Eco-Hydrology Research Project Proposal
C.L. Browning Ranch, Blanco County, Texas
February 26, 2008

Introduction

The C.L. Browning Ranch, located four miles east of Johnson City, Texas, is in the process of planning a long-term (twenty years) land management research project. This project will document changes in hydrology, vegetation and aquatic biodiversity that result from brush clearing, native vegetation restoration, and prescribed fire. The project intent is to identify land management practices that will increase water supply, improve range productivity and enhance the natural environment for wildlife. It is anticipated that the research results will help private landowners and other land stewards better manage upland aquifer systems in the Hill Country and throughout Texas.

The Browning Ranch is particularly well suited to this project because it contains four similar abutting tributaries that drain to a central creek. The preliminary vision of the project is to use half (2) of the tributaries for active management (~150 acres), and half as a control (~150 acres). In order to accurately measure the effects of various vegetation management techniques on the hydrologic and living systems, it will be necessary to employ the most up to date methodologies and monitoring techniques. Therefore, the C.L. Browning Ranch is seeking partners to plan and conduct the project, disseminate project results and share in project costs. Costs for the proposed research project are estimated to be $285,000.00 to install and $50,000 plus 8% inflation annually to maintain.

Site Description

Location and Setting

The C.L. Browning Ranch is located on the south bank of the Pedernales River, four miles east of Johnson City in Blanco County, Texas. This area is on the eastern edge of the Edwards Plateau and the general area is known as the Texas Hill Country. The Pedernales River drains into Lake Travis and the Colorado River.

The Ranch receives 30-32 inches of precipitation annually in bimodal form with typically wet springs and falls. The climate is classified as semi-arid/sub-tropical. Both droughts and flash floods are common.

Description of Watersheds

The Ranch consists of 977 acres of a 1,240 acre Honeycutt Hollow Creek watershed that drains directly into the Pedernales River. Honeycut Hollow Creek is the main drainage on the ranch, flowing north to the Pedernales River. It is a perennial stream below the Honeycut Hollow Creek Spring. Several ephemeral creeks or channels feed into Honeycut Creek. Four ephemeral creeks feed into Honeycut Creek from the west (from north to south): Turkey Creek, Red Tail Creek, Rock Creek, and Walnut Creek. The four tributary watersheds range in size from 45 acres to 112 acres with the highest elevation at 1,300 feet and the lowest elevation at 1100 feet. Slopes in the watersheds range from 5 to 20 percent with majority of the study area in the 10 to 15 percent slope classes. Water budget information is needed under pre-treatment conditions to define precipitation, runoff, and recharge in each watershed and account for the amount of baseflow each contributes to Honeycut Creek. The Pedernales River drains into the Colorado River.

Geology and Hydrology

Two main objectives of this part of the Browning Ranch watershed studies are (1) to better define the contact between the Glen Rose Limestone and the Hensel Sandstone that underlie the watersheds, and (2) to determine the depth of the water table and formational contact across each of the four creek valleys. The objectives were accomplished through observations of where the formational contact crops out and through geophysical sounding of the shallow subsurface.

Because the base-level discharge of water at the main Honeycut Creek Spring is sustained by groundwater flow through the aquifer and groundwater discharge at the spring, it is necessary to understand the hydrogeology of the aquifers that underlie the ranch in order to relate ecological changes (land management practices) to spring flow and other hydrologic aspects of the riparian habitat along Honeycut Creek.

The upper watersheds of the Browning Ranch are floored by Cretaceous-age limestone, marl, and sandstone of the Trinity Group. The Glen Rose Limestone caps the upland areas around the perimeter of the range. This rock is resistant to weathering and tends to hold up steep slopes. Below the Glen Rose lies the Hensel Formation. The Hensel sandstone, a thin layer approximately six to nine feet thick at the ranch, is not well cemented and underlies only part of the broad terrace of land between Honeycut Creek and the Glen Rose "upland escarpment." The sandstone layer of the Hensel is underlain by a thicker limestone layer thought to be a Cretaceous-age pedogenic (formed from soil processes) caliche. Erosion of Honeycut Creek valley has cut through the Hensel Formation in the northern part of the ranch and exposed the Cow Creek Limestone. The northernmost part of Honeycut Creek downstream of Honeycut Creek Spring exposes Paleozoic rocks, part of the so-called Llano Uplift aquifer.

There is an erosional unconformity between the Cretaceous rocks and the underlying lower Paleozoic rocks of the Ellenburger Group. The limestone and sandstone of the Ellenburger Group crop out in the valley and north of the Pedernales River, and occur at depth at the ranch beneath the Trinity Group.

The ranch lies at the northern edge of the Hill Country Trinity Aquifer (Mace and others, 2000). The Glen Rose and Hensel Formations where they are saturated with water make up part of the Trinity Aquifer. The general conceptual hydrogeologic model for the ranch is that ground water flow in the Trinity Aquifer is directed from recharge areas to discharge areas. The local recharge area at the ranch would include the broad upland area underlain by the Glen Rose and the terrace underlain by the Hensel. Recharge from infiltrated rainwater would move both downward beneath the upland areas and laterally toward Honeycut Creek and toward the Pedernales River. The general conceptual hydrogeologic model for the ranch is that groundwater moves from recharge to discharge areas along local-scale (e.g., discharge to Rock Creek), intermediate-scale (e.g., discharge to Honeycut Creek), and regional-scale (e.g., discharge to Pedernales River) flow paths:

- The shortest path (10s to 100s of feet) for groundwater to take is from recharge in the upland area to discharge as springs and seeps along the small channels of Turkey, Red Tail, Rock, and Walnut Creeks. This local flow path could be very curving or arcuate but would generally be from west to east with small north and south components directing water to the channel seeps.

- An intermediate-length flow path (100s to few 1000s of feet) would be from the upland recharge areas but with deeper downward circulation and with upward discharge in the lower reaches of Turkey, Red Tail, Rock, and Walnut Creeks, the upper reach of Honeycut Creek, or into the Paleozoic rocks beneath and subjacent to Honeycut Creek. Direction of flow is mainly eastward. Water that has moved cross-formationally into the Paleozoic rocks along Honeycut Creek might flow northward through karst bedding plane fractures to discharge at Honeycut Creek Spring.

- A long regional flow path (several 1000s of feet) would take recharged groundwater downward beneath upland areas into the underlying Paleozoic

Honeycut Creek Spring probably does not capture all of the groundwater flowing in the Paleozoic rocks beneath Honeycut Creek along the intermediate-scale flow path. Some groundwater flow would most likely bypass the spring and move in conduits to discharge farther north closer to the Pedernales River.

These three hypothesized local-, intermediate-, and regional-scale flow paths for groundwater at the Browning Ranch reflect an inferred three-dimensional flow field controlled by the location of recharge beneath the upland areas and the Hensel terrace and location of discharge areas in the watershed's creeks, Honeycut Creek, and the Pedernales River. The effect of karst heterogeneities on short-circuiting these flow paths is only beginning to be understood at the Browning Ranch. Honeycut Creek Spring appears to be a karst-fed spring at a solution-enlarged bedding plane. It is likely that a variety of karst conduits move water vertically and laterally in preferential flow paths on all these inferred scales of flow. The karst features of limestones typically mean that much of the water may be stored in unfractured matrix between karst conduits while the highest flow rates take place within the conduits. Groundwater moves into the matrix from the conduits during recharge events when fluid pressure in the conduits is high, and back out of the matrix into conduits during the recession-flow stage between recharge events, as long as the conduits remain saturated.

Small pools of standing water are found in the channels in the upper reaches of all watersheds throughout the year under normal rainfall conditions. Non-storm related streamflow (i.e., baseflow) is seen along most of the length of stream courses only during the dormant winter season. A large, but still unknown, portion of stream flow in the tributaries falls through the fractured base of creeks before reaching the confluence with Honeycut Creek.

The Glen Rose Limestone and Cow Creek Limestone can include karst solution features where fractures in the rock have been enlarged by dissolution. The main spring along Honeycut Creek shows some solution-enlarged joints. Groundwater issuing at the spring probably is flowing along solution-enlarged bedding planes and the vertical dissolution joints. The amount of karst features that might influence flow in the Glen Rose is not well known. Some of the region's main commercial and private caves are in the Glen Rose. While the Glen Rose beneath the ranch might not have significant caves, there could still be enough karst features to influence the storage and movement of groundwater.

Small pools of standing water are found in the upper reaches of all watersheds throughout the year under normal rainfall conditions. Most non-storm related stream-flow is seen throughout the stream course during the dormant winter season. A large, but still unknown, portion of stream-flow in the tributaries falls through the fractured base of the creek before reaching the confluence with Honeycutt Hollow Creek.

Review of Surficial Geology

Initial hydrogeological inspections at the Browning Ranch in late 2006 suggested the importance of mapping the stratigraphic contact between the Glen Rose Limestone and the Hensel Sandstone for siting surface-water gauging stations. Barnes (1982) shows a broad terrace underlain by Hensel Formation between the Glen Rose “upland escarpment” and Honeycut Creek. The Hensel is known in many locations as a sand-rich formation. The casual first impression of the terrace at Browning Ranch, therefore, was that it would be underlain by the easily weathered Hensel sandstone, which would account for the low topographic profile of the terrace. The early conceptual model of the site specified recharge in the upland Glen Rose limestone, runoff and baseflow to channels, some cross-formational flow into the Hensel, and various gaining and losing reaches of the channel crossing the Hensel terrace. This conceptual model underscored the need to separately gauge and monitor surface water flow at the contacts above and below the Hensel Formation to define the net base-flow contribution to flow from the Glen Rose.

This conceptual model, however, needs to be refined to incorporate the observation that the Hensel Formation at the Browning Ranch includes a thin upper sand and a thick, well-cemented caliche zone. Another hydrologic unit that might need to be taken into account is a black clay and limestone-float colluvium within and lining the floor of the small watershed channels.

Observations include:

- A contact between the Glen Rose limestone (base of Glen Rose) and Hensel sand (top of Hensel) is reported and exposed in a road cut along FM 2766 a few miles west of Browning Ranch (Follett, 1973). The Hensel sand at that location is friable, somewhat arkosic, and clayey. The Hensel sand at that road cut, however, is less than six feet thick. Beneath the sand is a well-indurated, hard, and massive limestone. That Hensel limestone is interpreted to be a Cretaceous-age pedogenic (formed from soil processes) caliche (Prochnow, personal communication, November 2007).

- The lower beds of the Glen Rose Limestone are readily recognized across most of the Browning Ranch. No contact of the quality seen on the FM2766 road cut, however, is easily found on the Browning Ranch, as discussed in the following bullet. The limestone that floors the ranch road across Rock Creek is thought to be equivalent to the Hensel caliche seen in the FM 2766 road cut. The Hensel sand on the Browning Ranch must be a bed that is less than five to six feet thick and occurs between recognizable lower Glen Rose limestone and the massive “caliche” limestone.

- Clean exposures of the thin Hensel sand are hard to find at the Browning Ranch because the sand is easily weathered and has been covered by a veneer of colluvium consisting of limestone flagstone ‘float’ and clay transported from the residual limestone soils. It is especially hard to pinpoint the contact within the channels of Turkey, Red Tail, Rock, and Walnut Creeks because of the history of scour and deposition that has occurred. In the past, significant surface water flow has cut the channels into the bedrock, more deeply in the easily weathered sand than in the limestone. More recently, soil creep, mass wasting, and sedimentation under slow flow conditions have filled in the older incisions in the Hensel sand. Shallow hand-dug excavations in the channel beds, therefore, only show colluvium made up of black clay, carbonate rock fragments, and small caliche nodules.

- Although the Hensel sand is only five to six feet thick at the Browning Ranch, it underlies a breadth of the terrace owing to the low topographic slope. It is not well exposed at ground surface or in stream channels but is covered by mixed colluvium, soil, and limestone-flagstone float.

To precisely locate the stratigraphic contact will require a number of boreholes drilled by powered flight auger, for example, a two-person post-hole auger. Auger depths of two to three feet are expected to be sure the colluvium is penetrated and Hensel sand is sampled.

Discussion

These geological observations and inferences suggest a need to (1) refine the conceptual model of local-scale flow systems to account for thin Hensel sand, thick Hensel caliche, and channels locally clogged with colluvium, and (2) use additional data to map hydrological flow units in the watersheds as a basis for siting permanent gauging stations for separating runoff from baseflow.

Siting permanent surface-water gauging stations precisely at the "formational" or "stratigraphic" contact between the Glen Rose Limestone and the uppermost sand bed of the underlying Hensel Formation solely on the basis of surface geology will be difficult. The formational contact is obscured by colluvium beneath most of the Browning Ranch. The Hensel sand is easily weathered and appears to have been scoured out to some depth (a guess of a few feet) beneath the channels of the Rock Creek and adjacent watersheds, but those incisions have since been filled in with colluvium. The colluvium itself might complicate local baseflow discharge along the channels.

Additional measurements are proposed to directly measure where the amount of baseflow changes along the course of Rock Creek, and other drainages, as a basis for siting permanent gauging stations. The location of the "hydrologic contact" between flow units can be defined at least as accurately as the stratigraphic contact that is covered by colluvium. The advantage is that one does not have to assume that flow units are identical to stratigraphic units. Also, flow mapping might show where seeps and springs are concentrated by karst activity such that gauge siting just needs to be between main seepage zones.

A transect of streamflow measurements in the small channels of the watersheds can be made, as described in Dutton (2008). This transect should demonstrate whether significant changes take place in rates of groundwater discharge along the length of the channel and where they occur.

The location of the "hydrological contact" between flow units can be defined at least as accurately as the "stratigraphic contact" obscured by colluvium. The advantage of siting the permanent gauging stations on the basis of direct baseflow-measurements is that one does not have to assume that the flow units exactly match the stratigraphic units. Direct baseflow measurements can also indicate, for example, where (possibly karst controlled) springs and seeps contribute most of the base flow within the Glen Rose and with in the Hensel. Locating the surface-water gaging station anywhere between these main seep areas might suffice if the baseflow contribution of the remaining stretch is negligible in comparison.

Vegetation

There is no evidence that fire has been present on the Browning Ranch for at least the last 65 years. As a result, the ranch is 70 percent wooded except for a few abandoned agricultural fields. This produces the vegetation pattern of heavily wooded uplands with less dense bottomlands. The upper elevations of the watersheds are dominated by Ashe juniper (*Juniperus ashei*) and live oak (*Quercus fusiformis*). Most of the upland is in the Steep Adobe range class, and is dominated by King Ranch bluestem. In the lowlands, live oak (*Quercus fusiformis*), cedar elm (*Ulmus crassifolia*), and post oak (*Quercus stellata*) can be found. Much of this area falls in the Clay Loam range class with more little bluestem (*Schizachyrium scoparium* var. *frequens*), and King Ranch bluestem (*Bothriochloa ischaemum* var. *songarica*). Riparian area vegetation consists of plane-leaf sycamores (*Platanus occidentalis*), black walnut (*Juglans nigra*), cedar elm, and live oak. Canadian wild-rye (*Elymus Canadensis*) and several annual and perennial herbaceous plants dominate the creek banks. Bank vegetation along the six creeks is continuous except for a few cattle trails and road crossings, and consists mostly of sedges (*Carex* spp.), rush (*Juncus* spp.) bushy bluestem (*Andropogon glomeratus*), Lindheimer muhly (*Muhlenbergia lindheimeri*), and King Ranch bluestem.

900 meters of vegetation transect in each of the four tributary watersheds were sampled in the fall of 2006, and again in the spring of 2007. Three 300 meter transects were established perpendicular to the direction of stream flow and include the three topographical variations found in each tributary watershed; upland, slope, and bottomland. 162 vegetation species were identified during these sampling events. Soil moisture and biomass levels were additionally recorded.

History of Land Use

Before Mr. C.L. Browning purchased the Ranch in 1942, the land was used for subsistence farming and ranching dating back to 1836. During Browning family ownership, cattle grazing continued with occasional periods of over-stocking. Brush clearing took place only in the lowlands, leaving the tops of the hills and slopes untouched. This consistent management history results in a very similar vegetation pattern for the study watersheds.

Project Preparation

Through the present (2008), activity on the project has involved contacts with the Texas Water Development Board, the Texas State Soil and Water Conservation Board, and the U.S. Geological Survey to discuss the initial potential for the project. In 2006, the University of Texas at San Antonio – Center for Water Research began a Geo-physical Assessment of the Browning Ranch tributary watersheds to model hydrogeologic properties. Again in 2007, the US Geological Survey began a Gain / Loss Survey on Honeycut Hollow Creek to define streamflow characteristics. In 2006, Texas State University – Department of Biology surveyed 3600 meters of vegetation in the tributary watersheds to record baseline conditions. Additional contacts have been made with the Lady Bird Johnson Wildflower Center, Texas A&M Department of Rangeland Ecology and Management, Blanco-Pedernales Groundwater Conservation District, Lower Colorado River Authority

Browning Ranch Accomplishments

Since 2003, the Browning Ranch has cleared over 600 acres under cost-share programs with the Texas Soil Water Conservation Board and the Texas Forest Service. Previous research projects on burn site revegetation have been presented at Society for Ecological Restoration and Private Forest Landowners Association conferences. Baseline wildlife data has been collected with the assistance of Texas A&M University, Travis Audubon Society, Texas Parks and Wildlife, and Texas State University. Prescribed burning and vegetation sampling have been conducted in association with the Lady Bird Johnson Wildflower Center. In April, 2006, the Browning Ranch was awarded the Forest Steward Award by the Texas Forest Service.

Project Description

General Assumptions

The Edwards Plateau region in central Texas has undergone significant change in less than 150 years. Today woody species, especially Ashe juniper (*Juniperus ashei)* and escarpment live oak (*Quercus fusiformis*), dominate the once oak-savannah grassland. This change in vegetative cover is believed to have dramatically affected the ability of land to absorb and store rainwater (Thurow, 1991). The thick canopies of these densely growing species impedes a higher percentage of rainfall from flowing through to the ground surface and inhibits the establishment of most herbaceous species, particularly deep rooted grasses, that are believed to aid in water infiltration into the soil, and reduced transpiration loss.

Evidence suggests (McCalla II, et.al 1984; McGinty, et.al 1991; Thurow et.al 1986) that as grazing pressure and woody vegetation cover increase over central Texas, runoff related sediment yield increases as sub-surface percolation decreases. The karst upland aquifer system of the Edwards Plateau relies upon infiltration through porous limestone at the tops of the watershed for recharge. Lower percolation in this upper portion of the aquifer results in reduced base flow from seeps and springs that supply many of the creeks and rivers of the region and contribute to a significant portion of the drinking water for the majority of the areas inhabitants. Recent decades have seen several first- order streams of the Hill Country dry up completely. This imbalance reduces freshwater ecosystem services and increases the number of aquatic organisms threatened by habitat adjustments (Jackson 2000)

Observation of land management programs of brush clearing followed by re-seeding of native grasses suggests that these practices can influence the rate of evaporation, runoff and groundwater percolation (Dugas 1998; Thurow 1991). However, there is comparatively little empirical data on stream flow. Related on-going studies include the Leon River Restoration Project, Seco Creek Project, and Honey Creek State Natural Area.

One main question is how the soil water and groundwater beneath the ranch respond to changing infiltration, and ultimately, to changes in the surface ecology associated with vegetation, water budget, and physiography.

We will start the project by assuming that there is a saturated groundwater zone within the Glen Rose. This saturated zone might usually or occasionally discharge to seeps and small springs around the edge or lower part of the upland escarpment. We will also assume that there is a thin shaley zone between the Glen Rose Limestone and the Hensel Sand. This thin shaley zone could retard the vertical movement of groundwater downward from the Glen Rose to the Hensel, and help to keep groundwater perched in the Glen Rose. We don't know how constant or ephemeral the water table aquifer in the Glen Rose might be. If the saturated part of the Glen Rose is thin, during drought years the part of the formation near the escarpment might go dry.

We do not know whether the entire thickness of the Hensel Sand is saturated or whether there is a free water surface or water table beneath the top of the Hensel. If downward flow from the Glen Rose is restricted and the Hensel and Glen Rose are slightly separated by a shaley interval, saturated conditions in the Glen Rose might be perched above a partly saturated Hensel section.

The Hensel most likely is recharged by downward flow or leakage from the Glen Rose. The Hensel might also be locally recharged at the ranch across the broad relatively flat plain where the Hensel crops out. We assume the Hensel discharges both to ephemeral creeks that cut into the Hensel and to the underlying Cow Creek Limestone.

General Questions

- Does vegetation management have an impact on creek flow, infiltration, and/or sediment yield?
- What controls the locations of perennial and ephemeral springs and seeps in hill country watersheds?
- Does vegetation management have an impact on the subsurface, terrestrial, and/or aquatic biota?
- How thick is the unsaturated zone in different parts of hill country watersheds?
- Is there a connection between shallow groundwater circulation in hill country watersheds and deeper circulation in regional aquifers?
- How perennial or ephemeral is the water-table aquifer in the Glen Rose Formation?

- What controls the perching of groundwater in the Glen Rose Formation?
- How much of the Hensell Sand tends to be saturated with groundwater?

RESEARCH PLAN

The basic study design uses a reference and treatment watershed approach. After baseline data collection objectives are met, the project will enter the Pre-treatment period. Data are to be collected simultaneously in the four watersheds during the first five years in order to collect a range of meteorological conditions. No treatment occurs on the watershed during this period. At the conclusion of the Pre-treatment period, a continuous vegetation management program (treatment) will begin in two of the four tributary watersheds. Initial juniper control will be accomplished using skid-steer/hydraulic shear and chainsaw crews. Native grass seed will be broadcast over the upland areas and around canyon rims. Four years after seeding, each treatment watershed will enter a five-year growing-season burn management cycle. Two growing seasons after a fire treatment, rotational grazing will occur in the treatment watersheds. All treatments will occur on the same year.

Data Acquisition

Interpretive geophysical surveys

The University of Texas at San Antonio – Center for Water Research (UTSA-CWR) plans a sequence of steps to collect and build on hydrogeological information. The first phase of study has three steps, which are intended to:

- provide information needed to design the surface water monitoring system,

- improve the conceptual model of the occurrence and movement of ground and surface water at the ranch, and
- provide a basis for interpreting how land management practices could influence spring flow and quality of riparian habitat that depends on groundwater discharge.

UTSA-CWR conducted seismic surveys, resistivity surveys, and ground conductivity electromagnetic surveys to indicate how the strike, dip, and elevation of the formations vary across the ranch, where the water table(s) lie at depth, and what the saturated thickness is in the Glen Rose and Hensel. The surveys were conducted at several locations within each geomorphic setting for each watershed, including the plateau on the Glen Rose, the plain on the Hensel, and along the trend of Honeycut Creek. Approximately 12 surveys in each watershed were conducted in the first phase of study, which defined the subsurface hydrogeologic setting in both wet and dry periods.

Gain/Loss Survey

Three Gain / Loss Surveys on Honeycutt Hollow Creek streamflow were conducted by the US Geological Survey. The gain/loss survey includes measurements made at seven cross sections starting at an upstream point near the southern boundary of the Browning Ranch upstream from the main spring orifice of Honeycutt Hollow Spring, to the confluence with the Pedernales River on the northern boundary of the Ranch.

Continuous Rainfall Data Collection

We will install one 12 inch Nova-Links rain gauge at Ranch Headquarters to begin baseline meteorological data collection. Data will be recorded at five-minute intervals.

Field Geology

Additional hydrogeological observations can be taken at ground surface:

(a) location and elevation of springs and seeps in the four studied watersheds;
(b) location of the contact between the Glen Rose and Hensel.
Our GIS map of the ranch will form the basis for collecting and storing mapped observations of where there are or might be springs and seeps in the four studied watersheds. Both direct and indirect evidence will be noted and recorded. To map out the contact between the Glen Rose and Hensel we can use a post hole digger, a backhoe, or both to make shallow excavations to expose the actual formational contact.

Test Well Borings

The conceptual hydrogeologic model for the Honeycutt Hollow watershed is that rainfall that does not runoff into the surface drainage system will percolate through the area's characteristic thin soils and enter the Glen Rose Limestone. Within the limestone, the recharge water flows through a network of solutionally-enhanced features, eventually concentrating at a local discharge point, such as a perennial and/or wet-weather springs emitting from the limestone outcrop throughout the Honeycutt Hollow watershed.

Test borings are needed in order to provide local control for interpretative geophysical surveys. One or two bore holes in each watershed would provide calibration data to ground truth the geophysical results. The paired test wells within each tributary watershed will be at different depths, representing the predominate underlying geology at various depths. The boreholes should extend at least to or below the elevation of the outfall of Honeycut Creek where it leaves the ranch, and into at least the upper part of the Lower Paleozoic Aquifers if possible. UTSA can deploy well-bore tools to log the drilled boreholes. All bore-hole locations will be mapped using GPS. The continuous data record, collected at 30-minute intervals, will be used to monitor possible changes in storage in the Trinity aquifer system.

Monitoring System Design

Surface Water Monitoring System

Surface-water gaging stations will be installed at five sites to continuously monitor streamflow discharges in the four tributary watersheds and the entire Honeycut Hollow Creek watershed. Stations will be located at the base of each tributary watershed above the confluence with Honeycut Hollow Creek. The tributary stations will include a surface water gauges and rainfall gauges. An additional surface-water gage will be located on Honeycutt Hollow Creek, down stream of the Honeycutt Hollow spring. This gage will include an auto sampler and a water quality monitor.

Theoretical weir-ratings will be used to quantify streamflow at the five streamflow gaging stations. Weirs will be constructed to design specifications so that every weir will be a flow-measuring device. The weir design will accommodate the expected range of discharge with the minimum amount of error within the expected range. Crest stage gages will be installed at each streamflow gaging station to verify peak stages. When possible, direct measurements of streamflow will be made to verify theoretical discharges.

To determine if changes in springflow occur after Ashe juniper removal in the treated watersheds, discharge from Honeycutt Hollow Spring will be measured continuously at five-minute intervals before (5 years) and after (15 years) treatment.

Meteorological Monitoring System

A total of five rain gauges will be used to adequately measure rain falling on the Browning Ranch. One rain gauge will be in conjunction with a full parameter weather station located in the vicinity of the Honeycut Hollow Creek gage. The remaining four will be located at the surface-water gages in the tributary watersheds. Rainfall data will be collected every five minutes to facilitate analysis rainfall-runoff relations, suspended-sediment loads, soil-infiltration rates, and groundwater recharge.

Two Eddy covariance micrometeorology systems (ET stations) will be used to compute daily actual evapotranspiration data on a continuous basis. The ET stations will situated to provide coverage over the tributary watersheds; one to represent the treated area, the other to represent the control area. Site locations will be similar in phreatophyte growth, wind-fetch, and topography. ET parameter measurements will be made at 15-minute intervals and will include: air temperature, relative humidity, wind speed and direction, net solar radiation, soil temperature, and soil moisture. From these parameters, calculations of ET will be made using the Eddy covariance method.

Vegetation Monitoring System

Vegetation data has collected to compare the herbaceous and woody plant response to brush clearing versus no clearing. It is hypothesized that total herbaceous plant matter will increase in the treatment watersheds, and decrease in the control watersheds. Special attention will be given to changes in riparian zone vegetation. It is further hypothesized that after brush management, the resulting increase in rainfall infiltration will increase the riparian zone of saturation. With increased zones of saturation, the resource availability for obligate and facultative wetland species increases. As the zone of saturation moves down stream, obligate and facultative wetland species will be able to increase in range and frequency.

Pre-treatment vegetation conditions have been determined through a 3,600 meter transect configuration, sampled bi-annually. Three 300-meter transects are permanently marked out in each of the tributary watersheds; one in the upland, one in the middle, and one in the lowlands. Each transect is centered on and runs perpendicular to the stream course. Five $10m^2$ quadrats per transect are situated on 75 meter intervals. Within each $10m^2$ quadrat, five $1m^2$ quadrats are nested so that the outside corners form $5m^2$ squares inside the larger quadrat. The five $1m^2$ will be utilized to measure and analyze herbaceous vegetation. The $10m^2$ and $5m^2$ will be utilized to measure and analyze the woody vegetation. . Fifteen (one per quadrat) 1-square meter plots in each watershed will be utilized to measure total biomass. Each plot lays tangent to the perimeter of its quadrat. After total biomass is collected and weighed, the sampling plot will be moved to a different location around the perimeter of the 10m^2 quadrat, to reduce the disturbance that is inherent in biomass collection.

The bank vegetation of each first order creek will be mapped using a frequency sample technique. A list of 30 locally common wetland indicator species will be drafted from which each creek will be assessed for the presence and total coverage area of these species. Obligate or facultative wetland species residing within the riparian zone will be identified, measured and mapped. Percent coverage along the riparian zone for each species will be calculated. Subsequent sample events will indicate an increase or reduction in colony size for the 30-wetland indicator species. Those data will indicate the rate at which the zone of saturation increases after brush clearing.

Aquatic Biodiversity Monitoring System

The response of aquatic ecological integrity to brush clearing will be measured. It is hypothesized that the increase in annual days of flow in the treatment watersheds will increase aquatic species richness, while overall species abundance decreases in the control watersheds. As the flow in the first order creeks becomes more consistent, a broader range of aquatic habitat needs will be met, resulting in increase biodiversity values.

A two - year baseline study to document spatial and temporal trends in the tributary watersheds, Honeycutt Hollow creek, and Pedernales River will determine fish and micro-invertebrate assemblage and habitat types. Once variability in temporal and spatial patterns is established, treatment practices in the tributary watersheds can be assessed to determine impacts (positive or negative) on the aquatic fauna and habitat. Changes in standard water quality parameters will be monitored in response to brush clearing. We hypothesize that increased rainfall effectiveness, resulting in increased stream flow consistency, will increase diversity levels in the treatment watersheds. The shift from woody species to herbaceous matter may provide a rainfall filtering effect as well and will moderate the impact on the soil during intense rain events, possibly resulting in reduced suspended and dissolved solids.

Macro-invertebrate assemblages and habitat composition at six sites along each of the six creeks will be documented. Two sites will be located at the gauging station stilling pool, two sites will be located in a natural pool structure, and the last two sites in a ripple zone. Three D-kick net samples per site will collect the organisms for on-site identification. Sample sites will be graded based on the Index of Biological Integrity values for indicator species.

Water quality field computers will collect all water quality parameters, such as pH, dissolved oxygen, percent saturation, temperature, total dissolved solids and total suspended solids, at each site for each sample date. Field observations and pictures of vegetation or substrate conditions will also be recorded to document any changes in streambed morphology.

Model Creation

After the five year Pre-treatment Data Collection period, all inputs will be processed along with the established hypothesis in the creation of a response model to the treatments. Five models will be created; one for each tributary watershed and one for the entire Honeycutt Hollow watershed.

At the conclusion of the Post-treatment Data Collection period, actual results will be compared to the models for analysis. All models could then be revised to illustrate the assumed/actual results for the project.

The final product then becomes field-verified models at two scales that quantify the actual results of Ashe juniper control on central Texas rangeland. These models will be published and distributed to all interested research and policy-making entities.

Post Processing Data Analysis

Baseline differences between the hydrology and water quality for the four-paired watersheds will be determined by use of statistical methods at the end of the Pre-treatment period. Analysis thereafter will be made every three years, producing four reports throughout the project. Hydrologic parameters compared will include unit-storm runoff, unit peak discharge, spring discharges, evapotranspiration, and potential evapotranspiration. Compared water quality parameters will be storm event flow-weighted water-quality constituents, storm rainfall constituents, and spring water-quality constituents. Vegetation parameters compared will be computed through an analysis of variance (ANOVA) and will include cumulative canopy, and percent bare ground.

Work Plan:

2007	Geophysical survey; Gain/Loss survey; Field geology
2008	Test borings; Post-processing analysis; Monitoring systems design
	Proposal completion; contractual funding arrangements
2009	Monitoring systems installation and test-run
2010	Pre-Treatment Data Collection and Model creation phases begin