intercept rainwater—both of which are very important. Transpiration and interception by shrubs can be directly measured and there are examples of this kind of work in the Edwards Plateau and south Texas (Owens *et al.*, 2006; Owens, 1996; Owens and Schreibe, 1992).

*Challenge:* Tree level measurements can be made but it is often difficult to determine what they mean on a landscape scale

*Application Area:* all areas

**RECOMMENDATIONS**

Each of the target areas are different and each pose opportunities and challenges in terms of monitoring.

Recommendation 1: Incorporate and apply the large scale remote sensing technology across the Region L area. In addition to addressing the effectiveness of the brush management program, it will provide very useful regional information related to water resources

Recommendation 2: In each of the target areas have at a network of ET towers in treated and untreated locations. These measurements should be complemented by monitoring of surface runoff so that recharge could be estimated by difference.

Recommendation 3: In the Carrizo-Wilcox area, complement ET tower measurements with detailed monitoring of soil moisture in treated and untreated areas

Recommendation 4: In the Guadalupe Watershed monitor spring flow as many locations in treated and untreated areas (ET towers would be in the same areas).

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# LAND-BASED WATER CONSERVATION & WATER YIELD PRACTICES IN REGION L: INFLUENCE OF LAND BASED CONSERVATION PRACTICES ON WATER YIELD

SUBMITTED TO
REGION L
SOUTH CENTRAL TEXAS REGIONAL WATER PLANNING GROUP
BY

TEXAS A&M Institute of Renewable Natural Resources

&

GRAZINGLAND MANAGEMENT SYSTEMS, INC.

STUDY SPONSORED BY
TEXAS WILDLIFE ASSOCIATION FOUNDATION

San Antonio, Texas
February 7, 2008

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**Abstract**

In this report we examine the potential for increasing water yield within region Region L though land management. Our assessment is based on the available literature and our own experience. The major land management practice which has the potential for affecting water yield would be that of reducing woody plant cover through brush control. Region L encompasses a large region in south-central Texas and includes several distinct vegetation and physiographic zones including the Edwards Plateau, South Texas Plains, Gulf Coast Prairies, Post Oak Savanna and Blackland Praire. The areas with the most potential for increasing water yield through brush control would be the Edwards Plateau overlying the Edwards Aquifer and the South Texas Plains that overly the Carrizo-Wilcox aquifer. The most current research indicates that within the Edwards Plateau, reducing ashe-juniper cover could result on average 40-60 mm of additional water yield per year. This translates into roughly an additional acre-ft of water for every 5-8 acres cleared. Within the South Texas plains, water yield (groundwater recharge) could be augmented up to10 - 20 mm/yr or about 1 acre-ft of water for every 15-30 acres cleared. Depending on the method and expense of brush clearing these estimates would translate into a cost of between $40 and $180 per acre-ft of water for the Edwards Plateau and $100 and $300 per acre-ft in regions of the South Texas Plains that overlie the Carrizo-Wilcox Aquifer

## Executive Summary

### Vegetation and Vegetation Management in the MLRA of Region L

Edwards Plateau

The northern parts of Uvalde, Medina, Bexar, Comal and Hays Counties of Region L are in the Edwards Plateau Major Land Resource Area (81C) immediately above the Balcones Escarpment. For the purpose of this report, soil series typical of the area are represented by a Low Stony Hill ecological site, an upland site with slope gradients mainly 1 to 8 percent but that can range up to 12 percent. The plant communities of a Low Stony Hill site are dynamic and vary in relation to grazing, fire and drought. Presettlement conditions were strikingly different than those found today. Large areas that were once open grasslands are now infested with heavy woody cover consisting of species such as Ashe juniper, liveoak, post oak, honey mesquite, agarito, Texas persimmon, elbowbush and lotebush.

Brush management treatment alternatives commonly used in the Edwards Plateau MLRA include mechanical and chemical practices, as well as prescribed fire and biological control associated with the use of goats. Ashe juniper is the primary target species for brush management a very high percentage of the time. Mechanical brush management treatments can be either broadcast when densities of plants are greater than 300 plants per acre or large enough to respond to treatments such as chaining or cabling, or individual plant treatments (IPT) when densities are low enough and/or plants are small enough to justify treating individual plants. Ashe juniper is non-sprouting species; that is, it will suffer mortality if all the above ground green material is removed. This allows top removal practices to be effective for brush management and the most popular of these methods currently is the use of a "skid-steer loader" equipped with a front-end attachment of hydraulically operated shears. The shears are placed with the skid steer at the base of a target plant species and the shears are then closed hydraulically so that they cut entirely through the trunk of the tree.

South Texas Plains

The South Texas Plains MLRA includes the largest portion of Region L. All or part of the following Region L Counties are in the MLRA; Uvalde, Zavala, Dimmitt, Medina, Frio, La Salle, Bexar, Atascosa, Wilson, Karnes, Goliad, DeWitt, and Gonzales. Upland soils are of three groups: dark, clayey soils over firm clayey subsoils; grayish to reddish brown, loamy to sandy soils; and brown loamy soils. Gray, clayey, saline, and sodic soils are extensive on the coastal fringe, along with Galveston deep sands. Bottomlands are typically brown to gray, calcareous silt loams to clayey alluvial soils. The original vegetation was an open grassland or savannah-type along the coastal areas and brushy chaparral-grassland in the uplands. The plant communities that can be found on this site range from a mid-grass dominant to a brush covered site with bare ground. This diversity in plant communities is in direct response to grazing management, fire, and drought. At this point the area is represented as a Shrubland with a canopy of brush greater than 20 percent and often reaching between 60 percent to total closure. In the heavy brush cover, understory vegetation will range from a cover of short and mid grasses to bare ground. Woody species include guajillo, blackbrush, condalia, wolfberry, pricklypear, Texas persimmon, paloverde , ceniza and coma.

The South Texas Plains are the heart of the Texas “Brush Country”, sharing that designation with the western part of the Gulf Coast Prairie MLRA. Brush stands in the area are often aggregates of 15 or more species, most characterized by thorns or spines and existing in three strata – overstory of trees, mid-story of shrubs and an understory of subshrubs and cacti. Chaining and rootplowing where the most popular of the early mechanical practices utilized in the area and have been applied on hundreds of thousand of acres in the MLRA. The MLRA also has a long history of the use of broadcast chemical brush management treatments.

Other MLRAs in Region L

Other MLRAs in Region L include the Gulf Coast Prairies and Marshes consisting of all or part of Refugio, Calhoun, Victoria and Goliad Counties. The Post Oak Savannah and Blackland Prairies are two additional MLRA that include portions of Counties within Region L. Compared to the Edwards Plateau, Gulf Coast Prairies and Marshes and South Texas Plains, the land areas of the Post Oak Savannah and Blackland Prairies within Region L are small.

**Potential to Augment Recharge and Streamflow Within Region L Through Shrub Control**

In this section, we examine the scientific basis for using shrub control as a means of increasing groundwater recharge with an explicit focus on two of the landcover types within the Region L Planning area: (1) juniper woodlands within the Edwards Plateau Major Land Resource Area (MLAR) and (2) South Texas shrublands within the South Texas Plains MLRA—in particular those shrublands overlying the Carizzo-Wilcox recharge zone within Zavala and Dimmitt counties.

Rangeland areas with the most potential for increasing recharge through shrub control are those areas where deep drainage (water movement beyond the herbaceous rooting zone) can occur (Seyfried et al. 2005, Wilcox et al. 2006). This characteristic is found, for example, where soils are shallow and overlie relatively permeable bedrock (such as karst limestones). An example in Texas is the Edwards Plateau area, which supports large tracts of juniper woodlands and has considerably more “flowing water” than would be expected for a semiarid or subhumid climate (ca. 700 mm/yr). The explanation lies in the karst geology—a substrate of fractured limestone that allows rapid flow of water to the subsurface. Other soil types that may enable deep drainage are sandy soils. Shrublands in region L that exhibit these characteristics are the juniper shrublands within the Edwards Plateau and the South Texas shrublands overlying the recharge zone of the Carrizo-Wilcox Aquifer.

Edwards Plateau

On the basis of the literature available, our current best estimate is that conversion of Ashe Juniper woodlands into open savannas would result in an average increase in water yield (streamflow and recharge) of around 50 mm/year. The influence of Ashe juniper on the water budget has been the subject of some confusion and disagreement, in part because the implications of the scale at which measurements were made have not been fully considered. For example, at the tree scale, the most common measurement is some index of evapotranspiration by trees. After removal of trees, these numbers have often been extrapolated up without taking into account the compensatory effects of regrowth of trees or replacement by other vegetation. These measurements do not take into account water use by replacement vegetation, as the larger-scale studies do. For example, at the tree scale, for an area with an average annual precipitation of 750 mm/yr, an individual tree will intercept and transpire virtually all of the available water. At the stand scale, however, as estimated by Dugas *et al.* (1998), the difference in water consumption between a woodland and a grassland is between 40-50 mm/yr. Newer work suggests differences as high as 90 mm/year however. Water balance studies at the small-catchment scale (where springs exist) indicate water savings of around 50 mm/yr. (Huang et al. 2006).

South Texas Shrublands

Our estimate that for the South Texas shrublands, average recharge on sandy soils could be increased by shrub control anywhere from 10 -20 mm/year. All of the available data strongly suggest that in the presence of dense shrub cover, there will be little if any recharge. However, both the modeling and field work suggest that in the absence of shrubs, recharge will be appreciably higher—especially for sandy soils. For example, Weltz et al (1995) found that when rainfall was slightly above average, recharge was around 20 mm/year for grass covered areas. The implications of this then are that shrub control over the recharge area would in the long term increase distributed recharge.

## Assessing the Cost Effectiveness of Brush Control to Enhance Off-site Water Yield

Estimates of added groundwater recharge cost reported herein are based only on the highly variable costs of the brush control practices and/or programs. Factors that influence brush control cost and contribute to the high variability include the type, size and density of the target brush species; the type, rock content and slope of soil in which the target species is growing; whether the target species sprouts re-growth from root buds; whether cost effective herbicides are available for controlling the target species; etc.

In addition, there are many other factors which would impact the ultimate costs; ie., program implementation and management, percent of costs born by landowners, extent of landowner participation, etc.

Edwards Plateau

In a previous section, it was reported that there are several different mechanical practices appropriate for use in the control of Ashe juniper. The costs of these various mechanical practices may vary from less than $100 to as much as $400 per acre (Pestman, 2007). Also in a previous section of this report the added ground water recharge estimated to result from control of Ashe juniper was reported to be 50mm/year. The inch equivalent of 50mm/yr. is 2 in. which is also equal to 0.167 ft. Therefore, control of Ashe juniper on an acre of land is estimated to result in 0.167 added ac.ft. of groundwater recharge per year.

The cost estimates are obtained by taking the per acre cost of the brush control practice, or cost of a program consisting of an initial plus follow-up practices, and dividing it by 0.167. This results in the estimated cost per acre foot of added groundwater recharge resulting from brush control if the practice, or program, is effective for only one year. If brush control programs were implemented and if provisions of the programs require participating landowners to reduce brush canopies to 5 percent and maintain them at this level or less for 10 years, then the costs per acre foot of added ground water recharge would be expected to range between $40 and $180 per acre foot in the Edwards Plateau.

South Texas Shrublands

In a previous section, it was stated that several herbicides and several different mechanical practices were appropriate for use in the control of mixed brush in South Texas. The costs of these various chemical practices are less variable and generally less costly than the mechanical practices in the Edwards Plateau as discussed above. In addition, the mechanical practices applicable to the control of mixed brush in South Texas would generally be less costly than when used in the Edwards plateau because the soils tend to be less rocky and the terrain is generally flatter in South Texas. Therefore, costs for mixed brush management in South Texas may vary from less than $50 to more than $100 per acre (Pestman, 2007). Also in a previous section of this report the added groundwater recharge estimated to result from control of mixed brush was reported to be between 10 and 20mm/year. To be conservative, we will use 10mm/year in the following analysis. The inch equivalent of 10mm/yr. is 0.4 in. which is also equal to 0.033 ft. Therefore, control of Ashe juniper on an acre of land is estimated to result in 0.033 added ac.ft. of groundwater recharge per year.

Using the same methods described for the Edwards Plateau, costs per acre foot of added ground water recharge would be expected to range between $100 and $300 per acre foot in The Carrizo – Wilcox Aquifer recharge area.

**LAND-BASED WATER CONSERVATION & WATER YIELD PRACTICES IN REGION L: INFLUENCE OF LAND BASED CONSERVATION PRACTICES ON WATER YIELD**

**Vegetation and Vegetation Management in the MLRA of Region L**

**Edwards Plateau**

General

General descriptions of soil, climate and vegetation resources for all Region L MLRA in this paper are from Hatch et al. (1990), Checklist of the vascular plants of Texas and adapted from the Natural Resources Conservation Service (NRCS) Ecological Site Descriptions (2007), web site: http://esis.sc.egov.usda.gov/ or were furnished upon request by NRCS as a proposed site description (Gray Sandy Loam for South Texas Plains 83B).

The northern parts of Uvalde, Medina, Bexar, Comal and Hays Counties of Region L are in the Edwards Plateau Major Land Resource Area (81C) immediately above the Balcones Escarpment. The Balcones Escarpment forms the distinct boundary of the Edwards Plateau on its eastern and southern borders. The area is a deeply dissected, rapidly drained stony plain having broad, flat to undulating divides.

Soil series typical of the area are included in a Low Stony Hill ecological site, an upland site with slope gradients mainly 1 to 8 percent but that can range up to 12 percent. The very shallow to shallow, well drained, moderately slow permeable soils of this site were formed in residuum over interbedded limestone, marls, and chalk. Soil thickness and depth to limestone ranges from 4 to 20 inches. Subrounded to angular pebbles, cobbles, and stones of limestone comprise 35 to 80 percent by volume of the soil. The soil is a clay soil and is alkaline to neutral. The depth of soil is one of the main factors affecting water holding capacity.

The climate is humid subtropical and is characterized by hot summers and relatively mild winters. The average first frost should occur around November 15 and the last freeze of the season should occur around March 19. The average relative humidity in mid-afternoon is about 50 percent. Humidity is higher at night, and the average at dawn is about 80 percent. The sun shines 70 percent of the time possible during the summer and 50 percent in winter. The prevailing wind direction is southeast. Approximately two-thirds of annual rainfall occurs during the April to September period. Rainfall during this period generally falls during thunderstorms, and fairly large amount of rain may fall in a short time. Mean annual precipitation ranges from over 30 inches in the eastern portion of the MLRA (Hays County) to about 24 inches in the western portion Uvalde County).

The plant communities of a Low Stony Hill site are dynamic and vary in relation to grazing, fire and drought. Presettlement conditions were strikingly different than those found today. One major vegetative difference was the presence of open prairies of tall grasses which were common throughout much of Texas. The historic climax plant community (HCPC) was greatly influenced by large herbivore grazing and fires. It is hypothesized that buffalo would come into an area, graze it down and then leave, not to come back for many months or even years, usually following a fire. This long deferment period allowed the better quality grasses and forbs to recover from heavy grazing. Fire was probably a very important factor in maintaining the original prairie vegetation and also had a major impact on the plant community structure. Species, such as Ashe juniper (*Juniperus ashei*), would invade the site, but not at the level we see today. Periodic fires, set either by Native Americans or by lightning, suppressed the range and density of Ashe juniper and other woody species. Woody plant control would vary in accordance to the intensity and severity of the fire encountered, which resulted in a mosaic of vegetation types within the same site.

While grazing was a natural component of this ecosystem, long-term overstocking and thus overgrazing by domestic animals had a tremendous impact on the site (Taylor 2004). Heavy grazing eliminates the possibility of fire and promotes the rapid encroachment of Ashe juniper. Continued overgrazing will lead to the demise of the higher quality grasses and forb species that are part of the HCPC. When site degradation is extreme, range planting may be the only means by which these species can be re-established on the site.

The HCPC, which was an open grassland with scattered oak (*Quercus* spp.) motts, included little bluestem (*Schizachyrium scoparium*), big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), and Eastern gamagrass (*Tripsacum dactyloides*). Continued overuse brought about the removal of these and many other species from a large portion of the site. Low successional, unpalatable grasses, forbs and shrubs have taken the place of the more desirable plant species. The loss of topsoil and soil organic matter makes it unlikely that these abused areas will return to the HCPC in a reasonable period of time. The diversity of native forbs and grasses has been reduced, while the presence of introduced and non-native species appears to be increasing. However, little bluestem and other native species will slowly return to the site with a sound range management program mimicking the historic management.

Ashe juniper, because of its dense low growing foliage, has the ability to retard grass and forb growth. Grass and forb growth can become almost nonexistent under dense juniper canopies. Many times there can be a resurgence of the better grasses, such as little bluestem and Indiangrass, when Ashe juniper is controlled and followed by proper grazing management.

The tallgrasses of the HCPC and similar community composition aided in increasing the infiltration of rainfall into the slowly permeable soil. The loss of soil organic matter due to overgrazing has a negative effect on infiltration. More rainfall is directed to overland flow, which causes increased soil erosion and flooding. Soils are also more prone to drought stress since organic matter acts like a sponge and aids in moisture retention for plant growth. Mulch buildup under the Ashe juniper canopy, following brush management and incorporation into the soil, can have a positive effect on increasing infiltration.

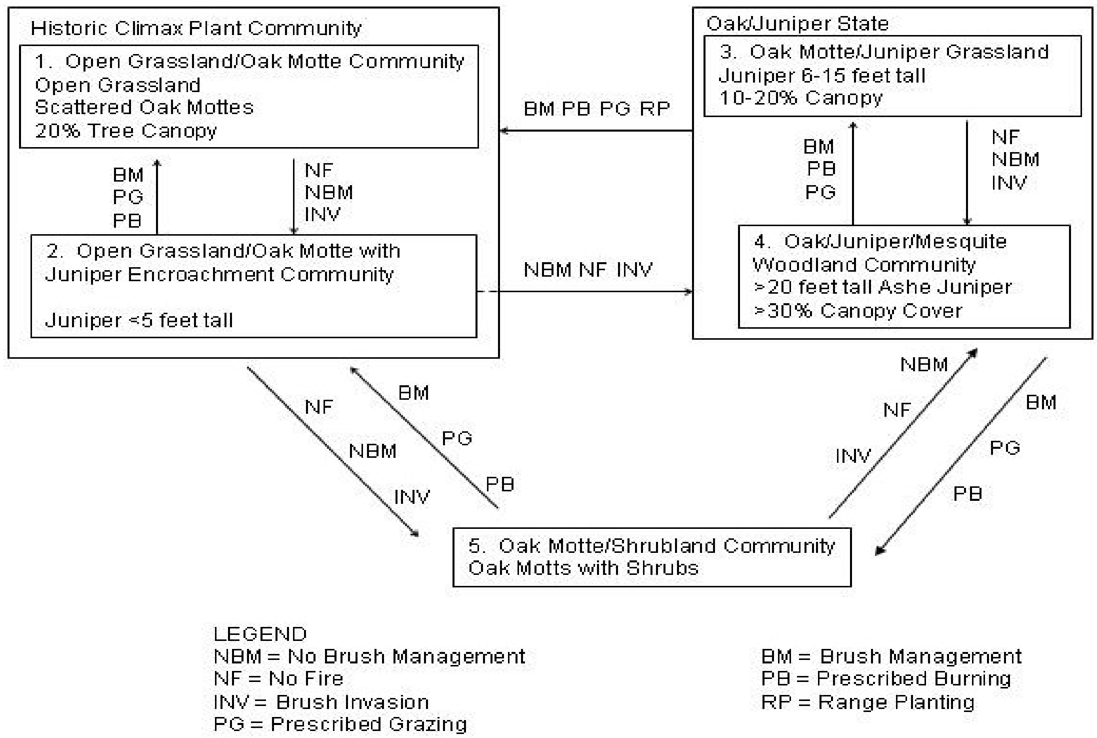
The Edwards Plateau is 98 percent rangeland; arable lands are found only along narrow streams and some divides. The rangeland is used primarily for mixed livestock (combinations of cattle, sheep, and goats) and wildlife production. The area is known as the major wool-and mohair-producing region in the United States, however in recent years there has been a move to greater meat goat production and a reduction in angora goats. The area also supports the largest deer population in North America. Most ranches in the area maintain livestock production, but wildlife has become increasingly important and may equal or exceed livestock in management emphasis and income on many ranch operations. Exotic big-game ranching is also important, and axis, sika, and fallow deer and blackbuck antelope have increased in numbers. Management for all resources, livestock, wildlife, and recreation, provides the best use of the rangeland, although other products such as cedar oil and wood products have local importance. Forage, food, and fiber crops such as sorghum, peanuts, plums, and peaches are well adapted to arable land.

The increasing concern for wildlife habitat, especially white-tailed deer, over the past four decades has dictated a change in the approach to rangeland vegetation manipulation with brush control practices from wide-scale broadcast treatments, such as chaining, to a more limited "sculpted" approach. However, brush management for increased forage production for domestic livestock is still an important practice in the area.

Specific Reference to a Dominant Ecological Site

Ecological Site Descriptions (ESD) developed by the Natural Resources Conservation Service provide a detailed means to view landscapes in the MLRA. For the purpose of this paper, a dominant ecological site in the Edwards Plateau will be used to show the vegetation steady states and transitions that occur from the HCPC through the process of retrogression to those communities more commonly existing today. A Low Stony Hill ecological site is one of the most commonly occurring sites in the MLRA.The ESD for a Low Stony Hill site includes the state and transition model shown in Figure 1.

Figure 1. State and Transition model for a Low Stony Hill Site, Edwards Plateau MLRA




The HCPC for the site is shown as plant community 1. In its pristine (HCPC) condition, this site is a fire-climax, open grassland with scattered oak mottes with about 20 percent tree canopy. The liveoaks (*Quercus virginiana*) are most abundant along water courses, where elm (*Ulmus* spp.) and hackberry (*Celti*s spp.) trees also grow. The herbaceous plant community is dominated by little bluestem. Indiangrass and big bluestem are subdominants, and may even dominate locally. Also native to the site, but occurring less frequently or in lesser amounts are the wildryes (*Elymus* spp.), sideoats grama (*Bouteloua curtipendula*), tall dropseed (*Sporobolus compositus*), feathery bluestems (*Bothriochloa* spp.), green sprangletop (*Leptochloa dubia*), vine mesquite (*Panicum obtusum*), Texas wintergrass (*Nassella leucotricha*) and Texas cupgrass (*Eriochloa sericea*). The site also grows an abundance of climax forbs, shrubs and woody vines.

Retrogression from the HCPC to plant community 2 is indicated by reduction in the occurrence of fire on the site, no brush management and the invasion of woody plants, primarily Ashe juniper. The model indicates that communities 1 and 2 are contained within the same steady state (large box) and that community 1 can be restored from community 2 by brush management, prescribed burning and prescribed grazing. However, as retrogression continues to occur, a new steady state, an oak/juniper state, develops that includes plant communities 3 and 4. Alternatively, steady state 5 can establish as an oak motte/shrubland community from either of the other steady states.

Brush management, prescribed burning and prescribed grazing can be used to restore the site to more closely resemble the HCPC, but as the size of juniper increases beyond that effectively controlled with prescribed fire, so does the cost of brush management. For example, in the oak/juniper steady state costly practices, such as mechanical removal of juniper must be employed, as well as range planting in areas where the native seed source is judged to be depleted. Representative composition by different plant types and total annual production of the HCPC are provided in Table 1.

Table 1. Annual Production by Plant Type (HCPC)

| | Annual Production (lbs/AC) | | |
|---|---|---|---|
| Plant Type | Low | Representative Value | High |
| Forb | 65 | 110 | 135 |
| Grass/Grasslike | 1950 | 3250 | 3900 |
| Shrub/Vine | 45 | 75 | 90 |
| Tree | 180 | 300 | 360 |
| Total: | 2240 | 3735 | 4485 |

As a contrast and to show the influence of heavy invasion on the site from Ashe juniper and other woody species, Table 2 provides plant types and production from plant community 4, the Oak/Juniper Woodland community. Community 4 has developed as a result of a severe vegetation shift from an original plant community which was a grassland with scattered oak mottes to a plant community which is predominately tall woody plants and limited tallgrass vegetation. This community will exhibit Ashe juniper 20 feet tall and taller, with canopies in excess of 30%. Grass and grasslike vegetation is significantly reduced due to the severe competition that Ashe juniper and other woody species present regarding sunlight and moisture.

Large areas that were once open grasslands are now infested with heavy woody cover consisting of species such as Ashe juniper, liveoak, post oak (*Quercus stellata*), honey mesquite (*Prosopis glandulosa*), agarito (*Mahonia trifoliata*), Texas persimmon (*Diospryos texana*), elbowbush (*Forestiera pubescens*) and lotebush (*Ziziphus obtusifolia*)

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Table 2. Annual Production by Plant Type (Community 4)

| | | Annual Production (lbs/ac) | |
|---|---|---|---|
| | | Representative | |
| Plant Type | Low | Value | High |
| Forb | 30 | 50 | 70 |
| Grass/Grasslike | 400 | 650 | 800 |
| Shrub/Vine | 100 | 150 | 200 |
| Tree | 720 | 1200 | 1450 |
| Total: | 1250 | 2050 | 2520 |

Management alone will not allow this community to shift back towards the climax community. Implementation of brush management programs involving heavy equipment and very high treatment cost is the only option if decision-makers desire to transition this site back towards the historic plant community. By implementing other conservation measures, such as prescribed burning and prescribed grazing, land managers can maintain the community as a grassland community following initial brush management practices.

As the plant community degenerates to community 4, big and little bluestem, Indiangrass and the wildryes decrease and Sideoats grama, tall dropseed, silver bluestem, Texas wintergrass and buffalograss (*Bouteloua dactyloides*) are initial increasers on the site. Prolonged overuse of these plants usually results in a community of Texas wintergrass, curlymesquite *(Hilaria belangeri*), buffalograss and woody species. The following grasses and forbs are commonly found on this site in a deteriorated condition: western ragweed (*Ambrosia psilostachya*), broomweed (*Amphiachyris* spp.), prairie coneflower (*Ratibida columnifera*), snow-on-the-Mountain (Euphorbia marginata), silverleaf nightshade (*Solanum elaeagnifolium*), milkweeds (*Asclepias* spp.), Leavenworth eryngo (*Eryngium leavenworthii*), two-leaf senna (*Cassia roemariana*), gray goldaster (*Heterotheca canescens*), horehound (*Marrabium vulgare*), evax (*Evax* spp.), buffalograss, *curlymesquite, Texas grama (Bouteloua rigidiseta), hairy tridens (Erioneuron* pilosum), red grama (*Bouteloua trifida*), tumblegrass (*Schedonnardus panniculatus*), windmillgrasses (*Chloris* spp.) and annual bromegrasses (*Bromus* spp.).

Woody species dominate the site in this community with Ashe juniper being the dominant. Shade tolerant species such as cedar sedge (*Carex planostachys*) and uniola species (*Uniol*a spp.) dominate the understory that is void of sunlight. The majority of the soil surface on this densely canopied site will have a thick mat of cedar leaves and other woody tree and shrub leaf material. The open areas between canopies will produce a grass cover of primarily low successional species such as gramas (*Bouteloua* spp.), three-awns (*Aristida* spp.), tridens (*Tridens* spp.), and dropseeds (*Sporobolus* spp.). The total grasslike production potential for this community is severely restricted.

A key difference  between plant community 1 and 4 is herbaceous forage production. Plant community 1 can produce up to 3900 lbs./acre of grass/grasslike plants in an above average year versus only 800 lbs./acre in plant community 4. It is significant that these same plants, the grass and grasslike species, are also the fine fuel that can potentially carry effective fires contributing to control of Ashe juniper.

Brush Management Practices

Brush management treatment alternatives commonly used in the Edwards Plateau MLRA include mechanical and chemical practices, as well as biological control associated with the use of goats. Selection of these treatments depends on the size and density of the woody plant species, primarily Ashe juniper. Some ranchers will remove oak species with brush management practices, but these are more likely shinoak species or oaks that are thinned within mottes, rather than mature oaks. Live oaks, Spanish oaks, post oaks, or other oak species are generally not considered in brush management scenarios, meaning that Ashe juniper is the target woody plant species a very high percentage of the time. Mechanical brush management treatments can be either broadcast when densities of plants are greater than 300 plants per acre or large enough to respond to treatments such as chaining or cabling, or individual plant treatments (IPT) when densities are low enough and/or plants are small enough to justify treating individual plants.

Chaining is usually accomplished by pulling a ships anchor chain between two crawler tractors, commonly D7 size or greater, depending on the size and density of the target species. The tractors are arranged in a “J” configuration, with one tractor moving slightly ahead of the other and the chain or cable being pulled in-between the tractors to make a swath width that is roughly equal to one-half the length of the chain. Commonly used chain lengths vary from 150-300 ft., giving a swath width of about 75-150 ft. Again, the length of chain and swath width would depend on the density and size of the juniper and the power of the tractors (Scifres 1980). Keeping the swath width at one-half the chain length allows the chain to be pulled from directly behind the tractor and reduces pull from the side that causes maintenance problems. Chaining or cabling work best when trees are large enough to provide significant resistance to the pull of the chain so that they can be uprooted rather than broken off or simply bent over and allowed to remain connected to the subterranean root structure. Mortality of the target species associated with chaining or cabling is usually in direct proportion to the stature of the trees and the degree of uprooting that is accomplished. Two-way chaining, covering the area twice in opposite directions, usually gives better control than one-way chaining (Welch 1985). Raking and stacking may be necessary to remove woody debris after chaining of heavy brush cover to allow maximum development and utilization of range forages and to minimize livestock handling problems. The degree of slope on the land must be considered as a hazard to use of equipment in the area, with slopes of 15% or greater limiting the application of these practices.

In areas of the MLRA where soils are deep, rootplowing is an option for removal of woody vegetation. Rootplowing is a nonselective treatment used to sever woody plants below ground. This practice is very energy intensive and costly, but results in a high degree of mortality of the target plant species. A rootplow is pulled behind a crawler tractor, normally of D7 or D8 size. The rootplow is a heavy steel V-shaped blade that is attached to shanks carried on a toolbar behind the tractor. The rootplow blade travels under and parallel to the soil surface cutting through all the subterranean root material of plants. Depth of the blade beneath the soil surface will vary, but in deep soils it may be 12-16 inches, depending on the density and size of the trees, soil texture, soil moisture and power of the tractor. Rootplowing causes a high level of soil disturbance and can destroy most perennial grasses. Thus, seeding is often necessary as a follow-up treatment. If rootplowed areas are not seeded, the majority of forage production for the first year or two may be from annuals and other plants low on the successional scale. The flush of forbs on rootplowed areas may dramatically improve wildlife forage until perennial grasses become dominant (Welch 1985).

Bulldozing has been used many years for clearing Edwards Plateau rangeland of unwanted woody plant species. When Ashe juniper is the target species, all plants attacked by bulldozing will suffer mortality if they are either uprooted or sheared off from their roots below the lowermost above ground green growth. Conversely, resprouting species, such as honey mesquite, will produce multiple new sprouts from buds in the stem base and root crown area of the plant (Welch 1991).The bulldozer can place the cleared trees in piles or windrows.

Since Ashe juniper is a non-sprouting species, this allows top removal practices to be effective for brush management and the most popular of these methods currently is the use of a “skid-steer loader” equipped with a front-end attachment of hydraulically operated sheers. The sheers are placed with the skid steer at the base of a target plant species and the shears are then closed hydraulically so that they cut entirely through the trunk of the tree. The hydraulic system on the skid steer can be used to place cut trees in piles or in windrows, or they can be left in place on the soil surface. Both bulldozing and sheering of Ashe juniper have been shown to produce enough soil disturbance to provide an adequate seedbed for seeding Mannel (2007.)

Another broadcast brush management practice that is infrequently used in the MLRA is roller chopping. Roller chopping is accomplished with a heavy drum-type roller with blades mounted on the surface of the drum parallel to the axis. The blades cut through woody plants as the roller chopper is pulled over them by a crawler tractor, commonly D6 to D8 size. The drums can be filled with water to increase their overall weight and the weight per unit of blade surface area contact with woody stems that results in greater cutting performance. Roller chopping has limited capability to cause mortality on woody species, since it is a simple top removal practice that leaves a high percentage of plant subterranean material in place and often does not remove all of the above ground plant material necessary to result in mortality of Ashe juniper. Roller chopper blades may penetrate the soil several inches deep, depending on soil texture and moisture and the size and weight of the chopper. Thus, soil disturbance may be significant, resulting in improved water infiltration. Seeded grass stands have been established on seedbeds prepared by offset, tandem roller choppers.

Hydraulic shredders, such as the “Hydro Axe” are also used for woody plant control and are effective on Ashe juniper if the cut by the shredder is below the lowermost green plant material. A Hydro-Axe shredder is mounted on the front of a large rubber-tired tractor and is powered by a hydraulic motor. The entire shredding unit can be raised and lowered to shred down large trees. While the shredders can take down larger trees, they are probably most economically efficient in brush with 3-6 inch stem diameters. With the exception of Ashe juniper as stated above, most undesirable plants will resprout vigorously following shredding. Like roller chopping, shredding may increase browse availability and quality by increasing the number of young, succulent sprouts. Prescribed fire can be used as a follow-up to roller chopping or shredding to suppress woody regrowth.

Individual plant treatment (IPT) mechanical practices include “lopping” with manual sheers that cut Ashe juniper plants near ground level and result in a high level of control. In recent years the use of “track hoes” or “excavators”, large self-propelled backhoes on tracks that have a reach of about 25 feet in 180 degrees, has become popular, especially in the western Edwards Plateau where redberry juniper, a sprouting species, requires extirpation below the bud zone (Wiedemann 2004). These large grubbers cover a 50 ft. Swath when moving in a straight line and can be used for other resprouting species, as well as for Ashe juniper if desired, particularly in areas where the size of trees or soils (primarily rockiness) may limit the use of smaller grubbing equipment. The bucket, equipped with rock-digging teeth, is very effective for removing junipers from rocky soil and stacking them. A U-shaped grubbing blade can be used in place of the bucket (Wiedemann 2004). Low-energy grubbing can also be used in some soils for juniper control. “Low–energy” grubbers are those that use hydraulic power in the grubbing unit to offset the need for tractor horsepower (Wiedemann 2004). Rotating cutter blades mounted on heavy duty “Weed Eaters” are also effective for quick removal of Ashe juniper up to 2 inches in stem diameter at ground level.

There are no currently recommended broadcast chemical treatments for Ashe juniper control. However, there are IPT practices that are recommended for use, including picloram (Tordon 22k), Hexazinone liquid (Velpar L) and Hexazinone pellets (Pronone Power Pellets). All of these treatments will give a very high level of Ashe juniper mortality if properly applied. Texas Cooperative Extension Bulletin 1466 (2007) provides explicit instructions for selection, mixing and application of herbicides.

Perhaps the most economically effective treatment alternative for Ashe juniper control is prescribed burning. Fire can be very effective for causing mortality of small Ashe juniper plants that are up to about 3 feet tall and even taller if the fine fuel load is adequate in amount and continuity to carry an effective fire. When small, Ashe juniper can be effectively controlled with cool season prescribed burns that limit risk compared to hot summer burns. Combination of prescribed burning with other practices, such as mechanical or chemical control is highly recommended to preserve the benefits of high cost initial practices by low-cost maintenance practices. An excellent discussion on the use of fire in juniper ecosystems can be found in Blair et al. (2004).

Biological control is accomplished in the MLRA via the use of goats. Angora goats are still significant in the area, but have declined in numbers over the past decade. Meat goats, including Spanish and Boer goats and crosses thereof, as well as other meat breeds, have increased in the area during this same time period. Overall, goats are still very much present and have an impact on woody plant competition with herbaceous species. For example, goats will utilize seedling cedar plants or young regrowth until the plants have reached a threshold when leaf material age diminishes use with the increased content of terpenoids (Taylor 2000). Goats also utilize oak sprouts and harvest buds, leaves and small twigs of trees up to a browse line of about 6 feet. Goats can be concentrated in high densities and rotated through pastures to help suppress woody plants. They can also be used following mechanical brush management practices to utilize woody plant regrowth when it is succulent and within reach. The Texas Agricultural Experiment Station at Sonora is experimenting with goats that will consume a higher percent of juniper in their diets in order to maximize biological control (Taylor 2004).

**Gulf Coast Prairies and Marshes**

General

All of Refugio and Calhoun Counties, most of Victoria County and a small portion of Goliad County that are contained within Region L are included within the Gulf Coast Prairies and Marshes MLRA. The USDA NRCS divides the MLRA into two components, the Gulf Coast Marshes (150B), covering approximately 500,000 acres, that are on a narrow strip of lowlands adjacent to the coast and the barrier islands (e.g., Padre Island) and which extend from Mexico to Louisiana, as well as the Gulf Coast Prairies (150A), about 9 million acres, that include the nearly flat plain extending 30 to 80 miles inland from the Gulf Marshes.

The Gulf Coast Marshes are a low, wet, marshy coastal area, commonly covered with saline water, and range from sea level to a few feet in elevation. The Gulf Coast Prairies are nearly level and virtually undissected plains having slow surface drainage and elevations from sea level to 250 feet.

Soils of the Gulf Coast Marshes are dark, poorly drained sandy loams and clays, and light neutral sands, typically showing little textural change with depth. The loamy and clayey soils are commonly saline and sodic. Prairie soils are dark, neutral to slightly acid clay loams and clays in the northeastern parts. Further south in the subhumid Coastal Bend, the soils are less acidic. A narrow band of light acid sands and darker loamy to clayey soils stretches along the coast. Inland from the dark clayey soils is a narrow belt of lighter acid fine sandy loam soils with gray to brown, and red mottled subsoils. Soils of the river bottomlands and broad deltaic plains are reddish brown to dark gray, slightly acid to calcareous, loamy to clayey alluvial.

The climate of MLRA is humid subtropical with mild winters. Canadian air masses that move southward across Texas and out over the Gulf in winter produce cool, cloudy, rainy weather. Precipitation is most often in the form of slow and gentle rains. Spring weather is variable though moderate overall. March is relatively dry while thunderstorm activities increase in April and May. Summer weather varies little by having abundant sunshine and drier than in the spring. Occasional slow-moving thunderstorms or other weather disturbances may dump excessive amounts of precipitation on the area. Fall has moderate temperatures. Fall experiences an increase of precipitation and frequently has periods of mild, dry, sunny weather. Heavy rain may occur early in fall in association with tropical disturbances, which moves westward from the gulf. Tropical storms are a threat to the area in the summer and fall but severe storms are rare.

The total annual precipitation ranges from 28 inches in the southwest part of the region to 44 inches in the eastern part of the region. On average, approximately 38 inches occur around Victoria. Approximately 65 percent of the rainfall falls between April and September which includes the growing season for most crops. In two years out of ten, the rainfall for April through September is less than twenty inches. Thunderstorms occur on about fifty days each year and most occur during the summer.

The Gulf Coast Marsh areas, being variously salty, support species of sedges (*Carex* and *Cyperus*), rushes (*Juncus*), bulrushes (*Scirpus*), several cordgrasses (*Spartina*), seashore saltgrass (*Distichlis spicata* var. *spicata*), common reed (*Phragmites australis*), marshmillet (*Zizaniopsis miliacea*), longtom (*Paspalum lividum*), seashore dropseed (*Sporobolus virginicus*), and knotroot bristlegrass (*Setaria geniculata*). Marshmillet and maidencane (*Panicum hemitomon*) are two of the most important grasses of the fresh-water marshes of the upper coast. Common aquatic forbs are pepperweeds (*Lepidium*), smartweeds (*Polygonum*), docks (*Rumex*), bushy seedbox (*Ludwigia alternifolia*), green parrotfeather (*Myriophyllum pinnatum*), pennyworts (*Hydrocotyle*), water lilies (*Nymphaea*), narrowleaf cattail (*Typha domingensis*), spiderworts (*Tradescantia*), and duckweeds (*Lemna*). Common halophytic herbs and shrubs on salty sands are spikesedges (*Eleocharis*), fimbries (*Fimbristylis*), glassworts (*Salicornia*), sea-rockets (*Cakile*), maritime saltwort (*Batis maritima*), morningglories (*Ipomoea*), and bushy sea-ox-eye (Jones 1982).

The low marshy areas provide excellent natural wildlife habitat for upland game and waterfowl. The higher elevations of the Gulf Coast Marshes are used for livestock and wildlife production. Ranch units are mostly in large landholdings. These marshes and barrier islands contain most of our National Seashore parks. Urban, industrial, and recreational developments have increased in recent years. Most land is not well suited for cultivation because of periodic flooding and saline soils. The Gulf Coast Prairies are used for crops, livestock grazing, wildlife production, and increasingly for urban and industrial centers. About one-third of the area is cultivated mostly for rice, sorghum, corn, and tame pastures. Bermudagrass and several introduced bluestems (*Dichanthium* and *Bothriochloa*) are common tame pasture grasses.

Ranches in both components of the MLRA are primarily cow-calf operations that use forage produced from rangeland and tame pasture. Zebu or crossbreeds having Zebu blood are the most widely adapted and used cattle. Recreation, hunting, and fishing provide excellent multiple-use opportunities in the Gulf Prairies and Marshes.

The original vegetation types of the Gulf Coast Prairies were tallgrass prairie and post oak savannah. However, trees and shrubs such as honey mesquite (*Prosopis glandulosa*), oaks (*Quercus*), and acacia (*Acacia*) have increased and thicketized in many places. Characteristic oak species are live oak (*Quercus virginiana*) and post oak (*Q. stellata*). Typical acacias are huisache (*Acacia smallii*) and blackbrush (*A. rigidula*). Bushy sea-ox-eye (*Borrichia frutescens*), a dwarf shrub, is also typical.

Principal climax grasses of the Gulf Coast Prairies are Gulf cordgrass (*Spartina spartinae*), big bluestem (*Andropogon gerardii* var. *gerardii*), little bluestem (*Schizachyrium scoparium*), indiangrass (*Sorghastrum nutans*), eastern gamagrass (*Tripsacum dactyloides*), gulf muhly (*Muhlenbergia capillaris*), tanglehead (*Heteropogon contortus*), and many species of Panicum and Paspalum. Common increasers and invaders are yankeeweed (*Eupatorium compositifolium*), broomsedge bluestem (*Andropogon virginicus*), smutgrass (*Sporobolus indicus*), western ragweed (*Ambrosia psilostachya*), tumblegrass (*Schedonnardus paniculatus*), threeawns (*Aristida*), and many annual forbs and grasses. Pricklypear (*Opuntia*) are common throughout the area. Characteristic forbs include asters (*Aster*), Indian paintbrush (*Castilleja indivisa*), poppy mallows (*Callirhoe*), phloxs (*Phlox*), bluebonnets (*Lupinus*), and evening primroses (*Oenothera*) (Jones 1982).

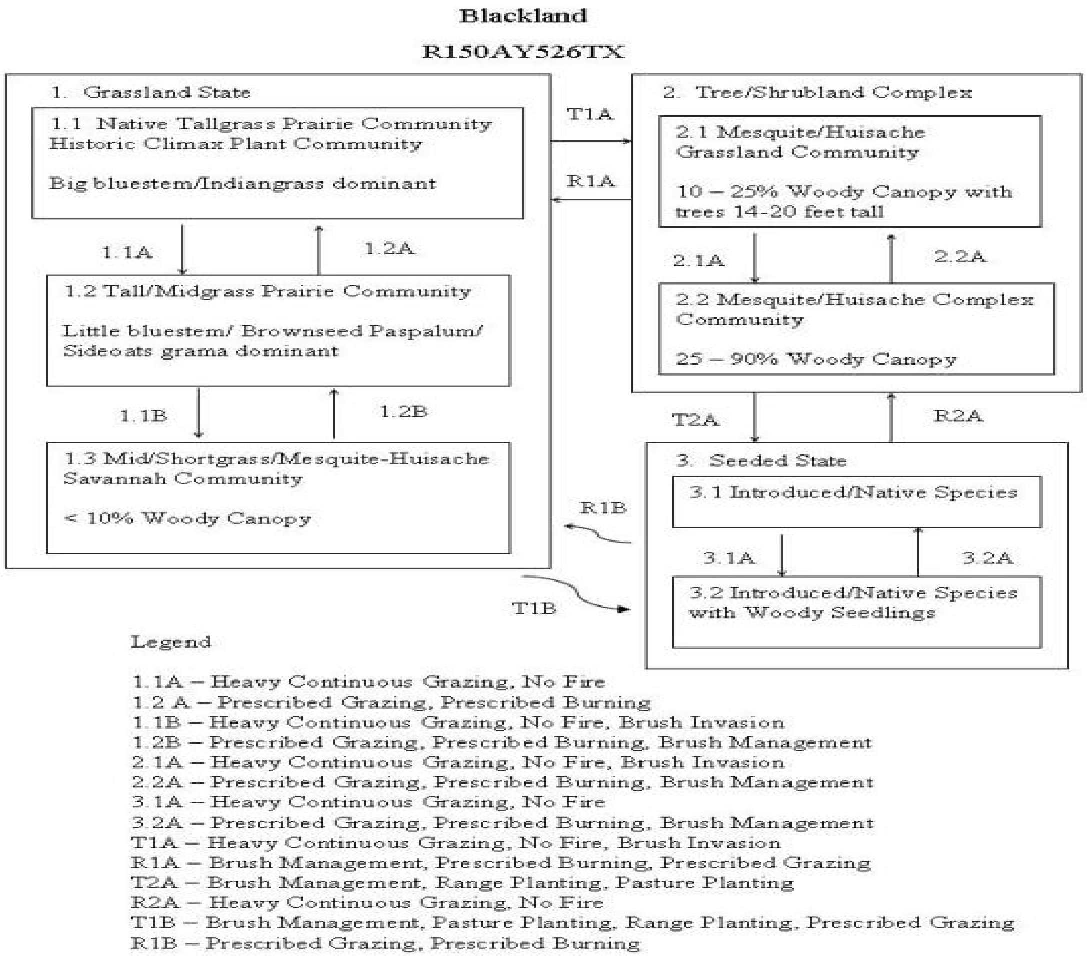
<u>Specific Reference to a Dominant Ecological Site</u>

Ecological Site Descriptions (ESD) developed by the Natural Resources Conservation Service provide a detailed means to view landscapes in the MLRA. For the purpose of this paper, a dominant ecological site in the Gulf Coast Prairies (150A) will be used to show the vegetation steady states and transitions that occur from the HCPC through the process of retrogression to those communities more commonly existing today. A Blackland ecological site is one of the most commonly occurring sites in the Gulf Coast Prairie component of the MLRA.The ESD for a Blackland site includes the state and transition model shown in Figure 2.

The Blackland site in MRLA 150A was formed by clayey fluviodeltaic sediments in the Beaumont Formation of Late Pleistocene age. These nearly level to very gently sloping soils are on the South Texas coastal plain. Slopes are mainly less than 1 percent but can range as high as 8 percent. Runoff is medium on 0 to 1 percent, high on 1 to 3 percent, and very high on slopes greater than 3 percent. Undisturbed areas exhibit gilgai microrelief. Elevation ranges from 15 to 200 feet.

The average relative humidity in mid afternoon is about 60 percent. Humidity is higher at night and the average at dawn is about 90 percent. The sun shines 70 percent of the time possible in summer and 50 percent in winter. The prevailing wind is from the south-southeast. Average windspeed is highest, about 12 miles per hour, in spring.

Figure 2. State and Transition Model for a Blackland Site, Gulf Coast Prairies and Marshes MLRA




The HCPC for the site is shown as plant community 1 (Grassland state). It was composed of tall and midgrasses and is the reference plant community for the site. Tallgrasses make up over 60% of annual production percent, midgrasses approximately 30 percent, and associated grasses, forbs, shrubs and woody vines make up the remainder. Bison grazing was intermittent and fires were both frequent (3 to 8 years) and intense. Annual forbs occur in greater or lesser amounts in response to grazing intensity, fire, drought, or excessive precipitation. This prairie site was extensively heavily grazed by large numbers of domestic livestock by the late 1800's. Overgrazing with no rest was exacerbated by the introduction of barbed wire fencing and water development. Overgrazing resulted in reduced production of biomass, reduced litter accumulation, loss of tallgrass and some midgrass species and reduction of fire frequency and intensity. Some mid and shortgrasses increased as a result of this overgrazing and eventually annual forbs and grasses replaced some perennials. Representative composition by different plant types and total annual production of the HCPC are provided in Table 3.

Table 3. Annual Production (lbs/ac) by Plant Type (HCPC)

| | Annual Production (lbs/ac) | | |
|---|---|---|---|
| Plant Type | Low | Representative Value | High |
| Forb | 325 | 400 | 475 |
| Grass/Grasslike | 5850 | 7200 | 8550 |
| Shrub/Vine | 325 | 400 | 475 |
| Tree | 0 | 0 | 0 |
| Total: | 6500 | 8000 | 9500 |

As a contrast and to show the influence of heavy invasion on the site from woody species, Table 4 provides plant types and production from plant community 2.2, Mesquite/Huisache Complex Community of the S/T model.

Over time, with continued heavy grazing, no fire, and no brush management, the Blackland Site may be transformed into a Mesquite-Huisache and Macartney rose Woodland community with canopies of 90 percent. The herbaceous community is greatly reduced and is dominated by low panicums and paspalums, Texas wintergrass, gaping panicum, bentgrass, sedges, and annual forbs and grasses.

Major cultural inputs, both chemical and mechanical, are often required and applied to restore this community to grassland or a savannah state. A common practice is the use of aerial applied herbicides to reduce the canopy, allow sunlight to penetrate to the soil surface, and grow enough herbaceous fuel loads for suitable burning. Aerial spraying is followed by the use of prescribed fire to remove some of the woody vegetation and maintain semi-open wooded grassland for several years following treatment. Although these practices kill some of the woody vegetation, much of it remains and re-sprouts from the crown and in a relatively short period of time will again attain a dominating woody plant canopy. Often with this community, mechanical means such as rootplowing and raking are utilized and the land is converted to cropland or tame pasture (see seeded state in S/T model Figure 2). A key difference between plant community 1 and 2.2 is herbaceous forage production. Plant community 1 can produce up to 8,500 lbs./acre of grass/grasslike plants in an above average year versus only 750 lbs./acre in plant community 2.2. This difference in production on the same site is the result of retrogression from the tall and midgrass community to the brush dominated state that is prevalent over much of the rangeland in the MLRA today.

Table 4. Annual Production (lbs/ac) by Plant Type (Community 2.2)

| Plant Type | Low | Annual Production (lbs/AC) Representative Value | High |
|---|---|---|---|
| Forb | 200 | 250 | 300 |
| Grass/Grasslike | 300 | 500 | 750 |
| Shrub/Vine | 400 | 450 | 550 |
| Tree | 500 | 650 | 975 |
| Total: | 1400 | 1850 | 2575 |

Distribution of woody vegetation follows the major soil types on the Coastal Prairie. Live oak savannahs are common in the southern and western portions. Live oak forms dense, almost pure stands on deep sands or is associated on the heavier soils with various *acacias*, such as huisache and with species such as spiny hackberry and lotebush. Post Oak and blackjack oak occur with live oak or in isolated communities in the northwest part of the Coastal Prairie. The post oak-blackjack oak vegetation type is characterized by moderate to dense stands of underbrush including many species characteristic of the Post Oak Savannah.

Honey mesquite occurs throughout the Coast Prairie but more sparsely than in other parts of the state except for the Pineywoods. Honey mesquite inhabits deep loams and clays in the eastern portion of the area (Refugio, Bee and Victoria Counties). It intermingles with post oak, blackjack oak, and live oak on lighter soils and with low-growing, xerophytic mixed brush characterized by *acacias* on the uplands.

In addition to honey mesquite, the most characteristic troublesome species of the Coastal Prairie are huisache and Macartney rose. These species combine to form unique communities in some areas, especially on the heavy, slowly permeable soils. Such communities are typical in Victoria County on Victoria and Lake Charles clays where brush control is practiced regularly. Huisache is distributed throughout the Coast Prairie. It may form dense, almost pure stands on lowland areas, and it thrives on the more mesic upland in association with species typical of mixed-brush communities. Macartney rose may occur with an overstory of honey mesquite and huisache but may dominate the vegetation on heavier soils.

Brush Management Practices

The western portion, or the more inland side of the Gulf Coast Prairies and Marshes MLRA, is joined by the South Texas Plains MLRA and shares the same reputation as being part of the "South Texas brush Country". Rangeland areas of both MLRA are often heavily invaded by a wide array of woody plant species that suppress herbaceous forage production, while at the same time providing a significant component of high quality habitat for income producing wildlife, primarily white-tailed deer and quail. Therefore, land managers commonly seek ways to modify brush stands to optimize a dual vegetation composition between herbaceous and woody plant species.

The Brush management treatment alternatives commonly used in the Gulf Coast Prairies and Marshes MLRA include mechanical and chemical practices and prescribed fire. When considered in combination with the South Texas Plains, no other MLRA in Texas have had greater implementation of brush management practices. The two most prevalent broadcast mechanical practices, chaining and rootplowing, were used early and frequently over vast acreages in the area beginning as early as the 1930's (Hamilton and Hanselka 2004). The mechanics of these practices are explained in the section of this paper for the Edwards Plateau MLRA. However, unlike the shallow, rocky soils that dominate the Edwards Plateau, the soils of the Gulf Coast Prairies are mostly deep and well suited to use of rootplowing. The practice is used for brush management; that is, to remove the resident woody plant composition and allow native herbaceous plant species to be restored, or, in other cases, rootplowed areas are seeded to promote more rapid response of grasses, commonly introduced species, such as buffelgrass (*Cenchrus ciliaris)*. There is a variety of degrees of treatment involved with rootplowing for brush management. Since the practice leaves the land very rough and with large amounts of debris from downed woody plants, it is often followed by raking to gather the debris, both from the surface and below ground in the plowed portion of the soil profile. The raking, usually followed by stacking and burning of brush piles, breaks up the massive clods left by the rootplow and smoothes the soil surface, greatly enhancing seedbed preparation and subsequent stands of seeded species. A still greater degree of land clearing that follows rootplowing involves raking in two directions, stacking and burning piles, additional cleanup, such as hand picking or the use of farm-type tractors to finally prepare the land for planting. At this point, the land can be changed from rangeland to pastureland use, denoting a perennial forage species that will receive some cultural inputs for maintenance, or even to cropland (annual crops) based on the management objective for land use.

Chaining was accomplished in the MLRA on many thousands of acres beginning in the 1930's and 40's, but like rootplowing, primarily with greatest emphasis in the post-World War II era when powerful crawler tractors became more readily available. The greatest value of chaining is the low initial cost of quickly knocking down, uprooting and thinning out moderate to dense stands of medium to large trees. Chaining alone generally offers only temporary benefits, particularly if the trees in the treated area are not large enough to allow uprooting. If a high percentage of the woody plants are not uprooted by the chain, regrowth from the species composing the brush complex in the region is extremely fast, quickly reducing the initial benefits of greater forage plant production. However, when used in combination with other methods, such as prescribed fire and/or chemical treatments, it may contribute to significant brush control for extended time periods. Chaining is also used in the region as the initial treatment in dense stands of very large plants to take down trees prior to rootplowing for brush control or land use conversion to pastureland or cropland. It should be noted that rootplowing and chaining, as well as other mechanical practices applied in the MLRA, are known to spread pricklypear

(*Opuntia* spp.). Any method that breaks the pricklypear plant into individual cladophylls (pads) and scatters the pads simply serves to transplant the species. Therefore, where pricklypear exists in the stand of brush to be treated mechanically, an additional treatment, such as a modified front-end stacker that can remove a high percentage of the pricklypear plants (Hamilton and Hanselka 2004), or an effective chemical treatment, such as the broadcast use of picloram (Tordon 22K®, may be necessary to prevent an increased density of the pricklypear.

Broadcast simple top removal practices, such as roller chopping or shredding, are also used in the MLRA, but the resprouting ability of the plants in the brush complex greatly limits the time that relief from woody plant competition can be expected. Studies have shown that several of the woody species in the area are capable of replacing 50% of more of their pretreatment height within the same growing season following spring top removal (Hamilton et al. 1981, Rasmussen et al. 1983). Bulldozing that cuts off woody plants and leaves the root system in place below ground is equally ineffective at causing plant mortality compared to roller chopping and shredding. Still, roller chopping and shredding are used to reduce the stature of brush, increase visibility, improve cattle working and increase forage production. Much the same as with broadcast herbicides, roller chopping and shredding can be done in patterns that optimize the benefits of the treatment for both increased forage production and wildlife habitat.

In addition to the standard or traditional-type roller chopper described in the section of this report for the Edwards Plateau, a unit known as an “aerator/renovator”, but that functions in brush as a roller chopper, is being used effectively in the Coastal Prairie and South Texas Plains. This recent advancement in roller choppers is the use of small blades welded to the heavy drums in a staggered, cylindrical pattern. The advantage of the aerators is that the small blades chop debris and form basins in the soil to capture and hold rainfall. In addition, the staggered, cylindrical blade pattern prevents the vibration caused by the longitudinal blade placement on a standard roller chopper. The blade design and positioning on the drums direct more of the total weight of the unit to the area of contact with woody plant material, thus improving the cutting effect. The aerators are usually two drums mounted on a frame similar to on offset disk, and are pulled by a crawler tractor or a specially-equipped rubber-tired tractor. The drum diameters measure from 18 to 42 inches and can be filled with water for increased weight. Aerators are used in moderate to dense shrub-infested rangeland or pastures to remove top growth of shrubs and to improve rainfall retention. Removal of top growth produces a flush of regrowth. This is desirable for browsing animals when used on palatable brush species in the region. When seeding is used in combination with chopping, the basins enhance seedbed preparation and seedling establishment (Weidemann 2004).

Heavy disks suitable for use on rangeland are another option for broadcast brush management given an appropriate soil and brush species for the equipment to work. Blade diameters for rangeland disks usually range from 24 to 36 inches and many are scalloped. Thirty-six inch disks are used for brush management, while the smaller disks are normally used for seedbed preparation. Disk units can range in width from 8 to 12 feet. Whitebrush and blackbrush acacia are species that have been successfully controlled with disking in the South Texas Plains and Gulf Coast Prairie. Several other species, including, Texas colubrina (*Colubrina texensis*), desert yaupon (*Schaefferia cunnefolia*), shrubby blue sage (*Salvia ballotiflora*) and small blackbrush (*Acacia rigidula*), are also susceptible to disking. Disking is especially suited to species that have relatively shallow and lateral roots, rather than tap-rooted plants, such as huisache and mesquite.

The high density of woody species that generally exist on rangeland in the MLRA makes broadcast treatments more economically efficient for initial treatments, rather than individual plant treatments (IPT). However, once brush densities have been reduced by broadcast treatments, IPT may be effective as a follow-up or maintenance practices. There are a variety of chemical IPT that can be used, as well as the practice of mechanically grubbing individual plants. Among the IPT mechanical practices, the low-energy grubbers are effective and economical depending on plant density of up to about 300 plants per acre. These grubbers have the capacity in the deep soils to remove all the below ground plant tissue that can potentially produce new sprouts.

The MLRA has a long history of the use of broadcast chemical brush management treatments. Prior to the late 1960's when picloram was labeled for use in Texas, 2,4-D and 2,4,5-T were the "standby" chemicals for broadcast weed and brush control in Texas. Of the two compounds, 2,4,5-T was superior for woody plant control. Dow Chemical Co. marketed a product, Tordon 225E®, a mixture of 2,4,5-T with picloram (Tordon 22k®) in a 1:1 ratio applied at 1.0 lb. per acre for brush control. This product was more effective for mesquite control and improved the spectrum of woody species that could be controlled in the south Texas mixed brush complex. Since this time there have been several new products introduced that are effective for individual species and mixed species composition. For example, Bulletin 1466 that provides guidance to herbicides for rangeland brush and weed control suggests the following application for south Texas mixed brush that includes blackbrush, catclaw acacia (*Acacia greggii*), guajillo (*Acacia berlandieri*), spiny hackberry (*Celtis pallida*), mesquite, pricklypear, retama (*Parkinsonia aculeata*), tasajillo (Opuntia leptocaulis) and twisted acacia (*Acacia Schaffneri*): a broadcast application of a mixture of 2 pints [.5 lb.active ingredient (a.i.)] picloram (Tordon 22k) + 1 pint (.5 lb.a.i.) triclopyr (Remedy®) applied aerially as a 4 gallon per acre oil-in-water emulsion (1 quart to 1 gallon diesel fuel oil and water to make 4 gallon per acre (1:5 oil to water ratio is optimum.). This application is expected to give an overall moderate level of mortality (36-55%) of the target species when applied under optimum conditions.

Certain herbicide compounds provide more optimum results for individual target plant species. For example, clopyralid (Reclaim®) applied broadcast alone or in combination with picloram or triclopyr will give a moderate to high (36-75%) mortality of honey mesquite. The soil applied herbicide tebuthiuron (Spike 20P®) provides a very high level (76-100%) of mortality on oak species. Several of the approved herbicides for broadleaf weed control will give very high levels of mortality.

Individual plant treatments with herbicides, either foliar applied or stem basal spray, offer moderate to very high levels of control of several problem species in the Gulf Coast

Prairie, including huisache, mesquite and pricklypear These woody species are included in the “Brush Busters” IPT method for brush control that is highly effective. Other species common to the area can be successfully controlled with herbicides shown in Bulletin 1466 with rates of applications, mixing instructions, timing of application and other information.

**South Texas Plains**

General

The South Texas Plains MLRA includes the largest portion of Region L. All or part of the following Region L Counties are in the MLRA; Uvalde, Zavala, Dimmitt, Medina, Frio, La Salle, Bexar, Atascosa, Wilson, Karnes, Goliad, DeWitt, and Gonzales. The area is the western extension of the Gulf Coast Plains merging with the Mexico Plains on the west. The area is a nearly level to rolling, slightly to moderately dissected plain. Scifres and Hamilton (1993) adapted Welch and Haferkamp (1987) to delineate four components within the area considered the South Texas Plains, the Northern Rio Grande Plains, Western Rio Grande Plains, Central Rio Grande Plains and Lower Rio Grande Valley. Other authors have divided the area into many more physiognomic regions and vegetation types (McMahan et al. 1984). Therefore, it is noted that much more detailed information related to soils and vegetation is available. For the purposes of this paper, the South Texas Plains MLRA will follow Hatch et al. (1990) which encompasses the area that lies roughly south of a line from San Antonio to Del Rio, Texas and continues until it joins the Gulf Coast Prairies and Marshes on the east and the Rio Grande River on the south and west.

Upland soils are of three groups: dark, clayey soils over firm clayey subsoils; grayish to reddish brown, loamy to sandy soils; and brown loamy soils. Gray, clayey, saline, and sodic soils are extensive on the coastal fringe, along with Galveston deep sands. Bottomlands are typically brown to gray, calcareous silt loams to clayey alluvial soils.

South Texas climate is recognized as unique, being the only east-coast subtropical steppe anywhere on earth, and a question exists among meteorologists as to why a semiarid climate lies where it should not, immediately downwind of the great moisture reservoir of the Gulf of Mexico (Trewartha 1968, Norwine and Bingham 1985).Mean annual precipitation ranges from near 36 inches in the eastern part of the area (DeWitt and Gonzales Counties) to 20 inches in the extreme western portion (Dimmitt County). The area is notoriously prone to great fluctuations in precipitation, ranging from extreme droughts to floods, primarily from Gulf disturbances in the late summer and fall. In a study by Norwine and Bingham (1985), “normal years”, those with precipitation between 90 and 110 percent of the long-term median rainfall, were observed only 30 percent of total years, while 36 percent of the years had rainfall less than normal and 34 percent had rainfall of more than 110 percent of the median.

The original vegetation was an open grassland or savannah-type along the coastal areas and brushy chaparral-grassland in the uplands (Johnston 1963). Originally, oaks and mesquite and other brushy species formed dense thickets only on the ridges, and oak, pecan, and ash were common along streams (Inglis 1964). Continued grazing and cessation of fires altered the vegetation to such a degree that the region is now commonly called the Texas Brush Country. Many woody species have increased, including mesquite, live oak, acacias, brazil (*Zizyphus obovata*), spiny hackberry (*Celtis Pallida*), whitebrush (*Aloysia gratissima*), lime pricklyash (*Zanthoxylum fagara*), Texas persimmon (*Diospyros texana*), shrubby blue sage (*Salvia ballotiflora*), and lotebush (*Zizyphus obtusifolia*).

Characteristic grasses of the sandy loam soils are seacoast bluestem (*Schizachyrium scoparium* var. *littorale*), bristlegrasses (*Setaria*), paspalums, windmillgrasses (*Chloris*), silver bluestem, big sandbur (*Cenchrus myosuroides*), and tanglehead. The dominants on the clay and clay loams are silver bluestem, Arizona cottontop (*Digitaria californica*), buffalograss, common curlymesquite (*Hilaria belangeri*), and species of *Setaria, Pappophorum, and Bouteloua*. Low saline areas are characterized by gulf cordgrass, seashore saltgrass, alkali sacaton (*Sporobolus airoides*), and switchgrass. Forbs include orange zexmania (*Zexmania hispida*), bush sunflowers (*Simsia*), velvet bundleflower (*Desmanthus velutinus*), tallowweeds (*Plantago*), lazy daisies (*Aphanostephyus*), Texas croton (*Croton texensis*), and western ragweed. Grasses of the oak savannahs are mainly little bluestem, Indiangrass, switchgrass, crinkleawn (*Trachypogon secundus*), and species of Paspalum. Pricklypear is characteristic throughout most of the area. Forbs generally associated with all but the most saline soils are bush sunflower, orange zexmania, shrubby oxalis (*Oxalis berlandieri*), white milkwort (*Polygala alba*), American snoutbean (*Rhynchosia americana*), and greenthread (*Thelesperma nuecense*).

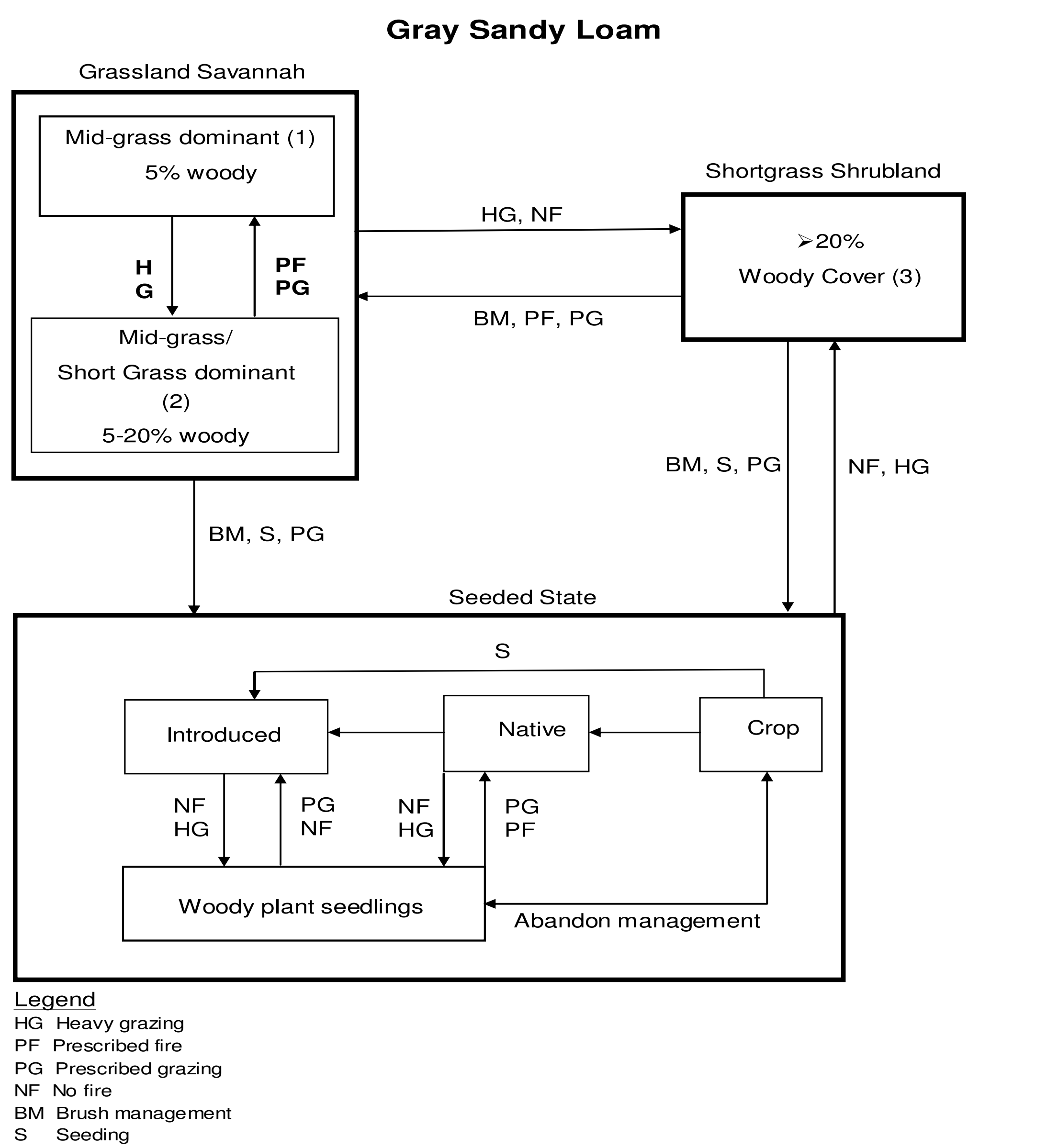
Because the South Texas Plains lie almost entirely below the hyperthermic line, introduced tropical species do well. The introduced species buffelgrass (*Cenchrus ciliaris*) has proliferated and is common on loamy to sandy soils in the western half of the area. Coastal bermudagrass, kleingrass (*Panicum coloratum*), and rhodesgrass (*Chloris gayana*) are also common introduced species in tame pastures.

Range is the major land use, but irrigated and dryland cropping of cotton, sorghum, flax, small grains, and forages are also important. Citrus, vegetables, and sugarcane do well in the Lower Rio Grande Valley. Many acres are in large landholdings, such as the King Ranch (825,000 acres). Livestock production is primarily cow-calf range operations, and wildlife production for hunting and recreational use are becoming increasingly important. The South Texas Plains vegetational area is known nationwide for its large white-tailed deer (*Odocolieus virginianus*). Quail (*Colinus virginiana*), mourning dove (*Zenaida macroura*), turkey (*Meleagris gallopavo*), feral pigs (*Sus scrofa*), and javelina (*Dicotyles tajacu*) are other major game species. Stocker operations and feedlot operations are intermixed with cow-calf operations. Sheep and goat enterprises, once common throughout the area, are now confined mostly to the northernmost part because of coyote predation. Integrated use of range, crops, and forages is increasing as is vegetable and peanut production where irrigation is possible.

Specific Reference to a Dominant Ecological Site

For the purpose of this paper, a proposed ecological site (submitted but not yet available in approved ESD on NRCS web site) in the South Texas Plains (83B) will be used to illustrate the vegetation steady states and transitions that occur from the HCPC through the process of retrogression to those communities more commonly existing today. A Gray Sandy Loam ecological site is a commonly occurring sites in the MLRA.The proposed ESD for a Gray Sandy Loam site includes the state and transition model shown in Figure 3.

Figure 3. State and Transition model (proposed), Gray Sandy Loam site, South Texas Plains PE 19-31.



The plant communities that can be found on this site range from a mid-grass dominant to a brush covered site with bare ground. This diversity in plant communities is in direct response to grazing management, fire, and drought.

The historic climax plant community (1) was composed of predominantly mid-grasses such as, trichloris (*Chloris spp*.), Plains bristlegrass (*Setaria macrostachya*), pink pappusgrass (*Pappophorum bicolor*), Arizona cottontop (*Digitaria californica*), silver bluestem (*Bothriochloa laguroides*), green sprangletop (*Leptochloa dubia*), sideoats grama and lovegrass tridens (*Tridens eragrostoides*). A small percentage of woodies such as guajillo, blackbrush, spiny hackberry, vine ephedra (*Ephedra antisyphilitica*), condalias (*Condalia* spp.) and many others were scattered across the landscape. Numerous perennial forbs occurred on the site including snoutbean, velvet bundleflower, sensitivebrier, bush sunflower, orange zexmenia, gaura, skeletonleaf goldeneye and numerous annual forbs. It was maintained by periodic grazing by roaming herds of wildlife, and numerous fires that were set by lightning and the native Americans. The site was productive, and maintained a high percentage of ground cover with forage production ranging from 1000 (low year) to 3400 (high year) pounds per acre (Table 5). Runoff of rainfall was medium, being in the hydrologic group B, with a hydrologic curve number of about 60. Soil fertility and available water-holding capacity are low to medium.

After settlement by European man, the area was fenced and in many instances stocked beyond its natural capacity with livestock. Fires were stopped by the reduction of fine fuel due to over grazing and the efforts of ranchers to extinguish wildfires to protect their investments in forage, livestock, facilities, and life. The combination of these activities coupled with periodic drought natural to the area, caused the plant community to change.

In the historic climax plant community, the mid-grasses dominated the short grasses due to their ability to capture sunlight and shade the shorter grasses. The mid-grasses also had deeper root systems that allowed them to capture the deep moisture while the short grasses had shorter root systems and could capture only the shallow moisture. Due to these differences, the mid-grasses maintained dominance over the short grasses as they could produce more food and maintain a higher state of health and vigor in times of drought. Fire occurred on a regular basis as there was normally good fine fuel. When fires started They could often burned for days, as there was nothing but rivers or denuded low producing ecological sites to stop them. These fires maintained the woody component to a small percentage of the total production, as well as canopy cover. Fires assisted in maintaining a good component of perennial forbs on the site by opening the ground cover to allow their establishment and regeneration and breaking the dormancy of the seeds.

As the stocking rates exceeded the carrying capacity of he land and the natural graze-rest cycles were broken by continuous grazing, the mid-grasses were grazed to the point that they could no longer produce the food in their leaves to maintain there health and vigor. When they were consistently grazed to the point where little leaf area was left, they stopped supplying the root system with food, as all available food produced was being used to grow more leaf area to enhance the food manufacturing process. If overgrazing persisted, root systems of the overgrazed plants continued to recede. In time, with continued close grazing, the mid-grasses would become more shallow rooted, weaker plants with small leaf area less able to survive the frequent droughts in the area. Long-term over utilization of the mid-grasses caused these species to decline and fostered spread of the short grasses on the site. These short grasses were fall witchgrass (*Panicum dichotomiflorum*), sand dropseed (*Sporobolus cryptandrus*), hooded windmillgrass (*Chloris cucullata*), curlymesquite (*Hilaria belangeri*), buffalograss (*Buchloe dactyloides*), perennial threeawn (*Aristida* spp.), and slim tridens (*Tridens muticus*). If heavy continuous grazing continued, common invaders were croton, ragweed (*Ambrosia* spp.), tumblegrass (*Schedonnardus paniculatus*), perennial broomweed (*Gutierrezia sarothrae*), grassbur (*Cenchrus incertus*), Texas bristlegrass (*Setaria texana*), and halls panicum (*Panicum hallii*).

As this reduction of mid-grasses and expansion of short grasses was occurring, fires were reduced as explained above. This allowed guajillo to dominate the site to form a dense canopy together with blackbrush, condalia, wolfberry (Lycium berlandieri), pricklypear, Texas persimmon (*Diospyros texana*), paloverde (*Parkinsonia texana*), ceniza (*Leucophyllum frutescens*) and coma (*Bumelia* spp). With their domination, these plants now captured the sunlight first and occupied the soil profile with root systems, therefore placing the short grasses and the remnants of mid-grasses in a sub-dominant position. At this point the area is represented by the Shrubland site (3) with a canopy of brush greater than 20 percent and often reaching between 60 percent to total closure. In the heavy brush cover, understory vegetation will range from a cover of short and mid grasses to bare ground. The Shrubland state is a new steady state that will exist until energy is applied to reduce the brush competition, increase the mid-and tallgrass species through proper grazing and a brush management maintenance program. The area may need to be seeded with a seed source of native seeds and a good grazing management program established to maintain the health and vigor of the forage component.

Plant community 1 in the S/T model (Table 5) represents the HCPC. It is a fire climax, midgrass plant community that has less than 5 percent canopy of woody plants. The grasses are trichloris, Arizona cottontop, Plains bristlegrass, pink pappusgrass, silver bluestem, green sprangletop, sideoats grama, lovegrass tridens, fall witchgrass, sand dropseed, hooded windmillgrass, curlymessquite, buffalograss, perennial threeawn, and slim tridens. The woody plants are blackbrush, spiny hackberry, vine ephedra, condalias, wolfberry, guajillo, guayacan, Texas persimmon, paloverde, cactus, desert yaupon, Texas kidneywood, allthorn, ceniza coma and mesquite. There are numerous forbs including snoutbean, velvet bundleflower, sensitivebrier, dalea bushsunflower, orange zexmenia gaura, skeletonleaf goldeneye and numerous annual forbs. Recurrent fire and grazing by bison and other wildlife were natural components of the ecosystem.

With settlement by European man came long-term overstocking the range with domestic animals. Naturally occuring fires no longer provided control of the woody plants as the fine fuel (primarily grasses) was reduced so that it would not carry a fire, or the fire was stopped by ranchers to protect their investment. The change of these two very important components of the ecosystem caused a dramatic change in the plant communities. The midgrasses gave way to the short grasses and the brush started to increase causing a shift to the Mid-grass/ Short Grass Dominant, 5-20 % canopy phase, plant community (2). This phase can be managed back to the Mid-grass Dominant, 5% woody phase through the use of prescribed grazing and prescribed fire. Once the woody canopy exceeds approximately 20 %, a threshold will have been passed to the Shrubland steady state. In this case, energy in the form of heavy equipment and/or herbicides will be required along with prescribed grazing to shift the plant community back to the Grassland Savannah steady state.

The Grassland Savannah steady state can be converted to the Seeded steady state by controlling the brush and seeding to native or introduced grasses. It may also be plowed and converted to cropland.

Table 5. Annual Production (lbs/ac) by Plant Type (HCPC)

| Plant Type | Low | Representative Value | High |
|---|---|---|---|
| Grass/Grasslike· | 750 | 2295 | 3060 |
| Forb | 100 | 128 | 170 |
| Shrub/Vine | 150 | 127 | 170 |
| Total | 1000 | 2550 | 3400 |

This phase of the Grassland Savannah steady state (community 2) still exhibits a savannah plant structure with the woody species canopy being as much as 20%. Guajillo is the major increaser brush species with blackbrush, condalia, wolfberry, pricklypear, Texas persimmon, paloverde, ceniza and coma. This is a result of fire being removed as a component of the site. Heavy continuous grazing takes many of the mid-grasses out of the site and they are replaced by short grasses such as hooded windmillgrass, sand dropseed, perennial threeawn, slim tridens, buffalograss, and curly mesquite. If heavy grazing continues, tumblegrass, grassbur, Texas bristlegrass, halls panicum, croton, and ragweed invade the site. This phase can still be managed back to the Midgrass Dominant, 5% woody phase if desired. It will take the introduction of fire to the ecosystem or some method of brush management that allows selective removal of the plants. A Prescribed Grazing plan will be essential to reverse the trend toward the short grass dominant community and increasing the midgrasses in the plant community.

Table 6. Annual Production (lbs/ac) by Plant Type (Community 2)

| Plant Type | Low | Representative Value | High |
|---|---|---|---|
| Grass/Grasslike | 360 | 1560 | 1850 |
| Forb | 100 | 200 | 300 |
| Shrub/Vine | 440 | 440 | 600 |
| Total | 900 | 2200 | 2750 |

If prolonged heavy grazing continues, and with the exclusion of fire, community 2 will transition to the Shortgrass Shrubland, >20% Woody Cover steady state. This plant community is a result of an irreversible transition from the Grassland Savannah to the Shrubland steady state. This threshold is passed when the woody canopy becomes such that insufficient fuel is produced to carry a fire that will control the woody canopy. The under story is very limited in production due to the competition for sunlight, water and nutrients. Guajillo dominates the site and forms a dense canopy together with blackbrush, condalia, wolfberry, pricklypear, Texas persimmon, paloverde, ceniza and coma. Invading forbs are croton, ragweed and perennial broomweed. Tumblegrass, grassbur, Texas bristlegrass and halls panicum invade the site. At this point there is very little under story production. There is much bare ground. Water infiltration is reduced on the site. Water infiltration does occur directly under some of the woody species such as mesquite as it moves down the trunk of the tree to the base. During the growing season, light showers are captured in the canopy of the shrubs and evaporate. Energy flow is predominantly through the shrubs and most nutrients are used by the shrubs. Winter rains can produce under story forage by the cool season annual forbs and grasses. Notice the decline in the high level of production of grass/grasslike from 3060 lbs/ac in community 1 to 1850 lbs/ac in community 2 and 300 lbs/ac in community 3. This represents a dramatic decrease in both forage resources and potential fuel load for prescribed fires.

Table 7. Annual Production (lbs/ac) by Plant Type (Community 3)

| Plant Type | Low | Representative Value | High |
|---|---|---|---|
| Grass/Grasslike | 50 | 200 | 300 |
| Forb | 50 | 200 | 300 |
| Shrub/Vine | 1200 | 1300 | 1400 |
| Total | 1300 | 1500 | 2000 |

<u>Brush Management Practices</u>

The South Texas Plains are the heart of the Texas "Brush Country", sharing that designation with the Gulf Coast Prairie, as previously noted. Brush stands in the area are often aggregates of 15 or more species, most characterized by thorns or spines and existing in three strata – overstory of trees, mid-story of shrubs and an understory of subshrubs and cacti. Frequently the cover is so heavy that only shade-tolerant herbaceous plants exist and the access to grazing animals is precluded.

The brush management practices described for the Gulf Coast Prairies earlier in this paper are similar for the South Texas Plains. Chaining and rootplowing where the most popular of the early mechanical practices utilized in the area and have been applied on hundreds of thousand of acres in the MLRA. While rootplowing may obtain near 100 percent mortality of the existing woody plant species on the treated area, the soil seed bank ensures that most species will eventually recover on the treated sites. However, there is a differential recovery rate by species, with some of the least desirable browse species, such as mesquite and twisted acacia recovering much more quickly than the better browse plants, such as spiny hackberry (Hamilton et al.1981). With proper grazing management, rootplowing is expected to provide an increase in forage production for as long as 15-20 years when used on heavily brush infested sites in the area. If follow-up maintenance practices, such as IPT chemical or mechanical are used, the increase in productivity of the site can be extend for many additional years.

Chaining was used primarily in the 1940' and 50's on the original stands of large mesquite infesting the area. Where the practice was applied on sandy or sandy loam soils (rather than heavy clay soils) and/or if soil moisture was optimum, large areas were essentially cleared of mesquite or other large trees in the same treatment area. However, as has been well documented, the shrubby species that were present at the time of chaining and that were not uprooted grew vigorously in the post-treatment are a following their release form the over story mesquite competition. Chaining and rootplowing are credited also with the spreading of pricklypear on many sites (Dodd 1968). Other mechanical practices, including roller chopping, shredding, disking, bulldozing and grubbing are all used in the region, both as broadcast treatments or as IPT when feasible based on brush size and densities. The resprouting nature of woody species in the area limits the effectiveness of the skid steer loaders and shears, however, some operators are using a "cut stump" herbicide application on the plants immediately following shearing. The herbicide application equipment is built into the machine so that the shearing and herbicide applications are done in a single operation.

Chemical brush management practices also have a long history of use in the MLRA and are similar to the Gulf Coast Praires previously described herein. Mesquite and pricklypear tend to be greater problems in the South Texas Plains, while huisache is reduced in significance compared to the Gulf Coast Prairies, especially in the more western counties, such as Zavala and Dimmitt.

## POST OAK SAVANNAH and BLACKLAND PRAIRIES

General

There are two additional MLRA that include portions of Counties within Region L. The Post Oak Savannah includes portions of DeWitt, Guadalupe and Caldwell Counties, as well as very minor portions of Victoria, Goliad, Gonzales and Wilson Counties. The

Blackland Prairies includes portions of Hayes, Comal, Bexar, Guadalupe, Caldwell, Gonzales and DeWitt Counties. Compared to the Edwards Plateau, Gulf Coast Prairies and Marshes and South Texas Plains, the land areas of the Post Oak Savannah and Blackland Prairies within Region L are very small and will be included together for this paper.

The Post Oak Savannah lies just to the west of the Pineywoods and mixes considerably with the Blackland Prairies area in the south. The Post Oak Savannah is a gently rolling, moderately dissected wooded plain.

Upland soils are gray, slightly acid sandy loams, commonly shallow over gray, mottled or red, firm clayey subsoils. They are generally droughty and have claypans at varying depths, restricting moisture percolation. The bottomland soils are reddish brown to dark gray, slightly acid to calcareous, loamy to clayey alluvial. Short oak trees occur in association with tallgrasses. Thicketization occurs in the absence of recurring fires or other methods of woody plant suppression. This distinctive pattern of predominantly post oak and blackjack oak (*Quercus marilandica*) in association with tallgrasses also characterizes the vegetation of the Cross Timbers and Prairies vegetational area. Associated trees are elms, junipers (*Juniperus*), hackberries (*Celtis*), and hickories (*Carya* spp.). Characteristic understory vegetation includes shrubs and vines such as yaupon (*Ilex vomitoria*), American beautyberry, coralberry (*Symphoricarpos orbiculatus*), greenbriar, and grapes.

Climax grasses are little bluestem, indiangrass, switchgrass (*Panicum virgatum*), silver bluestem (*Bothriochloa saccharoides*), Texas wintergrass (*Stipa leucotricha*), brownseed paspalum, purpletop, narrow leaf woodoats (*Chasmanthium sessiliflorum*), and beaked panicum (*Panicum anceps*). Lower successional species include brownseed paspalum, threeawn, broomsedge bluestem, splitbeard bluestem (*Andropogon ternarius*), rosette grasses, and lovegrasses (*Eragrostis*).

Forbs similar to the true prairie species are wild indigo, indigobush (*Amorpha fruticosa* var. *augustifolia*), senna, tickclover, lespedezas (*Lespedez* spp.), prairie clovers (*Petalostemon* spp.), western ragweed, crotons (*Croton* spp.), and sneezeweeds (*Helenium*).

The area is well suited to grain crops, cotton, vegetables, and fruit trees. It was extensively cropped through the 1940's, but many acres have since been returned to native vegetation or tame pastures. Pasturelands have frequently been seeded with introduced species such as bermudagrass, bahiagrass, weeping lovegrass (*Eragrostis curvula*), and clover.

Deer, quail, and squirrel are perhaps the most economically important wildlife species for hunting enterprises although many other small mammals and birds exist in the region. The major livestock enterprise is mixed cow-calf-yearling operations with many small herds on small landholdings. Livestock use either tame pastures, native pastures, or the woodland areas for forage throughout the year. Wheat, oats, and rye are often planted for winter pasture.

The Blackland Prairies area intermingles with the Post Oak Savannah in the southeast and has divisions known as the San Antonio and Fayette Prairies. This rolling and well-dissected prairie represents the southern extension of the true prairie that occurs from Texas to Canada.

The upland blacklands are dark, calcareous shrink-swell clayey soils, changing gradually with depth to light marls or chalks. Bottomland soils are generally reddish brown to dark gray, slightly acid to calcareous, loamy to clayey and alluvial. The soils are inherently productive and fertile, but many have lost productivity through erosion and continuous cropping.

This once-luxuriant tallgrass prairie was dominated by little bluestem, big bluestem, indiangrass, tall dropseed (*Sporobolus asper* var. *asper*), and Silveus dropseed (*S. silveanus*). Minor species such as sideoats grama (*Bouteloua curtipendula*), hairy grama (*B. hirsuta*), Mead's sedge (*Carex meadii*), Texas wintergrass, and buffalograss (*Buchloe dactyloides*) have increased with grazing pressure. Common forbs are asters (*Aster* spp.), prairie bluet (*Hedyotis nigricans* var. *nigricans*), prairie-clover, and late coneflower (*Rudbeckia serotina*). Common legumes include snoutbeans (*Rhynchosia* spp.) and vetch. Mesquite, huisache, oak, and elm are common invaders on poor-condition rangelands and on abandoned cropland. Oak, elm, cottonwood, and native pecan (*Carya*) are common along drainages.

About 98 percent of the Blackland Prairie was cultivated to produce cotton, sorghum, corn, wheat, and forages during the latter part of the 19th century and the first part of the 20th century. Since the 1950's, pasture and forage crops for the production of livestock have increased, and now only about 50 percent of the area is used as cropland. Tame pastures occupy more than 25 percent of the land area, and the rest is used as rangeland. Small remnants of native vegetation exist for grazing or for native hay production. Livestock production with both cow-calf and steer operations are the major livestock use. Winter cereals are used extensively for livestock grazing in conjunction with tame pasture forages. Potential is good for increased production of food and fiber crops as well as forages. Mourning dove and bobwhite quail on the uplands and squirrel along streams are the most important game species.

Specific Reference to an Ecological Site

A Claypan Prairie site is typical of the Blackland Prairie MLRA and will also be used to illustrate the Post Oak Savannah MLRA as well. This tallgrass prairie site evolved and was maintained by the grazing and herding effects of native large ungulates, by rodents and rabbits, and by insects as well as the occurrence of periodic fire. Extreme climatic fluctuations over time may also have been important in the maintenance of the historic plant community.

The soils of this site are deep, noncalcareous sandy loams and clay loams. The topsoil is underlain at rather shallow depths by dense, hard, clayey material which restricts air, water movement, and root growth. The soils take in water slowly, but can hold large amounts of water and plant nutrients. The soils of this site give up water grudgingly to growing plants. Plants may wilt even though the soil has comparatively high moisture content. Heavy surface crusts develop in the absence of good vegetative cover.

The first killing frost occurs about November 15th and the last killing frost about March 15th. The growing season is about 300 days. Site specific weather data should be used for land management decision making. For site specific weather conditions, obtain data from a weather station close to the site. Site specific weather data may be obtained at NRCS county offices or from the Internet at http://www.wcc.nrcs.usda.gov/water/wetlands.html.

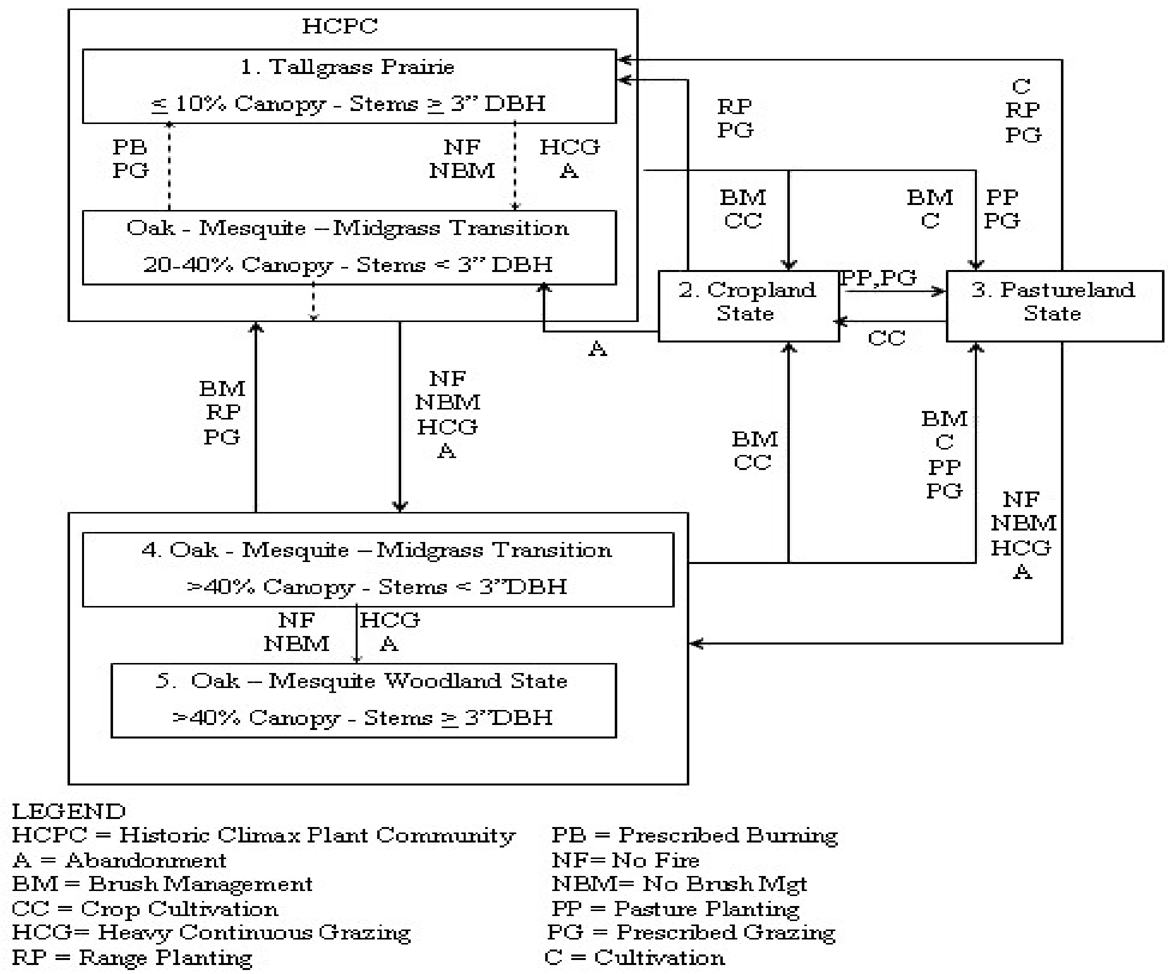
Table 8. Climatic data for a Claypan Prairie site, Blackland MLRA

| | Minimum | Maximum |
|---|---|---|
| Frost-free period (days): | 266 | 274 |
| Freeze-free period (days): | 298 | 302 |
| Mean annual precipitation (inches): | 34.0 | 42.0 |

Continuous overgrazing by confined livestock or wildlife and the suppression of fire degrades the historic climax plant community. Continuous grazing will remove big bluestem (*Andropogon gerardii*), Indiangrass (*Sorghastrum nutans*), little bluestem (*Schizachyrium scoparium*), switchgrass (*Panicum virgatum*), and preferred forbs such as Engelmanndaisy (*Engelmannia peristenia*), Illinois bundleflower (*Desmanthus illinoensis*), gayfeather (*Liatris* spp.), and compass plant (*Silphium* spp.). These plants will be replaced by less productive perennial and annual grasses and forbs including silver bluestem (*Bothriochloa laguroides*), windmillgrass (*Chloris* spp.), threeawns (*Aristida* spp.), croton (*Croton* spp.), annual broomweed (*Amphiachyris dracunculoides*), and snow on the prairie (*Euphorbia bicolor*). With continued overgrazing, no brush management, and the absence of fire, a community dominated by woody species including mesquite (*Prosopis glandulosa*), post oak (*Quercus stellata*), hackberry (*Celtis* spp.), winged elm (*Ulmus alata*), and Eastern red cedar (*Juniperus virginiana*) will replace the grassland.

The historic climax plant community (HCPC) of this site is a prairie or very open savannah. Live oak (Quercus virginiana), winged elm, or hackberry may occur along water courses or in scattered motts and provide 5 to 10 percent canopy cover. Large old post oak trees may be widely scattered over this site. The herbaceous plant community is dominated by little bluestem and Indiangrass which usually constitutes 50 to 65 percent of the total annual yield. Switchgrass, big bluestem, Florida paspalum (*Paspalum floridanum*), sideoats grama (*Bouteloua curtipendula*), silver bluestem, and tall dropseed (*Sporobolus compositus*) are important components of the warm season grass population. Virginia (*Elymus virginicus*) and Canada (*Elymus canadensis*) wildrye and Texas wintergrass (*Nassella leucotricha*) are components of the cool season grass population. Important forbs include Engelmanndaisy, gayfeather (*Liatris* spp.), bundleflower, prairie petunia (*Ruellia humilis*), and yellow neptunia (*Neptunia lutea*). Grazing prescriptions that permit acceptable grazing periods and allow adequate rest periods along with prescribed fire every three to five years are important in the maintenance of the historic climax plant community and the prairie landscape structure. Continuous overgrazing or over-rest and the absence of fire tend to favor a vegetative shift towards woody species such as mesquite, elm, hackberry, post oak, persimmon (*Diospyros virginiana*), and honey locust (*Gleditsia triacanthos*). Without corrective measures, this shift will continue to a mesquite-oak shrub dominated community.

Figure 4. State and Transition Model, Claypan Prairie Site, Blackland Prairie MLRA



As with other sites discussed previously, the S/T Model for the Claypan Prairie site indicates the dramatic decline in production of forage species as retrogression away from the HCPC occurs. To illustrate this for a site representative of the MLRA, the following annual production tables are provided. The first table (Table 9) shows at the high level of production 6050 lbs/ac, of which 4850 lbs/ac is from grass and grasslike plants. Most of this production is from tall and midgrasses..

Table 9. Annual Production (lbs/ac) by Plant Type (HCPC)

| | Annual Production (lbs/AC) | | |
|---|---|---|---|
| Plant Type | Low | Representative Value | High |
| Forb | 300 | 450 | 600 |
| Grass/Grasslike | 2425 | 3600 | 4850 |
| Shrub/Vine | 150 | 225 | 300 |
| Tree | 150 | 225 | 300 |
| Total: | 3025 | 4500 | 6050 |

Table 10 provides the annual production (lbs/ac) for the Oak-Mesquite-Midgrass transition state in the S/T model. This plant community is a transitional community between the prairie, pastureland, or cropland and the oak-mesquite woodland state. It develops in the absence of fire or mechanical or chemical brush management treatments. It is usually the result of abandonment following cropping or yearly continuous grazing. In addition to the naturally occurring winged elm, hackberry, bumelia (*Sideroxylon lanuginosum*), live oak, and post oak - mesquite and Eastern red cedar increase in density and canopy coverage (20 to 40 percent). In some cases, especially in abandoned cropland situations, mesquite may dominate the woody component of the community. Species whose seed is windblown (elm) or animal dispersed (mesquite, Eastern red cedar, bumelia) are the first to invade and dominate the site. Remnants of little bluestem and Indiangrass may still occur, but the herbaceous component of the community becomes dominated by lesser producing grasses and forbs. Silver bluestem (*Bothriochloa saccharoides*), windmill grass (*Chloris* spp.), white tridens (*Tridens albescens*), fall witchgrass (*Digitaria cognata*), threeawn (*Aristida* spp.), Texas wintergrass (*Nassella leucotricha*), Halls panicum (*Panicum hallii*), western ragweed (*Ambrosia psilostach*ya), croton (*Croton* spp.), annual broomweed (*Amphiachyris dracunculoides*), and snow on the prairie (*Euphorbia bicolor*) commonly occur.

If the woody shrub canopy has not exceeded 40 percent prescribed burning on a 3 to 5 year interval in conjunction with prescribed grazing is a viable option for returning this community to a tallgrass prairie that may resemble the historic clima x plant community. If the woody canopy has exceeded 40 percent (Oak-Mesquite-Midgrass transition state, community 4), chemical or mechanical brush control must be applied to move this transitional community back towards the historic plant community. Total production on the site has dropped from 6050 lbs/ac in the HCPC community to 4200 lbs/ac in the Oak-

Mesquite-Midgrass transitional community (4). Grass and grasslike species provide approximately 2400 lbs/ac, most of which is composed of mid and short grasses that are less desirable as forage plants than plant community 1.

Table 10. Annual Production (lbs/ac) by Plant Type (Plant Community 4)

| | Annual Production (lbs/AC) | | |
|---|---|---|---|
| Plant Type | Low | Representative Value | High |
| Forb | 300 | 450 | 600 |
| Grass/Grasslike | 1200 | 1800 | 2400 |
| Shrub/Vine | 450 | 675 | 900 |
| Tree | 150 | 225 | 300 |
| Total: | 2100 | 3150 | 4200 |

The final Community (5) used to contrast site production based on deviation from the HCPC steady state is the Oak-Mesquite-Woodland state (Table 11). This plant community is dominated by woody species including post oak, mesquite, hackberry, Eastern red cedar, honey locust, prickly ash, and bumelia. Canopy cover exceeds 40 percent. Understory shrubs and vines include coral berry, greenbriar (Smilax sp.), grape (Vitis sp.), prickly pear (Opuntia sp.), and baccharis (Baccharis halimifolia). Herbaceous composition and production is directly related to canopy cover. Texas wintergrass, purpletop tridens (Tridens flavus), silver bluestem, threeawn, sedges (Carex sp.), croton, and annual broomweed commonly occur. If the site is not abandoned cropland, chemical brush control along with prescribed grazing and prescribed burning is a viable treatment option for moving this community back towards the historic plant community. Mechanical brush control and seeding is usually the most viable treatment option when the objective is to return this state to a community that resembles the historic climax plant community. Production of forage species is dramatically reduced, with the shrubs, vines and trees making up over 55 percent of total site production at the high level. Grass and grasslike plants account for only 1200 lbs/ac at the high level of production. It is also significant that at the low level of production, indicative of frequent drought conditions, community 5 produces only about 600 lbs/ac of grass and grasslike plants.

Table 11. Annual Production (lbs/ac) by Plant Type (Plant Community 5)

| | Annual Production (lbs/AC) | | |
|---|---|---|---|
| Plant Type | Low | Representative Value | High |
| Forb | 150 | 225 | 300 |
| Grass/Grasslike | 600 | 900 | 1200 |
| Shrub/Vine | 500 | 750 | 1000 |
| Tree | 850 | 1275 | 1700 |
| Total: | 2100 | 3150 | 4200 |

## Brush Management Practices

When a Claypan Prairie site has retrogressed to plant communities 4 and 5, there is a thicketizing of woody vegetation that may include trees, such as post oak, elms, mesquite and hackberry, large enough to be effectively controlled with chaining. Soils on the site are deep and favorable in many areas for use of rootplowing. Bulldozing to push and uproot large trees is also a common practice. For woody species that are smaller than mature trees and where tree density is low (100-200 trees/ac), power grubbing is another mechanical treatment alternative. In low tree densities and where size is not limiting (stem diameters of <4 inches), low-energy grubbing is also a mechanical alternative. Understory vegetation including yaupon, coralberry, greenbrier and others will quickly expand in density following overstory removal. Simple top removal practices, such as shredding and roller chopping will give temporary relief from these shrub species, but should be followed with prescribed fire or IPT mechanical or chemical treatments to maintain brush control. For individual plants that occur in the woody plant composite and that are not resprouting species, sheering with a skid-steer loader would be an option. Eastern red cedar that occurs on the site is an example of a non-sprouting species that can be effectively controlled by sheering. The mechanical equipment discussed here has been described in detail in other sections of the paper.

Innovative IPT equipment, such as “El Tiburon”, the shark, has been developed to uproot woody plants with stem diameters up to 5 inches. This equipment operates on a 3-point hitch behind a rubber-tired tractor and “grabs” the tree trunk with two claw-type arms by closing hydraulic cylinders and then pulls the plant from the soil profile.

Chemical control on the site can be very effective for oak species. Broadcast chemical treatment with tebuthiuron (Spike 20P) at a rate of 10 lbs. of pellets (2 lbs. a.i.) will give a very high level of mortality of blackjack oak, post oak and winged elm. For other woody species, including hackberry, baccharis, elm, greenbrier, yaupon, Chinese tallow and pricklyash, chemical IPT provides a very high level of control (76-100% mortality). Eastern red cedar is effectively contolled chemically with IPT using picloram (Tordon 22K) or hexazinone (Velpar L® or Pronone Power Pellets®). Chemical control methods for huisache and mesquite will be the same as described earlier in this paper for these species. For example, clopyralid (Reclaim®) applied broadcast alone or in combination with picloram (Tordon 22k) or triclopyr (Remedy) will give a modenate to high (36-75%) mortality of honey mesquite. Huisache and retama do not respond as well to broadcast chemicals as mesquite, but can be controlled to a moderate level (36-55%) of mortality with several herbicide compounds, including combinations of picloram (Tordon 22k) and triclopyr (Remedy) or picloram and clopyralid (Reclaim). Huisache can also be controlled at the same level with boardcast applications of fluroxypyr and picloram (1:1) (Surmount) and picloram (Tordon 22k) alone. Both mesquite and huisache can be effectcively controlled (very high mortality 76-100%) with IPT chemical treatments applied as either stem basal, cut stump or foliage sprays.

## Potential to Augment Recharge and Streamflow Within Region L Through Shrub Control

In this section, we examine the scientific basis for using shrub control as a means of increasing groundwater recharge with an explicit focus on two of the landcover types within the Region L Planning area: (1) juniper woodlands within the Edwards Plateau Major Land Resource Area (MLAR) and (2) South Texas shrublands within the South Texas Plains MLRA—in particular those shrublands overlying the Carizzo-Wilcox recharge zone within Zavala and Dimmitt counties. We are focusing on these two areas because they offer the greatest opportunities for enhanced recharge through land management.

### General Overview-Shrub Control and Water

Despite the uncertainties that remain, we are confident of a number of things regarding the connection between woody plants and streamflow. We know, for example, that this connection becomes stronger as annual rainfall and/or available water increases. There is extensive literature showing that in forests, streamflow increases following a reduction in the number of trees (Bosch and Hewlett 1982, Stednick 1996, Zhang et al. 2001). For rangelands, however, relatively fewer studies have shown that streamflow and or recharge can be increased by reducing the cover of woody plants. In most but not all semiarid regions, the energy available for evaporation of water is sufficiently high that most of the comparatively low amount of precipitation is “lost” to evapotranspiration, regardless of the type of vegetation present.

Rangeland areas with the most potential for increasing recharge through shrub control are those areas where deep drainage (water movement beyond the herbaceous rooting zone) can occur (Seyfried et al. 2005, Wilcox et al. 2006). This characteristic is found, for example, where soils are shallow and overlie relatively permeable bedrock (such as karst limestones). An example in Texas is the Edwards Plateau area, which supports large tracts of juniper woodlands and has considerably more “flowing water” than would be expected for a semiarid or subhumid climate (ca. 700 mm/yr). The explanation lies in the karst geology—a substrate of fractured limestone that allows rapid flow of water to the subsurface. Other soil types that may enable deep drainage are sandy soils. Shrublands in region L that exhibit these characteristics are the juniper shrublands within the Edwards Plateau and the South Texas shrublands overlying the recharge zone of the Carrizo-Wilcox Aquifer. In this report, we summarize the available literature for both of these two areas.

**Part I: Ashe Juniper Woodlands of the Edwards Plateau**

The presence of springs is an excellent indication that subsurface flow exists in a region. On Texas rangelands, springs are most commonly associated with limestone or karst geology. Two important features of such sites—namely, shallow soils (which cannot store much water) and fractured parent material (which allows rapid, deep drainage of rainfall)—facilitate the presence of springs. Rangelands of this type, which in Texas mainly occupy the central part of the state, are typically dominated by Ashe juniper and live oak. There is a significant body of work examining how Ashe juniper affects the water cycle. We summarize these findings for the following spatial scales: (1) individual tree or small plot (the space occupied by a single tree); (2) hillslope or stand (large enough to encompass many trees, and thereby to manifest important hillslope processes such as overland flow, depression storage, and sediment deposition); (3) small catchment (large enough to incorporate channel and groundwater flow processes); and (4) landscape (encompasses watersheds of 20 $km^2$ or larger).

<u>Tree Scale</u>

Evergreen shrubs such as juniper have a large capacity for capturing precipitation, not only because they retain their leaves year round, but because they have a high leaf area per tree (Hicks and Dugas 1998). Owens *et al.* (2006) estimated that the canopy and litter layer of an Ashe juniper tree together intercept about 40% of the precipitation that falls on the tree annually. At the same time, the percentage varied dramatically depending on the size of the storm: close to 100% of the rainfall from small storms (<12 mm) was captured by interception, whereas a much smaller percentage (around 10%) was intercepted and evaporated during large storms. Transpiration from an Ashe juniper community should be greater than that from an herbaceous community because Ashe juniper transpires throughout the year, typically has a much greater community leaf area, and can access water at greater depths. Owens and Ansley (1997), on the basis of direct measurement of Ashe juniper transpiration rates, concluded that a mature Ashe juniper tree transpired as much as 150 l/d, which they estimated would be equivalent to 400 mm/yr.

In summary, dense stands of juniper intercept and transpire large quantities of water. In regions where juniper cover is extensive and dense, therefore, this species can have a major impact on the water cycle at the tree scale. However, because removal of juniper may result in increased growth and density of other vegetation, which would also transpire and intercept water, it is uncertain how much water would be “saved” by juniper removal. As discussed below, larger-scale studies are required to make such an assessment.

Stand Scale

At this scale, the primary measurements of evapotranspiration have been direct estimates made by means of micrometeorological technology. We know of only one such study for Ashe juniper communities: Dugas *et al.* (1998) measured evapotranspiration from an Ashe juniper community using the Bowen ratio/energy balance method. Two paired areas, each 200 x 600 m in size, were selected for measurement over a 5-year period. After the first 2 years, all Ashe juniper trees were removed from one of the areas by hand-cutting and burning. For the 2-year period following this treatment, the difference in evapotranspiration between the two areas was about 40 mm/yr; but this treatment effect disappeared in the third year of the study, after which evapotranspiration was similar in the treated and untreated areas. Some very recent work, also using micrometeorological technology, however estimates that evapotranspiration rates may be as much as 90 mm higher for woodlands than grasslands (James Heilman—personal communication)

Small Catchment Scale

Small catchments with springs. Over the past 150 years, many springs in Texas have dried up, perhaps owing to increased groundwater pumping (Brune 2002) and/or the spread of woody plant cover. There are many anecdotal accounts of springs drying following the encroachment of woody plants, and of spring flow returning after woody plant cover was removed or reduced. Increases in discharge from springs or spring-fed catchments following the removal of Ashe juniper have been documented in two studies. Wright (1996), working on a 3-ha catchment in the Seco Creek Watershed of central Texas, reported an increase in spring flow from 11.7 l/min during the 2-year pre-treatment period to 14.4 l/min following partial removal of Ashe juniper—this despite the fact that precipitation was lower in the post-treatment period. This increase in flow translates to about 40 mm/yr of additional water. Similarly, Huang et al. (2006) estimate that runoff from a small spring-fed catchment increased by about 45 mm/yr following removal of Ashe juniper from around 60% of the catchment.

Small catchments without springs. A few studies have examined the effect of juniper removal on small catchments where no springs were present. Richardson et al. (1979) compared runoff from two 3.7-ha catchments for an 11-year period. Juniper was removed from one of the catchments the fifth year, by root plowing. Surface runoff (presumably generated as Horton overland flow) was about 20% (13 mm/yr) lower following this treatment, but this was attributed to increased surface roughness that enhanced shallow surface storage. In another paired-catchment study (in the Seco Creek watershed), Dugas *et al*. (1998) found that when juniper cover was removed by hand-cutting, the treatment had little influence on surface runoff from these small (6- and 4-ha) catchments. Runoff accounted for about 5% of total precipitation and occurred only when precipitation intensity was high. Similarly, Wilcox *et al.* (2005) concluded that changes in density of Ashe juniper had little influence on streamflow from small catchments in the western portion of the Edwards Plateau.

Landscape Scale

For Ashe juniper rangelands, no large-scale experiments have been conducted. However, we may be able to infer information from analysis of historical streamflow.

Streamflow data going back to the early 1900s are available for many of the major rivers in Texas. These long-term data can provide insight into the nature and variability of streamflow and the relationship of streamflow to climate. In addition, such records may shed light on the sensitivity of streamflow to landscape-scale changes in vegetation cover. For example, we have good evidence that woody plant cover on the Edwards Plateau increased dramatically during the last century (Smeins et al. 1997). Therefore, if there is indeed a strong connection between streamflow and woody plant cover, we should be able to detect a decrease in streamflow that is independent of precipitation differences.

To date, only a few attempts at such analysis have been made for the Edwards Plateau. One of these studies, by the Lower Colorado River Authority, examined flow from 1939 to 2000 on one of the major rivers in the region, the Pedernales, which drains an area of over 2300 $km^2$ (LCRA 2000). The results showed no evidence of changes in streamflow that were independent of changes in climate during this period. If woody plant cover has increased in this basin, as it has throughout much of the Edwards Plateau (Smeins et al. 1997), then these results would indicate that at very large scales, rivers are relatively insensitive to changes in woody plant cover. Unfortunately, since there has been no detailed assessment of vegetation change in the Pedernales basin, we cannot definitively say to what extent woody plant cover has changed during the last 60 years—if it has changed at all.

**Part II: South Texas Shrublands**

Within the South Texas Shrublands MLRA, the areas with the most potential for enhanced groundwater recharge through vegetation management, would be those overlying sandy soils. Of particular importance would be those areas overlying the recharge zone of the Carrizo-Wilcox aquifer.

Field Studies

There have been relatively few investigations in the South Texas Plains that examine the influence of woody plants on recharge. We will review what literature is available and then relate it to work in other landscapes.

The only published study completed in South Texas is that by Weltz et al. (1995). This work was conducted at the La Copita Research Area in Jim Wells County. Dominant woody plants at this location are mesquite, brasil, spiny hackberry, and lime prickly ash. Soils on the site were within the Delfina fine sand loam-Miguel fine sandy loam soil complex. This study compared recharge rates on three vegetation type: bare, herbaceous cover, and woody plants. Recharge was estimated on the basis of soil water monitoring to a depth of 2 meters. Monitoring occurred for two years, but rainfall during one of those years was well below normal and no recharge occurred on any of the sites. During the other year, when rainfall was 887 mm recharge was 78, 22, and 0 on the bare, grass, and shrub plots respectively. On the basis of this study, we would conclude (1) that little to no recharge occurs if woody plants dominate (2) if woody plants are removed there will be some recharge that is equivalent to around 3% of rainfall and finally (3) recharge may be around 10% of rainfall in the complete absence of vegetation cover. This would perhaps be comparable to fallow dryland agriculture.

There have been no other studies conducted in South Texas but the results of this study are generally consistent with work conducted elsewhere in Texas (Wilcox 2002, Wilcox et al. 2006). Work on mesquite rangelands in the Rolling Plains of Texas suggests that annual recharge rates are 3 mm or less for mesquite covered areas and 5-10 mm if the mesquite are removed. In the absence of vegetation annual recharge was around 15 mm (Carlson et al. 1990). Mesquite removal had a much larger effect on deep recharge in the Blackland Prairie region of Texas and recharge in general was much higher(Richardson et al. 1979). This is because the soils in the Blackland Prairie will form deep cracks during dry periods which periodically provide opportunities for significant and deep recharge. In all of the studies mentioned above, recharge rates were determined by monitoring soil moisture. An alternative approach is that of using flux towers for determining evapotranspiration rates. A study of this type on mesquite rangelands of North Texas (Dugas and Mayeux 1991) concluded that recharge rates were little affected by mesquite removal.

The studies that have been completed in Texas are generally consistent with work in other semiarid locations which highlights the strong control that vegetation cover has on recharge (Sandvig and Phillips 2006, Scanlon et al. 2006). Almost without exception, recharge rates are low to zero under shrub canopies (Seyfried et al. 2005). Also, the complete removal of vegetation generally results in significant increases in recharge (Scanlon et al. 2005).

Hydrological Modeling

Hydrological models can provide insight concerning recharge dynamics. A comprehensive modeling exercise of recharge dynamics for the state of Texas has just been completed (Keese et al. 2005). This work highlights the strong influence of climate, soils and vegetation on recharge (Figure 5). Their simulations would suggest that for the Region L area, recharge would be less than 5-10 mm/year.

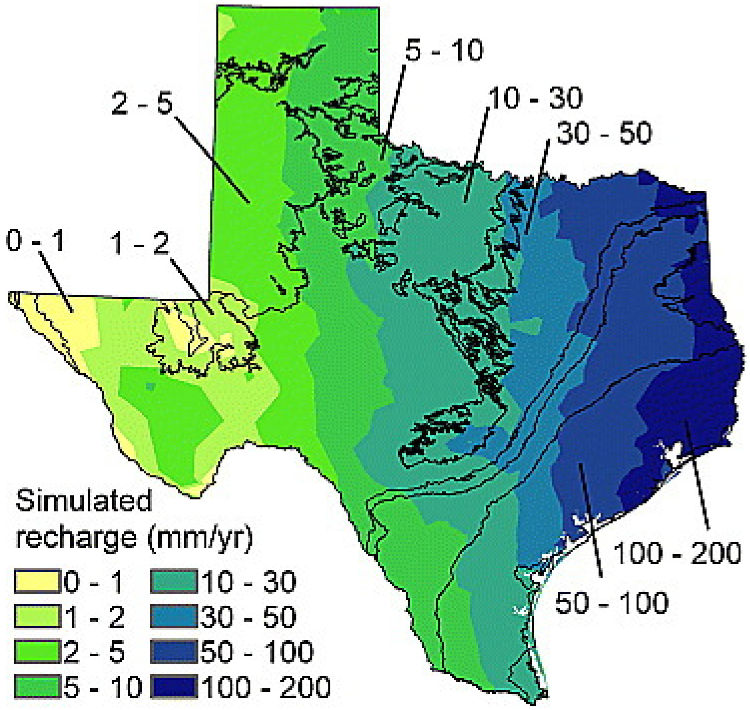


Figure 5. Simulated recharge rates for the state of Texas (Keese et al. 2005).

The influence of soil texture and vegetation on simulated recharge is summarized in Figure 6 below. Keese et al. (2005) found that the recharge rate declined by a factor of 2-30 times when vegetation was added to the model. These results would suggest that vegetation management on sandy soils can have a strong affect on recharge.

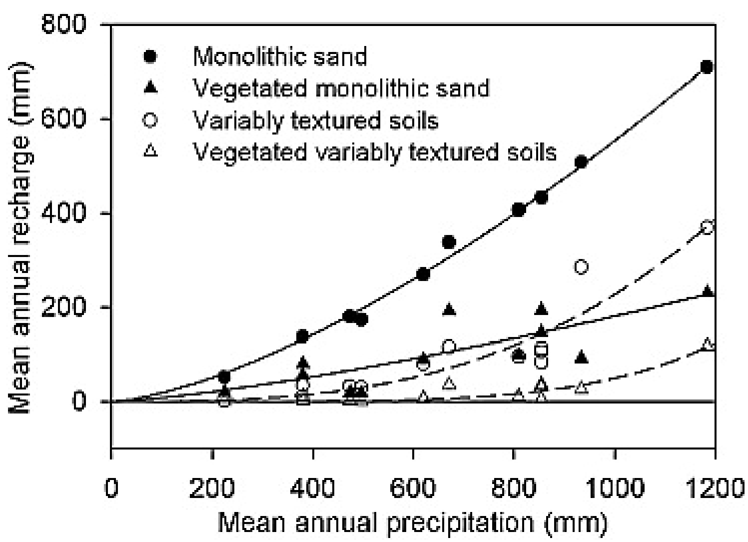


Figure 6. Results from the Keese et al. (2005) modeling study showing the relationship between simulated recharge, vegetation cover and soil texture.

**Summary and Implications**

Ashe Juniper Rangelands on the Edwards Plateau

The influence of Ashe juniper on the water budget remains the subject of some confusion and disagreement, in part because the implications of the scale at which measurements were made have not been fully considered. For example, at the tree scale, the most common measurement is some index of evapotranspiration by trees. After removal of trees, these numbers have often been extrapolated up without taking into account the compensatory effects of regrowth of trees or replacement by other vegetation. These measurements do not take into account water use by replacement vegetation, as the larger-scale studies do. For example, at the tree scale, for an area with an average annual precipitation of 750 mm/yr, an individual tree will intercept and transpire virtually all of the available water. At the stand scale, however, as estimated by Dugas *et al.* (1998), the difference in water consumption between a woodland and a grassland is between 40-50 mm/yr. Newer work suggests differences as high as 90 mm/year however. Water balance studies at the small-catchment scale (where springs exist) indicate water savings of around 50 mm/yr. (Huang et al. 2006).

From these results, we are increasingly confident that conversion of Ashe juniper woodlands to grasslands or more open savannas will translate to increases in spring flow and/or groundwater recharge at the small catchment scale. But it remains uncertain whether similar results will be seen at larger scales. At the landscape scale we have not found evidence of water savings due to changes in vegetation cover. The reason for this lack of evidence is not yet clear—whether (1) there has been no net change in woody plant cover; (2) there has been a change in woody plant cover but this has no influence on streamflow; or (3) there has been a change in woody plant cover and it has affected streamflow, but the signal cannot be detected because of too much "noise" in the data.

On the basis of the literature available, our current best estimate is that conversion of Ashe Juniper woodlands into open savannas would result in an average increase in water yield (streamflow and recharge) of around 50 mm/year.

South Texas Shrublands

On the basis of this review, we believe that recharge in the South Texas shrublands is very limited if shrub cover is dense. All of the available data strongly suggest that in the presence of dense shrub cover, there will be little if any recharge. However, both the modeling and field work suggest that in the absence of shrubs, recharge will be appreciably higher—especially for sandy soils. For example, Weltz et al (1995) found that when rainfall was slightly above average, recharge was around 20 mm/year for grass covered areas. The implications of this then are that shrub control over the recharge area would in the long term increase distributed recharge.

Our estimate that for the South Texas shrublands, average recharge on sandy soils could be increased by shrub control anywhere from 10 -20 mm/year. In the figure below, we make a rough calculation of the potential increase in recharge that may occur if shrubs were removed within the Carrizo Wilcox recharge zone. For example, distributed recharge would be around 5000 ac-ft / year if shrubs were cleared on 200,000 acres of rangeland if recharge rates were about 10 mm/ year.

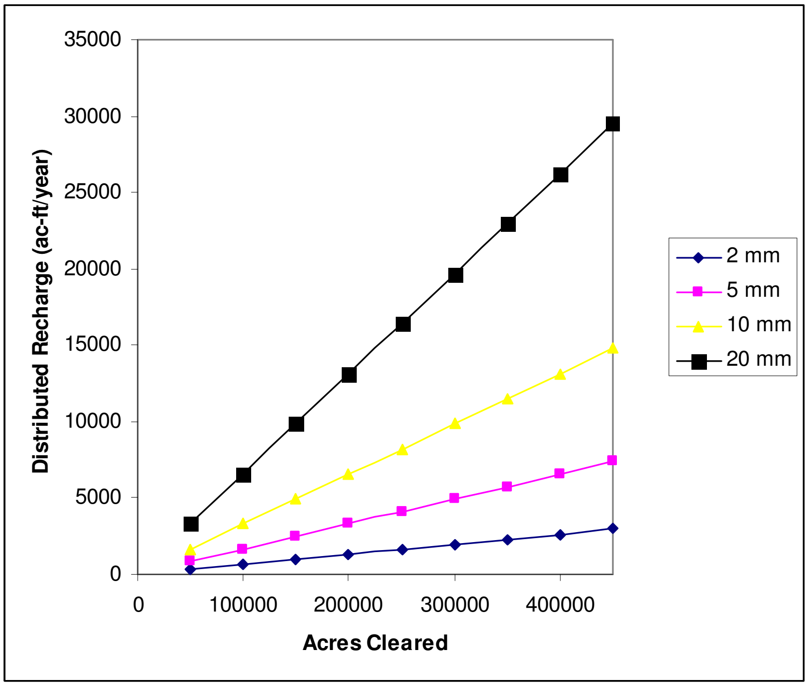



Figure 7. The potential increase in recharge from shrub control over the recharge zone in the Wintergarden Groundwater Area.

## Assessing the Cost Effectiveness of Brush Control to Enhance Off-site Water Yield

### Introduction

This section reports the assumptions and methods for estimating the cost effectiveness of a program to encourage rangeland owners to engage in brush control for purposes of enhancing groundwater recharge. Vegetative cover, applicable methods of brush control and the estimation of increased water yield from control of the dominate brush species are described in earlier sections of this report.

This section provides details on how the costs per acre foot (ac.ft.) of added water resulting from brush control were calculated for the different brush types-regions. The estimates of additional groundwater recharge resulting from the control of Ashe juniper in the areas of the Edwards Plateau which contribute to recharge of the Edwards Aquifer and estimates of additional groundwater recharge resulting from the control of mixed brush on sandy soils in the areas of Dimmit and Zavala counties which contribute to recharge of the Carrizo-Wilcox Aquifer are used along with brush control cost estimates from other studies to obtain estimates of per acre-foot costs of added water.

**Cost of Brush Control Methods**

Data on costs of various brush control practices for Texas have recently been obtained from an array of contractors, technical experts and agricultural technical service agency personnel in conjunction with another study being conducted by two of the authors of this report (Pestman, 2007). The data indicate that brush control costs are highly variable. Factors that influence cost and contribute to the high variability include the type, size and density of the target brush species; the type, rock content and slope of soil in which the target species is growing; whether the target species sprouts re-growth from root buds; whether cost effective herbicides are available for controlling the target species; etc.

Edwards Plateau

In a previous section, it was reported that any of several different mechanical practices were appropriate for use in the control of Ashe juniper. The costs of these various mechanical practices may vary from less than $100 to as much as $400 per acre (Pestman, 2007). Also in a previous section of this report the added ground water recharge estimated to result from control of Ashe juniper was reported to be 50mm/year. The inch equivalent of 50mm/yr. is 2 in. which is also equal to 0.167 ft. Therefore, control of Ashe juniper on an acre of land is estimated to result in 0.167 added ac.ft. of groundwater recharge per year.

Another consideration in estimating the cost of the added groundwater recharge is the duration of the impact of the brush control practice on the increase in the annual rate of groundwater recharge. For example, if the brush control program is limited to only the initial practice, then re-growth of the brush will occur, such that 5 to 10 years after the initial treatment, the brush canopy will approach its pre-treatment level and there will no longer be any increase in groundwater recharge. Alternatively, by using follow-up brush control practices after the initial treatment to control the brush re-growth, the increased groundwater recharge gained from the initial brush control practice can be maintained for many more years into the future.

Fortunately, the follow-up brush control practices, like prescribed fire or chemical or mechanical individual plant treatments, are relatively inexpensive compared to the cost of the initial treatments. Therefore, brush control programs consisting of an initial practice plus appropriate follow-up practices at 3-6 year intervals after the initial practice can result in maintaining brush canopy at low levels and also maintaining the resulting increases in ground water recharge for many years into the future.

The results of extending the years of reduced brush canopy, and the resulting increased groundwater recharge, on the cost per acre foot of added groundwater recharge are illustrated in Table 12. below. The cost estimates or obtained by taking the per acre cost of the brush control practice, or cost of a program consisting of an initial plus follow-up practices, and dividing it by 0.167. This results in the estimated cost per acre foot of added groundwater recharge resulting from brush control if the practice, or program, is effective for only one year. Results of this calculation for several alternative levels of brush control costs are shown in the second column of Table 12. Alternatively, the third and fourth columns illustrate the per acre foot costs of added groundwater recharge resulting from brush control if the brush control practice, or program, is effective for a period of five and ten years respectively.

Table 12. Cost/ac.ft. of added water for selected control costs and years of life of brush control practice – Edwards Plateau

| Brush control cost/ac | Years brush control effective 1yr | 5yr | 10yr |
|---|---|---|---|
| $ 70.00 | $ 419.16 | $ 83.83 | $ 41.92 |
| $ 150.00 | $ 898.20 | $ 179.64 | $ 89.82 |
| $ 200.00 | $1,197.60 | $ 239.52 | $ 119.76 |
| $ 300.00 | $1,796.41 | $ 359.78 | $ 179.64 |

South Texas Shrublands

In a previous section, it was stated that several herbicides and several different mechanical practices were appropriate for use in the control of mixed brush in South Texas. The costs of these various chemical practices are less variable and generally less costly than the mechanical practices in the Edwards Plateau as discussed above. In addition, the mechanical practices applicable to the control of mixed brush in South Texas would generally be less costly than when used in the Edwards plateau because the soils tend to be less rocky and the terrain is generally flatter in South Texas. Therefore, costs for mixed brush management in South Texas may vary from less than $50 to more than $100 per acre (Pestman, 2007). Also in a previous section of this report the added groundwater recharge estimated to result from control of mixed brush was reported to be between 10 and 20mm/year. To be conservative, we will use 10mm/year in the following analysis. The inch equivalent of 10mm/yr. is 0.4 in. which is also equal to 0.033 ft. Therefore, control of Ashe juniper on an acre of land is estimated to result in 0.033 added ac.ft. of groundwater recharge per year.

The need for follow-up practices to extend the effective life of initial control practices for mixed brush is as critical as it is for Ashe juniper control in the Edwards Plateau. The results of extending the years of reduced brush canopy, and the resulting increased groundwater recharge, on the cost per acre foot of added groundwater recharge is illustrated in Table 13. below. The cost estimates or obtained by taking the per acre cost of the brush control practice, or cost of a program consisting of an initial plus follow-up practices, and dividing it by 0.033. This results in the estimated cost per acre foot of added groundwater recharge resulting from brush control if the practice, or program, is effective for only one year. Results of this calculation for several alternative levels of brush control costs are shown in the second column in Table 13. Alternatively, the third and fourth columns illustrate the per acre foot costs of added groundwater recharge resulting from brush control if the brush control practice, or program, is effective for a period of five and ten years respectively.

Table 13. Cost/ac.ft. of added water for selected control costs and years of life of brush control practice – Carrizo - Wilcox

| Brush control cost/ac | Years brush control effective 1yr | 5yr | 10 yr |
|---|---|---|---|
| $ 35.00 | $1,060.61 | $ 212.12 | $ 106.06 |
| $ 50.00 | $1,515.15 | $ 303.03 | $ 151.52 |
| $ 75.00 | $2,272.73 | $ 454.55 | $ 227.27 |
| $ 100.00 | $3,030.30 | $ 606.06 | $ 303.03 |

Cost Effectiveness Summary

If brush control programs were implemented for the two regions described above, and if provisions of the programs require participating landowners to reduce brush canopies to 5 percent and maintain them at this level or less for 10 years, then the costs per acre foot of added ground water recharge would be expected to range between $40 and $180 per acre foot in the Edwards Plateau and between $100 and $300 per acre foot in The Carrizo – Wilcox Aquifer recharge area. It should be noted that these estimates of added groundwater recharge cost are based only on the highly variable costs of the brush control practices and/or programs. There are many other factors which would impact the ultimate costs, several of which are discussed in the next section.

**Additional Considerations**

It should be noted that public benefit in the form of additional water depend on landowner participation and proper implementation and maintenance of the appropriate brush control practices. It is also important to understand that landowner participation in a brush control program primarily depends on the landowner's expected economic consequences resulting from participation (Bach and Conner , 1998). With this in mind, the analyses described in this report are predicated on the objective of limiting rancher costs associated with participation in the program to no more than the benefits that would be expected to accrue to the landowner as a result of participation. Landowner benefits are usually based on expected increases in net returns from the typical livestock (cattle, sheep, or goats) and wildlife enterprises that would be reasonably expected to result from implementation of the brush control program (Conner and Bach, 2000). Previous studies based on these limits to landowner costs have shown that landowner’s share of brush control costs would vary from 37 to 8 percent of total direct costs of brush control programs (Olenick, et al., 2004a) .

It is explicitly assumed that the difference between the total cost of the brush control practices and the value of the practice to the participating landowner would have to be contributed by the state in order to encourage landowner participation. Thus, the state (public) must determine whether the benefits, in the form of additional water for public use, are equal to or greater than the state's share of the costs of the brush control program.

Success of each brush management scenario in improving groundwater recharge depends on the willingness of landowners to participate. One reason why landowners may be reluctant to participate is the perceived impacts to hunting enterprises, especially deer hunting. These impacts could include loss of wildlife habitat due to fragmentation, loss of thermal and/or escape cover, loss of wildlife diversity, and a potential loss of food sources (Rollins, 2000). Another reason that less than 100% of the brush will be enrolled is that many of the tracts containing brush will be so small that it will be infeasible to enroll them in the control program. Similarly, much of the brush infested land, particularly in the Edwards Plateau, will have more than 15% slope, and thus not practical for mechanical brush control practices due to safety considerations (Olenick, et al., 2004a).

Another reason why brush management programs may cause landowners to be reluctant to participate is the importance of brush to property values. The top motives for the purchase of the majority of landholdings throughout the state are recreation followed by the desire for rural homesites (Wilkins et al., 2000). Agriculture production, which generally benefits from decreased levels of brush, is not the driving force behind property purchases that it once was.

One cost not incorporated into the cost effectiveness calculations is the transaction costs associated with implementing any cost-share program. These include costs associated with contract development, monitoring, and any public hearings.

In order for brush control programs to work, the public must be willing to enroll their land in such a program. Landowner surveys conducted by the TAES (Narayanan, et al., 2002; Olenick , et al., 2005) indicate that landowners in the Edwards Plateau would include only 49.15 percent of their moderate cover and 52.73 percent of their heavy cover in a brush management program. An additional consideration is found in research work by Thurow, et. al. that indicated that only about 66% of ranchers surveyed were willing to enroll their land in a similarly characterized program.

Finally, some aspects of the expected changes in ecosystem health and services, including groundwater recharge, provided by brush control practices can be extremely difficult or impossible to economically quantify (Olenick, et al., 2004b). Improvements in ecosystem stability and resilience, changes in non-game animal composition and abundance, and alterations of carbon sequestration capacity, all important concepts from an ecological viewpoint, are not addressed in this analysis.

## Future Reports

Two additional reports on Land-based Water Conservation & Water Yield Practices in Region L will be produced if the Sponsor desires to continue this contract. Report II will contain a prioritized set of spatially explicit recommendations based on the information obtained and described in this report. Report II will include recommendations for the most cost effective land-based water conservation practices that could be implemented to enhance ground and/ or surface water availability.

Report III will include recommended monitoring protocols that, if used with the implemented conservation practices to be delineated in Report II, would provide effective measures of the effectiveness of each practice implemented. The recommendations would be consistent with Texas Water Development Board protocols.

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# Restoring Native Texas Rangelands for Increased Water Yield: Executive Summary

Canyon Lake. Photo credit: Edward Jackson ©2008

Performance of water catchments and the land-based water cycle is heavily influenced by vegetation and the management of that vegetation. Vegetation in south central Texas has undergone significant change over time, shifting from a grassland-dominated savanna to a heavily wooded landscape. This is due to the invasion of Ashe juniper (sometimes called "cedar") in the Edwards Plateau and mesquite in the South Texas Plains. This transformation to woodland may have reduced water available for recharge and streamflow. Woody plant invasion can be reversed through rangeland restoration. Initial costs, however, are generally more than a landowner can justify when considering livestock production alone.

Under certain circumstances, additional water yield results from rangeland restoration. As is suggested by several studies, there may be opportunities for creating incentive-based programs that lead to additional water yield through rangeland restoration.

Photo credit: Zereshk ©2008

Texas Hill Country, just north of Garner State Park.

**With sponsorship from the Texas Wildlife Association Foundation, a team of Texas A&M University scientists have conducted a technical evaluation of land-based water conservation practices and their potential for water yield in south central Texas. The purpose of this evaluation was to determine the feasibility of rangeland restoration for increasing water yield. This team identified areas in south central Texas suitable for rangeland restoration programs. This report is a summary of their findings.**

TEXAS A&M | Institute of Renewable Natural Resources

**A summary of a technical report by:**
Richard Conner
Wayne Hamilton
Brad Wilcox

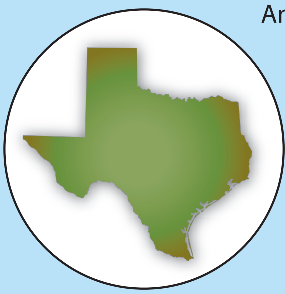
**With input from:**
Neal Wilkins
David K. Langford
Todd Snelgrove

TWAF

## Background

The South Central Texas Regional Water Planning Group, also known as Region L, is one of 16 regional water planning groups across the state. These groups identify water needs, assess potential water supplies, and recommend strategies for meeting those needs for the Texas Water Development Board. It includes over 20 counties and the seventh largest city in the United States—San Antonio. The population of this area was about 2.0 million in 2000 and is projected to grow to about 4.3 million by 2060. Obviously, securing adequate supplies of fresh water for Region L is a mounting concern. Total water use (municipal, industrial, and agricultural uses) in the region was approximately 896,000-acre feet/year (an acre-foot is about 325,000 gallons) in 2000 and is projected to increase by 43 percent to 1.28 million acre-feet/year by 2060 (SCTRWPG 2006). Nearly 80 percent of the region's fresh water is obtained from underground aquifers—primarily the Edwards and the Carrizo-Wilcox. Due to the high demand placed on these aquifers, the amount of water withdrawn exceeds recharge. Thus the need to increase water available for recharge and streamflow is essential.

### LAND STEWARDSHIP LANGUAGE IN THE TEXAS CODE



Anyone seeking to officially fund and implement land stewardship programs can now find authorization in our state law. Senate Bill 3 of the 2007 Session of the Texas Legislature amended Article 2, Section 2.02, Subchapter A, Chapter 1 of the Texas Water Code by adding Section 1.004. In this section, our leaders note the benefits of voluntary land stewardship and define the term. It reads:

**Sec. 1.004. FINDINGS AND POLICY REGARDING LAND STEWARDSHIP.**

**(a)** *The legislature finds that voluntary land stewardship enhances the efficiency and effectiveness of this state's watersheds by helping to increase surface water and groundwater supplies, resulting in a benefit to the natural resources of this state and to the general public. It is therefore the policy of this state to encourage voluntary land stewardship as a significant water management tool.*

**(b)** *"Land stewardship," as used in this code, is the voluntary practice of managing land to conserve or enhance suitable landscapes and the ecosystem values of the land. Land stewardship includes land and habitat management, wildlife conservation, and watershed protection. Land stewardship practices include runoff reduction, prescribed burning, managed grazing, brush management, erosion management, reseeding with native plant species, riparian management and restoration, and spring and creek-bank protection, all of which benefit the water resources of this state.*

With this language, the Texas Legislature officially recognized voluntary land stewardship practices as a means to improve water quality and quantity, opening the door for the development of effective land conservation/management programs designed to benefit water resources.

## Influence of Woody Species on the Water Cycle

The two major natural areas of Region L are the Edwards Plateau and the South Texas Plains. Prior to European settlement in the 1800s, the Edwards Plateau and South Texas Plains were dominated by grassland. In the absence of fire and the presence of overgrazing, Ashe juniper has invaded large areas of the Edwards Plateau, and mesquite and mixed brush have overtaken much of the South Texas Plains. There is some evidence that rangelands dominated by these woody shrubs and trees may not yield as much water as rangelands dominated by grasses and herbaceous vegetation. A significant amount of research has been performed that addresses this issue at several scales.

**EDWARDS PLATEAU**—Research within the Edwards Plateau has focused on the water use of Ashe juniper at the individual tree level. A single, mature juniper tree can transpire approximately 33 gallons per day (Owens and Ansley 1997). In addition, as much as 40% of the precipitation that falls on a juniper tree is intercepted by the canopy and lost to evaporation (Owens et al. 2006). As a consequence, in an area that receives approximately 29.5 inches of annual rainfall, a mature juniper tree will intercept and transpire nearly all of the available water falling within its canopy.

### How much water yield?

An additional acre-foot can be gained for every 5 to 8 acres of brush converted to native rangeland in the Edwards Plateau and for every 15 to 30 acres converted in the South Texas Plains.

Based on this, available water can be negatively impacted in regions where extensive juniper cover exists. However, this does not take into account the difference in water usage between juniper and the grasses and other vegetation that would replace it when restored.

Studies conducted at the stand scale have compared the differences in water usage between rangeland grasses and Ashe juniper. These studies show that in areas cleared of juniper, evapotranspiration rates (water lost to the atmosphere through evaporation and use by plants) were 1.6 inches/acre/year less than areas with intact juniper (Dugas et al. 1998).

Balcones Escarpment.

There are several anecdotal accounts of springs drying following encroachment by juniper. Studies at the small catchment scale that focus on catchments with springs have shown increases in spring discharge following the removal of juniper. In some instances this occurred even when precipitation was below average following juniper removal. These studies estimate that 1.6 to 1.8 inches/acre/year of additional water were made available after restoration of rangelands (Wright 1996, Huang et al. 2006).

Although there have been no large-scale experiments conducted that look at the landscape-scale impacts of juniper encroachment on streamflow, confidence is increasing that restoring rangelands on the Edwards Plateau will increase streamflow and recharge at the small catchment scale.

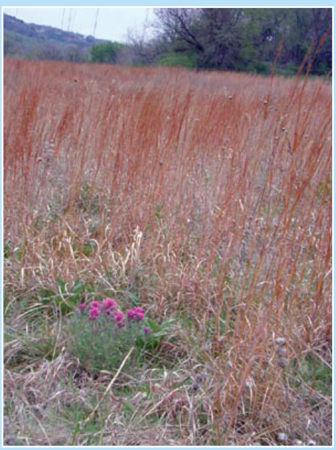

***Based on current research, the best estimate is that converting 5 to 8 acres of juniper to rangeland would result in an approximate increase in recharge and streamflow of 1 acre-foot of water per year.***

**SOUTH TEXAS PLAINS—** Compared to the Edwards Plateau, there has been little effort to study the influence of woody plants on recharge in the South Texas Plains. In studies that have been conducted, there has been evidence that rangeland restoration increases recharge. One field study indicated that there was no recharge on plots with dense shrub cover and 0.9 inches/acre/year of recharge on plots with grass cover (Weltz and Blackburn 1995). On the basis of this study, it can be concluded that recharge is limited on sites dominated by brush and that recharge can be increased if dense shrub cover is converted to grassland. Studies in other regions of Texas dominated by brush have yielded similar results.

Recent work using hydrologic modeling focuses on the strong influence of climate, soils, and vegetation on recharge in Texas. Based on these simulations, it is estimated that recharge for the South Texas Plains is less than 0.2 to 0.4 inches/acre/year (Keese et al. 2005). Further investigation shows that the recharge rate declined by a factor of 2 to 30 times when vegetative cover was included in the model rather than focusing solely on climate and soil texture (Keese et al. 2005). This suggests that rangeland restoration on sandy soils where water has a chance to make it past the root zone may have a strong effect on recharge in the South Texas Plains.

All of the available research in the South Texas Plains suggests that little, if any, recharge occurs in the presence of dense shrub cover. However, both hydrologic modeling and fieldwork suggest that when rangeland grasses are restored, recharge will be higher—especially on sandy soils. ***On the basis of current research, best estimates are that 15 to 30 acres of south central Texas brushland restored to rangeland would yield 1 acre-foot of water per year.***

## RANGELAND RESTORATION



Rangelands comprise 60 percent (90 million acres) of Texas land. In addition to supporting livestock production and providing habitat for native wildlife, they serve as the state's largest watershed.

The precipitation that falls on Texas rangeland is a major source of surface flow and aquifer recharge. The management of rangelands can have major impacts on the water available to Texas. Healthy rangelands provide high-quality drinking water, promote recharge, conserve soil, filter overland flow of water, provide forage for livestock, and provide wildlife habitat (Hays et al. 1998). Over the last century, encroachment of woody species across much of Texas' rangelands has degraded many of these services.

Rangeland restoration programs strive to reverse this trend. Through the use of sound management practices, woody species on Texas rangelands can be controlled, and rangelands can be restored.

There are many benefits to rangeland restoration including increased forage for livestock production. This allows the opportunity to increase stocking rates and ultimately increase revenue for landowners. Rangeland restoration can enhance wildlife habitat, thus enhancing hunting opportunities—a major source of income for Texas landowners.

Healthy rangelands provide a tremendous public benefit to Texans. Wise stewardship of this resource will have positive impacts on Texas for many generations—the greatest of which is a plentiful and clean supply of fresh water.

*Saving the water and the soil must start where the first raindrop falls.*
*—Lyndon B. Johnson, 1947*

## Rangeland Restoration Techniques and Brush Management

The vast differences in terrain and vegetation between the Edwards Plateau and South Texas Plains require different approaches to rangeland restoration and brush management. Costs for both regions are highly variable based on a number of factors including size and density of the target brush species; the type, rock content, and slope of soil in which the target species is growing; whether the target species sprouts re-growth from root buds; and whether cost-effective herbicides are available for controlling the target species.

**EDWARDS PLATEAU**—Within the Edwards Plateau, Ashe juniper is the primary species targeted for brush management and subsequent restoration of rangelands. Ashe juniper is a non-sprouting species; i.e., juniper will die when all of the aboveground green material is removed. There are three primary methods used for controlling Ashe juniper—mechanical, prescribed fire, and biological. There are limited chemical treatments for the control of Ashe juniper.

Mechanical treatments involve the use of large equipment such as a bulldozer or skid steer loader that physically removes the aboveground portion of the juniper. Costs are variable, but based on current market

### $ How much does it cost?

Assuming rangeland restoration practices are effective for at least 10 years, the cost to produce an additional acre-foot of water in the Edwards Plateau would be \$40 to \$180 depending on the method. Likewise, over the Carrizo-Wilcox Aquifer in south central Texas, the range is \$100 to \$300 per additional acre-foot.

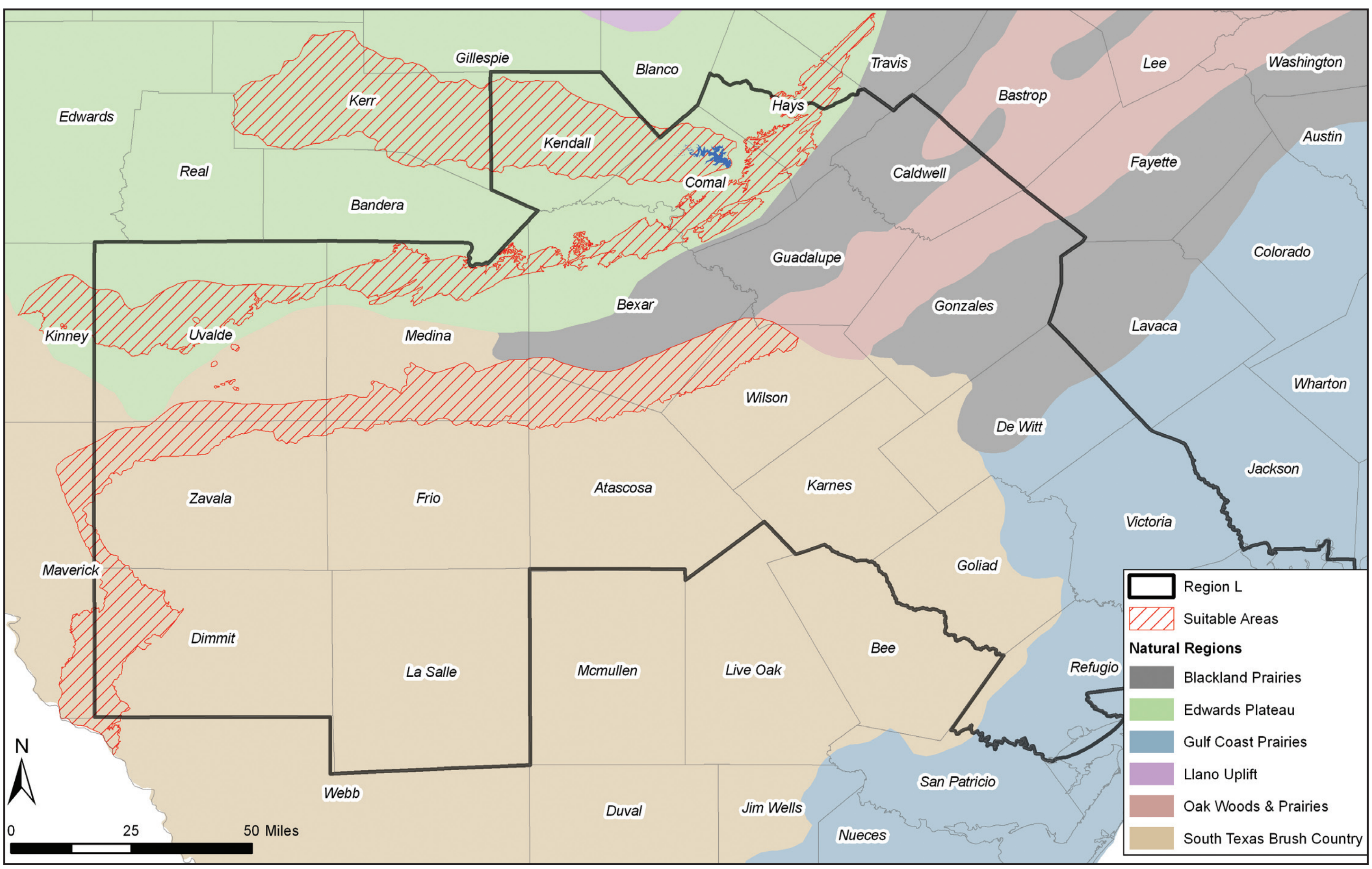
rates, they range from $75 to $400/acre (Pestman 2007). Perhaps the most economically effective treatment for juniper control is prescribed fire. Prescribed fire can be combined with other high-cost initial practices such as mechanical brush control to enhance or maintain brush control benefits for many years. Costs are variable, but based on current market rates, they can range from $3 to $8/acre. Biological control of Ashe juniper can also be achieved through the use of goats. Goats will browse on the young saplings of both juniper and hardwoods. When concentrated in high densities and rotated through pastures, they represent an effective means of controlling woody brush.

**SOUTH TEXAS PLAINS**—The South Texas Plains are the heart of the Texas "Brush Country," and no other region in Texas has seen more widespread implementation of brush management practices. Brush stands in this region are often mixtures of more than 15 species such as mesquite, acacia, and prickly pear. Most brush species in this region will re-sprout after treatment, which causes significant management challenges. The primary methods of controlling brush in the South Texas Plains are mechanical, chemical, and prescribed fire (Hamilton et al. 2004).

Mechanical methods that involve the use of a root plow, bull dozer, or chaining are highly variable depending on density and target species. These methods range from $30 to $250/acre based on current market rates (Pestman 2007). Due to the re-sprouting nature of most target species in the South Texas Plains, chemical methods represent a cost- effective method for controlling brush and maintaining range conditions. Based on current market rates, costs for chemical control methods range from $20 to $120/acre. Prescribed burning can be combined with other initial practices such as mechanical brush control to enhance or maintain brush control benefits for many years. Costs are variable, but based on current market rates, they range from $3 to $8/acre.

### Where does rangeland restoration work?

Water yield resulting from rangeland restoration is likely to be effective only on sites receiving at least 18 inches of annual rainfall and having geology and soil characteristics leading to rapid runoff and infiltration (Hibbert 1983, Seyfreid et al. 2005, Wilcox et al. 2006).




Aquifer recharge zones and river basins within Region L suitable for rangeland restoration efforts to increase water yield based on vegetative cover, geology, and soil characteristics.

### Cost of other methods?

The cost of additional water yield through rangeland restoration compares favorably to other methods of acquiring additional available water. For example, municipal conservation efforts cost $50 to $200/acre-foot, and seawater desalination costs $619/acre-foot (SCTRWPG 2006).

## Rangeland Restoration and Water

Areas within Region L with the greatest potential for increasing recharge through brush management and rangeland restoration are those areas where deep drainage (water movement beyond the root zone) can occur. This characteristic is found where soils are shallow and overlie relatively permeable bedrock. The Edwards Plateau region is a prime example of this type of situation. It has considerably more "flowing water" than would be expected for a semiarid climate (about 27.5 inches of precipitation per year). The explanation lies in the karst geology—a substrate of fractured limestone that allows rapid flow of water to the subsurface. Other soil types that may enable deep drainage are sandy soils—like those found in the Carrizo-Wilcox Aquifer recharge zone. Large areas of Region L exhibit these characteristics and support vast expanses of brush that provide opportunities for increasing water yield through rangeland restoration.

Based on current research within the Edwards Plateau, the best estimate is that the conversion of Ashe juniper woodlands into grassland-dominated savannas (woody cover < 10%) would result in an average increase in water yield (streamflow and recharge) of approximately 1.5 to 2.4 inches/acre/year. Thus, for every 5 to 8 acres of Ashe juniper converted to open savannas, an additional acre-foot of water would become available for recharge and streamflow. Current research within the south central Texas shrublands indicates that average recharge on sandy soils could be increased by shrub control from 0.4 to 0.8 inches/acre/year. This translates to an additional acre-foot of water for every 15 to 30 acres of brush cleared. For example, if recharge rates were at the lowest estimated level (0.4 inches/acre/year), restoring 200,000 acres of rangeland over the Carrizzo-Wilcox recharge zone would increase recharge by about 5,000 acre-feet/year. Based on average annual water consumption, an acre-foot is enough water to satisfy the needs of five Texans for an entire year.

The cost-effectiveness of implementing a brush management program for increasing recharge and streamflow cannot be assessed strictly on the basis of the initial cost of rangeland restoration. For example, if a rangeland restoration program is limited to the initial practice, re-growth of brush will eventually occur to the point that there will no longer be any increase in groundwater recharge. Alternatively, by using follow-up brush control practices after the initial treatment to control brush re-growth, the increased groundwater recharge gained from the initial brush control practice can be maintained for many more years into the future. Fortunately, follow-up range management practices, like prescribed fire, are relatively inexpensive. Therefore, rangeland restoration programs consisting of an initial treatment plus appropriate maintenance practices at 3- to 6-year intervals after the initial practice can result in maintaining range condition and the resulting increase in ground water recharge for many years into the future.

For example, clearing juniper on the Edwards Plateau ranges from $100 to $400 per acre. On average, this yields an increase in recharge of approximately 0.167 acre-feet per year. The results of extending the years of reduced brush cover, and the subsequent increased groundwater recharge, on the cost per acre-foot of added groundwater recharge are illustrated in Table 1. The cost estimates are obtained by taking the per-acre cost of the restoration practice, or cost of a program consisting of an initial restoration plus follow-up practices, and dividing it by 0.167. This yields the estimated

| | YEARS BRUSH CONTROL EFFECTIVE | | | |
|---|---|---|---|---|
| | Brush Control Cost/Acre | 1 Year | 5 Years | 10 Years |
| | COST/ACRE-FOOT/YEAR OF ADDED WATER | | | |
| EDWARDS PLATEAU | $70 | $419 | $83 | $41 |
| | $150 | $898 | $179 | $89 |
| | $200 | $1,197 | $239 | $119 |
| | $300 | $1,796 | $359 | $179 |
| CARRIZO-WILCOX | $35 | $1,060 | $212 | $106 |
| | $50 | $1,515 | $303 | $151 |
| | $75 | $2,272 | $454 | $227 |
| | $100 | $3030 | $606 | $303 |

Table 1. Cost per acre-foot of added water for selected control costs and effective duration of brush control practice within the Edwards Plateau and Carrizon-Wilcox Aquifer.

cost per acre-foot of added groundwater recharge resulting from brush control if the program is effective for only one year. Results for several alternative levels of brush control costs are detailed in Table 1. The third and fourth columns of Table 1 illustrate the per-acre-foot costs of added groundwater recharge resulting from brush control if the brush control practice, or program, is effective for a period of five and ten years, respectively.

If rangeland restoration programs were implemented that require participating landowners to maintain range conditions with 5 percent woody cover for a period of 10 years, then the costs per acre-foot of added groundwater recharge would be expected to range between $40 and $180 per acre-foot in the Edwards Plateau and between $100 and $300 per acre-foot in the Carrizo-Wilcox Aquifer recharge zone. It should be noted that the estimates of added groundwater recharge costs are based on the highly variable costs of the brush control practices and/or programs. Additionally, there are many other factors that would impact the ultimate costs, including landowner participation rates, proper implementation and maintenance of brush management, and availability of cost-share funding.


Photo credit: Texas Parks and Wildlife Department ©2008

Pedernales River.

## Incentive-Based Programs

Rangeland restoration is generally recognized to be a long-term investment that often requires a large monetary investment with benefits extending several years into the future. Landowner benefits are based on expected increases in returns from livestock and wildlife enterprises (Conner and Bach 2000). Even after benefits are realized, they may not be enough to cover the costs of clearing and maintenance activities. Landowners who receive cost-share funding will realize a profit from their investment more quickly regardless of the cost of clearing if they are reimbursed for a portion of restoration expenses. In addition, studies have shown that when cost-share funds are available, landowner participation rates increase (Olenick et al. 2004). An incentive-based program that shares the cost of rangeland restoration with the landowner could provide opportunities for increasing water yield.


Photo credit: Darcy Stumbaugh ©2008

Golden-cheeked warbler.

## Endangered Species Management

A rangeland restoration program, if implemented, would need to account for endangered species habitat. Within Region L, the golden-cheeked warbler, a federally listed endangered bird, inhabits mature oak-juniper woodlands. This habitat would not be a candidate for rangeland restoration efforts. Impacts to the Black-capped vireo, another federally listed endangered bird, would also have to be considered. Any juniper removal performed in areas that have the potential for becoming black-capped vireo habitat would have to be done selectively and followed with prescribed fire to enhance that potential. Any brush clearing should be conducted by a certified brush management contractor who has received training on how to recognize and work around endangered species habitat.


Photo credit: Michael Male ©2008

Black-capped vireo.

## Where do we go from here?

Additional work should be performed to determine the number of acres suitable for rangeland restoration efforts to increase water yield. In addition, studies should be conducted that assess the impact of incentive-based programs on landowner participation. When combined, these two efforts will give a better estimate of expected water yield from rangeland restoration.

## Conclusion

Over the next several decades, Region L will continue to face an ever-increasing demand for a limited resource—fresh water. Based on the research available, there is a better understanding of the influence of vegetation and vegetation management on the performance of water catchments and the land-based water cycle. Land-based water conservation practices, specifically rangeland restoration, offer great promise for augmenting fresh water supplies in the Edwards Plateau and South Texas Plains of Texas. With long-term costs per acre-foot of added water ranging from $40 to $180 for the Edwards Plateau and $100 to $300 for the South Texas Plains, brush management represents a cost-effective alternative for increasing available water when compared to other water management strategies. In order for a rangeland restoration program to be successful, an incentive-based program that helps defray the high initial landowner costs of brush clearing must be developed. Additional programs should be developed that provide incentives for landowners to maintain rangeland in a manner producing the greatest public benefit, i.e., increased water yield and the other benefits healthy rangelands provide.

## Contact Information:


TEXAS A&M | Institute of Renewable Natural Resources

**Texas A&M Institute of Renewable Natural Resources**
1500 Research Parkway, Suite 110
College Station, Texas 77843-2260
(979) 862-3199
Email: irnr@tamu.edu

**Texas Wildlife Association Foundation**
2800 NE Loop 410, Suite 105
San Antonio, Texas 78218
(210) 826-2904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# LAND-BASED WATER CONSERVATION & WATER YIELD PRACTICES IN REGION L: GUIDELINES FOR SPATIAL ANALYSIS AND RECOMMENDED BRUSH MANAGEMENT PRACTICES

SUBMITTED TO
REGION L
SOUTH CENTRAL TEXAS REGIONAL WATER PLANNING GROUP
BY

TEXAS A&M | Institute of Renewable Natural Resources

&

GRAZINGLAND MANAGEMENT SYSTEMS, INC.

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## ABSTRACT

Spatial analysis is to be conducted for three sub-areas of Region L: the Carrizzo-Wilcox aquifer recharge zone, the Edwards aquifer recharge zone and the Guadalupe River watershed above Canyon Lake. The spatial analysis should delineate: aquifer/watershed and county boundaries, land cover by type, canopy density category for brush, land ownership (public/private), tract size of privately owned land, areas with slope > 15%, areas with moderate to high probability of containing golden-cheeked warbler (GCW) habitat and for the Carrizzo-Wilcox aquifer recharge zone, areas with deep sandy soils.

Brush management practices in the Edwards Plateau and Guadalupe watersheds will be primarily directed at Ashe juniper, a non-sprouting species that suffers mortality when the above ground live plant material is removed. Both individual plant treatments (IPT) and broadcast mechanical treatments are recommended for Ashe juniper control. Chemical treatment is limited to IPT. Fire is an especially effective treatment alternative for Ashe juniper and is, under some conditions, used as an initial reclamation practice or, most commonly, as a maintenance practice to extend benefits from an initial mechanical practice. South Texas brush is a composite of as many as 20 species, the majority of which are resprouting species that do not suffer mortality from top removal. Brush management practices for south Texas include both mechanical and chemical as IPT or broadcast treatments, depending on plant density and need for revegetation. Because of the regrowth potential, rootplowing, a whole plant removal broadcast practice, is especially effective for south Texas brush stands. Recommended maintenance treatments that follow initial applications include mechanical and chemical IPT, as well as prescribed fire. Costs of the various treatment alternatives vary widely due to different plant densities, size and regrowth potential of the species.

## GUIDELINES FOR SPATIAL ANALYSIS

Spatial analysis is to be conducted for three sub-areas of Region L:

1. Carrizzo-Wilcox aquifer recharge zone in Dimmit, Caldwell, Guadalupe, Bexar, Atascosa, Wilson, Medina, and Zavala counties. Counties outside the boundary of Region L which also contain areas of the Carrizzo-Wilcox aquifer recharge zone and which may also be considered for inclusion in the program are Maverick and Webb.
2. Edwards aquifer recharge zone in Uvalde, Medina, Bexar, Comal and Hays counties. Kinney, Travis, Williamson and Bell counties are outside of the Region L boundary, but contain parts of the Edwards aquifer recharge zone and could be considered for inclusion in the program.
3. The Guadalupe River watershed above Canyon Lake including Comal and Kendall counties which are in Region L and Blanco and Kerr counties which are outside the Region L boundary.

The spatial analysis should delineate:

Aquifer/watershed boundaries
County boundaries
Land cover by type (brush –other) and by canopy density category for brush (eg., < 20%, 20-40%, and > 40%)
Land ownership (public/private) and for private land, tract size (eg., < 25ac, 25-50ac, 50-100ac, > 100ac, etc.)
For private land, with Tract sizes > 50 ac, areas with slope > 15%
For private land, with Tract sizes > 50 ac, areas with low, moderate and/or high probability of containing GCW habitat
For the Carrizzo-Wilcox aquifer recharge zone, delineate areas of the recharge zone with deep sandy soils.

The spatial analysis report should provide maps showing locations and acres of parcels of private land that were within the aquifer/watershed boundaries, with parcel size of 50 acres or more, with > 10% shrub/brush canopy cover and slopes < 15% and, for the Carrizzo-Wilcox aquifer recharge zone, areas with deep sandy soils. The report should also indicate which such parcels have low, moderate or high probability of containing GCW habitat.

# RECOMMENDED BRUSH MANAGEMENT PRACTICES

## Introduction

All herbicide applications must follow EPA label directions and be in accordance with state and county restrictions. Applications will be made during weather conditions and at distances from critical off-target areas conducive to the avoidance of herbicide drift. It is recommended that Texas AgriLife Extension bulletin 1466 be used as a basis for matching herbicide compounds with target plant species and for instructions in timing, additives and application methods. The use of prescribed fire should be under the direction of Certified Prescribed Burn Managers and applied within guidelines provided by the State of Texas for outdoor burning and any county or other regulations that may be in effect. All brush management applications; chemical, mechanical and prescribed fire, will avoid adverse impacts to rare, threatened or endangered species and other sensitive environmental resources found in the area to be treated.

## Edwards Plateau and Guadalupe Watershed

Brush management treatment alternatives commonly used in the Edwards Plateau MLRA include mechanical and chemical practices, as well as prescribed fire and biological control associated with the use of goats. Selection of these treatments depends on the size and density of the woody plant species, primarily Ashe juniper (*Juniperus ashei*). Some ranchers will remove oak species (*Quercus spp*.) with brush management practices, but these are more likely shinoak species or oaks that are thinned within mottes, rather than mature oaks. Live oaks, Spanish oaks, post oaks, or other oak species are generally not considered in brush management scenarios, meaning that Ashe juniper is the target woody plant species a very high percentage of the time.

Mechanical brush management treatments can be either broadcast when densities of plants are greater than 300 plants per acre or large enough to respond to treatments such as chaining or cabling, or individual plant treatments (IPT) when densities are low enough and/or plants are small enough to justify treating individual plants. It should be remembered that all brush management is temporary, even when a very high percentage of the resident target species suffer mortality from the initial brush management practice. For example, Ashe juniper will recover very quickly in an area following effective control from seeds in the soil profile that germinate and establish seedlings. Maintenance or "follow-up" practices, either IPT mechanical or chemical or the use of prescribed fire or goats that will utilize juniper seedlings are highly recommended. When fire is used, it is highly recommended that it be under the direction of a Certified Prescribed Burn Manager. It is also recommended that landowners using prescribed fire join the prescribed burning association in their county, if one has been organized. Information on available prescribed burning associations in the Edwards watershed can be obtained from the Edwards Plateau Prescribed Burning Association at the Texas A&M research Station at Sonora, Texas.

Woody plant species in the watershed will be distinguished for recommended brush management practices and cost estimates as follows:

<u>Ashe Juniper and Ashe Juniper – Oak (Quercus spp.) mix</u>

- Individual Plant Treatment (IPT)

    Mechanical
    Chemical

- Broadcast

    Mechanical
    Chemical

<u>Ashe juniper</u>

Ashe juniper is non-sprouting species that it will suffer mortality if all the above ground green material is removed. This allows top removal practices to be effective for brush management and the most popular of these methods currently is the use of a "skid-steer loader" equipped with a front-end attachment of hydraulically operated shears. Since the skid-steer is used to attack individual plants, it can be considered an IPT practice and is recommended primarily for Ashe juniper densities of 300 plants per acre or less. Light to high densities should range in cost between $80 and $300 per acre. Mortality of Ashe juniper treated with this method should be near 100%. The advantage of the skid-steer and IPT is that it is very selective and can remove juniper without damage to associated oaks of other desirable woody speice.s. An alternate selective IPT mechanical method would be use of an excavator, ranging in cost between $40 and $140 per acre depending on density of the juniper.

The recommended IPT chemical treatment for Ashe juniper is a soil applied spot treatment with Hexazinone or picloram liquid at an estimated cost of between $6 and $10 per 100 plants using a $7.00 per hour charge for labor. Mortality of Ashe juniper treated with this method would be very high (76-100% mortality).

When Ashe juniper densities exceed 300 plants per acre, it is generally recommended that broadcast treatments be considered rather than IPT. The use of a crawler tractor and bulldozer blade is a standard practice for broadcast treatment of Ashe juniper and is recommended. Costs will vary widely with density and size of trees, but should be in the range of $75-$150 per acre. Mortality of the target species will be very high. When the topography (slope and surface roughness) are within acceptable levels, two-way chaining of heavy juniper stands is a recommended broadcast treatment alternative. Two-way chaining will cost an estimated $30-$50 per acre. However, chaining cannot be discriminating for oak or other desirable species that will suffer mortality or be damaged. In limited areas of the Edwards Plateau where soil depth and slope permit, rootplowing may be a broadcast alternative mechanical practice. If juniper is in very large, dense stands, a pre-treatment of bulldozing may be required. Rootplowing alone is estimated to cost $110 per acre and pre-dozing $60 per acre when needed. Seeding to restore grasses following rootplowing would cost an additional $40 per acre (total cost $210 per acre).

There are no recommended broadcast chemical treatments for Ashe juniper control.

Ashe juniper – Oak mix

Where oak species are mixed with Ashe juniper, it is assumed that the juniper will be the target species for brush management and that tree shearing with a skid loader will be the IPT treatment in order to selectively take out the juniper and leave the oak. Light to high densities of juniper should range in cost between $80 and $300 per acre. Mortality of Ashe juniper treated with this method should be near 100%. An alternate selective IPT mechanical method would be use of an excavator, ranging in cost between $40 and $140 per acre depending on density of the juniper.

Chemical IPT for mixed Ashe juniper and oak stands would present a problem if oak trees were considered desirable. The chemical compounds for oak control, hexazinone and tebuthiuron are both soil applied herbicides. Hexazinone and picloram soil applied herbicides are recommended for Ashe juniper control. The possibility of damage to desirable trees with the use of any of these compounds would be high. However in areas where it can be used, hexazinone IPT would cost $10 per 100 plants.

Broadcast mechanical treatments would also present a problem for juniper-oak mixed stands. The use of treatments such as chaining would not be practical in order to leave the oak. Use of a bulldozer would be acceptable to take out primarily the juniper while working around the oak, although in mixed stands the likelihood of some oak removal would be moderate to high. Bulldozing would cost between $75-$150 per acre depending on the density of the juniper in the stand.

There are no recommended broadcast chemical treatments for Ashe juniper control and the use of a broadcast treatment for oak in the Edwards Plateau would not be likely. However, Tebuthiuron is effective for oak control as a broadcast application at a cost of $80 per acre.

## South Texas

The South Texas Plains are dominated by a woody plant complex of a dozen or more species, most of which have vigorous resprouting potential after top removal. Resprouting is primarily from basal stem buds and buds contained in the crowns of these woody plants near the soil surface or several inches below the soil surface. Honey mesquite (*Prosopis glandulosa*) is often the dominant species in the mixed brush complex, but other individual species that can dominate on certain ecological sites include pricklypear cactus (*Opuntia berlandieri*), blackbrush acacia (*Acacia rigidula*), and oak (*Quercus spp*.). These species will be addressed as the dominate species in mixed brush stands in the recommendations for brush management treatment alternatives and costs as follows:

- Individual Plant treatment (IPT)
  - Mechanical
  - Chemical
- Broadcast
  - Mechanical
  - Chemical

Mesquite dominated mixed brush

For densities of mesquite less than 300 plants per acre, IPT is recommended. For plants up to 5 inches in stem diameter a "low-energy" grubber can be used effectively. Low-energy grubbing can be accomplished for an estimated cost of $30-$40 per acre. For low densities of mesquite trees that are larger than 5 inches stem diameter, a larger power grubber, is recommended with an estimated cost of $40 -$100 per acre.

Chemical IPT for mesquite includes more than a dozen treatments that provide a very high level of plant mortality. These treatments include foliar herbicide applications to individual plants, stem basal herbicide applications, and a cut stump treatment. For the purpose of these recommendations, a stem basal treatment with triclopyr (concentrate) (a general use herbicide) and diesel at a cost of $10 per 100 plants (smooth barked) and $14 (rough barked) will be used. Mortality of treated plants is expected to be very high, 76-100%.

For a broadcast treatment of mesquite dominated areas, rootplowing is recommended. This practice gives the highest level of mortality and moderate term relief from significant brush reinfestation. Rootplowing alone is estimated to cost and average of $110 per acre, however, it should be noted that in very heavy, dense stands of mesquite and mixed brush, a pre-treatment to rootplowing may be required consisting of bulldozing or the use of a brush stacker. This will increase the cost to approximately $170 per acre. In many instances it is advisable to reseed areas following rootplowing that suffer loss of the resident perennial grass composition. It is also common to rake or disk areas following rootplowing in order to smooth the soil surface left very rough by the rootplowing treatment and to prepare a seedbed for planting. The added seedbed preparation and seeding costs will increase the total cost to approximately $210 per acre.

Broadcast chemical treatments of mesquite dominated areas in south Texas include many options similar to the IPT alternatives, but only one (clopyralid) will give a high level of mesquite control with a broadcast foliar application. Clopyralid is recommended at a cost of $39 per acre (fixed wing application) where mesquite is highly dominant and other species greatly subordinate. If there are significant other species in the mix, then picloram plus clopyralid is recommended at a cost of $50 per acre (fixed wind application). If a helicopter is used to apply the herbicides, add $8.50 per acre to the cost.

Pricklypear dominated mixed brush

There are no mechanical IPT recommended for pricklypear. Pricklypear infestations can be controlled mechanically with a broadcast treatment that uses a large, modified front-end rake called a brush stacker. The cost of stacking averages about $65 to $90 per acre. “Railing” is another broadcast mechanical practice that can be used for pricklypear control at an estimated cost of $30-$40 per acre. Although the brush stacker and railing have the potential to reduce pricklypear infestation, most of the mechanical practices have the potential to spread prickly pear by breaking the cladophylls away from the plants and spreading them across the soil surface where they will root. Where pricklypear is present, a chemical control application should be considered prior to broadcast mechanical treatments, such as rootplowing or chaining.

Chemical IPT for pricklypear includes several choices, all of which will give a very high level of mortality. However, recent research and demonstrations indicate that a combination of picloram and fluroxypyr (1:1) provides a faster kill of the pear than other recommended treatments at the same or slightly less cost. The cost for this treatment is estimated to be $3.20 per 100 plants. Another IPT combination treatment of a low rate application of picloram following fire in the spring will provide a very high level of pricklypear control at an estimated cost of $20 per acre.

The same chemical combination used for IPT for pricklypear control is recommended for broadcast treatment. Picloram:floroxypyr (1:1) will give an estimated high level of mortality (55-76%) on pricklypear plants at an estimated cost of $22 per acre assuming a fixed wing aerial application method. If a helicopter is used add $8.50 per acre.

Shinnery oak

There are no mechanical IPT or broadcast treatments recommended for shinnery oak. While it is unlikely that shinnery oak will occur in densities suitable for chemical IPT, recommendations for IPT can be applied as spot treatments.The recommended chemical treatment for this plant is tebuthiuron (20%) applied IPT at an estimated cost of $47 per 100 plants, or as a broadcast treatment at a cost of $44 per acre.

Tree-type Oak

The recommended mechanical treatment alternative for large tree-type oak control would be two-way chaining followed by raking and stacking . This practice is estimated to cost between $110 and $190 per acre.

Tebuthiuron (20%) is recommended for control of tree-type oaks as a broadcast application at a cost of $80 per acre.

Blackbrush acacia

For densities of blackbrush less than 300 plants per acre, IPT with low-energy grubbing can be used effectively for an estimated cost of $30-$40 per acre and will provide a very high level of plant mortality.

Blackbrush usually does not have stem diameters greater than 2-3 inches and shredding can be used as a broadcast treatment for top removal. In heavy densities of the largest stem diameters of blackbrush and associated species, a self-propelled hydraulic shredder, such as the "Hydro Axe", is recommended for a cost ranging from $115.00 - $230.00 per acre. For light densities of smaller stature plants, a drag-type modified farm shredder can be used for a cost of approximately $20-$35 per acre. However, blackbrush is a resprouting species following top removal and followup maintenance practices will be necessary to maintain control. Rootplowing alone is estimated to cost an average of $110 per acre, however, it should be noted that in very heavy, dense stands of mesquite and mixed brush, a pre-treatment to rootplowing may be required consisting of bulldozing or the use of a brush stacker. This will increase the cost to approximately $170 per acre. In many instances it is advisable to reseed areas following rootplowing that suffer loss of the resident perennial grass composition. It is also common to rake or disk areas following rootplowing in order to smooth the soil surface left very rough by the rootplowing treatment and to prepare a seedbed for planting. The added seedbed preparation and seeding costs will increase the total cost to approximately $210 per acre.

Triclopyr (concentrate) + diesel can be used for IPT in low densities of blackbrush as a stem basal application and will give a very high level of plant mortality. This application will cost approximately $13 per 100 plants.

There is no recommended broadcast chemical treatment for blackbrush that will give a very high level of expected plant mortality. While several chemical compound combinations are recommended for moderate levels of control, only one, tebuthiuron (20%) pellets, will provide a high level of mortality (55-76%) at a cost of approximately $114 per acre. This treatment cost is over twice those recommended for chemical treatments that give the moderate control level.

**Edwards Plateau and Guadalupe Watersheds**

| Species | Treatment | IPT Cost 100 plants | Broadcast Cost/Acre | Alternative | IPT Cost 100 plants | Broadcast Cost/Acre |
|---|---|---|---|---|---|---|
| | | | | | | |
| Ashe juniper | Tree Shear | | $80-$300[1] | Excavator | | $40-$140[1] |
| | Hexazinone/picloram | $6.00-10.00 | | | | |
| | Bulldozer | | $75-$150 | Two-way chain | | $30-$50 |
| | Rootplow | | $110-$210 | | | |
| | | | | | | |
| Juniper-Oak | Tree shear | | $80-$300[1] | Excavator | | $40-$140[1] |
| | Bulldozer | | $75-$150 | | | |
| | Hexazinone | $10.00 | | | | |
| | Tebuthiuron | | $80.00 | | | |

**South Texas Watersheds**

| | | | | | | |
|---|---|---|---|---|---|---|
| Mesquite | Low-energy grub | $30-$40 | | | | |
| | Power Grub | $40-$100 | | | | |
| | Triclopyr + diesel | $10-$14 | | | | |
| | Rootplowing | | $110-$210 | | | |
| | Clopyralid | | $39 | | | |
| | Clopyralid + picloram | | $50 | | | |
| | | | | | | |
| Pricklypear | Brush Stacker | | $65-$90 | Railing | | $30-$40 |
| | Picloram + fluroxypyr | $3.20 | | | | |
| | PIcloram + fire | $20.00 | | | | |
| | Picloram + fluroxypyr | | $22.00 | | | |
| | | | | | | |
| Oak[2] | Tebuthiuron (20%) | $47.00 | | | | |
| | Tebuthiuron (20%) | | $44.00 | | | |
| Oak[3] | Tebuthiuron (20%) | | $80.00 | | | |
| | 2-way chain/stack | | $110-$190 | | | |
| | | | | | | |
| Blackbrush | Low-energy Grub | $40-$100 | | | | |
| | Hydro-Axe | | $115-$230 | | | |
| | Farm Shredder | | $20-$35 | | | |
| | Rootplow | | $110-$210 | | | |
| | Triclopyr + diesel | $13.00 | | | | |
| | Tebuthiuron (20%) | | $114.00 | | | |

[1]Practice can be used IPT or broadcast

[2]Running or shinnery oak

[3]Tree type oak

# APPENDIX 4

## Summary of USDA Farm Programs

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2008 Farm Bill Conservation Programs
(as of August 2009 – final rules expected by end of this year *see income eligibility statement at end of last page)

**Conservation Reserve Program (CRP)***

- Program run by Farm Services Agency (FSA), producer signs up at FSA office.
- Purpose of program is to remove highly erodible and environmentally sensitive land from production.
- Federal lands ineligible, land must have been cropped 4 of 6 years between 1996 - 2001 (soon to be 2002-2007).
- Limited to announced signup periods except for Continuous CRP.
- Application evaluated on environmental benefits, regionally based competition with bonus points for landowners living in same or contiguous county as offered property.
- Counties capped when they reach 25% of total county cropland acres enrolled in the program but cap can be waived for CCRP, CREP or WRP if landowners have difficulty implementing conservation plans and if county government concurs that exceeding the cap will not adversely affect the local economy.
- 50% cost share for establishing cover, plus annual maintenance and rental payments (limited to $50,000/year).
- National acreage cap reduced from 39.2 to 32 million acres starting Oct 1, 2009.
- Midterm management required to maintain land productivity for wildlife, can receive 50% cost share up to $50/acres/yr with a cap of $100/acre on a 10 yr and $125/acre on 15 yr contract.
- Provides for managed haying including biomass, routine gazing, prescribed grazing for the control of invasive species, emergency haying & grazing & placement of wind turbines with reduction in rental rates.
- CRP transition incentive program allows sale/lease of expiring CRP by retired/retiring producers to new, socially or economically disadvantaged producers wishing to put land back into production. Requires comprehensive conservation plan meeting sustainability requirement. Provides former landowners with up to 2 years of payments if new landowner isn't family member. New landowners can to sign up for appropriate EQIP or CSP practices or reenroll a CCRP practice before CRP contract expiration.
- Includes the Continuous Conservation Reserve Program (CCRP) directed at environmentally sensitive land – riparian buffers, field borders, filter & wind strips.
    - Continuous enrollment - 50% Cost Share on required practices
    - Owners receive incentive payments for establishing certain practices, annual rental rate for 10-15 year contract.
    - Signup Incentive Payments (SIP) - $10/acre/yr of contract up to $100/acre, former CRP/some practices ineligible
    - Practice Incentive Payment (PIP) - 40% of eligible practices (on top of 50% cost share)
    - Provides 50% cost share for replanting or thinning trees on CRP to accomplish original practice purpose, provide multi-resources benefits and improve condition of the resources on the land.

  - Farmable wetlands program now includes wetlands constructed for nitrogen removal, aquaculture ponds and intermittently flooded farmland cropped at least 3 out of 10 years from 1990 to 2002. Enrollment limited to 40 acres for wetlands/constructed wetlands, 20 acres for intermittently flooded tract. Buffer size to be determined by USDA in consultation with State Tech Committee.

**Wetlands Reserve Program (WRP)***

- Program run by NRCS, applications taken year round at NRCS offices, competition for contracts is statewide.
- Purpose of program is to restore, enhance and protect wetlands on private or tribal property.
- Eligible land limited to private or tribal land, outside CRP capped counties (unless CRP cap is waived locally).
- Eligible land includes wetlands farmed under natural conditions, croplands and adjacent land functionally dependent on wetland converted prior to Dec 23, 1985, cropland/grassland used for agricultural production prior to flooding from the natural overflow of a closed basin lake or pothole & adjacent land functionally dependent on the cropland or grassland.
- Prohibits agreements and easements on land where ownership has changed during previous 7 years unless waived by State Conservationist.
- Applications accepted year round, ranked once per year, ranking based on maximizing environmental benefits,
- Caps national acreage enrollment at 3,041,200 acres.
- Options for permanent or 30-year easements (30 year contract option for tribes), or restoration cost share agreements.
- USDA pays 100% of the lowest of one of these 3 amounts: 1) fair market value 2) geographic cap or 3) landowner offer plus restoration costs on permanent easements and 75% of the lowest amount and costs on 30-year easements. Easement recording costs are also paid.
- Restoration cost share agreements receive up to 75% of restoration costs, no easement placed on property but payments limited to $50,000 annually for any person or legal entity.
- Provides cost assistance for maintenance activities.
- Landowner controls access, non-developed recreational activities (hunting, fishing) and right to lease recreational uses for financial gain. Other uses must be approved.
- Wetland Reserve Enhancement Program (WREP) established and available to States, Tribes and NGO's for special wetland programs. WREP contracts can allow retention of grazing rights.

**Environmental Quality Incentives Program (EQIP)***

- Program run by NRCS, applications taken year round at NRCS offices.
- Purpose is to install & maintain conservation practices that sustain food & fiber production while enhancing soil, water & related natural resources & energy conservation.
- Eligible land includes confined livestock feeding operations, crop, range, grass and

pastureland and nonindustrial forestland. States and local governments are not eligible. Private individuals operating on government lands maybe eligible under certain circumstances.

- EQIP applications ranked at least once per year, competition is statewide.
- 60% of annual program funding targeted at livestock related activities.
- Includes planning for organic production, forest, wildlife, wetland, grazing, nutrient, air quality, invasive species, residue, animal carcass, pest, pollinator and fuels management and energy conservation.
- Provides an overall payment limitation of $300,000 per individual, regardless of the number of farms or contracts, over 6 years starting with contracts signed after October 1, 2008. Possible waiver to $450,000 for projects having special environmental significance. Contracts over $150,000 require regional NRCS Assistant Chief approval.
- Can provide up to 75% cost-share on most contracts. Can provide up to 90% cost-share for beginning or limited resource or socially disadvantaged farmers and ranchers who can also receive up to 30% advance payments to install practices.
- Payments include planning and income recovery costs. Incentive payments have been eliminated.
- Organic production transition payments limited to $20,000/yr or $80,000 over 6 years.
- Contract length: Minimum 1 yr after implementation of last scheduled practice, Max-10 yrs
- Conservation Innovation Grants (CIG) are used to stimulate innovative approaches in environmental enhancement and protection. Awarded on a competitive basis. Special program for air quality.
- Agricultural Water Enhancement Program (AWEP) promotes water quality, conservation planning, restoration or enhancement projects on ag lands. Includes irrigation efficiency, conversion to dryland farming and drought mitigation. Funding through NRCS or partner.

**Wildlife Habitat Incentives Program (WHIP)***

- Program run by NRCS, applications taken year round at NRCS offices
- Purpose of WHIP is to help landowners or lessees develop and improve wildlife habitat.
- Eligible land: tribal lands, private agricultural land and non-industrial private forest land on which livestock, agriculture or forest products are produced. State & federal land ineligible.
- Applications ranked once per year, competition is statewide.
- Prioritizes projects that further state, regional or national habitat goals and priority habitats.
- Up to 75% cost-share for people who own/control land & want to develop/improve habitat. Up to 90% cost share for historically underserved producers and for contracts 15 or more years in length.
- Normally contracts run 5-10 years with a goal of 25% long term (15+ yr) contracts.
- National limit $50,000/person or legal entity/year.

**Farm and Ranch Lands Protection Program (FRPP)***

- Program run by NRCS through participating entities, generally local land trusts. Continuous signup.
- Purpose is to protect agricultural use and conservation values by limiting nonagricultural uses of land.
- Eligible land: privately owned and contains at least 50% prime, unique or state or locally important farmland, contains historical or archeological resources or will further a State or local policy consistent with the purposes of the program and is subject to a pending offer from an eligible entity.
- Includes incidental range, grassland, pasture or forestland that contributes to an agricultural operation or buffers development. Offered property must be not more than two-thirds forestland.
- Provides 50% appraised market value to state, tribal or local government or nonprofit entities to purchase conservation easements.
- Minimum entity contribution is 25% of easement acquisition purchase price.
- Entity determines terms & condition of deed, chooses approved appraisal method.
- Secretary certifies approved entities. USDA holds no interest in easements except the right of enforcement.
- Can use charitable donation from the landowner as part of non-Federal cost share.
- Highly erodible land requires conservation plan, may require conversion to less intensive use.

**Grasslands Reserve Program (GRP)***

- NRCS administers permanent easements, FSA handles rental contracts. Continuous signup at USDA Service Centers.
- Purpose is to maintain healthy grazing lands and protect them from development. No minimum acreage requirement.
- Eligible land privately or tribally owned and can be restored or restorable, improved, or natural grass, range, pastureland or prairie for which grazing is the predominant use, or which contains historic or archeological resources or addresses State, regional or national conservation priorities.
- Authorizes enrollment of up to an additional 1.22 million acres. Prioritizes enrollment of CRP land whose contract is within 1 yr of expiring, but limits CRP enrollment to 10% of yearly acreage allotment.
- 10, 15 or 20 year rental contracts, permanent or max easement length allowed by state law.
- Not more than 40 percent of the funds are available for 10, 15 or 20 year rental contracts.
- Rental contracts annual rental rate equals 75% of grazing value. Rental payments are limited to $50,000/person or legal entity/year and can be received in addition to other farm bill payments.
- Renters must suspend cropland base and allotment history of land.
- Permanent easements purchased at fair market value, minus grazing value, cropland base permanently eliminated.
- Easements may be transferred to entities, generally trusts. Entity pays at least as much of the purchase price as USDA.

- Restoration agreements provide up to 50% of cost not to exceed $50,000/person or entity/year.

**Conservation Stewardship Program (CSP)*** (formerly Conservation Security Program)
- NRCS administers the program, runs from 2009-2012.
- Purpose is to reward good stewardship & provide incentives to address additional resource concerns on working lands.
- Eligible land: tribal agricultural lands, private agricultural lands, incidental non-industrial private forest lands not currently enrolled in CRP, WRP, and GRP.
- Eligible land must have a cropping history 4 of the 6 years before 2008, meet stewardship threshold for 1 USDA identified resource concern, and achieve threshold for State identified priority resource concern by the end of contract.
- Contracts are for 5 years with the option to renew for another 5 years.
- May enroll up to 12,769,000 acres/yr with amount based on eligible acres in state.
- Continuous signup with at least one ranking period in the first quarter of each fiscal year (Oct-Jan)
- 3-5 priority resource concerns are to be designated in each state or watershed
- Applications ranked on present and proposed conservation activities, number and extent of resource concerns addressed and cost effectiveness of expected environmental benefits.
- Applicants must account for stewardship operations covering their entire agricultural operation.
- Program payment cap of $200,000/five years/person or legal entity.
- Animal waste storage or treatment facilities are not eligible.
- Payments cover planning, installing, improving and maintaining conservation activities, foregone income and expected environmental benefits.

**Healthy Forestry Reserve Program (HFRP)**
- Administered by NRCS in coordination with FWS and NMFS, limited signup period advertised on NRCS website.
- Purpose is to assist landowners in restoring and enhancing forest ecosystems, promote recovery of federal, state and NRCS listed species, improve biodiversity and enhance carbon sequestration.
- Eligible land: private land capable of supporting federal candidate, threatened or endangered species, state or NRCS listed species, enhancing biodiversity or storing carbon in a functioning forest ecosystem.
- This includes land owned by Indian Tribes and private industrial forest owners.
- Land enrollment through 10 year restoration cost-share agreements, 30 year contract (only available to Tribes or tribal individuals), or permanent easement.

**Community Forest and Open Space Conservation Program** provides grants up to 50% to local entities to acquire private forest land that is in danger of conversion to nonforest uses and provides public benefits to communities.

**Cooperative Forest Innovation Partnership Project** provides grants up to 50% to state or local governments, tribes, land grant universities and private individuals who develop innovative education, outreach or technology transfer projects designed to increase USDA's ability to address private working forest landscape management for multiple values and uses, protect or restore forests impacted by natural threats and development or enhance public benefits such as air and water quality, soil conservation, biological diversity, carbon storage, forest products and jobs, production of renewable energy, wildlife, wildlife corridors and habitat and recreation.

**Conservation Technical Assistance Program –** Conservation technical assistance is the help NRCS and its partners provide to land users to address opportunities, concerns, and problems related to the use of natural resources and to help land users make sound natural resource management decisions on private, tribal, and other non-federal lands.

This assistance can help land users:

- Maintain and improve private lands and their management
- Implement better land management technologies
- Protect and improve water quality and quantity
- Maintain and improve wildlife and fish habitat
- Enhance recreational opportunities on their land
- Maintain and improve the aesthetic character of private land
- Explore opportunities to diversify agricultural operations and
- Develop and apply sustainable agricultural systems

This assistance may be in the form of resource assessment, practice design, resource monitoring, or follow-up of installed practices.

Although the CTA program does not include financial or cost-share assistance, clients may develop conservation plans, which may serve as a springboard for those interested in participating in USDA financial assistance programs. CTA planning can also serve as a door to financial assistance and easement conservation programs provided by other Federal, State, and local programs.

**Conservation of Private Grazinglands Program -** The NRCS Conservation of Private Grazing Land (CPGL) initiative will ensure that technical, educational, and related assistance is provided to those who own private grazing lands. It is not a cost share program. This technical assistance will offer opportunities for: better grazing land management; protecting soil from erosive wind and water; using more energy-efficient ways to produce food and fiber; conserving water; providing habitat for wildlife; sustaining forage and grazing plants; using plants to sequester greenhouse gases and increase soil organic matter; and using grazing lands as a source of biomass energy and raw materials for industrial products.

*__Conservation programs eligibility__ limited to individuals or entities making less than $1 million/yr average adjusted gross nonfarm income (AGI) for the preceding 3 years unless 66% or more of the income comes from farming, ranching or forestry.  Secretary of Agriculture can waive AGI limit for projects on environmentally sensitive land of special significance.  These payment limitations do not extend to federally recognized Indian tribes.

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# APPENDIX 5

United States Army Corps of Engineers Programs

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US Army Corps of Engineers

# Planning Processes

Rob Newman
Chief, Planning Section
817-886-1762



US Army Corps of Engineers

## Study Authorization

- For a study to begin, must have one of the following:
  - –Current "existing" authorization
  - –Authorization by WRDA or other bill
- After authorization, must be appropriated to begin a feasibility study

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## Project Phases

- Four Main Phases
  - –Reconnaissance Phase
  - –Feasibility Phase
  - –Preconstruction, Engineering, and Design Phase
  - –Construction Phase

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## Reconnaissance Phase

- First phase of any authorized study
  - $100,000 fully Federally funded
  - Usually about a year long
  - Culminates with a 905(b), which determines Federal interest
  - If Federal interest, begin Feasibility Phase

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## Feasibility Phase

- Develop Project Management Plan (PMP)
- Execute a feasibility cost sharing agreement (FCSA)
  - 50/50 cost share for investigation studies
- Conduct 6-step Planning Process
- Normally 3-5 years long
- Results in a Chief's Report and hopefully an authorized Project

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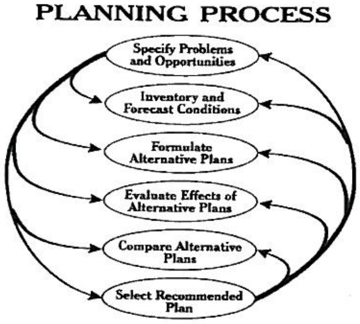
## PLANNING PROCESS

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## PED Phase

- After Chiefs' Report
  - Project must be Authorized by WRDA
  - Funds must be appropriated
  - PED typically cost shared 75/25
  - Design Agreement must be executed
- Detailed design begins
  - 1-3 years depending on size and cost of study
  - 35% Designs
  - 65% Designs
  - 95% Designs
  - 100% and Ready to Advertise

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## Construction Phase

- Funds must be appropriated for construction
- Prepare Project Partnership Agreement (PPA)
- Can take several years depending on funding
- Various cost sharing on projects depending on type of Authorization
  - Typically 65/35
  - Can be as much as 50/50 for structural projects
  - Can be 75/25 for CAP 1135
- Award construction contract
- Manage contract and provide QA/QC
- Closeout when complete and turnover to sponsor for operations and maintenance

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## GSAR Studies

- Leon Creek in Feasibility Phase
  - Primarily Flood Risk Management
  - Ecosystem Restoration can be added
  - Recharge potential if there is detention
- Cibolo Creek in Feasibility Phase
  - Multi-purpose flood risk management
  - Ecosystem restoration
  - Recharge
  - Recreation

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## Nueces

- Nueces in Feasibility Phase
  - –Multi-purpose Flood Risk Management
  - –Ecosystem Restoration
  - –Recharge
  - –Recreation

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## Section 206
## Aquatic Ecosystem Restoration Authority

### Spring Lake & San Marcos River Projects

Jeff Tripe
Regional Technical Specialist
817-886-1716

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## Section 206 Aquatic Ecosystem Restoration

| | |
|---|---|
| Program: | Continuing Authorities Program (CAP) |
| Authority: | Section 206 of the Water Resources Development Act of 1996, as amended (33 USC 2330) |
| Objective: | To restore degraded aquatic ecosystem structure, function, and process to a less degraded more natural condition |
| Requirements: | Improve quality of the environment, is in the public interest, and is cost effective |
| Cost Sharing: | Feasibility Phase (50/50), Design & Implementation Phase (65/35) |
| Sponsor Share: | LERRDs, Cash, or WIK credit |

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## Project Phases

| Feasibility Phase | Design & Implementation Phase |
|---|---|
| Request for Assistance *(Sponsor letter of request)* | Plans & Specifications *(Project Partnership Agreement)* |
| Federally Funded Portion *(Federal Interest Determination)* | Construction |
| Cost Shared Portion *(Feasibility Cost Sharing Agreement)* | Close-Out *(Project Completion Report)* |
| Final Decision Document *(MSC Commander approval)* | Sponsor O&M *(OMRR&R Manual)* |

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## Project Phases

### Feasibility Phase – Federally Funded Portion

- Initiated through a non-Federal Sponsor letter of request
- First $100,000 of Feasibility costs are fully Federally funded
- Determine if the proposed project meets Federal interests
- Problem(s) specification and potential project solutions
- Identify non-Federal project sponsor(s)
- 6 to 9 months to complete

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## Project Phases

### Feasibility Phase – Cost Shared Portion

Feasibility Cost Sharing Agreement (FCSA) – feasibility costs above and beyond the initial $100 K are cost shared 50/50

Identify & describe existing environmental degradation

Evaluate potential restoration alternatives

Recommend potential restoration features

Integrated Environmental Assessment (NEPA compliance)

District & Division approval

18 to 24 months to complete

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## Project Phases

- **Design & Implementation Phase**
  - First action is to execute the Project Partnership Agreement (PPA) – design & implementation is cost shared 65/35
  - Complete final design, real estate requirements, and compliance with environmental regulations
  - Award of construction contract(s)
  - Completion of physical construction and warranty period
  - OMRR&R Manual and Project Completion Report
  - Non-Federal Share – cash, work-in-kind credit (100%), and the value of project lands (LERRDs)

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## Program Limitations

### Section 206 Projects

- Studies and projects are subject to the availability of Federal funds
- The total Federal participation in a single project is limited to $5 million
- Recreation features are cost shared at 50% Federal and 50% non-Federal and cannot increase the total Federal restoration costs by more than 10%

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## Restoration Activities

- Riparian corridor rehabilitation
- Aquatic habitat restoration
- Bank stabilization
- Wetland creation
- Prairie restoration
- Debris removal
- Invasive and exotic vegetation removal
- Recreation Amenities (trails, observation points, docks)

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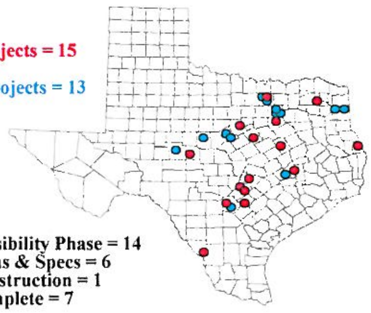
206 Projects = 15

1135 Projects = 13



Feasibility Phase = 14
Plans & Specs = 6
Construction = 1
Complete = 7

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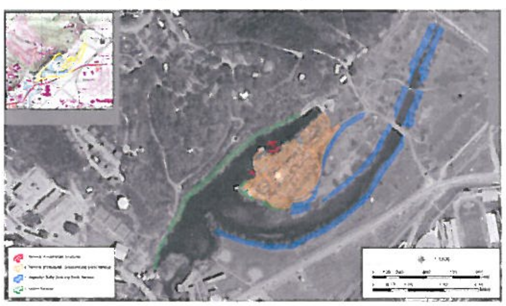
## Spring Lake 206 Project



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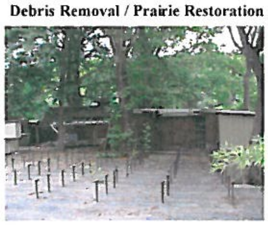
Debris Removal / Prairie Restoration



Aquatic Habitat Improvement

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## San Marcos River 206 Project

- Riparian corridor revegetation
- Exotic terrestrial & aquatic vegetation removal
- Dam removal & modification
- Debris & hardpan removal
- Nutrient & sediment control
- Sediment removal
- Wetland creation
- Recreational & educational enhancement
- Bank stabilization

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## To Request Assistance or for Additional Information, Please Contact:

Ms. Marcia Hackett
Programs and Project Management Division
U.S. Army Engineer District, Fort Worth
P.O. Box 17300, Fort Worth, Texas 76102
Email: Marcia.R.Hackett@swf02.usace.army.mil
Phone: (817) 886-1373, Fax: (817) 886-6443

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**Sample Project Request Letter**

District Engineer
U.S. Army Corps of Engineers
CESWF-EN
P.O. Box 17300
Fort Worth, Texas 76102-0300

Dear Sir:

This letter is to seek the assistance of the U.S. Army Corps of Engineers under (reference specific authority under which assistance is requested) to (identify the type and location of the problem).

(Briefly describe your perception of the nature and severity of the problem).

(Briefly describe the known issues which could affect the acceptability of any recommended solutions, from the perspective of municipal and local governments, and/or the public).

We are aware as a local non-Federal sponsor that we will assume costs for lands, easements, rights of way, relocations, and disposal areas (LERRDs) and/or assume costs to demonstrate ownership of such. We also will assume responsibility for any operation and maintenance of the proposed project.

Your consideration of this request will be appreciated. Please contact (name, address, telephone, e-mail) for future coordination.

Sincerely,

(April 2009)

Prepared by:
Jeffry A. Tripe
U.S. Army Corps of Engineers
Fort Worth District
Environmental Branch
P.O. Box 17300
Fort Worth, Texas 76102-0300

817-886-1716

**Project Milestones**

- Sponsor notifies the Fort Worth District of the problem(s) with a letter requesting assistance
- The Corps conducts an initial site investigation to determine Federal interest
- The Corps request Feasibility study funds
- The Corps conducts the Feasibility study
- The sponsor and Corps sign the PPA agreement to design, implement, and maintain the project
- The Corps prepares the Plans & Specifications
- The Corps initiates project construction
- Following completion of physical construction, a warranty period, monitoring, and/or adaptive management may be performed
- After project close-out, the non-Federal sponsor is responsible for the project's long-term operation and maintenance

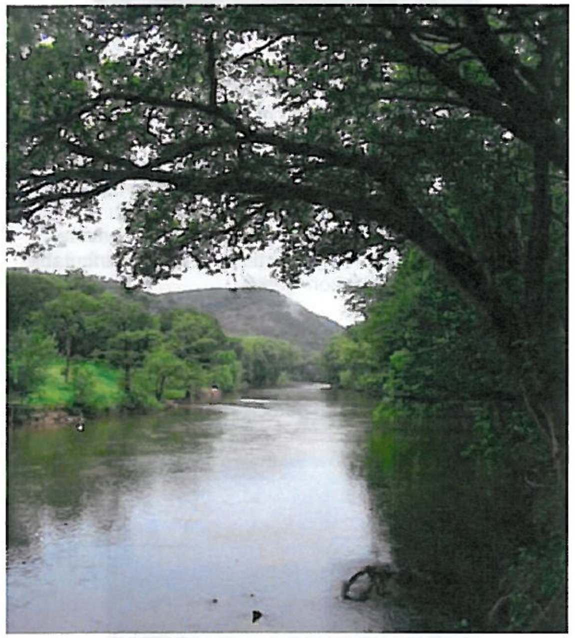
**For further information contact the Fort Worth District:**

Call: 817-886-1373
Fax: 817-886-6443
http://www.swf.usace.army.mil

Or write to:
Programs & Project Management Division
U.S. Army Corps of Engineers
Fort Worth District
P.O. Box 17300
Fort Worth, Texas 76102-0300

# Working With You

**Continuing Authorities Program**



**US Army Corps of Engineers**
**Fort Worth District**

**Introduction**
The Continuing Authorities Program (CAP) consists of a group of 10 legislative authorities under which the Secretary of the Army, acting through the Chief of Engineers, is authorized to plan, design, and implement certain types of water resources projects without additional project specific congressional authorization. A requirement for application is sponsorship and cost sharing. The sponsoring agency may be a state, county, city, or other group. Additional requirements for each of the small project authorities are detailed in this brochure.

**Purpose and Scope**
The purpose of the CAP is to plan and Implement projects of limited size, cost, scope, and complexity. To promote comprehensive collaborative planning, the formulation of multipurpose projects may be accomplished under CAP. Examples of multipurpose project categories include: flood risk management, ecosystem restoration, recreation, water supply, navigation, storm damage reduction, and education.

**Project Phases**
CAP projects shall be implemented in two phases: the Feasibility phase and the Design & Implementation phase. Each phase is carried out under the provisions of a separate cost sharing agreement that is executed between the District Engineer and the non-Federal sponsor.

**Project Cost Sharing & Agreements**
The first $100,000 of the Feasibility phase is 100 percent Federally funded. Any additional costs during this phase shall be cost shared 50 percent Federal and 50 percent non-Federal sponsor pursuant to the terms of a Feasibility Cost Sharing Agreement (FCSA). All Costs beyond the Feasibility phase are considered part of the Design & Implementation phase, with cost sharing to be specified in the authorizing legislation for that purpose. Specific requirements for the Design & Implementation phase shall be detailed in the Project Partnership Agreement (PPA).

**Sponsor Contributions**
The non-Federal sponsor has the opportunity to provide their share of project costs in the form of cash, Work-In-Kind (WIK) credit, and/or lands, easements, rights-of-way, relocations, and disposal areas (LERRDs). Cost sharing for LERRDs as well as operation, maintenance, repair, replacement, and rehabilitation (OMRR&R) varies by project authority.

**Emergency Streambank and Shoreline Erosion Protection of Public Works and Non-Profit Public Services**
Section 14 – Flood Control Act of 1946

**Project Scope:**
Provides the authority to the Corps for emergency streambank erosion protection to prevent damage to public, non-profit, or historic facilities endangered by floods or storms.

**Project Costs:**
- Sponsor pays 35% of total project costs with a minimum of 5% cash
- Maximum Federal participation is $1 million

**Beach Erosion and Hurricane & Storm Damage Reduction Projects**
Section 103 – Rivers & Harbors Act of 1962

**Project Scope:**
Provides authority to the Corps for protecting public and private properties against damages caused by storm driven waves and currents.

**Project Costs:**
- Sponsor pays 35% (hurricane/storm damage reduction), 50% (recreation), and 100% (privately owned shores) of total project costs
- Maximum Federal participation is $3 million

**Navigation Improvement Projects**
Section 107 – Rivers & Harbors Act of 1960

**Project Scope:**
Provides Corps Authority for construction of small commercial navigation projects such as jetties, channels, and breakwaters to ensure safe and efficient use of the nation's navigable waterways.

**Project Costs:**
- Sponsor cost varies by depth and type
- Maximum Federal participation is $4 million

**Shore Damage Prevention or Mitigation Caused By Federal Navigation Projects**
Section 111 – Rivers & Harbors Act of 1968

**Project Scope:**
Provides authority to the Corps for investigation and construction of projects for prevention or mitigation of shore damages to public or privately owned shores along coastlines that are attributable to Federal navigation works.

**Project Costs:**
- Cost sharing percentage correlates to the existing navigation project
- Maximum Federal participation is $5 million

**Placement of Dredged Material on Beaches**
Section 145 – WRDA of 1976

**Project Scope:**
Provides Corps authority for placement of beach quality sand, that has been dredged in navigation inlets and channels adjacent to such beaches, when the costs are greater than the least cost disposal plan, provided that (1) a State requests it, (2) it is in the public interest, (3) it is justified by a reduction in hurricane and storm damages,(4) the sponsor participates in cost sharing, and (5) public use and access are provided.

**Project Costs:**
- Sponsor pays 35% of total project costs during design & implementation

**Beneficial Uses of Dredged Material**
Section 204 – WRDA of 1992

**Project Scope:**
Provides authority to the Corps for restoration, protection, and creation of aquatic-wetland habitats associated with dredging for authorized projects.

**Project Costs:**
- Sponsor pays 25% of total project costs during design & implementation

**Small Flood Control Projects**
Section 205 – Flood Control Act of 1948

**Project Scope:**
Provides for local protection from flooding by the construction or improvement of flood control works.

**Project Costs:**
- Sponsor pays 35% of total project costs with a minimum of 5% cash
- Maximum Federal participation is $7 million

**Aquatic Ecosystem Restoration**
Section 206 – WRDA of 1996

**Project Scope:**
Provides authority to the Corps for aquatic ecosystem restoration and protection if the project will improve the quality of the environment, is in the public interest, and is cost effective.

**Project Costs:**
- Sponsor pays 35% of total project costs during design & implementation
- Maximum Federal participation is $5 million

**Snagging & Clearing for Flood Risk Management**
Section 208 – Flood Control Act of 1954

**Project Scope:**
Provides authority for minimal measures to reduce nuisance flood damages caused by debris and minor shoaling of rivers.

**Project Costs:**
- Sponsor pays 35% of total project costs with a minimum of 5% cash
- Maximum Federal participation is $500,000

**Project Modifications for Improvement of the Environment**
Section 1135 – WRDA of 1986

**Project Scope:**
Provides authority to the Corps to review and modify water resources structures and operations constructed by the Corps for the purpose of improving the quality of the environment.

**Project Costs:**
- Sponsor pays 25% of total project costs
- WIK credit toward the Sponsor share is limited to 80%
- Maximum Federal participation is $5 million

# APPENDIX 6

## United States Fish and Wildlife Service Programs

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Endangered Species Act
Section 6
Cooperative Endangered Species Conservation Fund

Section 6 grants are awarded through the state, for information about how to apply, contact Dr. Craig Farquhar at TPWD:

Dr. Craig Farquhar, Endangered Species Grants Coordinator Wildlife Division Texas Parks and Wildlife Department 4200 Smith School Road Austin, TX 78744 Office telephone: 512-389-4933 Office fax: 512-389-8043

Or for more information about the program, contact Christina Williams for questions about the "Traditional" program, or Nathan Allan for the "Nontraditional" program.

Christina Williams
Fish & Wildlife Biologist
US Fish and Wildlife Service
Austin Ecological Field Office
107ll Burnet Rd., Suite 200
Austin, TX 78758
Office (512) 490 0057 x 235
Fax (512) 490 0974

Nathan Allan
Fish & Wildlife Biologist
US Fish and Wildlife Service
Austin Ecological Field Office
107ll Burnet Rd., Suite 200
Austin, TX 78758
Office (512) 490 0057 x 237
Fax (512) 490 0974

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U.S. Fish & Wildlife Service

# Cooperative Endangered Species Conservation Fund Grants

## *(Section 6 of the Endangered Species Act)*

Because more than half of all species currently listed as endangered or threatened spend at least part of their life cycle on privately owned lands, the U.S. Fish and Wildlife Service (FWS) recognizes that success in conserving species will ultimately depend on working cooperatively with landowners, communities, and Tribes to foster voluntary stewardship efforts on private lands. States play a key role in catalyzing these efforts.

A variety of tools are available under the Endangered Species Act (ESA) to help States and landowners plan and implement projects to conserve species. One of the tools, the *Cooperative Endangered Species Conservation Fund* (section 6 of the ESA) provides grants to States and Territories to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. The program provides funding to States and Territories for species and habitat conservation actions on non-Federal lands. States and Territories must contribute a minimum non-Federal match of 25% of the estimated program costs of approved projects, or 10% when two or more States or Territories implement a joint project. A State or Territory must currently have, or enter into, a cooperative agreement with the Secretary of the Interior to receive grants. Most States and Territories have entered into these agreements for both plant and animal species.

The FWS awarded approximately $67 million in Federal funding in FY 2009 under four grant programs that are available through the Cooperative Endangered Species Conservation Fund:

*Section 6 funding has helped fragile ecosystems and the species that depend on them, such as the endangered hairy rattleweed. Photo credit Georgia DNR*

**Conservation Grants ($10 M)** provide financial assistance to States and Territories to implement conservation projects for listed species and at-risk species. Funded activities include habitat restoration, species status surveys, public education and outreach, captive propagation and reintroduction, nesting surveys, genetic studies, and development of management plans.

**Habitat Conservation Planning Assistance Grants ($ 7.6 M)** provide funds to States and Territories to support the development of Habitat Conservation Plans (HCPs) through support of baseline surveys and inventories, document preparation, outreach, and similar planning activities.

**HCP Land Acquisition Grants ($36 M)** provide funding to States and Territories to acquire land associated with approved HCPs. Grants do not fund the mitigation required of an HCP permittee; instead, they support conservation actions by the State or local governments that complement mitigation.

**Recovery Land Acquisition Grants ($14.1 M)** provide funds to States and Territories for acquisition of habitat for endangered and threatened species in support of draft and approved recovery plans. Acquisition of habitat to secure long-term protection is often an essential element of a comprehensive recovery effort for a listed species.

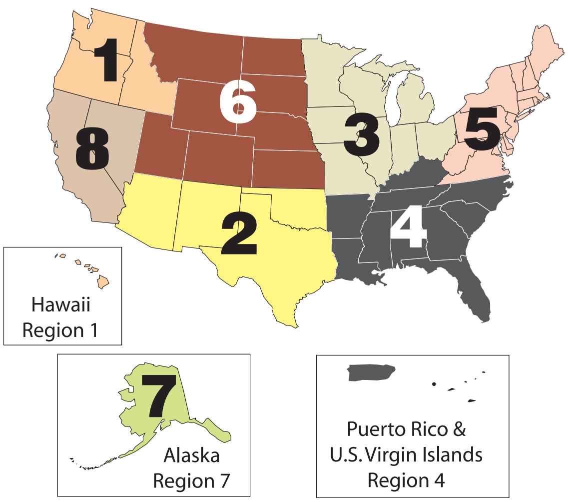
**Regional Office Boundaries**

*Region One — Pacific*
U.S. Fish and Wildlife Service
Eastside Federal Complex
911 N.E. 11th Avenue
Portland, OR  97232-4181
Program Contact: Heather Hollis,
503/231-2372

*Region Two — Southwest*
U.S. Fish and Wildlife Service
500 Gold Avenue SW., Room 4012
Albuquerque, NM  87102
Program Contact: Vanessa Sanchez,
505/248-5420

*Region Three — Great Lakes – Big Rivers*
U.S. Fish and Wildlife Service
Bishop Henry Whipple Federal Building
One Federal Drive
Fort Snelling, MN 55111-4056
Program Contact: Peter Fasbender,
612/713-5343

*Region Four — Southeast*
U.S. Fish and Wildlife Service
1875 Century Boulevard, Suite 200
Atlanta, GA  30345
Program Contact: Kelly Bibb,
404/679-7132 OR
David Dell, 404/679-7313




*Region Five — Northeast*
U.S. Fish and Wildlife Service
300 Westgate Center Drive
Hadley, MA  01035-9589
Program Contact: Alison Whitlock,
413/253-8536

*Region Six — Mountain-Prairie*
U.S. Fish and Wildlife Service
134 Union Blvd., Suite 645
Lakewood, CO 80228
Program Contact: Amelia Orton-Palmer,
303/236-4211

*Region Seven — Alaska*
U.S. Fish and Wildlife Service
1011 East Tudor Road
Anchorage, AK  99503-6199
Program Contact: Judy Jacobs
907/786-3472

*Region Eight — California and Nevada*
U.S. Fish and Wildlife Service
Federal Building
2800 Cottage Way, Room W-2606
Sacramento, CA 95825-1846
Program Contact: Diane Elam,
916/414-6464

*Section 6 funding has helped States provide unfragmented habitats for imperiled species including the grizzly bear. The purchased habitat will help meet the recovery goals for this species by providing critical connectivity of landscapes and long-term protection. Photo Credit - Dr. Christopher Servheen, U.S. Fish and Wildlife Service*

**Contact Us**

For more information on how to apply for Federal grants to assist States, Territories, and landowners in conserving species on non-Federal lands, please contact the FWS Regional office from the list below with responsibility for the State or Territory in which the proposed project would occur.

Additional information is also available at **http://www. fws.gov/endangered/grants/section6/index.html** You may also access www.grants.gov and search the site using the program title Cooperative Endangered Species Conservation Fund or by the Catalog of Federal Domestic Assistance (CFDA) number 15.615.

**U. S. Fish and Wildlife Service**
**Endangered Species Program**
**Branch of State Grants, Don Morgan**
**4401 N. Fairfax Drive, Room 420**
**Arlington, VA 22203**
**703-358-2171**
**http://www.fws.gov/endangered/**
**July 2009**

Partners for Fish and Wildlife

The following link provides information about Partners for Fish and Wildlife, which is a voluntary program that provides technical and financial assistance to private landowners to restore or enhance fish and wildlife habitats for Federal trust species (e.g. migratory birds, threatened, endangered, and candidates species and other declining species).

http://www.fws.gov/partners/

A copy of the Texas Partners for Fish and Wildlife Program brochure can be downloaded here:

http://www.fws.gov/southwest/es/arlingtontexas/pdf/PFW%20Fact%20Sheet.pdf

The statewide coordinator is Don Wilhelm, who can be contacted at:

Don R. Wilhelm, State Coordinator
Partners for Fish and Wildlife Program
U.S. Fish and Wildlife Service
711 Stadium Drive, Suite 252
Arlington, Texas 76011
817-277-1100
817-277-1129 Fax

For Central Texas, Wade Harrell and Tim Schumann are the primary points of contact for the Partners Program, and they can be contacted at:

Wade Harrell
Supervisory Fish & Wildlife Biologist
Partners for Fish and Wildlife Program
107ll Burnet Rd., Suite 200
Austin, TX 78758
Office (512) 490 0057 x 244
Fax (512) 490 0974
Mobile (512) 203 6043

and

Tim Schumann
Fish & Wildlife Biologist
Partners for Fish and Wildlife Program
107ll Burnet Rd., Suite 200
Austin, TX 78758
Office (512) 490 0057 x 245
Fax (512) 490 0974

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## Process

1. Landowner, agency personnel, etc. contacts appropriate FWS field office.

2. FWS private lands biologist conducts a site visit.

3. Proposed project developed with landowner, often with other conservation partner input.

4. Private Lands Agreement which stipulates FWS/ landowner's cost-shares, project design, and management plan is signed by landowner and submitted to FWS field office.

5. Once the project is approved at the field office level and based upon the availability of funds, the Agreement is sent to the Regional office (Albuquerque, NM) for final approval, archeological/pesticide use clearances (if necessary), and other processing.

6. Landowner receives signed agreement from FWS regional office; project construction may begin.

**Restoration of native grassland using seed hay**
Photograph by: U.S. Fish and Wildlife Service

**If you would like to learn more about the PFW program, our contact information is at the end of this brochure. We look forward to hearing from you!**


**For Further Information:**
Don R. Wilhelm, *State Coordinator*
Partners for Fish and Wildlife Program
U.S. Fish and Wildlife Service
711 Stadium Drive, Suite 252
Arlington, Texas76011
817-277-1100
817-277-1129 Fax
Visit our National PFW Program website:
**http://partners.fws.gov/**


**PFW Program Biologists in Texas:**

**Northcentral/Northeast Texas:**
Steve Arey, Arlington, 817-277-1100

**East Texas**:
Jeff Reid, Lufkin, 936-639-8546

**Texas Panhandle:**
John Hughes, Canadian, 806-323-6636

**Central Texas:**
Tim Schumann, Austin, 512-490-0057

**West (Trans Pecos)/Southwest Texas:**
Aimee Roberson, Alpine, 432-837-0747

**Southeast Texas/Upper Texas Coast:**
Ron Jones, Houston, 281-286-8282

**South Texas/Lower Texas Coast:**
Tim Anderson , Corpus Christi, 361-994-9005


**October 2008**


**Front cover: Texas Coastal Prairie**
*Photo by: U.S. Fish and Wildlife Service*

**U.S. Fish and Wildlife Service**

# Partners for Fish and Wildlife Program

# *Texas*

## ACCOMPLISHMENTS
### 1990-Present

**The U.S. Fish and Wildlife Service has entered into over 1,300 voluntary partnerships with private landowners, involving the restoration or enhancement of over 325,000 acres of fish and wildlife habitat in Texas, including:**

- **62,000 acres of wetlands,**
- **6,500 acres (188 miles) of riparian area,**
- **165,000 acres of grasslands,**
- **43,000 acres of woodlands and shrublands, and**
- **49,000 acres of habitat for endangered, threatened, or candidate species.**

## General Information

The Partners for Fish and Wildlife (PFW) program is a voluntary conservation program that provides technical and financial assistance to private landowners to restore or enhance fish and wildlife habitats for Federal trust species (e.g. migratory birds, threatened, endangered, and candidates species and other declining species). The PFW program has been very well received by our participating private landowner Cooperators. Several Cooperators have been honored as recipients of National and Regional wetland stewardship awards and also with local Wildlife Conservationists awards. A close working relationship exists with personnel from other State and Federal conservation agencies and private conservation organizations.

### Texas PFW Activities

- **Restoring habitat for migratory birds and declining, threatened, and endangered species in:**
    - **Grasslands**
    - **Riparian corridors and other wetland areas**
    - **Longleaf pine forests, central Texas shrublands, and south Texas brushlands**
    - **Other specific habitats for rare species**
- **Establishment of native vegetation**
- **Wildlife and livestock management**
- **Protection of rare natural resources**
- **Controlling invasive & non-native vegetation**
- **Public outreach and education**

## Habitats of Special Concern

*Grasslands*

Native grasslands are some of our most imperiled habitats in North America. Today, less than .5% of the tallgrass prairie in Texas remains in relatively pristine condition. What remains of our native grasslands is being rapidly consumed by urbanization and brush encroachment.

**Lesser prairie-chickens during courtship displays on lek at a PFW project site in the Texas panhandle**
Photograph by: U.S. Fish and Wildlife Service

*Riparian Areas and Other Wetlands*

Of an original 16 million acres of wetlands in Texas, it has been estimated that over one-half have been lost. Restoration of coastal wetlands, wetlands within the floodplains of river, and other isolated wetlands scattered across Texas, provide wetland functions lost due to human activities which have adversely affected natural ecological functions.

**Landowner and future generation enjoying restored wetland area**
Photograph by**:** U.S. Fish and Wildlife Service

*Unique Habitats and Restoration Activities*

The PFW program also places a high priority on opportunities to restore unique or rare habitat types across the State. These include the longleaf pine forest in east Texas, south Texas brush, Karst systems in central Texas, as well as habitats which support federally listed plants or animals.

**Longleaf pine restoration project in east Texas**
Photo by: U.S. Fish and Wildlife Service

*Outdoor Learning Areas*

The PFW Program funds outdoor learning areas intended to provide schoolchildren and communities with "hands-on" educational opportunities. These projects benefit fish and wildlife and the human communities that learn from them.