DEVELOPMENT OF AN EDYS ECOLOGICAL MODEL OF THE CENTRAL SAN ANTONIO RIVER WATERSHED: KARNES AND WILSON COUNTIES

DRAFT FINAL REPORT

PREPARED FOR:

SAN ANTONIO RIVER AUTHORITY
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EXECUTIVE SUMMARY

San Antonio River Authority (SARA) is interested in developing an integrated set of ecological simulation models for the San Antonio River system. To accomplish this, EDYS ecological models are being developed for each county along the San Antonio River. The models can be used as individual models or can be linked so that the entire San Antonio River watershed can be simulated. The first two models of this project are for Karnes County and Wilson County. This report presents descriptions of these two models, including the calibration process, and ecological and hydrological results from ten land management simulation scenarios.

Description of the Models

Karnes County covers about 754 mi^2 (482,291 acres) and Wilson County covers about 809 mi^2 (517,485 acres). Wilson County is located to the immediate southeast of Bexar County and Karnes County immediately southeast of Wilson County. The San Antonio River flows through the centers of both counties. The entire area of each county is included in the spatial footprint of the respective model.

The basic spatial unit of the EDYS model is the cell. The cell size for the San Antonio River models is 40 m x 40 m (0.40 acre). This results in the Karnes County model containing about 1.2 million cells and the Wilson County model about 1.3 millions cells. Because of the large number of cells, the two models are constructed as two separate, but linked, models.

Surface topography in the models is defined by an average elevation for each cell, with slope and aspect defined by differences in elevation among adjacent cells. The elevation data used in the models are Lidar data, with 5-m horizontal resolution and a vertical resolution of about 15 cm.

The spatial domain of the two counties is divided into seven precipitation zones, with separate precipitation files used for the cells in each zone. The models simulate precipitation on a daily basis. For each of the seven zones, a 128-year (1885-2012) daily precipitation record was created based on statistical relationships among recorded precipitation data from 31 stations in an 11-county region including and surrounding Karnes and Wilson Counties.

A detailed soil profile description was assigned to each of the 2.5 million cells in the two models. These profiles were developed from NRCS soil survey descriptions of the soils in the counties and from additional data available in the literature. A total of 99 soil types are included in the models and each cell is assigned to one of the 99 types based on the location of the cell on the spatial landscape. Each of the 99 soil types is divided into 20 layers, with the thickness and physical and chemical characteristics of each layer varying among the types. Some of the soil variables remain constant throughout a simulation (e.g., soil texture) while the values of other variables (e.g., soil moisture) change by layer on a daily basis dependent on environmental factors such as amount of rainfall received and amount of water and nutrients extracted by plants.

The number of plant species included in a specific EDYS application is flexible. A total of 66 species are included in the Karnes and Wilson models. Dynamics of each species are modeled by use of 346 parameter variables, with each variable having different values for each species. Changes in the vegetation are modeled in EDYS on a plant species (or plant part) basis by simulating differential responses, defined by the different parameter values, to changes in environmental factors (e.g., rainfall, grazing, season).

The spatial footprint of the models is initially divided into plant communities and land management units (e.g., cultivation, urban, roads) by assigning each cell to one of 37 vegetation types. The locations of the vegetation types were based on NRCS soil survey maps. Each vegetation type was further divided based on amount of woody plant cover present, with these values visually estimated from 2012 NAIP aerial photographs. Initial (i.e., start of a simulation) biomass values were entered for each plant species in each vegetation type, based on species composition for each vegetation type. Biomass (above- and belowground) values change for each plant species and each plant part (e.g., fine roots, trunks, leaves) per species at each time step (daily) during an EDYS simulation.

The animal component in EDYS models consists of the effects of herbivory by different types of animals, both domestic and wildlife, on the vegetation. Herbivory is modeled as a plant-part and plant-species specific process, where selection of plant parts and plant species varies by animal species. Densities of each animal species are entered and the model calculates the quantity of plant material the animals would consume daily and then determines how much of each species is removed based on selectivity, accessibility, and competitiveness among the animals. Animals included in the Karnes and Wilson models are insects, rabbits, deer, and cattle. Horses and feral hogs can also be added but were not in these models because of lack of information as to densities and distributions of these two species.

Calibration

Calibration in EDYS consists of adjustments of parameter values, if needed, to achieve target values for the variables under consideration. Target values are from independent validation data, either experimental validation studies or existing field data, if these data are available. In the absence of independent validation data, values based on professional judgement are used.

Vegetation validation plots were established in Karnes and Wilson (Atascosa) Counties in 2014 but data from these plots will not be available until late 2015. In the absence of independent validation data, data from published studies in the South Texas region and professional judgment were used to calibrate the vegetation dynamics of the models. Ten-year simulations for seven plot types (five native plus improved pasture and cultivation) were used in the vegetation calibration process. Results of simulated vegetation change in response to fluctuations in rainfall and time (succession) were compared to published results from 23 studies and to our professional experience in the region. The simulation results compared favorably to the patterns and levels expected from these studies and regional experience.

Simulated amounts of evapotranspiration (ET), surface runoff, and sediment loadings were compared to literature values for the region and for similar types of vegetation. The simulated ET and interception values corresponded well with the reported values in the literature. Simulated runoff values also compared favorably with published values. For example, annual runoff averaged over the seven plot types used in the calibration was 1.6 inches, or 4.9% of annual rainfall. Corresponding USGS values for three gauged rangeland sites in San Patricio

County were 1.86 inches, or 3.0% of annual rainfall. These results suggest that the EDYS evaporation, interception, transpiration, and runoff values are reasonable.

Sediment loadings were evaluated on both a plot type (small-scale) basis and as corresponding sediment loadings in the river and creeks. In both cases, the EDYS values were low. The reason for the low values has been identified and corrections are being made. However, revised data incorporating these modifications are not available in time for incorporation into this report. The current sediment loadings in surface runoff (i.e., landscape prior to moving into the waterways) are about one-third of those reported in the literature and waterway loadings are less than 10% of USGS estimates for the San Antonio River. Preliminary revised surface runoff values average about 0.31 $g/m^2/cm$ of rainfall, compared to 0.29 $g/m^2/cm$ from three published studies for native grassland communities in South Texas, the Edwards Plateau, and Rolling Plains.

EDYS simulated flow rates for the San Antonio River and Cibolo and Ecleto Creeks were compared to gauged values from five gauge stations over a two-year period (2006-07). The EDYS rates closely matched the patterns and flow rates at the two San Antonio River stations (Floresville and Falls City) for most dates. EDYS under-estimated some high runoff peaks and over-estimated a major runoff event at the Falls City gauge, apparently because EDYS did not sufficiently account for over-bank flooding. EDYS under-estimated flow rates on the Cibolo Creek at the Sutherland Springs gauge, in part because a substantial portion of the contributing watershed is outside the EDYS spatial domain. EDYS also under-estimated peak flows on the Cibolo Creek at the Falls City (Cestohowa) gauge, in part because of the under-estimation of the flow coming down Cibolo Creek from the Sutherland Spring gauge. When adjusting for this under-estimation, the fit between EDYS and gauged values for the Falls City gauge improved considerably.

The EDYS simulated flow rates for Ecleto Creek at Runge did not match the gauged data. Possible reasons for this poor match are discussed in the report. In addition to a poor fit between the gauged data and the EDYS results, there was also a poor fit between measured rainfall and the gauged data at this station. The reasons for these poor fits are being investigated and the results will be incorporated into EDYS upon completion of the review. One area of investigation is related to lag times between rainfall and sub-surface flow rates in sandy soils.

Results

Ten 25-year scenarios were simulated as examples of how the models can be used. Three scenarios were included to illustrate the response to fluctuations in rainfall patterns. Only rainfall was varied in these three scenarios. One was baseline, which used the rainfall data from the 25 continuous years (1925-1949) which had a mean nearest the long-term mean. The second scenario used the rainfall data from the driest 25 continuous years (1893-1917) and the third scenario from the wettest 25 continuous years (1957-1981). Three scenarios illustrated responses to brush management. In Scenario 4, 90% of the woody biomass was removed from areas with 50% or more woody cover in the first year of the simulation. Pecan and live oak were excluded from brush removal and this scenario used baseline rainfall data (1925-1949). Scenario 5 used the same brush control regime as Scenario 4, but simulated dry conditions (1893-1917 rainfall). Scenario 6 used the same brush control regime but also repeated it in Year 15 to simulate re-treatment. These scenarios used baseline rainfall (1925-1949). Two scenarios illustrated impacts from changes in cultivation, and both used the baseline rainfall regime. In Scenario 7, 50% of the cultivated land was converted to improved pasture and in Scenario 8, the amount of cultivated land was increased by 25% by converting native rangeland to cultivation. The final two scenarios illustrated effects of urban growth. Both used the baseline rainfall regime and there were annual increases in amount of urban (houses and yards) and industrial land. Scenario 9 increased these footprints by 1% per year and they were increased by 2% per year in Scenario 10. The report presents results of each of these scenarios on vegetation and hydrology.

Vegetation change in the simulation scenarios varied by plot type and management scenario. Two major plot types are clay loam and sandy loam. Under the baseline scenario (average rainfall, moderate grazing by cattle), shrubs (especially whitebrush) increased on the clay loam site over the 25 years and decreased on the sandy loam type. Midgrasses, especially the four mid- or late-seral dominant species, increased on both types. Under the dry scenario (about 10% reduction in rainfall), total aboveground biomass decreased by 10-19% on the sandy loam type and 15-18% on the clay loam site. Vegetation change under the wet regime was complex, with grasses increasing substantially on most types and some shrub species increasing while others decreased, apparently in response to increased competition from grasses.

The brush management treatments were applied to 227 cell types (combinations of vegetation and soil types over seven precipitation zones) in Karnes County and 160 in Wilson County. Vegetation responses in the simulations varied among these cell types. The single brush treatment under the baseline precipitation regime resulted in a 10-78% reduction in total aboveground biomass after 25 years, depending on vegetation type and county. Responses also varied by shrub species and soil type, with some species recovering more rapidly than others and on some soil types more rapidly than on other soil types. On the clay loam type, for example, mesquite and granjeno were substantially lower at the end of 25 years but whitebrush had almost fully recovered from the root-plowing operation. Responses of the various herbaceous species also varied by species and by soil type. There were substantial increases in ragweed on the sandy loam type and increases in Johnsongrass on the bottomland type following brush control. The single brush management application under the dry regime reduced total aboveground biomass at the end of the 25-year simulation by an additional 3-18% compared to baseline precipitation and the re-treatment scenario reduced all impacted species more than did the single treatment scenario, except for Johnsongrass on the bottomland type.

The simulation results support conclusions from observations of land management operations in the region. Root-plowing is an effective brush management technique. Without follow-up treatments, it is most effective on sandier soils. On clay loam sites, some follow-up treatment is necessary to reduce regrowth of aggressive species such as whitebrush and prickly pear. Resonses of individual woody species to root-plowing and drought are not consistent across types and rainfall regimes. Interactions between interspecific competition and moisture regime result in different response patterns. If dense stands of brush are treated, re-seeding of grass species is required to re-establish the grass component within a reasonable (less than 25 years) time. Bottomland and other moist sites are likely to become dominated by Johnsongrass following brush control unless a successful re-seeding progam is applied.

Under the baseline scenario, simulated runoff averaged 2,400-17,700 acre-feet per year for the six watersheds combined, or about 0.4-1.0 inch per acre per year. This compares to 0.86-inch per year averaged over three USGS-gauged watersheds on rangeland in San Patricio County.

On most of the six watersheds, the simulated wet regime had minimal effect on surface runoff but surface runoff decreased 21-54% from baseline under the dry regime (10% less rainfall). The brush management scenarios had minimal effect on surface runoff. The change varied by watershed and by brush control scenario, but ranged from a reduction in runoff of less than 1% to an increase up to 4%. Although brush control had little impact on surface runoff, it likely did affect the overall water budget of the sites by reducing ET and increasing soil water storage and perhaps deep percolation of water.

Neither the cultivation nor the urbanization scenarios had major impacts of surface runoff. This was because 1) the amount of directly affected area was relatively small (0.6-1.5% of the spatial footprint) and 2) the impacted cells were surrounded by non-impacted cells that moderated the direct effects of the treatments. Had the changes been made in a more spatially concentrated manner, the effect on runoff would have been much greater. Although the overall impact of cultivation and urbanization was minimal, some watersheds were more sensitive than others. For example, surface runoff decreased almost 6% on Watershed 2 (San Antonio River at Floresville) in response to a 25% increase in cropland compared to 0.1-1.2% on the other watersheds.

Sediment loadings in the simulations increased in the wet regime by 5-17% over baseline in the three watersheds that flow directly into the San Antonio River and decreased by 12-25% in the three watersheds that flow into either the Cibolo or Ecleto Creeks. Sediment loadings decreased on all six watersheds under the dry regime (22-58% lower than under baseline). The brush management treatments increased sediment loadings on all six watersheds, by an overall average of 36% under the baseline (average rainfall) regime and 43% under the dry regime. The brush control re-treatment scenario increased sediment loadings by an average of 38% over the single root-plowing treatment.

In general, the cultivation scenarios had minimal impact on sediment loadings. The cultivation scenarios changed average annual sediment loads by an average of 2% or less for all watersheds except Watershed 1 (Cibolo Creek at Sutherland Springs), where the levels were about 18% higher. Urbanization had a somewhat larger effect on sediment loadings than did cultivation. Under the higher urbanization rate (2% per year), sediment loadings increased by about 4% compared to baseline, averaged over all watersheds. The three watersheds draining directly into the creeks were more sensitive to urbanization impacts than the three that drain directly into the river (6.5% and 1.2%, respectively).

Summary

The Karnes and Wilson EDYS models provide tools useful for quantifying vegetation and hydrologic responses to various environmental changes, especially for quantifying relative differences resulting from environmental change. Vegetation dynamics are simulated in an ecologically reasonable manner, with results comparable with those from published studies.

Flow and surface runoff dynamics fit both patterns and amounts suggested by gauged data and published literature values. Sediment loadings are currently too low in the simulations but the reasons for the low values have been identified and changes in the algorithm variable values are being tested and will be incorporated into the models upon completion of the review process.

1.0 INTRODUCTION

The San Antonio River begins in Bexar County and flows southeastward through five counties before merging with the Guadalupe River and then flowing into San Antonio Bay on the central Texas Coast. Wilson and Karnes Counties are the first two of the five counties through which the San Antonio River flows (Fig. 1.1).

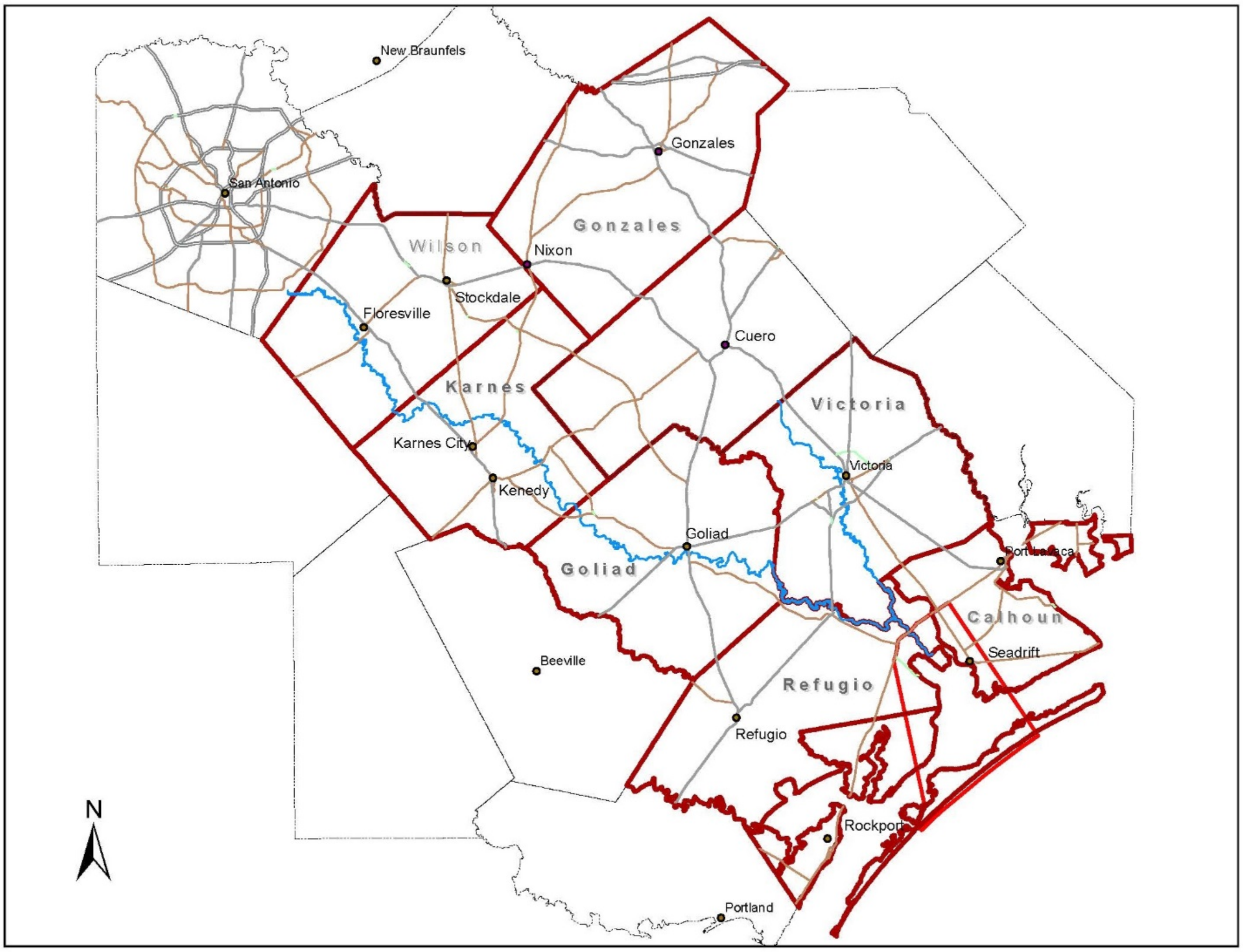


Figure 1.1 Map of the region through which the San Antonio River flows.

The San Antonio River Authority (SARA) has the dual responsibility of managing water quality and quantity in the San Antono River and its tributaries. The quality and quantity of river water are affected by both in-stream factors and characteristics of the respective watershed. SARA recognizes the importance of understanding the effects of in-stream responses and watershed ecohydology to making good management decisions relative to the San Antonio River system. SARA also recognizes the complex, dynamic, and interconnected nature of this river system. Natural and anthropgenic changes across the landscape can have major impacts on the water quality and quantity of the river.

Management tools that integrate spatial and temporal ecological dynamics at multi-species and multi-scale levels provide valuable support to the environmental decision-making process.

Ecological simulation modeling is a tool that allows complex hydrologic, ecological, and management reponses to be integrated in a practical and scientifically valid manner, the results of which can substantially improve land-use planning and decision making.

SARA is interested in developing an integrated set of ecological models for the entire San Antonio River system for the purpose of supporting their decision-making process related to the management of the San Antonio River. In June 2011, SARA began the application of the EDYS model to San Antonio Bay as the first step in developing this set of integrated ecological models. EDYS is a mechanistic, spatially-explict, dynamic ecosystem simulation model that has been widely applied to land management decision making (Childress and McLendon 1999; Childress et al. 2002; Price et al. 2004; Mata-Gonzalez et al. 2007; Coldren et al. 2011a, 2011b; McLendon and Coldren 2011). In June 2013, SARA began the expansion of this model development to include up-river segments of the linked river-bay system. Karnes and Wilson Counties were selected as the first two counties to be included in the integrated model complex. In September 2013, SARA expanded work on the linked-model complex to include Goliad, Refugio, and Victoria Counties.

Work on the Karnes-Wilson models was authorized to proceed in two phases. This document reports on the results of those two phases. It provides an overview of the models and presents results of a set of simulation secnarios.

2.0 SPATIAL FOOTPRINT

Karnes County covers 753.6 mi^2 (482,291acres) and Wilson County covers 808.6 mi^2 (517,485 acres). Both counties lie on the northeast edge of South Texas (South Texas Plains, Hatch et al. 1990). The San Antonio River flows through the center of both counties in an approximately NNW to SSE direction.

In EDYS, the spatial footprint is divided into cells. A cell is the smallest unit that EDYS simulates in a particular application and it can be of any size, as determined by the requirements of the application. EDYS averages values for each variable across an individual cell, therefore the cell size selected is a balance between 1) the largest size for which average values are acceptable and 2) reasonable simulation run times and memory requirements. The smaller the cell size, the more spatially precise the simulation is. However, smaller cell sizes result in more cells and a larger number of cells results in a slower run time per time step and more memory requirement.

The primary cell size selected for the Karnes-Wilson model was 40 m x 40 m (0.40 acre). The entire area of both counties was modeled at this spatial resolution resulting in approximately 1.2 million cells for Karnes County and 1.3 million cells for Wilson County. The following components (discussed in following sections) are included for each cell: topography (DEM elevation, slope, aspect), soil, depth to groundwater, vegetation, and land use.

A practical upper limit for efficient EDYS operation (relative to run time and memory requirement) on appropriate PCs is about 1.5 million cells. Combining Karnes and Wilson Counties into one model and retaining the 40 m x 40 m cell size would result in a model with about 2.5 million cells. EDYS can simulate that sized model, but run times would be slow and memory requirements large. The alternative for use in large models with relatively small cell sizes is to divide the spatial footprint into separate models and then link the models. This has two primary advantages. First, it allows large spatial domains to be included with small cell sizes. Second, it allows for separate individual models that can be run either as linked models or separately as individual models. An advantage in having separate models available is that simulations can be run for the separate domains much faster than if there was only one large model. Having separate, but linked, models for each county also allows for the linked model to be easily expanded so that additional counties (e.g., Bexar, Goliad, Refugio) can be added in the future.

The model linkage in EDYS works by having one model run through one time step while the other model is inactive ("asleep"). At the end of the time step, all output data from the first model that affects the second model (e.g., river flow, surface runoff to adjacent cells) become input data for that time step to the second model. At that point, the first model becomes inactive and the second model is activated ("wakes up") and simulates the time step. At the end of that time step, the process is repeated for the next time step with the second model going back to "sleep" and the first model "waking up".

Wilson County is upstream (northwest) of Karnes County. Therefore, the Wilson County model is the "first" model in the linked system and Karnes County is the "second" model. A heavy rainfall event confined to Karnes County is not likely to have substantial effects on ecohydrologic conditions in Wilson County. However, a heavy rainfall event in Wilson County is much more likely to affect ecohydrology in Karnes County.

EDYS has the ability to simulate selected areas at a finer resolution than the primary cell size used in the overall model. This capability is particularly useful for simulating ecological dynamics in critical areas where the smaller scale becomes important (e.g., some aquatic systems, critical habitat areas, urban development patterns). Any area within the spatial footprint can be selected as a fine-scale model area. This is accomplished by drawing a polygon around the area of interest and designating what scale (cell size) is desired.

The limitation in this procedure is related to the availability of finer-scale input data. Precipitation data are not affected because it is entered on a cell-by-cell basis. Elevation, and therefore topography, is currently entered at a 5 m x 5 m resolution, based on LIDAR data. For scales finer than 5 m x 5 m, LIDAR elevations are available (down to 1 m x 1 m) but those grids will need to be constructed. Soil and vegetation data are linked to the spatial sizes of the various polygons (soil types and plant communities). These vary in size across the landscape. Depending on the size and location of the finer-scale cells, these individual cells may or may not fit within a specific soil or vegetation type.

Even with these limitations, the use of a finer-scale subdivision may be useful. Although the initial input values for the fine-scale cells may be the same as for the associated large-scale cell, using mulitiple finer-scale cells will allow for more spatially detailed changes to be simulated, which will likely result in some effects on the resulting ecological and hydrological responses.

3.0 TOPOGRAPHY

Surface topography is an important component in EDYS simulations. It controls the flow pattern and velocity of runoff water, inundation depth of flood water, water depth in ponds and lakes, and tidal depths and patterns in coastal wetlands, and it influences movement patterns for some wildlife species, foot and vehicle traffic, and fire events.

Elevation, slope, and aspect are the three topographic variables used in EDYS. All three are derived by EDYS from input elevation data. The most common source of these data are USGS DEM elevations. Elevation contours, typically 10 m between contours with a vertical resolution of about 15 cm, are used to develop an elevation grid for the EDYS spatial footprint, with average elevation values used for each cell. EDYS calculates slope (angle from horizontal) and aspect (direction) from the elevation data. In EDYS, slope is the difference in average elevations between adjacent cells. Aspect is determined by the relative elevations between any two cells.

In EDYS, precipitation is applied to each cell. If that cell has the same elevation as all four adjacent cells (i.e., flat topography), there is no runoff and the water has maximum opportunity for infiltration into the soil profile, the only loss in this case is from evaporation. If any of the adjacent cells have lower elevations than the central cell, some water flows from the central cell to the adjacent cells with lower elevations. The amount of water that flows to the lower cells depends on the infiltration rate of the soil in the central cell, the slope between the central cell and each lower-elevation adjacent cell, and the intensity of the rainfall event. If an adjacent cell has a higher elevation than the central cell, water flows from the higher-elevation cell to the central cell, this amount of water is added to the quantity in the central cell available for runoff, and the total amount in excess of infiltration is moved to the adjacent lower-elevation cells. This process continues as a downslope process until all runoff water is moved to the lowest elevation cells or removed from the spatial footprint (surface flow export).

Higher resolution elevation data (LIDAR) are available from SARA for both Wilson and Karnes County. SARA provided both 5-m and 1-m horizontal resolution LIDAR data. The 1-m resolution data are too fine-scale for use in these county-wide models (1.9 billion points in the case of Karnes County). However they can be used in smaller-scale spatial footprints within Karnes or Wilson Counties. For the county-wide models, the 5-m horizontal resolution (5-m distances between grid points) were used, with a vertical resolution (accuracy) of approximately 15 cm. These data have been entered into EDYS and have replaced the USGS DEM data. Using the LIDAR data provides two advantages over the USGS DEM data. First, the LIDAR data provide more within-cell elevation points from which average elevation for the cell is calculated. The mean elevation in each 5 m x 5 m LIDAR cell is an average of 25 of the 1-m readings (points) and there are 64 of these cells within each 40 m x 40 m EDYS cell. Therefore, the average elevation for each EDYS cell is the average of 1,600 Lidar points. This large number of readings provides the potential for much more accurate elevation estimates to be made for each EDYS cell. Secondly, the LIDAR elevation data allows topography to be modeled on a much finer-scale than using the USGS DEM data.

4.0 PRECIPITATION

Precipitation is a very important driving variable for many ecological processes. Both temporal and spatial variations are ecologically important.

4.1 Temporal Variability

EDYS inputs precipitation on a daily basis. Use of shorter-term periods (e.g., hourly) is possible in EDYS and can be used in simulations when necessary. The default time step used in the Karnes and Wilson Counties models is daily.

Precipitation typically varies in patterns that are short-, medium- and long-term. Short-term fluctuations include 1) annual variations around a mean, with some years being either drier or wetter than average, and 2) series of below- or above-average precipitation years, the series generally lasting 2-5 years but sometimes lasting a decade or more. For example, the long-term (1895-2013) mean annual precipitation recorded at Runge (station with the longest period of record for Karnes or Wilson Counties) is 30.20 inches. The driest year on record was 13.60 inches in 1917 (45% of long-term mean) and the wettest year on record was 51.93 inches in 1973 (172% of long-term mean) (Appendix Table A.8). The driest short-term (3 continuous years) period on record was 2011-13, during which annual precipitation averaged 17.86 inches (59% of long-term mean) and the wettest short-term (3 continuous years) period on record was 1958-60, during which annual precipitation averaged 40.01 inches (132% of long-term mean).

Short-term periodicity at Runge involves wet-dry cycles of 8-21 years each (average of 14 years)(Fig. 4.1). The wet portions of each cycle have an average length of 8.7 years and have average annual means of approximately 34-38 inches. These are followed by dry periods averaging 6.8 years long and with average annual means of 18-28 inches. There have been six of these wet-dry cycles since 1918 and the average difference in mean annual precipitation between the wet and the dry periods is 11.90 inches (Fig. 4.1).

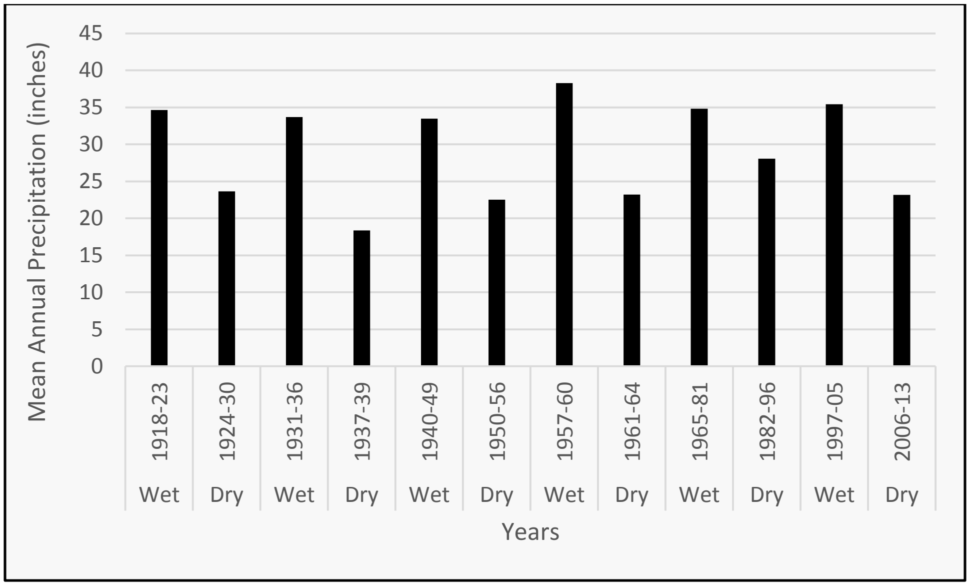


Figure 4.1 Mean annual precipitation (inches) during six consecutive wet-dry periods at Runge, Karnes County, Texas (1918-2013).

Medium-term changes tend to be on the order of 40-60 years and, in the southwestern United States, are correlated with the Pacific Decadal Oscillation and the Atlantic Multidecadal Oscillation (Cayan et al. 1999; Hidalgo 2004). For example, mean annual precipitation at Runge during 1915-1956 (42 years) was 12% less than the annual average during 1957-2005 (49 years)(28.34 and 32.29 inches, respectively). This pattern of 40-50 years of lower average precipitation followed by 40-50 years of higher average precipitation is repeated in other regions of Texas. Mean annual precipitation in San Antonio during 1892-1956 was 26.10 inches compared to a mean of 32.56 inches during 1957-2004, or an average of 20% less during 1892-1956 than in 1957-2004. Mean annual precipitation at the Sonora Experiment Station during 1924-1965 (42 years) was 13% less than the annual average during 1966-2077 (42 years).

These medium-length precipitation fluctuations are not confined to arid or semi-arid regions. Humid regions also experience similar cycles. Tree-ring data from North Carolina indicate that region has undergone alternating wet-dry cycles of about 30 years each and that 1956-1984 was one of the five wettest periods of the past 1600 years (Stahle et al. 1988). Oxygen ratios from stalagmites in Belize indicate that major droughts have occurred in the Yucatan at 100-200 year intervals over the past 1800 years and have lasted 50-80 years each occurrence (Kennett et al. 2012).

In addition to these annual and decadal fluctuations, precipitation changes over longer periods of time, e.g., centuries and millennia. Climatic patterns may be relatively stable for periods on the order of centuries and then, relatively rapidly (e.g., decades), change sufficiently to cause major vegetation shifts in the region. Much of the western United States underwent a 2000-year period of increasing aridity beginning about 2600 years ago during which many woodlands in the region decreased in extent and shrublands increased (Tausch et al. 2004). Then, about 650 years ago, the Little Ice Age began and conditions became much cooler, resulting in an increase in extent of woodlands, grasslands, and wetlands. During that period, vegetation patterns were very different from current patterns (Tausch et al. 2004). Little Ice Age conditions lasted until about 150 years ago and then climate shifted again, with aridity once again increasing. Much of northwestern Iowa was covered in deciduous forest from 9100-5400 BP, then changed to prairie grassland in 5400-3500 BP, and shifted to oak savanna after 3500 BP (Chumbley et al. 1990). These shifts in vegetation correspond to periods of rapid warming (3^o C) followed by cooling (4^o C)(Dorale et al. 1992). Similarly, Neilson (1986) suggested that the black grama (*Bouteloua eriopoda*) desert grasslands encountered in the northern Chihuahuan Desert 100 years ago were a vegetation type established under, and adapted to, 300 years of Little Ice Age conditions and are only marginally supported, and perhaps not likely to be re-established, under present climatic conditions.

4.2 Spatial Variability

Precipitation also varies spatially, often at relatively short distances. For example, there are two stations at Goliad and they are approximately 1 mile apart. For the period of record where data are available for the same years at each station (37 years) the average annual precipitation at the northern station is 35.83 inches compared to 32.19 inches at the southern station. The difference in the average annual precipitation between the two stations is 3.64 inches, or 11% of the annual mean of the southern station. In contrast, the average annual precipitation at Runge for years in common (35 years) with the southern Goliad station is 30.55 inches compared to 32.61 inches for the same years at the southern Goliad station. The difference between these two means is 2.06 inches, or 6% of the mean at the southern Goliad station, although Runge is 26 miles west of the southern Goliad station.

Spatial and temporal interactions can also occur across a landscape. Karnes City is located 12 miles west of Runge, both in Karnes County. From 1920 through 1958, annual average precipitation was higher in Karnes City than in Runge (31.59 and 28.92 inches, respectively for the 35 common years). From 1959 through 2005, annual average precipitation was lower in Karnes City than in Runge (29.31 and 31.67 inches, respectively for the 35 common years). Over this 86-year period, the pattern of annual precipitation reversed.

Spatial differences in precipitation may be very important in accounting for ecological dynamics across a landscape. In EDYS, precipitation is entered cell by cell across the spatial footprint. Use of precipitation data from a single station cannot provide realistic estimates of these patterns. To account for at least some of this spatial variation, the EDYS spatial footprint is divided into precipitation zones, each zone associated with a precipitation station. As a first approximation, all cells within a zone receive precipitation values associated with their respective station. Although this will result in sudden changes in values as zone boundaries are crossed, a more realistic pattern is achieved than if data from only one station were used. If precipitation differences between zones seem sufficiently large, a linear difference approach can be used that provides cell-by-cell differences in precipitation based on average differences among adjacent stations (Appendix Tables A.1-A.7). In the Karnes-Wilson model, the first approximation approach is currently used.

In determining precipitation zones in EDYS, data are summarized from all available stations in a region, the region consisting of the counties included in the model (Karnes and Wilson in this case) and all adjacent counties (Atascosa, Bee, Bexar, DeWitt, Goliad, Gonzales, Guadalupe, Live Oak, and McMullen in this case). Stations with data for more than 20 years are considered as primary stations and stations (Table 4.1) with data for 20 years or less are considered secondary stations. Rossville in Atascosa County was included as a primary station because of the relatively early dates of its data (1907-1926). Primary stations are used to define precipitation zones. The distances among primary stations are calculated and each county is divided into a zone defined by the closest primary station to that area of the county.

Table 4.1 Primary precipitation stations, with corresponding data summaries, used in the EDYS model for Karnes, Wilson, and surrounding Counties.

County	Station	Mean Annual Precipitation (inches)	Period of Record	Number of Years with Complete 12 mo Data
Karnes	Cestohowa	27.94	1944-1982	21
Karnes	Karnes City	30.18	1919-2006	72
Karnes	Kenedy	30.50	1948-1977	24
Karnes	Runge	30.25	1895-2013	102
Karnes	Falls City (7 WSW)	27.38	1946-2013	60
Wilson	Floresville	29.02	1916-2013	79
Wilson	Nixon	32.68	1921-2013	76
Wilson	Stockdale	33.51	1940-45; 1978-2013	34
Atascosa	Charlotte	27.05	1962-2012	47
Atascosa	Jourdanton	25.78	1916-22; 1947-2011	58
Atascosa	Poteet	27.63	1941-2013	68
Atascosa	Rossville	27.28	1907-1926	16
Bee	Beeville	31.18	1894-2013	105
Bexar	San Antonio	29.12	1850-51, 1958-60, 1870-2013	145
DeWitt	Cuero	34.48	1901-2013	100
DeWitt	Yoakum	38.25	1917-2013	75
DeWitt	Yorktown	34.14	1940-2013	60
Goliad	Goliad	34.83	1912-2013	97
Goliad	Goliad (1 SE)	32.19	1949-2005	37
Gonzales	Dreyer	33.77	1940-1975	33
Gonzales	Gonzales	33.92	1940-2013	72
Gonzales	Jeddo	36.22	1940-2013	66
Gonzales	Waelder	33.15	1944-1993	37
Guadalupe	Seguin	31.30	1922-1972, 1992-2013	68
Live Oak	George West	27.05	1916-2013	90
Live Oak	Three Rivers	26.40	1922-1987	61
Live Oak	Three Rivers (6 W)	25.50	1983-2013	24
Live Oak	Three Rivers (8 NE)	26.47	1988-2013	24
Live Oak	Whitsett	26.34	1914-2013	88
McMullen	Calliham	25.38	1978-2013	29
McMullen	Tilden	24.26	1903-11; 1928; 1958-2010	47

The spatial footprint of the two counties was divided into seven zones based on minimum distance to the nearest primary precipitation station (Table 4.2 and Fig. 4.2). Three of these zones were located in Karnes County, one zone was located in Wilson County, and three zones included portions of both counties (Fig. 4.2). Within each zone, daily precipitation at the included primary precipitation station (Table 4.2) was used as the precipitation input for the entire zone. This zone-wide approach is being used initially in the models. A more precise approach would be to vary the precipitation amount received at any particular cell by a proportional distance factor between the two (or more) closest precipitation stations. However, that approach is much more complicated than the initial approach. Advantages and disadvantages to this more complex approach are being evaluated. If it is deemed sufficiently useful to justify the increased complexity, the distance-prorated approach will be substituted for the zone-wide approach.

Table 4.2 Precipitation stations assigned to each of the seven precipitation zones in the Karnes-Wilson EDYS model.

Zone	Station	General Location	Mean Precipitation (inches)
1	Kenedy	southwest Karnes County	30.50
2	Runge	east Karnes County	30.18
3	Karnes City	central Karnes County	30.15
4	Falls City	northwest Karnes County; south Wilson County	27.42
5	Nixon	north Karnes County; northeast Wilson County	32.70
6	Stockdale	east central Wilson County; northwest Karnes County	33.50
7	Floresville	west Wilson County	28.96

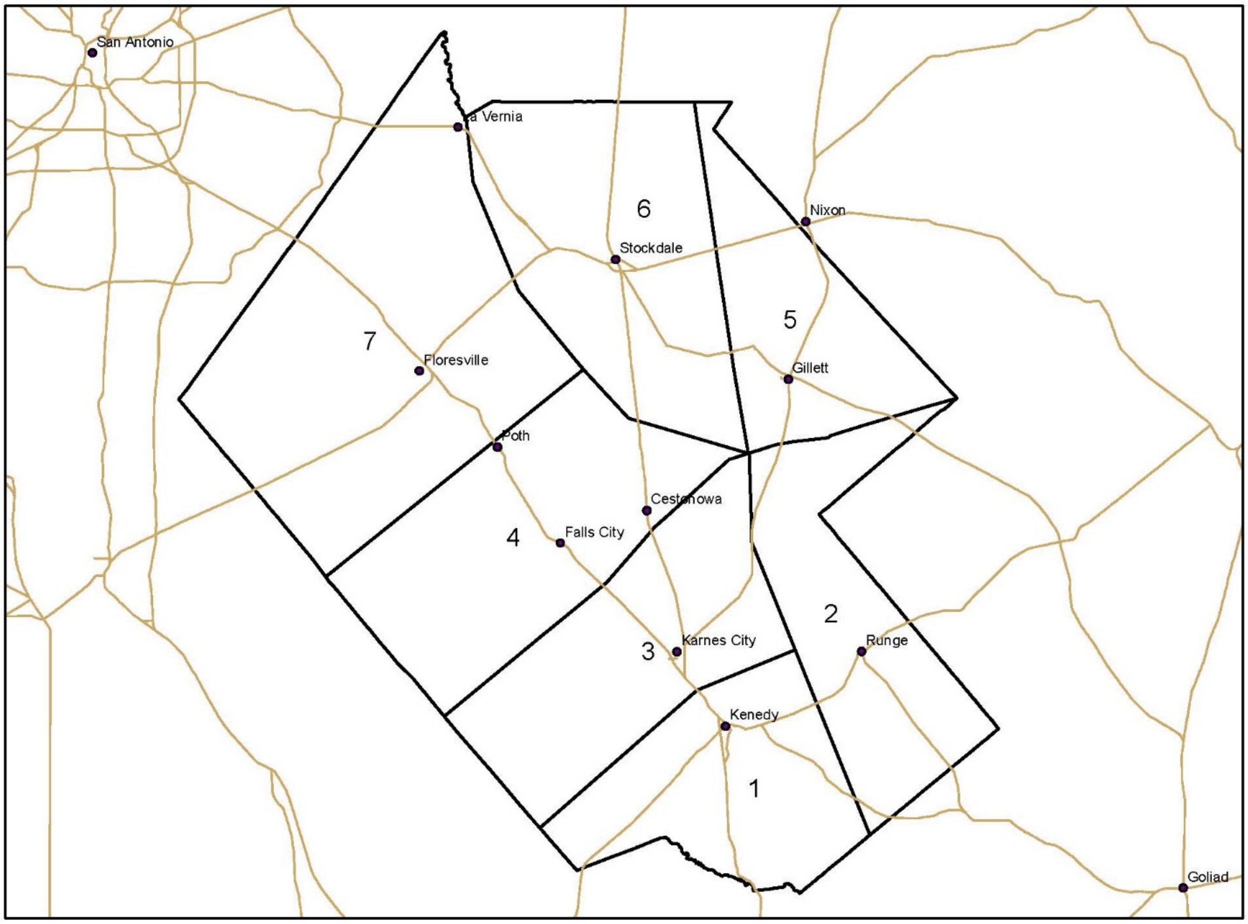


Figure 4.2 Precipitation zones included in the EDYS models for Karnes and Wilson Counties.

The value of precipitation data in simulation modeling, as in most ecological studies, increases substantially as the length of the period of record increases. Long-term (more than 100 years) precipitation data are available for only one of the seven Karnes-Wilson primary stations and the periods of record vary substantially among the 7 sites (Table 4.1). In addition, none of the 7 stations or the 23 stations in surrounding counties have complete data sets for their respective period of record (i.e., there are some years with missing data for at least one month of the respective year). Consequently, constructed precipitation data sets were developed for each station.

Constructed precipitation data sets are long-term data sets that include recorded data for those dates where these data are available for a particular station and estimated values for dates where recorded data are not available or where the recorded values are strongly suspect. The purposes for using constructed data sets in EDYS models are to 1) extend the length of the data set, 2) account for missing data, 3) adjust for apparent errors in the recorded data, and 4) provide data for all dates over a common period of record so that sites can be more appropriately compared. The estimated values in the constructed precipitation data sets are not presented as precise estimates of the actual amounts received. Instead, they represent reasonable estimates based on the temporal and spatial patterns of the area.

The first step in developing constructed data sets was to determine the relationships between precipitation patterns at each two-station combination involving the seven selected stations (Table 4.2) with each of the 29 surrounding primary stations (Karnes, Wilson, and surrounding counties). Two factors were calculated for each comparison and these calculations were based on annual precipitation for those years with complete (12-month) recorded data for both stations of a comparison. The first factor was a conversion ratio (Table 4.3). This is the ratio of average annual precipitation at the station being estimated to the average annual precipitation at the station being used to estimate, with the averages calculated from common years only. These ratios provide a means for estimating precipitation received at any of the seven stations from precipitation received at any of the other 28 stations. The second factor was the average difference (absolute value) between annual precipitation received at one station and that received at a second station (Table 4.4). This factor provided a measure of which station had the most similar precipitation pattern (based on annual totals) to each target station.

Table 4.3 Conversion ratios for calculation of missing annual precipitation (PPT) data for the primary precipitation stations in each zone within Karnes and Wilson Counties. Ratios were calculated from means in Appendix Tables A.11-A.17 and were calculated using only those common years with complete data for both stations of a comparison.

Station PPT	Karnes-Wilson Stations Calculated For							
Calculated From	**Runge**	**Karnes 1920-58**	**Karnes 1959-05**	**Kenedy**	**Falls City**	**Floresville**	**Nixon**	**Stockdale**
Karnes County								
Runge	1.000	1.092	0.935	1.030	0.907	0.933	1.075	1.093
Karnes City 1920-58	0.920	1.000	-----	-----	-----	-----	-----	-----
Karnes City 1959-05	1.082	-----	1.000	1.074	0.951	0.938	1.044	1.108
Kenedy	0.970	-----	0.931	1.000	0.895	0.980	0.999	
Falls City	1.111	-----	1.052	1.117	1.000	1.081	1.180	1.209
Wilson County								
Floresville	1.070	-----	1.066	1.020	0.925	1.000	1.124	1.144
Nixon	0.930	-----	0.957	1.001	0.848	0.890	1.000	1.001
Stockdale	0.915	-----	0.903	0.827	0.874	0.999	1.000	
Atascosa County								
Charlotte	1.183	-----	1.076	1.152	1.046	1.106	1.246	1.258
Jourdanton	1.159	-----	1.106	1.215	1.030	1.085	1.245	1.242
Poteet	1.110	-----	1.087	1.177	1.003	1.045	1.183	1.207
Bee County								
Beeville	0.958	-----	0.966	1.048	0.877	0.904	1.034	1.005
Bexar County								
San Antonio	1.004	-----	0.977	1.105	0.902	0.955	1.070	1.034
DeWitt County								
Cuero	0.871	-----	0.888	0.948	0.804	0.836	0.931	0.970
Yoakum	0.802	-----	0.806	0.875	0.717	0.769	0.863	0.840
Yorktown	0.907	-----	0.881	0.959	0.802	0.861	0.980	0.966
Goliad County								
Goliad	0.863	0.875	0.900	0.756	0.815	0.919	0.905	
Goliad 1S	0.946	-----	0.915	1.036	0.848	0.879	1.003	1.024
Gonzales County								
Dryer	0.898	-----	0.913	0.937	0.835	0.861	0.954	1.005
Gonzales	0.902	-----	0.887	0.974	0.811	0.859	0.959	0.960
Jeddo	0.837	-----	0.815	0.881	0.761	0.813	0.907	0.916
Waelder	0.891	-----	0.849	0.950	0.813	0.827	0.923	0.944
Guadalupe County								
Seguin	0.956	-----	0.985	1.002	0.836	0.902	1.015	1.004
Live Oak County								
George West	1.106	-----	1.131	1.148	0.997	1.039	1.194	1.223
Three Rivers	1.128	-----	1.168	1.238	1.085	1.037	1.183	1.215
Whitsett	1.124	-----	1.138	1.174	1.003	1.050	1.213	1.181
McMullen County								
Calliham	1.201	-----	1.124	1.030	1.079	1.298	1.266	
Tilden	1.297	-----	1.238	1.436	1.171	1.218	1.428	1.392

Table 4.4 Average difference in precipitation (inches) received each year for primary precipitation stations in Karnes and Wilson Counties. Differences are averages of the absolute values of the differences in monthly precipitation between each pair based on those years common to both stations.

	Runge	Karnes 1920-58	Karnes 1959-05	Kenedy	Falls City	Floresville	Nixon	Stockdale
Karnes County								
Runge	0.00	4.96	4.26	3.31	5.61	5.18	5.36	6.34
Karnes City 1920-58	4.96	----	0.00	----	----	----	----	----
Karnes City 1959-05	4.26	----	0.00	4.20	4.63	4.59	5.23	5.57
Kenedy	3.31	----	4.20	0.00	4.59	4.80	4.19	x.xx
Falls City	5.61	----	4.63	4.59	0.00	4.95	6.46	6.99
Wilson County								
Floresville	5.18	----	4.59	4.80	4.95	0.00	5.40	5.96
Nixon	5.36	----	5.23	4.19	6.46	5.40	0.00	3.77
Stockdale	6.34	----	5.57	6.99	5.96	3.77	0.00	
Atascosa County								
Charlotte	7.60	----	5.03	5.67	4.79	5.98	8.63	7.51
Jourdanton	6.16	----	5.20	5.57	4.18	5.37	7.11	6.88
Poteet	6.19	----	4.82	6.45	4.28	5.03	6.47	6.22
Bee County								
Beeville	4.66	----	5.65	4.57	5.90	5.75	5.73	5.76
Bexar County								
San Antonio	4.81	----	5.13	5.96	5.87	5.17	5.38	5.06
DeWitt County								
Cuero	5.87	----	5.64	3.59	7.17	7.32	4.83	6.05
Yoakum	8.63	----	9.28	6.68	11.51	9.93	7.31	9.71
Yorktown	4.10	----	5.94	4.58	7.51	6.84	5.34	6.42
Goliad County								
Goliad	5.71	----	6.37	4.42	9.09	7.68	5.53	6.52
Goliad 1S	4.75	----	5.63	3.22	7.01	7.98	6.09	6.52
Gonzales County								
Dryer	4.92	----	5.75	4.85	5.81	6.14	3.91	2.73
Gonzales	5.47	----	6.00	3.68	7.52	6.58	4.15	5.01
Jeddo	7.26	----	8.84	6.44	9.53	8.31	5.80	6.14
Waelder	5.63	----	7.68	5.60	7.80	7.43	4.81	5.71
Guadalupe County								
Seguin	5.39	----	5.90	4.84	7.03	5.37	4.18	4.89
Live Oak County								
George West	5.67	----	5.34	7.22	5.83	5.78	7.58	8.12
Three Rivers	5.10	----	5.76	5.82	3.92	4.93	6.94	6.47
Whitsett	5.42	----	5.66	6.56	5.53	5.68	8.04	7.50
McMullen County								
Calliham	6.81	----	5.55	5.10	5.60	8.09	9.14	
Tilden	7.34	----	6.82	10.14	6.00	7.48	10.30	10.54

Where values for Karnes City appear only under one Karnes column or row (1920-58 or 1959-05) the data are for the entire period of record. Where values appear in both columns or rows, there was a substantial shift in pattern between the two periods.

The longest continual precipitation data set available for the area is for San Antonio. Continual data are available for San Antonio from 1885. Constructed precipitation data sets were built for each of the seven Karnes-Wilson stations beginning in 1885. For each date without data for a particular station, an estimated value was calculated. These values were calculated from the station that had a recorded value for that particular date and that was either closest to the target station (Appendix Tables A.1-A.7) or had the least difference value (Table 4.4) to the station being estimated. Data from San Antonio were used for all stations from 1885 through 1893. Data became available for Beeville in 1894 and for Runge in 1895 (Table 4.1). Data for 1894 were therefore estimated from either Beeville or San Antonio, depending on which station was closest to or had the least difference to the Karnes-Wilson station being estimated. Beeville is closer to and had the least average difference for Kenedy and Runge and was used for these two stations. Beeville is closer to Karnes City than is San Antonio, but the average difference between Karnes City and San Antonio is less than for Karnes City and Beeville. In this case, the closer station (Beeville) was used. San Antonio had the least average difference and was closest to Floresville, Nixon, and Stockdale (Table 4.4). Falls City is about equi-distant between Beeville and San Antonio and average difference between Falls City and Beeville and San Antonio were also about equal. Data for San Antonio were used to estimate values for Falls City. Beginning in 1895, data were available for three stations: Beeville, Runge, and San Antonio and data from additional stations became available after 1900.

Constructed annual precipitation from 1885-2012 for the seven precipitation zones are presented in Table 4.5. Station data, recorded or estimated, used to calculate these values appear in Appendix Table A.18. Although constructed annual precipitation values are presented in Table 4.5, the precipitation input data used in EDYS are daily values calculated from the same stations as presented in the monthly data shown in Appendix Table A.18.

Table 4.5 Long-term (128 years) constructed annual precipitation data (inches) for the seven precipitation zones of the Karnes-Wilson EDYS models.

Year	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7
	Kenedy	Runge	Karnes City	Falls City	Nixon	Stockdale	Floresville
1885	36.39	33.05	32.17	29.71	35.23	34.02	31.44
1886	28.96	26.32	25.63	23.66	28.06	27.12	25.04
1887	22.23	20.20	19.67	18.15	21.52	20.81	19.22
1888	45.91	41.72	40.58	37.47	44.47	42.97	39.66
1889	43.03	39.09	38.05	35.11	41.67	40.28	37.20
1890	33.00	29.97	29.17	26.93	31.94	30.85	28.52
1891	33.19	30.14	29.36	27.10	32.13	31.06	28.68
1892	28.41	25.82	25.11	23.17	27.51	26.59	24.55
1893	20.16	18.30	17.82	16.46	19.52	18.84	17.43
1894	22.89	20.90	21.31	19.66	23.33	22.55	20.82
1895	27.00	29.30	31.38	26.54	31.47	26.95	24.90
1896	28.07	27.28	29.79	24.75	29.33	35.25	32.56
1897	16.45	15.22	15.82	14.49	17.16	16.46	15.21
1898	25.56	23.39	23.03	20.30	24.04	23.26	21.47
1899	21.71	19.73	19.19	17.72	21.03	20.33	18.76
1900	37.29	36.12	39.35	32.75	38.86	38.45	35.52
1901	22.83	22.16	23.52	19.57	25.39	16.98	15.70
1902	40.71	39.50	43.10	35.82	38.69	25.64	23.69
1903	46.35	45.00	49.15	40.83	47.92	34.24	31.62
1904	30.29	29.38	32.05	26.65	38.79	30.39	28.04
1905	35.58	33.97	31.82	26.81	42.41	33.70	31.14
1906	26.89	25.09	22.11	19.45	24.59	21.12	19.49
1907	22.19	21.15	24.01	20.75	36.02	28.73	26.50
1908	32.69	31.74	34.66	28.82	36.07	29.48	27.23
1909	19.51	18.94	20.68	17.18	21.82	15.43	14.25
1910	28.23	27.36	29.83	24.85	35.59	16.77	15.48
1911	28.72	27.89	30.12	25.04	29.50	19.33	17.85
1912	24.83	23.68	23.94	20.56	24.73	24.52	22.67
1913	31.21	30.72	33.48	27.90	37.63	38.95	35.99
1914	41.57	40.35	44.05	22.01	55.05	35.26	32.56
1915	20.83	20.23	22.07	18.33	28.38	28.20	26.06
1916	18.55	18.39	23.20	20.06	20.05	24.91	22.22
1917	14.02	13.60	14.85	8.48	11.97	9.01	7.88
1918	31.66	30.75	33.58	27.03	35.84	34.80	30.39
1919	47.16	45.80	48.30	51.01	50.82	52.98	46.29
1920	26.42	25.62	21.47	29.72	25.63	23.39	20.45
1921	30.96	30.06	23.18	24.63	24.67	30.21	21.42
1922	30.30	29.38	28.18	29.44	23.31	23.31	28.70

Table 4.5 (Cont.)

Year	Zone 1 Kenedy	Zone 2 Runge	Zone 3 Karnes City	Zone 4 Falls City	Zone 5 Nixon	Zone 6 Stockdale	Zone 7 Floresville
1923	46.96	45.57	44.29	42.17	44.28	44.28	43.34
1924	21.24	20.65	20.93	19.91	21.73	21.73	24.15
1925	15.89	15.43	22.90	21.81	18.36	18.36	16.86
1926	33.24	32.28	33.67	32.05	36.52	36.53	25.53
1927	22.98	22.29	25.23	24.06	30.72	30.72	24.84
1928	23.58	22.91	27.96	26.58	27.44	27.44	28.20
1929	35.90	34.89	42.24	40.20	39.49	39.49	28.83
1930	17.41	16.96	24.04	22.91	21.54	21.54	20.39
1931	37.58	36.53	33.16	31.59	22.62	22.62	27.07
1932	27.78	26.98	32.25	30.69	29.31	29.31	29.30
1933	26.12	25.41	24.24	23.03	30.26	30.26	21.24
1934	37.60	36.50	38.92	36.99	34.54	33.56	25.77
1935	46.59	45.26	56.52	53.81	44.12	44.12	45.93
1936	32.21	31.36	49.97	47.54	39.06	39.07	42.12
1937	20.31	19.73	24.77	23.58	25.70	25.70	22.56
1938	16.63	16.14	24.67	23.50	31.00	31.00	19.16
1939	19.78	19.24	17.08	16.25	16.64	16.64	13.75
1940	48.27	46.87	40.66	38.71	39.51	38.80	32.53
1941	42.67	41.44	51.76	49.20	48.92	43.29	37.25
1942	28.05	27.30	34.72	32.98	37.53	42.72	35.77
1943	28.87	28.08	24.85	23.67	21.89	25.70	22.88
1944	31.98	31.07	28.22	26.89	32.69	38.25	24.08
1945	22.64	21.97	17.78	16.72	27.40	24.31	16.65
1946	46.73	45.42	50.30	52.09	58.06	58.08	44.55
1947	29.61	28.76	22.52	22.99	20.90	20.90	18.64
1948	28.59	25.08	28.09	19.77	21.86	21.86	22.06
1949	38.14	38.86	30.84	39.04	32.00	32.01	34.82
1950	19.97	14.84	18.10	18.94	25.21	25.22	16.90
1951	30.37	26.92	24.69	20.81	20.83	20.83	22.47
1952	28.59	33.23	28.71	22.19	34.60	34.61	26.90
1953	22.67	22.73	28.71	28.34	24.25	24.25	22.53
1954	15.89	13.76	18.97	17.29	18.28	18.28	18.29
1955	24.21	19.99	23.06	18.59	23.15	23.15	22.79
1956	17.27	17.42	16.68	11.34	17.22	21.62	17.90
1957	42.41	43.14	44.75	41.13	52.15	52.16	38.68
1958	36.78	35.49	46.80	31.79	37.45	37.45	43.40
1959	26.97	31.11	28.11	21.81	27.68	27.68	32.08
1960	46.20	43.43	36.13	46.03	45.89	45.89	39.69

Table 4.5 (Cont.)

Year	Zone 1 Kenedy	Zone 2 Runge	Zone 3 Karnes City	Zone 4 Falls City	Zone 5 Nixon	Zone 6 Stockdale	Zone 7 Floresville
1961	23.82	20.79	18.93	28.94	32.53	32.53	26.86
1962	27.31	26.67	25.69	24.18	26.00	26.00	19.90
1963	22.88	18.15	24.32	22.36	18.83	18.83	16.97
1964	23.63	27.23	22.82	21.06	24.32	24.32	24.42
1965	41.88	41.53	37.03	29.34	42.63	42.63	34.13
1966	25.27	28.68	21.76	22.02	26.36	26.28	27.23
1967	46.44	44.32	46.96	37.90	36.12	36.13	38.77
1968	44.97	31.46	33.57	41.90	39.66	39.66	45.94
1969	34.01	31.88	28.63	30.21	38.10	38.10	35.29
1970	33.15	28.73	27.97	23.96	27.01	27.01	23.45
1971	32.75	31.89	24.00	24.92	30.57	30.57	19.75
1972	28.72	29.96	24.22	29.89	33.51	33.52	22.34
1973	41.99	51.93	37.78	43.75	47.36	47.36	54.35
1974	26.75	27.48	26.35	27.98	36.44	36.44	32.50
1975	28.94	25.90	28.07	24.71	31.45	31.45	29.96
1976	40.06	45.20	38.11	35.30	47.28	47.28	36.52
1977	34.39	33.57	23.45	22.09	30.93	30.93	25.29
1978	34.90	33.88	27.84	29.40	33.59	35.83	30.89
1979	37.97	36.90	33.79	29.65	40.50	42.48	29.95
1980	29.15	28.35	23.28	32.53	28.20	30.95	24.15
1981	41.75	40.50	41.61	28.45	34.56	35.78	24.88
1982	22.86	22.24	26.01	29.58	21.79	27.79	28.82
1983	27.41	26.59	27.12	26.69	36.72	30.10	27.72
1984	23.20	22.32	22.37	16.83	27.90	18.95	20.09
1985	38.04	36.96	34.83	32.38	37.57	38.19	27.98
1986	29.47	28.68	28.23	26.72	29.76	32.62	27.29
1987	33.01	32.10	24.79	34.14	40.14	38.53	22.15
1988	20.67	20.08	15.87	16.14	14.36	18.01	14.20
1989	21.71	21.14	23.16	21.42	27.78	25.22	19.74
1990	21.46	20.89	25.61	27.46	24.03	24.17	28.93
1991	41.36	40.29	35.22	38.64	42.81	42.16	34.02
1992	33.91	32.94	41.38	36.54	58.50	56.52	52.06
1993	24.72	24.02	25.54	28.84	40.05	37.21	46.09
1994	40.63	39.49	27.58	36.56	35.84	33.84	32.73
1995	23.52	22.86	25.08	18.75	30.48	31.17	19.78
1996	25.37	24.67	20.51	20.72	26.48	16.51	21.68
1997	40.71	39.60	36.69	26.86	35.31	32.64	29.92
1998	39.92	38.80	36.01	28.04	44.00	37.22	35.62
1999	16.15	15.71	20.35	24.25	23.07	21.80	15.47
2000	36.28	35.27	31.44	31.74	37.63	34.41	31.64

Table 4.5 (Cont.)

Year	Zone 1 Kenedy	Zone 2 Runge	Zone 3 Karnes City	Zone 4 Falls City	Zone 5 Nixon	Zone 6 Stockdale	Zone 7 Floresville
2001	40.31	39.17	39.38	28.47	42.30	36.65	31.80
2002	42.05	40.89	38.21	35.90	39.60	40.31	41.01
2003	33.84	32.90	26.56	27.92	25.77	25.77	29.16
2004	45.12	43.87	42.31	37.98	44.11	46.90	40.90
2005	33.67	32.72	20.70	17.00	23.24	19.90	18.37
2006	25.90	25.16	20.65	18.06	23.62	32.11	28.33
2007	46.25	45.17	47.30	40.67	49.26	51.23	48.86
2008	17.09	16.62	18.12	14.27	19.80	25.83	13.41
2009	34.48	33.49	36.56	25.03	40.50	38.84	29.71
2010	34.34	33.38	36.48	26.39	27.30	29.81	35.82
2011	15.62	15.17	16.57	14.81	16.44	14.77	13.56
2012	20.07	19.45	21.26	16.52	27.02	33.23	29.70

5.0 SOILS

Two soil components are included in an EDYS model. First, a soils map is constructed that indicates the spatial location of each soil unit (soil series or soil type) included in the spatial footprint of the model. Second, profile descriptions are developed for each of the soil units.

5.1 Soils Map

A total of 99 soil units are included in the Karnes and Wilson models (Appendix Table B.1). Most (85) of these occur in both counties, but 10 occur in Karnes County but not in Wilson County and 4 occur in Wilson County but not in Karnes County. The list of soils and their spatial locations were taken from the NRCS soil surveys for each county (Taylor 1977; Molina 2000). The NRCS mapped soil units were displayed on a aerial photograph (Fig. 5.1) and each 40 m x 40 m EDYS cell was then assigned one of the 99 soil units, based on the location of the cell in relation to the spatial locations of the soil units.

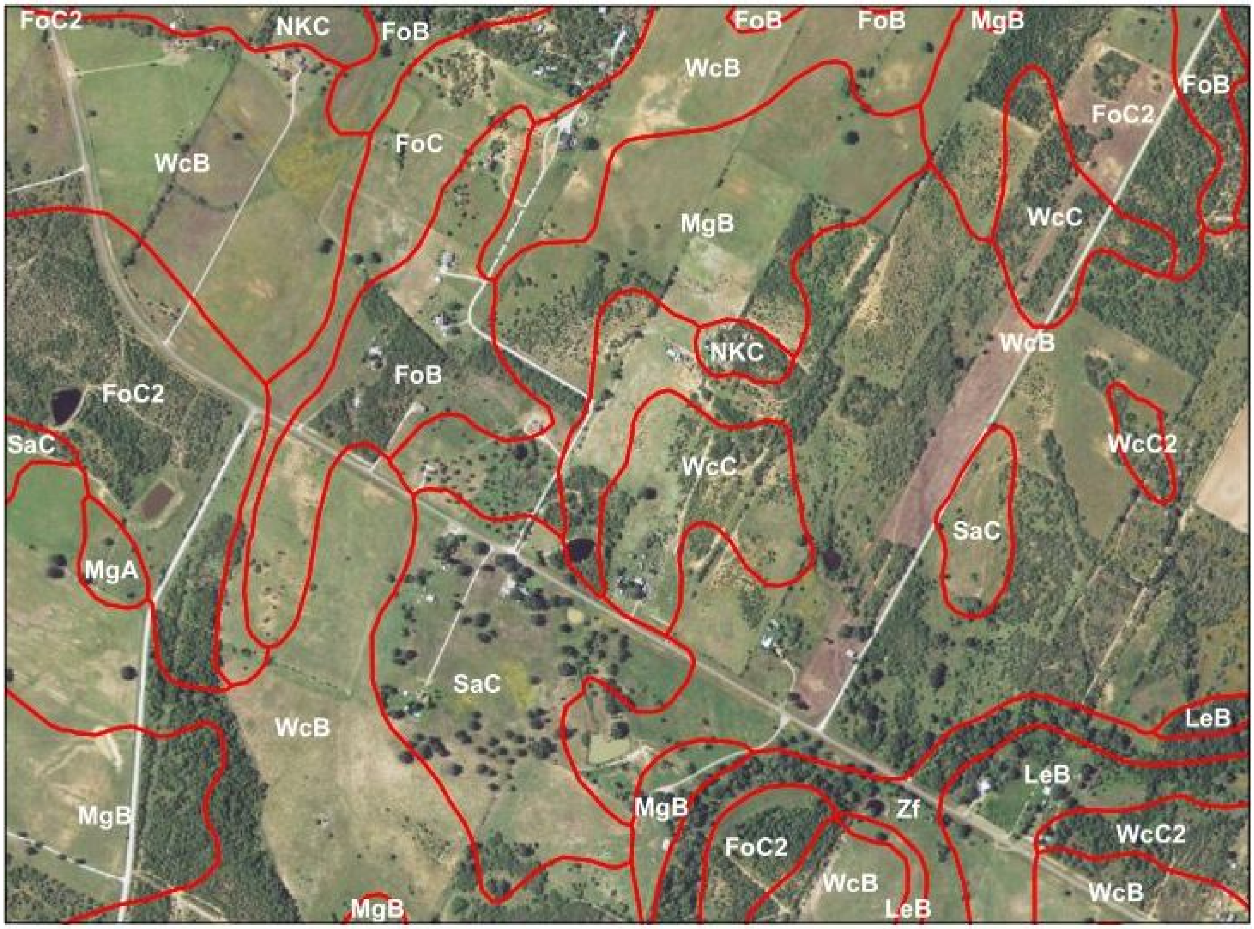


Figure 5.1 Example of the spatial distribution of NRCS soil units on a portion of the Wilson County landscape.

5.2 Profile Descriptions

A soil profile is a vertical section of a particular soil. Soils are composed of layers, called horizons, each horizon differing in some major physical or chemical variable from the layer above and and the layer below it. Horizons are designated by capital letters (e.g., A, B, C) in a top-down order. Horizons are often subdivided and these subdivisions are designated by lower-case letters (e.g., Ap, Bk, Bt), the letters referring to specific types of soil conditions, and/or numbers (e.g., A1, A2, Bt1, Bt2), with the number designating vertical order within the horizon (capital letter). General profile descriptions of each soil occurring in a particular county are provided in the NRCS Soil Survey for that county. The Weesatche sandy clay loam, a soil found in both Karnes and Wilson Counties, is presented as an example (Table 5.1).

Table 5.1 NRCS profile description of the Weesatche sandy clay loam soil (Molina 2000).

Horizon	Depth (cm)	Texture	Color	Structure	Alkaline
A	00-020	sandy clay loam	very dark gray	weak subangular blocky	Slightly
Bt1	20-038	sandy clay loam	very dark gray	moderate angular blocky	Slightly
Bt2	38-060	sandy clay loam	dark brown	weak prismatic	Slightly
Btk	60-083	sandy clay loam	brown	weak subangular blocky	moderately
Bk	83-128	sandy clay loam	brown	weak subangular blocky	moderately
BCk	128-200	sandy clay loam	pink	weak subangular blocky	moderately

EDYS soil profiles are based on the NRCS profiles, but differ in two primary ways. First, EDYS profiles contain more layers and extend to greater depths than their repective NRCS profiles. The usual time step in EDYS simulations is daily. Daily changes in belowground components that affect plant growth (e.g., available soil moisture, root growth, availability of soil nutrients) occur at finer spatial scales (soil depths) than those designated for NRCS soil horizons. For example, many precipitation events supply only small amounts of water. The median summer precipitation event in many drier regions is less than 5 mm (Schwinning and Sala 2004). In many soils, a 5-mm rainfall event will supply water to only the top 5 cm (2 inches) of the soil profile, and at that depth most of the rainfall-supplied water will be extracted by evaporation before it can be used by plants in transpiration. In contrast, a 10-mm rainfall event on the same soil might supply some moisture to a depth of 10 cm or more and, at that depth, some of the water would be extracted by evaporation and some by transpiration. Only that water used in transpiration would be available to support plant growth. Therefore, small differences in soil depth can substantially affect plant growth responses. For this reason, thinner soil layers are used in EDYS.

The number of soil layers in EDYS is flexible, but commonly 20 layers are used per soil. This is the case for the Karnes and Wilson models. Although there are 20 soil layers in each of these EDYS soils profiles, the thickness (depth) and characteristics of each layer vary among soils. The EDYS soil layers are subdivisions of NRCS horizons and subhorizons, with each NRCS horizon or subhorizon divided into one or more EDYS layers. However, no EDYS layer combines portions of more than one NRCS horizon or subhorizon. For example, no EDYS layer would include the 018-022 cm depth of the Weesatche sandy clay loam (Table 5.1) because that would combine different horizons.

NRCS profile descriptions do not include the subsoil material. EDYS profiles extend much deeper, the lower depth based on the maximum potential rooting depth of the deepest rooted plant species included in the particular EDYS application. These deeper depths are included in EDYS because plant roots extend into these zones and those zones contain moisture and nutrients that can be accessed by the plants. The thickness and other characteristics of the lower EDYS soil layers are estimated from parent material information provided in the NRCS soil surveys and from other literature sources. These lower EDYS layers are thicker than the upper soil layers because daily changes in moisture inputs and root dynamics are not as dynamic as those in the upper layers and because less information is available relative to the characteristics of the lower layers.

The second primary way that EDYS profiles differ from NRCS profiles is that some soil variables are included in the EDYS profiles that are not included in the NRCS profiles. Variables included in NRCS profiles are largely descriptive variables, i.e., those useful in classifying soils. Variables included in EDYS profiles are functional variables, i.e., variables that affect ecological responses. For example, soil color is a major classification variable in NRCS profile desciptions (Table 5.1) but soil color has little direct impact on ecological or hydrological responses and is therefore not included in EDYS profiles. Conversely, total available moisture content is a very important variable influencing plant growth but is not useful in classifying a soil. Hence it is included in EDYS profile descriptions but not in NRCS profile descriptions. Data used to provide values for the EDYS soil variables are taken from NRCS soil surveys, other literature sources, and estimates based on existing information.

Eleven soil variables are included, by soil layer, for each EDYS soil profile (Table 5.2). EDYS simulates belowground dynamics based on these 11 variables and the changes in their values that occur during a simulation. Five variables (soil texture, bulk density, maximum moisture content at saturation, field moisture capacity level, permanent wiling moisture level) remain constant. Five variables (moisture content, nutrient content, organic matter content, salinity levels and contents of any contaminants) change during a simulation as resources enter or exit the various soil layers. Thickness of each layer remains constant unless erosion or deposition occurs. If deposition occurs, the thickness of the top layer increases by the corresponding amount. If erosion occurs, the thickness of the top layer decreases by the corresponding amount. If erosion is sufficient to remove all of the top layer, then the process shifts to the second layer and this process continues as long as erosion continues.

Table 5.2 Soil variables used in EDYS simulations.

Variable	Unit	Comment
Layer thickness	cm	Initial values entered as inputs.
Soil texture (sand, silt, clay)	%	Not directly used as an input variable. Used to calculate soil water holding capacities and infiltration and percolation rates.
Bulk density	g/cc	Not directly used as an input variable. Used to calculate pore space.
Max moisture content at Saturation	g/layer	Calculated from (pore space – organic matter content).
Field capacity level	g/layer	Calculated from soil texture, unless specific laboratory data available.
Permanent wilting level	g/layer	Calculated from soil texture, unless specific laboratory data available.
Available moisture content	g/layer	Calculated from (amount of water in layer – amount held at permanent wilting).
Nutrient levels	g/layer	Initial values entered as inputs.
Organic matter content	g/layer	Initial values entered as inputs.
Salinity levels	ppm	Initial values entered as inputs.
Contaminant levels	ppm	Initial values entered as inputs.

Water is the major factor controlling belowground dynamics. Terrestrial plants uptake the water they need for maintenance and growth from the soil (including groundwater in the subsoil). The location (depth) of water stored in the soil (i.e., soil moisture) in relation to root architecture of the various plant species is an important factor controlling the competition among these species. Nutrients and contaminants become available for plant uptake as they enter into soil solution and their concentrations vary as amounts are moved among layers by water movement. Organic matter is also moved among layers by water movement and the decomposition and mineralization rates of organic matter are controlled, in part, by moisture content of the soil.

In EDYS, water can arrive at the surface of a spatial cell in two ways, by a precipitation event and by surface movement from a surrounding cell (i.e., run-on). Some of this water can enter the soil profile (infiltration) and some leaves the cell as runoff. Litter on the soil surface has the first opportunity for absorption of water in EDYS. If litter is present and is at less than its maximum moisture content, it can absorb sufficient water to bring it up to maximum moisture content. The remaining water is available for infiltration into the soil profile and runoff from the cell.

In EDYS, the amount of water that can potentially enter into the soil profile is modeled as a step function. Each rainfall event is divided into five parts (10%, 20%, 40%, 20%, and 10% of the total event amount). The amount of water available in Step 1 (10% of the rainfall event plus any run-on water) is compared to the available storage capacity (saturation capacity minus current moisture content) of the first layer. If the amount of water available is less than or equal to the available storage capacity, all the water is moved into the first soil layer. If the amount is in excess of the available storage capacity, the excess amount is moved to adjacent cells as runoff. This process is repeated through each of the next four steps, with the number of layers used to calculate available storage capacity increasing by one layer at each step (e.g., Step 3 = 40% of rainfall event compared to storage capacity of top three layers).

Once water moves into a soil layer it is moved downward using a “tipping bucket” algorithm. Any water in excess of field capacity of the first layer moves into the second layer. Any water in excess of field capacity for that layer is moved into the third soil layer. This process continues in a top-down manner until the amount of water is stored in the various soil layers, or if some remains once the wetting front reaches saturated soil (groundwater), the surplus amount is added to groundwater. If the groundwater is unconstrained (i.e., groundwater lateral flow can occur), this amount of added water is removed as “export”. If the groundwater is constrained, then the water content of the layer immediately above the saturated layer increases above field capacity. This increase can continue until the saturation level is reached for that layer, at which time the process continues in an upward manner into the next unstaturated layer.

As water moves downward by percolation, soluable materials (nutrients, contaminants, organic matter) can be moved with the water. As water moves into the next layer at each time step, the concentrations of the soluable materials in that layer are recalculated based on the amount of those materials in the layer prior to entry of the new water and the new concentration resulting from all the surplus water (not just field capacity) that at least temporarily moves into that layer. Then if some water continues to move downward out of that layer, that water transports with it the amount of nutrients, contaminants, and organic matter corresponding to its relative concentration.

Soil water (including groundwater) is extracted from each layer at each time step by plant uptake (transpiration). The amount removed from each layer is determined by the amount of roots of each plant species in that layer, the depth of the layer (root uptake is modeled as a top-down process), and the amount of water transpired by each species. Soil water can also be extracted by evaporation. However, evaporation occurs directly only from the surface soil layer. Stored soil moisture can be moved from a maximum of the next three soil layers upward to the surface soil layer and then lost by evaporation, but this is a time-step controlled process and plant roots get first priority use of the water as it moves upward from the second, third, and fourth layers.

In addition to movement by water, organic matter can be added to a soil layer by death of plant material (roots) in that particular layer and by some movement of surface litter into the upper soil layer. The deposition of this material is based on root death rates specific to each species and decomposition rates that are influenced by moisture content and nitrogen availability.

6.0 VEGETATION

6.1 Plant Species

The number of plant species included in a specific EDYS application is flexible. How many and which species to be included depends on the requirements of the application and the level of complexity desired. The inclusion of more species increases the potential for the model to simulate the complexity common to most landscapes, but it also increases run times and memory requirements.

The EDYS data base includes ecological data on over 250 species, not all of which occur in South Texas and not all of which have data for all plant parameter variables used in EDYS. In each EDYS application, a subset of all species occurring in the spatial domain is used. Several factors are considered in the selection of this subset.

- The subset should include the major species of the area, based on both ecological and management importance. Ecological importance includes dominant and sub-dominant species for each of the included plant communities, as well as species important successionally and threatened and endangered species if they are present.

- There must be sufficient ecological data available for the included species such that the required parameter variable values can be determined or reasonably estimated. Data for all parameter variables may not be available for a major species. In such cases, reasonable estimates can often be made based on available data for closely-related or ecologically similar species.

- For species where a substantial amount of their parameter values are estimated, care must be taken that the estimates are not based largely on data from species used to estimate values for other included species. Otherwise, little new information is actually included in the model by adding another species.

- The inclusion of the species should be expected to sufficiently increase the ability of the model to simulate ecological responses to justify any associated increase in run time, memory requirements, or time required to interpret results.

- The inclusion of the species should not unduly increase unaccounted error (i.e., "noise") into the model output.

Based on these factors, 66 plant species are included in the models (Table 6.1).

Table 6.1 Plant species included in the Karnes-Wilson EDYS model.

Lifeform	Species	Common Name
Tree	*Acacia farnesiana*	Huisache
Tree	*Carya illinioensis*	Pecan
Tree	*Celtis laevigata*	sugar hackberry
Tree	*Diospyros texana*	Texas persimmon
Tree	*Prosopis glandulosa*	mesquite
Tree	*Quercus stellata*	post oak
Tree	*Quercus virginiana*	live oak
Shrub	*Acacia berlandieri*	Guajillo
Shrub	*Acacia rigidula*	blackbrush
Shrub	*Aloysia lycioides*	whitebrush
Shrub	*Baccharis texana*	prairie baccharis
Shrub	*Celtis pallida*	granjeno
Shrub	*Mahonia trifoliolata*	Agarito
Shrub	*Sesbania drummondii*	Rattlepod
vine	*Vitis mustangensis*	mustang grape
cacti	*Opuntia lindheimeri*	prickly pear
perennial grass	*Andropogon gerardii*	big bluestem
perennial grass	*Aristida purpurea*	purple threeawn
perennial grass	*Bothriochloa ischaemum*	King Ranch bluestem
perennial grass	*Bothriochloa saccharoides*	silver bluestem
perennial grass	*Bouteloua curtipendula*	sideoats grama
perennial grass	*Bouteloua hirsuta*	hairy grama
perennial grass	*Buchloe dactyloides*	buffalograss
perennial grass	*Cenchrus incertus*	sandbur
perennial grass	*Chloris cucullata*	hooded windmillgrass
perennial grass	*Chloris pluriflora*	trichloris
perennial grass	*Cynodon dactylon*	bermudagrass
perennial grass	*Digitaria californica*	Arizona cottontop
perennial grass	*Elymus virginicus*	Virginia wildrye
perennial grass	*Leersia hexandra*	clubhead cutgrass
perennial grass	*Panicum coloratum*	kleingrass
perennial grass	*Panicum obtusum*	vine-mesquite
perennial grass	*Panicum virgatum*	switchgrass
perennial grass	*Paspalum lividum*	longtom
perennial grass	*Paspalum setaceum*	thin paspalum
perennial grass	*Schizachyrium scoparium*	little bluestem
perennial grass	*Setaria geniculata*	knotroot bristlegrass
perennial grass	*Setaria texana*	Texas bristlegrass
perennial grass	*Sorghum halepense*	Johnsongrass

Table 6.1 (Cont.)

Lifeform	Species	Common Name
perennial grass	*Sporobolus asper*	tall dropseed
perennial grass	*Stipa leucotricha*	Texas wintergrass
annual grass	*Sorghum bicolor*	milo
annual grass	*Triticum aestivum*	wheat
annual grass	*Zea mays*	corn
grass-like	*Carex microdonta*	littletooth sedge
grass-like	*Cyperus odoratus*	flatsedge
grass-like	*Fimbristylis puberula*	fimbry
grass-like	*Typha latifolia*	cattail
perennial forb	*Ambrosia psilostachya*	ragweed
perennial forb	*Clematis drummondii*	old-mans beard
perennial forb	*Desmanthus velutinus*	bundleflower
perennial forb	*Phyla nodiflora*	frogfruit
perennial forb	*Ratibida columnifera*	prairie coneflower
perennial forb	*Rhynchosia americana*	snoutbean
perennial forb	*Ruellia nudiflora*	ruellia
perennial forb	*Simsia calva*	bush sunflower
perennial forb	*Verbena halei*	Texas verbena
perennial forb	*Zexmenia hispida*	orange zexmenia
annual forb	*Ambrosia trifida*	giant ragweed
annual forb	*Amphiachyris dracunculoides*	annual broomweed
annual forb	*Chamaecrista fasciculata*	partridge pea
annual forb	*Croton texensis*	Texas doveweed
annual forb	*Helianthus annuus*	sunflower
annual forb	*Lemna minor*	duckweed
annual forb	*Lupinus texensis*	Texas bluebonnet
annual forb	*Thymophylla tenuiloba*	dogweed

6.2 Vegetation Formations

A vegetation formation is a subdivision of a biome (McLendon 1991), with the subdivision based on either a general environmental factor (e.g., sandy prairie, riparian woodland) or the dominant genus or species (e.g., oak woodland). Twelve major vegetation formations occur in Karnes and Wilson Counties (Table 6.2), with several to numerous plant communities in each formation.

Table 6.2 Major vegetation formations in Karnes and Wilson Counties, Texas.

Woodlands	Shrublands	Grasslands	Aquatic	Agricultural
Huisache woodlands	Mesquite shrublands	Clay/clay loam prairies	Lakes/ponds	Cultivated
Mesquite woodlands	Xeric shrublands	Sand prairies	River/creeks	Pasture
Oak woodlands				
Riparian woodlands				

6.2.1 Woodlands

Riparian woodlands occur along the banks of the San Antonio River and banks of the larger perennial creeks. These woodlands commonly have a continuous or nearly continuous canopy cover of trees. The trees tend to be medium-sized to large and of mixed composition. The width of the community generally increases as the size and flow of the associated drainage increases. This bottomland community can extend outward 100-200 m, or more, from each bank of the San Antonio River in some areas, or be as narrow as 10-20 m along some areas of the mid-sized creeks.

Huisache (*Acacia farnesiana*) is a small- to medium-sized tree that can form dense stands on frequently-flooded sites, recently-disturbed sites, and grassland sites (both native and pasture). Huisache is an aggressive, mid-seral colonizer. It is particularly well-adapted to relatively wet sites, where the surface is frequently flooded and the water table is near the soil surface. However, it also forms extensive, but less dense, stands on drier sites. On drier, especially clay loam sites, huisache has a competitive advantage over mesquite (*Prosopis glandulosa*) earlier in succession but mesquite tends to have the competitive advantage over time.

In Karnes and Wilson Counties, mesquite woodlands are particularly well-developed on clay loam sites with relatively deep soils that are not frequently flooded. Mesquite woodlands often occur as strips along the drier edges of the riparian woodlands and along the edges of oak woodlands. In these areas, the mesquite can become large (1-m diameter trunks) and form nearly continuous canopies. Many former grassland sites now support mesquite woodland because of long-term overgrazing by livestock and suppression of fire.

Oak woodlands occur on sites that are moderate to deep sands. Some oak, especially live oak (*Quercus virginiana*) are common components of the riparian woodlands. But as the soils become sandier, oaks tend to become the dominant species. Post oak (*Q. stellata*) woodlands tend to be somewhat continuous across the landscape, whereas live oak woodlands tend to form mottes, some of which can be extensive. However, both species can occur in relatively extensive stands or in clusters. The oak woodlands occur in both counties, but are more abundant in Wilson County.

6.2.2 Shrublands

There are two primary shrubland formations in these two counties, mesquite shrublands and xeric shrublands. Mesquite shrublands occur mostly on clay and loam sites that are either drier than those supporting mesquite woodlands or have been more recently or frequently disturbed.

The drier nature of these sites often occurs because there is either a deeper water table or a caliche layer nearer the surface, as compared to soils supporting mesquite woodlands. The mesquite on these sites tends to be smaller than those in the woodlands, although they can obtain tree size (e.g., 3-8 m tall). Shrubs are abundant in this formation, often forming dense stands under the canopies of scattered mesquite. Granjeno (*Celtis pallida*), prickly pear (*Opuntia lindheimeri*), and whitebrush (*Aloysia lycioides*) are common in the shrub component, but mixtures of 10-20 species are common (McLendon 1991).

The xeric shrublands occur mostly on shallow, limestone (caliche) sites. These sites are scattered throughout the two counties but are most common in the southern and western parts of Karnes County. The soils are thin (0-20 cm) over a generally fractured limestone substrate, the upper portion of which varies between somewhat soft to dense, indurated caliche. The vegetation on these sites tend to be short (2-4 m tall), dense shrublands. Blackbrush (*Acacia rigidula*) is the most common dominant and often occurs as very dense, almost monoculture, stands with little understory vegetation (McLendon 1991). On the shallowest soils, guajillo (*Acacia berlandieri*) becomes dominant or, in the western portions, co-dominant with cenizo (*Leucophyllum frutescens*). Numerous other xeric shrubs occur in this formation, along with small, scattered mesquite.

6.2.3 Grasslands

Native grasslands were probably extensive in both Karnes and Wilson Counties in the past, but cultivation, conversion to improved pastures, and increases in woody species have reduced their extent. There is relatively little area in native clay or clay loam grasslands remaining in the two counties. Those that do exist have mostly been restored, either from previously cultivated land or from brush removal. These clay/clay loam grasslands were midgrass prairie, dominated mostly by bluestems (e.g., *Bothriochloa saccharoides* and *Schizachyrium scoparium*), with substantial amounts of other midgrass species such as sideoats grama (*Bouteloua curtipendula*), trichloris (*Chloris pluriflora*), Arizona cottontop (*Digitaria californica*), Texas cupgrass (*Eriochloa sericea*), and plains bristlegrass (*Setaria leucopila*). More mesic sites such as low-lying areas and ecotones to the riparian woodlands also contained large amounts of tallgrasses, such as big bluestem (*Andropogon gerardii*), indiangrass (*Sorghastrum nutans*), switchgrass (*Panicum virgatum*), and eastern gamagrass (*Tripsacum dactyloides*).

Sand prairies have also been reduced in area over time, but there are still substantial amounts remaining, primarily mixed between strips and mottes of the oak woodlands. The sand prairies are most abundant in Wilson County, but there are also areas in northeastern Karnes County. The sand prairies are midgrass prairies also, typically dominated by little bluestem (*Schizachyrium scoparium*) and tall dropseed (*Sporobolus asper*). Forbs are common in these prairies and, when moisture is sufficient, extensive stands of bluebonnets (*Lupinus texensis*), Indian paintbrush (*Castilleja indivisa*), coreopsis (*Coreopsis tinctoria*), and Indian blanket (*Gaillardia pulchella*) can be spectacular.

6.2.4 Aquatic Systems

There are no large lakes in Karnes or Wilson Counties but there are abundant ponds, mostly man-made. The vegetation associated with these ponds (including stock tanks) varies by the size, depth, and perennial water-holding capability of the pond, but is typical of this type of wetland vegetation in the region. There is often an open water surface with little emergent or surface vegetation. As the water depth decreases, floating species may occur if the pond has permanent water. Then there is commonly a zone of emergent vegetation, typically cattails (*Typha* spp.) and bulrushes (*Scirpus* spp.), then a zone of wetland species including cutgrass (*Leersia hexandra*), sedges (*Carex* spp.), spikerushes (*Eleocharis* spp.), flatsedges (*Cyperus* spp.), longtom (*Paspalum lividum*), and rattlepod (*Sesbania drummondii*). These zones can be narrow (25-50 cm) or wider (e.g., 10 m) depending on the size, structure, and permanency of the pond. Heavy use by livestock often reduces the size and complexity of these zones.

The San Antonio River flows through both counties and numerous small to medium sized creeks flow into the river. Vascular plant development in the river and larger creeks is limited because of high turbidity. In most sections of the river in these two counties, it is relatively slow moving. Therefore, vegetation along the edges of the river, and similarly along the edges of the larger creeks, is similar to that along the edges of the ponds where the river and creek banks have a gradual slope. Where the river and creek banks drop abruptly into the river, the aquatic vegetation is limited to a thin strip of wetland species. In many of these abrupt areas, the canopies of the riparian trees overhang and may touch the surface of the river. Upslope from the river and creek banks, the vegetation transitions to riparian or mesquite woodland, a wetland, or a shrubland depending on conditions adjacent to the bank.

Many of the mid-sized and smaller creeks in Karnes and Wilson County are ephemeral streams. Along these streams, there are generally mesquite or huisache woodlands, the width of which may vary from 10-100 m. The streambeds are often bare of vegetation if water flows fairly frequently, but most streambeds are covered with forbs and grasses during dry periods.

6.2.5 Agricultural

Approximately 165,000 acres (34%) in Karnes County are under cultivation and an additional 121,000 acres (25%) in improved pasture (Molina 2000). In Wilson County, about 235,000 acres (45%) are under cultivation and 80,000 acres (15%) are in improved pasture (Taylor 1977). The major crops in Karnes County are grain sorghum, corn, wheat, and cotton. The major crops in Wilson County are peanuts, grain sorghum, corn, wheat, and cotton. Most cultivation is dryland, with irrigation mostly limited to specialty crops such as vegetables.

Major improved pasture grasses are bermudagrass (*Cynodon dactylon*), kleingrass (*Panicum coloratum*), and forage sorghums. Improved pastures are subject to invasion by woody species, especially huisache and mesquite. Woody plant invasion is slower in pastures that are routinely hayed but woody species still tend to invade over time, especially huisache which has the ability to spread low-growing branches horizontally beneath the cutting height for hay production. Because of invasion by woody plants, improved pastures must be routinely maintained or they will revert to savannas (open stand of small trees with grass understory) in 10-20 years and woodlands in 20-40 years.

Native rangeland and most improved pasture are used to support beef cattle, mostly cow-calf operations, and hunting. However, dairy farming is important and there is a substantial poultry industry in both counties. About 5% of the area in both counties is devoted to non-agricultural non-native vegetation uses, such as urban, industrial, roads, and mineral production.

6.3 Plant Communities

In EDYS, each cell is assigned an initial vegetation composition based on some combination of the plant species included in the application (Table 6.1). Because species composition data are not available for each cell in the spatial footprint, initial vegetation assignments are made on the basis of plant communities. A first-approximation of species composition of the plant communities, as well as their spatial distribution, is made using NRCS soil survey maps (Taylor 1977; Molina 2000). Each soil series is assigned an initial plant community based on NRCS ecological site descriptions, other available literature, and professional experience. NRCS ecological site descriptions are largely based on late-successional conditions, which seldom occur on site. Instead, the sites are generally in a lower successional stage and often have some level of woody plant cover. Estimates of lower successional conditions and amount of woody plant cover (estimated from aerial photographs) are used to adjust the literature data to arrive at initial estimates of species composition and biomass levels for each plant community.

An initial plant community may closely coincide spatially with its associated soil type. However, in some cases the plant communities associated with two or more soil types may be very similar and therefore be pooled, or visual observations from the aerial photographs may indicate that two or more areas in the same soil type have very different woody plant coverage and therefore are separated into two or more plant communities.

Once all plant communities have been defined and mapped, all cells within a particular plant community are given the same initial species composition data. Although each cell within a vegetation polygon (initial plant community) has the same initial species composition, it does not necessarily remain the same during a simulation. Differences in topographic features, precipitation zones, depths to groundwater, natural disturbances (e.g., fire), and management impacts (e.g., livestock grazing intensity, reseeding, brush control) often result in some cells within an initial vegetation polygon changing sufficiently that they form a separate vegetation polygon.

In addition to literature data and aerial photographs, ground truthing of the initial spatial distribution of the vegetation is generally conducted. The level of this field mapping depends on the needs of the project as defined in the scope of work. Once the initial spatial footprint, including vegetation patterns, has been developed and initial simulations conducted, it may be deemed desirable to conduct additional field surveys to increase the detail of the spatial mapping. This can be done and updates made into EDYS with a reasonable amount of effort.

Twenty-one initial native plant communities were identified for the Karnes-Wilson model (Table 6.3). These 21 communities were derived from the NRCS range sites and modified on the basis of information in the literature and from amounts of woody plant coverage. Woody plant coverage was estimated from NAIP aerial photographs. Literature data used to modify the NRCS range site descriptions of the vegetation for Karnes and Wilson Counties (Appendix Table C.2) were summarized from Archer (1990), Archer et al. (1988), Bovey et al. (1970, 1972), Box (1961), Box and White (1969), Buckley and Dodd (1969), Diamond and Smeins (1984), Dodd and Holtz (1972), Drawe (1994), Drawe and Box (1969), Drawe et al. (1978), Johnston (1963), McLendon (1991, 1994), McLendon and Dahl (1983), Powell and Box (1967), Scifres et al. (1980), Smeins (1994a, 1994b), and Smeins and Diamond (1983).

Table 6.3 Initial native plant communities used in the EDYS models for Karnes (K) and Wilson (W) Counties, with their associated NRCS range sites and primary associated soil types.

Plant Community	Range Site	County	Primary Soil Type
Clay Soils			
mesquite-hackberry-live oak	clayey bottomland	KW	Aransas clay
mesquite-silver bluestem-trichloris	Blackland	KW	Elmendorf-Denhawken
mesquite-silver bluestem-buffalograss	rolling blackland	KW	Coy clay loam
Clay Loam Soils			
live oak-mustang grape-Johnsongrass	loamy bottomland	KW	Gowen clay loam
mesquite-granjeno-silver bluestem	clay loam	KW	Weesatche sandy clay loam
mesquite-buffalograss-purple threeawn	sloping clay loam	K	Schattel clay loam
Sandy Loam Soils			
mesquite-granjeno-hooded windmillgrass	gray sandy loam	KW	Colibro sandy clay loam
mesquite-buffalograss-silver bluestem	tight sandy loam	KW	Crockett fine sandy loam
mesquite-buffalograss-trichloris	Hardland	W	Willamar fine sandy loam
mesquite-little bluestem-thin paspalum	sandy loam	KW	Runge fine sandy loam
Sandy Soils			
mesquite-live oak-little bluestem	Sandy	K	Nusil fine sand
live oak-mesquite-little bluestem	loamy sand	KW	Wilco loamy fine sand
live oak-little bluestem-thin paspalum	deep sand	W	Sarita fine sand
post oak-little bluestem-purple threeawn	deep sand savanna	W	Eufaula and Patilo soils
Shallow Soils			
post oak-mesquite-silver bluestem	sandstone hills	KW	Nocken stony/Rock outcrop
post oak-sideoats-little bluestem	very gravelly	W	Vernia gravelly loamy sand
live oak-silver bluestem-buffalograss	chalky ridge	K	Shiner fine sandy loam
blackbrush-silver bluestem-purple threeawn	Shallow	K	Ecleto sandy clay loam
blackbrush-guajillo-silver bluestem	gravelly ridge	K	Devine gravelly sandy loam
blackbrush-guajillo-purple threeawn	shallow ridge	KW	Picosa loam
Wetland Sites			
huisache-flatsedge-bermudagrass	Lakebed	K	Tiocano clay

Ten land-use types were also included in the models (Table 6.4). These include urban areas, industrial sites, mineral developments, disturbed areas, cultivation, improved pastures, and areas subjected to brush control. They are treated in EDYS in a manner similar to vegetation types.

Table 6.4 Land-use types included in the EDYS models for Karnes and Wilson Counties.

Land-Use Type	Vegetation	Comment
Urban houses	mesquite-live oak-bermudagrass	50% of the area vegetated (lawns)
Buildings/industrial	mesquite-huisache-baccharis	% woody plant cover from aerial photographs
Disturbed area	mesquite-huisache-baccharis	% woody plant cover from aerial photographs
Oil/drill pad	mesquite-huisache	% woody plant cover from aerial photographs
Road	None	
Tilled (cultivated)	milo (grain sorghum)	
Irrigated (cultivated)	milo (grain sorghum)	
Orchard	Pecan	
Improved pasture	bermudagrass-huisache-mesquite	% woody plants from aerial photographs
Brush control	mesquite-silver bluestem-buffalograss	% woody plants from aerial photographs; grasses = 10% of rolling blackland type

The urban houses type was considered to be 50% of the spatial area covered with buildings and pavement and 50% in some type of yard. The grass component of the yards were considered to be bermudagrass and the woody plants were considered to be 75% mesquite and 25% live oak, with the amount of canopy cover estimated from aerial photographs.

Woody plant cover in cells classified as buildings/industrial, disturbed areas, or oil/drill pads was considered to consist of combinations of mesquite, huisache, and baccharis. These were considered to be either areas not cleared when the sites were disturbed or the plants were the result of re-invasion. Amount of canopy cover was estimated from aerial photographs.

Crops grown on individual cultivated fields vary throughout the two counties. No effort was made to distinguish different crops from the aerial photographs. Instead, all cultivated areas were assumed to be planted each year to milo (grain sorghum). All orchards were assumed to be pecan orchards.

There are several improved pasture species that are common in Karnes and Wilson Counties. Most common are coastal bermudagrass, kleingrass, King Ranch bluestem (*Bothriochloa ischaemum*), Kleberg bluestem (*Dichanthium annulatum*), and various types of forage sorghums (*Sorghum* spp.). Wheat is sometimes planted as a winter forage crop. Regardless of the species planted, other species tend to invade these improved pastures over time. Common invading woody species include huisache, mesquite, hackberry, and baccharis, and common invading herbaceous species include Johnsongrass (*Sorghum halepense*), King Ranch bluestem, ragweed (*Ambrosia psilostachya*), and sunflower (*Helianthus annuus*).

The initial forage species planted, the potential productivity of the pasture, and the most common invading species all vary by soil type, the pre-planting vegetation, and the surrounding vegetation (Appendix Table C.22). Determining what the current composition is for each of the improved pasture polygons in the two counties would require a substantial effort. As a first approximation, only one improved pasture type (sandy loam, Appendix Table C.22) was used for the initial biomass values for all improved pasture polygons. Even though they are initially set with the same biomass values, changes in these improved pastures will occur during model simulation runs because of differences in associated soils and precipitation zones.

Brush control is a management option in the models. However, it was apparent from the aerial photographs that some areas had been subjected to mechanical brush control without being converted to improved pastures. This was most often the case where brush had been removed in strips from the native vegetation. This is a common practice in South Texas, used especially to improve wildlife habitat. The brush strips are left to provide shelter and the cleared strips are used to provide food, in particular forbs, for wildlife, along with clearing viewing areas for hunting.

In small-scale applications of EDYS, these brush strips and adjacent cleared strips can be treated as separate plot types and the composition of both brush and cleared strips can be varied across the spatial footprint. On large-scale applications, this effort becomes too complex. Therefore, average values were used for the vegetation in these brush control polygons. The initial vegetation data was based on that for the Rolling Blackland Range Site (Appendix Table C.2). The same woody plant composition was used for the brush control plots as for the Rolling Blackland Site, along with the same amounts and composition of forbs. However, grass biomass was reduced by 90% with composition remaining the same. The amount of woody plant cover in these polygons was estimated from the aerial photographs.

6.4 Spatial Heteogeneity of Vegetation

Simulation run times and memory requirements increase as the complexity of the model application increases. Model application complexity is influenced by a number of factors. Spatial heterogeneity has the greatest effect.

Spatial heterogeneity includes several components. One component is number of cells, which is determined by cell size and the size of the overall spatial footprint of the model. A practical upper limit is about 1.5 million cells (Section 2.0).

Although EDYS can keep track of changes in condition in all 1.5 million cells at each time step, that is too many cells on which to simulate all dynamics. Instead, EDYS simulates dynamics on plot types and then applies the resulting value, at each time step, to all cells containing that particular plot type. For example, an area of mesquite-granjeno shrubland might contain 100 cells, each with the same vegetation and the same soil. Instead of EDYS making 100 sets of calcuations for that area (polygon) at each time step, EDYS makes one set of calculations and then applies the results of those calculations to all 100 cells.

A plot type is a unique combination of soil, vegetation type (including land-use types), and amount of woody plant cover. Karnes County, for example, contains 60 soil types (Appendix Table B.1) and 37 vegetation-landuse types (Appendix Table B.3), resulting in 310 unique combinations (not all types occur on all soils). There is an average of five woody plant cover categories per vegetation-landuse type. This results in 1550 potential plot types for Karnes County.

Plot types often become subdivided during EDYS simulations. This happens when some disturbance or treatment factor (e.g., fire, brush control, cross fencing, placement of water facilities or buildings) affects one part of the plot type but not another part. The affected portion, including all cells in it, then becomes a different plot type (e.g., root plowed mesquite-granjeno community). Depending on the length of the simulation run and the number of management scenarios applied, this plot proliferation can increase the number of plot types during the simulation run by a factor of 4-5. The use of different precipitation zones (Fig. 4.2) also increases the number of plot types. Two areas with the same initial plot type (soil-vegetation combination) but that occur in different precipitation zones will function as different plot types because of receiving different amounts of precipitation.

Because of plot type proliferation, the number of potential plot types in the Karnes County application may increase from 1550 at the beginning of the simulation run to 6000 or more at the end of the run. The upper limit to number of plot types in an EDYS application with 750,000-1,000,000 cells (e.g., Karnes and Wilson County applications) is about 1700.

There are two approaches that can be taken to account for plot type proliferation. One approach is to not allow it. This approach fixes the number of plot types at the original number (1550 in the case of Karnes County). The advantage in using this approach is that greater initial ecological spatial heterogeneity can be included. The disadvantage is that no spatial changes can occur during a simulation. The vegetation can change within a polygon but the polygon cannot be subdivided because of disturbance or management.

The alternative approach is to reduce the number of initial plot types and then allow proliferation to occur during the simulation. The advantage of this approach is that the landscape becomes spatially dynamic as well as temporally dynamic. The disadvantage is that less ecological spatial heterogeneity can be included at the beginning of the simulation.

Which approach is selected depends on the relative importance of spatial dynamics versus increased spatial ecological complexity. For the Karnes and Wilson Counties models, the second approach was selected. Spatial changes across the landscape, resulting from both natural and anthrogenic factors, were considered to be of high importance. In addition, much of the increased spatial complexity in ecological factors was considered to be of lesser importance. For example, differences in over half of the 60 soil types were relatively minor variations based on slope (Appendix Table B.1).

More complex input data is retained in the EDYS data files for the Karnes and Wilson applications for use in fine-scale applications of the models. The fine-scale applications will utilize smaller spatial footprints and, even though the cell sizes will also be smaller, the number of potential plot types will be smaller. This will allow for more spatially detailed ecological data to be used. For applications using the entire county as the spatial footprint, a reduced number of initial plot types is used. For the county-wide applications, one representative soil type is used for each vegetation type and for each land-use type (Appendix Table B.3), resulting in 37 initial combinations. With an average of four woody cover levels per type, there are approximately 170 initial plot types. Including four precipitation zones per county (Fig. 4.2), the number of initial plot types increases to 680. This allows each initial plot type to be subdivided an average of 2.5

to 3.0 times during the simulation. This seems to be a reasonable balance between initial ecological spatial heterogeneity and spatial dynamics during the simulation run.

6.5 Plant Parameter Variables

EDYS is a mechanistic model. It simulates ecological dynamics by simulating how the various ecological components function. For plants, this is accomplished by using mathematical algorithms to model how plants grow and respond to various environmental stressors, such as drought, fire, and herbivory.

There are a large number of algorithms associated with plant dynamics in the EDYS model (Childress et al. 2002, Coldren et al. 2011a). Each algorithm is applied to each plant species at each time step during a simulation to simulate the change in that plant or plant component from one time step to the next. Each algorithm contains one or more plant response variables (parameters). Differential responses among plant species are achieved in EDYS by assigning species-specific values to each of these plant parameters. For example, one of the algorithms is plant growth, more specifically, increase in plant biomass. This algorithm contains a number of parameters, one of which is “water to production”. This parameter (water to production) is the amount of water (in kilograms) required to produce one gram of new plant biomass, and it is species specific (i.e., the water-use efficiency varies by species). Two major perennial grasses in the Karnes-Wilson models are little bluestem and buffalograss. The water-to-production value for little bluestem is 0.90 and the value for buffalograss is 0.74. Buffalograss is the more xeric of the two grasses and indeed has a higher water-use efficiency.

There are 346 plant parameter variables in EDYS and each one of these has a specific value for each species in an application (66 species in the case of Karnes-Wilson). These variables are arranged into 37 matrices (Coldren et al. 2011a). Selected examples are presented in Appendix D along with corresponding values for each of the species included in the Karnes and Wilson County models.

General characteristics of the species are presented in Appendix Table D.1. Appendix Tables D.2-D.4 are the tissue allocation matrices. At each time step, EDYS calculates the amount of new biomass produced by each species. This amount is based on 1) amount of current photosynthetically active biomass, 2) potential growth rate, and 3) amount of required resources available to the species (function of amount of resources available in the system and the competitive ability of the specific species). The amount of new biomass produced by each species is then allocated to the various plant parts based on the values in the allocation matrices.

Appendix Table D.2 provides the information that EDYS uses to allocate the beginning biomass values (Appendix Table C.2) to the various plant parts to begin a simulation. During a simulation, new biomass production is allocated during each time step to the various plant parts based on the values in Appendix Table D.3. For example, if 10 g of new biomass is produced by huisache, 0.8 g would be coarse roots, 2.0 g would be fine roots, 0.9 g would be added to trunk, 2.2 g would be added to stems, and 4.1 g would be added to leaves. These ratios are used throughout the growing season, except in months when the species flowers or undergoes green-out. Green-out occurs following winter dormancy, drought dormancy, or following severe defoliation. For months when green-out occurs, the values from Appendix Table D.4 are used.

Root architecture varies substantially among plant species and these variations are important in determining competitive responses among species for belowground resources (e.g., water and nutrients). Two components of root architecture of primary importance are distribution of roots by soil depth and maximum potential rooting depth. Appendix Table D.9 provides the values for these two parameters for each of the species included in the models. These values are used in EDYS to determine the initial spatial distribution of root biomass.

The amount of roots for a particular species at the beginning of a simulation is determined by multiplying the coarse and fine root allocation values (Appendix Table D.2) by the initial biomass value for that species in a given plot type (Appendix Table C.2). The values in Appendix Table D.9 are then used to allocate this root biomass (coarse and fine) by soil depth. This is calculated as the product of:

(total root biomass)(% in a proportion of the rooting depth)(maximum potential rooting depth).

For example, 4% of the roots of huisache are assumed to be located in the first 1% of the rooting depth of huisache, which is 12.62 m (Appendix Table D.9). Therefore, 4% of the initial root biomass of huisache is located in the upper 12.62 cm of the soil. If the maximum depth of a soil in a particular plot type is less than the maximum potential rooting depth, the maximum soil depth is used instead.

The values in Appendix Table D.9 are used to calculate the initial distribution of roots in an EDYS simulation. At each time step during a simulation run, new root biomass is added (e.g., Appendix Table D.3). This new root biomass is allocated to those soil depths where active root uptake of water and nutrients are taking place. This results in potential changes in root distribution during a simulation caused by resource distribution.

Appendix Table D.11 provides values used to determine when specified physiological processes occur. These processes are 1) green-out (breaking of winter dormancy), 2) beginning of winter dormancy, 3) months in which flowering and seed production can occur, and 4) months in which seed germination can occur.

Appendix Table D.13 provides values used to determine water requirements of each species for maintenance and production of new biomass. Maintenance water requirements (old and new growth) refers to the amount of water used each month to support existing biomass. Water to production is the amount of water required to produce 1 g of new biomass (i.e, water-use efficiency). Green-out requirement is the amount of water required to support the production of new biomass during green-out.

At each time step during the growing season for a particular species (Appendix Table D.11), EDYS calculates the amount of water that species would require if it produced at its maximum potential rate (Appendix Table D.14) plus the amount required for maintenance of existing tissue. EDYS then calculates how much soil moisture is available to that species at that time step, as determined by the distribution of soil moisture in the soil at that time and the competition for that water among all species with roots in each particular soil layer. If the amount of water available is equal to or greater than the amount required, the plant produces that much new biomass and that quantity of water is removed from the respective soil layers. If the amount of water available is less than the amount required, maintenance requirements are met first and any remaining water is used to produce new biomass, the amount of which is proportional to what can be produced on the remaining amount of water (water to production).

EDYS also determines nutrient requirements in a manner similar to water requirements. If nutrients are more limiting than water requirements at that time step, the amount of new growth produced is determined by the amount of nutrients available rather than the amount of water available.

Appendix Table D.14 provides values used to determine maximum potential growth rate, size of the plants, and the maximum rate of tissue loss from drought. Maximum potential growth rate is the maximum rate that new biomass can be produced, under optimum conditions for that species. Maximum potential growth rate is genetically determined for each species. Actual growth rate is most often less than this value because of resource limitations and tissue loss (e.g., herbivory, trampling). The values in Appendix Table D.14 are multiplied by the amount of photosynthetically-active tissue (Appendix Table D.16) present in that species at that time step. The product is the maximum amount of new tissue that species can produce in that particular month. The actual amount produced is generally less than this maximum amount, based on resource limitations (water, nutrients, light, temperature).

Maximum aboveground biomass is the maximum amount of standing crop biomass (g/m^2) that can be supported by that species. This variable limits the accumulation of biomass to realistic values for the species. Maximum old biomass drought loss is the maximum amount (proportion of existing biomass) that can be lost in one month from drought.

Appendix Table D.15 provides a seasonal growth function for each species. A value of 1.00 indicates that the species can potentially grow at its maximum rate (Appendix Table D.14) during that month. Values less than one result in proportional decreases in the maximum potential growth rate during those months. The values in this table are estimates based on responses to both temperature and photoperiod.

Maximum potential growth rates (Appendix Table D.14) are based on photosynthetically-active tissue. For most species, the tissue with the highest potential photosynthetic rate are the leaves. Cacti are an exception. Cacti leaves are their thorns. Roots and trunks of most species are structural tissues and do not contribute directly to photosynthesis, although there are exceptions (e.g., trunks of retama and paloverde trees). Stems of many species contribute somewhat to photosynthesis, but generally at a lower rate than leaves. Again a major exception are the cacti, whose pads are their stems. Appendix Table D.16 provides values for the photosynthetic potential of each plant part for each species. The values are proportions of maximum rates for that species (leaves for most species).

Green-out in plants, whether as spring green-up or recovery from defoliation, requires an energy source. Carbohydrates stored in various tissues are used to produce the new biomass. Some storage is in areas near the meristematic regions (e.g., bud zones) whereas other storage is in more distant tissues (e.g., coarse roots, bases of trunks) and must be translocated to the points of new growth. In both cases, there is a loss of biomass in some tissues (stored carbohydrates). Appendix Table D.17 provides values used to determine how much current biomass (stored carbohydrates) can be used to produce new tissue during green-out. A value of 1.00 indicates that the amount of tissue in that plant part can be doubled during a green-out month. A value of 0.10 indicates that 10% of the biomass in that plant part can be transformed into new biomass during one month of green-out. During a green-out month, that amount of biomass is removed from the particular plant part and transferred to new biomass and allocation according to the ratios in Appendix Table D.4.

Appendix Table D.18 contains values for four physiological control variables. These variables are used in EDYS to assure that plant structure does not become unbalanced and that the conversion from seeds to new plant biomass occurs properly. Each species has a characteristic root:shoot ratio (Appendix Table D.9). This is the relative amount of roots and shoots for that species. However, these ratios change during the growing season as new aboveground biomass is added and over years as perennial tissues accumulate belowground. Growing season maximum root:shoot ratio is a control over too much root biomass accumulating over time. If this value is exceeded during a growing season, no new biomass is allocated to roots until the value drops below this maximum value. Growing season green-out shoot:root ratio has a similar function. Maximum 1-month seed germination limits the amount of the seed bank that can germinate in any one month. Maximum first-month seedling growth provides the value to convert germinated seed biomass to new plant biomass. The amount of germinated seed biomass is multiplied by this value and the product becomes new plant tissue for that species.

At the end of the growing season (Appendix Table D.11), plants enter winter dormancy (or summer dormancy for cool-season species) and loose some tissue. An obvious example are deciduous trees shedding their leaves. But other tissue losses also occur. Some stems die. There can be some loss of trunk biomass. Root death occurs. Appendix Table D.19 provides the values used to calculate these losses.

A major factor in competition among species in many areas is shading, i.e., competition for light. Tall plants have a shading effect on shorter plants. Appendix Table D.20 provides for this competitive response. The values listed are a reduction in maximum potential growth rate of the **shaded** species resulting from a 100% canopy cover of the **shading** species. The values are estimates based on 1) relative heights of the species, 2) canopy foliage characteristics, and 3) shade-tolerance of understory species. The values in Appendix Table D.20 do not represent the competitive effect of overstory species on understory, only the direct effect of shading. Overstory species also effect the growth of understory species in other ways, e.g., competition for water and nutrients. Those competitive effects are simulated in EDYS using other parameters. The shading parameter only reflects competition for light.

In EDYS, values are averaged within a cell (Section 2.0). The Karnes and Wilson County EDYS models utilize a 40 m x 40 m cell size. Within each cell, estimates were made of the amount of woody plant cover (e.g., 10-25%) based on aerial photographs. A 25% cover of woody plants could result from various combinations of clusters (mottes) of trees and shrubs. In effect, the cell would consist of at least two vegetation types, one associated with the woody species and distributed over 25% of the surface of the cell and the other associated with herbaceous vegetation and distributed over the remaining 75% of the cell. However, the EDYS routine is to average the two types across the cell, because the cell is the smallest subdivision within an EDYS application. In effect, this reduces the size of the woody plants (25% of actual size in this example) and assumes that biomass is average across the cell. If the shading factor is ignored, this averaging does not substantially alter the vegetation and hydrologic dynamics in the cell. But with shading, the effect is to reduce herbaceous understory vegetation across the entire cell instead of just under the woody plant canopy over 25% of the cell.

We are working on an update that will account for this spatial heterogeneity within a cell. However, that update will not be completed in time to be included in this initial version of the Karnes-Wilson model. In the interim, the shading factor is utilized in this version for the effect of woody species on other woody species (i.e., under the woody plant canopy) but not for the effect of woody species on herbaceous species. The shading factor is included to simulate the shading effect of herbaceous species on other herbaceous species (e.g., midgrasses shading shortgrasses). This dual-component approach allows dynamics of herbaceous species to be simulated in the portion not covered by woody species, while maintaining the major aspect of shading within the area covered by woody plants. This dual pattern is a major characteristic of the shrub and woodland mosaics in South Texas, which have little herbaceous vegetation under the woody canopies but relatively abundant grasses and forbs in the interspacies (Drawe et al. 1978, McLendon 1991). In addition, reduction in herbaceous species under woody plant canopies may not occur until cover of woody species increases above about 30-50% (Scifres et al. 1982; Fuhlendorf et al. 1997).

7.0 ANIMALS

The animal component of EDYS consists of herbivory by different types of animals, both domestic and wildlife. Population dynamics are not currently included in most applications, but could be included if required. Five types of herbivores are included and others can be added as needed.

7.1 Insects

Insect herbivory is modeled in the Karnes and Wilson models as consumption by grasshoppers. An average density of 3 grasshoppers/m^2 is used, with an average consumption rate of 0.1 g/m^2/day.

7.2 Rabbits

Rabbits are considered to be eastern cottontails in the Karnes and Wilson models. An average density of about 1.2/ha (1 cottontail per 2 acres) is used. Rabbits are assumed to consume an amount of plant material equivalent to 5.4% of their body weight in each day (Kanable 1977), or about 73 g per cottontail per day. This equals about 0.0086 g forage/m^2/day.

7.3 Deer

Daily food intake (dry-weight basis) by white-tailed deer in South Texas is equal to about 3.23% of their live body weight, for high-quality feed (Wheaton 1981). Daily intake in the western portion of the Edwards Plateau has been estimated to be 2.2% of live body weight (Bryant et al. 1979). Mature white-tailed does average about 43 kg (95 lbs) on the Welder Wildlife Refuge (central Texas Coast) and mature bucks average about 63 kg (139 lbs)(Knowlton et al. 1979), and mature does in the western part of the Edwards Plateau weigh about 45 kg (Bryant et al. 1979). Deer in the central portion of South Texas tend to be larger.

In South Texas, deer consume a combination of shrubs, forbs, and grasses, with the specific combinations dependent on vegetation conditions of the site. In a mixed shrubland in Kleberg County, diets of free-ranging white-tailed deer (bite-count method) consisted of 45% shrubs, 34% forbs, and 21% grasses (Graham 1982). In that study, a total of 141 plant species were consumed over an 18-month period, with 22 plant species comprising a total of 80% of the diet. On the Welder Wildlife Foundation, San Patricio County, deer consumed 70-90% forbs, 10-20% grasses, and 3-10% shrubs (Chamrad et al. 1979; Kie et al. 1980). Based on preference ratings, deer on the Welder Wildlife Refuge selected mostly for forbs (69%), then for grasses (18%) and browse (13%)(Drawe and Box 1968). In Jim Hogg County, deer were found to consume 37% forbs, 33% browse, 18% cacti, and 2% grasses, with 10% of their rumen contents unidentifiable material (Everitt and Drawe 1974). White-tailed deer on the Sonora Experiment Station in the southwestern portion of the Edwards Plateau were found to consume 61% shrubs, 31% forbs, and 8% grasses (Bryant et al. 1979).

7.4 Cattle

Cattle are primarily grazers (consumers of herbaceous species) instead of browsers (consumers of leaves and twigs of woody species)(Stoddart et al. 1975:257). In many systems, grasses make up 85-99% of the diets of cattle (Sanders 1975; Durham and Kothmann 1977; Frasure et al. 1979), although the proportion of grasses may be lower (75%) in South Texas (Drawe and Box 1968; Everitt et al. 1981). They consume some forbs, especially during seasons when grasses are dormant and the forbs are growing. Cattle also consume some shrubs, especially as a source of additional protein (Dalrymple et al. 1965; Herbel and Nelson 1966) or during the winter (Everitt et al. 1981). Cattle diets in South Texas often contain higher proportions of shrubs (6-10%, Drawe and Box 1968; Frasure et al. 1979; Smith and McLendon 1981; McLendon et al. 1982) than cattle diets in many other areas because of the abundance and diversity of shrubs in South Texas.

The amount of forage intake by cattle depends on a number of factors, including type of forage, size of the animal, and reproductive state. Of particular importance are the protein content, moisture content, and digestibility of the forage species. A general rule for herbivores is that their daily intake, expressed on a dry-weight basis, equals about 3% of their body weight. Using this rule, a 1000-lb cow would consume about 30 lbs of forage per day. Results from six grazing studies indicate a range in daily forage intake of 20 lbs/AUD in a desert grassland of New Mexico to 59 lbs/AUD on fertilized sand prairie on the Texas Coast, with an average of 34.9 lbs/AUD (Table 7.1). The average of 35 lbs/AUD was used as the estimated forage requirement in the Karnes and Wilson Counties models.

Table 7.1 Forage consumption rate (forage disappearance) by cattle in selected studies reported in the literature.

Vegetation	Location	Amount/AUD		Reference
		lbs	grams	
Bluestem prairie, upland	Kansas	45.33	20,580	Anderson et al. 1970
Bluestem prairie, limestone breaks	Kansas	24.59	11,164	Anderson et al. 1970
Bluestem prairie, upland	Kansas	56.09	25,465	Owensby & Anderson 1967
Bluestem prairie, limestone breaks	Kansas	30.28	13,747	Owensby & Anderson 1967
Bluestem prairie, medium stocking	Louisiana	34	15,436	Duvall & Linnartz 1967
Bluestem prairie, heavy stocking	Louisiana	26	11,804	Duvall & Linnartz 1967
Black grama desert grassland	New Mexico	20	9,080	Paulsen & Ares 1962
Coastal sand prairie, unfertilized	Texas	27.29	12,390	Drawe & Box 1969
Coastal sand prairie, fertilized	Texas	58.79	26,691	Drawe & Box 1969
Pasture, coastal Bermuda	Texas	32.25	14,642	McCawley 1978
Pasture, kleingrass	Texas	36.11	16,394	McCawley 1978
Pasture, Bell rhodesgrass	Texas	28.09	12,753	McCawley 1978
Mean		34.90	15,846	

AUD = animal unit day = amount of forage (dry weight) consumed by a 1000-lb cow of one day.

Long-term moderate stocking rates under good management are often based on removal of 40-60% of annual forage production (Paulsen and Ares 1962; Duvall and Linnartz 1967; Owensby and Anderson 1967; Drawe and Box 1969; Anderson et al. 1970). Average annual forage production for each ecological type, under late-seral condition, for Karnes and Wilson Counties are presented in the NRCS Soil Surveys (Taylor 1977; Molina 2000). Average current forage production, accounting for the fact that most rangelands in South Texas are not in late-seral condition, was estimated at 70% of the values presented in the Soil Surveys (Appendix Table C.2). Proper management stocking rates were assumed to be based on 50% harvest of average annual available forage (Appendix Table E.1). These amounts were further reduced on the basis of amount of woody plant cover present (Appendix Table C.2).

The estimated amount of annual available forage was used to arrive at an estimated stocking rate. Daily forage consumption rate (35 lbs/AUD, Table 7.1) was multiplied by 365 to arrive at an annual animal unit (AU) forage requirement. This value (12,775 lbs/AU) was divided by the estimated amount of annual available forage for each plot type. The resulting values were the stocking rates used for each plot type (Table 7.2). The medium stocking rates were used as the default values in the models. Averaged over all types, the mean moderate stocking rate was 12.2 acres/AU. This was increased to adjust for woody plant cover. Light stocking rate (32% forage utilization) on a sandy loam site on the Welder Wildlife Refuge in San Patricio County is 15 acres/AU (Drawe and Box 1969), which compares to a moderate stocking rate of 9.4 acres/AU on sandy loam and 11.9 acres/AU on deep sand savanna sites in the models (Table 7.2). A moderate stocking rate (46% utilization) on silt loam bluestem sites in central Louisiana is 8.1 acres/AU (Duvall and Linnartz 1967). The stocking rate used in the model on clay loam sites is 8.9 acres/AU.

Table 7.2 Cattle stocking rates and initial forage estimates used in the Karnes and Wilson Counties models. Values are averages over both counties.

Range or Land Use Type	Annual Forage Production				Stocking Rate	
	No Woody Cover		Mean Woody Cover		No Woody Cover	Mean Woody Cover
	(g/m2)	(lbs/ac)	(g/m2)	(lbs/ac)	(ac/AU)	(ac/AU)
Blackland	266	2370	156	1390	10.85	21.51
Chalky ridge	137	1220	88	870	21.22	36.01
Clay loam	326	2900	175	1560	8.85	18.96
Clayey bottomland	455	4060	219	1950	6.46	15.10
Deep sand	245	2180	174	1550	11.83	18.09
Deep sand savanna	242	2160	139	1240	11.93	23.20
Gravelly ridge	151	1350	105	940	19.24	29.71
Gray sandy loam	252	2250	150	1340	11.45	21.17
Hardland	305	2720	158	1410	9.49	21.01
Lakebed	294	2620	87	780	9.82	38.24
Loamy bottomland	385	3430	184	1640	7.52	20.33
Loamy sand	277	2480	192	1710	10.46	16.73
Rolling blackland	249	2220	152	1360	11.64	22.04
Sandstone hills	168	1500	121	1080	17.18	26.75
Sandy	280	2500	205	1830	10.31	15.21
Sandy loam	308	2740	192	1710	9.37	17.09
Shallow	147	1310	119	1060	19.77	25.10
Shallow ridge	207	1840	143	1280	14.01	21.45
Sloping clay loam	175	1560	142	1270	16.56	21.48
Tight sandy loam	245	2180	165	1470	11.83	19.70
Very gravelly ridge	217	1930	121	1080	13.36	27.17
Improved pasture	505	4500	348	3100	5.73	8.31
Mean					12.22	22.02

The range or land-use types are divided in the models on the basis of amount of woody plant coverage, and stocking rates are adjusted proportionately. No woody cover = forage production and stocking rates without woody plant coverage. Mean woody cover = values averaged (weighted by number of cells) over all woody coverage classes for that type (reduced forage because of woody plants).

7.5 Horses

The models have the capability of including horses in the grazing options. However, at the present they are not included because of lack of information on stocking rates and locations. Although there are a substantial number of horses in Karnes and Wilson Counties, most of these do not consume most of their feed from range vegetation. Instead, substantial portions are provided as hay and concentrates. In addition, their numbers are not distributed evenly throughout the landscape. Most horses in these two counties are maintained for pleasure and are confined in areas near towns or near buildings in rural areas. These uneven distribution and supplemental feed factors make it likely that uniform modeling assumptions will lead to more inaccurate estimates in the simulations than if horses were included at this point in the modeling effort. When included in the model, horses are considered to have the grazing equivalent of 1.25 AU (Stoddart et al. 1975), i.e., one horse consumes the same amount of forage at 1.25 1000-lb cows.

7.6 Feral Hogs

Feral hogs are a major species of concern throughout Texas, including Karnes and Wilson Counties. They are physically destructive to many habitats, especially wetlands, they compete against native wildlife and domestic livestock for food and habitat space, and their numbers are increasing. Modeling the impacts of feral hogs at large landscape scales, such as the Karnes and Wilson models, is difficult and perhaps counter-productive for the same reasons that modeling the impacts of grazing by horses is difficult on a landscape basis. The density and distribution patterns of feral hogs are not documented on a county-wide scale. Therefore, any scenarios including these estimates would be subject to substantial speculation. A more productive approach would be to model a specific scenario without feral hogs included and then compare those results to those from the same scenario except with specific spatial and density assumptions made relative to feral hog populations. No such scenarios were included in the ten scenarios simulated for this report.

8.0 CALIBRATION

Calibration in EDYS consists of adjustments of parameter values if needed to achieve target values for the variables under consideration. Target values are from independent validation data, either from experimental validation studies or from existing field data, if these data are available. In the absence of independent validation data, values based on professional judgement are used.

8.1 Vegetation

Independent validation data are not currently available for vegetation dynamics in Karnes and Wilson Counties. Field validation studies were established in August 2014 and data from those field sites can be used to test the models beginning in 2015. Because field validation data are not currently available, reasonable ecological estimates were used as target values for calibration comparisons.

8.1.1 General Procedure

The approach used in the calibration is to begin with one vegetation type, obtain reasonable results for that type, and then add a second type, the second type having a substantially different combination of species. Once acceptable calibration results are obtained for both types, in combination, then a third type is added. This iterative process is continued until a sufficient number of types are included that, in combination, include all the major species included in the model. In addition to adding types, variations in woody plant cover are also included in the calibration process.

EDYS contains a large number of variables (parameters), the values of any combination of which can be adjusted during the calibration process. The following general procedure is used to determine which parameters are adjusted and to what extent.

Prior experience has shown vegetation responses in EDYS to be more sensitive to changes in some parameters than others. We start the calibration process with those parameters we expect the model to be more sensitive to changes in. Examples include water-use efficiency, root architecture, allocation of current production, and end of growing season dieback. For most of these variables, we have a range in values in our data base that have been compiled from various literature references and from our own studies. For example, we have root architecture data for buffalograss (*Buchloe dactyloides*) from nine profiles (Weaver and Clements 1939; Weaver and Darden 1949; Hopkins 1953). We begin the calibration process using the mean of these nine profiles. If necessary, we can change the values of initial root biomass in each layer (Appendix Table D.9) to provide a better fit with expected buffalograss biomass values changes in the model simulations. However, whatever changes are made in the root architecture parameters for buffalograss must not exceed the range of values in our data base (i.e., the parameter values remain consistent with reported values in the literature). A second example is water-use efficiency. Silver bluestem is a major perennial grass species in the Karnes-Wilson models. McGinnies and Arnold (1939) reported an average water-use efficiency in production of new biomass for silver bluestem of 685 g water/g aboveground biomass. However, they reported a range over a two-year period of 337-1221, depending on season and amount of water available. Our calibration converged on a value of 760 (Appendix Table D.13), which was very near (765) the mean of the values reported by McGinnies and Arnold (1939) for the period May-September in their study.

By comparing changes in biomass of various species within a vegetation type and changes in biomass of the same species among vegetation types between calibration runs, as parameter values are modified, it can be determined which variables are controlling the changes (sensitivity analysis). Values in these parameter sets can be changed and the results compared in the next simulation. Once the values of the major plant species have stabilized near their target values, the vegetation calibration process is considered complete. It should be emphasized that the completed calibration process results in single values for each of the parameters, i.e., the same value is used for that particular species for the respective parameter for all vegetation types in the model. The benefit of this approach is that simulated responses are consistent across vegetation types throughout the spatial landscape.

8.1.2 Examples

Seven vegetation types in Karnes County were used to calibrate the model. Ten-year (2000-2009) simulations were conducted for each calibration run. For each calibration run, initial composition and associated standing crop biomass values were defined for all vegetation types in the model (Section 6.3) and the entire model was run for a 10-year simulation. This allowed for surface hydrology interactions among all the vegetation types over time. Standing crop biomass values for each species were downloaded for each of the calibration types at the end of October (approximate end of growing season for most species in the model) of each year of the simulation.

Calibration was conducted without grazing by livestock, for two reasons. First, studies of vegetation change over time (especially successional studies) generally utilize grazing exclosures. This is done in order to determine natural patterns of secondary succession. Likewise, the calibration process must first determine if changes in species composition in the simulations are proceding in a realistic ecological manner (e.g., trees and midgrasses increase during periods of higher rainfall and xeric shrubs and shortgrasses increase during periods of lower rainfall, forbs decrease as midgrasses increase and increase as midgrasses decrease). The second reason for excluding livestock grazing during calibration is that the level of livestock grazing is unknown for the various spatial units in a county-wide model. Therefore, if grazing was included calibration results would most likely reflect the effects of the grazing levels entered into the model rather than successional effects and responses to rainfall variations. Once the models were calibrated, livestock grazing was included in the various management scenarios (Section 9.0).

8.1.2.1 Tight Sandy Loam

Calibration began with Plot Type 103 (NRCS type = tight sandy loam; Appendix Table C.2), 10-25% woody plant cover, using precipitation data from Zone 5 (Nixon, Fig. 4.2). This type is a sandy loam grassland, with scattered mottes of live oak and lesser amounts of mesquite around the edges of the oak mottes. Initial conditions for each calibration simulation represented a live oak dominated community, with moderate shrub and grass components (Table 8.1). Total aboveground biomass (including woody portions of tree and shrub species) was set at 2,440 g/m^2, 73% of which was tree biomass. Shrubs had the second-highest amount of initial biomass (13%), with granjeno and blackbrush the primary species. Shortgrasses were the major herbaceous component (7% of total aboveground biomass), followed by midgrasses (4%) and forbs (4%). Major herbaceous species were buffalograss, purple threeawn (*Aristida purpurea*), trichloris, thin paspalum (*Paspalum setaceum*), tall dropseed, and hairy grama (*Bouteloua hirsuta*).

Table 8.1 Calibration results for 10-year simulations for the tight sandy loam, 10-25% woody cover, vegetation type (Plot Type 103), Karnes County. Values are total aboveground biomass (g/m^2) in October of each year.

Lifeform or Species	Initial	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Trees	1778	1690	1719	1730	1711	1671	1638	1605	1610	1590	1556
Shrubs	316	329	343	357	362	342	319	299	295	283	273
Midgrasses	86	46	94	131	174	176	147	163	350	196	182
Shortgrasses	178	113	140	175	191	203	181	185	240	179	151
Perennial forbs	36	23	50	116	144	154	118	107	233	130	98
Annual forbs	43	12	1	tr	0	0	0	0	0	0	0
Total aboveground	2437	2213	2347	2509	2582	2546	2403	2359	2728	2378	2260
Litter	100	254	119	142	99	91	176	113	108	139	125
Live oak	1538	1447	1469	1478	1462	1426	1397	1367	1368	1351	1322
Mesquite	240	243	250	252	249	245	241	238	242	239	234
Blackbrush	91	93	94	94	93	85	76	70	68	65	62
Granjeno	131	143	158	174	182	172	160	147	147	140	135
Prickly pear	95	93	91	89	87	85	83	82	80	78	76
Silver bluestem	20	19	36	56	74	72	53	58	126	65	59
Sideoats grama	5	2	3	4	6	6	6	6	10	9	7
Trichloris	27	13	24	29	54	60	56	62	137	79	72
Arizona cottontop	2	1	1	1	1	1	1	1	1	1	1
Little bluestem	5	3	9	19	32	30	25	30	70	37	38
Tall dropseed	27	8	21	22	7	6	6	6	6	5	5
Purple threeawn	31	19	26	33	33	34	26	28	48	29	21
Hairy grama	25	15	9	7	6	5	4	4	3	3	2
Buffalograss	37	33	47	59	74	87	82	85	117	95	79
Sandbur	11	3	2	2	1	1	1	tr	tr	tr	tr
Hooded windmillgrass	20	10	6	5	5	4	4	4	3	3	3
Thin paspalum	30	18	31	45	47	43	31	33	35	16	14
Texas wintergrass	24	15	19	24	25	29	33	31	34	33	32
Ragweed	13	12	35	102	142	153	117	105	232	130	97
Bundleflower	1	1	1	1	1	1	1	1	1	tr	tr
Snoutbean	6	2	1	tr	tr	tr	0	tr	0	0	tr
Bush sunflower	16	8	13	13	1	tr	0	1	0	0	1
Broomweed	6	2	tr	tr	0	0	0	0	0	0	0
Partridge pea	2	3	1	tr	0	0	0	0	0	0	0
Texas doveweed	14	3	0	0	0	0	0	0	0	0	0
Sunflower	19	4	0	0	0	0	0	0	0	0	0
Texas bluebonnet	2	0	0	0	0	0	0	0	0	0	0
Annual precipitation (inches)		37.6	42.3	39.6	25.8	44.1	23.2	23.6	49.3	19.8	40.5

Trace amount (< 0.5 g/m^2) is indicated by “tr”.

At the end of the 10-year simulation, total aboveground biomass had decreased 7% compared to initial conditions (Table 8.1). Tree biomass declined 12%, shrubs 14%, and shortgrasses 15%.

Midgrasses more than doubled (112% increase) and forbs increased 24%. The two major environmental factors affecting these changes were rainfall and succession. Long-term mean annual rainfall for Nixon (the precipitation zone used in the calibration for this type) is 32.70 inches (128-year constructed data set; Table 4.5) and the mean for the 10-year simulation period (2000-2009) was 34.6 inches, or about 6% above the long-term mean. Above-average rainfall might be expected to increase tree biomass, as well as biomass of midgrasses. Biomass of midgrasses did increase in the simulations, but tree biomass declined. This decrease can be attributed to the fact that three of the four years preceding Year 10 were drought years (less than 73% of average rainfall) and the preceding year (2008) was especially dry (61% of average; Table 8.1). Woody species generally decline during periods of drought. For example, woody plant cover declined on the La Copita Research Area in Jim Wells County by 37% between 1941 and 1960 (Archer et al. 1988), a period which included the drought years of 1950-56. Most of the decline in tree biomass in the calibration simulation was from a decrease in live oak and this is consistent with drought effects on oak woodlands (Drawe et al. 1978). The tenth year (2009) was a wet year. This resulted in an increase in herbaceous species, especially midgrasses, which can respond to increased soil moisture faster than woody species.

Total aboveground biomass of herbaceous species averaged 460 g/m^2 over the 10-year simulation (Table 8.1). Total aboveground biomass in EDYS simulations includes the basal crown (trunk) biomass that is rarely sampled in clipping studies. Trunk biomass accounts for about 40% of total aboveground biomass of herbaceous species in EDYS simulations. Adjusting total aboveground herbaceous biomass to account only for clippable biomass results in an average of 276 g/m^2 per year on the tight sandy loam site. This compares favorably (239 g/m^2) with a three-year average on a fine sandy loam site on the Welder Wildlife Refuge in San Patricio County (Drawe and Box 1969).

Plant succession is a species replacement process, resulting from competitive dynamics among species. In EDYS, these competitive dynamics are modeled by the mechanistic responses of the various species to changes in environmental conditions during a simulation. As such, patterns of vegetation change over time in EDYS simulations should correspond to successional changes that would occur under the environmental conditions of the simulation. This is what occurred for this type in the 10-year calibration simulation.

Woody species decreased, in part, because of the dry years that preceeded the tenth year. However, some woody species in South Texas have decreased during periods of average or above average rainfall. Overall, rainfall was slightly (6%) above average during the 10 years and two of the last three years of the simulation had high rainfall (+51% in 2007 and +24% in 2009). Blackbrush is an example of a woody species that decreases on sandy loam and clay loam sites during more mesic conditions (Drawe et al. 1978). This occurred in the simulations on the tight sandy loam type, where blackbrush decreased 32% over 10 years (Table 8.1). Prickly pear is another brush species that has decreased on many sites in South Texas since the drought of the 1950s (Drawe et al. 1978), and prickly pear decreased over the ten years in the simulations (Table 8.1).

More mesic conditions (higher rainfall) should also result in an increase in midgrasses and a decrease in shortgrasses (Drawe et al. 1978). This is especially true in the case of bluestem grassland that began in mid-seral conditions (Weaver 1954; Jensen and Schumacher 1969). Trichloris and silver bluestem more than doubled in biomass over the 10 years. Both of these species are mid-successional dominants in the area (Drawe et al. 1978; McLendon 1991). Little bluestem is a late-successional dominant species on the sandy grasslands of this region (Diamond and Smeins 1984; McLendon 1991) and it increased the most proportionately in the simulation. Four of the seven species of shortgrasses substantially declined in biomass and three increased. The three species that increased (buffalograss, thin paspalum, and Texas wintergrass [*Stipa leucotricha*]) are mid-seral species and would be expected to remain in the grassland community as sub-ordinate species even under late-seral midgrass conditions.

Six other vegetation plot types were used in the calibration process (Table 8.2). Vegetation changes occurred on these types in response to variation in rainfall and in response to succession, as they did on the tight sandy loam site.

Table 8.2 Initial (00) and tenth-year (10) values (aboveground biomass, g/m^2) for lifeforms and plant species in six of the vegetation plot types used in the vegetation calibration process. Percentages refer to amount of woody plant cover.

Lifeform or Species	Plot 1102 Clay Loam 10-25%		Plot 602 Bottomland 10-25%		Plot 3401 Gravel Ridge 10-25%		Plot 8102 Lakebed 25-50%		Plot 117 Pasture 0-1%		Plot 9501 Cultivated 0-1%	
	00	10	00	10	00	10	00	10	00	10	00	10
Trees	393	305	1191	1054	88	83	1670	1634	82	76	89	100
Shrubs	445	404	312	223	942	990	480	596	---	---	---	---
Midgrasses	208	353	240	244	39	9	11	10	---	---	---	---
Shortgrasses	139	147	271	123	125	61	126	94	533	643	---	---
Grass-likes	---	---	---	---	---	---	136	107	---	---	---	---
Perennial forbs	91	5	122	55	27	70	33	35	26	9	---	---
Annuals	29	0	53	0	21	0	43	0	---	---	550	716
Total aboveground	1255	1214	2189	1699	1242	1213	2499	2476	641	728	639	816
Litter	100	91	100	135	100	125	100	94	100	70	100	237
Huisache	16	20	20	24	---	---	426	572	20	24	---	---
Pecan	---	---	167	197	---	---	---	---	---	---	---	---
Sugar hackberry	---	---	236	199	---	---	1244	1062	---	---	---	---
Texas persimmon	20	17	16	14	20	17	---	---	---	---	---	---
Mesquite	307	268	239	195	68	68	---	---	62	52	---	---
Live oak	---	---	513	425	---	---	---	---	---	---	---	---
Guajillo	---	---	---	---	312	352	---	---	---	---	---	---
Blackbrush	47	24	117	61	587	601	---	---	---	---	---	---
Whitebrush	129	144	26	11	---	---	---	---	---	---	---	---
Prairie baccharis	14	4	14	4	---	---	430	567	---	---	---	---
Granjeno	168	151	101	86	---	---	---	---	---	---	---	---
Agarito	1	1	---	---	---	---	---	---	---	---	---	---
Rattlepod	---	---	---	---	---	---	50	29	---	---	---	---
Mustang grape	---	---	45	54	---	---	---	---	---	---	---	---
Prickly pear	86	80	9	7	43	36	---	---	---	---	---	---
Big bluestem	---	---	5	3	---	---	---	---	---	---	---	---
Silver bluestem	89	147	27	14	32	7	---	---	---	---	---	---
Sideoats grama	26	66	---	---	4	1	---	---	---	---	---	---
Trichloris	78	126	39	4	---	---	---	---	---	---	---	---
Arizona cottontop	4	1	---	---	3	1	---	---	---	---	---	---
Virginia wildrye	---	---	9	1	---	---	---	---	---	---	---	---
Switchgrass	---	---	6	2	---	---	---	---	---	---	---	---
Little bluestem	6	12	30	44	---	---	---	---	---	---	---	---
Johnsongrass	---	---	124	176	---	---	11	10	---	---	---	---
Tall dropseed	5	1	---	---	---	---	---	---	---	---	---	---
Purple threeawn	41	49	41	2	31	2	---	---	---	---	---	---
King Ranch bluestem	---	---	---	---	---	---	---	---	62	333	---	---
Hairy grama	13	1	---	---	49	5	---	---	---	---	---	---
Buffalograss	27	71	132	69	---	---	27	2	---	---	---	---
Hooded windmillgrass	13	1	13	2	12	1	---	---	---	---	---	---
Bermudagrass	---	---	---	---	---	---	50	47	471	310	---	---
Cutgrass	---	---	---	---	---	---	4	tr	---	---	---	---
Vine-mesquite	5	tr	16	2	---	---	4	3	---	---	---	---
Longtom	---	---	---	---	---	---	9	1	---	---	---	---
Thin paspalum	---	---	15	2	---	---	---	---	---	---	---	---
Knotroot bristlegrass	---	---	34	46	---	---	32	41	---	---	---	---
Texas bristlegrass	5	tr	20	tr	21	22	---	---	---	---	---	---
Texas wintergrass	39	25	---	---	12	31	---	---	---	---	---	---

Table 8.2 (Cont.)

Lifeform or Species	Plot 1102 Clay Loam 10-25% 00	10	Plot 602 Bottomland 10-25% 00	10	Plot 3401 Gravel Ridge 10-25% 00	10	Plot 8102 Lakebed 25-50% 00	10	Plot 117 Pasture 0-1% 00	10	Plot 9501 Cultivated 0-1% 00	10
Littletooth sedge	---	---	---	---	---	---	18	1	---	---	---	---
Flatsedge	---	---	---	---	---	---	105	99	---	---	---	---
Fimbry	---	---	---	---	---	---	5	tr	---	---	---	---
Cattail	---	---	---	---	---	---	8	7	---	---	---	---
Ragweed	31	3	18	1	13	70	18	7	26	9	---	---
Old-mans beard	12	1	47	52	---	---	---	---	---	---	---	---
Bundleflower	4	1	7	2	---	---	---	---	---	---	---	---
Frogfruit	2	tr	3	tr	---	---	15	28	---	---	---	---
Prairie coneflower	7	0	3	0	3	0	---	---	---	---	---	---
Snoutbean	11	tr	1	0	---	---	---	---	---	---	---	---
Ruellia	5	0	34	tr	2	0	---	---	---	---	---	---
Bush sunflower	6	tr	9	tr	---	---	---	---	---	---	---	---
Texas verbena	2	0	---	---	3	0	---	---	---	---	---	---
Orange zexmenia	11	tr	---	---	6	0	---	---	---	---	---	---
Milo	---	---	---	---	---	---	---	---	---	---	550	716
Giant ragweed	---	---	34	0	---	---	15	0	---	---	---	---
Broomweed	14	0	---	---	11	0	---	---	---	---	---	---
Texas doveweed	---	---	8	0	---	---	---	---	---	---	---	---
Sunflower	15	0	11	0	3	0	28	0	---	---	---	---
Dogweed	---	---	---	---	7	0	---	---	---	---	---	---

Trace amount (< 0.5 g/m^2) is indicated by “tr”.
Dashes (---) indicate that the species does not occur in the respective type.

8.1.2.2 Clay Loam

The clay loam type (Plot 1102, 10-25% woody cover) is the most common vegetation type in northeastern South Texas (Drawe et al. 1978; McLendon 1991). Mesquite is the most abundant woody species on this type, but there are numerous associated woody species, with granjeno, whitebrush, and prickly pear the most abundant secondary species. Much of this type was probably once midgrass prairie with scattered shrub mottes, but now it commonly supports moderate to dense shrublands unless recently cleared by brush control. The ten-year simulation resulted in a 15% decrease in woody plant biomass in the tenth year, compared to estimated conditions in 2000 (Table 8.2). This decrease was likely the result of low rainfall in three of the last five years of the simulation (Table 8.1). Mesquite cover decreased by 12% on clay loam sites on the Welder Wildlife Refuge over a 15-year period, along with decreases in both blackbrush and granjeno (Drawe et al. 1978). All three of these species decreased on the clay loam sites in the simulations. Two woody species (huisache and whitebrush) had higher biomass in 2009 than in 2000 in the simulations, and both of these species are rapidly-growing woody species which could respond to the higher rainfall in 2007 and 2009 more quickly than most woody species. Huisache has increased on the Welder Wildlife Refuge on clay loam sites (Drawe et al. 1978). Comparing data from Box (1961) to data from Box and White (1969) on the Welder Wildlife Refuge, there were decreases in relative cover of mesquite and blackbrush and increases in huisache and granjeno.

Both midgrasses and shortgrasses increased by the end of the ten years, but midgrasses increased by almost 70% compared to only 6% for shortgrasses. An increase in grasses, especially midgrasses, should be expected under the conditions of the calibration simulations, i.e., exclusion of livestock grazing and a decrease in woody plant biomass (Drawe et al. 1978). For example, midgrasses replaced shortgrasses as the dominant herbaceous species on clay loam sites on the Welder Wildlife Refuge in 10-15 years following reduction in livestock stocking rates, with silver bluestem being a major increasing species (Drawe et al. 1978). Replacement of shortgrasses by bluestem prairie following drought in the central Great Plains takes 8-12 years (Weaver 1954).

Herbaceous aboveground biomass was 505 g/m^2 in Year 10 (2009) of the simulations (Table 8.2). This includes basal crown biomass, which is generally not included in the biomass values reported in literature studies of grassland production. Clippable biomass for grasses in EDYS simulations varies by species, but it averages about 60% of total aboveground biomass. Converting the Year 10 total herbaceous aboveground biomass (505 g/m^2) to clippable biomass results in a value of 303 g/m^2 for the clay loam site (silver bluestem-trichloris herbaceous community). This compares favorably with values reported in the literature for bluestem and coastal prairies (Table 8.3).

Table 8.3 Aboveground production (g/m^2 clippable biomass) and annual precipitation (inches) reported for various bluestem and coastal prairie communities.

Community	Location	Precipitation	Production	Reference
Big bluestem-little bluestem	Kansas	34.4	357	Briggs & Knapp 1995
Big bluestem-little bluestem	Kansas	31.9	325	Owensby & Anderson 1967
Big bluestem-little bluestem	Oklahoma	44.8	349	Brummer et al. 1988
Little bluestem-big bluestem	Oklahoma	32.7	422	Hazell 1967
Tall dropseed-silver bluestem	Oklahoma	32.7	355	Hazell 1967
Sandhill bluestem-splitbeard bluestem	Louisiana	57.9	340	Duvall & Linnartz 1967
Sandhill bluestem-splitbeard bluestem	Lousiana	57.9	377	Grelen & Epps 1967
Little bluestem-tall dropseed	Texas	31.5	208	McLendon et al. 2001
Buffalograss-silver bluestem	Texas	28.3	164	Box & White 1969
Knotroot bristlegrass-plains bristlegrass	Texas	28.3	249	Box & White 1969
Gulf cordgrass-bermudagrass	Texas	35.0	543	Garza et al. 1994
Mean		36.9	335	

8.1.2.3 Bottomland

The bottomland type (Plot Type 602, 10-25% woody cover) includes both riparian woodland communities and smaller wooded drainages. Common overstory species in the riparian woodland version this type include pecan (*Carya illinoensis*), sugar hackberry (*Celtis laevigata*), cedar elm (*Ulmus crassifolia*), black willow (*Salix nigra*), box elder (*Acer negundo*), eastern cottonwood (*Populus deltoides*), and mustang grape (*Vitis mustangensis*)(Drawe et al. 1978, Smeins 1994b, Bio-West 2014). Live oak, post oak, mesquite, and huisache often become important components along the outer edges of the riparian woodland. Shrub understory often consists of low to medium densities of granjeno, whitebrush, blackbrush, agarito (*Mahonia* *trifoliolata*), and prairie baccharis (*Baccharis texana*)(Drawe et al. 1978; McLendon 1991). Herbaceous understory vegetation varies considerably, depending in large part on density of the overstory.

Smaller drainages include creeks, ephemeral streams, and dry drainages. Species composition along the creeks and ephemeral streams may be similar to that of the riparian woodlands, except for smaller and fewer species of trees and a corresponding increase in shrubs and herbaceous species. Oaks, mesquite, and huisache become more abundant along these smaller drainages. The dry drainages tend to support species more similar to the surrounding shrubland communities, but with larger individual trees and shrubs. Common species include mesquite, sugar hackberry, Texas persimmon (*Diospyros texana*), live oak, granjeno, whitebrush, wolfberry (*Lycium berlandieri*), lotebush (*Zizyphus obtusifolia*), brasil (*Condalia obovata*), and prickly pear (Archer et al. 1988; McLendon et al. 2013). Huisache and retama (*Parkinsonia aculeata*) increase in importance as moisture levels and flooding frequency increase.

The calibration simulations resulted in an increase in pecan, huisache, and mustang grape in this type and a decrease in other woody species (Table 8.2). Pecan is the tallest tree species included in the model and would be expected to increase in cover provided sufficient water was available. Mustang grape is a woody vine that has the potential for covering most of the riparian woodland species, thereby decreasing the cover of the trees and shrubs and increasing the coverage of the grape vines. Huisache is increasing on many sites in South Texas, while live oak is decreasing on some lowland sites (Drawe et al. 1978). Archer et al. (1988) suggested that mesquite and granjeno would likely decrease in drainages over time as larger species with more dense canopies increased in abundance. This was the pattern indicated by the simulations.

Most herbaceous species decreased in biomass during the 10-year simulations. There were four exceptions (Table 8.2). Three grasses increased in biomass: little bluestem, Johnsongras, and knotroot bristlegrass. Little bluestem is a late-seral dominant in both sandy and clay loam grasslands and should be expected to increase in the woodland openings in the absence of livestock grazing. Johnsongrass is an aggressive invading species on moist sites throughout South Texas and has the potential for high levels of aboveground production. It increased 42% on these bottomland sites over the 10 years of the simulations. That is a reasonable increase under conditions of no livestock grazing. It is not uncommon for abandoned cropland in South Texas to support 25-50% cover of Johnsongrass within 4-5 years of abandonment. The third grass that increased on this type in the simulations was knotroot bristlegrass (*Setaria geniculata*). This is a common sub-dominant species on frequently flooded clay and clay loam sites in South Texas (McLendon and Dahl 1983; McLendon 1991) and is one of the species that typically increases on these sites when livestock grazing pressure is reduced (Drawe et al. 1978).

Old-man’s beard (*Clematis drummondii*) was the only forb to increase on the bottomland sites in the simulations. This is an herbaceous vine that can form extensive and dense colonies that can cover herbaceous species, shrubs, and lower portions of trees (Drawe et al. 1978; McLendon 1991).

8.1.2.4 Gravel Ridge

The gravel ridge type (Plot Type 3401, 10-25% woody) includes several shallow-soil sites (gravel, sandstone, limestone). They occur on exposed tops of hills and ridges, have shallow topsoils, and are dominated by xeric shrubs. Both co-dominant shrubs, blackbrush and guajillo, increased in the calibration simulations. Blackbrush increased by 2% and guajillo by 13% (Table 8.2). Mesquite remained stable and Texas persimmon and prickly pear decreased (15% and 16%, respectively). Most herbaceous species decreased. The exceptions were Texas bristlegrass (*Setaria texana*), Texas wintergrass, and ragweed. Texas bristlegrass is a small perennial grass that is most abundant under shrub canopies. It decreases in abundance with heavy livestock grazing and with increases in abundance of midgrasses. The increase in shrub biomass and the decreases in midgrass biomass that occurred in the calibration scenarios would logically result in an increase in this species.

The gravel ridge sites are harsh sites for most herbaceous species because of the shallow soils and resulting lack of soil moisture storage capacity. Therefore, herbaceous recovery from grazing would logically occur more slowly on these sites than on deeper soil sites such as the clay loams and tight sandy loams. This is precisely what occurred in the simulations. The two herbaceous species that had substantial increases in biomass were Texas wintergrass (158% increase) and ragweed (more than four-fold increase). Texas wintergrass was among the first perennial grasses to substantially increase following the reduction in grazing pressure on the Welder Wildlife Refuge (Box and White 1969; Drawe et al. 1978). Ragweed is a major herbaceous species on many of these shallow-soil sites (McLendon 1991).

8.1.2.5 Lakebed

The lakebed type (Plot Type 8102, 25-50% woody cover) includes all non-permanent water-holding features. Examples include: 1) seasonal wetlands, 2) abandoned stock tanks (ponds), 3) swales, and 4) basins with no outlets. The initial conditions were that the sites already supported stands (25-50%) of woody plants, consisting of hackberry and huisache trees with a shrub understory of baccharis and rattlepod (Table 8.2). The initial herbaceous community consisted of a complex of wetland species, including flatsedge (*Cyperus odoratus*), bermudagrass, knotroot bristlegrass, buffalograss, ragweed, and littletooth sedge (*Carex microdonta*). These are common herbaceous species on frequently flooded depressions in South Texas (Drawe et al. 1978; Scifres et al. 1980; McLendon and Dahl 1983).

Huisache and baccharis increased over the 10 years of the calibration simulations and hackberry and rattlepod decreased (Table 8.2). Huisache increased by 34% and baccharis by 32%, compared to a 15% decrease in hackberry and a 42% decrease in rattlepod. Both huisache and baccharis are aggressive invading species on frequently flooded sites. The increase in huisache has been one of the most striking features of vegetation change on the Welder Wildlife Refuge. In 1939, there were only scattered, small areas of huisache on sandy prairies compared to large areas of dense stands by the mid-1960s (Box and Chamrad 1966; Drawe et al. 1978). Between 1957 and 1973, huisache increased in the mesquite-mixed grass communities of the Refuge by 46% (Box et al. 1979). The decrease in hackberry biomass can be attributed to the effect of competition from huisache. Rattlepod is an early-successional woody species that can maintain a presence on wetland sites for lengthy periods, but cannot compete successfully with huisache and other tall woody species as the density of the taller species increases.

Herbaceous production in Year 10 of the simulations was 246 g/m^2 total (Table 8.2). This was equal to reported herbaceous production in huisache woodlands at Welder Wildlife Refuge (242 g/m^2) when tree coverage was about 40% (Scifres et al. 1982).

8.1.2.6 Pasture

The pasture type (Plot Type 117, 0-1% woody cover) includes all improved pastures. In the simulations, composition was considered to be primarily bermudagrass (84% of herbaceous biomass), with some King Ranch bluestem (11%) and ragweed (5%). Small amounts of mesquite and huisache were also included. This combination represents an older bermudagrass pasture, with some invading species.

In Year 10 of the simulations, the proportion of King Ranch bluestem increased substantially (51% of herbaceous biomass), with a corresponding decrease in composition of bermudagrass (48%). Overall production of grasses was higher in Year 10 than under initial conditions (643 g/m^2 and 533 g/m^2, respectively). These values compare favorably with values reported for bermudagrass pastures in South Texas, e.g., 490 g/m^2 in Kleberg County (Kapinga 1982) and 683 g/m^2 in San Patricio County (McCawley 1978). Kleberg bluestem pastures tend to have higher production than bermudagrass pastures (1180 g/m^2, Kapinga 1982). Mesquite decreased slightly by Year 10 of the simulations and huisache increased.

8.1.2.7 Cultivated

Cultivated land was considered to be planted in early March each year to grain sorghum. Harvest was simulated in late-July, with stubble remaining until the end of October. In Year 10, aboveground biomass in October was 716 g/m^2 (Table 8.2). Some mesquite trees were included in this type. These were included because some trees were observed in the aerial photographs, generally along edges (fence-rows) of the fields or, in some cases, as scattered individuals within portions of the fields. Mesquite increased in the simulations, from an initial value of 89 g/m^2 to a value of 100 g/m^2 in Year 10, an increase of 11% over the ten years.

8.2 Ecohydrology

Three ecohydrolocial components were assessed in the model calibration: 1) evapotranspiration, 2) surface runoff and sedimentation, and 3) groundwater-use by vegetation. These components were also combined to develop several basic water balances. Direct field data were not available for use in these calibrations. Instead, literature values and professional judgment were used.

8.2.1 Evapotranspiration

In EDYS, evapotranspiration (ET) is separated into its two primary components: evaporation (E) and transpiration (T). Evaporation is the conversion of liquid water to water vapor, with the subsequent movement of the water vapor into the atmosphere. Transpiration is the process of water loss from plants by evaporation through their stomates. In EDYS, transpiration is accounted for as a function of water use by individual plant species. Evaporation is subdivided into interception and evaporation, where interception is the amount of water intercepted by the vegetation canopy and then evaporated and evaporation is the amount of water evaporated from the soil surface (including bare ground, litter, and rocks and other bare surfaces).

The amount of ET varies widely among plant communities, regions, seasons, and years. Three primary variables determining the amount of ET are 1) temperature, 2) available moisture, and 3) vegetation. Warmer regions, or warmer seasons, have higher ET rates than cooler regions or seasons, other factors held constant. Under the same temperature regime, an increase in available moisture results in an increase in ET. Conversely, as conditions become drier, less water is available for evaporation and transpiration and therefore ET decreases. However, drier regions are often warmer than more mesic regions and this increase in temperature also has an effect on ET rates. Potential evaporation rates are often estimated for a locale from measurements of evaporation from a free-water surface. Evaporation rates from exposed surfaces (e.g., leaf surfaces, rocks, surface of the litter) may approximate this rate. Evaporation from a soil surface is generally less than the maximum potential rate because the water is being translocated to the surface from which evaporation actually occurs and this translocated process slows the rate of evaporation. If the soil surface is shaded, the lower temperature also reduces the evaporation rate.

Plants move water from various soil depths, into their roots, through the plant, and into stomatal cavities where the evaporation actually occurs. This movement of water is in response to a water potential gradient between the various soil layers and atmosphere at the leaf surface. The largest gradient occurs when the atmosphere is very dry and the soil is very wet. Very little transpiration occurs when the atmosphere is moist (high relative humidity) or when the soil is very dry. In the first case, the water potential gradient is too weak to result in much water movement. In the second case, there is too little water to move.

Therefore the **rate** of transpiration is largely dependent on the water potential gradient and the amount of water available to the roots. However, the **amount** of transpiration is largely dependent on the amount, and type, of vegetation present and the amount of water available to the plants. As the amount of transpiring surface (primarily leaf surface area) increases, the amount of water transpired increases, provided there is sufficient moisture available in the rooting zone of the particular vegetation. For example, ET in mesquite-shrublands in South Texas was about 37% higher than on bare soil in wet years, but only about 30% higher on adjacent short-grass sites than on bare soil (Table 8.4). In dry years, ET from bare soil decreased by almost 68% compared to wet years and decreased by about 64% on vegetated sites.

Table 8.4 Evapotranspiration (ET; mm) and rainfall (PPT; mm) in dry and wet years on the La Copita Experiment Station in South Texas (data from Weltz and Blackburn 1995).

Vegetation	PPT	ET	ET/PPT	PPT	ET	ET/PPT
Mesquite-granjeno shrubland	310	330	1.06	887	881	0.99
Red grama-threeawn grassland	310	298	0.96	887	833	0.94
Bare soil	310	208	0.67	887	643	0.72

Under conditions of limited available moisture, the effect of plant species on ET rates is primarily a function of different rooting depths among species. In dry years, the mesquite-granjeno community ET exceeded the amount of rainfall received that year (Table 8.4), indicating the use of deeper soil moisture stored from previous wetter years. Conversely, the ET of the shallower-rooted grasses was less than the annual rainfall.

Differences in root architecture can also have a substantial effect on ET when deeper soil layers contain higher soil moisture. On an arid site in eastern California, a saltgrass (*Distichlis spicata*) community with some rabbitbrush (*Chrysothamnus nauseosus*) had an annual ET of 47.2 cm (18.6 inches) and a nearby rabbitbrush-sacaton community had an annual ET of 60.5 cm (23.8 inches)(Duell 1990). Both communities had similar depth to groundwater (DTW = 3.3 and 3.2 m, respectively). The reason for the higher ET in the rabbitbrush-sacaton community was because of the abundance of the deeper-rooted rabbitbrush shrubs and alkali sacaton (*Sporobolus airoides*), a deep-rooted perennial grass. In a similar study in southern Arizona, a big sacaton (*Sporobolus wrightii*) community had an ET of less than half that of an adjacent, deeper-rooted mesquite community at similar depths to groundwater (Table 8.5).

Table 8.5 Evapotranspiration (ET) and depth to groundwater for two communities of the San Pedro River floodplain in southern Arizona (data from Scott et al. 2000, 2006).

	Big sacaton grassland		**Mesquite woodland**	
Depth to groundwater (m)	2.5	3.0	2.0	10.0
Evapotranspiration (cm)	40.6	27.2	84.8	63.8
Evapotranspiration (inches)	16.0	10.7	33.4	25.1

In arid regions, evaporation often comprises the greater portion of ET because vegetative cover is low. In more mesic regions, transpiration comprises the greater portion of ET because of higher vegetative cover, less bare ground, and cooler soil surfaces as a result of shading. In the Owens Valley of eastern California, a part of the Mojave Desert with a high water table, ET for three species of grasses with an average canopy cover of 37% had an average E:T ratio of 55:45, with ET comprising 40-69% of evaporation (Evans et al. 2013; Mata-Gonzalez et al. 2014). A desert site in North Africa had an average E:T ratio of 57:43, with a range of 38-78% evaporation (Floret et al. 1982).

8.2.1.1 Tight Sandy Loam

The tight sandy loam (Plot Type 103) is a sandy loam grassland community with scattered mottes of live oak and lesser amounts of mesquite around the edges of the oak mottes (Table 8.1). In the calibration, we used precipitation data from Zone 5 (Nixon, Fig. 4.2). Annual rainfall varied during the 10-year calibration simulation from 19.80 inches to 49.26 inches, with an average of 34.58 inches (Table 8.6). Simulated ET averaged 31.10 inches, or 90% of annual precipitation. This equates to an ET rate of 3.2 mm/day for a 245-day growing season (March-October) or an annual (365-day) ET rate of 2.2 mm/day. These are reasonable rates based on literature values. An average daily rate for a mesquite-granjeno community on a sandy loam site in South Texas is 2.6 mm (Weltz and Blackburn 1995) and 2.5 mm for a mesquite riparian community in southern Arizona (Scott et al. 2000, 2006). Annual ET for the tight sandy loam calibration simulations averaged 90% of annual rainfall (Table 8.6), which is similar to the 97% value reported for mesquite-grasslands in the Rolling Plains of Texas (Carlson et al. 1990), 95%

for oak-grasslands in the Edwards Plateau (Thurow et al. 1988), and 94% on bluestem prairie in Kansas (Bremer et al. 2001).

Table 8.6 Annual rainfall (inches) and evapotranspiration (ET) variables (inches) for the 10-year calibration simulation for the tight sandy loam type, Karnes County EDYS model.

Year	Rainfall	Interception	Evaporation	Total Evaporation	Transpiration	ET	ET/Rainfall
2000	37.63	0.64	2.21	2.85	20.31	23.16	0.607
2001	42.30	0.55	1.00	1.55	28.24	29.79	0.661
2002	39.60	1.22	1.32	2.54	37.46	40.00	0.935
2003	25.77	1.75	1.45	3.20	34.62	37.82	1.501
2004	44.11	1.83	2.34	4.17	36.58	40.75	0.974
2005	23.24	0.87	1.46	2.33	23.58	25.91	1.066
2006	23.62	0.66	0.73	1.39	20.21	21.60	0.897
2007	49.26	1.32	2.37	3.69	44.34	48.03	0.879
2008	19.80	0.77	1.91	2.68	20.08	22.76	1.368
2009	40.50	0.53	1.27	1.80	19.42	21.22	0.514
SUM	345.83	10.14	16.06	26.20	284.84	311.04	

OVERALL ET/RAINFALL = 311.04/345.83 = 0.899
OVERALL TRANSPIRATION/ET = 284.84/311.04 = 0.916
OVERALL INTERCEPTION/ET = 10.14/345.83 = 0.029

Total evaporation = Interception + Evaporation.

The ratio of annual ET to annual rainfall fluctuates among years, in part, because the supply of soil water is not entirely dependent on the amount of rainfall received in the particular year. Some soil water may be carried over from a previous year and late-season rainfall may not be fully-utilized by plants in the year that it was received (Table 8.7). ET exceeded annual rainfall in one-third of the years in the Rolling Plains study (Table 8.7). By comparison, ET exceeded annual rainfall in 30% of the years of the calibration simulations (Table 8.6).

Table 8.7 Annual rainfall and evapotranspiration (ET) at sites in the Rolling Plains (Carlson et al. 1990) and in South Texas (Weltz and Blackburn 1995) in wet and dry years.

	Rolling Plains						South Texas			
	Grassland			Mesquite-Grassland			Grassland		Mesquite-Granjeno	
Rainfall (mm)	769	677	629	769	677	629	310	887	310	887
ET (mm)	644	804	555	658	756	511	298	833	330	881
Balance	125	-127	74	111	- 79	118	12	54	-20	6
ET/Rainfall	0.86	1.19	0.88	0.86	1.12	0.81	0.96	0.94	1.06	0.99

The tight sandy loam vegetation intercepted an annual average of 1.01 inches of rainfall in the calibration simulations (Table 8.6), or an average of 3% of annual rainfall. This is lower than typically reported values in the literature: 4% for shadscale shrubland in Utah (West and Gifford 1976), 8% for California grasslands (Corbett and Crouse 1968), 8% for huisache woodlands in Nuevo Leon (Carlyle-Moses 2004), and 11% for curly-mesquite, 18% for sideoats grama, and 25% for live oak in the Edwards Plateau (Thurow et al. 1987).

8.2.1.2 Other Vegetation Types

Average annual ET varied between 23.3 and 32.7 inches per year on the seven types (Table 8.8). The highest annual average ET was on the clay loam type. This type is typical of the mesquite shrublands of South Texas, with a substantial amount of midgrasses in the interspaces (Table 8.2). Weltz and Blackburn (1995) reported an average annual ET of 33.7 inches for a mesquite shrub-grassland in South Texas in a year receiving 34.9 inches of rain. This is a very similar ET to the 32.7 inches for the simulations at an average annual rainfall of 34.6 inches (Table 8.8). In the simulations, ET on the clay loam site averaged 94.5% of annual rainfall. This compares to 94% for bluestem grasslands (Bremer et al. 2001), 95% for oak-grasslands (Thurow et al. 1988), and 97% for mesquite-grasslands (Carlson et al. 1990).

Table 8.8 Average annual rainfall (inches) and evapotranspiration (ET) variables (inches) for the 10-year calibration simulation for the seven vegetation plot types, Karnes County EDYS model.

Type	Rainfall	Interception	Evaporation	Total Evaporation	Transpiration	ET	ET/Rainfall
Tight sandy loam	34.58	1.01	1.61	2.62	28.48	31.10	0.899
Clay loam	34.58	1.16	1.79	2.95	29.75	32.70	0.945
Clay bottomland	27.70	0.69	1.68	2.37	20.93	23.30	0.841
Lakebed	34.58	2.38	2.51	4.89	24.76	29.65	0.857
Pasture	34.58	2.95	2.49	5.44	26.39	31.83	0.920
Cultivated	35.50	1.79	4.02	5.81	19.33	25.14	0.708
Gravelly ridge	34.58	3.78	0.92	4.70	26.44	31.14	0.901
Mean	33.73	1.97	2.15	4.11	25.15	29.27	0.867

The lakebed type represents swales, depressions, ephemeral wetlands, and abandonded ponds and stock tanks. Evaporation was relatively high on this type (4.9 inches; Table 8.8), which might be expected on occasionally wet sites. Annual ET averaged 29.7 inches and this compares to reported values of 24.5 inches for saltgrass-sacaton meadow with depth to groundwater (DTW) of 2.4 m and 32.3 inches for a shrub-grassland meadow with a DTW of 1.8 m (Duell 1990). Daily ET (annual rate/365 days) averaged 2.1 mm on this site and this value compares favorably with values for similar semi-wetland communities such as sacaton grasslands in Arizona and New Mexico (2.4 mm/d; Weeks et al. 1987, Scott et al. 2006) and saltgrass in Nevada (2.2 mm/d; Grosz 1972), and they are about half those reported for permanent wetlands in Florida (4.7 mm/d for cattail, Mao et al. 2002; 6.0 mm/d for freshwater marsh, Rushton 1996).

The cultivated (grain sorghum) type had an average ET of 25.1 inches (Table 8.8). This type assumed the crop was planted in early March, harvested in July, and the stubble allowed to remain in place through October. Assuming a 240-d growing season (March-October), this equates to a daily ET of 2.7 mm. Typical growing season (June-September) daily ET rates for unirrigated corn in Illinois are 2.8-3.2 mm (Reimann et al. 1946; Peters and Russell 1959). Average canopy interception rates (annual rainfall basis) for corn in Illinois are on the order of 1.9-2.0 inches (Reimann et al. 1946). The average interception rate for the cultivated type in the simulations was 1.8 inches (Table 8.8).

The gravelly ridge type was dominated by xeric shrubs, in particular blackbrush. Blackbrush tends to grow in relatively dense thickets and has small leaves. Canopy interception data are not available, to our knowledge, for blackbrush. However, a blackbrush community is a similar structure-type to chaparral communities of southern California and southern Arizona. Plant canopies in California chaparral communities intercept an average of 1.7-3.9 inches of precipitation annually, or about 8% of annual rainfall (Hamilton and Rowe 1949). Canopy interception on the gravelly ridge site in the calibration simulations averaged 3.8 inches per year (Table 8.8) and varied between 2.2 and 7.1 inches per year. Canopy interception on the gravelly ridge type averaged 11% of annual rainfall. Simulation ET values for the gravelly ridge type averaged 2.1-3.3 mm/day (365-d and 240-d growing season, respectively) compared to 3.7 mm/day for an acacia-tarbush shrubland community in southern Arizona (Emmerich 2007).

In summary, the ET and interception values from the calibration simulations corresponded well with values reported in the literature. These results suggest that the EDYS evaporation, interception, and transpiration values are reasonable. In addition, mean monthly EDYS simulated ET values and USGS-monitored values were not significantly different for the Honey Creek Watershed (McLendon et al. 2009).

8.2.2 Surface Runoff

Surface runoff (overland flow) occurs when the rate at which supply of water exceeds the infiltration rate of the soil. This most commonly occurs during intense rainfall events or when soils become saturated because of an extended rainfall period. As runoff water flows downslope, it can increase in quantity as runoff water from adjacent locations are added to the flow or the quantity can decrease if the runoff water flows across a drier soil. In addition to the supply rate of incoming water, the amount of runoff is affected by slope (as slope increases, amount of runoff increases), soil texture (related to infiltration rate), and surface roughness. Surface roughness refers to changes in the topography of the soil surface, including the presence of objects at the soil surface (e.g., rocks, litter, and stems, crowns, and trunks of plants). Other factors held constant, runoff decreases as surface roughness increases.

There are both spatial and temporal aspects to the dynamics of runoff. Runoff changes spatially across a landscape in response to differences in topography and soils. Ockerman (2002) reported runoff from a loamy sand range site and a nearby clay range site on the Welder Wildlife Refuge. Both sites received approximately the same amount and intensity of rainfall at the same dates. Surface runoff averaged 2.7 inches/year on the loamy sand site but only 0.6 inch/year of the clay site. Wright et al. (1976) reported runoff from adjacent sites on the northern edge of the Edwards Plateau, one site being nearly level and one with 13% slope. Runoff averaged 0.5 inch/year on the level site and 2.7 inches on the slope.

Temporal changes in runoff occur for a variety of reasons. Intensity of the rainfall event is a primary factor influencing the amount of runoff from a site. Most rainfall events do not result in measurable runoff. Along the central Texas Coast, rainfall events less than two inches generally do not result in runoff (Ockerman and Petri 2001; Ockerman 2002) and in the Edwards Plateau the threshold level is about 0.7 inch (Thurow et al. 1988). In San Patricio County, there were only nine runoff events recorded over a two-year period and five of these were minor (0.07 inch or less; Ockerman 2001). Even at the lower threshold level (0.7 inch) in the Edwards Plateau, there was an average of only nine runoff events per year over a six-year period (Thurow et al. 1988).

Amount of runoff is also affected by antecendent soil moisture conditions. A specific rainfall event is likely to result in much different runoff amounts when the event occurs following a dry period than when the soil is near field capacity. A 4.7-inch rainfall event in October 2000 resulted in less than 0.02 inch of runoff at a site in San Patricio County, compared to 0.34 inch of runoff from a 4.2-in rain in November of the following year (Ockerman 2002). The October 2000 event was preceded by a very dry period and the November 2001 event occurred 10 weeks after a 7.5-inch rainfall event. A 4.6-inch rainfall event in early October 1998 resulted in 1.0 inch of runoff from an agricultural watershed in Kleberg and Nueces Counties in South Texas and a 5.5-inch rainfall event later than month produced 2.7 inches of runoff from the same, but now rain-soaked, watershed (Ockerman and Petri 2001).

A third important factor affecting landscape-level runoff dynamics is vegetation. And vegetation is itself very dynamic. Carlson et al. (1990) compared runoff from nearby locations in the Rolling Plains of Texas where the vegetation had been manipulated. Annual runoff, averaged over three years, was 1.2 inches on sites with mesquite overstory and a grass understory, 0.4 inch where the mesquite had been removed but the grasses remained, and 3.8 inches where both mesquite and grasses were removed. Grazing management can have a substantial impact on runoff. Runoff on the Sonora Experiment Station on the western edge of the Edwards Plateau averaged 2.9% of annual precipitation on a continuously-grazed pasture and 3.5% on a nearby site grazed under a four-pasture rotation system (Thurow et al. 1988). Both sites were moderately-stocked. Brush control methods can also affect amount of runoff. Wright et al. (1976) measured runoff on plots in the northern Edwards Plateau that had been previously bulldozed to reduce juniper density. Plots that were burned to remove the juniper slash and regrowth had 10% less runoff than on plots where the slash and regrowth had not been removed.

8.2.2.1 Tight Sandy Loam

Simulated annual runoff varied between 0.0 and 6.5 inches for the tight sandy loam plot type (Table 8.9). Annual runoff averaged 1.32 inches in the simulations, compared to 1.27 inches for a gauged loamy sand rangeland watershed on the Welder Wildlife Refuge over a two-year period (Ockerman 2002). Annual runoff in the simulations averaged 3.8% of annual rainfall (Table 8.8) and this compares favorably to the 3.84% of annual rainfall reported for the Welder Wildlife Refuge watershed. The ratio between annual runoff and annual rainfall in the simulations varied between 0.0 and 16.0% (Table 8.9) and it varied on the gauged watershed between 0.02 and 14.5% (Ockerman 2002).

Table 8.9 Annual rainfall and surface runoff for the 10-year calibration simulation, Karnes County EDYS model.

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Mean
Runoff (inches)	0.15	1.86	1.84	0.00	0.48	0.15	0.45	1.56	0.19	6.47	1.32
Rainfall(inches)	37.63	42.30	39.60	25.77	44.11	23.24	23.62	49.26	19.80	40.50	34.58
Runoff/Rainfall	0.004	0.044	0.046	0.000	0.011	0.006	0.019	0.032	0.010	0.160	0.038

8.2.2.2 Other Vegetation Types

Annual runoff, averaged over the seven plot types and the 10 years of the calibration simulations, was 1.6 inches, or 4.9% of annual rainfall (Table 8.10). Annual runoff from field studies on vegetated sites typically varies between 0.2 and 2.6 inches (Table 8.11), with an average of 1.23 inches per year. Annual runoff averaged 3.1% of annual rainfall on vegetated sites in the measurement studies and varied between 0.8 and 5.0% (Table 8.11).

Table 8.10 Average annual rainfall and surface runoff for the 10-year simulations for seven plot types used in the calibration of the Karnes County EDYS model.

	Tight Sandy Loam	Clay Loam	Clay Bottomland	Lakebed	Improved Pasture	Cultivated	Gravelly Ridge	Mean
Runoff (inches)	1.32	0.58	3.07	2.92	1.63	0.66	1.04	1.60
Rainfall (inches)	34.58	34.58	27.70	34.58	34.58	34.50	34.58	33.73
Runoff/Rainfall	0.038	0.017	0.111	0.084	0.047	0.019	0.030	0.049

Table 8.11 Examples of average annual runoff values (inches) in Texas reported in the literature, with corresponding runoff:precipitation ratios (RO/PPT).

Vegetation Type	Location	Runoff	RO/PPT	Reference
Mesquite-grassland	Rolling Plains	1.22	0.042(0.021-0.081)	Carlson et al. 1990
Grassland (mesquite removed)	Rolling Plains	0.43	0.015(0.004-0.036)	Carlson et al. 1990
Bare soil	Rolling Plains	3.82	0.141(0.087-0.195)	Carlson et al. 1990
Grassland, nearly level	N Edwards Plateau	0.24	0.008	Wright et al. 1976
Grassland, 13% slope	N Edwards Plateau	1.10	0.039	Wright et al. 1976
Oak-mixed grass (HILF)	W Edwards Plateau	----	0.050	Thurow et al. 1988
Oak-mixed grass (4-pasture)	W Edwards Plateau	----	0.035	Thurow et al. 1988
Oak-mixed grass (continuous)	W Edwards Plateau	----	0.029	Thurow et al. 1988
Rangeland + cultivated	San Patricio Co.	2.40	0.039(0.001-0.148)	Ockerman 2002
Loamy sand rangeland	San Patricio Co.	2.56	0.041(0.000-0.174)	Ockerman 2002
Clay rangeland	San Patricio Co.	0.63	0.011(0.000-0.042)	Ockerman 2002
Cultivated (PPT = 12.9 in)	Kleberg-Nueces Cos.	0.04	0.004(0.000-0.042)	Ockerman & Petri 2001
Cultivated (PPT = 26.7 in)	Kleberg-Nueces Cos.	4.06	0.152(0.012-0.488)	Ockerman & Petri 2001
Cultivated (PPT = 38.1 in)	Kleberg-Nueces Cos.	6.38	0.167(0.003-0.502)	Ockerman & Petri 2001

RO/PPT values outside parentheses are annual mean, values inside parentheses are ranges for individual PPT events.
HILF = high-intensity low-frequency grazing system.

Simulated runoff averaged 0.58 inch (1.7% of precipitation) on the clay loam type (Table 8.10), compared to 0.63 inch (1.1% of precipitation) measured in San Patricio County (Table 8.11). Simulated runoff on cultivated areas was lower than that reported for Kleberg and Nueces Counties (0.7 and 3.5 inches, respectively), but the simulated value fell within the reported values for individual rainfall events (Table 8.11). Simulated runoff averaged 1.04 inches (3.0%

of annual rainfall) on the gravelly ridge type. The nearest ecological and topographic equivalent to this type in the reported data are the 13% slope grassland site in the northern Edwards Plateau (Wright et al. 1976) and the oak-mixed grass communities in the western Edwards Plateau (Thurow et al. 1988). Annual runoff on the northern Edwards Plateau slope averaged 1.10 inches (Table 8.11), very near the 1.04 inches for the simulated gravelly ridge type, and annual runoff averaged 2.9-5.0% of annual rainfall on the four Edwards Plateau sites.

Overall, the runoff values in the simulations corresponded well with measured values from similar sites in Texas, especially sites in South Texas. These results indicate that the EDYS runoff values, both amount and proportional to rainfall, are reasonable. In addition, EDYS simulated runoff values and USGS-monitored values were similar for the Honey Creek Watershed (McLendon et al. 2009).

8.3.3 Sediment Loadings

The amount of sediments transported in runoff water is of major importance in watershed management. Sediment loadings tend to increase as the amount and intensity of a rainfall event increases and as surface roughness, especially vegetation cover, decreases. For example, typical sediment loadings at the Sonora Experiment Station are 25-50 g/m^2/yr (Thurow et al. 1988), but following a high intensity event (0.8 inch in 30 minutes) can be as high as 387 g/m^2/yr (McCalla et al. 1984), a ten-fold increase. Similarly, annual sediment loadings on a mesquite-grassland in the Rolling Plains of Texas averaged 140 g/m^2 compared to 2,337 g/m^2 on nearby bare soil (Carlson et al. 1990).

Type, as well as amount, of vegetation cover also affects the amount of sedimentation. Grass cover tends to decrease both soil erosion (dislodging of soil particles) and sediment transport (movement of water-borne particles), compared to cover by woody species. Mesquite-grasslands in the Rolling Plains had annual sediment loadings of 140 g/m^2 compared to 25 g/m^2 on adjacent sites where the mesquite had been removed. Sediment loadings on sites at the Sonora Experiment Station covered in midgrasses (e.g., sideoats grama and bluestems) were less than 40% the loadings on adjacent sites covered by shortgrasses (e.g., curly mesquite and hairy grama)(McCalla et al. 1984).

Typical sediment loadings from rangelands in Texas vary between about 2 and 140 g/m^2/yr, or an equivalent of 0.03-2.13 g/m^2/cm of annual precipitation (Table 8.12). A sediment loading of 2 g/m^2/cm is equivalent to about 5 g/m^2/inch or about 50 lbs/ac/inch of rainfall.

Table 8.12 Examples of measured sediment loadings on sites in the Edwards Plateau and Rolling Plains of Texas.

Vegetation	Location	Amount ($g/m^2/yr$)	Sediments/Rainfall ($g/m^2/cm$ PPT)	Reference
Oak-mixed grass (rotation)	W Edwards Plateau	41	0.74	Thurow et al. 1988
Oak-mixed grass (continuous)	W Edwards Plateau	25	0.45	Thurow et al. 1988
Grassland (level, unburned)	N Edwards Plateau	2	0.03	Wright et al. 1976
Grassland (level, burned)	N Edwards Plateau	2	0.03	Wright et al. 1976
Grassland (13% slope unburned)	N Edwards Plateau	17	0.23	Wright et al. 1976
Grassland (18% slope, burned)	N Edwards Plateau	51	0.61	Wright et al. 1976
Mesquite-grassland	Rolling Plains	140	2.13	Carlson et al. 1990
Grassland (mesquite removed)	Rolling Plains	25	0.38	Carlson et al. 1990
Bare soil	Rolling Plains	2337	35.52	Carlson et al. 1990

Daily sediment loading data from the USGS are available for two years for Gauge 3 (San Antonio River at Falls City) and Gauge 4 (Cibolo Creek at Falls City [Cestohowa]). These values are USGS estimates of daily sediment loads based on regression equations (Crow et al. 2014). The sediment loadings at both of these stations include sediments entering the river within their respective watersheds plus river sediments entering Wilson County from Bexar County. Bexar County is not included in the modeled domain. Therefore, sediment loadings in the river at gauge stations near the Bexar-Wilson County line need to be subtracted from the downstream measurements. These data are available from the Elmendorf gauge station for the San Antonio River but are not available for Cibolo Creek. Consequently, only the Gauge 3 (Falls City) data can be used to evaluate EDYS sediment loadings. To do so, average daily sediment loads for the Elmendorf station in 2011 and 2012 were subtracted from the average daily loads for Gauge 3 (Falls City). These values were then compared to the EDYS sediment loads from the Gauge 2 (Floresville) and Gauge 3 (Falls City) watersheds (Section 8.3.4). In addition, maximum daily sediment loads were compared in a similar manner.

The EDYS sediment loads were substantially lower than the measured values for the San Antonio River (Table 8.13). Mean daily EDYS loadings were only 3-6% of the measured values and maximum daily values were 5% of measured values in a dry year (2011) and 17% in a wet year (2012).

Table 8.13 Comparison of sediment loadings (tons/day), annual daily average and maximum daily, combined from two San Antonio River watersheds (Gauge 2 Floresville and Gauge 3 Falls City) in EDYS simulations to USGS reported values.

2011				2012			
Daily Mean		Maximum Daily		Daily Mean		Maximum Daily	
EDYS	USGS	EDYS	USGS	EDYS	USGS	EDYS	USGS
1.0	15.8	179	3,369	6.0	174.0	1,473	8,530

EDYS values are sediment loadings from the two watersheds. USGS values are differences between the loadings recorded at Gauge 3 Falls City and the Gauge at Elmendorf, with the Falls City readings lagged one day from the Elmendorf readings.

The EDYS values were also compared to values recorded from small-plot studies in Texas (Table 8.12). Averaging the annual sediment loads per centimeter of rainfall from a continuously-grazed oak-mixed grass type (0.45), level and 13% slope unburned grassland (0.13), and rolling plains grassland (0.38), results in an average of 0.32 g sediments/m^2/yr per cm rainfall. The combined Gauge 2 and Gauge 3 watersheds contain an area of 691,041,273 m^2. The EDYS values for surface sediment transport from these two watersheds was 0.49 g/m^2/yr in 2011 and 2.44 g/m^2/yr in 2012 (0.013 and 0.050 g/m^2/cm, respectively). The EDYS values are in the range of the values reported for level grassland in the northern Edwards Plateau (2 g/m^2/yr or 0.03 g/m^2/cm), but are lower than the values reported for other sites (Table 8.12).

The reason for the low EDYS values has been identified and is being corrected. The cause was related to the maximum amount of sediments that can be transported downslope in runoff water and in the method of accounting for the effect of litter on reducing sediment loss. Correct values to be used for these two variables are being investigated. Preliminary corrected values result in sediment loading values that are very close to surface-flow sediment values reported in the literature. The revised sediment loading values are 4.00 g/m^2/yr (0.104 g/m^2/cm) for 2011 and 25.93 g/m^2/yr (0.526 g/m^2/cm) for 2012. These are very similar to the values reported for northern Edwards Plateau grasslands, western Edwards Plateau oak-mixed grass, and Rolling Plains grassland communities (Table 8.12).

8.3.4 Flow Rates

Flow data are available for six gauges (Fig. 8.1). Two are in Wilson County and four are in Karnes County. Three of these gauges (2, 3, and 6; Fig. 8.1) are on the San Antonio River, two (1 and 4; Fig. 8.1) are on Cibolo Creek, and one (5; Fig. 8.1) is on Ecleto Creek. The most complete data set is for the years 2006-2007, and this period was selected for calibration. Data are not available for the San Antonio River gauge at Runge (Gauge 6) until 2011, therefore this station was not included in the calibration process.

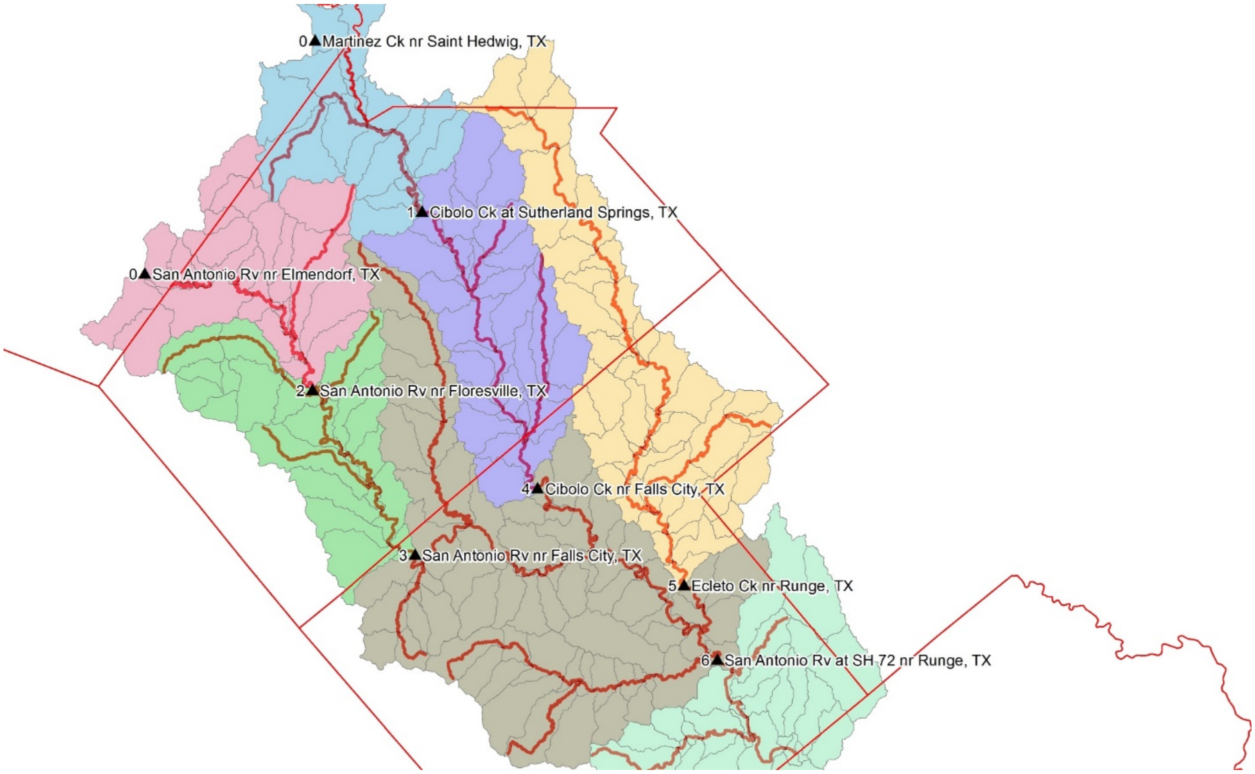


Figure 8.1 Locations of the six gauge stations and their associated watersheds, Karnes and Wilson Counties, Texas.

8.3.4.1 Gauge 2, San Antonio River near Floresville

There were 11 gauged flow events in 2006 that exceeded 500 cfs at Gauge 2 and 23 major gauged flow events (greater than about 900 cfs) in 2007 (Fig. 8.2). The simulated flows from EDYS closely matched the patterns of these 34 events. For the 2006 data, the EDYS values were typically about 10-15% below the gauged values (Fig. 8.2A). Comparing values for 2007 (Fig. 8.2B), the EDYS values averaged about 3% higher than the gauged values. Most of increase in EDYS over gauged occurred with the 2500 cfs event in July, where the EDYS value was about 20% higher than the gauged event. If that event is excluded, the EDYS simulated flow rates averaged less than 0.5% more than the gauged values.

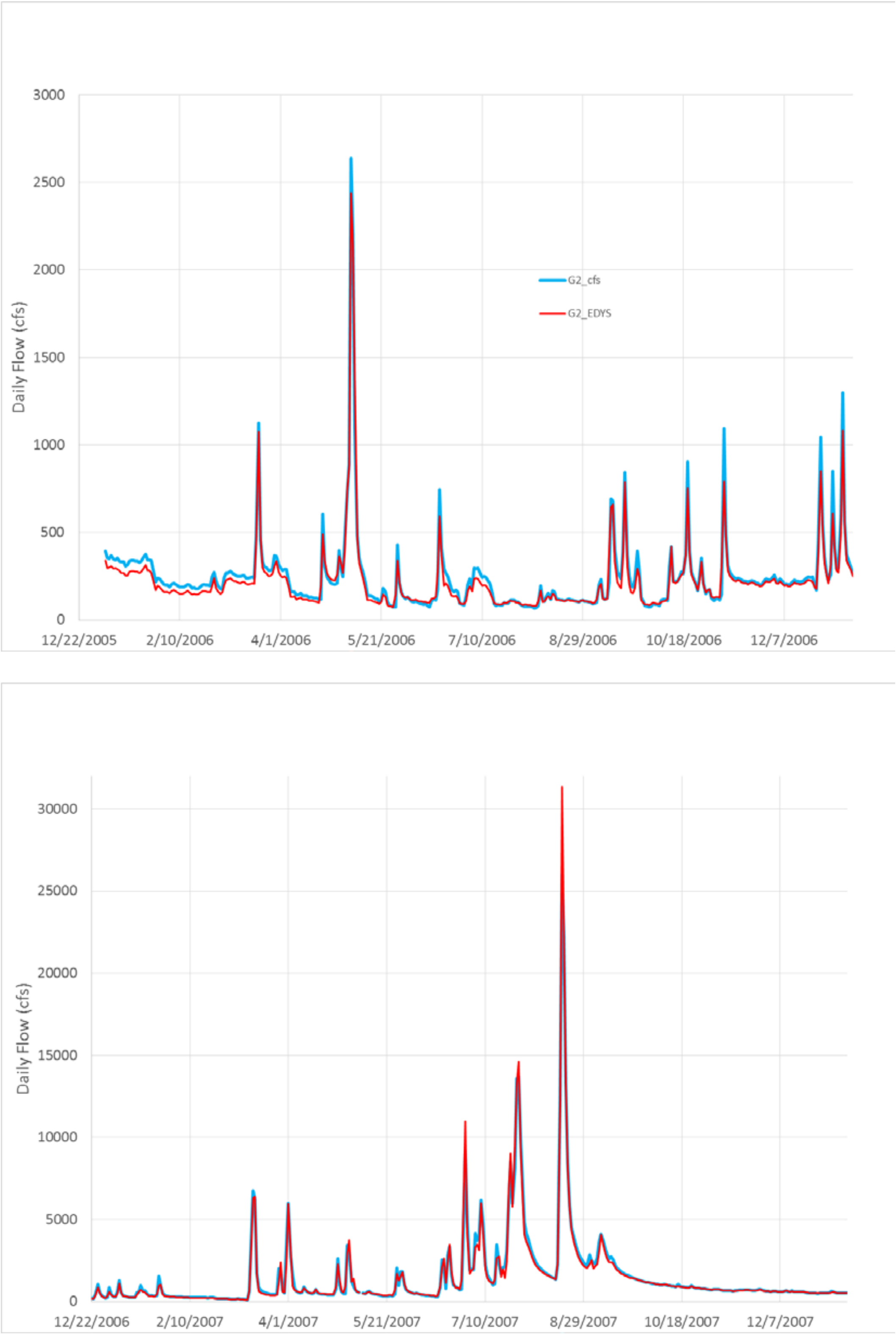


Figure 8.2 Comparison of gauged (blue) and simulated (red) flow rates (daily average cfs) at Gauge 2 on the San Antonio River near Floresville, 2006 (upper) and 2007 (lower).

The gauged flows at the Floresville station are dominated by the quantity of water flowing in the river. The EDYS simulations use inputs from the Elmendorf gauge station (Fig. 8.1) as river flow into Wilson County. Therefore, the close match between simulation and gauged values at the Floresville station are, in part, strongly influenced by the river input data.

8.3.4.2 Gauge 3, San Antonio River near Falls City

The comparisons of simulated and gauged data at Gauge 3 are similar to those at Gauge 2. The EDYS simulated flows closely match the gauged flows, both as to timing and amount (Fig. 8.3). There were 23 gauged flow events in 2006 that increased flow by about 100 cfs or more and 17 events in 2007 that exceeded about 150 cfs. The EDYS flow values tended to be higher than the gauged values in the first half of 2006 and the second half of 2007, and lower than gauged values in the second half of 2006 and the first half of 2007 (Fig. 8.3). On average, EDYS peak flows exceeded gauged values by 10-15% during the first half of 2006. Most of these differences occurred when average daily flow exceeded about 400 cfs (Fig. 8.3A). From July 2006 through June 2007, EDYS simulations of peak flows tended to be lower than gauged peak flows, by about 10-15%. Once again, most of the differences occurred at high peak flows (more than 4000 cfs). EDYS simulated peak flows exceeded gauged peak flows in the second half of 2007 (Fig. 8.3B), by about 15%.

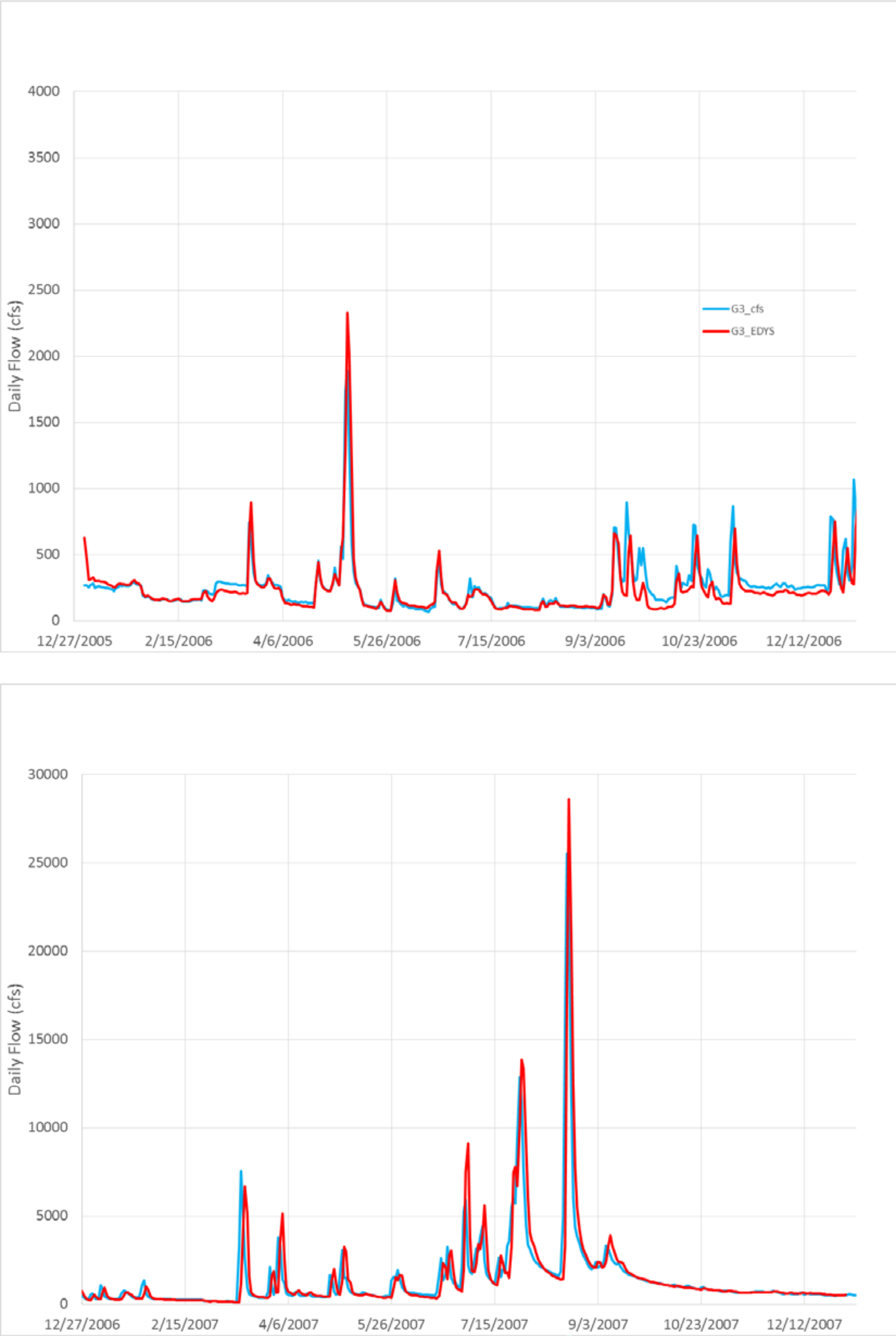


Figure 8.3 Comparison of gauged (blue) and simulated (red) flow rates (daily average cfs) at Gauge 3 on the San Antonio River near Falls City, 2006 (upper) and 2007 (lower).

Gauged flow at the Floresville station during the high-flow event of May 2006 was about 2650 cfs (Fig. 8.2A). The value at the Falls City gauge station for the same event was 1850 cfs (Fig. 8.3A), or a decrease in flow of about 800 cfs between Floresville and Falls City. One explanation for the decrease would be that the river overflowed its banks between Floresville and Falls City and a substantial amount of water was lost from the river. The EDYS values do not reflect the substantial loss. The simulated flow rate at Floresville was about 2450 cfs and about 2350 cfs at Falls City. Therefore a likely source of error in the EDYS values may be inadequate over-bank flooding.

In March 2007, there was a spike in gauged flow rates between Floresville and Falls City (Figs. 8.2B and 8.3B). The peak flow rate at Floresville was about 7000 cfs and the rate at Falls City for the same event was about 8000 cfs. There was therefore a substantial input of water into the river between the two stations, presumably from storm runoff. The corresponding flow rates from EDYS were about 6400 cfs and 6800 cfs, respectively. If 7000 cfs of the 8000 cfs reported at Falls City was upstream river flow (i.e., flow at Floresville), then the difference (1000 cfs) can be accounted as storm runoff in the Gauge 3 watershed (Fig. 8.1). The difference in EDYS values between the two stations is about 400 cfs. By this accounting, EDYS may have underestimated storm runoff by about 40% (400/1000).

8.3.4.3 Gauge 1, Cibolo Creek at Sutherland Springs

The EDYS simulations consistently underestimated flow rates at Sutherland Springs (Fig. 8.4). The EDYS base flow was about 25% less than the gauged flow (22 and 30 cfs, respectively; Fig. 8.4A). There were 10 major increases in gauged flow rates at Sutherland Springs in 2006. The EDYS simulated flow values differed from the gauged values by an average of 14% of the gauged peak flow for the 10 events. EDYS values were greater than gauged values on two of the ten occasions and below on seven occasions (they were equal on one occasion).

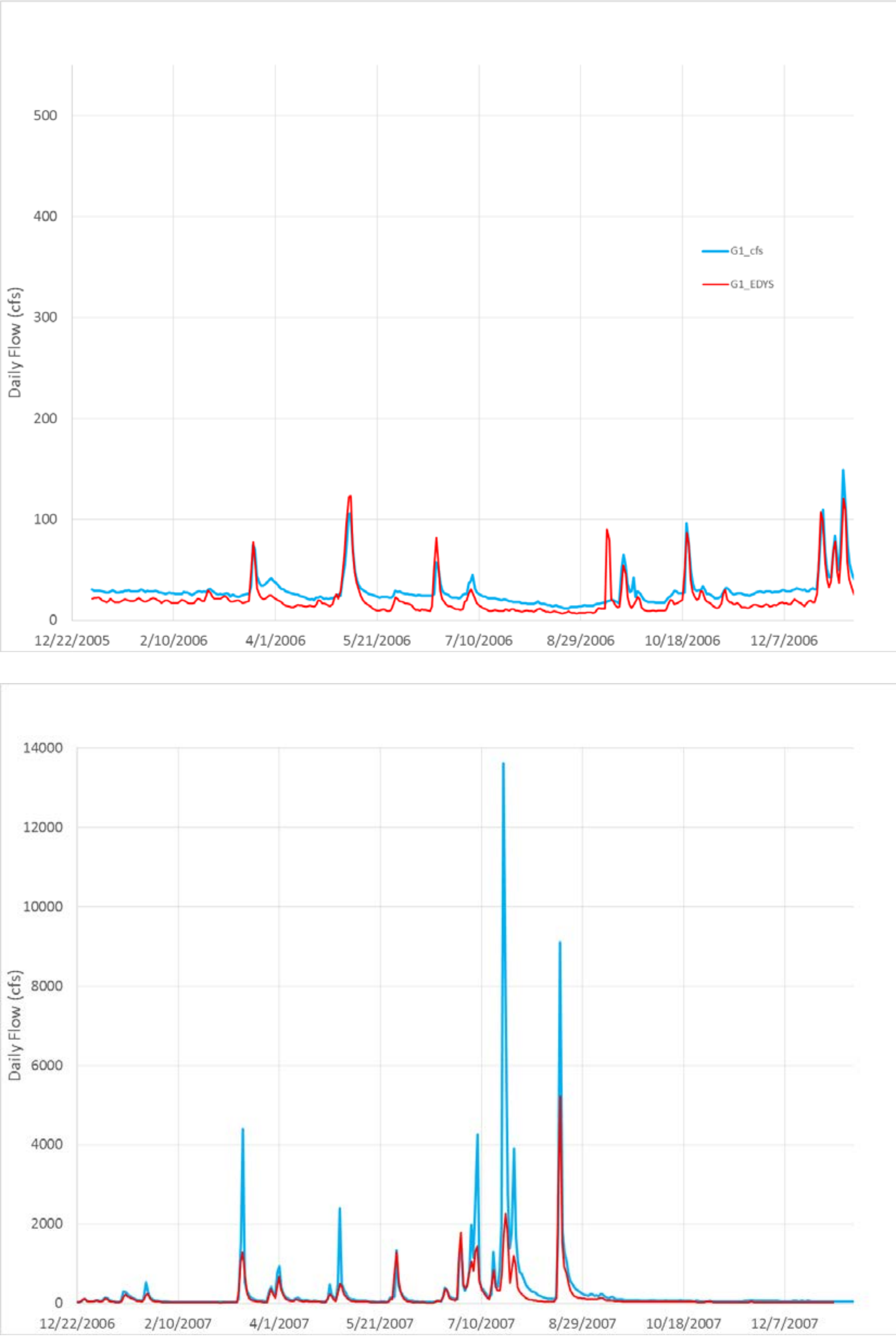


Figure 8.4 Comparison of gauged (blue) and simulated (red) flow rates (daily average cfs) at Gauge 1 on Cibolo Creek at Sutherland Springs, 2006 (upper) and 2007 (lower).

In 2007, a much wetter year than 2006 (Table 4.5), EDYS simulations underestimated flow rates at Sutherland Springs whenever flow exceeded about 1500 cfs (Fig. 8.4B). During these high-flow events, EDYS values were only about one-third the gauged values. Two factors contributed to these lower EDYS values. First, about one-third of the watershed that contributes runoff to the Sutherland Springs gauge station is not included in the EDYS spatial footprint (Fig. 8.1). This excluded watershed is part of Bexar and Guadalupe Counties. The second factor is that the inflow into the Cibolo Creek from Bexar County was estimated and these values are likely to be low, even for base flow. Given that the base flow values are about 25% too low, flows into Cibolo Creek during high rainfall events (corresponding to spikes in gauged flow rates at Sutherland Springs) are also likely to be low, perhaps by the same amount (25%).

8.3.4.4 Gauge 4, Cibolo Creek near Falls City (Cestohowa)

At low-flow rates (100 cfs or less), the EDYS simulated flow rates were similar to the gauged rates at Gauge 4. Whenever gauged flow at Gauge 4 was more than about 120 cfs, the EDYS simulated flow values were substantially lower than the gauged values (Fig 8.5). Gauge 4 is located on the Cibolo Creek downstream from Gauge 1 (Fig. 8.1). Simulated flow rates were low at Gauge 1 because of several factors (Section 8.3.4.4). Adjusting (increasing) the EDYS flows at Gauge 1 to account for these low values results in a better fit between EDYS and gauged values at Gauge 4, for some of the dates (Fig. 8.6).

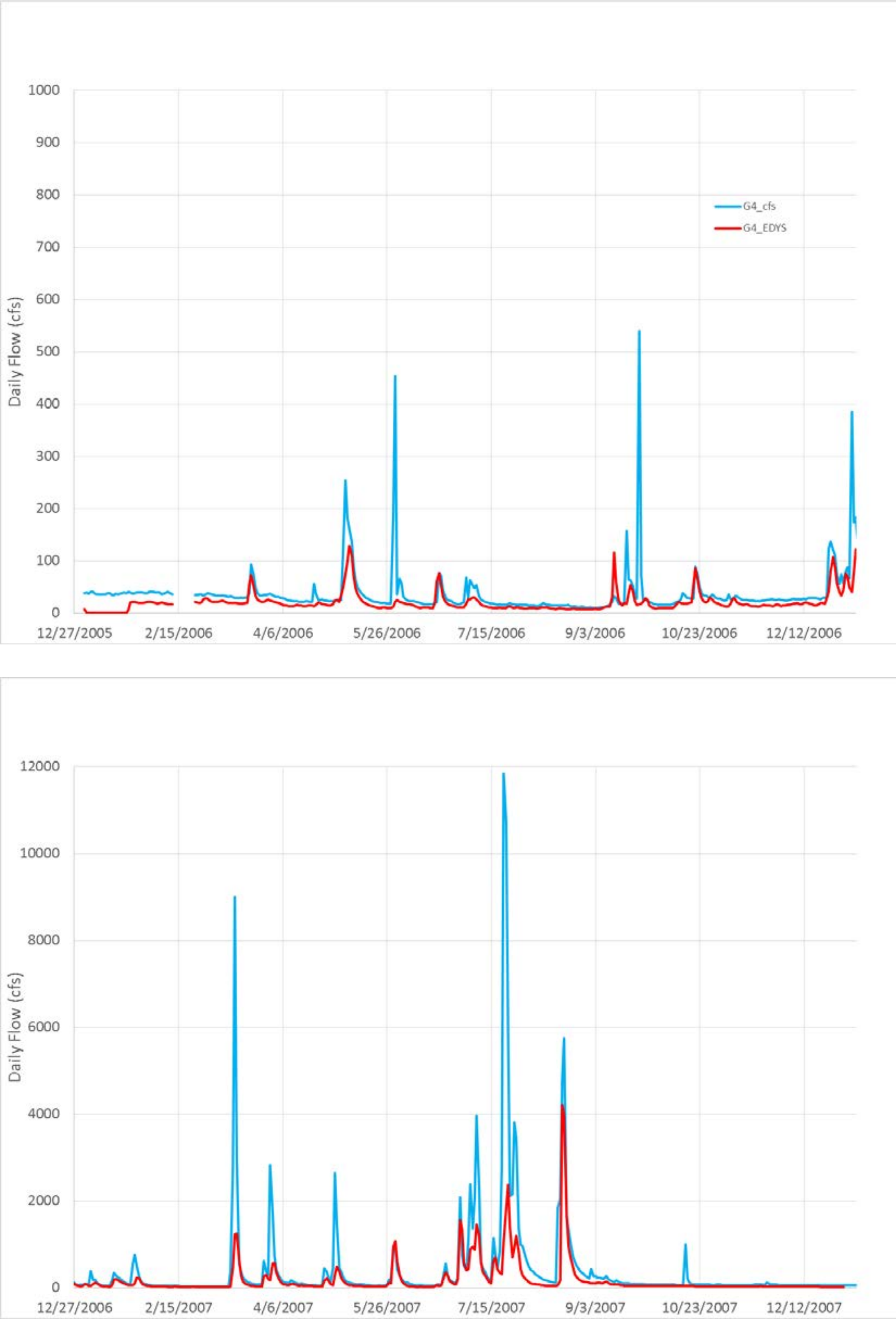


Figure 8.5 Comparison of gauged (blue) and simulated (red) flow rates (daily average cfs) at Gauge 4 on Cibolo Creek near Falls City (Cestohowa), 2006 (upper) and 2007 (lower).

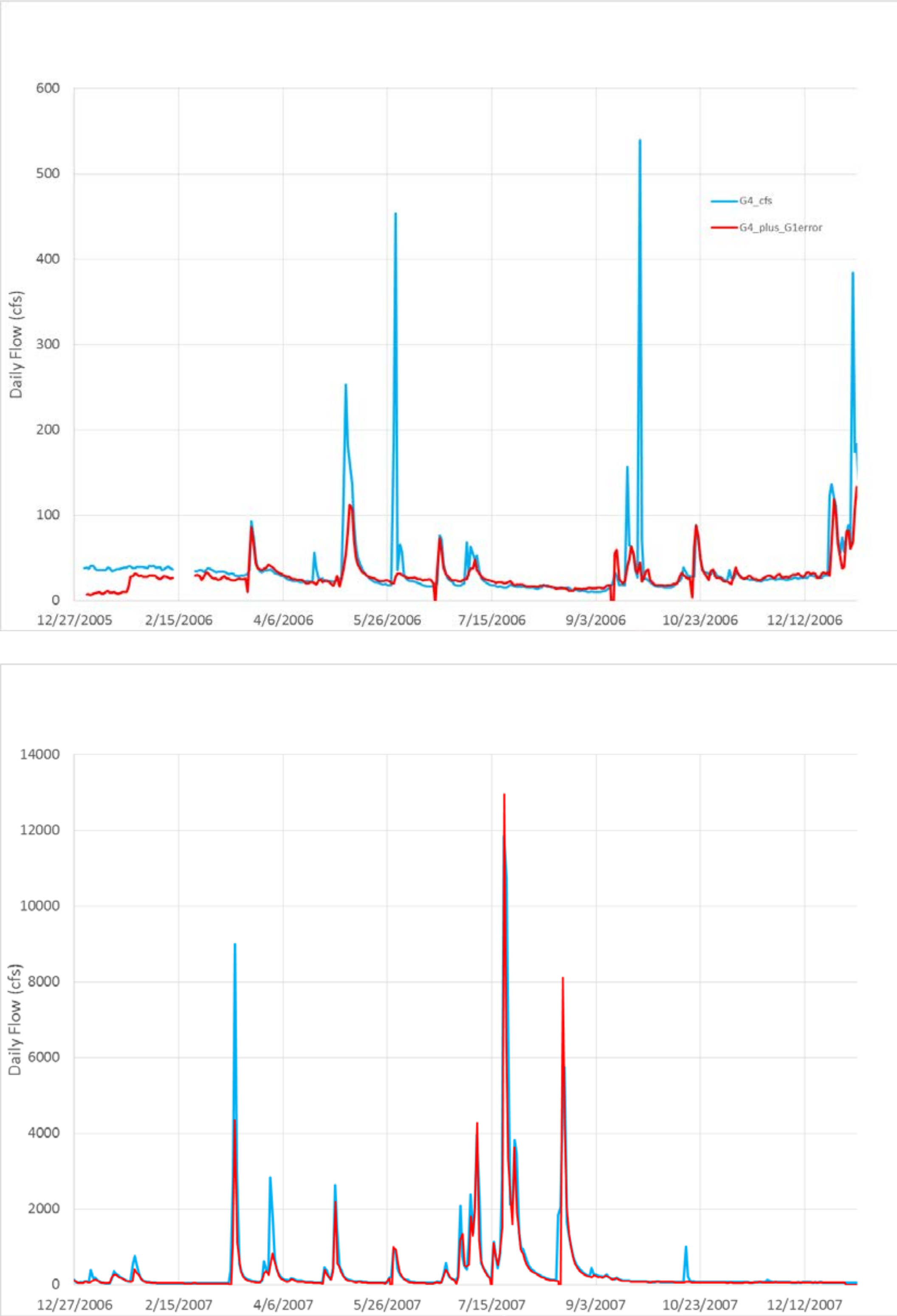
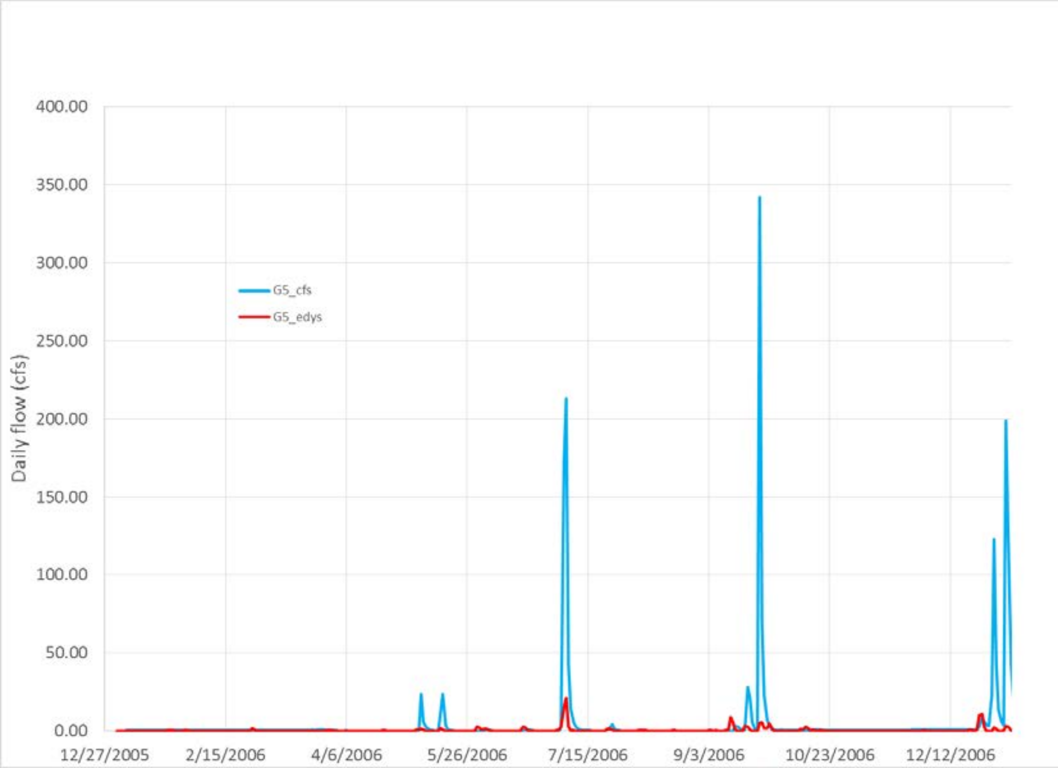


Figure 8.6 Comparison of gauged (blue) and adjusted simulated (red) flow rates (daily average cfs) at Gauge 4 on Cibolo Creek near Falls City (Cestohowa), 2006 (upper) and 2007 (lower). The adjustment made to the simulated rates was to account for the error in the simulated flow rates at Gauge 1 (Sutherland Springs).

After making the adjustments to account for errors in simulated flows at Gauge 1, the EDYS and gauged base flow rates for Gauge 4 match closely (Fig. 8.6). The EDYS simulations continued to underestimate gauged values for high peak flows between May 2006 and April 2007, but provided reasonable to good estimates from May 2007. There were approximately 26 major spikes in the gauged flow rates at Gauge 4 between March 2006 and October 2007. Using the adjusted EDYS values (Fig. 8.6), the simulations underestimated the gauged rates for 20 of the events, overestimated for 4 events, and the values were equal for 2 events. Averaged over all 26 events, the EDYS simulated peak flow values were only about 50% of the gauged values. The average gauged daily flow of the 13 peak events in 2006 was about 175 cfs, compared to an EDYS average of about 70 cfs. In 2007, the average gauged daily flow for the 13 peak events was about 2850 cfs, compared to an EDYS simulated average of about 1810 cfs (Fig. 8.6).

8.3.4.5 Gauge 5, Ecleto Creek near Runge

There is a very poor fit between gauged and simulated peak flow events at Gauge 5 (Fig. 8.7). The EDYS simulations do have spikes in the flow that correspond to spikes recorded at Gauge 5, but the EDYS values are only a small fraction of the amounts recorded at Gauge 5.



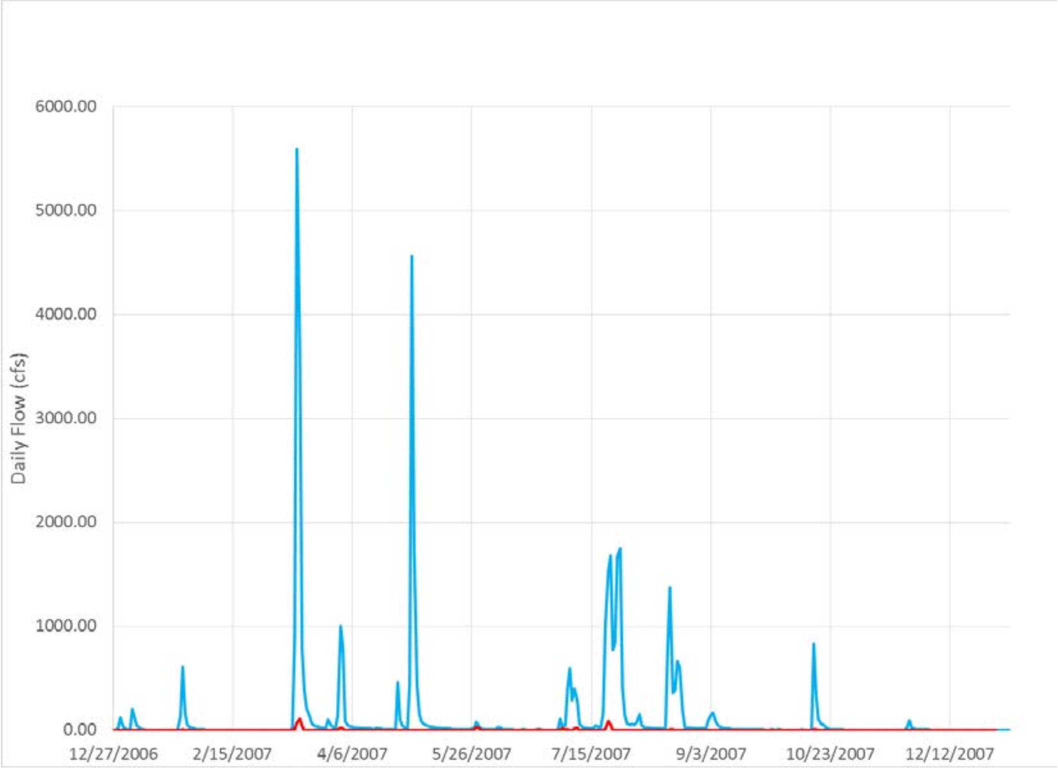


Figure 8.7 Comparison of gauged (blue) and simulated (red) flow rates (daily average cfs) at Gauge 5 on Ecleto Creek near Runge, 2006 (upper) and 2007 (lower).

Gauge 5 records flows from the Ecleto Creek watershed (Fig. 8.1). This watershed differs from the other watersheds in that there is little or no base flow along Ecleto Creek. The flows recorded at Gauge 5 are the result of rainfall events in the watershed. However, there is a poor correlation between rainfall events and the gauged peak flows recorded at Gauge 5. In 2006 (a dry year), there were four major spikes in flow (more than 100 cfs) recorded at Gauge 5 (Fig. 8.7A). There were substantial rains in the watershed associated with each of these events (Fig. 8.8). However, there were other substantial rainfall events that produced no increase in flow at Gauge 5. In 2007 (a wet year), there was a major spike in flow at Gauge 5 in March and there was high rainfall associated with that event. Another major spike in gauged flow occurred in April, also associated with high rainfall, although the rainfall was less than half the amount associated with the March event. A number of high rainfall events occurred in June-August, some of which were equal to the March event, but gauged peak flows during this period were much lower than in March and April. Periods of high rainfall between December 2007 and October 2009 produced little or no peak flows (Fig. 8.8). Two high flows occurred in December 2009 and Feburary 2010, and both were associated with high rainfall, but periods of high rainfall following those two events produced no spikes in gauged flow.

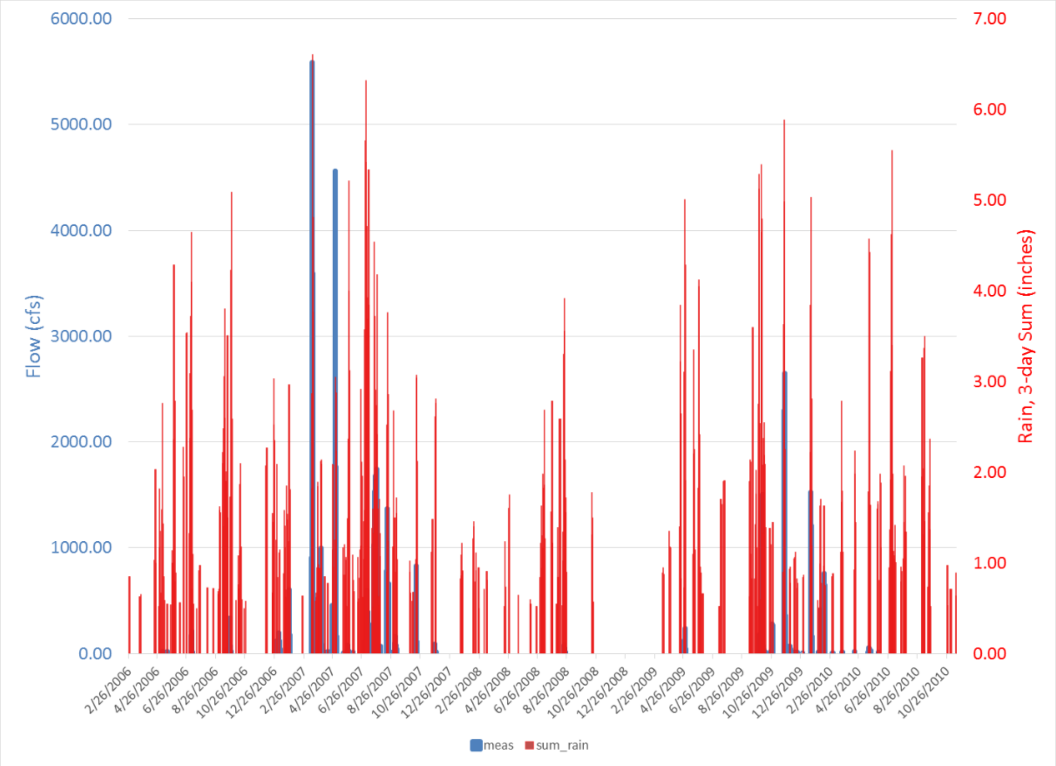


Figure 8.8 Daily flow (cfs) at Gauge 5 (Runge) and average cumulative (3-day) rainfall for the Ecleto Watershed (average of Nixon, Runge, and Stockdale).

All major flow events (greater than 150 cfs) at Gauge 5 from July 2006 through February 2010 were associated with cumulative (3-day) rainfall of greater than 0.5-inch (Fig. 8.9). However, there is no correlation between the amount of rainfall above 0.5 inch and the magnitude of the peak flow. Very high rainfall (more than 5 inches) occurred seven times but produced very high flows (greater than 1600 cfs) only twice. The second highest flow (4500 cfs) was associated with a 2.6-inch rainfall event. Rainfall events between 2.5-6.1 inches occurred 13 times, but produced a 3000$^+$ cfs flow rate only this one time.

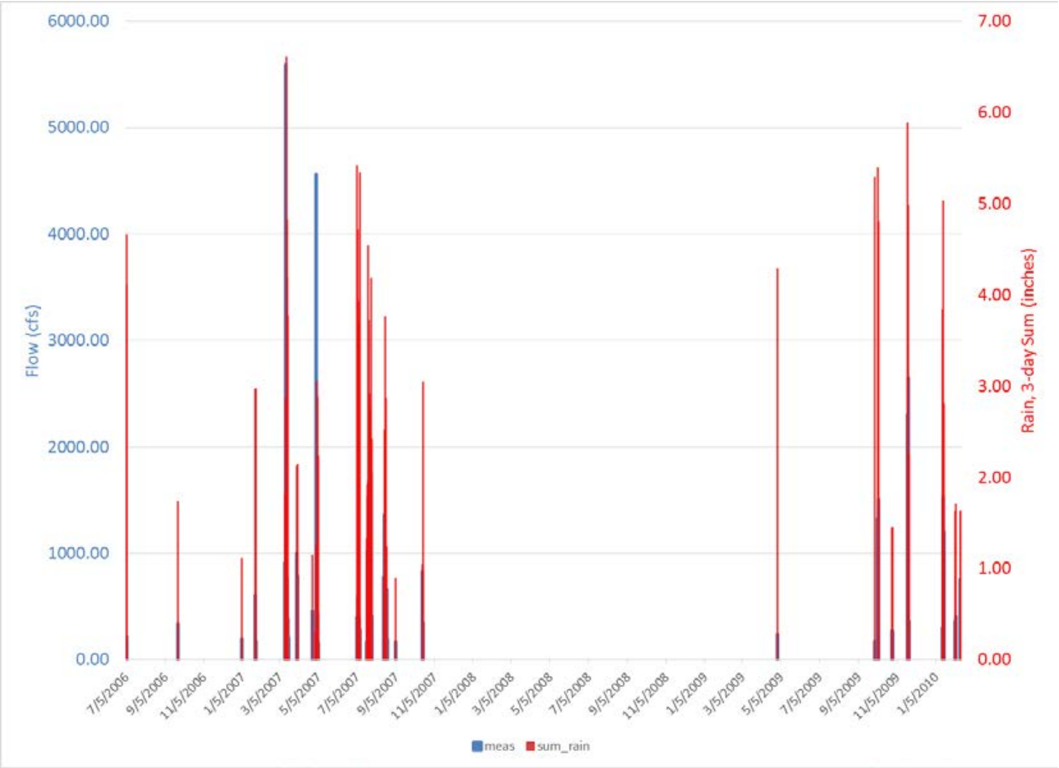


Figure 8.9 Major daily flow events (greater than 150 cfs) at Gauge 5 and average cumulative (3-day) rainfall for the Ecleto Watershed (average of Nixon, Runge, and Stockdale).

High rainfall following dry periods produced proportionately lower peak flows (Fig. 8.9), as might be expected. Dry soils have the capacity for greater water intake than the same soils when wet. This can explain the low peak flows in July 2006 and May 2009. However, 2007 was a wet year and, with the exception of the two major peak flows in the spring of 2007, higher peak flows were not correlated with higher rainfall.

Soils in the Ecleto watershed are predominately sandy. Data presented by Ockerman (2002) from San Patricio County indicates that 1) a minimum of 1.5 inches of rain are required to produce any runoff on a loamy sand site, 2) 1.5-5 inch rainfall events produced less than 0.25 inch of runoff, and 3) 6-8 inch rainfall events produced about 1 inch of runoff. The topography in northern Karnes County is more hilly than in eastern San Patricio County so the amount of runoff from sandy soils may be greater in Karnes County. However, the general proportions between rainfall and runoff amounts probably also hold for the Ecleto watershed.

There were about 11 rainfall events between April 2006 and September 2010 that exceeded 5 inches over a 3-day period (Fig. 8.10). One produced a peak flow of over 5500 cfs, one a peak flow of about 2600 cfs, four peak flows of 1500-2000 cfs, and five produced peak flows of less than 100 cfs. There were 7 rainfall events (3-day) that produced 4-5 inches of rainfall. Two of these produced peak flows of 1000-2000 cfs and the other five produced flows of less than about 200 cfs.

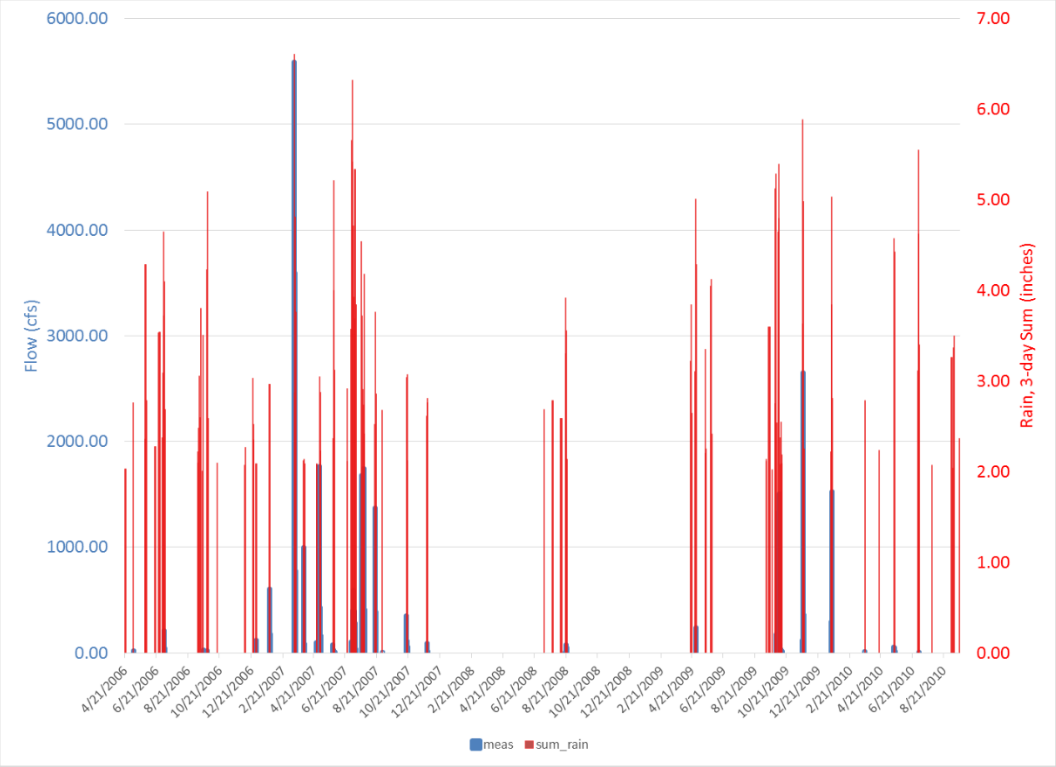


Figure 8.10 Daily flow (cfs) at Gauge 5 (Runge) and rainfall events (3-day cumulative) in excess of two inches in the Ecleto Watershed (average of Nixon, Runge, and Stockdale).

Regardless of what is controlling the actual amount of runoff in the Ecleto Watershed, the EDYS simulations are underestimating the amount. Further investigation of possible factors and additional calibrations for sandy soils will be conducted. Once these are completed, the results can be incorporated into the EDYS algorithms. One area of productive investigation may be to better understand the relationship between cumulative rainfall and lag-time for an associated increase in flow rate at Gauge 5. For example, Ockerman (2002) found that a 6.1-inch 4-day rain event produced 1.1 inches of runoff on a loamy sand. After about 6 months of relatively dry conditions, a 4.7-inch 1-day rain produced 0.1 inch of runoff. This would tend to support the concept of a dry soil storing a larger portion of the rainfall. A 7.5-inch 4-day rain event a year later produced 0.9 inch of runoff. But it was followed in six weeks by a 4.2-inch 2-day event that produced only 0.2 inch of runoff. Although the 4.2-inch event, following a wet period, produced more runoff than a 4.7-inch event following a dry period, the 4.7-inch event occurred in one day compared to two days for the 4.2-inch event.

9.0 SCENARIOS

A scenario in EDYS consists of a specific simulation run. Each scenario is defined by a choice of inputs that can include any combination of precipitation, stressor, management, and time factors. These combinations can be applied across the entire spatial footprint or can be localized. Ten scenarios were defined as examples to be included in this report. A 25-year simulation period was used for each of the 10 scenarios.

1. Baseline. No changes in land management options; daily precipitation data from 1925-1949 were used as most indicative of long-term average conditions (1885-2013 mean for Runge = 29.45 inches; 1925-1949 mean for Runge = 29.47 inches).

2. Dry Cycle. No changes in land management options; daily precipitation data from 1893-1917 used; 1893-1917 were the driest 25 consecutive years on record for Runge (annual mean = 26.38 inches = 0.896 of long-term mean).

3. Wet Cycle. No changes in land management options; daily precipitation data from 1957-1981 used; 1957-1981 were the wettest 25 consecutive years on record for Runge (annual mean = 33.53 inches = 1.139 of long-term mean).

4. Brush management, average rainfall. 90% of woody species (pecan and live oak excluded) aboveground biomass and 50% of herbaceous species aboveground biomass removed (root plowing) on all non-urban areas with 50% or more woody plant cover, treatment in Year 1; average rainfall pattern (1925-1949).

5. Brush management, dry period. 90% of woody species (pecan and live oak excluded) aboveground biomass and 50% of herbaceous aboveground biomass removed (root plowing) on all non-urban areas with 50% or more woody plant cover, treatment in Year 1; dry rainfall cycle (1893-1917).

6. Brush management with re-treatment, average rainfall. 90% of woody species (pecan and live oak excluded) aboveground biomass and 50% of herbaceous species aboveground biomass removed (root plowing) on all non-urban areas with 50% or more woody plant cover, treatment in Year 1 and re-treatment in Year 10; average rainfall pattern (1925-1949).

7. Decrease in cultivated land. 50% of current cultivated land changed to improved pasture; average rainfall pattern (1925-1949).

8. Increase in cultivated land. 25% increase in acreage of cultivated land; native vegetation adjacent to current cultivated land changed to cultivation; average rainfall pattern (1925-1949).

9. Urban footprint increased at 1% per year. Acreage of rural buildings plus mineral developments increased at 1% per year; average rainfall pattern (1925-1949).

10. Urban footprint increased at 2% per year. Acreage of rural buildings plus mineral developments increased at 2% per year; average rainfall pattern (1925-1949).

9.1 Vegetation

9.1.1 Baseline

Under baseline conditions (average rainfall over 25 years, moderate stocking rate of cattle), woody species increased on the clay loam and lakebed types and decreased on the sandy loam, gravel ridge, and pasture types (Tables 9.1 and 9.2). Except for the pasture type, woody plant cover averaged 10-25% or more at the beginning of the simulations for the types listed in Tables 9.1 and 9.2. The clay loam type is typical of much of the area of Karnes County and the southeastern portion of Wilson County. It is a mesquite-granjeno shrubland with the openings supporting a silver bluestem-trichloris-threeawn grassland. At the end of the 25-year simulation, there was an increase in mesquite, granjeno, prickly pear, and especially whitebrush. Overall, woody plant biomass almost tripled on this type during the 25 years. This would likely have occurred as both an increase in shrub density in the initial stands of shrubs and an increase in area covered by shrubs. Grasses increased by about 40% during the 25 years, with midgrasses doubling and shortgrasses decreasing. Most of the increase in midgrasses occurred as increases in silver bluestem, trichloris, and sideoats.

Table 9.1 Aboveground biomass (g/m^2), by lifeform and major species, in six plot types[1] at the end of growing season in the first (01) and last (25) years of a 25-year simulation under the baseline scenario, Karnes County EDYS model.

Lifeform or Species	Sandy Loam		Clay Loam		Bottomland		Gravel Ridge		Lakebed		Pasture	
	01	25	01	25	01	25	01	25	01	25	01	25
Trees	1670	1557	351	356	1217	976	90	131	1800	1388	89	71
Shrubs	321	217	405	1789	250	154	708	267	390	1091	---	---
Midgrasses	35	315	62	148	70	408	19	0	2	6	---	---
Shortgrasses	86	199	51	13	119	208	62	0	51	6	345	674
Grass-likes	---	---	---	---	---	---	---	---	38	103	---	---
Forbs	19	112	38	3	41	1	17	548	21	1	12	2
Total aboveground	2131	2400	907	2309	1697	1747	896	946	2302	2595	446	747
Litter	132	79	124	80	173	83	92	62	103	84	81	75
Huisache	---	---	22	21	27	23	---	---	577	537	27	22
Pecan	---	---	---	---	227	159	---	---	---	---	---	---
Sugar hackberry	---	---	---	---	232	157	---	---	1223	852	---	---
Texas persimmon	---	---	20	14	16	11	20	1	---	---	---	---
Mesquite	244	188	309	321	241	238	70	130	---	---	62	49
Live oak	1426	1369	---	---	473	388	---	---	---	---	---	---
Guajillo	---	---	---	---	---	---	213	72	---	---	---	---
Blackbrush	90	37	31	14	80	35	445	173	---	---	---	---
Whitebrush	---	---	92	1396	18	11	---	---	---	---	---	---
Prairie baccharis	---	---	9	1	9	2	---	---	294	1081	---	---
Granjeno	134	110	176	219	105	66	---	---	---	---	---	---
Rattlepod	---	---	---	---	---	---	---	---	95	10	---	---
Mustang grape	---	---	---	---	29	35	---	---	---	---	---	---
Prickly pear	97	70	96	159	9	5	50	21	---	---	---	---

Table 9.1 (Cont.)

Lifeform or Species	Sandy Loam		Clay Loam		Bottomland		Gravel Ridge		Lakebed		Pasture	
	01	25	01	25	01	25	01	25	01	25	01	25
Big bluestem	---	---	---	---	*	3	---	---	---	---	---	---
Silver bluestem	13	78	35	63	11	5	17	0	---	---	---	---
Sideoats grama	2	44	6	38	---	---	1	0	---	---	---	---
Trichloris	9	96	16	36	9	2	---	---	---	---	---	---
Arizona cottontop	1	*	2	*	---	---	1	0	---	---	---	---
Virginia wildrye	---	---	---	---	2	*	---	---	---	---	---	---
Switchgrass	---	---	---	---	2	1	---	---	---	---	---	---
Little bluestem	3	95	2	11	10	104	---	---	---	---	---	---
Johnsongrass	---	---	---	---	36	293	---	---	2	6	---	---
Tall dropseed	7	2	1	*	---	---	---	---	---	---	---	---
Purple threeawn	13	1	16	1	18	*	16	0	---	---	---	---
KR bluestem	---	---	---	---	---	---	---	---	---	---	31	371
Hairy grama	13	*	6	*	---	---	27	0	---	---	---	---
Buffalograss	22	194	13	9	62	10	---	---	8	*	---	---
Sandbur	6	0	---	---	---	---	---	---	---	---	---	---
Hooded windmill	9	1	5	1	3	*	5	0	---	---	---	---
Bermudagrass	---	---	---	---	---	---	---	---	26	4	314	303
Vine-mesquite	---	---	*	*	7	126	---	---	1	1	---	---
Thin paspalum	15	2	---	---	6	*	---	---	---	---	---	---
Knotroot bristle	---	---	---	---	17	72	---	---	15	1	---	---
Texas bristlegrass	---	---	1	0	5	0	9	0	---	---	---	---
Texas wintergrass	7	*	10	1	---	---	4	---	---	---	---	---
Littletooth sedge	---	---	---	---	---	---	---	---	5	*	---	---
Flatsedge	---	---	---	---	---	---	---	---	28	100	---	---
Fimbry	---	---	---	---	---	---	---	---	1	*	---	---
Cattail	---	---	---	---	---	---	---	---	3	3	---	---
Ragweed	12	112	17	2	7	*	12	548	8	1	12	2
Old-mans beard	---	---	2	*	9	*	---	---	---	---	---	---
Bundleflower	1	*	3	1	4	1	---	---	---	---	---	---
Frogfruit	---	---	1	*	2	*	---	---	10	*	---	---
Prairie coneflower	---	---	1	0	*	0	*	0	---	---	---	---
Snoutbean	1	0	3	0	*	0	---	---	---	---	---	---
Ruellia	---	---	2	0	13	0	1	0	---	---	---	---
Bush sunflower	3	0	2	0	3	0	---	---	---	---	---	---
Texas verbena	---	---	1	0	---	---	1	0	---	---	---	---
Orange zexmenia	---	---	3	0	---	---	1	0	---	---	---	---
Giant ragweed	---	---	---	---	1	0	---	---	2	0	---	---
Broomweed	1	0	1	0	---	---	2	0	---	---	---	---
Partridge pea	*	0	---	---	---	---	---	---	---	---	---	---
Texas doveweed	*	0	---	---	*	0	---	---	---	---	---	---
Sunflower	*	0	---	---	*	0	---	---	1	0	---	---
Dogweed	---	---	---	---	---	---	---	---	---	---	---	---

[1] Woody plant coverage in Year 1 was 10-25% for tight sandy loam, clay loam, clay bottomland, and gravel ridge types, 25-50% for lakebed, and 0-1% for pasture.

Trace amount (<0.5 g/m^2) is indicated by an asterick (*).

Dashes (---) indicate that the species does not occur in the respective type.

Table 9.2 Aboveground biomass (g/m^2), by lifeform and major species, in five plot types[1] at the end of growing season in the first (01) and last (25) years of a 25-year simulation under the baseline scenario, Wilson County EDYS model.

Lifeform or Species	Sandy Loam		Clay Loam		Bottomland		Gravel Ridge		Pasture	
	01	25	01	25	01	25	01	25	01	25
Trees	1672	1422	352	315	2584	1886	4015	3122	646	542
Shrubs	313	214	412	1175	535	1500	387	268	---	---
Midgrasses	36	402	70	298	64	120	54	560	---	---
Shortgrasses	81	10	59	51	103	20	36	1	337	738
Forbs	14	297	36	2	36	1	20	91	13	6
Total aboveground	2116	2345	929	1841	3322	3527	4512	4042	996	1286
Huisache	---	---	22	20	58	53	---	---	164	141
Pecan	---	---	---	---	482	337	---	---	---	---
Sugar hackberry	---	---	---	---	493	333	---	---	---	---
Texas persimmon	---	---	20	14	34	23	---	---	---	---
Mesquite	243	266	310	281	515	387	---	---	482	401
Post oak	---	---	---	---	---	---	4015	3122	---	---
Live oak	1429	1156	---	---	1002	753	---	---	---	---
Blackbrush	80	35	32	14	169	75	171	75	---	---
Whitebrush	---	---	95	862	39	430	---	---	---	---
Prairie baccharis	---	---	9	1	20	3	---	---	---	---
Granjeno	136	105	178	169	225	146	---	---	---	---
Mustang grape	---	---	---	---	62	835	---	---	---	---
Prickly pear	97	74	97	129	20	11	216	193	---	---
Big bluestem	---	---	---	---	*	1	1	1	---	---
Silver bluestem	13	100	37	102	9	3	17	2	---	---
Sideoats grama	2	67	7	101	---	---	17	314	---	---
Trichloris	10	97	21	80	8	2	5	1	---	---
Arizona cottontop	1	*	2	*	---	---	3	*	---	---
Virginia wildrye	---	---	---	---	2	*	---	---	---	---
Switchgrass	---	---	---	---	2	*	---	---	---	---
Little bluestem	2	136	2	15	10	19	11	242	---	---
Johnsongrass	---	---	---	---	33	95	---	---	---	---
Tall dropseed	8	2	1	*	---	---	---	---	---	---
Purple threeawn	13	*	18	3	15	*	12	*	---	---
King Ranch bluestem	---	---	---	---	---	---	---	---	36	464
Hairy grama	12	*	6	*	---	---	---	---	---	---
Buffalograss	22	7	16	19	54	8	11	*	---	---
Sandbur	4	0	---	---	---	---	---	---	---	---
Hooded windmillgrass	8	1	4	*	3	*	9	1	---	---
Bermudagrass	---	---	---	---	---	---	---	---	301	274
Vine-mesquite	---	---	*	*	6	1	---	---	---	---
Thin paspalum	14	2	---	---	5	*	4	*	---	---
Knotroot bristlegrass	---	---	---	---	16	11	---	---	---	---
Texas bristlegrass	---	---	1	*	4	0	---	---	---	---
Texas wintergrass	8	*	14	29	---	---	---	---	---	---
Ragweed	11	297	17	1	6	*	18	91	13	6
Old-mans beard	---	---	2	*	9	*	---	---	---	---
Bundleflower	1	*	3	1	4	1	---	---	---	---
Frogfruit	---	---	1	*	1	*	---	---	---	---
Prairie coneflower	---	---	1	0	*	0	---	---	---	---
Snoutbean	2	0	4	0	*	0	1	0	---	---
Ruellia	---	---	2	0	12	0	---	---	---	---
Bush sunflower	---	---	1	0	2	0	---	---	---	---
Texas verbena	---	---	1	0	---	---	---	---	---	---
Organge zexmenia	---	---	3	0	---	---	1	0	---	---
Giant ragweed	---	---	---	---	2	0	---	---	---	---
Broomweed	*	0	1	0	---	---	---	---	---	---

[1] Woody plant coverage in Year 1 was 0-1% for pasture and 10-25% for the other types.

Trace amount (<0.5 g/m^2) is indicated by an asterick (*). Dashes (---) indicate that the species does not occur in the respective type.

Tree and shrub biomass decreased on the bottomland type in Karnes County (Table 9.1) and tree biomass decreased on this type in Wilson County (Table 9.2). However, shrub biomass increased substantially on this type in Wilson County. Whitebrush and mustang grape were the two species providing most of the increase. The ten-fold increase in mustang grape during the 25 years of the simulation was a likely reason for the decrease in tree biomass in the bottomland type. Dense stands of grape vines draped over the trees can substantially reduce leaf biomass of the trees.

The increases in woody plants on the lakebed (wetland) type was the result of an increase in baccharis. Herbaceous biomass remained about the same at the end of 25 years as it had at the beginning, but species composition changed substantially. There were increases in flatsedge and Johnsongrass and decreases in the shortgrasses, sedges, and forbs (Table 9.1).

The sandy loam type is an abundant type in the northern portions of both counties. Woody plant biomass decreased on this type by about 10% over the 25 years. Grass biomass increased substantially, with most of the increase coming from all four of the major midgrasses (silver bluestem, sideoats, trichloris, and little bluestem). Buffalograss was the only shortgrass to increase on this type. There was also a large increase in ragweed.

The gravel ridge type is a shrubland dominated by blackbrush and guajillo. These are dry sites with shallow soils. After 25 years, shrub biomass decreased for both of the dominant shrubs, but increased for mesquite and there was a large increase in ragweed. These responses are likely the result of the way cattle grazing was modeled in these scenarios. The stocking rate used was not unreasonable (30 ac/AU; Table 7.2) for this type. However, in these scenarios the cattle were not rotated out of this type. Instead they grazed it year-round at this stocking rate. This resulted in the cattle grazing out the grasses and consuming guajillo and some blackbrush, especially during the winter. This confined continuous grazing on the type allowed the unpalatable ragweed to increase more than it would under actual grazing management. Under most ranching operations, cattle are allowed to utilize multiple vegetation types, moving back and forth as forage conditions change. The shallow soil types, such as the gravel ridge type, are usually grazed by cattle more during the winter and during drought periods, preferring the more productive clay loam, sandy loam, and bottomland types when forage is available there.

9.1.2 Dry and Wet Cycles

The 25-year dry simulation cycle had an annual rainfall of 26.4 inches, or 10.4% less than the baseline (average) cycle. This reduction in annual rainfall resulted in lower total annual production and changes in species composition on all types. In Karnes County (Table 9.3), overall aboveground biomass decreased by 10% on the sandy loam and pasture types, 16% on bottomland, 18% on clay loam, and 28% on the gravel ridge type. Compared to the average rainfall scenario, mesquite increased on the sandy loam type and decreased on the clay loam type, while most other woody species decreased on most types. Grass production decreased on all types except the clay loam type where it increased by 17%, most likely because of a 22% decrease in whitebrush. Sideoats and trichloris were the major grass species that increased on the clay loam site under the dry scenario. On the bottomland type, mesquite increased slightly and there was an increase in knotroot bristlegrass, probably because of a major decline in vine-mesquite. Johnsongrass declined but at a lesser proportion than grasses overall. Both bermudagrass and King Ranch bluestem decreased under the dry scenario, but bermudagrass declined more proportionally, suggesting that during drier conditions King Ranch bluestem will increase in dominance.

Table 9.3 Aboveground biomass (g/m^2), by lifeform and major species, in five plot types[1] at the end of 25 years under dry (D), average (B), and wet (W) rainfall scenarios, Karnes County EDYS model.

Life form or Species	Sandy Loam			Clay Loam			Bottomland			Gravel Ridge			Pasture		
	D	B	W	D	B	W	D	B	W	D	B	W	D	B	W
Trees	1535	1557	1475	330	356	312	967	976	932	131	131	150	70	71	68
Shrubs	199	217	219	1370	1789	393	160	154	150	264	267	292	---	---	---
Midgrasses	231	315	505	168	148	605	243	408	211	0	0	52	---	---	---
Shortgrasses	15	199	314	21	13	176	88	208	399	0	0	71	534	674	874
Forbs	208	112	1	2	3	1	1	1	1	392	548	527	1	2	1
Total	2188	2400	2514	1891	2309	1487	1459	1747	1693	787	946	1092	605	747	943
Huisache	---	---	---	20	21	19	24	23	22	---	---	---	22	22	21
Pecan	---	---	---	---	---	---	159	159	159	---	---	---	---	---	---
Sugar hackberry	---	---	---	---	---	---	158	157	157	---	---	---	---	---	---
Texas persimmon	---	---	---	14	14	14	11	11	11	1	1	13	---	---	---
Mesquite	246	188	182	296	321	279	230	238	207	130	130	137	48	49	47
Live oak	1289	1369	1293	---	---	---	385	388	376	---	---	---	---	---	---
Guajillo	---	---	---	---	---	---	---	---	---	72	72	76	---	---	---
Blackbrush	37	37	39	14	14	14	35	35	35	174	173	186	---	---	---
Whitebrush	---	---	---	1090	1396	184	17	11	12	---	---	---	---	---	---
Prairie baccharis	---	---	---	1	1	2	2	2	2	---	---	---	---	---	---
Granjeno	106	110	126	176	219	134	67	66	62	---	---	---	---	---	---
Mustang grape	---	---	---	---	---	---	34	35	34	---	---	---	---	---	---
Prickly pear	56	70	53	89	159	59	5	5	5	18	21	30	---	---	---
Big bluestem	---	---	---	---	---	---	1	3	4	---	---	---	---	---	---
Silve rbluestem	52	78	86	63	63	156	4	5	9	0	0	47	---	---	---
Sideoats grama	25	44	51	44	38	190	---	---	---	0	0	5	---	---	---
Trichloris	70	96	262	53	36	246	2	2	3	---	---	---	---	---	---
Switchgrass	---	---	---	---	---	---	1	1	2	---	---	---	---	---	---
Little bluestem	82	95	104	8	11	13	30	104	68	---	---	---	---	---	---
Johnsongrass	---	---	---	---	---	---	205	293	125	---	---	---	---	---	---
Tall dropseed	2	2	2	*	*	*	---	---	---	---	---	---	---	---	---
Purple threeawn	*	1	78	3	1	5	*	*	*	0	0	*	---	---	---
KR bluestem	---	---	---	---	---	---	---	---	---	---	---	---	330	371	539
Hairy grama	*	*	*	*	*	*	---	---	---	0	0	1	---	---	---
Buffalograss	11	194	230	15	9	148	7	10	177	---	---	---	---	---	---
Hooded windmill	1	1	1	*	1	*	*	*	*	0	0	1	---	---	---
Bermudagrass	---	---	---	---	---	---	---	---	---	---	---	---	204	303	335
Vine-mesquite	---	---	---	*	*	*	*	126	157	---	---	---	---	---	---
Thin paspalum	2	2	4	---	---	---	*	*	*	---	---	---	---	---	---
Knotroot bristle	---	---	---	---	---	---	81	72	65	---	---	---	---	---	---
Texas bristlegrass	---	---	---	0	0	0	0	0	*	0	0	*	---	---	---
Texas wintergrass	1	*	1	3	1	23	---	---	---	0	0	69	---	---	---
Ragweed	208	112	1	1	2	*	*	*	*	392	548	527	1	2	1
Bundleflower	*	*	*	1	1	1	1	1	1	---	---	---	---	---	---
Frogfruit	---	---	---	*	*	*	*	*	*	---	---	---	---	---	---

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[1] Woody plant coverage in Year 1 was 0-1% for pasture and 10-25% for the other types.
Trace amount (< 0.5 g/m^2) is indicated by an asterick (*).
Dashes (---) indicate that the species does not occur in the respective type.

Under the wet scenario (13.8% increase in rainfall over baseline), total aboveground production increased over baseline in three of the five types but decreased in two (Table 9.3). Aboveground production increased 4.8% over baseline in the sandy loam type and by 26.2% in the improved pastures. In both types, there was a substantial increase in grasses but this increase was somewhat offset in the sandy loam type by a decrease in forbs. On the sandy loam type, the grasses were more competitive against the forbs under the higher rainfall regime and the relative impact of livestock grazing on grasses was less. Total aboveground biomass also increased on the gravel ridge site (15.4% over baseline), but changes in species composition were also manifested on this type. All woody species increased, but the increase in Texas persimmon was particularly apparent as were increases in grasses, especially silver bluestem, sideoats, and Texas wintergrass. Under the dry and baseline scenarios, there was very little grass biomass present on this type after 25 years. Under the wet scenario, grass biomass totaled 123 g/m^2. This increase can be attributed to the higher rainfall offsetting some of the impact of livestock grazing.

Aboveground biomass decreased on two types under the wet scenario (Table 9.3). On the clay loam site the decrease was the result of a major decrease in whitebrush, apparently the result of competition from grasses. Grass biomass increased by over 600 g/m^2 and whitebrush decreased by about twice that amount. Apparently the livestock stocking rates used for this type in the simulations were too high under the baseline regime (160 g/m^2 of grasses remaining at the end of the growing season; Table 9.3). Whitebrush was able to take advantage of this condition to increase its biomass. Conversely, under the wet scenario the stocking rate became relatively light to moderate and the grasses increased in vigor and productivity, thereby limiting the increase in whitebrush.

Mesquite also decreased on the clay loam site under the wet regime. The initial aboveground biomass for mesquite on this type was 309 g/m^2 (Table 9.1). This decreased to 279 g/m^2 at the end of 25 years (Table 9.3), or a decrease of 10%. Mesquite canopy cover in the mesquite-mixed grass community on the Welder Wildlife Refuge decreased by 11% during a 15-year wet period (1958-73), based on relative cover of woody species (Drawe et al. 1978). The equivalent decrease in relative cover of mesquite in the EDYS wet-regime scenario was 4%.

The other type to have decreased production under the wet scenario was the bottomland type. On this type, there was an increase in shortgrasses and a decrease in mesquite and Johnsongrass.

Similar responses to the dry regime occurred in Wilson County (Table 9.4) as occurred in Karnes County. Aboveground production decreased on all types by an average of 14.5%. Average annual rainfall in the dry scenario was 10.5% below that of baseline. The proportionately greater decrease in plant biomass was likely the result of differential responses by plant species to drought and the impact of both livestock and wildlife herbivory. Livestock stocking rate was not reduced to account for drought conditions, therefore the impact from grazing was proportionately heavier. The greatest proportional decrease (21.5%) occurred on the improved pastures. This was the result of most of the plant community consisting of grasses and this type had the highest stocking rate of any of the types (Table 7.2). The effect of drought was least on the gravel ridge type, where biomass decreased only 6.5% compared to baseline. Plant species characteristic of the gravel ridge type are better adapted to drier conditions than those of other types and therefore were better able to tolerate the drought conditions. Aboveground biomass decreased more (18.8%) on the sandy loam type than on the clay loam type (14.9%).

Table 9.4 Aboveground biomass (g/m^2), by lifeform and major species, in five plot types[1] at the end of 25 years under dry (D), average (B), and wet (W) rainfall scenarios, Wilson County EDYS model.

Life form or Species	Sandy Loam			Clay Loam			Bottomland			Gravel Ridge			Pasture		
	D	B	W	D	B	W	D	B	W	D	B	W	D	B	W
Trees	1345	1422	1301	293	315	285	1862	1886	1867	3137	3122	3100	500	542	496
Shrubs	212	214	191	1143	1175	557	1196	1500	889	248	268	225	---	---	---
Midgrasses	137	402	343	110	298	437	63	120	293	302	560	813	---	---	---
Shortgrasses	9	10	387	19	51	131	17	20	85	*	1	1	388	738	785
Forbs	200	297	*	2	2	1	1	1	1	91	91	13	1	6	1
Total	1903	2345	2222	1567	1841	1411	3139	3527	3135	3778	4042	4152	889	1286	1282
Huisache	---	---	---	20	20	19	51	53	50	---	---	---	134	141	133
Pecan	---	---	---	---	---	---	336	337	336	---	---	---	---	---	---
Sugar hackberry	---	---	---	---	---	---	332	333	333	---	---	---	---	---	---
Texas persimmon	---	---	---	14	14	14	23	23	23	---	---	---	---	---	---
Mesquite	240	266	204	259	281	252	371	387	370	---	---	---	366	401	363
Post oak	---	---	---	---	---	---	---	---	---	3137	3122	3100	---	---	---
Live oak	1105	1156	1097	---	---	---	749	753	755	---	---	---	---	---	---
Blackbrush	35	35	35	14	14	14	75	75	75	75	75	75	---	---	---
Whitebrush	---	---	---	845	862	330	335	430	248	---	---	---	---	---	---
Prairie baccharis	---	---	---	2	1	2	3	3	3	---	---	---	---	---	---
Granjeno	101	105	98	151	169	136	129	146	137	---	---	---	---	---	---
Mustang grape	---	---	---	---	---	---	643	835	416	---	---	---	---	---	---
Prickly pear	76	74	58	131	129	75	11	11	10	173	193	150	---	---	---
Big bluestem	---	---	---	---	---	---	1	1	4	*	1	1	---	---	---
Silver bluestem	23	100	54	44	102	134	3	3	8	*	2	3	---	---	---
Sideoats grama	14	67	39	28	101	113	---	---	---	133	314	398	---	---	---
Trichloris	44	97	209	31	80	177	1	2	2	*	1	1	---	---	---
Switchgrass	---	---	---	---	---	---	*	*	1	---	---	---	---	---	---
Little bluestem	54	136	39	7	15	13	16	19	53	169	242	410	---	---	---
Johnsongrass	---	---	---	---	---	---	42	95	225	---	---	---	---	---	---
Tall dropseed	2	2	2	*	*	*	---	---	---	---	---	---	---	---	---
Purple threeawn	*	*	147	2	3	15	*	*	*	*	*	*	---	---	---
KR bluestem	---	---	---	---	---	---	---	---	---	---	---	---	225	464	547
Buffalograss	5	7	232	14	19	90	7	8	16	*	*	*	---	---	---
Hooded windmill	1	1	2	*	*	*	*	*	*	*	*	1	---	---	---
Bermudagrass	---	---	---	---	---	---	---	---	---	---	---	---	163	274	238
Vine-mesquite	---	---	---	*	*	*	*	1	1	---	---	---	---	---	---
Thin paspalum	2	2	6	---	---	---	*	*	*	*	*	*	---	---	---
Knotroot bristle	---	---	---	---	---	---	10	11	68	---	---	---	---	---	---
Texas bristlegrass	---	---	---	0	*	0	0	0	*	---	---	---	---	---	---
Texas wintergrass	1	*	*	3	29	26	---	---	---	---	---	---	---	---	---
Ragweed	200	297	*	1	1	*	*	*	*	91	91	13	1	6	1
Old-mans beard	---	---	---	*	*	*	*	*	*	---	---	---	---	---	---
Bundleflower	*	*	*	1	1	1	1	1	1	---	---	---	---	---	---
Frogfruit	---	---	---	*	*	*	*	*	*	---	---	---	---	---	---

[1] Woody plant coverage in Year 1 was 0-1% on the pasture type and 10-25% on the other types.
Trace amount (< 0.5 m^2) is indicated by an asterick (*).
Dashes (---) indicate that the species does not occur in the respective type.

Responses to the wet cycle in Wilson County were mixed (Table 9.4). Aboveground biomass increased on the gravel ridge type because of an increase in grasses. This is the expected response. There was little overall increase in biomass on the improved pasture type. Biomass of

King Ranch bluestem increased, but this increase was offset by a decrease in bermudagrass and mesquite. The other three types had decreases in overall aboveground biomass in the wet scenario. In each case, there was a decrease in biomass of woody species and an increase in biomass of grasses. On the sandy loam type, the primary decrease was in ragweed instead of woody species. The higher rainfall increased the amount of grasses present and competition from the grasses decreased the amount of ragweed. Under baseline and dry scenarios, livestock grazing also favored an increase in ragweed and this factor was largely eliminated under the higher rainfall of the wet scenario. The decrease in biomass on the clay loam type was largely the result of a decrease in whitebrush, apparently caused by increased competition from grasses. This is similar to what occurred in the Karnes County simulations. There was very little change in tree biomass on the bottomland site under the wet scenario but there was a decrease in whitebrush and mustang grape and an increase in Johnsongrass and, proportionately, increases in the native bluestems.

9.1.3 Brush Management

Three brush management scenarios were simulated for both counties. In each case, the basic brush treatment was the same. Ninety percent of the aboveground woody biomass (excluding pecan and live oak) and 50% of the aboveground herbaceous biomass was removed from all non-urban areas that initially had 50% or more woody plant cover. Brush control occurred in March of Year 1. In the first brush management scenario, the average (baseline) rainfall regime was used in the simulation. In the second scenario, the dry rainfall regime was used. In the third brush management scenario, the average rainfall regime was used but brush re-treatment was simulated in Year 10. Re-treatment consisted of the same initial brush control treatment (90% woody, 50% herbaceous removal) applied, but in Year 15.

The brush control (root-plowing) was applied to those areas with the most dense stands of woody species. In actual practice, this probably would not be the case on a county-wide basis. Different landowners throughout the county would make brush control decisions based on conditions on their particular land and density of brush treated would likely vary across the county. However, simulating treatment of the most dense brush throughout the county should provide an estimate of the maximum effect that brush control might have on ecohydrology, given the specific amount of area treated. In the case of Karnes County, 22% of the area in the county was treated and 30% of the area of Wilson County was treated.

Each of the affected vegetation-soil-precipitation zone cell types responded somewhat differently to the brush management scenarios. The ecohydrological responses are integrations of the vegetation and land-use mosaics over each watershed. However, reporting vegetation responses for each vegetation type would be a substantial effort. There were 227 cell types that received brush control (50-75% intial woody plant cover) in Karnes County and 160 in Wilson County. Instead, results of vegetation responses on four major vegetation types are presented to illustrate the effects of the brush management scenarios on vegetation (Tables 9.5 and 9.6).

Table 9.5 Aboveground biomass (g/m^2), by lifeform and major species, in four plot types[1] at the end of 25 years under five brush management scenarios[2], Karnes County EDYS model.

Lifeform/Species	**Sandy Loam**					**Clay Loam**					**Bottomland**					**Gravel Ridge**				
	NB	**SB**	**RB**	**ND**	**SD**	**NB**	**SB**	**RB**	**ND**	**SD**	**NB**	**SB**	**RB**	**ND**	**SD**	**NB**	**SB**	**RB**	**ND**	**SD**
Trees	5826	5415	5435	5250	4503	1044	173	18	981	127	3214	2350	2272	3130	2180	284	47	5	276	37
Shrubs	1545	212	99	1465	221	3710	4147	2797	3032	2571	2347	845	37	2320	54	2892	2809	2172	2658	2494
Midgrasses	3	0	0	4	0	0	0	0	0	0	20	268	476	15	418	0	0	0	0	0
Shortgrasses	1	0	0	2	0	0	0	0	0	0	4	1	1	5	1	0	0	0	0	0
Forbs	72	89	50	200	315	6	6	3	4	32	28	1	*	1	*	*	*	*	*	*
Total	7447	5716	5584	6921	5039	4760	4326	2818	4017	2730	5613	3465	2786	5471	2654	3176	2856	2177	2934	2532
Huisache	---	---	---	---	---	68	7	1	66	7	87	10	1	86	9	---	---	---	---	---
Pecan	---	---	---	---	---	---	---	---	---	---	558	560	562	556	562	---	---	---	---	---
Sugar hackberry	---	---	---	---	---	---	---	---	---	---	550	56	6	549	55	---	---	---	---	---
Texas persimmon	---	---	---	---	---	47	5	*	47	5	38	4	*	38	4	47	4	*	47	4
Mesquite	662	69	7	750	65	929	161	17	868	115	653	70	7	628	63	237	43	4	229	32
Live oak	5164	5346	5428	4500	4438	---	---	---	---	---	1328	1650	1696	1273	1487	---	---	---	---	---
Guajillo	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	272	33	3	270	28
Blackbrush	124	13	1	124	12	50	5	1	50	5	124	13	1	124	12	1760	377	35	1544	68
Whitebrush	---	---	---	---	---	1844	1704	1376	1458	1391	499	2	*	553	2	---	---	---	---	---
Granjeno	326	27	3	363	24	483	176	61	415	127	252	27	3	224	19	---	---	---	---	---
Mustang grape	---	---	---	---	---	---	---	---	---	---	1448	791	27	1397	9	---	---	---	---	---
Prickly pear	1095	172	95	978	185	1327	2261	1359	1084	1047	19	12	6	17	11	860	2399	2134	844	2398
Big bluestem	---	---	---	---	---	---	---	---	---	---	*	*	*	*	*	---	---	---	---	---
Silver bluestem	1	0	0	1	0	0	0	0	0	0	*	1	*	*	1	0	0	0	0	0
Sideoats grama	*	0	0	*	0	0	0	0	0	0	---	---	---	---	---	0	0	0	0	0
Trichloris	1	0	0	1	0	0	0	0	0	0	*	1	*	*	1	---	---	---	---	---
Little bluestem	*	0	0	*	0	0	0	0	0	0	2	1	*	1	1	---	---	---	---	---
Johnsongrass	---	---	---	---	---	---	---	---	---	---	17	265	474	13	416	---	---	---	---	---
Tall dropseed	1	0	0	1	0	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---
Purple threeawn	*	0	0	*	0	0	0	0	0	0	*	*	*	*	*	0	0	0	0	0
Buffalograss	*	0	0	*	0	0	0	0	0	0	*	*	*	*	*	---	---	---	---	---
Hooded windmill	1	0	0	1	0	0	0	0	0	0	*	*	*	*	*	0	0	0	0	0
Vine-mesquite	---	---	---	---	---	0	0	0	0	0	*	*	*	*	*	---	---	---	---	---
Thin paspalum	*	0	0	*	0	---	---	---	---	---	*	*	*	*	*	---	---	---	---	---
Knotroo tbristle	---	---	---	---	---	---	---	---	---	---	3	*	*	4	*	---	---	---	---	---
Texas wintergrass	*	0	0	*	0	0	0	0	0	0	---	---	---	---	---	0	0	0	0	0
Ragweed	72	89	50	200	315	*	1	*	*	*	*	*	*	*	*	*	*	*	*	*

[1] Woody plant coverage in Year 1 was 50-75%.

[2] NB = no brush control, average rainfall; SB = brush control in Year 1, average rainfall; RB = brush control in Year 1 and re-treated in Year 10, average rainfall; ND = no brush control, dry rainfall regime; SD = brush control in Year 1, dry regime.

Table 9.6 Aboveground biomass (g/m^2), by lifeform and major species, in four plot types[1] at the end of 25 years under five brush management scenarios[2], Wilson County EDYS model.

Lifeform/Species	**Sandy Loam**					**Clay Loam**					**Bottomland**					**Gravel Ridge**				
	NB	**SB**	**RB**	**ND**	**SD**	**NB**	**SB**	**RB**	**ND**	**SD**	**NB**	**SB**	**RB**	**ND**	**SD**	**NB**	**SB**	**RB**	**ND**	**SD**
Trees	4881	4374	4306	4662	4002	990	157	16	951	111	3103	1957	1870	3079	1975	5215	548	48	5220	523
Shrubs	2748	221	76	2202	270	3703	4044	2763	2892	2637	2349	2046	102	1851	63	385	212	54	249	55
Midgrasses	3	0	0	3	0	0	0	0	0	0	3	21	523	8	320	*	0	0	0	0
Shortgrasses	2	0	0	1	0	0	0	0	0	0	1	1	*	2	*	0	0	0	0	0
Forbs	137	593	591	114	318	5	4	3	3	20	2	3	*	1	1	554	568	555	349	379
Total	7771	5188	4973	6982	4590	4698	4205	2782	3846	2768	5458	4028	2495	4942	2359	6154	1328	656	5918	956
Huisace	---	---	---	---	---	67	7	1	65	7	89	9	1	86	9	---	---	---	---	---
Pecan	---	---	---	---	---	---	---	---	---	---	556	557	561	555	561	---	---	---	---	---
Sugar hackberry	---	---	---	---	---	---	---	---	---	---	549	56	6	548	56	---	---	---	---	---
Texas persimmon	---	---	---	---	---	47	5	*	47	5	38	4	*	38	4	---	---	---	---	---
Mesquite	825	69	7	780	65	876	145	15	839	99	632	75	7	616	77	---	---	---	---	---
Post oak	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	5215	548	48	5220	523
Live oak	4056	4305	4299	3882	3937	---	---	---	---	---	1239	1256	1295	1236	1268	---	---	---	---	---
Blackbrush	125	13	1	125	12	50	5	1	50	5	124	13	1	124	12	124	13	1	125	12
Whitebrush	---	---	---	---	---	1941	1783	1424	1346	1267	455	2	*	450	2	---	---	---	---	---
Granjeno	1352	28	3	817	25	467	146	36	399	98	212	20	2	197	21	---	---	---	---	---
Mustang grape	---	---	---	---	---	---	---	---	---	---	1535	1999	93	1058	14	---	---	---	---	---
Prickly pear	1271	180	72	1260	233	1237	2109	1302	1073	1266	18	11	6	17	13	261	199	53	224	43
Big bluestem	---	---	---	---	---	---	---	---	---	---	0	*	*	0	0	0	0	0	0	0
Silver bluestem	1	0	0	1	0	0	0	0	0	0	0	1	*	0	0	0	0	0	0	0
Sideoats grama	*	0	0	*	0	0	0	0	0	0	---	---	---	---	---	0	0	0	0	0
Trichloris	1	0	0	1	0	0	0	0	0	0	0	1	*	0	0	0	0	0	0	0
Little bluestem	*	0	O	*	0	0	0	0	0	0	0	1	*	*	1	*	0	0	0	0
Johnsongrass	---	---	---	---	---	---	---	---	---	---	3	19	523	8	320	---	---	---	---	---
Tall dropseed	1	0	0	1	0	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---
Purple threeawn	*	0	0	*	0	0	0	0	0	0	0	*	*	0	*	0	0	0	0	0
Buffalograss	*	0	0	*	0	0	0	0	0	0	0	*	*	0	0	0	0	0	0	0
Thin paspalum	*	0	0	*	0	---	---	---	---	---	0	*	*	0	0	0	0	0	0	0
Knotroot bristle	---	---	---	---	---	---	---	---	---	---	1	*	*	2	*	---	---	---	---	---
Texas wintergrass	*	0	0	*	0	0	0	0	0	0	---	---	---	---	---	---	---	---	---	---
Ragweed	137	593	591	113	318	*	1	*	*	*	*	*	*	*	*	554	568	555	349	379

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[1] Woody plant coverage in Year 1 was 50-75%.

[2] NB = no brush control, average rainfall; SB = brush control in Year 1, average rainfall; RB = brush control in Year 1 and re-treated in Year 10, average rainfall; ND = no brush control, dry rainfall regime; SD = brush control in Year 1, dry regime.

Under the baseline (average) rainfall regime, the single-treatment brush control scenario (SB) reduced total aboveground biomass at the end of 25 years by 10-78%, depending on vegetation type and county. There were 23-38% reductions on the tight sandy loam and bottomland types, with most of the reduction coming from decreased shrub biomass. On the sandy loam type, there were similar proportional reductions in mesquite and blackbrush, but proportionately greater reduction in granjeno and less for prickly pear. Live oak was not subjected to brush control and it increased by 3-4% in response to reduced competition. On the bottomland type, pecan and live oak were both protected and they both increased in biomass following brush control. Whitebrush was particularly reduced by the brush control and mustang grape was proportionately the least affected of the woody species.

Twenty-five years after brush control, the sandy loam types produced an average of 286 g/m^2 of biomass by woody species subjected to brush control (SB; Tables 9.5 and 9.6). This 25-year woody plant regrowth of 286 g/m^2 (12.4 g/m^2 per year) compares favorably with the 114 g/m^2 of regrowth seven years after bulldozing (16.3 g/m^2 per year) in a shrub-type live oak type on a sandy loam site in Victoria County (Bovey et al. 1972). Bulldozing is less extensive a brush control method than root-plowing because bulldozing causes minimum damage to the sub-surface plant material and Victoria County received more rainfall than Karnes and Wilson Counties. Therefore, the regrowth rate in Victoria County should be somewhat higher than in Karnes and Wilson Counties.

Herbaceous biomass was very low on these types initially, the result of the dense woody plant cover. Over the 25-year simulations, biomass of grasses decreased further because of continued grazing pressure. In the brush control options, grazing by livestock was eliminated for two years immediately following brush control. However, in most cases this was not sufficient to eliminate the grazing effect at the end of 25 years. The brush management scenarios did not include reseeding. Reseeding, followed by several years deferment of grazing, might result in an increase in grass biomass following brush control. Under the simulated scenarios, two herbaceous species increased following brush control. Ragweed increased on the sandy loam type and Johnsongrass increased substantially on the bottomland type. Both of these species are highly competitive under early seral conditions. Johnsongrass increased in the simulations as frequency of disturbance increased. Johnsongrass biomass averaged 18 g/m^2 on the bottomland type with no brush control, averaged 142 g/m^2 with a single root-plowing, and averaged 499 g/m^2 with two root-plowing treatments (Tables 9.5 and 9.6). Under the re-treatment scenario (RB), there was little other vegetation in the types other than an open overstory of live oak and pecan. These conditions, plus multiple root-plowing spreading the Johnsongrass rhizomes, would create an ideal site for a productive stand of Johnsongrass. Aboveground biomass production from improved pastures on these types of soils in the Coastal Bend are commonly on the order of 500-1100 g/m^2 (McCawley 1978; Kapinga 1982).

Total aboveground biomass also decreased following brush control on the clay loam type (Fig. 9.1), but the decrease primarily resulted from lower biomass of mesquite and granjeno (Fig. 9.2). Whitebrush decreased initially but then produced substantial regrowth, almost producing as much biomass at the end of the 25 years as was produced under the no brush control scenario. Prickly pear almost doubled in biomass following root-plowing. This is a common response of this species to root-plowing without effective raking following the brush treatment.

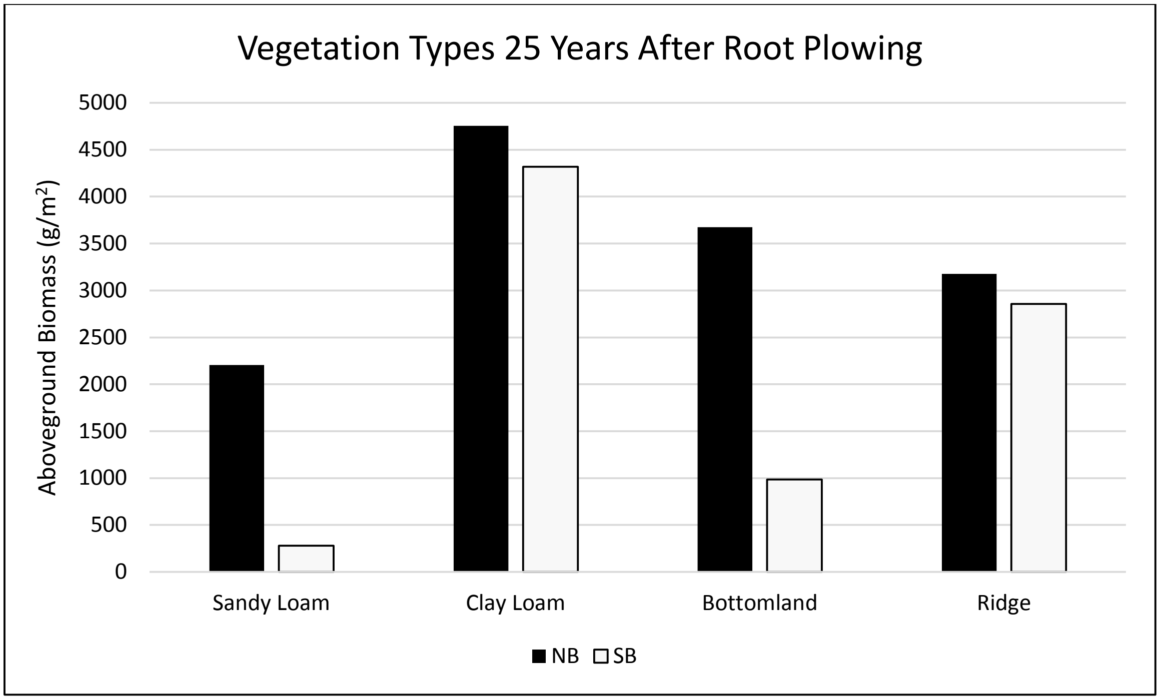

Figure 9.1 Aboveground biomass (g/m^2) of those woody species subjected to brush control on four vegetation types 25 years after root-plowing (SB) and on the same types without root-plowing (NB), baseline rainfall regime, Karnes County EDYS model simulations.

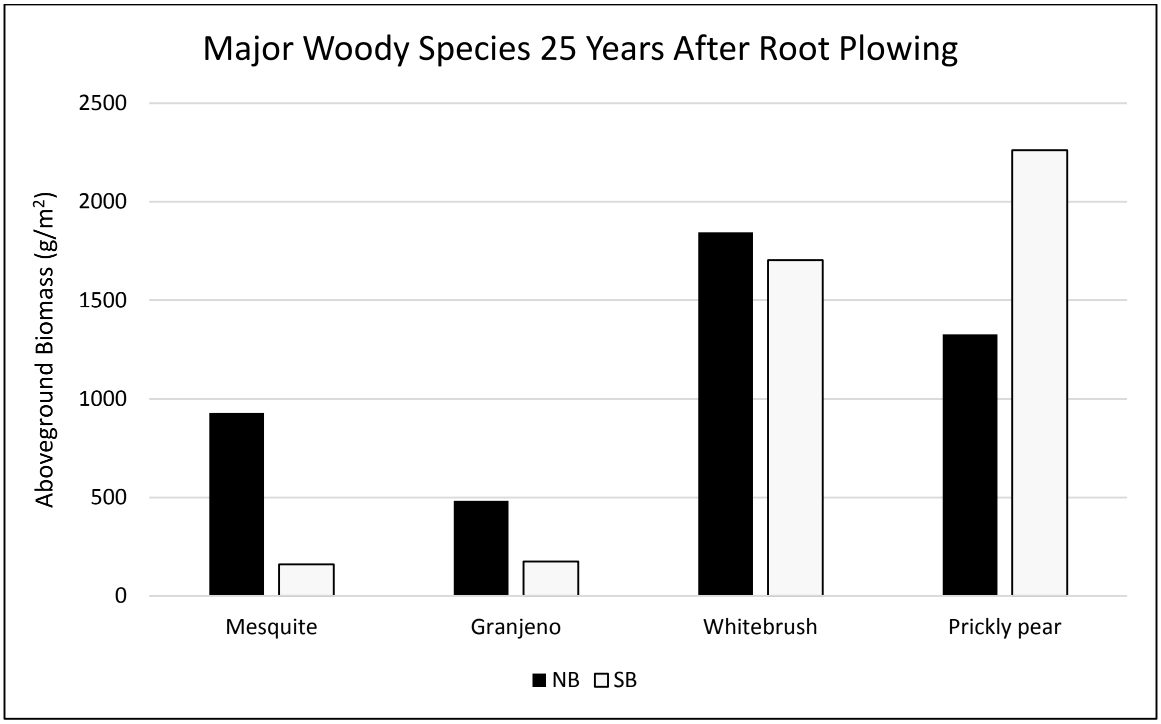

Figure 9.2 Aboveground biomass (g/m2) of major woody species on the clay loam site with (SB) and without (NB) root-plowing in Year 25 using baseline rainfall regime, Karnes County EDYS model.

Aboveground biomass of woody species (excluding prickly pear) 25 years after root-plowing was equal to 60% of aboveground biomass of woody species (excluding prickly pear) without root-plowing (2059 and 3427 g/m^2 respectively, Table 9.5). Stated differently, there was 60% recovery of brush after 25 years. Based on average height of shrub stands, Drawe et al. (1978) reported a 60% recovery of brush in the chaparral-mixed grass community on the Welder Wildlife Refuge 30-35 years after root-plowing.

The gravel ridge type in Karnes County was a dense blackbrush-dominated community, with very little understory vegetation. Brush control substantially reduced the amounts of blackbrush, guajillo, and mesquite, but increased the amount of prickly pear. The gravel ridge type in Wilson County was dominated by post oak. Brush control on this type reduced both the post oak and the associated shrubs, including prickly pear.

The re-treatment scenario (RB), with a second root-plowing operation conducted in Year 15, reduced all non-protected species when compared to the single root-plowing operation, except for Johnsongrass on the bottomland type. The re-treatment brush control reduced prickly pear and whitebrush when compared to the single treatment, but less so than the other species. Re-treatment was more effective in reducing whitebrush on the bottomland type than on the clay loam type because of greater competition from other woody species on the bottomland type.

Total aboveground biomass under the 25-year dry regime (ND) was 3-18% less than under the baseline (average) regime (NB)(Tables 9.5 and 9.6). The reduction was greatest (16-18%) on the clay loam type and least (3-10%) on the other three types. Under dry conditions, sandy soils function as ecologically wetter soils than adjacent clays because less of the soil water is held to sand particles than clay particles. On the bottomland site, much of the biomass was from established tree species, the roots of which were in contact with groundwater or near-groundwater moisture. The gravel ridge sites are xeric sites with relatively shallow soils, therefore the vegetation on those sites are adapted to lower moisture levels. Conversely, the clay loam sites have relatively deep soils with high clay content. They are very productive soils, but are particularly susceptible to drought. Biomass of huisache, mesquite, whitebrush, granjeno, and prickly pear all decreased on this site under the drier conditions. In contrast, mesquite and granjeno increased on the sandy loam sites under the drier conditions, as did the herbaceous species ragweed.

The single brush control treatment under dry conditions (SD) had similar effects on vegetation as it did under the baseline rainfall regime. Total aboveground biomass decreased in comparision to the dry regime without brush control somewhat more than it decreased with brush control under the baseline regime (Tables 9.5 and 9.6). Averaged over the four types, total aboveground biomass following brush control was 11 percentage points less under the dry regime than under baseline rainfall (31% reduction and 20% reduction, respectively) in Karnes County and 13 percentage points less (51% and 64% reduction, respectively) in Wilson County. This greater effect of brush control was likely the result of increased physiological stress from the drier condtions.

The simulation results support information gained from observation of land management responses in the region.

- Root-plowing can be a effective method of reducing woody plant coverage on sandy loam sites. Single applications can result in 80-90% reductions of target species even after 25 years. However, without re-seeding of desired herbaceous species, the site will likely be dominated by forbs, such as ragweed, for decades.
- Initially, root-plowing is equally effective on clay loam sites, but without follow-up treatments the sites will likely become dominated by aggressive shrub species such as whitebrush and prickly pear. Without further treatments to control these species, the sites are likely to become thickets of whitebrush and prickly pear, with scattered clusters of mesquite and granjeno.
- Root-plowed bottomland sites are likely to become dominated by Johnsongrass unless a successful re-seeding program is implemented.
- Dry cycles, e.g., 25 years with average rainfall 10% less than long-term average, may reduce woody plant production but the level of the reduction varies by type. On sandy loam and bottomland types, the reduction is likely to be 10% or less. On clay loam sites, the reduction is likely to be more on the order of 15-20%.
- The responses of individual woody species to root-plowing and to drought are not consistent across types and rainfall regimes. Interactions between interspecific competition and moisture regime result in different response patterns by individual species.

9.2 Hydrology

9.2.1 Runoff

Simulated runoff averaged 2,400-17,700 acre-feet per year over 25 years for each of the six watersheds under baseline conditions, or about 0.4-1.0 inch per acre per year (Table 9.11). This compares to 1.38 inches per year from loamy sand rangeland, 0.25 inch from clay rangeland, and 0.95 inch from mixed rangeland and cultivated land in San Patricio County (Ockerman 2002), or an average of 0.86 inch for the three sites. Average annual runoff combined over the six watersheds was about 45,800 acre-feet (Fig. 9.3).

Table 9.11 Average annual runoff (acre-feet) from six watersheds in Karnes and Wilson Counties under baseline conditions (average rainfall pattern) for 25-year EDYS simulations.

	Gauge 2 SA River Floresville	Gauge 3 SA River Falls City	Gauge 1 Cibolo Crk Sutherland	Gauge 4 Cibolo Crk Falls City	Gauge 5 Ecleto Crk Runge	Gauge 6 SA River Runge
Annual runoff (ac-ft)	2,510	4,644	4,511	7,179	9,201	17,706
Area (acres)	78,772	91,984	51,703	114,781	128,663	254,186
Runoff/acre (feet)	0.0319	0.0505	0.0872	0.0625	0.0715	0.0697
Runoff/acre (inches)	0.3828	0.6060	1.0464	0.7500	0.8580	0.8364

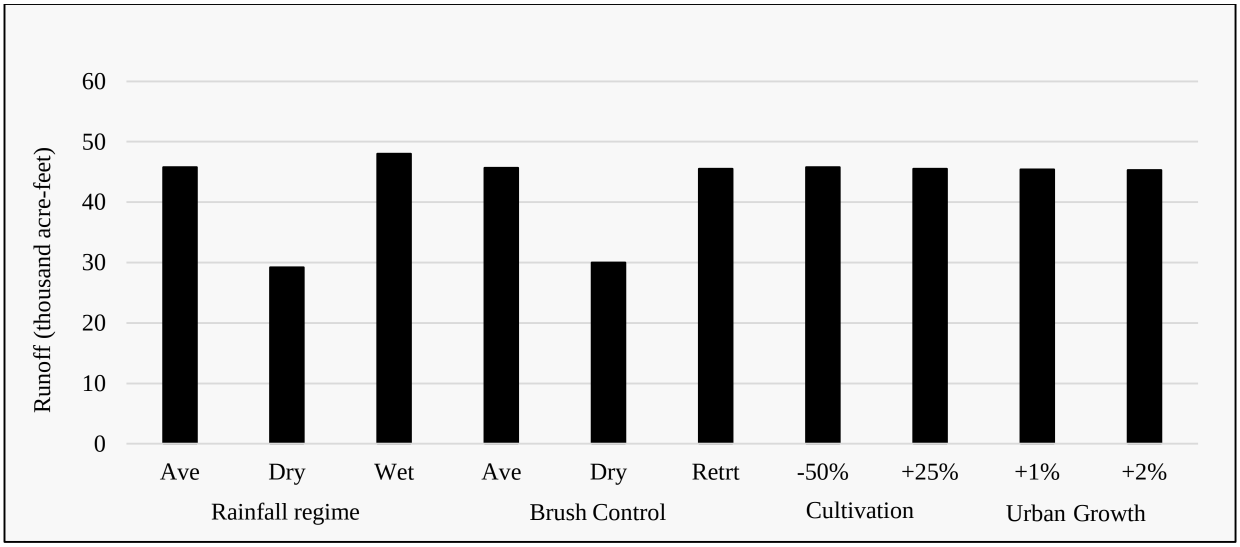

Figure 9.3 Average annual runoff (thousand acre-feet) from the combined six watersheds in Karnes and Wilson Counties. Values are annual averages for 25-year EDYS simulations for 10 scenarios.

9.2.1.1 Effect of Rainfall Regime

On most of the six sub-watersheds, the higher rainfall regime (about a 14% increase in annual rainfall) had only a minimal effect on amount of runoff (Table 9.12). Aveage annual runoff on Sub-watershed 2 (San Antonio River at Floresville) increased by only 0.4% in the wet cycle compared to baseline and average annual runoff at Sub-watersheds 1 (Cibolo Creek at Sutherland Springs), 4 (Cibolo Creek at Falls City), and 5 (Ecleto Creek at Runge) decreased slightly (3%, 3%, and 2%, respectively) under the wet regime. These responses were likely the result of increased grass production under the wetter regime. Averaged over five major vegetation types, grass production was 49% higher under the wet regime than under the baseline rainfall regime (Table 9.4). This higher grass production likely reduced surface runoff, allowing much of the increased rainfall to be infiltrated into the soil. On Sub-watersheds 3 (San Antonio River at Falls City) and 6 (San Antonio River at Runge), surface runoff increased under the wet regime (8% and 13%, respectively).

Table 9.12 Average annual runoff (acre-feet) from six watersheds in Karnes and Wilson Counties. Values are annual averages for 25-year EDYS simulations for each of 10 scenarios.

Scenario	Gauge 2 SA River Floresville	Gauge 3 SA River Falls City	Gauge 1 Cibolo Crk Sutherland	Gauge 4 Cibolo Crk Falls City	Gauge 5 Ecleto Crk Runge	Gauge 6 SA River Runge
Baseline, Ave PPT	2,510	4,644	4,511	7,179	9,201	17,706
Baseline, Dry PPT	1,451	2,475	2,130	3,331	5,891	13,960
Baseline, Wet PPT	2,520	5,013	4,365	7,050	9,110	19,978
Brush Mgt, Ave PPT	2,422	4,689	4,561	7,050	9,241	17,726
Brush Mgt, Dry PPT	1,462	2,582	2,199	3,393	6,053	14,266
Brush Mgt, Re-Treat	2,411	4,724	4,531	6,993	9,198	17,660
Decreased cropland	2,504	4,637	4,514	7,179	9,213	17,734
Increased cropland	2,367	4,639	4,506	7,130	9,188	17,637
Urban growth, 1%	2,508	4,638	4,491	7,053	9,051	17,671
Urban growth, 2%	2,503	4,539	4,477	7,046	9,124	17,629

Runoff decreased substantially in all sub-watersheds under the dry regime (Table 9.12). Average annual rainfall was about 10% less under the dry regime than under the baseline regime but runoff decreased by 21-54% compared to baseline, depending on sub-watershed. The decrease was greatest (54%) on Sub-watershed 4 (Cibolo Creek at Falls City) and least (21%) on Sub-watershed 6 (San Antonio River at Runge). Combined over the six sub-watersheds, runoff averaged 29,238 acre-feet under the dry regime, or about 36% less than under the baseline regime (Fig. 9.3).

Maximum annual runoff is the highest single year runoff during the 25-year simulation. Maximum annual runoff increased under the wet regime over baseline in four of the sub-watersheds and decreased in two (Table 9.13). Maximum annual runoff increased by 15-21% on Sub-watersheds 1-3 (mostly Wilson County) and by 51% in Sub-watershed 6 (Runge). Although average annual runoff did not increase substantially under the wet regime, maximum annual runoff did. In fact, it increased more than rainfall increased. This suggests that the increased grass cover under the wet regime was able to utilize the increased rainfall under average conditions, but not in the wettest years. A similar response was displayed in the year with minimal annual runoff (Table 9.14). Under the wet regime, minimum annual runoff was higher in all sub-watersheds than under baseline. Both maximum and minimum annual runoff decreased substantially under the dry regime compared to baseline.

Table 9.13 Maximum annual runoff (acre-feet) from six watersheds in Karnes and Wilson Counties. Values are maximum annual totals over a 25-year EDYS simulation for each of 10 scenarios.

Scenario	Gauge 2 SA River Floresville	Gauge 3 SA River Falls City	Gauge 1 Cibolo Crk Sutherland	Gauge 4 Cibolo Crk Falls City	Gauge 5 Ecleto Crk Runge	Gauge 6 SA River Runge
Baseline, Ave PPT	14,761	24,099	17,930	34,299	44,902	72,885
Baseline, Dry PPT	8,715	10,589	11,495	13,355	18,874	54,503
Baseline, Wet PPT	17,859	28,351	20,655	24,653	39,496	109,930
Brush Mgt, Ave PPT	14,507	24,022	18,002	32,914	44,876	72,644
Brush Mgt, Dry PPT	8,398	10,713	11,481	13,178	19,079	54,430
Brush Mgt, Re-Treat	14,506	24,026	17,785	31,674	43,514	72,647
Decreased cropland	14,676	24,052	17,918	34,311	44,952	72,918
Increased cropland	13,810	24,121	17,916	34,372	44,808	75,583
Urban growth, 1%	14,750	24,075	17,812	32,203	43,391	72,835
Urban growth, 2%	14,750	24,038	17,796	32,609	44,165	72,946

Table 9.14 Minimum annual runoff (acre-feet) from six watersheds in Karnes and Wilson Counties. Values are minimum annual totals over a 25-year EDYS simulation for each of 10 scenarios.

Scenario	Gauge 2 SA River Floresville	Gauge 3 SA River Falls City	Gauge 1 Cibolo Crk Sutherland	Gauge 4 Cibolo Crk Falls City	Gauge 5 Ecleto Crk Runge	Gauge 6 SA River Runge
Baseline, Ave PPT	72	363	144	96	45	312
Baseline, Dry PPT	21	59	37	59	50	198
Baseline, Wet PPT	144	462	364	507	814	1,192
Brush Mgt, Ave PPT	74	356	156	127	54	332
Brush Mgt, Dry PPT	17	61	38	58	63	276
Brush Mgt, Re-Treat	74	438	157	126	54	332
Decreased cropland	72	360	141	96	45	309
Increased cropland	72	363	140	95	45	307
Urban growth, 1%	72	361	141	96	45	310
Urban growth, 2%	72	352	140	96	45	209

Maximum single-event runoff increased in the three sub-watersheds located primarily in Wilson County (1-3) and decreased in the three located primarily in Karnes County (4-6)(Table 9.15). The two San Antonio River sub-waterheds in Wilson County (2 and 3) had the highest proportional increases in single-event runoff (15% and 35%, respectively) from the wet regime. Maximum single-event runoff under the dry regime was substantially lower than baseline on all sub-watersheds except Sub-watershed 1 (Cibolo Creek at Sutherland). In Sub-watershed 1, maximum single-event runoff under the dry regime exceeded the values under both baseline and wet regimes, suggesting than the effect of the dry regime on vegetation in this sub-watershed was probably more detrimental than in the other sub-watersheds.

Table 9.15 Maximum single-event runoff (acre-feet) from six watersheds in Karnes and Wilson Counties. Values are the maximum daily total over a 25-year EDYS simulation for each of 10 scenarios.

Scenario	Gauge 2 SA River Floresville	Gauge 3 SA River Falls City	Gauge 1 Cibolo Crk Sutherland	Gauge 4 Cibolo Crk Falls City	Gauge 5 Ecleto Crk Runge	Gauge 6 SA River Runge
Baseline, Ave PPT	14,181	17,002	10,456	15,266	12,420	41,522
Baseline, Dry PPT	8,602	10,264	11,244	12,510	8,150	37,528
Baseline, Wet PPT	16,248	23,000	11,151	14,855	10,955	37,969
Brush Mgt, Ave PPT	13,934	16,900	10,316	14,886	12,302	41,250
Brush Mgt, Dry PPT	8,479	10,170	11,225	12,303	8,146	37,102
Brush Mgt, Re-Treat	13,932	16,901	10,316	14,889	12,308	41,430
Decreased cropland	14,102	16,969	10,415	15,260	12,416	41,531
Increased cropland	13,326	17,022	10,471	15,082	12,424	41,273
Urban growth, 1%	14,178	16,992	10,449	15,269	12,426	41,450
Urgan growth, 2%	14,181	16,978	10,393	15,206	14,426	41,560

In summary, rainfall regime affected runoff but not in a linear manner nor consistently across sub-watersheds. In general, average annual runoff did not increase under the wet regime (14% increase in annual rainfall) probably because of a substantial (49%) increase in grasses under the wet regime. Average annual runoff decreased under the dry regime (10% less annual rainfall) and did so to a greater level than the decrease in annual rainfall on most sub-watersheds. Maximum runoff, both annual and single-event, tended to be substantially higher under the wet regime on most sub-watersheds, suggesting that the increased grass component could reduce surface runoff up to a point, but not under the heaviest rainfall conditions.

9.2.1.2 Brush Mangement

Brush management had an effect on surface runoff, but this effect was minimal in most cases. In all cases, average annual runoff, maximum annual runoff, and maximum single-event runoff were within 1-4% of baseline values under each of the three brush management scenarios (Tables 9.12 and 9.13). In most cases, re-treatment reduced runoff slightly, but this reduction was generally less than 1% compared to a single brush treatment. Brush control had somewhat more of an effect on minimum annual runoff in some sub-watersheds. Under baseline rainfall regime, minimum annual runoff was higher in Sub-watershed 4 (Cibolo Creek at Falls City) following brush control (32% higher than without brush control) and was higher following brush control in Sub-watersheds 5 and 6 (both of the Runge stations) in dry years (26% and 39% higher than with no brush control, respectively).

The reason for a minimal change in runoff following brush control was probably because grasses did not replace the shrubs that were removed (Tables 9.5 and 9.6). The brush management scenarios simulated were 90% removal of target woody species in some of the most dense stands of brush in the two counties. Shrub and tree species are not as effective in reducing runoff as are grasses. Prior to brush control, rainfall fell on the brush canopies where most of the rain then dripped to the soil surface and became potential runoff. Without the brush canopies, approximately the same amount of rain reached the soil surface and from that point there was little difference in water flowing around the shrub trunks and water flowing across the mostly bare ground.

This does not suggest that the water budget of the watershed was not affected. Given the same amount of rainfall and about the same amount of runoff with or without the brush, about the same amount of water would enter into the soil profile. However, without the dense brush, there would be less evapotranspiration (ET). Therefore, more of the water would likely move vertically and laterally through the soil profile. If the soil was relatively deep, much of this increase in water would be stored in the profile and eventually used by the brush species in regrowth. If the soil was shallower or there was an extended wet period where the water moved deeper into the subsurface layers, there would likely be an increase in deep percolation, groundwater recharge, or spring flows.

9.2.1.3 Cultivation

The cultivation scenarios had only a minor effect on runoff. The simulated 25% increase in cropland (conversion of native brush communities to cultivation) resulted in a slight decrease in average annual runoff (0.1-1.2%) in five of sub-watersheds and a somewhat larger decrease (5.7%) in Sub-Watershed 2 (San Antonio River at Floresville) (Table 9.12). The reason for the decreased runoff was likely increase in surface roughness and infiltration rate on the cultivated land as compared to the brush communities. The increased cultivated land scenario had more mixed results for maximum runoff events (Tables 9.13 and 9.15), with runoff increasing in some watersheds and decreasing in others, but in all cases the responses were minimal.

The simulated conversion of 50% of the existing cropland to improved pasture (decreased cultivation scenario) also had mixed effects on the sub-watersheds, but in all cases the effects were minimal (Table 9.12). This was also true from maximum runoff events (Tables 9.13 and 9.15).

9.2.1.4 Urbanization

Urbanization had very little effect on runoff. Averaged over the six subwatersheds, there was 0.4% less average annual runoff with a 1% annual increase in urbanization (50% from houses and 50% from buildings/industrial) and 1.1% less with a 2% increase in annual urbanization (Table 9.12). This was the opposite response to urbanization to what was reported for the Upper Cibolo Creek Watershed (Price et al. 2004). Urbanization resulted in a substantial increase in runoff in the Upper Cibolo Creek simulations. The Upper Cibolo Creek Watershed includes much more steep topography than occurs in Wilson and Karnes Counties. The steeper slopes and the shallower soils of the limestone hills in northern Bexar County have high potential for runoff once the vegetation is removed.

Two factors contribute substantially to the minor effect of urbanization in the Wilson and Karnes simulations. First, the amount of surface area involved in the urbanization was relatively low. Initially, there were only 64,029 urban/industrial EDYS cells in the two counties (78% in Wilson County) out of a total of over 2,525,535 cells. The 1% annual growth rate increased the number of urban/industrial cells by 16,752 cells at the end of 25 years and the 2% annual growth rate increased the number of urban/industrial cells by 37,417 cells. Even at the 2% rate, this total increase was less than 1.5% of the entire spatial footprint.

The second factor contributing to the minor response to urbanization was the fact that half of the surface area of the housing cells were modeled as grass lawns. Housing comprised over 88% of the combined total urban/industrial cells and therefore their runoff dynamics dominated the overall response of the urbanization scenarios. Roofs and driveways associated with housing increase runoff but lawns decrease runoff. Many of the new urbanization cells were replacing moderate to dense shrubland vegetation with low amounts of herbaceous vegetation. Therefore, the increase in lawns compensated for the increased in runoff from the roofs and driveways. In addition, the new urbanization cells were located in rural areas and therefore were surrounded by mostly native vegetation. Net runoff from the new urbanization cells moved across this native vegetation, wherein a portion of the water percolated into the soils supporting the native vegetation. A different runoff response would likely occur if the same increase in urbanization was concentrated such as would occur as towns expanded into urban subdivisions.

9.2.2 Sediment Load

The calibration comparisons indicate that the EDYS simulated sediment loads are probably too low (5-20% of likely values; Table 8.3). Therefore the absolute values reported in this section should be viewed with caution. However, the proportional responses, relative to the scenarios being simulated, are still likely to provide useful estimates of the probable effects of the scenarios on sediment loadings.

Average annual sediment load (sediments transported in surface runoff) combined over the six watersheds was about 5,100 tons/year in the baseline simulation scenario (Fig. 9.4). Sediment loads were strongly affected by rainfall (dry regime) and brush control, but not by the cultivation or urban growth scenarios.

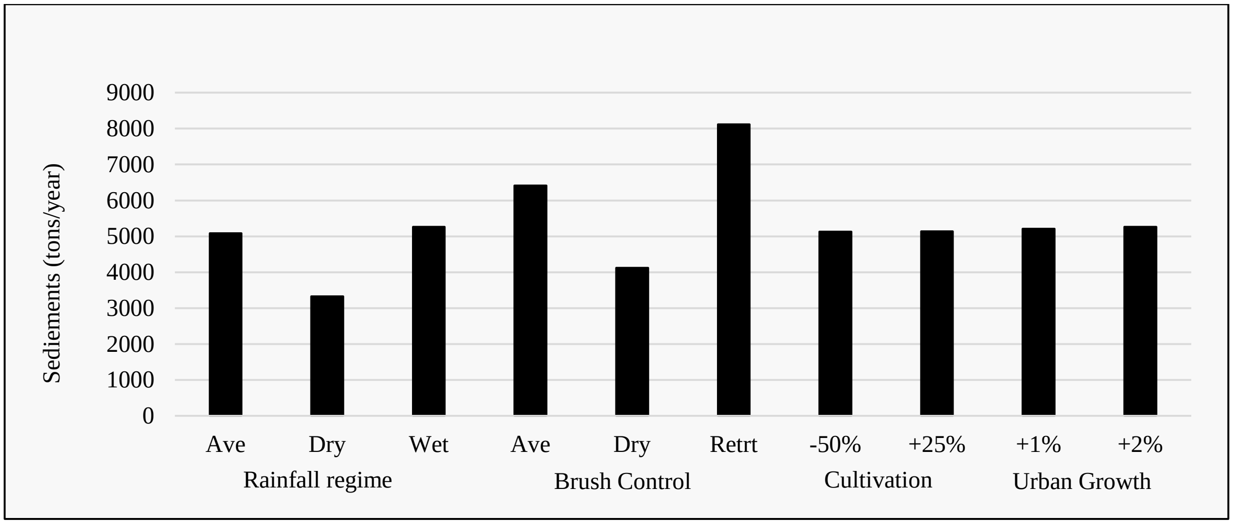

Figure 9.4 Average annual surface-transported sediment loads (tons/year) from the combined six watersheds in Karnes and Wilson Counties. Values are annual averages for 25-year EDYS simulations for 10 scenarios.

9.2.2.1 Rainfall Regime

Sediment loadings from the three sub-watersheds that flow directly into the San Antonio River (2, 3, and 6; Table 9.16) increased in the wet regime and sediment loadings in the three sub-watersheds that flow into creeks (1, 4, and 5; Table 9.16) decreased. The increases in average annual sediment loads were 5-17% over baseline and the decreases were 12-25%. These values, both increases and decreases, were larger than those for runoff. Average annual runoff increased or decreased by 1-13%. The conclusion from this is that during wet cycles, the quality of the runoff water is affected much more than the quantity of runoff water. Sediment loads under the dry regime were 22-58% lower than under the baseline rainfall regime.

Table 9.16 Average annual sediment load (tons/year) from six watersheds in Karnes and Wilson Counties. Values are annual averages for 25-year EDYS simulations for each of 10 scenarios.

Scenario	**Gauge 2 SA River**	**Gauge 3 SA River**	**Gauge 1 Cibolo Crk**	**Gauge 4 Cibolo Crk**	**Gauge 5 Ecleto Crk**	**Gauge 6 SA River**
Baseline, Ave PPT	1,199	932	227	518	436	1,779
Baseline, Dry PPT	767	562	118	219	269	1,392
Baseline, Wet PPT	1,258	1,037	210	408	385	1,969
Brush Mgt, Ave PPT	1,407	1,052	461	775	635	2,088
Brush Mgt, Dry PPT	889	624	240	361	385	1,623
Brush Mgt, Re-Treat	1,604	1,185	875	1,309	797	2,418
Decreased cropland	1,196	933	266	516	437	1,784
Increased cropland	1,196	931	267	524	445	1,781
Urban growth, 1%	1,202	934	290	545	437	1,802
Urban growth, 2%	1,204	948	282	563	458	1,806

Values are annual totals averaged over the 25 years of the simulation.

Maximum annual sediment loadings during the wet regime were higher than those under baseline conditions in only two of the sub-watersheds (2 and 6; Table 9.17), but minimum annual loadings were higher than baseline in all six sub-watersheds (Table 9.18). Maximum single-event sediment loadings followed the same pattern as did average annual loadings, with higher loadings under the wet regime in the three sub-watersheds that flow directly into the river and lower loadings in the three that flow into creeks (Table 9.19).

Table 9.17 Maximum annual sediment load (tons/year) from six watersheds in Karnes and Wilson Counties. Values are maximum annual totals over a 25-year EDYS simulation for each of 10 scenarios.

Scenario	Gauge 2 SA River	Gauge 3 SA River	Gauge 1 Cibolo Crk	Gauge 4 Cibolo Crk	Gauge 5 Ecleto Crk	Gauge 6 SA River
Baseline, Ave PPT	7,694	5,115	1,611	3,217	2,545	7,920
Baseline, Dry PPT	4,117	2,079	752	1,001	1,110	5,554
Baseline, Wet PPT	8,584	4,628	791	1,470	1,786	10,526
Brush Mgt, Ave PPT	9,044	5,696	2,154	4,219	3,795	7,543
Brush Mgt, Dry PPT	4,894	2,207	1,417	1,639	1,628	6,320
Brush Mgt, Re-Treat	9,033	5,696	5,761	9,048	5,024	11,783
Deceased cropland	7,664	5,112	1,614	3,229	2,548	6,249
Increased cropland	7,686	5,101	1,606	3,242	2,570	7,919
Urban growth, 1%	7,709	5,122	1,840	3,230	2,220	8,074
Urban growth, 2%	8,353	5,163	1,705	2,954	2,717	6,347

Table 9.18 Minimum annual sediment load (tons/year) from six watersheds in Karnes and Wilson Counties. Values are minimum annual totals over a 25-year EDYS simulation for each of 10 scenarios.

Scenario	Gauge 2 SA River	Gauge 3 SA River	Gauge 1 Cibolo Crk	Gauge 4 Cibolo Crk	Gauge 5 Ecleto Crk	Gauge 6 SA River
Baseline, Ave PPT	55.5	38.6	2.5	2.2	1.3	13.3
Baseline, Dry PPT	7.9	5.7	1.6	2.0	2.2	15.7
Baseline, Wet PPT	83.6	66.7	9.9	25.3	38.5	116.6
Brush Mgt, Ave PPT	56.7	62.7	7.1	6.6	1.6	15.4
Brush Mgt, Dry PPT	8.6	7.2	3.9	5.4	3.7	17.9
Brush Mgt, Re-Treat	56.7	41.0	6.1	6.6	1.6	15.4
Decreased cropland	55.2	38.3	2.5	2.2	1.3	13.1
Increased cropland	54.9	38.4	2.4	2.4	1.3	13.1
Urban growth, 1%	53.7	38.3	2.7	2.2	1.3	13.3
Urban growth, 2%	54.1	38.4	2.5	2.3	1.3	13.2

Table 9.19 Maximum single-event daily sediment load (tons/day) from six watersheds in Karnes and Wilson Counties. Values are the maximum daily total over a 25-year EDYS simulation for each of 10 scenarios.

Scenario	Gauge 2 SA River	Gauge 3 SA River	Gauge 1 Cibolo Crk	Gauge 4 Cibolo Crk	Gauge 5 Ecleto Crk	Gauge 6 SA River
Baseline, Ave PPT	7,327	2,533	670	1,224	578	3,219
Baseline, Dry PPT	3,716	1,423	733	935	461	4,154
Baseline, Wet PPT	7,559	3,021	363	803	522	3,873
Brush Mgt, Ave PPT	8,633	2,758	1,013	1,595	905	3,832
Brush Mgt, Dry PPT	4,390	1,510	1,364	1,567	632	4,655
Brush Mgt, Re-Treat	8,562	2,758	2,415	3,682	1,246	3,828
Decreased cropland	7,300	2,532	676	1,233	578	3,222
Increased cropland	7,324	2,540	665	1,220	577	3,224
Urban growth, 1%	7,350	2,563	771	1,227	584	3,219
Urban growth, 2%	7,358	2,540	715	1,306	641	3,221

9.2.2.2 Brush Management

The brush management treatment increased sediment loadings in all sub-watersheds under both baseline (average) and dry regimes (Table 9.16). The increases averaged 36% under the wet regime and 43% under the dry regime. The root-plowing effect on sediment loads was very different than the effect of root-plowing on amount of runoff. The single root-plowing treatment increased annual runoff by 1-4% under baseline rainfall compared to 17-73% increases in sediment loadings. So although there was not much additional water coming off the landscapes, the water quality was much lower. Under the dry regime, sediment loading from Sub-watershed 1 (Cibolo Creek at Sutherland Springs) was particularly sensitive to root-plowing, where the increase was 30 percentage points higher under the dry regime than baseline (103% increase and 73% increase, respectively).

The brush control re-treatment also had a substantial effect on sediment loads (Table 9.16). This also was different from the response of runoff to retreatment. Average annual sediment loadings were an average of 38% under the re-treatment scenario compared to the single root-plowing treatment. In contrast, average annual runoff was only about 1% higher under the re-treatment scenario compared to the single brush control treatment.

9.2.2.3 Cultivation

The simulated cultivation scenarios generally had minimal effect on sediment loadings. Average annual sediment loads changed from baseline conditions by 2% or less for all sub-watersheds except Sub-watershed 1 (Cibolo Creek and Sutherland Springs), where both increased and decreased cropland acreage increased sediment loadings by 18% (Table 9.16). Maximum sediment loadings were not substantially affected by the cultivation scenarios on any of the six sub-watersheds.

Location is a major consideration in evaluating the impact of amount of cultivated land on sediment loadings. The cultivation simulation scenarios impacted a relatively small area. There were initially 14,645 cultivated cells in Karnes County out of a total of 1,219,110 and 33,798 cultivated cells in Wilson County out of a total of 1,306,425. Although the simulated increases and decreases in cultivated area were substantial on a proportional basis (25% and 50% of initial cultivated cells, respectively), the total number of cells remained small in comparison to overall number of cells in the counties. The 50% decrease in cultivation, for example, directly affected only 0.6% of the area of Karnes County and 1.3% of Wilson County. These relatively few cells were located throughout each county and were therefore surrounded by large numbers of unaffected cells. Had the same number of cells converted to, or removed from, cultivation been concentrated in a few areas the effect on sediment loadings would have been greater. This would be especially true if the affected areas were concentrated near streams or the river because the proportion of increased runoff, and hence sediments, entering drainages increases as distance to the point of discharge decreases (Fish and Rainwater 2007; McLendon 2013).

9.2.2.4 Urbanization

Increased urbanization had minimal impacts on sediment loadings (Table 9.16), for the same reasons that it had minimal impacts on runoff, i.e., the affected areas were small (less than 1.5% of the total area) and most affected cells were converted to houses which had 50% lawns. Under the 2% rate of increase in urbanization, average annual sediment loadings increased by an average of 3.9% compared to baseline (averaged over the six sub-watersheds). As was the case with rainfall regime and root-plowing, the three creek sub-watersheds (1, 4, and 5) had higher increases in sediment loadings from urbanization than did the three river sub-watersheds (2, 3, and 6). Average annual sediment loadings under the 2% growth rate increased by an average of 6.5%, compared to a 1.2% increase in loadings on the three sub-watersheds draining directly into the San Antonio River. Sub-watershed 4 (Cibolo Creek at Falls City) was particularly sensitive to increased sediment loadings from urbanization, with an 8.7% increase in average annual sediment loads compared to baseline.

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APPENDIX A

CALCULATION OF CONSTRUCTED DATA SETS FOR TEMPORAL AND SPATIAL VARIATION IN PRECIPITATION IN KARNES AND WILSON COUNTIES, TEXAS

The comparisons in Appendix Tables A.1-A.7 are based on raw averages for annual precipitation. The averages are for the period of record for each primary station and have not been adjusted for comparisons over the same years.

Appendix Table A.1 Distances between Karnes City, Karnes County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annual precipitation at Karnes City = 30.18 inches.

	Station	County	Distance (mi)	Mean Annual PPT (inches)
North of Karnes City				
	Cestohowa	Karnes	12	27.94
	Stockdale	Wilson	25	33.51
	Nixon	Wilson	28	32.68
	Seguin	Guadalupe	50	31.30
Northeast of Karnes City				
	Yorktown	DeWitt	27	34.14
	Cuero	DeWitt	41	34.48
	Yoakum	DeWitt	56	38.25
	Dreyer	Gonzales	50	33.77
	Gonzales	Gonzales	52	33.92
	Waelder	Gonzales	66	33.15
	Jeddo	Gonzales	70	36.22
East of Karnes City				
	Runge	Karnes	12	30.25
Southeast of Karnes City				
	Kenedy	Karnes	7	30.50
	Beeville	Bee	35	31.18
	Goliad	Goliad	37	34.83
	Goliad SE	Goliad	38	32.19
Southwest of Karnes City				
	Whitsett	Live Oak	27	26.34
	Three Rivers	Live Oak	34	26.40
	George West	Live Oak	40	27.05
	Calliham	McMullen	31	25.38
	Tilden	McMullen	48	24.26
West of Karnes City				
	Jourdanton	Atascosa	38	25.78
	Charlotte	Atascosa	48	27.05
Northwest of Karnes City				
	Falls City WSW	Wilson	13	27.38
	Floresville	Wilson	23	29.02
	San Antonio	Bexar	55	29.12
	Poteet	Atascosa	41	27.63
	Rossville	Atascosa	49	27.28

Appendix Table A.2 Distances between Kenedy, Karnes County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annual precipitation at Kenedy = 30.50 inches.

	Station	County	Distance (mi)	Mean Annual PPT (inches)
North of Kenedy				
	Stockdale	Wilson	29	33.51
	Nixon	Wilson	33	32.68
Northeast of Kenedy				
	Runge	Karnes	10	30.25
	Yorktown	DeWitt	25	34.14
	Cuero	DeWitt	38	34.48
	Yoakum	DeWitt	55	38.25
	Seguin	Guadalupe	52	31.30
	Dreyer	Gonzales	52	33.77
	Gonzales	Gonzales	55	33.92
	Waelder	Gonzales	70	33.15
	Jeddo	Gonzales	75	36.22
Southeast of Kenedy				
	Beeville	Bee	29	31.18
	Goliad	Goliad	30	34.83
	Goliad SE	Goliad	31	32.19
Southwest of Kenedy				
	Whitsett	Live Oak	30	26.34
	Three Rivers	Live Oak	32	26.40
	George West	Live Oak	38	27.05
	Calliham	McMullen	40	25.38
	Tilden	McMullen	49	24.26
West of Kenedy				
	Charlotte	Atascosa	54	27.05
Northwest of Kenedy				
	Karnes City	Karnes	7	30.18
	Cestohowa	Karnes	17	27.94
	Falls City WSW	Wilson	20	27.38
	Floresville	Wilson	30	29.02
	San Antonio	Bexar	63	29.12
	Jourdanton	Atascosa	43	25.78
	Poteet	Atascosa	47	27.63
	Rossville	Atascosa	55	27.28

Appendix Table A.3 Distances between Runge, Karnes County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annul precipitation at Runge = 30.25 inches.

	Station	County	Distance (mi)	Mean Annual PPT (inches)
North of Runge				
	Nixon	Wilson	28	32.68
Northeast of Runge				
	Yorktown	DeWitt	13	34.14
	Cuero	DeWitt	30	34.48
	Yoakum	DeWitt	45	38.25
	Dreyer	Gonzales	43	33.77
	Gonzales	Gonzales	50	33.92
	Waelder	Gonzales	63	33.15
	Jeddo	Gonzales	67	36.22
Southeast of Runge				
	Goliad	Goliad	25	34.83
	Goliad SE	Goliad	26	32.19
South of Runge				
	Beeville	Bee	33	31.18
Southwest of Runge				
	Kenedy	Karnes	10	30.50
	Whitsett	Live Oak	38	26.34
	Three Rivers	Live Oak	43	26.40
	George West	Live Oak	46	27.05
	Calliham	McMullen	50	25.38
	Tilden	McMullen	61	24.26
West of Runge				
	Karnes City	Karnes	12	30.18
	Jourdanton	Atascosa	50	25.78
	Charlotte	Atascosa	63	27.05
Northwest of Runge				
	Cestohowa	Karnes	18	27.94
	Falls City WSW	Wilson	26	27.38
	Floresville	Wilson	33	29.02
	San Antonio	Bexar	64	29.12
	Stockdale	Wilson	30	33.51
	Seguin	Guadalupe	52	31.30
	Poteet	Atascosa	54	27.63
	Rossville	Atascosa	61	27.28

Appendix Table A.4 Distances between Falls City WSW, Wilson County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annual precipitation at Falls City WSW = 27.38 inches.

	Station	County	Distance (mi)	Mean Annual PPT (inches)
North of Falls City WSW				
	Floresville	Wilson	16	29.02
Northeast of Falls City WSW				
	Cestohowa	Karnes	12	27.94
	Stockdale	Wilson	23	33.51
	Nixon	Wilson	33	32.68
	Seguin	Guadalupe	45	31.30
	Yorktown	DeWitt	38	34.14
	Cuero	DeWitt	53	34.48
	Yoakum	DeWitt	67	38.25
	Gonzales	Gonzales	58	33.92
	Dreyer	Gonzales	70	33.77
	Waelder	Gonzales	73	33.15
	Jeddo	Gonzales	79	36.22
Southeast of Falls City WSW				
	Karnes City	Karnes	13	30.18
	Kenedy	Karnes	20	30.50
	Runge	Karnes	26	30.25
	Beeville	Bee	43	31.18
	Goliad	Goliad	49	34.83
	Goliad SE	Goliad	50	32.19
South of Falls City WSW				
	Three Rivers	Live Oak	33	26.40
	George West	Live Oak	42	27.05
Southwest of Falls City WSW				
	Whitsett	Live Oak	22	26.34
	Calliham	McMullen	37	25.38
	Tilden	McMullen	37	24.26
West of Falls City WSW				
	Jourdanton	Atascosa	24	25.78
	Charlotte	Atascosa	37	27.05
Northwest of Falls City WSW				
	Poteet	Atascosa	28	27.63
	Rossville	Atascosa	36	27.28
	San Antonio	Bexar	47	29.12

Appendix Table A.5 Distances between Floresville, Wilson County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annual precipitation at Floresville = 29.02 inches.

	Station	County	Distance (mi)	Mean Annual PPT (inches)
Northeast of Floresville				
	Stockdale	Wilson	13	33.51
	Nixon	Wilson	25	32.68
	Seguin	Guadalupe	33	31.30
	Gonzales	Gonzales	49	33.92
	Dreyer	Gonzales	55	33.77
	Waelder	Gonzales	65	33.15
	Jeddo	Gonzales	69	36.22
	Yoakum	DeWitt	63	38.25
East of Floresville				
	Cuero	DeWitt	53	34.48
Southeast of Floresville				
	Cestohowa	Karnes	17	27.94
	Karnes City	Karnes	23	30.18
	Kenedy	Karnes	30	30.50
	Runge	Karnes	33	30.25
	Beeville	Bee	58	31.18
	Yorktown	DeWitt	40	34.14
	Goliad	Goliad	58	34.83
	Goliad SE	Goliad	59	32.19
South of Floresville				
	Falls City WSW	Wilson	16	27.38
	Three Rivers	Live Oak	47	26.40
	George West	Live Oak	56	27.05
Southwest of Floresville				
	Poteet	Atascosa	28	27.63
	Rossville	Atascosa	33	27.28
	Jourdanton	Atascosa	29	25.78
	Charlotte	Atascosa	37	27.05
	Whitsett	Live Oak	35	26.34
	Calliham	McMullen	49	25.38
	Tilden	McMullen	54	24.26
Northwest of Floresville				
	San Antonio	Bexar	33	29.12

Appendix Table A.6 Distances between Nixon, Wilson County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annual precipitation at Nixon = 32.68 inches.

	Station	**County**	**Distance (mi)**	**Mean Annual PPT (inches)**
Northeast of Nixon				
	Gonzales	Gonzales	23	33.92
	Dreyer	Gonzales	30	33.77
	Waelder	Gonzales	40	33.15
	Jeddo	Gonzales	45	36.22
East of Nixon				
	Yoakum	DeWitt	38	38.25
Southeast of Nixon				
	Yorktown	DeWitt	27	34.14
	Cuero	DeWitt	31	34.48
	Goliad	Goliad	48	34.83
	Goliad SE	Goliad	49	32.19
South of Nixon				
	Karnes City	Karnes	28	30.18
	Runge	Karnes	28	30.25
	Kenedy	Karnes	33	30.50
	Beeville	Bee	63	31.18
Southwest of Nixon				
	Stockdale	Wilson	13	33.51
	Cestohowa	Karnes	19	27.94
	Floresville	Wilson	25	29.02
	Falls City WSW	Wilson	33	27.38
	Poteet	Atascosa	53	27.63
	Rossville	Atascosa	53	27.28
	Jourdanton	Atascosa	55	25.78
	Whitsett	Live Oak	54	26.34
	Charlotte	Atascosa	63	27.05
	Three Rivers	Live Oak	63	26.40
	George West	Live Oak	67	27.05
	Calliham	McMullen	68	25.38
	Tilden	McMullen	75	24.26
Northwest of Nixon				
	Seguin	Guadalupe	23	31.30
	San Antonio	Bexar	46	29.12

Appendix Table A.7 Distances between Stockdale, Wilson County, and surrounding primary precipitation stations and mean annual precipitation (PPT) at the stations. Mean annual precipitation at Stockdale = 33.51 inches.

	Station	County	Distance (mi)	Mean Annual PPT (inches)
North of Stockdale				
	Seguin	Guadalupe	23	31.30
Northeast of Stockdale				
	Nixon	Wilson	13	32.68
	Gonzales	Gonzales	37	33.92
	Dreyer	Gonzales	43	33.77
	Waelder	Gonzales	51	33.15
	Jeddo	Gonzales	55	36.22
	Yoakum	DeWitt	50	38.25
East of Stockdale				
	Cuero	DeWitt	43	34.48
Southeast of Stockdale				
	Runge	Karnes	30	30.25
	Yorktown	DeWitt	33	34.14
	Goliad	Goliad	53	34.83
	Goliad SE	Goliad	54	32.19
	Beeville	Bee	61	31.18
South of Stockdale				
	Cestohowa	Karnes	11	27.94
	Karnes City	Karnes	25	30.18
	Kenedy	Karnes	29	30.50
	George West	Live Oak	63	27.05
Southwest of Stockdale				
	Floresville	Wilson	13	29.02
	Falls City WSW	Wilson	23	27.38
	Poteet	Atascosa	39	27.63
	Jourdanton	Atascosa	42	25.78
	Rossville	Atascosa	46	27.28
	Charlotte	Atascosa	50	27.05
	Whitsett	Live Oak	46	26.34
	Three Rivers	Live Oak	56	26.40
	Calliham	McMullen	61	25.38
	Tilden	McMullen	65	24.26
Northwest of Stockdale				
	San Antonio	Bexar	37	29.12

Appendix Table A.8 Annual precipitation (inches) recorded at primary stations in Karnes and Wilson Counties for the period of record for each station.

Year	Karnes City	Kenedy	Runge	Falls City	Floresville	Nixon	Stockdale
1895			-----				
1896			27.28				
1987			-----				
1898			-----				
1899			-----				
1900			-----				
1901			-----				
1902			39.50				
1903			45.00				
1904			29.38				
1905			-----				
1906			-----				
1907			-----				
1908			31.74				
1909			18.94				
1910			-----				
1911			-----				
1912			-----				
1913			30.72				
1914			40.35				
1915			20.23				
1916			-----		-----		
1917			13.60		7.88		
1918			30.75		30.39		
1919	-----		45.80		46.29		
1920	21.47		25.62		20.45		
1921	23.18		30.06		21.42	-----	
1922	28.18		29.38		28.70	23.31	
1923	44.29		45.57		43.34	44.28	
1924	20.93		20.65		24.15	21.73	
1925	22.90		15.43		16.86	18.36	
1926	33.67		32.28		25.53	36.52	
1927	25.23		22.29		24.84	30.72	
1928	27.96		22.91		28.20	27.44	
1929	42.24		34.89		28.83	39.49	
1930	24.04		16.96		20.39	21.54	
1931	33.16		36.53		27.07	22.62	
1932	32.25		26.98		29.30	29.31	
1933	24.24		25.41		21.24	30.26	
1934	38.92		36.50		-----	-----	
1935	56.52		45.26		45.93	44.12	
1936	49.97		31.36		-----	39.06	
1937	24.77		19.73		-----	25.70	
1938	24.67		16.14		-----	31.00	
1939	17.08		19.24		13.75	16.64	
1940	40.66		46.87		32.53	39.51	-----
1941	51.76		41.44		37.25	48.92	43.29
1942	34.72		27.30		35.77	37.53	42.72
1943	24.85		28.08		22.88	21.89	25.70
1944	28.22		31.07		24.08	32.69	38.25
1945	-----		21.97		16.65	27.40	-----
1946	50.30		45.42	-----	44.55	58.06	
1947	-----		28.76	-----	-----	20.90	
1948	28.09	-----	25.08	-----	22.06	21.86	
1949	-----	38.14	38.86	39.04	34.82	32.00	
1950	18.10	19.97	14.84	18.94	-----	25.21	
1951	24.69	30.37	26.92	20.81	22.47	20.83	
1952	28.71	28.59	33.23	22.19	26.90	34.60	
1953	28.71	22.67	22.73	28.34	22.53	24.25	
1954	18.97	15.89	-----	17.29	18.29	18.28	
1955	23.06	24.21	19.99	18.59	22.79	23.15	
1956	16.68	17.27	17.42	11.34	17.90	-----	
1957	44.75	-----	43.14	41.13	38.68	52.15	
1958	46.80	36.78	35.49	31.79	43.40	37.45	
1959	28.11	26.97	31.11	21.81	32.08	27.68	

Year	Karnes City	Kenedy	Runge	Falls City	Floresville	Nixon	Stockdale
1960	36.13	46.20	43.43	46.03	39.69	45.89	
1961	18.93	23.82	20.79	28.94	26.86	32.53	
1962	25.69	27.31	26.67	24.18	-----	26.00	
1963	24.32	22.88	18.15	22.36	-----	18.83	
1964	22.82	23.63	27.23	21.06	24.42	24.32	
1965	37.03	41.88	41.53	29.34	-----	42.63	
1966	21.76	25.27	28.68	22.02	27.23	-----	
1967	46.96	46.44	44.32	37.90	38.77	36.12	
1968	33.57	44.97	31.46	41.90	-----	39.66	
1969	28.63	34.01	31.88	-----	35.29	38.10	
1970	27.97	33.15	28.73	23.96	23.45	27.01	
1971	24.00	32.75	31.89	24.92	19.75	30.57	
1972	24.22	-----	29.96	29.89	22.34	33.51	
1973	-----	41.99	51.93	43.75	54.35	47.36	
1974	-----	26.75	27.48	27.98	32.50	36.44	
1975	-----	-----	25.90	-----	29.96	31.45	
1976	-----	-----	45.20	35.30	36.52	47.28	
1977	-----	-----	33.57	22.09	25.29	30.93	
1978	27.84		33.88	29.40	30.89	33.59	-----
1979	33.79		36.90	29.65	29.95	-----	42.48
1980	23.28		28.35	32.53	24.15	-----	30.95
1981	41.61		40.50	28.45	24.88	34.56	35.78
1982	-----		22.24	29.58	-----	21.79	27.79
1983	-----		26.59	26.69	27.72	36.72	30.10
1984	22.37		-----	16.83	-----	-----	-----
1985	34.83		36.96	32.38	27.98	37.57	-----
1986	-----		28.68	-----	27.29	29.76	32.62
1987	22.79		32.10	34.14	-----	-----	38.53
1988	15.87		20.08	16.14	-----	-----	18.01
1989	23.16		21.14	21.42	-----	27.78	25.22
1990	25.61		20.89	27.46	-----	24.03	24.17
1991	35.22		40.29	38.64	-----	42.81	42.16
1992	41.38		32.94	36.54	52.06	58.50	56.52
1993	25.54		24.02	28.84	46.09	40.05	37.21
1994	-----		39.49	36.56	32.73	35.84	33.84
1995	-----		22.86	18.75	18.69	-----	31.17
1996	20.51		24.67	20.72	21.23	-----	16.51
1997	36.69		39.60	26.86	29.92	35.31	32.64
1998	36.01		38.80	28.04	35.62	44.00	37.22
1999	20.35		15.71	24.25	15.47	23.07	21.80
2000	31.44		35.27	31.74	31.64	37.63	34.41
2001	-----		39.17	-----	30.82	42.30	36.65
2002	38.21		40.89	35.90	41.01	-----	-----
2003	26.56		32.90	27.92	29.16	-----	25.77
2004	42.31		43.87	37.98	40.90	-----	46.90
2005	20.70		32.72	17.00	18.37	23.24	19.90
2006	-----		25.16	18.06	28.33	23.62	32.11
2007			-----	40.67	48.86	49.26	51.23
2008			16.62	14.27	13.41	19.80	25.83
2009			33.49	25.03	29.71	40.50	38.84
2010			33.38	26.39	35.82	-----	29.81
2011			15.17	14.81	13.56	-----	-----
2012			19.45	16.52	29.70	27.02	33.23
MEAN	30.15	30.50	30.29	27.38	29.02	32.68	33.51

Appendix Table A.9 Annual precipitation (inches) recorded at primary stations in DeWitt, Goliad, Gonzales, and Guadalupe Counties for the period of record for each station.

Year	Cuero	Yoakum	Yorktown	Goliad	Goliad 1S	Dreyer	Gonzales	Jeddo	Waelder
1902	41.52								
1903	51.40								
1904	41.63								
1905	45.56								
1906	26.42								
1907	38.69								
1908	38.71								
1909	23.42								
1910	38.22								
1911	31.69								
1912	26.57			-----					
1913	40.37			34.19					
1914	59.09			42.16					
1915	30.44			21.47			-----		
1916	20.78			19.99			-----		
1917	12.83			9.73					
1918	38.44	40.30		32.32					
1919	54.56	59.57		47.22					
1920	27.48	34.71		24.29					
1921	25.26	36.29		31.22					
1922	32.41	30.91		26.34					
1923	44.27	48.18		45.35					
1924	25.70	-----		22.37					
1925	20.38	-----		28.75					
1926	38.26	-----		32.83					
1927	23.27	-----		22.47					
1928	33.07	-----		29.59					
1929	54.21	48.18		44.59					
1930	27.48	29.39		25.94					
1931	24.97	30.77		40.03					
1932	35.23	40.19		35.15					
1933	35.26	22.51		31.65					
1934	39.4	34.30		41.89					
1935	40.33	45.65		38.31					
1936	48.13	53.29		36.54					
1937	31.93	29.63		26.77					
1938	24.96	35.54		27.28					
1939	21.80	31.76		21.65					
1940	57.07	54.54		38.28		-----	40.40	-----	
1941	46.12	-----	42.74	38.04		45.19	41.69	45.73	
1942	28.87	35.86	31.53	41.05		37.30	34.42	40.88	
1943	30.67	33.36	28.74	33.49		28.88	24.66	29.95	
1944	33.61	33.90	32.28	32.03		37.85	35.20	38.63	24.37
1945	21.80	23.09	23.65	29.42		26.54	33.23	34.51	23.56
1946	53.27	50.15	44.72	45.97		50.21	50.87	-----	-----
1947	-----	-----	-----	30.89		-----	25.25	25.57	26.80
1948	28.37	-----	22.72	26.74		21.10	30.94	18.12	-----
1949	44.25	-----	40.74	35.44	-----	43.39	39.41	37.04	-----
1950	23.37	-----	15.31	18.69	13.84	19.03	19.93	29.47	-----
1951	24.74	-----	26.17	37.5	31.52	21.46	24.21	-----	21.23
1952	33.41	-----	37.54	37.19	-----	35.29	36.18	38.83	39.40
1953	29.13	26.78	-----	28.49	24.5	30.24	27.59	30.43	32.18
1954	15.85	14.68	-----	16.14	16.1	14.17	11.78	18.13	20.24
1955	26.20	35.12	-----	25.27	19.35	26.66	27.87	25.22	23.54
1956	13.92	14.15	15.00	19.49	18.81	15.92	17.04	18.39	16.56
1957	46.29	46.15	43.37	51.48	52.56	54.44	52.33	49.05	52.77
1958	36.33	38.82	42.17	43.03	37.22	34.72	36.31	40.20	36.38
1959	35.58	42.88	33.96	32.35	29.35	40.92	32.77	37.15	34.94
1960	49.03	54.53	44.88	48.19	45.61	49.55	45.40	49.97	47.24
1961	32.87	41.55	26.33	28.99	21.00	32.77	29.02	47.06	39.17
1962	29.90	30.21	29.79	31.67	25.45	25.31	27.16	22.03	27.87
1963	21.24	23.81	19.58	23.59	20.50	21.34	16.37	21.76	20.76
1964	24.80	29.51	25.09	25.16	20.50	30.76	28.03	-----	28.64
1965	39.33	39.50	36.55	43.99	41.03	43.79	42.70	43.46	-----
1966	33.01	27.16	26.24	37.60	30.93	25.67	26.10	33.53	29.71

Year	**Cuero**	**Yoakum**	**Yorktown**	**Goliad**	**Goliad 1S**	**Dreyer**	**Gonzales**	**Jeddo**	**Waelder**
1967	46.75	31.59	50.71	44.03	40.25	45.01	37.76	31.05	29.52
1968	44.15	43.54	37.83	42.09	41.14	43.11	47.36	53.96	53.77
1969	-----	36.95	44.04	35.43	29.00	34.68	33.05	34.41	32.29
1970	28.21	34.94	28.92	30.17	28.19	25.84	28.80	35.35	27.78
1971	31.92	42.07	38.52	39.6	41.41	28.18	30.66	30.68	31.30
1972	-----	42.90	38.17	52.85	53.85	31.94	35.20	31.94	-----
1973	-----	55.18	-----	51.09	-----	54.64	48.56	53.18	-----
1974	-----	39.47	34.54	38.24	-----	38.44	37.12	38.46	-----
1975	-----	36.35	28.19	39.35	-----	-----	39.43	41.85	-----
1976	49.11	45.70	-----	55.31	49.42		43.98	58.23	50.89
1977	32.01	32.15	35.16	38.54	34.72		33.81	34.09	32.65
1978	31.69	40.78	30.38	29.46	26.39		31.86	38.78	38.30
1979	47.97	45.78	44.83	40.75	34.52		38.83	38.52	41.80
1980	24.87	27.45	28.64	35.57	32.87		26.99	27.36	25.89
1981	-----	55.64	50.04	59.44	62.94		47.84	57.33	52.64
1982	27.92	39.07	-----	26.64	-----		24.94	-----	26.56
1983	-----	40.56	34.78	36.55	-----		36.84	36.82	32.48
1984	25.94	29.88	28.23	28.39	33.45		26.91	29.08	-----
1985	42.24	43.11	-----	38.05	-----		-----	-----	-----
1986	32.94	-----	-----	-----	-----		34.66	44.56	39.38
1987	31.51	-----	-----	-----	-----		47.07	41.54	45.23
1988	20.21	24.97	-----	-----	-----		14.40	19.53	19.04
1989	27.33	-----	25.77	22.66	21.85		27.97	33.44	24.15
1990	-----	-----	30.10	32.79	-----		27.12	31.08	23.36
1991	53.28	48.14	45.44	47.39	-----		46.49	49.12	54.20
1992	42.00	48.01	39.91	40.93	39.09		50.25	53.28	-----
1993	38.11	43.74	32.14	37.94	-----		35.47	35.77	-----
1994	43.61	-----	37.38	43.23	-----		40.34	36.27	
1995	29.44	32.09	22.50	33.58	-----		28.77	30.78	
1996	21.83	33.31	19.96	23.91	17.34		26.37	25.19	
1997	54.30	68.62	49.27	53.79	-----		47.85	55.30	
1998	49.06	60.70	46.17	51.47	35.35		54.03	47.36	
1999	24.60	22.30	24.81	22.96	20.58		23.43	17.54	
2000	40.88	52.19	43.51	37.09	36.00		40.76	39.70	
2001	49.02	44.84	39.33	45.89	-----		32.70	37.35	
2002	-----	42.20	40.99	42.37	-----		42.91	50.20	
2003	29.10	-----	36.66	34.46	21.75		19.71	29.89	
2004	42.83	-----	43.60	47.93	42.55		48.30	57.61	
2005	22.99	-----	32.61	28.91	-----		20.79	-----	
2006	23.51	23.34	28.53	32.73			32.52	24.99	
2007	50.20	53.56	43.61	51.81			47.65	43.38	
2008	17.71	17.12	22.00	22.53			20.47	16.98	
2009	38.68	39.65	41.78	35.95			35.04	33.26	
2010	33.16	46.71	36.40	41.35			35.24	34.22	
2011	-----	17.75	-----	17.25			16.99	17.6	
2012	25.58	39.62	23.97	27.71			38.38	38.52	
MEAN	34.48	38.25	34.14	34.83	32.19	33.77	33.92	36.22	33.15

Appendix Table A.10 Annual precipitation (inches) recorded at primary stations in Atascosa, Bee, Bexar, Live Oak, and McMullen Counties for the period of record for each station.

Year	Charlotte	Jourdanton	Poteet	Beeville	San Antonio	George West	Three Rivers	Ray Point	Whitsett	Calliham	Tilden
1885					32.92						
1886					26.22						
1887					20.13						
1888					41.55						
1889					38.95						
1890					29.85						
1891					30.04						
1892					25.71						
1893					18.24						
1894				-----	21.80						
1895				-----	26.07						
1896				-----	34.09						
1897				-----	15.92						
1898				-----	22.49						
1899				-----	19.65						
1900				-----	37.19						
1901				-----	16.44						
1902				-----	24.79						
1903				49.11	33.11						-----
1904				-----	29.38						27.30
1905				39.62	32.59						-----
1906				31.22	20.42						-----
1907				19.10	27.77						-----
1908				35.65	28.52						-----
1909				30.80	14.92						-----
1910				29.78	16.22						-----
1911				23.46	18.68						-----
1912				29.99	23.73						-----
1913				32.76	37.68						-----
1914				46.56	34.09				-----		-----
1915				13.14	27.28				18.30		-----
1916		-----		23.39	27.66	24.54			21.73		-----
1917		8.26		12.08	10.13	7.65			5.19		-----
1918		-----		29.56	29.91	31.24			25.72		-----
1919		-----		47.43	50.30	46.27			45.45		-----
1920		28.84		22.27	19.56	18.84			20.99		-----
1921		-----		23.26	28.53	-----			25.99		-----
1922		-----		37.71	24.59	-----	-----		28.19		-----
1923		-----		46.43	32.71	-----	42.72		35.17		-----
1924		-----		21.58	23.65	19.29	24.03		20.91		-----
1925		-----		31.17	14.99	25.00	19.31		23.43		-----
1926		-----		31.60	30.39	30.35	26.50		25.11		-----
1927		-----		20.58	22.75	23.11	23.47		25.20		-----
1928		-----		36.81	30.20	27.35	25.18		20.82		-----
1929		-----		38.38	29.24	30.21	29.28		27.43		-----
1930		-----		26.91	22.79	27.57	31.50		27.36		-----
1931		-----		37.73	25.00	31.80	28.87		30.92		-----
1932		-----		42.69	35.57	23.32	21.51		27.98		-----
1933		-----		29.64	17.64	27.51	25.93		21.91		-----
1934		-----		32.09	27.65	29.50	27.32		29.97		-----
1935		-----		33.20	42.93	41.32	47.21		42.06		-----
1936		-----		33.71	34.11	36.26	30.55		24.92		-----
1937		-----		23.29	26.07	23.85	20.08		19.21		-----
1938		-----		21.05	23.26	17.20	13.76		14.05		-----
1939		-----		16.81	18.83	15.76	17.34		16.74		-----

Year	**Charlotte**	**Jourdanton**	**Poteet**	**Beeville**	**San Antonio**	**George West**	**Three Rivers**	**Ray Point**	**Whitsett**	**Calliham**	**Tilden**
1940		-----		33.03	30.79	37.02	38.81		31.29		-----
1941		-----	-----	47.51	26.34	41.81	44.49		46.41		-----
1942		-----	33.27	39.94	38.46	28.55	32.40		29.06		-----
1943		-----	23.40	33.56	20.51	22.76	22.69		22.60		-----
1944		-----	30.08	28.40	33.19	31.70	29.60		26.11		-----
1945		-----	25.35	25.94	30.46	16.45	24.44		21.47		-----
1946		-----	49.03	37.12	45.17	30.88	36.67		31.68		-----
1947		-----	16.82	-----	17.32	26.44	26.21		20.20		-----
1948		19.15	19.33	19.93	23.63	18.90	18.28		17.07		-----
1949		35.90	40.26	34.92	40.79	35.40	36.42		27.97		-----
1950		17.92	15.07	13.89	19.85	15.86	15.01		15.91		-----
1951		18.70	22.34	25.46	24.43	24.16	27.97		24.46		-----
1952		16.73	18.94	32.14	26.24	20.32	17.81		28.93		-----
1953		20.07	17.74	19.27	17.56	25.86	19.41		19.50		-----
1954		12.63	13.22	15.39	13.70	16.54	14.73		20.23		-----
1955		17.04	18.98	19.52	18.18	12.16	-----		15.98		-----
1956		13.67	14.95	19.34	14.29	19.47	13.10		8.93		-----
1957		-----	43.29	40.04	48.80	29.89	-----		33.04		-----
1958		37.25	43.76	33.05	39.66	44.71	32.47		49.34		-----
1959		26.83	25.05	30.85	24.49	21.59	18.62		-----		18.03
1960		35.76	35.44	43.41	29.75	36.23	40.33		-----		35.51
1961		21.14	24.75	23.73	26.46	17.65	18.88		-----		20.60
1962	-----	15.72	16.11	31.42	23.89	12.38	15.46		-----		11.92
1963	-----	20.36	17.14	-----	18.64	20.53	21.28		-----		16.94
1964	19.71	18.77	19.46	-----	31.84	17.21	18.47		-----		15.11
1965	-----	31.08	30.72	32.83	36.65	27.45	28.19		22.78		24.47
1966	23.69	27.87	22.23	26.15	21.44	25.47	20.82		22.09		26.89
1967	26.37	30.47	28.65	42.03	29.25	39.85	43.73		45.19		30.07
1968	47.86	41.82	37.28	31.51	30.39	33.38	31.97		32.84		29.16
1969	31.23	25.75	-----	29.47	31.40	26.40	27.04		26.42		21.15
1970	27.50	31.00	23.66	28.00	22.74	24.62	24.20		28.49		22.75
1971	28.26	27.07	26.84	44.17	31.79	37.87	27.35		31.24		-----
1972	21.55	25.69	28.97	35.87	31.48	-----	-----		15.31		25.72
1973	34.64	-----	45.19	46.24	52.25	-----	-----		-----		-----
1974	29.04	24.41	35.23	31.04	36.99	46.11	24.36		21.80		22.09
1975	33.39	31.10	32.85	29.42	25.66	18.59	16.41		16.29		22.52
1976	38.51	-----	40.21	43.48	39.11	44.09	39.46		36.51		38.14
1977	21.22	22.91	23.62	30.37	29.62	28.67	23.49		24.36		20.11
1978	23.22	-----	23.43	34.17	35.97	22.46	21.72		19.64	-----	25.01
1979	23.47	22.62	31.60	37.72	36.63	25.57	27.14		-----	19.18	18.15
1980	30.25	33.09	30.81	37.03	24.22	37.89	30.53		31.43	28.31	24.50
1981	25.25	30.85	31.15	46.65	36.35	43.04	28.66		30.33	31.73	35.05
1982	28.73	-----	28.40	21.61	22.95	23.94	25.68		23.49	22.18	20.61
1983	21.64	30.64	21.69	35.82	26.10	21.47	22.49		27.18	-----	-----
1984	19.25	19.43	26.99	27.15	25.95	23.99	20.27		18.37	-----	16.00
1985	29.56	38.52	32.06	31.33	41.42	38.22	33.29		38.78	33.34	-----
1986	34.20	30.75	33.09	35.81	42.71	21.40	29.00		32.33	22.38	27.11
1987	28.14	30.56	-----	35.81	37.92	-----	26.73		27.85	24.31	25.88
1988	9.81	13.32	-----	17.56	19.00	-----		12.71	17.48	17.03	-----
1989	16.22	15.46	15.82	18.47	22.13	15.98		-----	19.50	13.11	13.21
1990	23.03	-----	27.24	35.43	38.28	25.84		26.72	27.58	30.16	23.11
1991	34.50	-----	36.47	35.37	42.73	35.28		32.37	39.76	-----	32.35
1992	40.67	42.09	38.81	48.11	46.49	32.31		31.75	32.37	-----	29.96
1993	29.18	22.70	36.15	37.46	31.99	22.27		20.31	19.82	-----	17.92
1994	23.96	29.40	27.50	35.97	40.42	27.66		30.84	29.71	29.02	36.34
1995	20.52	22.39	22.40	20.41	23.19	18.64		20.37	23.88	22.81	21.45
1996	12.28	17.18	10.14	21.38	17.80	16.16		13.30	15.18	13.05	13.49
1997	32.97	28.76	32.54	40.51	33.91	37.48		39.12	49.07	33.57	36.02
1998	33.77	32.43	28.81	35.11	42.03	25.55		33.42	39.98	27.04	21.07
1999	17.91	17.96	19.45	23.46	16.41	21.16		13.18	21.91	16.25	12.44
2000	25.61	32.58	33.91	31.63	35.84	25.74		32.69	22.32	27.36	19.02
2001	21.31	24.21	26.75	38.54	36.71	32.66		23.42	31.21	20.79	23.91
2002	44.31	39.19	44.77	35.82	46.25	41.56		42.41	38.66	41.24	39.90
2003	27.44	25.05	-----	32.57	28.45	27.57		32.29	-----	32.57	33.24
2004	42.87	38.61	44.59	46.57	45.29	33.07		38.97	-----	33.43	34.88
2005	20.38	16.80	15.55	27.39	16.54	19.73		24.12	-----	19.27	16.88
2006	10.63	13.79	12.41	27.17	21.34	25.13		12.37	15.52	18.18	17.29
2007	56.97	48.62	47.80	46.64	47.23	48.26		50.63	46.47	39.09	38.35

Year	**Charlotte**	**Jourdanton**	**Poteet**	**Beeville**	**San Antonio**	**George West**	**Three Rivers**	**Ray Point**	**Whitsett**	**Calliham**	**Tilden**
2008	18.24	21.37	20.84	18.95	13.76	19.77		13.45	18.02	13.76	17.87
2009	23.31	20.99	24.67	30.97	30.68	18.31		25.07	27.63	27.66	20.78
2010	26.46	31.93	31.93	42.67	37.37	38.74		36.05	39.34	48.25	-----
2011	12.22	-----	11.49	12.47	17.57	12.40		11.63	15.07	11.28	
2012	-----		22.40	21.23	39.37	20.36		18.12	17.40	19.70	
MEAN	27.05	25.78	27.63	31.36	28.93	27.05	26.40	26.47	26.39	25.38	24.26

Note: Ray Point = Three Rivers (8 NE)

Appendix Table A.11 Two-way comparisons of annual precipitation (inches) between Runge, Karnes County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Runge	**Karnes**	**Diff**	**Runge**	**Kenedy**	**Diff**	**Runge**	**Falls City**	**Diff**	**Runge**	**Floresville**	**Diff**	**Runge**	**Nixon**	**Diff**	**Runge**	**Stockdale**	**Diff**
25.62	21.47	4.15	38.86	38.14	0.72	38.86	39.04	0.18	13.60	7.88	5.72	29.38	23.31	6.07	41.44	43.29	1.85
30.06	23.18	6.88	14.84	19.97	5.13	14.84	18.94	4.10	30.75	30.39	0.36	45.57	44.28	1.29	27.30	42.72	15.42
29.38	28.18	1.20	26.92	30.37	3.45	26.92	20.81	6.11	45.80	46.29	0.49	20.65	21.73	1.08	28.08	25.70	2.38
45.57	44.29	1.28	33.23	28.59	4.64	33.23	22.19	11.04	25.62	20.45	5.17	15.43	18.36	2.93	31.07	38.25	7.18
20.65	20.93	0.28	22.73	22.67	0.06	22.73	28.34	5.61	30.06	21.42	8.64	32.28	36.52	4.24	36.90	42.48	5.58
15.43	22.90	7.47	19.99	24.21	4.22	19.99	18.59	1.40	29.38	28.70	0.68	22.29	30.72	8.43	28.35	30.95	2.60
32.28	33.67	1.39	17.42	17.27	0.15	17.42	11.34	6.08	45.57	43.34	2.23	22.91	27.44	4.53	40.50	35.78	4.72
22.29	25.23	2.94	35.49	36.78	1.29	43.14	41.13	2.01	20.65	24.15	3.50	34.89	39.49	4.60	22.24	27.79	5.55
22.91	27.96	5.05	31.11	26.97	4.14	35.49	31.79	3.70	15.43	16.86	1.43	16.96	21.54	4.58	26.59	30.10	3.51
34.89	42.24	7.35	43.43	46.20	2.77	31.11	21.81	9.30	32.28	25.53	6.75	36.53	22.62	13.91	28.68	32.62	3.94
16.96	24.04	7.08	20.79	23.82	3.03	43.43	46.03	2.60	22.29	24.84	2.55	26.98	29.31	2.33	32.10	38.53	6.43
36.53	33.16	3.37	26.67	27.31	0.64	20.79	28.94	8.15	22.91	28.20	5.29	25.41	30.26	4.85	20.08	18.01	2.07
26.98	32.25	5.27	18.15	22.88	4.73	26.67	24.18	2.49	34.89	28.83	6.06	45.26	44.12	1.14	21.14	25.22	4.08
25.41	24.24	1.17	27.23	23.63	3.60	18.15	22.36	4.21	16.96	20.39	3.43	31.36	39.06	7.70	20.89	24.17	3.28
36.50	38.92	2.42	41.53	41.88	0.35	27.23	21.06	6.17	36.53	27.07	9.46	19.73	25.70	5.97	40.29	42.16	1.87
45.26	56.52	11.26	28.68	25.27	3.41	41.53	29.34	12.19	26.98	29.30	2.32	16.14	31.00	14.86	32.94	56.52	23.58
31.36	49.97	18.61	44.32	46.44	2.12	28.68	22.02	6.66	25.41	21.24	4.17	19.24	16.64	2.60	24.02	37.21	13.19
19.73	24.77	5.04	31.46	44.97	13.51	44.32	37.90	6.42	45.26	45.93	0.67	46.87	39.51	7.36	39.49	33.84	5.65
16.14	24.67	8.53	31.88	34.01	2.13	31.46	41.90	10.44	19.24	13.75	5.49	41.44	48.92	7.48	22.86	31.17	8.31
19.24	17.08	2.16	28.73	33.15	4.42	28.73	23.96	4.77	46.87	32.53	14.34	27.30	37.53	10.23	24.67	16.51	8.16
46.87	40.66	6.21	31.89	32.75	0.86	31.89	24.92	6.97	41.44	37.25	4.19	28.08	21.89	6.19	39.60	32.64	6.96
41.44	51.76	10.32	51.93	41.99	9.94	29.96	29.89	0.07	27.30	35.77	8.47	31.07	32.69	1.62	38.80	37.22	1.58
27.30	34.72	7.42	27.48	26.75	0.73	51.93	43.75	8.18	28.08	22.88	5.20	21.97	27.40	5.43	15.71	21.80	6.09
28.08	24.85	3.23				27.48	27.98	0.50	31.07	24.08	6.99	45.42	58.06	12.64	35.27	34.41	0.86
31.07	28.22	2.85				45.20	35.30	9.90	21.97	16.65	5.32	28.76	20.90	7.86	39.17	36.65	2.52
45.42	50.30	4.88				33.57	22.09	11.48	45.42	44.55	0.87	25.08	21.86	3.22	32.90	25.77	7.13
25.08	28.09	3.01				33.88	29.40	4.48	25.08	22.06	3.02	38.86	32.00	6.86	43.87	46.90	3.03
14.84	18.10	3.26				36.90	29.65	7.25	38.86	34.82	4.04	14.84	25.21	10.37	32.72	19.90	12.82
26.92	24.69	2.23				28.35	32.53	4.18	26.92	22.47	4.45	26.92	20.83	6.09	25.16	32.11	6.95
33.23	28.71	4.52				40.50	28.45	12.05	33.23	26.90	6.33	33.23	34.60	1.37	16.62	25.83	9.21
22.73	28.71	5.98				22.24	29.58	7.34	22.73	22.53	0.20	22.73	24.25	1.52	33.49	38.84	5.35
19.99	23.06	3.07				26.59	26.69	0.10	19.99	22.79	2.80	19.99	23.15	3.16	33.38	29.81	3.57
17.42	16.68	0.74				36.96	32.38	4.58	17.42	17.90	0.48	43.14	52.15	9.01	19.45	33.23	13.78
43.14	44.75	1.61				32.10	34.14	2.04	43.14	38.68	4.46	35.49	37.45	1.96			
35.49	46.80	11.31				20.08	16.14	3.94	35.49	43.40	7.91	31.11	27.68	3.43			
31.11	28.11	3.00				21.14	21.42	0.28	31.11	32.08	0.97	43.43	45.89	2.46			
43.43	36.13	7.30				20.89	27.46	6.57	43.43	39.69	3.74	20.79	32.53	11.74			
20.79	18.93	1.86				40.29	38.64	1.65	20.79	26.86	6.07	26.67	26.00	0.67			
26.67	25.69	0.98				32.94	36.54	3.60	27.23	24.42	2.81	18.15	18.83	0.68			
18.15	24.32	6.17				24.02	28.84	4.82	28.68	27.23	1.45	27.23	24.32	2.91			
27.23	22.82	4.41				39.49	36.56	2.93	44.32	38.77	5.55	41.53	42.63	1.10			
41.53	37.03	4.50				22.86	18.75	4.11	31.88	35.29	3.41	44.32	36.12	8.20			
28.68	21.76	6.92				24.67	20.72	3.95	28.73	23.45	5.28	31.46	39.66	8.20			
44.32	46.96	2.64				39.60	26.86	12.74	31.89	19.75	12.14	31.88	38.10	6.22			
31.46	33.57	2.11				38.80	28.04	10.76	29.96	22.34	7.62	28.73	27.01	1.72			
31.88	28.63	3.25				15.71	24.25	8.54	51.93	54.35	2.42	31.89	30.57	1.32			
28.73	27.97	0.76				35.27	31.74	3.53	27.48	32.50	5.02	29.96	33.51	3.55			
31.89	24.00	7.89				40.89	35.90	4.99	25.90	29.96	4.06	51.93	47.36	4.57			
29.96	24.22	5.74				32.90	27.92	4.98	45.20	36.52	8.68	27.48	36.44	8.96			
33.88	27.84	6.04				43.87	37.98	5.89	33.57	25.29	8.28	25.90	31.45	5.55			
36.90	33.79	3.11				32.72	17.00	15.72	33.88	30.89	2.99	45.20	47.28	2.08			
28.35	23.28	5.07				25.16	18.06	7.10	36.90	29.95	6.95	33.57	30.93	2.64			
40.50	41.61	1.11				16.62	14.27	2.35	28.35	24.15	4.20	33.88	33.59	0.29			
36.96	34.83	2.13				33.49	25.03	8.46	40.50	24.88	15.62	40.50	34.56	5.94			
32.10	24.79	7.31				33.38	26.39	6.99	26.59	27.72	1.13	22.24	21.79	0.45			
20.08	15.87	4.21				15.17	14.81	0.36	36.96	27.98	8.98	26.59	36.72	10.13			
21.14	23.16	2.02				19.45	16.52	2.93	28.68	27.29	1.39	36.96	37.57	0.61			
20.89	25.61	4.72							32.94	52.06	19.12	28.68	29.76	1.08			
40.29	35.22	5.07							24.02	46.09	22.07	21.14	27.78	6.64			
32.94	41.38	8.44							39.49	32.73	6.76	20.89	24.03	3.14			
24.02	25.54	1.52							22.86	18.69	4.17	40.29	42.81	2.52			
24.67	20.51	4.16							24.67	21.23	3.44	32.94	58.50	25.56			
39.60	36.69	2.91							39.60	29.92	9.68	24.02	40.05	16.03			
38.80	36.01	2.79							38.80	35.62	3.18	39.49	35.84	3.65			
15.71	20.35	4.64							15.71	15.47	0.24	39.60	35.31	4.29			
35.27	31.44	3.83							35.27	31.64	3.63	38.80	44.00	5.20			
40.89	38.21	2.68							39.17	30.82	8.35	15.71	23.07	7.36			
32.90	26.56	6.34							40.89	41.01	0.12	35.27	37.63	2.36			
43.87	42.31	1.56							32.90	29.16	3.74	39.17	42.30	3.13			
32.72	20.70	12.02							43.87	40.90	2.97	32.72	23.24	9.48			
									32.72	18.37	14.35	25.16	23.62	1.54			
									25.16	28.33	3.17	16.62	19.80	3.18			
									16.62	13.41	3.21	33.49	40.50	7.01			
									33.49	29.71	3.78	19.45	27.02	7.57			
									33.38	35.82	2.44						
									15.17	13.56	1.61						
									19.45	29.70	10.25						
MEANS:																	
30.29	30.45	4.61	30.21	31.13	3.31	30.56	27.51	5.61	30.97	28.90	5.18	30.37	32.65	5.36	30.17	32.97	6.34
	N = 70			N = 23			N = 57			N = 77			N = 74			N = 33	

Appendix Table A.12 Two-way comparisons of annual precipitation (inches) between Karnes City, Karnes County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Karnes	**Runge**	**Diff**	**Karnes**	**Kenedy**	**Diff**	**Karnes**	**Falls City**	**Diff**	**Karnes**	**Floresville**	**Diff**	**Karnes**	**Nixon**	**Diff**	**Karnes**	**Stockdale**	**Diff**
21.47	25.62	4.15	18.10	19.97	1.87	18.10	18.94	0.84	21.47	20.45	1.02	28.18	23.31	4.87	51.76	43.29	8.47
23.18	30.06	6.88	24.69	30.37	5.68	24.69	20.81	3.88	23.18	21.42	1.76	44.29	44.28	0.01	34.72	42.72	8.00
28.18	29.38	1.20	28.71	28.59	0.12	28.71	22.19	6.52	28.18	28.70	0.52	20.93	21.73	0.80	24.85	25.70	0.85
44.29	45.57	1.28	28.71	22.67	6.04	28.71	28.34	0.37	44.29	43.34	0.95	22.90	18.36	4.54	28.22	38.25	10.03
20.93	20.65	0.28	18.97	15.89	3.08	18.97	17.29	1.68	20.93	24.15	3.22	33.67	36.52	2.85	33.79	42.48	8.69
22.90	15.43	7.47	23.06	24.21	1.15	23.06	18.59	4.47	22.90	16.86	6.04	25.23	30.72	5.49	23.28	30.95	7.67
33.67	32.28	1.39	16.68	17.27	0.59	16.68	11.34	5.34	33.67	25.53	8.14	27.96	27.44	0.52	41.61	35.78	5.83
25.23	22.29	2.94	46.80	36.78	10.02	44.75	41.13	3.62	25.23	24.84	0.39	42.24	39.49	2.75	24.79	38.53	13.74
27.96	22.91	5.05	28.11	26.97	1.14	46.80	31.79	15.01	27.96	28.20	0.24	24.04	21.54	2.50	15.87	18.01	2.14
42.24	34.89	7.35	36.13	46.20	10.07	28.11	21.81	6.30	42.24	28.83	13.41	33.16	22.62	10.54	23.16	25.22	2.06
24.04	16.96	7.08	18.93	23.82	4.89	36.13	46.03	9.90	24.04	20.39	3.65	32.25	29.31	2.94	25.61	24.17	1.44
33.16	36.53	3.37	25.69	27.31	1.62	18.93	28.94	10.01	33.16	27.07	6.09	24.24	30.26	6.02	35.22	42.16	6.94
32.25	26.98	5.27	24.32	22.88	1.44	25.69	24.18	1.51	32.25	29.30	2.95	56.52	44.12	12.40	41.38	56.52	15.14
24.24	25.41	1.17	22.82	23.63	0.81	24.32	22.36	1.96	24.24	21.24	3.00	49.97	39.06	10.91	25.54	37.21	11.67
38.92	36.50	2.42	37.03	41.88	4.85	22.82	21.06	1.76	56.52	45.93	10.59	24.77	25.70	0.93	20.51	16.51	4.00
56.52	45.26	11.26	21.76	25.27	3.51	37.03	29.34	7.69	17.08	13.75	3.33	24.67	31.00	6.33	36.69	32.64	4.05
49.97	31.36	18.61	46.96	46.44	0.52	21.76	22.02	0.26	40.66	32.53	8.13	17.08	16.64	0.44	36.01	37.22	1.21
24.77	19.73	5.04	33.57	44.97	11.40	46.96	37.90	9.06	51.76	37.25	14.51	40.66	39.51	1.15	20.35	21.80	1.45
24.67	16.14	8.53	28.63	34.01	5.38	33.57	41.90	8.33	34.72	35.77	1.05	51.76	48.92	2.84	31.44	34.41	2.97
17.08	19.24	2.16	27.97	33.15	5.18	27.97	23.96	4.01	24.85	22.88	1.97	34.72	37.53	2.81	26.56	25.77	0.79
40.66	46.87	6.21	24.00	32.75	8.75	24.00	24.92	0.92	28.22	24.08	4.14	24.85	21.89	2.96	42.31	46.90	4.59
51.76	41.44	10.32				24.22	29.89	5.67	50.30	44.55	5.75	28.22	32.69	4.47	20.70	19.90	0.80
34.72	27.30	7.42				27.84	29.40	1.56	28.09	22.06	6.03	50.30	58.06	7.76			
24.85	28.08	3.23				33.79	29.65	4.14	24.69	22.47	2.22	28.09	21.86	6.23			
28.22	31.07	2.85				23.28	32.53	9.25	28.71	26.90	1.81	18.10	25.21	7.11			
50.30	45.42	4.88				41.61	28.45	13.16	28.71	22.53	6.18	24.69	20.83	3.86			
28.09	25.08	3.01				22.37	16.83	5.54	18.97	18.29	0.68	28.71	34.60	5.89			
18.10	14.84	3.26				34.83	32.38	2.45	23.06	22.79	0.27	28.71	24.25	4.46			
24.69	26.92	2.23				24.79	34.14	9.35	16.68	17.90	1.22	18.97	18.28	0.69			
28.71	33.23	4.52				15.87	16.14	0.27	44.75	38.68	6.07	23.06	23.15	0.09			
28.71	22.73	5.98				23.16	21.42	1.74	46.80	43.40	3.40	44.75	52.15	7.40			
23.06	19.99	3.07				25.61	27.46	1.85	28.11	32.08	3.97	46.80	37.45	9.35			
16.68	17.42	0.74				35.22	38.64	3.42	36.13	39.69	3.56	28.11	27.68	0.43			
44.75	43.14	1.61				41.38	36.54	4.84	18.93	26.86	7.93	36.13	45.89	9.76			
46.80	35.49	11.31				25.54	28.84	3.30	22.82	24.42	1.60	18.93	32.53	13.60			
28.11	31.11	3.00				20.51	20.72	0.21	21.76	27.23	5.47	25.69	26.00	0.31			
36.13	43.43	7.30				36.69	26.86	9.83	46.96	38.77	8.19	24.32	18.83	5.49			
18.93	20.79	1.86				36.01	28.04	7.97	28.63	35.29	6.66	22.82	24.32	1.50			
25.69	26.67	0.98				20.35	24.25	3.90	27.97	23.45	4.52	37.03	42.63	5.60			
24.32	18.15	6.17				31.44	31.74	0.30	24.00	19.75	4.25	46.96	36.12	10.84			
22.82	27.23	4.41				38.21	35.90	2.31	24.22	22.34	1.88	33.57	39.66	6.09			
37.03	41.53	4.50				26.56	27.92	1.36	27.84	30.89	3.05	28.63	38.10	9.47			
21.76	28.68	6.92				42.31	37.98	4.33	33.79	29.95	3.84	27.97	27.01	0.96			
46.96	44.32	2.64				20.70	17.00	3.70	23.28	24.15	0.87	24.00	30.57	6.57			
33.57	31.46	2.11							41.61	24.88	16.73	24.22	33.51	9.29			
28.63	31.88	3.25							34.83	27.98	6.85	27.84	33.59	5.75			
27.97	28.73	0.76							41.38	52.06	10.68	41.61	34.56	7.05			
24.00	31.89	7.89							25.54	46.09	20.55	34.83	37.57	2.74			
24.22	29.96	5.74							20.51	21.23	0.72	23.16	27.78	4.62			
27.84	33.88	6.04							36.69	29.92	6.77	25.61	24.03	1.58			
33.79	36.90	3.11							36.01	35.62	0.39	35.22	42.81	7.59			
23.28	28.35	5.07							20.35	15.47	4.88	41.38	58.50	17.12			
41.61	40.50	1.11							31.44	31.64	0.20	25.54	40.05	14.51			
34.83	36.96	2.13							38.21	41.01	2.80	36.69	35.31	1.38			
24.79	32.10	7.31							26.56	29.16	2.60	36.01	44.00	7.99			
15.87	20.08	4.21							42.31	40.90	1.41	20.35	23.07	2.72			
23.16	21.14	2.02							20.70	18.37	2.33	31.44	37.63	6.19			
25.61	20.89	4.72										20.70	23.24	2.54			
35.22	40.29	5.07															
41.38	32.94	8.44															
25.54	24.02	1.52															
20.51	24.67	4.16															
36.69	39.60	2.91															
36.01	38.80	2.79															
20.35	15.71	4.64															
31.44	35.27	3.83															
38.21	40.89	2.68															
26.56	32.90	6.34															
42.31	43.87	1.56															
20.70	32.72	12.02															
MEANS:																	
30.45	30.29	4.61	27.70	29.76	4.20	28.86	27.44	4.63	30.68	28.79	4.59	31.09	32.47	5.23	30.20	33.46	5.57
	N = 70			N = 21			N = 43			N = 57			N = 58			N = 22	

Appendix Table A.13 Two-way comparisons of annual precipitation (inches) between Kenedy, Karnes County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Kenedy	**Runge**	**Diff**	**Kenedy**	**Karnes**	**Diff**	**Kenedy**	**Falls City**	**Diff**	**Kenedy**	**Floresville**	**Diff**	**Kenedy**	**Nixon**	**Diff**
38.14	38.86	0.72	19.97	18.10	1.87	38.14	39.04	0.90	38.14	34.82	3.32	38.14	32.00	6.14
19.97	14.84	5.13	30.37	24.69	5.68	19.97	18.94	1.03	30.37	22.47	7.90	19.97	25.21	5.24
30.37	26.92	3.45	28.59	28.71	0.12	30.37	20.81	9.56	28.59	26.90	1.69	30.37	20.83	9.54
28.59	33.23	4.64	22.67	28.71	6.04	28.59	22.19	6.40	22.67	22.53	0.14	28.59	34.60	6.01
22.67	22.73	0.06	15.89	18.97	3.08	22.67	28.34	5.67	15.89	18.29	2.40	22.67	24.25	1.58
24.21	19.99	4.22	24.21	23.06	1.15	15.89	17.29	1.40	24.21	22.79	1.42	15.89	18.28	2.39
17.27	17.42	0.15	17.27	16.68	0.59	24.21	18.59	5.62	17.27	17.90	0.63	24.21	23.15	1.06
36.78	35.49	1.29	36.78	46.80	10.02	17.27	11.34	5.93	36.78	43.40	6.62	36.78	37.45	0.67
26.97	31.11	4.14	26.97	28.11	1.14	36.78	31.79	4.99	26.97	32.08	5.11	26.97	27.68	0.71
46.20	43.43	2.77	46.20	36.13	10.07	26.97	21.81	5.16	46.20	39.69	6.51	46.20	45.89	0.31
23.82	20.79	3.03	23.82	18.93	4.89	46.20	46.03	0.17	23.82	26.86	3.04	23.82	32.53	8.71
27.31	26.67	0.64	27.31	25.69	1.62	23.82	28.94	5.12	23.63	24.42	0.79	27.31	26.00	1.31
22.88	18.15	4.73	22.88	24.32	1.44	27.31	24.18	3.13	25.27	27.23	1.96	22.88	18.83	4.05
23.63	27.23	3.60	23.63	22.82	0.81	22.88	22.36	0.52	46.44	38.77	7.67	23.63	24.32	0.69
41.88	41.53	0.35	41.88	37.03	4.85	23.63	21.06	2.57	34.01	35.29	1.28	41.88	42.63	0.75
25.27	28.68	3.41	25.27	21.76	3.51	41.88	29.34	12.54	33.15	23.45	9.70	46.44	36.12	10.32
46.44	44.32	2.12	46.44	46.96	0.52	25.27	22.02	3.25	32.75	19.75	13.00	44.97	39.66	5.31
44.97	31.46	13.51	44.97	33.57	11.40	46.44	37.90	8.54	41.99	54.35	12.36	34.01	38.10	4.09
34.01	31.88	2.13	34.01	28.63	5.38	44.97	41.90	3.07	26.75	32.50	5.75	33.15	27.01	6.14
33.15	28.73	4.42	33.15	27.97	5.18	33.15	23.96	9.19				32.75	30.57	2.18
32.75	31.89	0.86	32.75	24.00	8.75	32.75	24.92	7.83				41.99	47.36	5.37
41.99	51.93	9.94				41.99	43.75	1.76				26.75	36.44	9.69
26.75	27.48	0.73				26.75	27.98	1.23						
MEANS:														
31.13	30.21	3.31	29.76	27.70	4.20	30.34	27.15	4.59	30.26	29.66	4.80	31.34	31.31	4.19
	N = 23			N = 21			N = 23			N = 19			N = 22	

No common years for Kenedy/Stockdale

Appendix Table A.14 Two-way comparisons of annual precipitation (inches) between Falls City, Wilson County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Falls City	**Runge**	**Diff**	**Falls City**	**Karnes**	**Diff**	**Falls City**	**Kenedy**	**Diff**	**Falls City**	**Floresville**	**Diff**	**Falls City**	**Nixon**	**Diff**	**Falls City**	**Stockdale**	**Diff**
39.04	38.86	0.18	18.94	18.10	0.84	39.04	38.14	0.90	39.04	34.82	4.22	39.04	32.00	7.04	29.65	42.48	12.83
18.94	14.84	4.10	20.81	24.69	3.88	18.94	19.97	1.03	20.81	22.47	1.66	18.94	25.21	6.27	32.53	30.95	1.58
20.81	26.92	6.11	22.19	28.71	6.52	20.81	30.37	9.56	22.19	26.90	4.71	20.81	20.83	0.02	28.45	35.78	7.33
22.19	33.23	11.04	28.34	28.71	0.37	22.19	28.59	6.40	28.34	22.53	5.81	22.19	34.60	12.41	29.58	27.79	1.79
28.34	22.73	5.61	17.29	18.97	1.68	28.34	22.67	5.67	17.29	18.29	1.00	28.34	24.25	4.09	26.69	30.10	3.41
18.59	19.99	1.40	18.59	23.06	4.47	17.29	15.89	1.40	18.59	22.79	4.20	17.29	18.28	0.99	34.14	38.53	4.39
11.34	17.42	6.08	11.34	16.68	5.34	18.59	24.21	5.62	11.34	17.90	6.56	18.59	23.15	4.56	16.14	18.01	1.87
41.13	43.14	2.01	41.13	44.75	3.62	11.34	17.27	5.93	41.13	38.68	2.45	41.13	52.15	11.02	21.42	25.22	3.80
31.79	35.49	3.70	31.79	46.80	15.01	31.79	36.78	4.99	31.79	43.40	11.61	31.79	37.45	5.66	27.46	24.17	3.29
21.81	31.11	9.30	21.81	28.11	6.30	21.81	26.97	5.16	21.81	32.08	10.27	21.81	27.68	5.87	38.64	42.16	3.52
46.03	43.43	2.60	46.03	36.13	9.90	46.03	46.20	0.17	46.03	39.69	6.34	46.03	45.89	0.14	36.54	56.52	19.98
28.94	20.79	8.15	28.94	18.93	10.01	28.94	23.82	5.12	28.94	26.86	2.08	28.94	32.53	3.59	28.84	37.21	8.37
24.18	26.67	2.49	24.18	25.69	1.51	24.18	27.31	3.13	21.06	24.42	3.36	24.18	26.00	1.82	36.56	33.84	2.72
22.36	18.15	4.21	22.36	24.32	1.96	22.36	22.88	0.52	22.02	27.23	5.21	22.36	18.83	3.53	18.75	31.17	12.42
21.06	27.23	6.17	21.06	22.82	1.76	21.06	23.63	2.57	37.90	38.77	0.87	21.06	24.32	3.26	20.72	16.51	4.21
29.34	41.53	12.19	29.34	37.03	7.69	29.34	41.88	12.54	23.96	23.45	0.51	29.34	42.63	13.29	26.86	32.64	5.78
22.02	28.68	6.66	22.02	21.76	0.26	22.02	25.27	3.25	24.92	19.75	5.17	37.90	36.12	1.78	28.04	37.22	9.18
37.90	44.32	6.42	37.90	46.96	9.06	37.90	46.44	8.54	29.89	22.34	7.55	41.90	39.66	2.24	24.25	21.80	2.45
41.90	31.46	10.44	41.90	33.57	8.33	41.90	44.97	3.07	43.75	54.35	10.60	23.96	27.01	3.05	31.74	34.41	2.67
23.96	28.73	4.77	23.96	27.97	4.01	23.96	33.15	9.19	27.98	32.50	4.52	24.92	30.57	5.65	27.92	25.77	2.15
24.92	31.89	6.97	24.92	24.00	0.92	24.92	32.75	7.83	35.30	36.52	1.22	29.89	33.51	3.62	37.98	46.90	8.92
29.89	29.96	0.07	29.89	24.22	5.67	43.75	41.99	1.76	22.09	25.29	3.20	43.75	47.36	3.61	17.00	19.90	2.90
43.75	51.93	8.18	29.40	27.84	1.56	27.98	26.75	1.23	29.40	30.89	1.49	27.98	36.44	8.46	18.06	32.11	14.05
27.98	27.48	0.50	29.65	33.79	4.14				29.65	29.95	0.30	35.30	47.28	11.98	40.67	51.23	10.56
35.30	45.20	9.90	32.53	23.28	9.25				32.53	24.15	8.38	22.09	30.93	8.84	14.27	25.83	11.56
22.09	33.57	11.48	28.45	41.61	13.16				28.45	24.88	3.57	29.40	33.59	4.19	25.03	38.84	13.81
29.40	33.88	4.48	16.83	22.37	5.54				26.69	27.72	1.03	28.45	34.56	6.11	26.39	29.81	3.42
29.65	36.90	7.25	32.38	34.83	2.45				32.38	27.98	4.40	29.58	21.79	7.79	16.52	33.23	16.71
32.53	28.35	4.18	34.14	24.79	9.35				36.54	52.06	15.52	26.69	36.72	10.03			
28.45	40.50	12.05	16.14	15.87	0.27				28.84	46.09	17.25	32.38	37.57	5.19			
29.58	22.24	7.34	21.42	23.16	1.74				36.56	32.73	3.83	21.42	27.78	6.36			
26.69	26.59	0.10	27.46	25.61	1.85				18.75	18.69	0.06	27.46	24.03	3.43			
32.38	36.96	4.58	38.64	35.22	3.42				20.72	21.23	0.51	38.64	42.81	4.17			
34.14	32.10	2.04	36.54	41.38	4.84				26.86	29.92	3.06	36.54	58.50	21.96			
16.14	20.08	3.94	28.84	25.54	3.30				28.04	35.62	7.58	28.84	40.05	11.21			
21.42	21.14	0.28	20.72	20.51	0.21				24.25	15.47	8.78	36.56	35.84	0.72			
27.46	20.89	6.57	26.86	36.69	9.83				31.74	31.64	0.10	26.86	35.31	8.45			
38.64	40.29	1.65	28.04	36.01	7.97				35.90	41.01	5.11	28.04	44.00	15.96			
36.54	32.94	3.60	24.25	20.35	3.90				27.92	29.16	1.24	24.25	23.07	1.18			
28.84	24.02	4.82	31.74	31.44	0.30				37.98	40.90	2.92	31.74	37.63	5.89			
36.56	39.49	2.93	35.90	38.21	2.31				17.00	18.37	1.37	17.00	23.24	6.24			
18.75	22.86	4.11	27.92	26.56	1.36				18.06	28.33	10.27	18.06	23.62	5.56			
20.72	24.67	3.95	37.98	42.31	4.33				40.67	48.86	8.19	40.67	49.26	8.59			
26.86	39.60	12.74	17.00	20.70	3.70				14.27	13.41	0.86	14.27	19.80	5.53			
28.04	38.80	10.76							25.03	29.71	4.68	25.03	40.50	15.47			
24.25	15.71	8.54							26.39	35.82	9.43	16.52	27.02	10.50			
31.74	35.27	3.53							14.81	13.56	1.25						
35.90	40.89	4.99							16.52	29.70	13.18						
27.92	32.90	4.98															
37.98	43.87	5.89															
17.00	32.72	15.72															
18.06	25.16	7.10															
14.27	16.62	2.35															
25.03	33.49	8.46															
26.39	33.38	6.99															
14.81	15.17	0.36															
16.52	19.45	2.93															
MEANS:																	
27.51	30.56	5.61	27.44	28.86	4.63	27.15	30.34	4.59	27.54	29.77	4.95	28.22	33.29	6.46	27.17	32.86	6.99
	N = 57		N = 43				N = 23			N = 48			N = 46			N = 28	

Appendix Table A.15 Two-way comparisons of annual precipitation (inches) between Floresville, Wilson County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Floresville	**Runge**	**Diff**	**Floresville**	**Karnes**	**Diff**	**Floresville**	**Kenedy**	**Diff**	**Floresville**	**Falls City**	**Diff**	**Floresville**	**Nixon**	**Diff**	**Floresville**	**Stockdale**	**Diff**
7.88	13.60	5.72	20.45	21.47	1.02	34.82	38.14	3.32	34.82	39.04	4.22	28.70	23.31	5.39	37.25	43.29	6.04
30.39	30.75	0.36	21.42	23.18	1.76	22.47	30.37	7.90	22.47	20.81	1.66	43.34	44.28	0.94	35.77	42.72	6.95
46.29	45.80	0.49	28.70	28.18	0.52	26.90	28.59	1.69	26.90	22.19	4.71	24.15	21.73	2.42	22.88	25.70	2.82
20.45	25.62	5.17	43.34	44.29	0.95	22.53	22.67	0.14	22.53	28.34	5.81	16.86	18.36	1.50	24.08	38.25	14.17
21.42	30.06	8.64	24.15	20.93	3.22	18.29	15.89	2.40	18.29	17.29	1.00	25.53	36.52	10.99	29.95	42.48	12.53
28.70	29.38	0.68	16.86	22.90	6.04	22.79	24.21	1.42	22.79	18.59	4.20	24.84	30.72	5.88	24.15	30.95	6.80
43.34	45.57	2.23	25.53	33.67	8.14	17.90	17.27	0.63	17.90	11.34	6.56	28.20	27.44	0.76	24.88	35.78	10.90
24.15	20.65	3.50	24.84	25.23	0.39	43.40	36.78	6.62	38.68	41.13	2.45	28.83	39.49	10.66	27.72	30.10	2.38
16.86	15.43	1.43	28.20	27.96	0.24	32.08	26.97	5.11	43.40	31.79	11.61	20.39	21.54	1.15	27.29	32.62	5.33
25.53	32.28	6.75	28.83	42.24	13.41	39.69	46.20	6.51	32.08	21.81	10.27	27.07	22.62	4.45	52.06	56.52	4.46
24.84	22.29	2.55	20.39	24.04	3.65	26.86	23.82	3.04	39.69	46.03	6.34	29.30	29.31	0.01	46.09	37.21	8.88
28.20	22.91	5.29	27.07	33.16	6.09	24.42	23.63	0.79	26.86	28.94	2.08	21.24	30.26	9.02	32.73	33.84	1.11
28.83	34.89	6.06	29.30	32.25	2.95	27.23	25.27	1.96	24.42	21.06	3.36	45.93	44.12	1.81	18.69	31.17	12.48
20.39	16.96	3.43	21.24	24.24	3.00	38.77	46.44	7.67	27.23	22.02	5.21	13.75	16.64	2.89	21.23	16.51	4.72
27.07	36.53	9.46	45.93	56.52	10.59	35.29	34.01	1.28	38.77	37.90	0.87	32.53	39.51	6.98	29.92	32.64	2.72
29.30	26.98	2.32	13.75	17.08	3.33	23.45	33.15	9.70	23.45	23.96	0.51	37.25	48.92	11.67	35.62	37.22	1.60
21.24	25.41	4.17	32.53	40.66	8.13	19.75	32.75	13.00	19.75	24.92	5.17	35.77	37.53	1.76	15.47	21.80	6.33
45.93	45.26	0.67	37.25	51.76	14.51	54.35	41.99	12.36	22.34	29.89	7.55	22.88	21.89	0.99	31.64	34.41	2.77
13.75	19.24	5.49	35.77	34.72	1.05	32.50	26.75	5.75	54.35	43.75	10.60	24.08	32.69	8.61	30.82	36.65	5.83
32.53	46.87	14.34	22.88	24.85	1.97				32.50	27.98	4.52	16.65	27.40	10.75	29.16	25.77	3.39
37.25	41.44	4.19	24.08	28.22	4.14				36.52	35.30	1.22	44.55	58.06	13.51	40.90	46.90	6.00
35.77	27.30	8.47	44.55	50.30	5.75				25.29	22.09	3.20	22.06	21.86	0.20	18.37	19.90	1.53
22.88	28.08	5.20	22.06	28.09	6.03				30.89	29.40	1.49	34.82	32.00	2.82	28.33	32.11	3.78
24.08	31.07	6.99	22.47	24.69	2.22				29.95	29.65	0.30	22.47	20.83	1.64	48.86	51.23	2.37
16.65	21.97	5.32	26.90	28.71	1.81				24.15	32.53	8.38	26.90	34.60	7.70	13.41	25.83	12.42
44.55	45.42	0.87	22.53	28.71	6.18				24.88	28.45	3.57	22.53	24.25	1.72	29.71	38.84	9.13
22.06	25.08	3.02	18.29	18.97	0.68				27.72	26.69	1.03	18.29	18.28	0.01	35.82	29.81	6.01
34.82	38.86	4.04	22.79	23.06	0.27				27.98	32.38	4.40	22.79	23.15	0.36	29.70	33.23	3.53
22.47	26.92	4.45	17.90	16.68	1.22				52.06	36.54	15.52	38.68	52.15	13.47			
26.90	33.23	6.33	38.68	44.75	6.07				46.09	28.84	17.25	43.40	37.45	5.95			
22.53	22.73	0.20	43.40	46.80	3.40				32.73	36.56	3.83	32.08	27.68	4.40			
22.79	19.99	2.80	32.08	28.11	3.97				18.69	18.75	0.06	39.69	45.89	6.20			
17.90	17.42	0.48	39.69	36.13	3.56				21.23	20.72	0.51	26.86	32.53	5.67			
38.68	43.14	4.46	26.86	18.93	7.93				29.92	26.86	3.06	24.42	24.32	0.10			
43.40	35.49	7.91	24.42	22.82	1.60				35.62	28.04	7.58	38.77	36.12	2.65			
32.08	31.11	0.97	27.23	21.76	5.47				15.47	24.25	8.78	35.29	38.10	2.81			
39.69	43.43	3.74	38.77	46.96	8.19				31.64	31.74	0.10	23.45	27.01	3.56			
26.86	20.79	6.07	35.29	28.63	6.66				41.01	35.90	5.11	19.75	30.57	10.82			
24.42	27.23	2.81	23.45	27.97	4.52				29.16	27.92	1.24	22.34	33.51	11.17			
27.23	28.68	1.45	19.75	24.00	4.25				40.90	37.98	2.92	54.35	47.36	6.99			
38.77	44.32	5.55	22.34	24.22	1.88				18.37	17.00	1.37	32.50	36.44	3.94			
35.29	31.88	3.41	30.89	27.84	3.05				28.33	18.06	10.27	29.96	31.45	1.49			
23.45	28.73	5.28	29.95	33.79	3.84				48.86	40.67	8.19	36.52	47.28	10.76			
19.75	31.89	12.14	24.15	23.28	0.87				13.41	14.27	0.86	25.29	30.93	5.64			
22.34	29.96	7.62	24.88	41.61	16.73				29.71	25.03	4.68	30.89	33.59	2.70			
54.35	51.93	2.42	27.98	34.83	6.85				35.82	26.39	9.43	24.88	34.56	9.68			
32.50	27.48	5.02	52.06	41.38	10.68				13.56	14.81	1.25	27.72	36.72	9.00			
29.96	25.90	4.06	46.09	25.54	20.55				29.70	16.52	13.18	27.98	37.57	9.59			
36.52	45.20	8.68	21.23	20.51	0.72							27.29	29.76	2.47			
25.29	33.57	8.28	29.92	36.69	6.77							52.06	58.50	6.44			
30.89	33.88	2.99	35.62	36.01	0.39							46.09	40.05	6.04			
29.95	36.90	6.95	15.47	20.35	4.88							32.73	35.84	3.11			
24.15	28.35	4.20	31.64	31.44	0.20							29.92	35.31	5.39			
24.88	40.50	15.62	41.01	38.21	2.80							35.62	44.00	8.38			
27.72	26.59	1.13	29.16	26.56	2.60							15.47	23.07	7.60			
27.98	36.96	8.98	40.90	42.31	1.41							31.64	37.63	5.99			
27.29	28.68	1.39	18.37	20.70	2.33							30.82	42.30	11.48			
52.06	32.94	19.12										18.37	23.24	4.87			
46.09	24.02	22.07										28.33	23.62	4.71			
32.73	39.49	6.76										48.86	49.26	0.40			
18.69	22.86	4.17										13.41	19.80	6.39			
21.23	24.67	3.44										29.71	40.50	10.79			
29.92	39.60	9.68										29.70	27.02	2.68			
35.62	38.80	3.18															
15.47	15.71	0.24															
31.64	35.27	3.63															
30.82	39.17	8.35															
41.01	40.89	0.12															
29.16	32.90	3.74															
40.90	43.87	2.97															
18.37	32.72	14.35															
28.33	25.16	3.17															
13.41	16.62	3.21															
29.71	33.49	3.78															
35.82	33.38	2.44															
13.56	15.17	1.61															
29.70	19.45	10.25															
MEANS:																	
28.90	30.97	5.18	28.79	30.68	4.59	29.66	30.26	4.80	29.77	27.54	4.95	29.63	33.31	5.40	30.09	34.41	5.96
	N = 77			N = 57			N = 19			N = 48			N = 63			N = 28	

Appendix Table A.16 Two-way comparisons of annual precipitation (inches) between Nixon, Wilson County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Nixon	**Runge**	**Diff**	**Nixon**	**Karnes**	**Diff**	**Nixon**	**Kenedy**	**Diff**	**Nixon**	**Falls City**	**Diff**	**Nixon**	**Floresville**	**Diff**	**Nixon**	**Stockdale**	**Diff**
23.31	29.38	6.07	23.31	28.18	4.87	32.00	38.14	6.14	32.00	39.04	7.04	23.31	28.70	5.39	48.92	43.29	5.63
44.28	45.57	1.29	44.28	44.29	0.01	25.21	19.97	5.24	25.21	18.94	6.27	44.28	43.34	0.94	37.53	42.72	5.19
21.73	20.65	1.08	21.73	20.93	0.80	20.83	30.37	9.54	20.83	20.81	0.02	21.73	24.15	2.42	21.89	25.70	3.81
18.36	15.43	2.93	18.36	22.90	4.54	34.60	28.59	6.01	34.60	22.19	12.41	18.36	16.86	1.50	32.69	38.25	5.56
36.52	32.28	4.24	36.52	33.67	2.85	24.25	22.67	1.58	24.25	28.34	4.09	36.52	25.53	10.99	34.56	35.78	1.22
30.72	22.29	8.43	30.72	25.23	5.49	18.28	15.89	2.39	18.28	17.29	0.99	30.72	24.84	5.88	21.79	27.79	6.00
27.44	22.91	4.53	27.44	27.96	0.52	23.15	24.21	1.06	23.15	18.59	4.56	27.44	28.20	0.76	36.72	30.10	6.62
39.49	34.89	4.60	39.49	42.24	2.75	37.45	36.78	0.67	52.15	41.13	11.02	39.49	28.83	10.66	29.76	32.62	2.86
21.54	16.96	4.58	21.54	24.04	2.50	27.68	26.97	0.71	37.45	31.79	5.66	21.54	20.39	1.15	27.78	25.22	2.56
22.62	36.53	13.91	22.62	33.16	10.54	45.89	46.20	0.31	27.68	21.81	5.87	22.62	27.07	4.45	24.03	24.17	0.14
29.31	26.98	2.33	29.31	32.25	2.94	32.53	23.82	8.71	45.89	46.03	0.14	29.31	29.30	0.01	42.81	42.16	0.65
30.26	25.41	4.85	30.26	24.24	6.02	26.00	27.31	1.31	32.53	28.94	3.59	30.26	21.24	9.02	58.50	56.52	1.98
44.12	45.26	1.14	44.12	56.52	12.40	18.83	22.88	4.05	26.00	24.18	1.82	44.12	45.93	1.81	40.05	37.21	2.84
39.06	31.36	7.70	39.06	49.97	10.91	24.32	23.63	0.69	18.83	22.36	3.53	16.64	13.75	2.89	35.84	33.84	2.00
25.70	19.73	5.97	25.70	24.77	0.93	42.63	41.88	0.75	24.32	21.06	3.26	39.51	32.53	6.98	35.31	32.64	2.67
31.00	16.14	14.86	31.00	24.67	6.33	36.12	46.44	10.32	42.63	29.34	13.29	48.92	37.25	11.67	44.00	37.22	6.78
16.64	19.24	2.60	16.64	17.08	0.44	39.66	44.97	5.31	36.12	37.90	1.78	37.53	35.77	1.76	23.07	21.80	1.27
39.51	46.87	7.36	39.51	40.66	1.15	38.10	34.01	4.09	39.66	41.90	2.24	21.89	22.88	0.99	37.63	34.41	3.22
48.92	41.44	7.48	48.92	51.76	2.84	27.01	33.15	6.14	27.01	23.96	3.05	32.69	24.08	8.61	42.30	36.65	5.65
37.53	27.30	10.23	37.53	34.72	2.81	30.57	32.75	2.18	30.57	24.92	5.65	27.40	16.65	10.75	23.24	19.90	3.34
21.89	28.08	6.19	21.89	24.85	2.96	47.36	41.99	5.37	33.51	29.89	3.62	58.06	44.55	13.51	23.62	32.11	8.49
32.69	31.07	1.62	32.69	28.22	4.47	36.44	26.75	9.69	47.36	43.75	3.61	21.86	22.06	0.20	49.26	51.23	1.97
27.40	21.97	5.43	58.06	50.30	7.76				36.44	27.98	8.46	32.00	34.82	2.82	19.80	25.83	6.03
58.06	45.42	12.64	21.86	28.09	6.23				47.28	35.30	11.98	20.83	22.47	1.64	40.50	38.84	1.66
20.90	28.76	7.86	25.21	18.10	7.11				30.93	22.09	8.84	34.60	26.90	7.70	27.02	33.23	6.21
21.86	25.08	3.22	20.83	24.69	3.86				33.59	29.40	4.19	24.25	22.53	1.72			
32.00	38.86	6.86	34.60	28.71	5.89				34.56	28.45	6.11	18.28	18.29	0.01			
25.21	14.84	10.37	24.25	28.71	4.46				21.79	29.58	7.79	23.15	22.79	0.36			
20.83	26.92	6.09	18.28	18.97	0.69				36.72	26.69	10.03	52.15	38.68	13.47			
34.60	33.23	1.37	23.15	23.06	0.09				37.57	32.38	5.19	37.45	43.40	5.95			
24.25	22.73	1.52	52.15	44.75	7.40				27.78	21.42	6.36	27.68	32.08	4.40			
23.15	19.99	3.16	37.45	46.80	9.35				24.03	27.46	3.43	45.89	39.69	6.20			
52.15	43.14	9.01	27.68	28.11	0.43				42.81	38.64	4.17	32.53	26.86	5.67			
37.45	35.49	1.96	45.89	36.13	9.76				58.50	36.54	21.96	24.32	24.42	0.10			
27.68	31.11	3.43	32.53	18.93	13.60				40.05	28.84	11.21	36.12	38.77	2.65			
45.89	43.43	2.46	26.00	25.69	0.31				35.84	36.56	0.72	38.10	35.29	2.81			
32.53	20.79	11.74	18.83	24.32	5.49				35.31	26.86	8.45	27.01	23.45	3.56			
26.00	26.67	0.67	24.32	22.82	1.50				44.00	28.04	15.96	30.57	19.75	10.82			
18.83	18.15	0.68	42.63	37.03	5.60				23.07	24.25	1.18	33.51	22.34	11.17			
24.32	27.23	2.91	36.12	46.96	10.84				37.63	31.74	5.89	47.36	54.35	6.99			
42.63	41.53	1.10	39.66	33.57	6.09				23.24	17.00	6.24	36.44	32.50	3.94			
36.12	44.32	8.20	38.10	28.63	9.47				23.62	18.06	5.56	31.45	29.96	1.49			
39.66	31.46	8.20	27.01	27.97	0.96				49.26	40.67	8.59	47.28	36.52	10.76			
38.10	31.88	6.22	30.57	24.00	6.57				19.80	14.27	5.53	30.93	25.29	5.64			
27.01	28.73	1.72	33.51	24.22	9.29				40.50	25.03	15.47	33.59	30.89	2.70			
30.57	31.89	1.32	33.59	27.84	5.75				27.02	16.52	10.50	34.56	24.88	9.68			
33.51	29.96	3.55	34.56	41.61	7.05							36.72	27.72	9.00			
47.36	51.93	4.57	37.57	34.83	2.74							37.57	27.98	9.59			
36.44	27.48	8.96	27.78	23.16	4.62							29.76	27.29	2.47			
31.45	25.90	5.55	24.03	25.61	1.58							58.50	52.06	6.44			
47.28	45.20	2.08	42.81	35.22	7.59							40.05	46.09	6.04			
30.93	33.57	2.64	58.50	41.38	17.12							35.84	32.73	3.11			
33.59	33.88	0.29	40.05	25.54	14.51							35.31	29.92	5.39			
34.56	40.50	5.94	35.31	36.69	1.38							44.00	35.62	8.38			
21.79	22.24	0.45	44.00	36.01	7.99							23.07	15.47	7.60			
36.72	26.59	10.13	23.07	20.35	2.72							37.63	31.64	5.99			
37.57	36.96	0.61	37.63	31.44	6.19							42.30	30.82	11.48			
29.76	28.68	1.08	23.24	20.70	2.54							23.24	18.37	4.87			
27.78	21.14	6.64										23.62	28.33	4.71			
24.03	20.89	3.14										49.26	48.86	0.40			
42.81	40.29	2.52										19.80	13.41	6.39			
58.50	32.94	25.56										40.50	29.71	10.79			
40.05	24.02	16.03										27.02	29.70	2.68			
35.84	39.49	3.65															
35.31	39.60	4.29															
44.00	38.80	5.20															
23.07	15.71	7.36															
37.63	35.27	2.36															
42.30	39.17	3.13															
23.24	32.72	9.48															
23.62	25.16	1.54															
19.80	16.62	3.18															
40.50	33.49	7.01															
27.02	19.45	7.57															
MEANS:																	
32.65	30.37	5.36	32.47	31.09	5.23	31.31	31.34	4.19	33.29	28.22	6.46	33.31	29.63	5.40	34.34	34.37	3.77
	N = 74			N = 58			N = 22			N = 46			N = 63			N = 25	

Appendix Table A.17 Two-way comparisons of annual precipitation (inches) between Stockdale, Wilson County, and other primary stations. Each comparison includes only those years with complete data for both stations of the comparison. Diff = absolute value of differences.

Stockdale	**Runge**	**Diff**	**Stockdale**	**Karnes**	**Diff**	**Stockdale**	**Falls City**	**Diff**	**Stockdale**	**Floresville**	**Diff**	**Stockdale**	**Nixon**	**Diff**
43.29	41.44	1.85	43.29	51.76	8.47	42.48	29.65	12.83	43.29	37.25	6.04	43.29	48.92	5.63
42.72	27.30	15.42	42.72	34.72	8.00	30.95	32.53	1.58	42.72	35.77	6.95	42.72	37.53	5.19
25.70	28.08	2.38	25.70	24.85	0.85	35.78	28.45	7.33	25.70	22.88	2.82	25.70	21.89	3.81
38.25	31.07	7.18	38.25	28.22	10.03	27.79	29.58	1.79	38.25	24.08	14.17	38.25	32.69	5.56
42.48	36.90	5.58	42.48	33.79	8.69	30.10	26.69	3.41	42.48	29.95	12.53	35.78	34.56	1.22
30.95	28.35	2.60	30.95	23.28	7.67	38.53	34.14	4.39	30.95	24.15	6.80	27.79	21.79	6.00
35.78	40.50	4.72	35.78	41.61	5.83	18.01	16.14	1.87	35.78	24.88	10.90	30.10	36.72	6.62
27.79	22.24	5.55	38.53	24.79	13.74	25.22	21.42	3.80	30.10	27.72	2.38	32.62	29.76	2.86
30.10	26.59	3.51	18.01	15.87	2.14	24.17	27.46	3.29	32.62	27.29	5.33	25.22	27.78	2.56
32.62	28.68	3.94	25.22	23.16	2.06	42.16	38.64	3.52	56.52	52.06	4.46	24.17	24.03	0.14
38.53	32.10	6.43	24.17	25.61	1.44	56.52	36.54	19.98	37.21	46.09	8.88	42.16	42.81	0.65
18.01	20.08	2.07	42.16	35.22	6.94	37.21	28.84	8.37	33.84	32.73	1.11	56.52	58.50	1.98
25.22	21.14	4.08	56.52	41.38	15.14	33.84	36.56	2.72	31.17	18.69	12.48	37.21	40.05	2.84
24.17	20.89	3.28	37.21	25.54	11.67	31.17	18.75	12.42	16.51	21.23	4.72	33.84	35.84	2.00
42.16	40.29	1.87	16.51	20.51	4.00	16.51	20.72	4.21	32.64	29.92	2.72	32.64	35.31	2.67
56.52	32.94	23.58	32.64	36.69	4.05	32.64	26.86	5.78	37.22	35.62	1.60	37.22	44.00	6.78
37.21	24.02	13.19	37.22	36.01	1.21	37.22	28.04	9.18	21.80	15.47	6.33	21.80	23.07	1.27
33.84	39.49	5.65	21.80	20.35	1.45	21.80	24.25	2.45	34.41	31.64	2.77	34.41	37.63	3.22
31.17	22.86	8.31	34.41	31.44	2.97	34.41	31.74	2.67	36.65	30.82	5.83	36.65	42.30	5.65
16.51	24.67	8.16	25.77	26.56	0.79	25.77	27.92	2.15	25.77	29.16	3.39	19.90	23.24	3.34
32.64	39.60	6.96	46.90	42.31	4.59	46.90	37.98	8.92	46.90	40.90	6.00	32.11	23.62	8.49
37.22	38.80	1.58	19.90	20.70	0.80	19.90	17.00	2.90	19.90	18.37	1.53	51.23	49.26	1.97
21.80	15.71	6.09				32.11	18.06	14.05	32.11	28.33	3.78	25.83	19.80	6.03
34.41	35.27	0.86				51.23	40.67	10.56	51.23	48.86	2.37	38.84	40.50	1.66
36.65	39.17	2.52				25.83	14.27	11.56	25.83	13.41	12.42	33.23	27.02	6.21
25.77	32.90	7.13				38.84	25.03	13.81	38.84	29.71	9.13			
46.90	43.87	3.03				29.81	26.39	3.42	29.81	35.82	6.01			
19.90	32.72	12.82				33.23	16.52	16.71	33.23	29.70	3.53			
32.11	25.16	6.95												
25.83	16.62	9.21												
38.84	33.49	5.35												
29.81	33.38	3.57												
33.23	19.45	13.78												
MEANS:														
32.97	30.17	6.34	33.46	30.20	5.57	32.86	27.17	6.99	34.41	30.09	5.96	34.37	34.34	3.77
	N = 33			N = 22			N = 28			N = 28			N = 25	

No common years for Stockdale/Kenedy

Appendix Table A.18 Equations used to calculate constructed precipitation data for primary locations in Karnes and Wilson Counties for years with missing data.

Zone 1: Kenedy, Karnes County

1885-1893: PPT = 1.105(San Antonio)
1894: PPT = 1.048(Beeville: Jul-Sep, Nov-Dec) + 1.105(San Antonio: Jan-Jun, Oct)
1895: PPT = 1.105(San Antonio: Jan) + 1.048(Beeville: Feb) + 1.030(Runge: Mar-Dec)
1896: PPT = 1.030(Runge)
1897: PPT = 1.030(Runge: Jan,Jun) + 1.048(Beeville: Feb,Mar) + 1.105(San Antonio: Apr-May,Jul-Dec)
1898: PPT = 1.030(Runge: Mar) + 1.105(San Antonio: Jan-Feb, Apr-Dec)
1899: PPT = 1.105(San Antonio)
1900: PPT = 1.030(Runge: Jan-Aug, Oct-Dec) + 1.105(San Antonio: Sep)
1901: PPT = 1.030(Runge: Jan-Nov) + 1.048(Beeville: Dec)
1902-1904: PPT = 1.030(Runge)
1905: PPT = 1.030(Runge: Jan, Apr-Dec) + 1.048(Beeville: Feb-Mar)
1906: PPT = 1.030(Runge: Feb-Jun) + 1.048(Beeville: Jan, Jul-Dec)
1907: PPT = 1.030(Runge: Mar-Apr, Aug-Dec) + 1.048(Beeville: Jan-Feb, May-Jul)
1908-1909: PPT = 1.030(Runge)
1910: PPT = 1.030(Runge: Jan, Mar-Dec) + 1.048(Beeville: Feb)
1911: PPT = 1.030(Runge: Feb-Dec) + 1.048(Beeville: Jan)
1912: PPT = 1.030(Runge: Feb-Jul, Nov) + 1.048(Beeville: Jan, Aug) + 0.900(Goliad: Sep-Oct, Dec)
1913: PPT = 1.030(Runge: Feb-Dec) + 0.900(Goliad: Jan)
1914-1915: PPT = 1.030(Runge)
1916: PPT = 1.030(Runge: Jan-Feb, Apr-Aug, Oct-Dec) + 0.900(Goliad: Mar, Sep)
1917-1947: PPT = 1.030(Runge)
1948: PPT = 13.75 + 1.030(Runge: Jan-Jul)
1949-1956: PPT = Kenedy
1957: PPT = 28.41 + 1.030(Runge: Jul-Oct)
1958-1971: PPT = Kenedy
1972: PPT = 10.11 + 1.030(Runge: Jun-Nov)
1973-1974: PPT = Kenedy
1975: PPT = 27.50 + 1.030(Runge: Dec)
1976: PPT = 34.19 + 1.030(Runge: Jan-Mar, Jul)
1977: PPT = 8.23 + 1.030(Runge: Jan-Feb, May-Dec)
1978-1983: PPT = 1.030(Runge)
1984: PPT = 1.030(Runge: Jan-Mar, Dec) + 1.074(Karnes City: Apr-Nov)
1985-2006: PPT = 1.030(Runge)
2007: PPT = 0.900(Goliad: Jan-Feb) + 1.030(Runge: Mar-Dec)
2008-2012: PPT = 1.030(Runge)

Order of stations used to estimate PPT data for Kenedy, with beginning year for station data: Runge (1895), Karnes City (1919), Goliad (1912), Beeville (1894), San Antonio (1885).

Zone 2: Runge, Karnes County

1885-1893: PPT = 1.004(San Antonio)
1894: PPT = 0.958(Beeville: Jul-Sep, Nov-Dec) + 1.004(San Antonio: Jan-Jun, Oct)
1895: PPT = 24.07 + 1.004(San Antonio: Jan-Feb)
1896: PPT = 27.28
1897: PPT = 3.85 + 0.958(Beeville: Feb-Mar) + 1.004(San Antonio: Apr-May, Jul-Dec)
1898: PPT = 2.28 + 1.004(San Antonio: Jan-Feb, Apr-Dec)
1899: PPT = 1.004(San Antonio)
1900: PPT = 35.15 + 1.004(San Antonio: Sep)
1901: PPT = 21.42 + 0.958(Beeville: Dec)
1902-1904: PPT = Runge
1905: PPT = 25.23 + 0.958(Beeville: Feb-Mar)
1906: PPT = 8.92 + 0.958(Beeville: Jan, Jul-Dec)
1907: PPT = 13.85 + 0.958(Beeville: Jan-Feb, May-Jul)
1908-1909: PPT = Runge
1910: PPT = 26.62 + 0.958(Beeville: Feb)
1911: PPT = 27.57 + 0.958(Beeville: Jan)
1912: PPT = 20.71 + 0.958(Beeville: Sep)
1914-1915: PPT = Runge
1916: PPT = 17.17 + 0.958(Beeville: Mar, Sep)
1917-1953: PPT = Runge
1954: PPT = 12.44 + 0.907(Beeville: Sep)
1955-1983: PPT = Runge
1984: PPT = 6.92 + 0.907(Yorktown: Apr-Nov)
1985-2006: PPT = Runge
2007: PPT = 38.40 + 0.907(Yorktown: Jan-Feb)
2008-2012: PPT = Runge

Order of stations used to estimate PPT for Runge, with beginning year for station data: Yorktown (1940), Beeville (1894), San Antonio (1885).

Zone 3: Karnes City, Karnes County

1885-1894: PPT = 0.977(San Antonio)
1895: PPT = 0.977(San Antonio: Jan-Feb) + 1.092(Runge: Mar-Dec)
1896: PPT = 1.092(Runge)
1897: PPT = 1.092(Runge: Jan, Jun-Jul) + 0.977(San Antonio: Feb-May, Aug-Dec)
1898: PPT = 1.092(Runge: Mar) + 0.977(San Antonio: Jan-Feb, Apr-Dec)
1899: PPT = 0.977(San Antonio)
1900: PPT = 1.092(Runge: Jan-Aug, Oct-Dec) + 0.977(San Antonio: Sep)
1901: PPT = 1.092(Runge: Jan-Nov) + 0.977(San Antonio: Dec)
1902-1904: PPT = 1.092(Runge)
1905: PPT = 1.092(Runge: Jan, Apr-Dec) + 0.977(San Antonio: Feb-Mar)
1906: PPT = 1.092(Runge: Feb-Jun) + 0.977(San Antonio: Jan, Jul-Dec)
1907: PPT = 1.092(Runge: Mar-Apr, Aug-Dec) + 0.977(San Antonio: Jan-Feb, May-Jul)
1908-1909: PPT = 1.092(Runge)
1910: PPT = 1.092(Runge: Jan, Mar-Dec) + 0.977(San Antonio: Feb)
1911: PPT = 1.092(Runge: Feb-Dec) + 0.977(San Antonio: Jan)
1912: PPT = 1.092(Runge: Feb-Jul, Nov) + 0.977(San Antonio: Jan, Aug-Oct, Dec)
1913: PPT = 1.092(Runge: Feb-Dec) + 0.977(San Antonio: Jan)
1914-1915: PPT = 1.092(Runge)
1916: PPT = 1.092(Runge: Jan-Feb, Apr-Aug, Oct-Dec) + 0.977(San Antonio: Mar, Sep)
1917-1918: PPT = 1.092(Runge)
1919: PPT = 6.76 + 1.092(Runge: Jan-Sep)
1920-1944: PPT = Karnes City
1945: PPT = 15.87 + 1.066(Floresville: Sep)
1946: PPT = Karnes City
1947: PPT = 18.60 + 1.092(Runge: Aug-Sep)
1948: PPT = Karnes City
1949: PPT = 28.69 + 0.931(Kenedy: Aug-Sep)
1950-1972: PPT = Karnes City
1973: PPT = 32.72 + 0.931(Kenedy: Apr)
1974: PPT = 25.32 + 0.931(Kenedy: Jun)
1975: PPT = 4.16 + 0.931(Kenedy: May-Nov) + 0.935(Runge: Dec)
1976: PPT = 0.931(Kenedy: Apr-Jun, Aug-Dec) + 0.935(Runge: Jan-Mar, Jul)
1977: PPT = 18.36 + 0.935(Runge: Jan-Mar)
1978-1981: PPT = Karnes City
1982: PPT = 24.02 + 0.935(Runge: Apr, Aug)
1983: PPT = 27.12 + 0.935(Runge: Apr)
1984-1985: PPT = Karnes City
1986: PPT = 24.39 + 0.935(Runge: Aug-Sep)
1987-1993: PPT = Karnes City
1994: PPT = 25.41 + 0.935(Runge: Dec)
1995: PPT = 12.27 + 0.935(Runge: Jan-Jun)
1996-2000: PPT = Karnes City
2001: PPT = 15.41 + 0.935(Runge: Aug-Nov)
2002-2005: PPT = Karnes City
2006: PPT = 16.93 + 0.935(Runge: Dec)
2007: PPT = 1.066(Floresville: Jan-Feb) + 0.935(Runge: Mar-Dec)
2008-2012: PPT = 0.935(Runge)
Order of stations used to estimate PPT data for Karnes City, with beginning year for station data: Kenedy (1948), Runge (1895), Floresville (1916), San Antonio (1885).

Zone 4: Falls City, Karnes and Wilson Counties

1885-1894: PPT = 0.902(San Antonio)
1895: PPT = 0.907(Runge: Mar-Dec) + 0.902(San Antonio: Jan-Feb)
1896: PPT = 0.907(Runge)
1897: PPT = 0.907(Runge: Jan, Jun) + 0.902(San Antonio: Feb-May, Jul-Dec)
1898-1899: PPT = 0.902(San Antonio)
1900: PPT = 0.907(Runge: Jan-Aug, Oct-Dec) + 0.902(San Antonio: Sep)
1901: PPT = 0.907(Runge: Jan-Nov) + 0.902(San Antonio: Dec)
1902-1904: PPT = 0.907(Runge)
1905: PPT = 0.907(Runge: Jan, Apr-Dec) + 0.902(San Antonio: Feb-Mar)
1906: PPT = 0.907(Runge: Feb-Jun) + 0.902(San Antonio: Jan, Jul-Dec)
1907: PPT = 0.907(Runge: Mar-Apr, Aug-Dec) + 0.902(San Antonio: Jan-Feb, May-Jul)
1908-1909: PPT = 0.907(Runge)
1910: PPT = 0.907(Runge: Jan, Mar-Dec) + 0.902(San Antonio: Feb)
1911: PPT = 0.907(Runge: Feb-Dec) + 0.902(San Antonio: Jan)
1912: PPT = 0.907(Runge: Feb-Jul, Nov) + 0.902(San Antonio: Jan, Aug-Oct, Dec)
1913: PPT = 0.907(Runge: Feb-Dec) + 0.902(San Antonio: Jan)
1914: PPT = 1.003(Whitsett: May-Dec) + 0.907(Runge: Jan-Apr)
1915: PPT = 1.003(Whitsett)
1916: PPT = 1.003(Whitsett: Jan-May) + 1.030(Jourdanton: Jun-Dec)
1917: PPT = 1.030(Jourdanton)
1918: PPT = 1.030(Jourdanton: Jan-May) + 0.925(Floresville: Jun-Dec)
1919: PPT = 0.925(Floresville: Jan-Sep) + 1.030(Jourdanton: Oct-Dec)
1920: PPT = 1.030(Jourdanton)
1921: PPT = 1.030(Jourdanton: Jan-May) + 0.951(Karnes City: Jun-Dec)
1922: PPT = 1.030(Jourdanton: Jan-Jul) + 0.951(Karnes City: Aug-Dec)
1923-1944: PPT = 0.951(Karnes City)
1945: PPT = 0.951(Karnes City: Jan-Aug, Oct-Dec) + 0.925(Floresville: Sep)
1946: PPT = 30.31 + 0.951(Karnes City: Jan-Jul)
1947: PPT = 17.91 + 0.951(Karnes City: Jun) + 1.030(Jourdanton: Sep-Dec)
1948: PPT = 12.77 + 1.030(Jourdanton: Jan-May)
1949-1968: PPT = Falls City
1969: PPT = 28.24 + 1.030(Jourdanton: Apr)
1970-1974: PPT = Falls City
1975: PPT = 24.67 + 1.030(Jourdanton: Jan)
1976-1985: PPT = Falls City
1986: PPT = 22.60 + 1.030(Jourdanton: Sep)
1987-2000: PPT = Falls City
2001: PPT = 16.20 + 1.030(Jourdanton: May-Sep)
2002-2012: PPT = Falls City

Order of stations used to estimate PPT data for Falls City, with beginning year for station data: Jourdanton (1916), Karnes City (1919), Floresville (1916), Whitsett (1914), Runge (1895), San Antonio (1885).

Zone 5: Nixon, Wilson and Karnes Counties

1885-1894: PPT = 1.070(San Antonio)
1895: PPT = 1.075(Runge: Mar-Dec) + 1.070(San Antonio: Jan-Feb)
1896: PPT = 1.075(Runge)
1897: PPT = 1.075(Runge: Jan, Jun) + 1.070(San Antonio: Feb-May, Jul-Dec)
1898-1899: PPT = 1.070(San Antonio)
1900: PPT = 1.075(Runge: Jan-Aug, Oct-Dec) + 1.070(San Antonio: Sep)
1901: PPT = 1.075(Runge: Jan-Nov) + 0.931(Cuero: Dec)
1902-1915: PPT = 0.931(Cuero)
1916: PPT = 0.959(Gonzales: Jan-Aug, Oct-Dec) + 0.931(Cuero: Sep)
1917-1920: PPT = 0.931(Cuero)
1921: PPT = 17.21 + 0.931(Cuero: Jan-May)
1922-1933: PPT = Nixon
1934: PPT = 33.56 + 1.015(Seguin: May)
1935-1955: PPT = Nixon
1956: PPT = 8.53 + 0.954(Dreyer: Feb-Aug)
1957-1965: PPT = Nixon
1966: PPT = 26.28 + 0.954(Dreyer: Nov)
1967-1978: PPT = Nixon
1979: PPT = 38.75 + 0.999(Stockdale: Dec)
1980: PPT = 25.20 + 0.999(Stockdale: Jan-Mar)
1981-1983: PPT = Nixon
1984: PPT = 26.80 + 0.959(Gonzales: Aug)
1985-1986: PPT = Nixon
1987: PPT = 39.43 + 0.999(Stockdale: Oct)
1988: PPT = 14.01 + 0.999(Stockdale: Jan)
1989-1994: PPT = Nixon
1995: PPT = 27.13 + 0.999(Stockdale: Oct-Dec)
1996: PPT = 25.56 + 0.999(Stockdale: Jan-Feb)
1997-2001: PPT = Nixon
2002: PPT = 24.38 + 0.999(Stockdale: Oct-Dec)
2003: PPT = 0.999(Stockdale)
2004: PPT = 3.20 + 0.999(Stockdale: Jan-Oct)
2005-2009: Nixon
2010: PPT = 26.03 + 0.999(Stockdale: Oct-Dec)
2011: PPT = 9.70 + 0.999(Stockdale: Jan-Aug)
2012: PPT = Nixon

Order of stations used to estimate PPT for Nixon, with beginning year for station data: Stockdale (1940), Dreyer (1940), Gonzales (1940), Seguin (1922), Cuero (1901), Runge (1895), San Antonio (1885).

Zone 6: Stockdale, Wilson County

1885-1915: PPT = 1.034(San Antonio)
1916: PPT = 1.034(San Antonio: Jan-May) + 1.144(Floresville: Jun-Dec)
1917-1920: PPT = 1.144(Floresville)
1921: PPT = 1.144(Floresville: Jan-May) + 1.001(Nixon: Jun-Dec)
1922-1933: PPT = 1.001(Nixon)
1934: PPT = 1.001(Nixon: Jan-Apr, Jun-Dec) + 1.144(Floresville: May)
1935-1939: PPT = 1.001(Nixon)
1940: PPT = 4.90 + 1.001(Nixon: Jan-Nov)
1941-1944: PPT = Stockdale
1945: PPT = 5.69 + 1.001(Nixon: Apr-Dec)
1946-1955: PPT = 1.001(Nixon)
1956: PPT = 1.001(Nixon: Jan, Sep-Dec) + 1.144(Floresville: Feb-Aug)
1957-1965: PPT = 1.001(Nixon)
1966: PPT = 1.001(Nixon: Jan-Oct, Dec) + 1.144(Floresville: Nov)
1967-1977: PPT = 1.001(Nixon)
1978: PPT = 25.67 + 1.001(Nixon: Jan-May)
1979-1983: PPT = Stockdale
1984: PPT = 18.31 + 1.144(Floresville: Aug)
1985: PPT = 32.18 + 1.001(Nixon: Jan, Mar)
1986-2001: PPT = Stockdale
2002: PPT = 38.91 + 1.001(Nixon: May)
2003-2010: PPT = Stockdale
2011: PPT = 11.39 + 1.001(Nixon: Sep-Oct)
2012: PPT = Stockdale

Order of stations used to estimate PPT for Stockdale, with beginning year for station data: Nixon (1921), Floresville (1916), Seguin (1922), Karnes City (1919), San Antonio (1885).

Zone 7: Floresville, Wilson County

1885-1915: PPT = 0.955(San Antonio)
1916: PPT = 13.86 + 0.955(San Antonio: Jan-May)
1917-1933: PPT = Floresville
1934: PPT = 25.02 + 0.938(Karnes City: Oct)
1935: PPT = Floresville
1936: PPT = 24.28 + 0.938(Karnes City: Aug-Nov)
1937: PPT = 20.57 + 0.938(Karnes City: Feb, Sep)
1938: PPT = 17.84 + 0.938(Karnes City: Jul)
1939-1946: PPT = Floresville
1947: PPT = 13.92 + 0.938(Karnes City: Jun, Jul) + 1.081(Falls City: Aug, Sep)
1948-1949: PPT = Floresville
1950: PPT = 9.62 + 0.963(Cestohowa: Jun-Aug)
1951-1961: PPT = Floresville
1962: PPT = 15.64 + 0.963(Cestohowa: Nov-Dec)
1963: PPT = 14.07 + 0.963(Cestohowa: Jan-Feb)
1964: PPT = Floresville
1965: PPT = 33.17 + 0.963(Cestohowa: Apr)
1966-1967: PPT = Floresville
1968: PPT = 33.92 + 0.963(Cestohowa: Aug-Sep)
1969-1981: PPT = Floresville
1982: PPT = 21.06 + 0.938(Karnes City: Oct-Nov)
1983: PPT = Floresville
1984: PPT = 16.75 + 0.938(Karnes City: Jan)
1985-1986: PPT = Floresville
1987: PPT = 20.33 + 0.938(Karnes City: Dec)
1988: PPT = 4.80 + 0.938(Karnes City: Mar, Jun-Jul, Sep-Oct)
1989: PPT = 6.44 + 0.938(Karnes City: Jan-May, Jul-Sep, Dec)
1990: PPT = 24.40 + 0.938(Karnes City: Apr)
1991: PPT = 25.92 + 0.938(Karnes City: Dec)
1992-1994: PPT = Floresville
1995: PPT = 18.69 + 0.938(Karnes City: Jul)
1996: PPT = 21.23 + 0.938(Karnes City: Feb)
1997-2000: PPT = Floresville
2001: PPT = 30.82 + 0.938(Karnes City: Jul)
2002-2012: PPT = Floresville

Order of stations used to estimate PPT data for Floresville, with beginning year for station data: Cestohowa (1944), Karnes City (1919), Falls City (1946), San Antonio (1885).

APPENDIX B SOILS

Appendix Table B.1 Soils included in the Karnes (K) and Wilson (W) Counties EDYS models.

Soil Series	Topography	Map Code	County	Range Site
Alum loamy fine sand	1-3% slopes	AmB	W	Loamy Sand
Alum loamy fine sand	3-5% slopes	AmC	W	Loamy Sand
Aransas clay		Ar	W	Clayey Bottomland
Aransas clay	frequently flooded	As	W	Clayey Bottomland
Bryde fine sandy loam	1-4% slopes	BrB	K	Tight Sandy Loam
Buchel clay	occasionally flooded	Bu	K	Clayey Bottomland
Buchel clay	frequently flooded	Bw	K	Clayey Bottomland
Clareville clay loam	0-1% slopes	CaA	KW	Clay Loam
Clareville clay loam	1-3% slopes	CaB	W	Clay Loam
Colibro sandy clay loam	1-3% slopes	CbB	W	Gray Sandy Loam
Colibro sandy clay loam	3-5% slopes	CbC	KW	Gray Sandy Loam
Colibro sandy clay loam	5-12% slopes	CbE	K	Gray Sandy Loam
Condido clay	0-2% slopes	CdA	K	Shallow
Conquista clay	1-3% slopes	CnC	K	Reclaimed U Mine
Conquista clay	20-40% slopes	CnG	K	Reclaimed U Mine
Coy clay loam	0-1% slopes	CoA	KW	Rolling Blackland
Coy clay loam	1-3% slopes	CoB	KW	Rolling Blackland
Coy clay loam	3-5% slopes	CoC	K	Rolling Blackland
Crockett fine sandy loam	0-1% slopes	CrA	W	Tight Sandy Loam
Crockett fine sandy loam	1-3% slopes	CrB	W	Tight Sandy Loam
Crockett fine sandy loam	2-5% slopes, eroded	CrC2	W	Tight Sandy Loam
Devine very gravelly fine sandy loam	1-4% slopes	DeB	K	Gravelly Ridge
Ecleto sandy clay loam	1-3% slopes	EcB	K	Shallow
Ecleto sandy clay loam	3-5% slopes	EcC	K	Shallow
Elmendorf-Denhawken complex	0-1% slopes	EdA	W	Rolling Blackland
Elmendorf-Denhawken complex	1-3% slopes	EdB	KW	Blackland
Eloso clay	1-3% slopes	EsB	K	Rolling Blackland
Eloso clay	3-5% slopes	EsC	K	Rolling Blackland
Eufaula and Patilo soils	undulating	EPB	W	Deep Sand Savanna
Fashing clay	2-5% slopes	FaC	K	Shallow
Floresville fine sandy loam	0-1% slopes	FoA	W	Tight Sandy Loam
Floresville fine sandy loam	1-3% slopes	FoB	W	Tight Sandy Loam
Floresville fine sandy loam	3-5% slopes	FoC	W	Tight Sandy Loam
Floresville fine sandy loam	2-5% slopes, eroded	FoC2	W	Tight Sandy Loam
Gillett fine sandy loam	1-4% slopes	GtB	K	Tight Sandy Loam
Gowen clay loam		Go	W	Loamy Bottomland
Gowen and Zavala soils	frequently flooded	Gz	W	Loamy Bottomland
Gullied land		Gu	K	Eroded Soils
Imogene fine sandy loam	0-1% slopes	Im	K	Tight Sandy Loam
Karnes loam	0-3% slopes	KaB	W	Gray Sandy Loam
Kaufman clay	frequently flooded	Kf	W	Clayey Bottomland
Leming loamy fine sand	0-3% slopes	LeB	W	Loamy Sand
Loire and Frio soils	frequently flooded	Lf	W	Loamy Bottomland
Luling clay	0-4% slopes	LuB	W	Rolling Blackland
Marcelinas clay loam	0-3% slopes	MaB	W	Rolling Blackland
Miguel fine sandy loam	0-1% slopes	MgA	W	Tight Sandy Loam
Miguel fine sandy loam	1-3% slopes	MgB	KW	Tight Sandy Loam
Miguel fine sandy loam	3-5% slopes	MgC	KW	Tight Sandy Loam
Miguel fine sandy loam	2-5% slopes, eroded	MgC2	W	Tight Sandy Loam
Monteola clay	0-1% slopes	MoA	K	Rolling Blackland
Monteola clay	1-3% slopes	MoB	K	Rolling Blackland
Monteola clay	3-5% slopes	MoC	K	Rolling Blackland
Monteola clay	5-8% slopes	MoD	K	Rolling Blackland
Nocken stony/Rock outcrop	1-8% slopes	NKC	W	Sandstone Hills
Nusil fine sand	1-5% slopes	NuC	K	Sandy

Appendix Table B.1 (Cont.)

Soil Series	Topography	Map Code	County	Range Site
Odem fine sandy loam	occasionally flooded	Od	K	Loamy Bottomland
Olmos very gravelly loam	1-8% slopes	OmD	K	Shallow Ridge
Orthents, rolling	severely eroded	OgD3	W	
Papalote loamy coarse sand	0-3% slopes	PaB	K	Loamy Sand
Papalote fine sandy loam	1-3% slopes	PbB	K	Tight Sandy Loam
Papalote fine sandy loam	3-5% slopes	PbC	K	Tight Sandy Loam
Parrita sandy clay loam	1-3% slopes	PcB	K	Shallow Ridge
Pavelek clay	0-3% slopes	PkB	K	Shallow Ridge
Pavelek clay	3-5% slopes, eroded	PkC	K	Shallow Ridge
Pernitas sandy clay loam	2-5% slopes	PnC	K	Gray Sandy Loam
Pernitas sandy clay loam	5-8% slopes	PnD	K	Gray Sandy Loam
Pettus loam	2-5% slopes	PtC	K	Shallow Ridge
Picosa loam	1-8% slopes	PcC	W	Shallow Ridge
Pits and dumps		Px	K	Uranium Mine Pits
Poth loamy fine sand	0-3% slopes	PtB	W	Loamy Sand
Quarry, sandstone		Qu	K	Sandstone Pits
Rhymes fine sand	1-5% slopes	RhC	K	Sandy
Rosanky fine sandy loam	1-3% slopes	RsB	W	Sandy Loam
Rosanky fine sandy loam	3-5% slopes	RsC	W	Sandy Loam
Rosenbrock clay	0-1% slopes	RoA	K	Rolling Blackland
Rosenbrock clay	1-3% slopes	RoB	K	Rolling Blackland
Rosenbrock clay	0-1%, rarely flooded	Rr	K	Rolling Blackland
Runge fine sandy loam	0-1% slopes	RuA	W	Sandy Loam
Runge fine sandy loam	1-3% slopes	RuB	W	Sandy Loam
Runge fine sandy loam	3-5% slopes	RuC	W	Sandy Loam
Sarita fine sand	0-5% slopes	SaC	W	Deep Sand
Sarnosa fine sandy loam	2-5% slopes	SeC	K	Gray Sandy Loam
Saspamco fine sandy loam	1-3% slopes	SpB	W	Gray Sandy Loam
Saspamco fine sandy loam	3-5% slopes	SpC	W	Gray Sandy Loam
Schattel clay loam	2-5% slopes	ShC	K	Sloping Clay Loam
Shiner fine sandy loam	1-8% slopes	SrD	K	Chalky Ridge
Sinton sandy clay loam	occasionally flooded	St	K	Loamy Bottomland
Tabor loamy fine sand	0-3% slopes	TbB	W	Loamy Sand
Tiocano clay	0-1% slopes	Tc	K	Lakebed
Tordia clay	0-1% slopes	TrA	W	Rolling Blackland
Tordia clay	1-3% slopes	TrB	KW	Rolling Blackland
Tordia clay	3-5% slopes	TrC	K	Rolling Blackland
Ustarents, loamy	2-5% slopes	Us	KW	Shallow Ridge
Venus clay loam	0-1% slopes	VeA	W	Clay Loam
Venus clay loam	1-3% slopes	VeB	W	Clay Loam
Vernia gravelly loamy sand	1-8% slopes	VrC	W	Very Gravelly
Weesatche fine sandy loam	2-5% slopes	WaC	K	Sandy Loam
Weesatche sandy clay loam	1-3% slopes	WeB	K	Clay Loam
Weesatche sandy clay loam	3-5% slopes	WeC	K	Clay Loam
Weigang fine sandy loam	1-5% slopes	WgC	K	Shallow
Weigang-Gillett complex	3-25% slopes, stony	WtF	K	Sandstone Hills
Wilco loamy fine sand	0-3% slopes	WcB	W	Loamy Sand
Wilco loamy fine sand	3-8% slopes	WcC	W	Loamy Sand
Wilco loamy fine sand	3-8% slopes, eroded	WcC2	W	Loamy Sand
Willamar fine sandy loam	0-2% slopes	WmA	W	Hardland
Yahola-Karnes complex	0-20% slopes	YkE	W	Loamy Bottomland
Zavala fine sandy loam		Za	W	Loamy Bottomland
Zavala fine sandy loam	frequently flooded	Zf	W	Loamy Bottomland
Zunker fine sandy loam	occasionally flooded	Zu	K	Loamy Bottomland

Appendix Table B.2 Representative soils for range sites and land-use types used in subwatershed-scale applications of the EDYS models for Karnes and Wilson Counties.

Range Site/Land-use	Code	Representative Soil	Area (acres)	Included Soils
Blackland	EdB	Elmendorf-Denhawken complex	2,850	EdB
Chalky Ridge	SrD	Shiner fine sandy loam	2,510	SrD
Clayey Bottomland	Ar	Aransas clay	12,920	Ar As
Clayey Bottomland	Bu	Buchel clay	19,060	Bu Bw
Clayey Bottomland	Kf	Kaufman clay	820	Kf
Clay Loam	CaA	Clareville clay loam	36,990	CaA CaB
Clay Loam	VeB	Venus clay loam	8,810	VeA VeB
Clay Loam	WeB	Weesatche sandy clay loam	22,600	WeB WeC
Deep Sand	SaC	Sarita fine sand	7,820	SaC
Deep Sand Savanna	EPB	Eufaula and Patilo soils	83,870	EPB
Gravelly Ridge	DeB	Devine gravelly fine sandy loam	8,510	DeB
Gray Sandy Loam	CbC	Colibro sandy clay loam	9,940	CbB CbC CbE
Gray Sandy Loam	KaB	Karnes loam	9,350	KaB
Gray Sandy Loam	PnC	Pernitas sandy clay loam	47,930	PnC PnD
Gray Sandy Loam	SeC	Sarnosa fine sandy loam	4,325	SeC
Gray Sandy Loam	SpB	Saspamco fine sandy loam	4,470	SpB SpC
Hardland	WmA	Willamar fine sandy loam	9,680	WmA
Lakebed	Tc	Tiocano clay	390	Tc
Loamy Bottomland	Go	Gowen clay loam	3,120	Go Gz
Loamy Bottomland	Lf	Loire and Frio soils	5,020	Lf
Loamy Bottomland	Od	Odem fine sandy loam	1,180	Od
Loamy Bottomland	St	Sinton sandy clay loam	11,640	St
Loamy Bottomland	YkE	Yahola-Karnes complex	3,790	YkE
Loamy Bottomland	Za	Zavala fine sandy loam	9,140	Za Zf
Loamy Bottomland	Zu	Zunker fine sandy loam	3,640	Zu
Loamy Sand	AmB	Alum loamy fine sand	5,860	AmB AmC
Loamy Sand	LeB	Leming loamy fine sand	8,570	LeB
Loamy Sand	PaB	Papalote loamy coarse sand	21,770	PaB
Loamy Sand	PtB	Poth loamy fine sand	2,090	PtB
Loamy Sand	TbB	Tabor loamy fine sand	22,640	TbB
Loamy Sand	WcC	Wilco loamy fine sand	54,390	WcB WcC WcC2
Rolling Blackland	CoB	Coy clay loam	77,110	CoA CoB CoC
Rolling Blackland	EdB	Elmendorf-Denhawken complex	42,700	EdA EdB
Rolling Blackland	EsB	Eloso clay	25,960	EsB EsC
Rolling Blackland	LuB	Luling clay	17,580	LuB
Rolling Blackland	MaB	Marcelinas clay loam	4,050	MaB
Rolling Blackland	MoC	Monteola clay	22,440	MoA MoB MoC MoD
Rolling Blackland	RoA	Rosenbrock clay	16,670	RoA RoB Rr
Rolling Blackland	TrB	Tordia clay	18,950	TrA TrB TrC
Sandstone Hills	NKC	Nocken stony/Rock outcrop	12,200	NKC
Sandstone Hills	WtF	Weigang-Gillett complex	4,030	WtF
Sandy	NuC	Nusil fine sand	8,610	NuC
Sandy	RhC	Rhymes fine sand	2,110	RhC

Appendix Table B.2 (Cont.)

Range Site/Land-Use	Code	Representative Soil	Area (acres)	Included Soils
Sandy Loam	RsB	Rosanky fine sandy loam	5,140	RsB RsC
Sandy Loam	RuB	Runge fine sandy loam	6,010	RuA RuB RuC
Sandy Loam	WaC	Weesatche fine sandy loam	34,463	WaC
Shallow	CdA	Condido clay	2,950	CdA
Shallow	EcC	Ecleto sandy clay loam	3,880	EcB EcC
Shallow	FaC	Fashing clay	1,090	FaC
Shallow	OgD3	Orthents, rolling	1,400	OgD3
Shallow	WgC	Weigang fine sandy loam	2,160	WgC
Shallow Ridge	OmD	Olmos very gravelly loam	4,590	OmD
Shallow Ridge	PcB	Parrita sandy clay loam	1,210	PcB
Shallow Ridge	PkB	Pavelek clay	23,770	PkB PkC
Shallow Ridge	PtC	Pettus loam	3,230	PtC
Shallow Ridge	PcC	Picosa loam	2,090	PcC
Shallow Ridge	Us	Ustarents, loamy	2,050	Us
Sloping Clay Loam	ShC	Schattel clay loam	5,350	ShC
Tight Sandy Loam	BrB	Bryde fine sandy loam	26,740	BrB
Tight Sandy Loam	CrB	Crockett fine sandy loam	11,490	CrA CrB CrC2
Tight Sandy Loam	FoB	Floresville fine sandy loam	50,770	FoA FoB FoC FoC2
Tight Sandy Loam	GtB	Gillett fine sandy loam	23,130	GtB
Tight Sandy Loam	Im	Imogene fine sandy loam	1,710	Im
Tight Sandy Loam	MgB	Miguel fine sandy loam	59,020	MgA MgB MgC MgC2
Tight Sandy Loam	PbB	Papalote fine sandy loam	16,360	PbB PbC
Very Gravelly	VrC	Vernia very gravelly loamy sand	3,530	VrC
Eroded Soils	Gu	Gullied land	1,120	Gu
Pits and Dumps	Px	Uranium mine pits	2,090	Px
Quarry, sandstone	Qu	Sandstone pits	230	Qu
Reclaimed Mine	CnC	Conquista clay	4,530	CnC CnG

Appendix Table B.3 Representative soils for range sites and land-use types used in county-wide applications of the EDYS models for Karnes (K) and Wilson (W) Counties.

Range Site/Land-use	Code	Representative Soil	Included Soils
Blackland	EdB	Elmendorf-Denhawken complex	EdB
Chalky Ridge	SrD	Shiner fine sandy loam	SrD
Clayey Bottomland	Bu	Buchel clay	Ar Bu Kf
Clay Loam	CaA	Clareville clay loam	CaA CaB VeA VeB WeB WeC
Deep Sand	SaC	Sarita fine sand	SaC
Deep Sand Savanna	EPB	Eufaula and Patilo soils	EPB
Gravelly Ridge	DeB	Devine gravel fine sandy loam	DeB
Gray Sandy Loam	PnC	Pernitas sandy clay loam	CbB CbC CbE KaB PnC PnD SeC SpB SpC
Hardland	WmA	Willamar fine sandy loam	WmA
Lakebed	Tc	Tiocano clay	Tc
Loamy Bottomland	St	Sinton sandy clay loam	Go Gz Lf Od St YkE Za Zf Zu
Loamy Sand	WcC	Wilco loamy fine sand	AmB AmC LeB PaB PtB TbB WcB WcC WcC2
Rolling Blackland	CoB	Coy clay loam	CoA CoB CoC EdA EsB EsC LuB MaB MoA MoB MoC MoD RoA RoB Rr TrA TrB TrC
Sandstone Hills	NKC	Nocken stony/Rock outcrop	NKC WtF
Sandy	NuC	Nusil fine sand	NuC RhC
Sandy Loam	WaC	Weesatche fine sandy loam	RsB RsC RuA RuB RuC WaC
Shallow	EcC	Ecleto sandy clay loam	CdA EcB EcC FaC OgD3 WgC
Shallow Ridge	PkB	Pavelek clay	OmD PcB PkB PkC PtC PcC Us
Sloping Clay Loam	ShC	Schattel clay loam	ShC
Tight Sandy Loam	MgB	Miguel fine sandy loam	BrB CrA CrB CrC2 FoA FoB FoC FoC2 GtB Im MgA MgB MgC MgC2 PbB PbC
Very Gravelly	VrC	Vernia gravelly loamy sand	VrC
Brush Contolled	CoB	Coy clay loam	
Cultivated (Karnes)	St	Sinton sandy clay loam	
Cultivated (Wilson)	EdB	Elmendorf-Denhawken complex	
Dams	CnC	Conquista clay	
Disturbed (Karnes)	PnC	Pernitas sandy clay loam	
Disturbed (Wilson)	FoB	Floresville fine sandy loam	
Eroded Soils	Gu	Gullied land	Gu Gp
House (Karnes)	PnC	Peernitas sandy clay loam	
House (Wilson)	EPB	Eufaula and Patilo soils	
Improved Pasture (K)	CoB	Coy clay loam	
Improved Pasture (W)	EPB	Eufaula and Patilo soils	
Industrial (Karnes)	PkB	Pavelek clay	
Industrial (Wilson)	NKC	Nocken stony/Rock outcrops	
Irrigated (Karnes)	Bu	Buchel clay	
Irrigaged (Wilson)	EdB	Elmendorf-Denhawken complex	
Oil Pad (Karnes)	PkB	Pavelek clay	
Oil Pad (Wilson)	NKC	Nocken stony/Rock outcrops	
Orchard (Karnes)	CoB	Coy clay loam	
Orchard (Wilson)	KaB	Karnes loam	
Pits and Dumps	Px	Uranium mine pits	Px Qu
Quarry, Sandstone	Px	Uranium mine pits	Px Qu
Reclaimed Mine	CnC	Conquista clay	CnC CnG
Road	NKC	Nocken stony/Rocky outcrops	
Water			

APPENDIX C VEGETATION

Appendix Table C.1 NRCS range sites and associated soils and EDYS plant communities (mid-seral) used in the Karnes (K) and Wilson (W) Counties EDYS models.

Range Site	**County**	**Soils**	**EDYS Plant Community**
Blackland	KW	EdB	mesquite-silver bluestem-trichloris
Chalky Ridge	K	SrD	live oak-silver bluestem-buffalograss
Clay Loam	KW	CaA CaB VeA VeB WeB WeC	mesquite-granjeno-silver bluestem
Clayey Bottomland	KW	Ar As Bu Bw Kf	mesquite-hackberry-live oak
Deep Sand	W	SaC	live oak-little bluestem-thin paspalum
Deep Sand Savanna	W	EPB	post oak-little bluestem-purple threeawn
Gravelly Ridge	K	DeB	blackbrush-guajillo-silver bluestem
Gray Sandy Loam	KW	CbB CbC CbE KaB PnC PnD SeC SpB SpC	mesquite-granjeno-hooded windmillgrass
Hardland	W	WmA	mesquite-buffalograss-trichoris
Lakebed	K	Tc	huisache-flatsedge-bermudagrass
Loamy Bottomland	KW	Go Gz Lf, Od St YkE Za Zf Zu	live oak-mustang grape-Johnsongrass
Loamy Sand	KW	AmB AmC LeB PaB PtB TbB WcB WcC WcC2	live oak-mesquite-little bluestem
Rolling Blackland	KW	CoA CoB CoC EdA EsB EsC LuB MaB MoA MoB MoC MoD RoA RoB Rr TrA TrB TrC	mesquite-silver bluestem-buffalograss
Sandstone Hills	KW	NKC WtF	post oak-mesquite-silver bluestem
Sandy	K	NuC RhC	mesquite-live oak-little bluestem
Sandy Loam	KW	RsB RsC RuA RuB RuC WaC	mesquite-little bluestem-thin paspalum
Shallow	K	CdA EcB EcC WgC	blackbrush-silver bluestem-purple threeawn
Shallow Ridge	KW	PcB PcC Us	blackbrush-guajillo-purple threeawn
Sloping Clay Loam	K	ShC	mesquite-buffalograss-purple threeawn
Tight Sandy Loam	KW	BrB CrA CrB CrC2 FoA FoB FoC FoC2 GtB Im MgA MgB MgC MgC2 PbB PbC	mesquite-buffalograss-silver bluestem
Very Gravelly	W	VrC	post oak-sideoats-little bluestem

In Appendix Table C.2, species composition under light grazing (late-seral conditions) was taken from data in Appendix Tables C.3-C.5. Species composition under moderate (mid-seral) grazing was based on data from Appendix Tables C.6-C.11.

Total grass biomass under mid-seral conditions was estimated at 70% of late-seral levels (Appendix Table C.20) and total forb biomass was estimated at 37% of grass levels (Box 1961, Powell and Box 1967, Box and White 1969; Appendix Table C.6).

For woody species, the values are relative composition (%) of woody plant cover. Herbaceous standing crop biomass is decreased as woody cover increases, using the relationship: amount = (amount at 0% woody cover)[1.00 - 0.008(% woody cover)], based on data from Appendix Table C.21.

Appendix Table C.2 Adjustment of plant species composition to account level of livestock grazing in plant communities in Karnes and Wilson Counties. Amounts are clippable biomass (g/m^2) for herbaceous species and relative cover for woody species. Mid-seral biomass = 70% of late seral (Appendix Table C.20)

NRCS Range Site: Blackland
EDYS Plant Community
Late-seral: little bluestem-trichloris-silver bluestem
Mid-seral: mesquite-silver bluestem-trichloris

Woody Species	Relative Cover (%)	Grasses	Biomass Late	Mid	Forbs	Biomass Late	Mid
live oak	1	little bluestem	110	7	ragweed	4	18
hackberry	1	trichloris	70	40	bundleflower	1	4
huisache	10	sideoats	40	4	frogfruit	0	1
mesquite	55	silver bluestem	45	44	prairie coneflower	1	5
Texas persimmon	3	Arizona cottontop	20	35	ruellia	2	12
blackbrush	6	Texas wintergrass	30	11	bush sunflower	0	3
whitebrush	6	tall dropseed	20	7	Texas verbena	2	3
granjeno	8	vine-mesquite	20	2	Texas doveweed	0	6
prickly pear	8	buffalograss	10	75	annual broomweed	0	24
agarito	2	hairy grama	5	4	sunflower	0	12
		purple threeawn	5	24			
		hooded windmillgrass	5	7			
		knotroot bristlegrass	0	4			
		sandbur	0	2			
		Total grasses	380	266	Total forbs	10	88

NRCS Range Site: Chalky ridge
EDYS Plant Community
Late-seral: live oak-little bluestem-sideoats
Mid-seral: live oak-silver bluestem-buffalograss

Woody Species	Relative Cover (%)	Grasses	Biomass Late	Mid	Forbs	Biomass Late	Mid
live oak	45	little bluestem	100	3	ragweed	15	20
mesquite	20	sideoats	20	15	annual broomweed	10	20
blackbrush	20	silver bluestem	20	25	ruellia	1	3
prickly pear	10	big bluestem	10	1	orange zexmenia	1	4
baccharis	5	tall dropseed	10	4	dogweed	0	4
		brownseed paspalum	10	3			
		Virginia wildrye	5	1			
		Texas wintergrass	5	25			
		buffalograss	5	25			
		purple threeawn	5	20			
		hairy grama	3	10			
		hooded windmillgrass	2	5			
		Total grasses	195	137	Total forbs	25	51

Appendix Table C.2 (Cont.)

NRCS Range Site: Clay loam
EDYS Plant Community
Late-seral: little bluestem-silver bluestem-sideoats
Mid-seral: mesquite-granjeno-silver bluestem

Woody Species	Relative Cover (%)	Grasses	Biomass Late	Biomass Mid	Forbs	Biomass Late	Biomass Mid
Mesquite	45	little bluestem	130	5	ragweed	5	35
Texas persimmon	5	silver bluestem	95	100	annual broomweed	5	25
huisache	4	sideoats	90	20	bundleflower	5	5
granjeno	20	trichloris	60	60	prairie coneflower	10	5
whitebrush	10	Arizona cottontop	20	5	snoutbean	5	10
blackbrush	4	tall dropseed	20	5	orange zexmenia	5	10
baccharis	1	Texas wintergrass	20	40	old-man's beard	0	5
agarito	1	vine-mesquite	5	1	frogfruit	0	2
prickly pear	10	purple threeawn	5	40	ruellia	0	4
		hairy grama	5	10	bush sunflower	0	5
		buffalograss	5	25	Texas verbena	0	2
		hooded windmillgrass	5	10	sunflower	0	13
		Texas bristlegrass	5	5			
		Total grasses	465	326	Total forbs	35	121

NRCS Range Site: Clayey Bottomland
EDYS Plant Community
Late-seral: hackberry-live oak-little bluestem
Mid-seral: mesquite-hackberry-live oak

Woody Species	Relative Cover (%)	Grasses	Biomass Late	Biomass Mid	Forbs	Biomass Late	Biomass Mid
live oak	10	little bluestem	140	27	ragweed	20	20
hackberry	10	switchgrass	70	5	giant ragweed	20	60
pecan	5	indiangrass	70	4	coneflower	10	2
huisache	5	trichloris	120	30	snoutbean	5	1
mesquite	35	Virginia wildrye	70	10	ruellia	5	30
Texas persimmon	4	vine-mesquite	50	15	sunflower	10	10
whitebrush	2	buffalograss	40	120	Texas doveweed	0	7
mustang grape	5	knotroot bristlegrass	70	35	bundleflower	0	8
baccharis	1	bushy bluestem	10	50	frogfruit	0	3
granjeno	12	Texas bristlegrass	10	20	bush sunflower	0	8
blackbrush	10	purple threeawn	0	40	old-man's beard	0	20
prickly pear	1	silver bluestem	0	30			
		hooded windmillgrass	0	10			
		thin paspalum	0	14			
		Johnsongrass	0	45			
		Total grasses	650	455	Total forbs	70	169

NRCS Range Site: Deep Sand
EDYS Plant community
Late-seral: live oak-little bluestem-thin paspalum
Mid-seral: live oak-little bluestem-thin paspalum

Woody Species	Relative Cover (%)	Grasses	Biomass Late	Biomass Mid	Forbs	Biomass Late	Biomass Mid
live oak	60	little bluestem	200	95	snoutbean	10	10
mesquite	20	indiangrass	30	4	bush sunflower	10	30
mustang grape	10	switchgrass	25	0	partridge pea	5	5
granjeno	5	tall dropseed	30	37	Texas doveweed	5	22
prickly pear	5	thin paspalum	40	50	sunflower	5	20
		purple threeawn	20	25	Texas bluebonnet	5	4
		sandbur	5	22			
		hairy grama	0	5			
		hooded windmillgrass	0	7			
		Total grasses	350	245	Total forbs	40	91

Appendix Table C.2 (Cont.)

	Woody Species	Relative Cover (%)	Grasses	Biomass		Forbs	Biomass	
				Late	Mid		Late	Mid
NRCS Range Site: Deep Sand Savanna								
EDYS Plant community								
Late-seral: post oak-little bluestem-tall dropseed								
Mid-seral: post oak-little bluestem-purple threeawn								
	post oak	60	little bluestem	200	48	bush sunflower	15	36
	mustang grape	30	indiangrass	30	0	snoutbean	10	5
	prickly pear	10	switchgrass	10	0	sunflower	5	18
			tall dropseed	40	33	partridge pea	5	9
			thin paspalum	20	44	Texas doveweed	5	17
			purple threeawn	20	48	Texas bluebonnet	5	4
			hairy grama	10	5	frogfruit	0	1
			hooded windmillgrass	10	14			
			sandbur	5	50			
			Total grasses	345	242	Total forbs	45	90
NRCS Range Site: Gravelly Ridge								
EDYS Plant community								
Late-seral: blackbrush-guajillo-sidoats								
Mid-seral: blackbrush-guajillo-silver bluestem								
	blackbrush	50	sideoats	40	3	ragweed	5	15
	guajillo	30	silver bluestem	40	36	coneflower	5	2
	prickly pear	5	Arizona cottontop	30	3	orange zexmenia	5	5
	mesquite	10	purple threeawn	30	30	annual broomweed	5	20
	Texas persimmon	5	hairy grama	25	38	dogweed	5	6
			hooded windmillgrass	30	9	ruellia	0	2
			Texas bristlegrass	20	21	Texas verbena	0	3
			Texas wintergrass	0	12	sunflower	0	3
			Total grasses	215	152	Total forbs	25	56
NRCS Range Site: Gray Sandy Loam								
EDYS Plant community								
Late-seral: mesquite-trichloris-sideoats								
Mid-seral: mesquite-granjeno-hooded windmillgrass								
	mesquite	35	trichloris	80	5	ragweed	5	20
	granjeno	25	sideoats	80	0	bush sunflower	5	10
	huisache	5	Arizona cottontop	55	3	orange zexmenia	5	8
	whitebrush	10	buffalograss	55	68	sunflower	5	10
	blackbrush	15	hooded windmillgrass	40	80	doveweed	5	5
	prickly pear	10	purple threeawn	40	20	annual broomweed	5	30
			sandbur	10	18	ruellia	0	4
			thin paspalum	0	8	snoutbean	0	4
			silver bluestem	0	25	Texas verbena	0	2
			Texas bristlegrass	0	10			
			Texas wintergrass	0	15			
			Total grasses	360	252	Total forbs	30	93
NRCS Range Site: Hardland								
EDYS Plant community								
Late-seral: little bluestem-trichloris-sideoats								
Mid-seral: mesquite-buffalograss-trichloris								
	mesquite	50	little bluestem	80	10	ragweed	10	55
	Texas persimmon	2	trichloris	70	35	prairie coneflower	5	3
	huisache	7	Arizona cottontop	25	3	ruellia	5	4
	granjeno	9	sideoats	70	3	annual broomweed	5	33
	blackbrush	6	silver bluestem	60	22	Texas doveweed	0	3
	whitebrush	6	vine-mesquite	25	10	old-man's beard	0	3
	agarito	2	buffalograss	40	80	frogfruit	0	1
	prickly pear	18	Texas wintergrass	30	35	Texas verbena	0	1
			purple threeawn	10	35	sunflower	0	7
			hairy grama	5	10			
			Texas bristlegrass	5	3			
			hooded windmillgrass	0	19			
			knotroot bristlegrass	5	35			
			Total grasses	435	300	Total forbs	25	110

Appendix Table C.2 (Cont.)

	Woody Species	Relative Coveer (%)	Grasses	Biomass Late	Biomass Mid	Forbs	Biomass Late	Biomass Mid
NRCS Range Site: Lakebed								
EDYS Plant community								
Late-seral: flatsedge-knotroot bristlegrass-longtom								
Mid-seral: huisache-flatsedge-bermudagrass								
	huisache	50	longtom	50	10	ragweed	20	25
	hackberry	25	buffalograss	40	30	frogfruit	15	20
	baccharis	15	bermudagrass	80	70	sunflower	5	30
	rattlepod	10	knotroot bristlegrass	70	40	giant ragweed	0	32
			vine-mesquite	20	5			
			cutgrass	10	5			
			sedge	20	15			
			flatsedge	80	90			
			fimbry	10	5			
			cattail	40	10			
			Johnsongrass	0	10			
			Total grasses	420	290	Total forbs	40	107
NRCS Range Site: Loamy Bottomland								
EDYS Plant community								
Late-seral: live oak-mustang grape-switchgrass								
Mid-seral: live oak-mustang grape-Johnsongrass								
	live oak	25	switchgrass	100	10	ragweed	20	20
	pecan	10	trichloris	90	60	old-man's beard	20	30
	hackberry	10	little bluestem	90	30	ruellia	5	5
	huisache	10	vine-mesquite	40	20	sunflower	10	32
	mesquite	5	sideoats	60	20	partridge pea	5	5
	mustang grape	25	buffalograss	50	30	giant ragweed	0	45
	whitebrush	5	Texas wintergrass	40	50	frogfruit	0	5
	granjeno	5	Virginia wildrye	40	20			
	baccharis	5	sedge	40	30			
			bermudagrass	0	50			
			Johnsongrass	0	65			
			Total grasses	550	385	Total forbs	60	142
NRCS Range Site: Loamy Sand								
EDYS Plant community								
Late-seral: little bluestem-sideoats-thin paspalum								
Mid-seral: live oak-mesquite-little bluestem								
	mesquite	30	little bluestem	80	92	ragweed	15	20
	live oak	40	switchgrass	30	0	snoutbean	5	5
	hackberry	5	thin paspalum	50	11	bush sunflower	10	25
	mustang grape	10	sideoats	60	1	orange zexmenia	5	5
	granjeno	10	Arizona cottontop	50	1	Texas doveweed	5	20
	prickly pear	5	silver bluestem	60	10	sunflower	5	20
			hooded windmillgrass	25	34	frogfruit	0	4
			hairy grama	10	28	Texas bluebonnet	0	3
			purple threeawn	25	28			
			sandbur	5	72			
			Total grasses	395	277	Total forbs	45	102
NRCS Range Site: Rolling Blackland								
EDYS Plant community								
Late-seral: sideoats-silver bluestem-trichoris								
Mid-seral: mesquite-silver bluestem-buffalograss								
	mesquite	45	sideoats	65	20	ragweed	5	30
	granjeno	25	silver bluestem	65	40	undleflower	5	5
	prickly pear	10	trichloris	60	35	coneflower	5	5
	whitebrush	10	Texas wintergrass	40	30	ruellia	5	5
	agarito	5	Arizona cottontop	40	10	sunflower	5	20
	huisache	5	buffalograss	40	50	frogfruit	0	5
			vine-mesquite	25	5	Texas verbena	0	5
			hairy grama	5	20	annual broomweed	0	18
			purple threeawn	10	30			
			hooded windmillgrass	5	10			
			Total grasses	355	250	Total forbs	25	93

Appendix Table C.2 (Cont.)

	Woody Species	Relative Cover (%)	Grasses	Biomass Late	Mid	Forbs	Biomass Late	Mid
NRCS Range Site: Sandstone Hills **EDYS Plant community** **Late-seral: post oak-little bluestem-tall dropseed** **Mid-seral: post oak-mesquite-silver bluestem**								
	post oak	50	little bluestem	75	24	ragweed	10	20
	mesquite	30	indiangrass	30	1	snoutbean	5	4
	mustang grape	12	silver bluestem	40	35	bush sunflower	10	15
	prickly pear	6	Virginia wildrye	10	2	partridge pea	5	4
	agarito	2	tall dropseed	40	30	sunflower	5	10
			thin paspalum	20	28	bluebonnet	5	5
			purple threeawn	10	25	Texas doveweed	0	5
			hooded windmillgrass	10	15			
			sandbur	5	10			
			Total grasses	240	170	Total forbs	40	63
NRCS Range Site: Sandy **EDYS Plant community** **Late-seral: mesquite-live oak-little bluestem** **Mid-seral: mesquite-live oak-little bluestem**								
	mesquite	45	little bluestem	200	112	ragweed	10	15
	live oak	30	tall dropseed	60	14	snoutbean	5	8
	granjeno	15	switchgrass	40	0	bush sunflower	5	27
	prickly pear	10	thin paspalum	40	70	partridge pea	5	7
			indiangrass	30	6	sunflower	5	27
			purple threeawn	15	25	bluebonnet	5	5
			hooded windmillgrass	10	11	Texas doveweed	5	15
			sandbur	5	36			
			hairy grama	0	6			
			Total grasses	400	280	Total forbs	40	104
NRCS Range Site: Sandy Loam **EDYS Plant community** **Late-seral: mesquite-little bluestem-trichloris** **Mid-seral: mesquite-little bluestem-thin paspalum**								
	mesquite	35	little bluestem	140	70	ragweed	10	20
	live oak	32	trichloris	80	30	bundleflower	5	5
	granjeno	15	silver bluestem	70	40	snoutbean	5	10
	whitebrush	10	sideoats	70	20	Texas verbena	5	5
	blackbrush	5	Arizona cottontop	25	5	bush sunflower	5	20
	prickly pear	3	purple threeawn	15	30	orange zexmenia	5	10
			hooded windmillgrass	15	15	partridge pea	5	10
			thin paspalum	15	50	sunflower	5	20
			hairy grama	5	10	bluebonnet	5	5
			sandbur	5	40	Texas doveweed	0	10
			Total grasses	440	310	Total forbs	50	115
NRCS Range Site: Shallow **EDYS Plant community** **Late-seral: blackbrush-sideoats-silver bluestem** **Mid-seral: blackbrush-silver bluestem-purple threeawn**								
	blackbrush	40	sideoats	60	10	ragweed	5	10
	guajillo	30	silver bluestem	55	35	dogweed	5	6
	live oak	8	Arizona cottontop	20	4	ruellia	0	3
	prickly pear	5	buffalograss	20	25	orange zexmenia	0	10
	mesquite	5	Texas wintergrass	20	22	annual broomweed	0	15
	Texas persimmon	5	hairy grama	10	15	Texas doveweed	0	4
	huisache	2	purple threeawn	10	25	sunflower	0	8
	granjeno	4	vine-mesquite	5	1			
	agarito	1	hooded windmillgrass	5	7			
			Texas bristlegrass	5	6			
			Total grasses	210	150	Total forbs	10	56

Appendix Table C.2 (Cont.)

	Woody Species	Relative Cover (%)	Grasses	Biomass Late	Biomass Mid	Forbs	Biomass Late	Biomass Mid
NRCS Range Site: Shallow Ridge								
EDYS Plant community								
Late-seral: blackbrush-guajillo-silver bluestem								
Mid-seral: blackbrush-guajillo-purple threeawn								
	blackbrush	45	silver bluestem	65	35	ragweed	5	10
	guajillo	40	sideoats	60	10	prairie coneflower	5	5
	prickly pear	10	little bluestem	30	5	Texas verbena	5	5
	agarito	5	Arizona cottontop	30	5	orange zexmenia	10	19
			purple threeawn	25	38	annual broomweed	5	28
			hairy grama	20	34	dogweed	5	10
			Texas wintergrass	20	20			
			buffalograss	20	25			
			hooded windmillgrass	10	15			
			littletooth sedge	10	10			
			Texas bristlegrass	5	10			
			Total grasses	295	207	Total forbs	35	77
NRCS Range Site: Sloping Clay Loam								
EDYS Plant community								
Late-seral: sideoats-trichloris-buffalograss								
Mid-seral: mesquite-buffalograss-purple threeawn								
	mesquite	50	sideoats	60	10	bundleflower	5	5
	Texas persimmon	6	trichloris	50	30	bush sunflower	10	15
	huisache	4	buffalograss	40	45	orange zexmenia	10	10
	blackbrush	20	purple threeawn	30	35	prairie coneflower	5	5
	granjeno	12	Arizona cottontop	25	5	ragweed	0	10
	prickly pear	7	Texas wintergrass	25	20	Texas broomweed	0	10
	agarito	1	hairy grama	20	25	ruellia	0	3
			hooded windmillgrass	0	5	Texas verbena	0	2
						sunflower	0	5
			Total grasses	250	175	Total forbs	30	65
NRCS Range Site: Tight Sandy Loam								
EDYS Plant community								
Late-seral: sideoats-silver bluestem-trichloris								
Mid-seral: mesquite-buffalograss-silver bluestem								
	mesquite	35	sideoats	60	5	ragweed	5	20
	live oak	30	silver bluestem	60	30	bush sunflower	5	15
	granjeno	15	trichloris	60	25	snoutbean	3	5
	prickly pear	10	little bluestem	30	5	partridge pea	3	5
	blackbrush	10	buffalograss	30	35	bundleflower	2	2
			Arizona cottontop	20	3	annual broomweed	2	10
			tall dropseed	20	25	sunflower	5	18
			Texas wintergrass	20	20	Texas doveweed	3	13
			hooded windmillgrass	15	17	Texas bluebonnet	2	2
			purple threeawn	10	25			
			hairy grama	10	20			
			thin paspalum	10	25			
			sandbur	5	10			
			Total grasses	350	245	Total forbs	30	90
NRCS Range Site: Very Gravelly Ridge								
EDYS Plant community								
Late-seral: post oak-little bluestem-sideoats								
Mid-seral: post oak-sideoats-little bluestem								
	post oak	80	little bluestem	100	25	ragweed	5	25
	blackbrush	10	sideoats	40	45	snoutbean	5	5
	prickly pear	10	indiangrass	30	5	Texas doveweed	5	10
			silver bluestem	30	40	sunflower	5	20
			trichloris	20	15	orange zexmenia	0	10
			Arizona cottontop	20	10	dogweed	0	10
			buffalograss	20	22			
			thin paspalum	10	10			
			purple threeawn	20	25			
			hooded windmill	20	20			
			Total grasses	310	217	Total forbs	20	80

Appendix Table C.3 Estimated species composition (% cover for woody species, g/m^2 annual aboveground production for herbaceous species) on clay and loam NRCS range sites under late-seral (excellent range condition) conditions in Karnes and Wilson Counties. (x = occurs in early- or mid-seral).

Species	**Blackland**	**Rolling Blackland**	**Hardland**	**Clay loam**	**Sloping Clay Loam**	**Clayey Bottomland**	**Loamy Bottomland**
live oak	5%					10%	10%
hackberry	x					10%	5%
pecan						5%	5%
huisache	x					x	x
mesquite	x	x	x	5%	5%	x	x
Texas persimmon						x	
mustang grape						x	10%
granjeno	x	x	x	3%		x	x
prickly pear	x	x	x		5%	x	
blackbrush					5%		
whitebrush		x		2%		x	x
prairie baccharis				x		x	x
agarito	x	x					
switchgrass						70	100
indiangrass						70	
little bluestem	110		80	130		140	90
trichloris	70	60	70	60	50	120	90
sideoats	40	65	70	90	60		60
silver bluestem	45	65	60	95			
tall dropseed	20			20			
Virginia wildrye						70	40
bushy bluestem						10	
Arizona cottontop	20	40	25	20	25		
Texas wintergrass	30	40	30	20	25		40
vine-mesquite	20	25	25	5		50	40
knotroot bristlegrass						70	
buffalograss	10	40	40	5	40	40	50
hairy grama	5	5	5	5	20		
purple threeawn	5	10	10	5	30		
hooded windmillgrass	5	5		5			
Texas bristlegrass			5	5		10	
littletooth sedge			5				40
ragweed	4	5	10	5		20	20
old-man's beard							20
bundleflower	1	5		5	5		
frogfruit							
prairie coneflower	1	5	5	10	5	10	
snoutbean				5		5	
ruellia	2	5	5			5	5
bush sunflower					10		
Texas verbena	2						
orange zexmenia				5	10		
giant ragweed						20	
Texas doveweed							
annual broomweed			5	5			
partridge pea							5
sunflower		5				10	10
Total herbaceous	350	380	450	500	280	720	610

Appendix Table C.4 Estimated species composition (% cover for woody species, g/m^2 annual aboveground production for herbaceous species) on sandy and sandy loam NRCS range sites under late-seral (excellent range condition) conditions in Karnes and Wilson Counties.

Species	**Deep Sand**	**Deep Sand Savanna**	**Sandy**	**Loamy Sand**	**Sandy Loam**	**Tight Sandy Loam**	**Gray Sandy Loam**	**Sandstone Hills**
live oak	5%		5%	5%	5%	5%		
post oak		15%						15%
mesquite	x		5%	5%	5%	5%	5%	x
hackberry				5%				
huisache							x	
prickly pear		x	x	x	x	5%	x	
granjeno			x	x	x	5%	5%	
blackbrush					x	5%	5%	
whitebrush					x		X	
indiangrass	30	30	30					30
switchgrass	25	10	40	30				
little bluestem	200	200	200	80	140	30		75
tall dropseed	30	40	60			20		40
sideoats				60	70	60	80	
silver bluestem				60	70	60		40
trichloris					80	60	80	
Arizona cottontop				50	25	20	55	
Virginia wildrye								10
thin paspalum	40	20	40	50	15	10		20
purple threeawn	20	20	15	25	15	10	40	10
buffalograss						30	55	
Texas wintergrass						20		
hairy grama		10		10	5	10		
hooded windmillgrass		10	10	25	15	15	40	10
sandbur	5	5	5	5	5	5	10	5
ragweed			10	15	10	5	5	10
bundleflower					5	2		
snoutbean	10	10	5	5	5	3		5
bush sunflower	10	15	5	10	5	5	5	10
Texas verbena					5		5	
orange zexmenia				5	5			
annual broomweed						2	5	
partridge pea	5	5	5		5	3		5
Texas doveweed	5	5	5	5		3	5	
sunflower	5	5	5	5	5	5	5	5
Texas bluebonnet	5	5	5		5	2		5
Total herbaceous	390	390	440	440	490	380	390	280

An "x" indicates that the species occurs in early- or mid-seral stages.

Appendix Table C.5 Estimated species composition (% cover for woody species, g/m^2 annual aboveground production for herbaceous species) on shallow NRCS range sites under late-seral (excellent range condition) conditions in Karnes and Wilson Counties.

Species	**Chalky Ridge**	**Gravelly Ridge**	**Very Gravelly Ridge**	**Shallow**	**Shallow Ridge**
live oak	10%			x	
post oak			5%		
mesquite	x			x	
Texas persimmon				x	
huisache				x	
blackbrush		15%		x	5%
guajillo		10%		x	5%
prickly pear	x	x		x	5%
granjeno				x	
agarito					5%
prairie baccharis	x				
little bluestem	100		100		30
big bluestem	10				
indiangrass			30		
sideoats	20	40	40	60	60
silver bluestem	20	40	30	55	65
trichloris			20		
tall dropseed	10				
Arizona cottontop		30	20	20	30
Virginia wildrye	5				
Texas wintergrass	5			20	20
buffalograss	5		20	20	20
purple threeawn	5	30	20	10	25
thin paspalum			10		
hairy grama	3	25		10	20
hooded windmillgrass	2	30	20	5	10
vine-mesquite				5	
Texas bristlegrass		20		5	5
littletooth sedge					10
ragweed	15	5	5	5	5
prairie coneflower		5			5
snoutbean			5		
Texas verbena					5
orange zexmenia		5			10
annual broomweed	10	5			5
Texas doveweed			5		
sunflower			5		
dogweed		5		5	5
Total herbaceous	220	240	330	220	330

An "x" indicates that the species occurs in early- or mid-seral stages.

Appendix Table C.6 Comparison of vegetation data from literature sources for clay and clay loam sites in South Texas.

Species	**Box & White (1969)**		**Box (1961)**		**Powell & Box 1967**	**Buckley & Dodd**	**Dodd & Holtz**	**Johnston**
	Relative	**Absolute**	**Victoria**	**Orelia**	**Victoria**	**1969 clay**	**(1972)**	**(1963)**
	Welder Wildlife Refuge					**Webb**	**Goliad**	**Kleberg**
Acacia farnesiana	10.0	4.7	5.5	1.3	x			
Acacia rigidula	9.0	4.2	18.4	0.5	x			
Acacia tortuosa	t	t	2.9	1.3				
Berberis trifoliolata	4.1	1.9	6.4	t	x			
Celtis pallida	5.0	2.4	1.2	---	x			
Condalia obovata	2.0	0.9	0.9	---	x			
Diospyros texana	1.0	0.5	---	---				
Lycium berlandieri	1.0	0.5	---	---				
Opuntia leptocaulis	4.7	2.2	---	---				
Opuntia linheimeri	8.4	3.7	t	52.3		x		
Parkinsonia aculeata						x		
Prosopis glandulosa	43.2	20.3	53.0	38.2	x	x		
Prosopis reptans	4.6	2.2	---	---				
Varilla texana						x		
Zanthoxylum fagara	3.8	1.8	3.9	1.3	x			
Zizyphus obtusifolia	2.5	1.2	7.8	5.1				
Total woody (abs cover)		46.5	19.6	39.4	48.6			
Aristida roemeriana	3.3	5.4	14.3	7.6	2.3			2%
Aristida spp.							6.4	
Bothriochloa saccharoides	8.7	14.1	0.6	0.5	4.5			
Bouteloua curtipendula							1.7	
Bouteloua rigidiseta					0.3		8.3	
Bouteloua trifida						2.3		
Buchloe dactyloides	24.4	39.8	27.6	11.3	28.6			30%
Cenchrus ciliaris						4.0		
Cenchrus incertus	---	---	0.1	7.3		1.9		2%
Chloris cucullata							1.2	
Chloris verticillata	1.4	2.2	2.5	25.0	1.6			15%
Cynodon dactylon					0.6			
Digitaria californica	---	---	0.3	0.1				
Eragrostis lugens					3.9			
Eriochloa contracta	---	---	0.4	t	3.9	0.3		
Hilaria belangeri	t	t	16.9	20.9	1.0	27.8		20%
Leptochloa dubia						6.6		
Leptochloa nealleyi					2.2			
Leptoloma cognatum	---	---	0.1	0.1			0.6	
Panicum filipes	3.0	4.8	10.6	2.3	6.9			5%
Panicum hallii						78.2		
Panicum obtusum	1.4	2.2	2	t	2.2			
Paspalum pubiflorum	3.9	6.4	0.4	0.6	6.0			
Schedonnardus paniculatus	0.3	0.4	---	---				2%
Schizachyrium scoparium							1.2	
Setaria geniculata	0.9	1.5	0.4	0.5	5.3			
Setaria leucopila	0.8	1.3	17.8	15.0	20.2		1.2	
Sporobolus asper	2.5	4.0	---	---	1.4			
Sporobolus cryptandrus							0.6	
Sporobolus pyramidatus	0.4	0.7	0.2	4.5	1.7	14.4		
Stipa leucotricha	5.3	8.6	0.9	0.9	5.8		1.7	
Tridens albescens	2.1	3.5	0.7	t	1.4			
Tridens congestus	1.5	2.5	---	---				
Tridens eragrostoides	---	---	t	0.5				
Tridens texensis							2.3	
Other grasses (4)	0.2	0.3	0.2	0.2			6.4	
Carex spp.							9.9	
Total grasses (g/m2)	60.1	97.7			99.8	135.5	41.5	
Total grasses (% cover)			96.0	97.3				

Appendix Table C.6 (Cont.)

Species	Box & White (1969)		Box (1961)		Powell & Box 1967	Buckley & Dodd	Dodd & Holtz	Johnston
	Relative	Absolute	Victoria	Orelia	Victoria	1969 clay	(1972)	(1963)
		Welder Wildlife Refuge				Webb	Goliad	Kleberg
Ambrosia psilostachya	4.9	8.6	---	---	20.4			
Carex spp.								
Cienfuegosa sulphurea	0.3	0.4	---	---				
Commelina erecta	1.6	2.7	0.1	t				
Croton monanthogynus	2.8	4.5	0.9	t				
Desmanthus virgatus	2.1	3.5	---	---				5%
Euphorbia albomarginata								2%
Evolvulus sericeus								2%
Lythrum californicum	0.1	0.2	---	---				
Malvastrum aurantiacum	0.2	0.3	---	---				
Phyla incisa	0.5	0.9	t	t				
Portulaca pilosa	0.5	0.9	---	---				
Ratibida columnaris	0.1	0.2	0.6	t				
Ruellia sp.	7.6	12.3	0.8	t				
Solanum eleagnifolium	1.6	2.6	---	---				
Verbesina microptera	2.1	3.5	---	---				
Xanthocephalum texanum	15.0	24.5	0.1	0.5	20.4			
Other forbs (11)	0.5	0.8	1.0	t				
Total forbs	39.9	65.9	3.5	0.5	40.8		104.2	
Total herbaceous (g/m2)	100.0	163.6			140.6		145.7	
Total herbaceous (% cover)			99.5	97.8				

Box and White (1969) was a chaparral community on Victoria clay. Box (1961) is % relative basal cover. Victoria communities are an average of mesquite and chaparral communities and Orelia community is a prickly pear site.

Appendix Table C.7 Basal cover (%) and composition (% relative basal cover) on late-successional Fayette Prairie clay and clay loam sites (Smeins and Diamond 1983).

Species	**Basal Cover**		**Composition**	
	Upland	**Lowland**	**Upland**	**Lowland**
Andropogon gerardii	3	t	2.0	t
Bouteloua curtipendula	6	0	3.7	0.0
Coelorachis cylindrica	3	0	2.0	0.0
Dichanthelium sphaerocarpon	2	0	1.0	0.0
Eragrostis intermedia	1	0	0.3	0.0
Eriochloa sericea	2	0	1.0	0.0
Muhlenbergia capillaris	3	0	1.7	0.0
Panicum virgatum	0	18	0.0	22.0
Paspalum floridanum	4	5	2.7	6.1
Paspalum plicatulum	7	0	4.3	0.0
Paspalum setaceum	3	0	1.7	0.0
Schizachyrium scoparium	59	t	39.0	t
Sorghastrum nutans	11	10	7.3	12.2
Sporobolus asper	4	2	2.7	2.4
Stipa leucotricha	3	0	2.0	0.0
Tripsacum dactyloides	12	41	7.7	50.0
Carex microdonta	4	t	2.7	t
Eleocharis montevidensis	2	3	1.0	3.7
Fimbristylis puberula	2	0	1.3	0.0
Scleria ciliata	2	0	1.3	0.0
Argythamnia humilis	2	0	1.0	0.0
Biforia americana	1	0	0.7	0.0
Cacalia plantaginea	3	0	1.7	0.0
Desmanthus illinoensis	0	2	0.0	2.4
Dyschoriste linearis	2	0	1.3	0.0
Echinacea angustifolia	1	0	0.7	0.0
Krigia occidentalis	2	0	1.3	0.0
Marshallia caespitosa	4	0	2.7	0.0
Physotegia intermedia	3	1	1.7	1.2
Rudbeckia hirta	2	0	1.3	0.0
Ruellia nudiflora	2	0	1.3	0.0
Grasses			79.1	92.7
Grass-likes			6.3	3.7
Forbs			13.7	3.6

Appendix Table C.8 Comparison of vegetation data from literature sources for sandy and sandy loam sites in South Texas.

Species	**Box (1961) Nueces fs**	**Drawe & Box (1969) Zavala fsl**		**Diamond & Smeins (1984) Alfisols**	**Bovey et al. (1972) Katy sl**
		g/m^2	**%**		
Quercus virginiana					114.2
Aristida purpurescens	1.2			6.0	x
Bouteloua hirsuta	1.8				
Brachiaria ciliatissima	3.2	22.0	9.3		
Cenchrus incertus	13.7	23.1	9.7		
Chloris cucullata	4.2				
Dichanthelium oligosanthes				4.0	
Elyonurus tripsacoides	3.1	30.0	12.3		
Eragrostis secundiflora	1.2				x
Leptoloma cognatum	2.1				
Paspalum floridanum				3.0	
Paspalum plicatulum	0.4			10.0	x
Paspalum setaceum	4.4			3.0	
Schizachyrium scoparium				41.0	x
Schizachyrium littoralis	20.7	13.8	5.7		
Setaria firmula	19.8	33.4	14.0		x
Sorghastrum nutans				7.0	x
Sporobolus asper				3.0	
Tridens strictus				1.0	
Other grasses		40.4	16.9		
Grasses (% cover)				78.0	
Grasses (relative cover)	75.8		67.9		
Grasses (g/m^2)		162.7			184.7
Fimbristyis puberula				3.0	
Rhynchospora spp.				1.0	
Acacia hirta				1.0	
Ambrosia psilostachya				3.0	
Aster pratensis				1.0	
Commelina erecta	0.8				
Croton capitatus	1.5	9.1	3.7		
Croton texensis	---	1.7	0.7		
Eriogonum multiflorum	1.4				
Heterotheca latifolia	---	49.8	21.3		
Liatris spp.				3.0	
Nama hispidum	6.6				
Phyla incisa	0.3				
Ratibida columnaris				1.0	
Schrankia uncinata				3.0	
Tragia urticifolia				1.0	
Verbesina enceloides	7.8	10.0	4.0		
Other forbs		5.4	2.3		
Forbs (% cover)				17.0	
Forbs (relative cover)	18.4		32.0		
Forbs (g/m^2)		76.0			18.5
Other species	5.8				

Trace species from Diamond and Smeins (1984): *Andropogon gerardii, Aster ericoides, Buchloe dactyloides, Cacalia plantaginea, Carex microdonta, Cirsium undulatum, Eryngium yuccifolium, Hedyotis nigricans, Linum medium, Muhlenbergia capillaris, Oxalis dillenii, Panicum virgatum, Ruellia nudiflora, Sabatia campestris, Scleria ciliata, Silphium laciniatum, Sisyrinchium pruinosum.*

Appendix Table C.9 Mean frequency (%) of plant communities on Pat Welder Ranch, San Patricio County (McLendon and Dahl 1983).

Species	**Mesquite-blackbrush-ragweed**	**Mesquite-blackbrush-knotroot bristlegrass**	**Mesquite-blackbrush-huisache**	**Mesquite-huisache-blackbrush**	**Mesquite-huisache-buffalograss**	**MEAN**
Prosopis glandulosa	41	53	37	59	46	47
Acacia farnesiana			13	15	13	8
Acacia rigidula	20	17	33	18	12	20
Celtis pallida				12		2
Agrostis hiemalis					11	2
Bothriochloa saccharoides		10		11		4
Buchloe dactyloides	10		14	15	33	14
Chloris verticillata				11		2
Paspalum plicatulum				11		2
Setaria geniculata	19	61	49	12	10	30
Stipa leucotricha		10		17		3
Ambrosia psilostachya	65	79	30	86	23	57
Chamaecrista fasciculata				14	16	6
Gutierrezia texana	25	13	34	29	27	46
Sida ciliaris	23		18	17	27	17
Oxalis dillenii	10			35	20	13

Appendix Table C.10 Woody plant density (plants/ha) and basal cover (m^2/ha) on Miguel and Papalote fine sandy loam soils on La Copita, Jim Wells County (Archer et al. 1988).

Species	**Density**			**Cover**	**Density of Plants**
	Clusters	**Openings**	**Drainages**	**Openings**	**> 2 m in Drainages**
Acacia farnesiana		70	44	0.027	37
Aloysia lycioides		0	2189	0.000	0
Bumelia spp.	x	0	35	0.000	9
Celtis pallida	x	0	775	0.000	283
Colubrina texensis		30	582	0.001	0
Condalia hookeri	x	0	462	0.000	97
Diospyros texana	x	16	1101	0.001	106
Lantana macropoda	x	0	---	0.000	0
Lycium berlandieri	x	0	197	0.000	0
Mahonia trifoliolata	x	0	39	0.000	0
Opuntia lindheimeri	x	100	982	-----	0
Opuntia leptocaulis	x	30	---	-----	0
Prosopis glandulosa	x	350	764	0.022	295
Salvia ballotaeflora	x	0	339	0.000	0
Schaefferia cuneifolia	x	0	314	0.000	0
Yucca treculeana		0	---	0.000	---
Zanthoxylum fagara	x	30	3229	0.003	318
Zizyphus obtusifolia	x	0	218	0.000	0
TOTALS		626	11270	0.054	1145

Archer et al. (1988) sites were on Miguel and Papalote fine sandy loams on the La Copita, Jim Wells County. #/ha = number of woody plants per hectare, BC = basal cover (%).

Density of plants > 2 m in drainages included in the values for drainages overall.

Average cluster was 18 m^2.

Woody plant coverage averaged 13.0% in 1940 and 36.4% in 1983. This is an annual increase of 0.55 percentage points per year. At that rate, cover in 2013 would be 52.9% (36.4% + 16.5%).

Appendix Table C.11 Woody plant density (plants/ha) and canopy cover (m^2/plant) in three plant communities on the Welder Wildlife Refuge, San Patricio County, Texas (Box 1961).

Species	**Density**			**Cover**		
	Mesquite	**Chaparral**	**Prickly pear**	**Mesquite**	**Chaparral**	**Prickly pear**
Acacia farnesiana	50	39	13	----	----	----
Acacia rigidula	3	193	56	11.75	3.69	0.87
Acacia tortuosa	13	34	13	----	----	----
Celtis pallida	t	19	t	----	----	----
Condalia hookeri	t	15	t	----	----	----
Mahonia trifoliolata	t	106	t	----	----	----
Opuntia lindheimeri	t	t	426	----	----	4.84
Prosopis glandulosa	364	174	2046	4.84	1.28	0.74
Zanthoxylum fagara	3	39	13	----	----	----
Zizyphus obtusifolia	14	116	56	----	----	----
TOTAL	447	735	2623			

Appendix Table C.12 Vegetation of the Welder Wildlife Refuge, San Patricio County (Drawe et al. 1978).

Mesquite-mixed grass community: Victoria clay

Moderate stands of mesquite (12-27% cover), with mottes of mixed brush; huisache is increasing (200-500 trees/ha).
Interspaces with dense stands of grass: 17% Texas wintergrass, 8% meadow dropseed, 2% silver bluestem; little bluestem, plains bristlegrass, Texas cupgrass, lovegrass tridens, sourgrass (*Digitaria insularis*).
Forbs (20%): prairie coneflower, western ragweed, ruellia, horsemint, one-seeded doveweed (*Croton monanthogynus*), bladderpod (*Lesquerella lindheimeri*), Texas broomweed.
Depressions: vine-mesquite, pink tridens, white tridens, frogfruit, water clover (*Marsilea mucronata*).
Swales: hackberry, longtom, sumpweed.

Chaparral-mixed grass community: drier clay and clay loam sites

Woody plant cover (34-55%): blackbrush (11%), mesquite, huisache, twisted acacia, agarito, creeping mesquite, granjeno, lotebush, brasil, Texas persimmon, colima. Areas root-plowed 30-35 years ago have brush 2-3 m tall. Mesquite and huisache have increased in height 1.0-1.5 m in 20-25 years and shrubs have increased 0.3-0.5 m.
Understory in mottes: some plains bristlegrass and bunch cutgrass (*Leersia monandra*).
Openings between mottes: similar to mesquite-mixed grass except more silver bluestem and little bluestem.

Chaparral-mixed grass community: sandy loam sites

Woody plant cover (25.7%): granjeno, colima, mesquite, huisache, blackbrush, agarito, lotebush, Texas persimmon, prickly pear (0.3%).
Major grasses: silver bluestem, knotroot bristlegrass, plains bristlegrass, Texas cottontop.

Halophyte-shortgrass community: saline sites adjacent to temporary lakes or swales

Few, scattered mesquite.
Padre Island dropseed, whorled dropseed, saltgrass, Texas willkommia (*Willkommia texana*), gulf cordgrass, shoregrass; sea oxeye, glasswort (*Salicornia virginica*), purslane, saltbush.

Paspalum-aquatic plant community: swales on clay soils

Sesbania and some scattered huisache.
Almost pure stands of hairyseed paspalum (*Paspalum publiflorum*). Some canarygrass (*Phlaris canariensis*), arrowhead, and water clover.
During dry periods, buffalograss and creeping lovegrass (*Neeragrostis reptans*) become abundant.

Gulf cordgrass community: frequently flooded clay swales

Upper clay loam sites: mesquite, granjeno, blackbrush, sea oxeye; bermudagrass, little barley
Upper sandy loam sites: huisache; bermudagrass, rescue grass, geranium
Mid-elevation sites: closed canopy of gulf cordgrass
Lower elevation sites: clubhead cutgrass (*Leersia hexandra*), cattail, and spikerush.

Huisache-mixed grass community: low swale areas

Dense stands of huisache.
Understory under closed canopy: Texas wintergrass, canarygrass, Ozarkgrass, sixweeks fescue
Understory under open canopy: hairyseed paspalum, knotroot bristlegrass, vine-mesquite
Wetter areas: spiny aster and longtom; drier areas: more silver bluestem, lovegrass tridens, plains bristlegrass.

Appendix Table C.12 (Cont.)

Bunchgrass-annual forb community: sandy and sandy loam soils

Open grassland with 25-40% grass cover. Relative cover = 75% grasses, 19% forbs, 6% shrubs.
Under light grazing: seacoast bluestem, big bluestem, Pan American balsamscale, tanglehead, switchgrass, Texasgrass (*Vaseochloa multinervosa*), trichloris, big sandbur, crinkleawn.
Under moderate grazing: increase in balsamscale and thin paspalum.
Under heavy grazing: sandbur and knotgrass (*Setaria formula*) are common.
Major forbs: skunk daisy (*Ximenesia encelioides*), Texas doveweed, woolly doveweed, wild buckwheat.
On sandy loam sites: increase in sideoats grama, brownseed paspalum, hooded windmillgrass, old-man's beard, and prickly pear.

Hogplum-bunchgrass community: sandy loam soils on river terraces

Stands of hogplum and old-man's beard, with scattered huisache and Texas kidneywood.
Hogplum dense on terraces, huisache dense in swales.
Understory: sideoats grama, brownseed paspalum, hooded windmillgrass, prickly pear.

Huisache-bunchgrass community: lower areas of Odem sandy loam soils

Moderate to dense stands of huisache and dense stands of old-man's beard.
Understory similar to bunchgrass-annual forb community, but with southwestern bristlegrass (*Setaria scheelei*), Texas wintergrass, Virginia wildrye, snoutbean, and ruellia.

Chittimwood-hackberry community: sandy loam soils

Dense stands of chittimwood (*Bumelia lanuginose*) and hackberry. Small trees (3-7 m tall), with canopies extending to near the ground.
Sparse understory: southwestern bristlegrass and Turk's cap (*Malvavicus drummondii*).

Live oak-chaparral community: sandy and sandy loam soils

Overstory: scattered stands of old live oak, 2% canopy cover.
Mid-level: mesquite (30%; 3-5 m tall), colima (14%), Texas persimmon (6%), blackbrush (6%), granjeno (5%), agarito (5%), chittimwood, hackberry, anacua, chapatillo (*Amyris texana*), tickle-tongue.
Understory: seacoast bluestem, brownseed paspalum, tanglehead; some big bluestem, switchgrass, indiangrass, trichloris, southwestern bristlegrass.
Heavier grazing: windmillgrasses, brownseed paspalum, thin paspalum, sandbur.
Turk's cap, pigeon berry (*Rivina humilis*), mistflower, skunk daisy, doveweed.

Mesquite-bristlegrass community: poorly-drained sands and sandy loams

Open stands of mesquite, with granjeno, colima, lotebush, agarito.
Understory: knotroot bristlegrass, brownseed paspalum, Hall panicum, silver bluestem, gummy lovegrass; western ragweed

Appendix Table C.12 (Cont.)

Riparian woodland community: riparian bottomlands

Stands of large trees: hackberry, anacua, cedar elm, pecan, with mustang grape.
Shrub understory: similar to that of live oak-chaparral community.
Herbaceous understory: southwestern bristlegrass, broadleaf uniola (*Chasmanthium latifolium*), Virginia wildrye, Turk's cap, velvet mallow (*Wissadula amplissima*).

Woodland-spiny aster community: mixed alluvial soils

Mixture of chaparral, western soapberry (*Sapindus saponaria*), and spiny aster.

Spiny aster-longtom community: low-lying areas where water stands for long periods following rains

Dense stands of spiny aster, with some longtom and little snoutbean (*Shynchosia minima*).

Lakes and Ponds

Submersed community: coontail (*Ceratophyllum demersum*), water nymph (*Najas quadalupensis*), water stargrass (*Heteranthera liebmanni*), wigeongrass (*Ruppia maritima*), sago pondweed (*Potamogeton pectinatus*), and muskgrass (*Chara* spp.).
Floating community: mostly lotus (*Nelumbo lutea*).
Lower marsh edges: bulrushes (*Scirpus* spp.), cattails, and sedges.
Upper marsh edges: clubhead cutgrass, longtom, sesbania.
As ponds dry: buffalograss, knotroot bristlegrass, creeping lovegrass.

Appendix Table C.13 Woody plants reported on other study sites in South Texas.

Species	**Campbellton Bovey et al. 1970**	**Webb Co. Buckley & Dodd 1969**	**Goliad Co. Dodd & Holtz 1972**
Acacia farnesiana	major		
Acacia greggii	scattered		
Acacia rigidula	major		308/ha
Celtis pallida	scattered		
Colubrina texensis	scattered		185/ha
Diospyros texana	scattered		124/ha
Eysenhardtia texana	scattered		
Lycium berlandieri	scattered		
Mahonia trifoliolata	scattered		62/ha
Opuntia leptocaulis	scattered		
Opuntia linheimeri	scattered	density = 1	
Parkinsonia aculeate		density = 4	
Prosopis glandulosa	scattered	density = 3	
Varilla texana		density = 2	
Yucca treculeana	scattered		
Zizyphus obtusifolia	scattered		62/ha
Other woody species			333/ha

Appendix Table C.14 Woody plant cover (%) at sites in South Texas.

Community	**Woody Cover**	**Location**	**Reference**
Blackbrush-mesquite	20.4	Welder WR, San Patricio Co.	Box (1961)
Blackbrush-mesquite	38.4	Welder WR, San Patricio Co.	Drawe et al. (1978)
Blackbrush-mesquite	48.6	Welder WR, San Patricio Co.	Powell & Box (1967)
Granjeno-colima	25.7	Welder WR, San Patricio Co.	Drawe et al. (1978)
Mesquite-buffalograss	18.6	Welder WR, San Patricio Co.	Box (1961)
Mesquite-huisache	47	Welder WR, San Patricio Co.	Box & White (1969)
Mesquite-mixed grass	20	Welder WR, San Patricio Co.	Drawe et al. (1978)
Mesquite-prickly pear	36.4	La Copita, Jim Wells Co.	Archer et al. (1988)
Prickly pear-mesquite	39.4	Welder WR, San Patricio Co.	Box (1961)

Appendix Table C.15 Species composition (%) in wetland communities on the Welder Wildlife Refuge, San Patricio County (Scifres et al. 1980).

Species	**Clubhead cutgrass**	**Cattail-cutgrass**	**Cutgrass spikerush**	**Cutgrass longtom**	**Wetland Mean**	**Gulf cordgrass**
Borrichia frutescens	0	1	t	0	t	2
Cynodon dactylon	2	5	t	5	3	t
Leersia hexandra	29	19	28	20	24	3
Paspalum lividum	20	14	14	29	19	4
Setaria geniculata	0	0	7	t	2	3
Spartina spartinae	0	0	t	t	t	65
Echinodorus cordifolius	9	4	6	7	6	2
Eleocharis spp	16	10	19	11	14	6
Fimbristylis castanea	6	5	8	3	5	5
Typha domingensis	t	32	t	0	8	0
Iva annua	0	0	0	6	2	0
Phyla incise	t	t	6	t	2	t
Polygonum ramosissimum	0	0	2	7	2	1
Rumex crispus	4	1	2	9	2	4
Sagittaria latifolia	4	3	3	1	3	4

Appendix Table C.16 Non-quantified species lists for South Texas plant communities.

Species	**Drawe (1994) Bluestem-corgrass**	**McLendon (1994) Mesquite-granjeno-acacia**	**Smeins (1994a) Little bluestem-indiangrass**	**Smeins (1994b) Little bluestem-post oak**	**Archer (1990) La Copita Jim Wells Co.**
Acacia farnesiana		common			
Acacia rigidula		common			
Acacia tortuosa		common			
Aloysia lycioides		common			
Celtis laevigata				common	
Celtis pallida		sub-dominant			common
Condalia hookeri		common			common
Diospyros texana		common			common
Mahonia trifoliolata		common			common
Opuntia linheimeri		common			
Porlieria angustifolia		common			
Prosopis glandulosa		dominant			dominant
Quercus buckleyi				common	
Quercus marilandica				common	
Quercus stellata				dominant	
Quercus virginiana				common	
Rhus aromatic				common	
Schaefferia cuneifolia					common
Smilax bona-nox				common	
Symphoricarpos orbiculatus				common	
Zanthoxylum fagara		common			common
Zizyphus obtusifolia		common			common
Andropogon gerardii				common	
Andropogon glomeratus	common				
Andropogon tenarius	common				
Andropogon virginicus	common				
Aristida purpurea	common	common	common	common	common
Bothriochloa saccharoides	common	common			
Bouteloua curtipendula		common	common	common	
Bouteloua hirsuta		common	common	common	
Bouteloua rigidiseta		common	common		common
Bouteloua trifida		common			common
Buchloe dactyloides	common	common	common	common	
Cenchrus ciliaris		common			
Cenchrus incertus		common			common
Chloris cucullata		common			common
Chloris pluriflora		common			
Dichanthium annulatum		common			
Distichlis spicata	common				
Elyonurus tripsacoides	common				
Hilaria belangeri		common			
Panicum obtusum		common			
Pappophorum bicolor		common			
Paspalum lividum	common				
Paspalum plicatulum	common				
Paspalum setaceum					common
Schizachyrium littoralis	dominant				
Schizachyrium scoparium	dominant		dominant	sub-dominant	
Setaria leucopila		common			
Setaria texana		common			
Sorghastrum nutans			sub-dominant	common	
Spartina spartinae	dominant				
Sporobolus asper	common		common	common	
Sporobolus indicus	common				
Sporobolus tharpii	common				
Stipa leucotricha	common		common	common	
Tridens congestus	common				

Appendix Table C.16 (Cont.)

Species	**Drawe (1994) Bluestem-corgrass**	**McLendon (1994) Mesquite-granjeno-acacia**	**Smeins (1994a) Little bluestem-indiangrass**	**Smeins (1994b) Little bluestem-post oak**	**Archer (1990) La Copita Jim Wells Co.**
Carex spp.	common				
Eleocharis spp.	common				
Fimbristylis spp.	common				
Scirpus spp.	common				
Ambrosia psilostachya	common				
Amphiachyris dracunculoides		common			
Clematis drummondii		common			
Croton spp.	common	common			
Cynanchum leave		common			
Desmanthus virgatus		common			
Dichondra micrantha	common				
Ericameria texana		common			
Eriogonum multiflorum	common				
Eupatorium incarnatum		common			common
Eupatorium odoratum		common			common
Evolvulus spp.					common
Gnaphalium obtusifolium		common			
Iva annua	common				
Lantana horrida		common			
Parietaria texana		common			
Parthenium incanatum		common			
Ratibida columnaris	common				
Rhynchosia spp.	common				
Sagittaria latifolia	common				
Sarcostemma cynanchoides		common			
Verbesina spp.					common
Zexmenia hispida		common			common

Remnants of the bluestem-cordgrass prairie remain as the Goliad Prairie, McFaddin Prairie (near Victoria), and east of Tivoli (Drawe 1994).

Appendix Table C.17 Summary of South Texas plant community composition data from various literature sources (Appendix Tables C.6-C.16). Woody plant values are % of total woody plant cover. Herbaceous values are % of total herbaceous biomass.

EDYS Species	**Clay Sites**	**Clay Loam**	**Sandy Loam**	**Sand Sites**	**Shallow**	**Riparian**	**Wetland**
Huisache	18	1	16	2		5	20
Pecan						5	
Sugar hackberry	1		3	3		10	5
Texas persimmon	2		6	4	16	12	
Mesquite	38	40	21	15	6	10	
Post oak			1	50			
Live oak			4	10		12	
Guajillo					20		
Blackbrush	12	1	4	2	42		
Whitebrush	3		5			15	
Prairie baccharis						8	10
Granjeno	15	5	27	3		10	
Agarito	2	1	6	2	8		
Rattlepod							65
Mustang grape				4		10	
Prickly pear	9	52	7	5	8	3	
Big bluestem			1			1	
Purple threeawn	8	15	7	6	22		
King Ranch bluestem	1					2	2
Silver bluestem	6	1	8		6	1	
Sideoats grama			1	2	2		
Hairy grama		1		1	10		
Buffalograss	20	30		2	5	1	3
Sandbur	2	5	5	6			
Hooded windmillgrass	4	10	2	4	12		
Trichloris	3	25	5	2		5	
Bermudagrass	1	2				5	3
Arizona cottontop	1	2	6				
Virginia wildrye	1		1			4	
Clubhead cutgrass							22
Kleingrass							
Vine-mesquite	1						
Switchgrass						1	
Longtom							18
Thin paspalum	2	1	10	11		4	
Little bluestem	1		20	34		4	
Knotroot bristlegrass	2	1	5			10	4
Texas bristlegrass	4		2		5	2	
Johnsongrass						20	6
Tall dropseed	4		10	13			
Texas wintergrass	11	3	1	3	3	2	
Littletooth sedge						1	13
Flatsedge						1	6
Fimbry			1				5
Cattail							7
Ragweed	8	2	2	4	10	5	4
Old-man's beard	1		2			5	
Bundleflower	2		1	2			
Frogfruit	1			4		1	1
Prairie coneflower	2		2	1			
Snoutbean			2				

Appendix Table C.17 (Cont.)

EDYS Species	Clay Sites	Clay Loam	Sandy Loam	Sand Sites	Shallow	Riparian	Wetland
Ruellia	3	1	1				
Bush sunflower	1		2	4			
Texas verbena			1				
Orange zexmenia					5		
Giant ragweed						20	2
Annual broomweed	8	1			10		
Partridge pea							
Texas doveweed	1		2	1			
Sunflower	1				5	5	
Duckweed							4
Texas bluebonnet							
Dogweed					5		

Sources of data for: 1) clay sites are Appendix Tables C.6 (Box & White 1969; Box 1961 Victoria; Powell & Box 1967; Johnston 1963), C.9, C.12, and C.16 (McLendon 1994); 2) clay loam sites are Appendix Tables C.6 (Box 1961, Orelia; Buckley & Dodd 1969); 3) sandy loam sites are Appendix Tables C.8 (Drawe & Box 1969; Diamond & Smeins 1984; Bovey et al. 1972), C.10, C.12, and C.16; 4) sand sites are Appendix Tables C.8 (Box 1961; Diamond & Smeins 1984),C.12, and C.16 (Smeins 1994a, 1994b); 5) shallow sites is Appendix Table C.13 (Dodd & Holtz 1972); 6) riparian sites are Appendix Tables C.10 and C.12; and 7) wetland sites are C.12 and C.15.

Appendix Table C.18 Effect of range condition on forage production.

Type	Location	Units	Excellent	Good	Fair	Poor	Reference
Bluestem prairie	LA	lb/ac	2828	3239	3351		Duvall & Linnartz 1967
Bluestem prairie	OK	lb/ac	3767			3172	Hazell 1967
Bluestem prairie	NE	% comp	83	46	11		Jensen & Schumacher 1969

Appendix Table C.19 Effect of grazing intensity on forage production.

Type	Location	Units	Ungrazed	Light	Medium	Heavy	Reference
Black grama grassland	NM	basal	0.73	1.00	0.69	0.57	Paulsen & Ares 1962
Tobosa grassland	NM	basal	0.51	1.00	1.09	0.94	Paulsen & Ares 1962
Blue grama stony hills	NM	lbs/ac	560		470		Pieper 1968
Blue grama loam upland	NM	lbs/ac	650		550		Pieper 1968
Blue grama bottomland	NM	lbs/ac	610		295		Pieper 1968

Appendix Table C.20 Summary of grazing intensity ratios.

Type	Location	Excellent	Good	Fair	Poor	Ungrazed	Light	Medium	Heavy
Bluestem prairie	LA	1.00	1.14	1.18					
Bluestem prairie	OK	1.00			0.84				
Bluestem prairie	NE	1.00	0.55	0.13					
Blue grama	NM					1.00		0.84	
Blue grama	NM					1.00		0.85	
Blue grama	NM					1.00		0.48	
Black grama	NM					0.73	1.00	0.69	0.57
Tobosa	NM					0.51	1.00	1.09	0.94
MEAN		1.00	0.85	0.61	0.84	0.85	1.00	0.79	0.76

Appendix Table C.21 Grass production under varying amounts of huisache canopy cover, Welder Wildlife Refuge, San Patricio County (Scifres et al. 1982).

	Huisache Canopy (%)							
	00	**10**	**20**	**30**	**40**	**50**	**60**	**70**
Production (g/m^2)	415	425	365	320	290	235	190	135
Proportion of 0% canopy	1.00	1.02	0.88	0.77	0.70	0.57	0.46	0.33

Approximate production = (amount at 0% cover)(0.8)(% woody plant cover)

Appendix Table C.22 Species composition and aboveground herbaceous production (clippable biomass) in improved pastures by soil series in Karnes and Wilson Counties.

NRCS Range Site	**Woody Species Relative Composition (%)**	**Herbaceous Species Initial Aboveground Biomass (g/m^2)**				
		BIOS	**CYDA**	**PACO**	**SOHA**	**AMPS**
Clay Soils						
Blackland	huisache 80; mesquite 20	55	0	500	27	28
Clayey Bottomland	huisache 70; hackberry 15; mesquite 15	102	0	920	51	51
Hardland	huisache 80; mesquite 20	65	0	588	32	33
Lakebed	huisache 60; rattlepod 20; baccharis 20	65	32	524	65	65
Rolling Blackland	huisache 80; mesquite 20	54	0	486	27	27
Clay Loam Soils						
Clay Loam	huisache 50; mesquite 50	71	0	739	18	35
Loamy Bottomland	huisache 40; mesquite 40; hackberry 20	87	0	779	22	43
Sloping Clay Loam	huisache 40; mesquite 60	40	0	358	10	20
Sandy Loam Soils						
Gray Sandy Loam	mesquite 80; huisache 20	40	402	0	0	20
Sandy Loam	mesquite 70; huisache 30	50	455	0	0	25
Tight Sandy Loam	mesquite 70; huisache 30	39	352	0	0	20
Sandy Soils						
Deep Sand	mesquite 90; live oak 10	40	402	0	0	20
Deep Sand Savanna	mesquite 90; live oak 10	40	402	0	0	20
Loamy Sand	mesquite 90; huisache 10	45	408	0	0	22
Sandstone Hills	mesquite 80; post oak 20	28	260	0	0	14
Sandy	mesquite 80; huisache 20	45	402	0	0	22
Shallow Soils						
Chalky Ridge	mesquite 50; blackbrush 50	23	204	0	0	11
Gravelly Ridge	mesquite 30; blackbrush 70	25	222	0	0	12
Shallow	mesquite 40; blackbrush 60	23	204	0	0	11
Shallow Ridge	blackbrush 90; guajillo 10	34	306	0	0	17
Very Gravelly	post oak 40; blackbrush 60	34	306	0	0	17

BOIS = King Ranch bluestem; CYDA = bermudagrass; PACO = kleingrass; SOHA = Johnsongrass; AMPS = ragweed.

Annual aboveground production (g/m^2) of three forage species, adjusted to mean annual precipitation for Karnes-Wilson Counties (30.50 inches), are 505 for bermudagrass, 698 for kleingrass, and 787 for Kleberg bluestem (McCawley 1978, Kapinga 1982) on Orelia fine sandy loam soils. Compared to production from native species (sandy loam), these are 1.03 for bermudagrass, 1.42 for kleingrass, and 1.61 for Kleberg bluestem. King Ranch bluestem is estimated to have a ratio of 1.30 (50% of the increase of Kleberg bluestem).

Major improved pasture species are assumed to be determined by soil texture: clays and clay loams = kleingrass; sands, sandy loams, and shallow soils = bermudagrass. King Ranch bluestem is considered to constitute 10% of the forage biomass on all improved pastures.

Appendix Table C.23 Aboveground biomass (g/m^2) for woody species included in the Karnes and Wilson Counties EDYS models (values based on 100% canopy cover of respective woody species).

Species	Common Name	Trunk	Stems	Leaves	Total
Acacia farnesiana	huisache	2,500	730	130	3,360
Carya illinioensis	pecan	23,650	3,890	330	27,870
Celtis laevigata	sugar hackberry	11,820	1,950	330	14,100
Diospyros texana	Texas persimmon	1,370	920	170	2,460
Prosopis glanduosa	mesquite	3,620	500	150	4,270
Quercus stellata	post oak	12,240	1,920	190	14,350
Quercus virginiana	live oak	24,270	3,830	380	28,480
Acacia berlandieri	guajillo	500	1,100	500	2,100
Acacia rigidula	blackbrush	630	1,300	440	2,370
Aloysia lycioides	whitebrush	700	1,500	400	2,600
Baccharis texana	prairie baccharis	1,240	1,240	260	2,740
Celtis pallida	granjeno	1,060	1,070	350	2,480
Mahonia trifoliolata	agarito	70	120	70	260
Sesbania drummondii	rattlepod	250	1,000	100	1,350
Vitis mustangensis	mustang grape	1,200	200	400	1,800
Opuntia lindheimeri	prickly pear	350	2,000	10	2,360

ADDITIONAL PLANT AND VEGETATION DATA

Bovey, R.W., R.E. Meyer, and H.L. Morton. 1972. Herbage production following brush control with herbicides in Texas. Journal of Range Management 25:136-142.

Victoria County, Katy gravelly sandy loam.
Live oak-little bluestem community (shrub live oak = 2 m tall): live oak, little bluestem, brownseed paspalum, indiangrass, threeawns, lovegrasses, knotroot bristlegrass, bitter sneezeweed, Lindheimer doveweed.
Oct 1967 herbaceous biomass = 185 g/m^2 grasses + 18 g/m^2 forbs
Area bulldozed in Jul 1963 and harvested in Apr 1970 = 114 g/m^2 live oak regrowth + 2 g/m^2 grasses + 2 g/m^2 forbs
Victoria 1967 PPT = 33.90 inches = 86.1 cm Oct 1966-Sep 1967 = 28.18 inches = 71.6 cm
PUE = 203 g/m^2/71.6 cm = 2.84 g/m^2/cm + live oak production

Box, Thadis W. and Richard S. White. 1969. Fall and winter burning of South Texas brush ranges. Journal of Range Management 22:373-376.

Chaparral community, Welder Wildlife Refuge. Mesquite-huisache-blackbrush community

Sampled Aug 1967
Herbaceous production (24% buffalograss, 9% silver bluestem, 8% ruellia, 15% Texas broomweed):
163.6 g/m^2 = 97.7 g/m^2 grasses + 65.9 g/m^2 forbs

Buckley, P.E. and J.D. Dodd. 1969. Heavy precipitation influences saline clay flat vegetation. Journal of Range Management 22:405-407.

18 mi NNE of Zapata. Prickly pear-saladillo-mesquite community. Root plowed in 1962.
Sampled in Nov 1967 following Beulah.
Herbaceous production (56% Hall panicum, 20% curly mesquite, 10% whorled dropseed): 136 g/m^2
1967 PPT at study site = 26.39 inches = 67.0 cm

PUE = 136 g/m^2/67.0 cm = 2.03 g/m^2/cm + shrub production

Dodd, J.D. and S.T. Holtz. 1972. Integration of burning with mechanical manipulation of South Texas grassland. Journal of Range Management 25:130-136.

Cartwright Ranch, Goliad County. Blackbrush-Texas persimmon-hogplum community.
Sampled Jun 1968.
Herbaceous production = 145 g/m^2 = 41 g/m^2 grass (24% sedge, 20% Texas grama, 16% threeawns) + 104 g/m^2 forbs (8% orange zexmenia, 4% Texas broomweed)
Jun 1967-May 1968 PPT at Goliad = 54.45 inches = 138.3 cm

PUE = 145 g/m^2/138.3 cm = 1.05 g/m^2/cm + shrub production

Drawe, D. Lynn and Thadis W. Box. 1969. High rates of nitrogen fertilization influence coastal prairie range. Journal of Range Management 22:32-36.

Bunchgrass-annual forb community on Zavala fine sandy loam, Welder Wildlife Refuge.
21% camphorweed, 14% knotgrass, 12% balsamscale, 10% sandbur, 9% signalgrass, 6% seacoast
Sampled in August of each year.

	1965	1966	1967	
Herbaceous production (g/m^2):	237	228	252	
Grasses (g/m^2):	159	137	192	
Forbs (g/m^2):	78	91	60	
Sep-Aug PPT (cm):	68.5	101.3	65.2	Refugio PPT(0.904)
PUE (g/m^2/cm):	3.46	2.25	3.87	Mean = 3.20

Jan 1964-Sep 1965 PPT Refugio = 50.59 inches
Jan 1964-Sep 1965 PPT WWR = 45.74 inches 45.74/50.59 = 0.904

Kapinga, Philibert X. 1982. Seasonal variation in yield and quality of six improved grass species under two levels of fertility and two clipping heights in South Texas. MSc Thesis. Texas A&I University. Kingsville. 79 p.

Study site was the Texas A&I University farm, 2 km north of Kingsville. Major soil series was Orelia fine sandy loam. Annual precipitation was 1205 mm (47.4 inches).

Forage production (g/m^2): bermudagrass = 490; kleingrass = 810; Kleberg bluestem = 1180.

Mean average annual precipitation for 7 Karnes-Wilson stations is 30.50 inches. 30.5/47.4 = 0.67.

McCawley, Paul F. 1978. An evaluation of three exotic grasses for pasture in the Coastal Bend. MSc Thesis. Texas Tech University. Lubbock. 107 p.

Study was conducted on the Pat Welder Ranch, 5 mi north of Sinton, Texas. Average annual precipitation = 30 inches. Major soil series was Orelia fine sandy loam.

Forage production (g/m^2): bermudagrass = 683; kleingrass = 856 (p. 69).

Powell, Jeff and Thadis W. Box. 1967. Mechanical control and fertilization as brush management practices affect forage production in South Texas. Journal of Range Management 20:227-236.

Chaparral-bristlegrass community, Victoria clay, Welder Wildlife Refuge.
Blackbrush-huisache-mesquite (49% brush cover).
Herbaceous: plains bristlegrass (15%), buffalograss (11%), ragweed, Texas broomweed (31% forbs)
Forage production: 101 g/m^2 in 1964; 162 g/m^2 in 1965

Oct 1963-Sep 1964 PPT = 0.904(Refugio) = 0.904(33.37) = 30.17 inches = 76.6 cm
Oct 1964-Sep 1965 PPT = 0.904(Refugio Oct-Dec) + 17.44 inches = 0.904(7.03) + 17.44 = 60.5 cm

1964 PUE = 101 g/m^2/76.6 cm = 1.32 g/m^2/cm 1965 PUE = 162 g/m^2/60.5 cm = 2.68 g/m^2/cm

APPENDIX D PLANT PARAMETERS

Appendix Table D.1 General species characteristics for species used in the Karnes and Wilson Counties EDYS models.

Species	Growth Form	Legume	Biennial
Huisache	deciduous tree	1	no
Pecan	deciduous tree	0	no
Sugar hackberry	deciduous tree	0	no
Texas persimmon	deciduous tree	0	no
Mesquite	deciduous tree	1	no
Post oak	deciduous tree	0	no
Live oak	evergreen tree	0	no
Guajillo	evergreen shrub	1	no
Blackbrush	deciduous shrub	1	no
Whitebrush	deciduous shrub	0	no
Prairie baccharis	deciduous shrub	0	no
Granjeno	deciduous shrub	0	no
Agarito	evergreen shrub	0	no
Rattlepod	deciduous shrub	1	no
Mustang grape	deciduous vine	0	no
Prickly pear	cacti	0	no
Big bluestem	perennial grass	0	no
Purple threeawn	perennial grass	0	no
King Ranch bluestem	perennial grass	0	no
Silver bluestem	perennial grass	0	no
Sideoats grama	perennial grass	0	no
Hairy grama	perennial grass	0	no
Buffalograss	perennial grass	0	no
Sandbur	perennial grass	0	no
Hooded windmillgrass	perennial grass	0	no
Trichloris	perennial grass	0	no
Bermudagrass	perennial grass	0	no
Arizona cottontop	perennial grass	0	no
Virginia wildrye	perennial grass	0	no
Clubhead cutgrass	perennial grass	0	no
Kleingrass	perennial grass	0	no
Vine-mesquite	perennial grass	0	no
Switchgrass	perennial grass	0	no
Longtom	perennial grass	0	no
Thin paspalum	perennial grass	0	no
Little bluestem	perennial grass	0	no
Knotroot bristlegrass	perennial grass	0	no
Texas bristlegrass	perennial grass	0	no
Johnsongrass	perennial grass	0	no
Tall dropseed	perennial grass	0	no
Texas wintergrass	perennial grass	0	no
Milo	annual grass	0	no
Wheat	annual grass	0	no
Corn	annual grass	0	no
Littletooth sedge	perennial grass-like	0	no
Flatsedge	perennial grass-like	0	no
Fimbry	perennial grass-like	0	no
Cattail	perennial grass-like	0	no
Ragweed	perennial forb	0	no
Old-mans beard	perennial forb	0	no
Bundleflower	perennial forb	1	no
Frogfruit	perennial forb	0	no
Prairie coneflower	perennial forb	0	no
Snoutbean	perennial forb	1	no
Ruellia	perennial forb	0	no
Bush sunflower	perennial forb	0	no

Appendix Table D.1 (Cont.)

Species	Growth Form	Legume	Biennial
Texas verbena	perennial forb	0	no
Orange zexmenia	perennial forb	0	no
Giant ragweed	annual forb	0	no
Annual broomweed	annual forb	0	no
Partridge pea	annual forb	1	no
Texas doveweed	annual forb	0	no
Sunflower	annual forb	0	no
Duckweed	annual forb	0	no
Texas bluebonnet	annual forb	1	no
Dogweed	annual forb	0	no

Appendix Table D.2 Tissue allocation in mature plants, by plant part (proportion of total), and root:shoot ratio (R:S) for species included in the Karnes and Wilson Counties EDYS models.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds	R:S Ratio
Huisache	0.34	0.12	0.38	0.11	0.05	0.00	0.85
Pecan	0.32	0.11	0.40	0.12	0.05	0.00	0.75
Sugar hackberry	0.16	0.06	0.55	0.17	0.06	0.00	0.28
Texas persimmon	0.32	0.11	0.40	0.12	0.05	0.00	0.75
Mesquite	0.19	0.06	0.39	0.27	0.09	0.00	0.34
Post oak	0.20	0.07	0.51	0.16	0.06	0.00	0.36
Live oak	0.24	0.08	0.48	0.15	0.05	0.00	0.46
Guajillo	0.27	0.12	0.34	0.18	0.09	0.00	0.65
Blackbrush	0.27	0.12	0.34	0.18	0.09	0.00	0.65
Whitebrush	0.26	0.12	0.34	0.19	0.09	0.00	0.61
Prairie baccharis	0.26	0.12	0.34	0.19	0.09	0.00	0.61
Granjeno	0.28	0.12	0.33	0.18	0.09	0.00	0.66
Agarito	0.35	0.14	0.28	0.15	0.08	0.00	0.97
Rattlepod	0.27	0.11	0.34	0.19	0.09	0.00	0.61
Mustang grape	0.23	0.10	0.35	0.17	0.15	0.00	0.50
Prickly pear	0.08	0.03	0.49	0.39	0.01	0.00	0.12
Big bluestem	0.24	0.24	0.10	0.21	0.21	0.00	0.86
Purple threeawn	0.25	0.25	0.15	0.05	0.30	0.00	1.00
King Ranch bluestem	0.25	0.25	0.15	0.05	0.30	0.00	1.00
Silver bluestem	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Sideoats grama	0.25	0.24	0.10	0.20	0.21	0.00	0.96
Hairy grama	0.18	0.18	0.21	0.06	0.37	0.00	0.56
Buffalograss	0.28	0.27	0.12	0.05	0.28	0.00	1.20
Sandbur	0.20	0.21	0.15	0.14	0.30	0.00	0.70
Hooded windmillgrass	0.23	0.24	0.14	0.05	0.34	0.00	0.90
Trichloris	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Bermudagrass	0.25	0.25	0.15	0.05	0.30	0.00	1.00
Arizona cottontop	0.23	0.24	0.11	0.21	0.21	0.00	0.90
Virginia wildrye	0.23	0.23	0.11	0.22	0.21	0.00	0.84
Clubhead cutgrass	0.30	0.30	0.12	0.04	0.24	0.00	1.50
Kleingrass	0.23	0.24	0.11	0.21	0.21	0.00	0.90
Vine-mesquite	0.22	0.21	0.11	0.23	0.23	0.00	0.76
Switchgrass	0.23	0.24	0.11	0.21	0.21	0.00	0.90
Longtom	0.36	0.35	0.08	0.03	0.18	0.00	2.50
Thin paspalum	0.22	0.21	0.17	0.06	0.34	0.00	0.76
Little bluestem	0.26	0.26	0.10	0.19	0.19	0.00	1.05
Knotroot bristlegrass	0.26	0.26	0.14	0.05	0.29	0.00	1.10
Texas bristlegrass	0.19	0.19	0.19	0.06	0.37	0.00	0.60
Johnsongrass	0.24	0.23	0.11	0.21	0.21	0.00	0.90
Tall dropseed	0.23	0.24	0.11	0.21	0.21	0.00	0.90
Texas wintergrass	0.25	0.25	0.15	0.05	0.30	0.00	1.00
Milo	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Wheat	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Corn	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Littletooth sedge	0.28	0.27	0.13	0.05	0.27	0.00	1.20
Flatsedge	0.36	0.35	0.06	0.12	0.11	0.00	1.55
Fimbry	0.36	0.35	0.06	0.11	0.12	0.00	1.55
Cattail	0.34	0.33	0.04	0.14	0.15	0.00	2.00
Ragweed	0.21	0.20	0.12	0.24	0.23	0.00	0.70
Old-mans beard	0.29	0.28	0.13	0.04	0.26	0.00	1.30
Bundleflower	0.16	0.17	0.20	0.07	0.40	0.00	0.50
Frogfruit	0.16	0.17	0.20	0.07	0.40	0.00	0.50
Prairie coneflower	0.25	0.24	0.10	0.21	0.20	0.00	0.96
Snoutbean	0.21	0.20	0.17	0.06	0.36	0.00	0.70
Ruellia	0.19	0.19	0.19	0.06	0.37	0.00	0.60
Bush sunflower	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Texas verbena	0.21	0.20	0.17	0.06	0.36	0.00	0.70
Orange zexmenia	0.25	0.25	0.10	0.20	0.20	0.00	1.00
Giant ragweed	0.16	0.17	0.13	0.27	0.27	0.00	0.50
Annual broomweed	0.19	0.19	0.12	0.25	0.25	0.00	0.60

Appendix Table D.2 (Cont.)

Species	Coarse Roots	Fine Roots	Trunks	Stems	Leaves	Seeds	R:S Ratio
Partridge pea	0.19	0.19	0.19	0.06	0.37	0.00	0.60
Texas doveweed	0.14	0.15	0.14	0.29	0.28	0.00	0.40
Sunflower	0.16	0.17	0.13	0.27	0.27	0.00	0.50
Duckweed	0.16	0.17	0.20	0.07	0.40	0.00	0.50
Texas bluebonnet	0.16	0.17	0.20	0.07	0.40	0.00	0.50
Dogweed	0.19	0.19	0.16	0.06	0.40	0.00	0.60

Data Sources

Root:Shoot Ratios

Huisache:	huisache seedling = 0.48 (Fulbright et al. 1997); *Leucaena leucocephala* seedling = 0.46 (Jones & Aliyu 1976; Huang et al. 1985); *Leucaena leucocephala* mature = 0.82 (Von Carlowitz & Wolf 1991); huisache mature = 0.82(0.48/0.46) = 0.85
Pecan:	Slow-growing hardwoods (Odum 1971:375)
Sugar hackberry:	*Fagus* sp. (Garelkov 1973)
Texas persimmon	Slow-growing hardwoods (Odum 1871:375)
Mesquite:	Twice the value reported by Barth et al. (1982)
Post oak:	Mean of *Quercus alba* (Nadelhoffer et al. 1985), *Q. rubra* (Nadelhoffer et al. 1985), *Q. robur* (Andersson 1970, Duvigneaud et al. 1971, Rodin & Bazilevich 1967), *Q. robus* (Duvigneaud et al. 1971), *Q. velutina* (Nadelhoffer et al. 1985)
Live oak:	Mean of *Quercus alba* and *Q. velutina* (Nadelhoffer et al. 1985)

Coarse:Fine Root Ratios

Coarse:Fine 75:25 trees; 70:30 shrubs; 50:50 herbaceous

Aboveground Tissue Allocation (Trunk:Stem:Leaves)

Trees:	0.70:0.22:0.08
Shrubs:	0.55:0.30:0.15
Herbaceous (stemmy):	0.2:0.4:0.4
Herbaceous (short):	0.3:0.1:0.6

Appendix Table D.3 Allocation of new biomass production by plant part (proportion of total) for species included in the Karnes and Wilson Counties EDYS models.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Huisache	0.08	0.20	0.09	0.22	0.41	0.00
Pecan	0.11	0.32	0.20	0.06	0.31	0.00
Sugar hackberry	0.06	0.16	0.27	0.08	0.43	0.00
Texas persimmon	0.11	0.32	0.20	0.06	0.31	0.00
Mesquite	0.08	0.30	0.13	0.20	0.29	0.00
Post oak	0.07	0.20	0.25	0.08	0.40	0.00
Live oak	0.03	0.10	0.05	0.05	0.77	0.00
Guajillo	0.06	0.20	0.04	0.18	0.52	0.00
Blackbrush	0.05	0.20	0.05	0.20	0.50	0.00
Whitebrush	0.04	0.18	0.04	0.25	0.49	0.00
Prairie baccharis	0.05	0.20	0.05	0.20	0.50	0.00
Granjeno	0.04	0.18	0.04	0.22	0.52	0.00
Agarito	0.07	0.25	0.10	0.10	0.48	0.00
Rattlepod	0.05	0.20	0.10	0.15	0.50	0.00
Mustang grape	0.03	0.20	0.10	0.15	0.52	0.00
Prickly pear	0.10	0.20	0.20	0.48	0.02	0.00
Big bluestem	0.10	0.24	0.05	0.30	0.31	0.00
Purple threeawn	0.12	0.25	0.08	0.05	0.50	0.00
King Ranch bluestem	0.12	0.25	0.10	0.05	0.48	0.00
Silver bluestem	0.12	0.24	0.05	0.25	0.34	0.00
Sideoats grama	0.12	0.24	0.05	0.26	0.33	0.00
Hairy grama	0.09	0.18	0.10	0.06	0.57	0.00
Buffalograss	0.16	0.27	0.10	0.12	0.35	0.00
Sandbur	0.10	0.20	0.08	0.14	0.48	0.00
Hooded windmillgrass	0.12	0.24	0.07	0.05	0.52	0.00
Trichloris	0.12	0.25	0.04	0.26	0.33	0.00
Bermudagrass	0.12	0.25	0.10	0.05	0.48	0.00
Arizona cottontop	0.12	0.24	0.05	0.30	0.29	0.00
Virginia wildrye	0.12	0.23	0.05	0.30	0.30	0.00
Clubhead cutgrass	0.15	0.30	0.12	0.04	0.39	0.00
Kleingrass	0.11	0.24	0.05	0.30	0.30	0.00
Vine-mesquite	0.11	0.21	0.06	0.30	0.32	0.00
Switchgrass	0.11	0.24	0.06	0.25	0.34	0.00
Longtom	0.13	0.25	0.08	0.22	0.32	0.00
Thin paspalum	0.11	0.21	0.09	0.20	0.39	0.00
Little bluestem	0.13	0.25	0.05	0.26	0.31	0.00
Knotroot bristlegrass	0.14	0.25	0.10	0.26	0.25	0.00
Texas bristlegrass	0.09	0.20	0.09	0.10	0.52	0.00
Johnsongrass	0.12	0.23	0.05	0.30	0.30	0.00
Tall dropseed	0.11	0.24	0.05	0.30	0.30	0.00
Texas wintergrass	0.10	0.20	0.05	0.40	0.25	0.00
Milo	0.10	0.20	0.05	0.25	0.40	0.00
Wheat	0.25	0.25	0.10	0.20	0.20	0.00
Corn	0.25	0.25	0.10	0.20	0.20	0.00
Littletooth sedge	0.14	0.27	0.07	0.10	0.42	0.00
Flatsedge	0.18	0.35	0.06	0.12	0.29	0.00
Fimbry	0.18	0.35	0.06	0.11	0.30	0.00
Cattail	0.20	0.20	0.04	0.28	0.28	0.00
Ragweed	0.15	0.20	0.10	0.30	0.25	0.00
Old-mans beard	0.15	0.28	0.10	0.24	0.23	0.00
Bundleflower	0.08	0.18	0.10	0.32	0.32	0.00
Frogfruit	0.08	0.17	0.10	0.30	0.35	0.00
Prairie coneflower	0.12	0.24	0.08	0.30	0.26	0.00
Snoutbean	0.10	0.20	0.10	0.30	0.30	0.00
Ruellia	0.15	0.25	0.15	0.05	0.40	0.00
Bush sunflower	0.12	0.25	0.10	0.26	0.27	0.00
Texas verbena	0.10	0.20	0.12	0.29	0.29	0.00
Orange zexmenia	0.13	0.25	0.10	0.25	0.27	0.00
Giant ragweed	0.16	0.17	0.13	0.27	0.27	0.00

Appendix Table D.3 (Cont.)

Species	Coarse Roots	Fine Roots	Trunks	Leaves	Stems	Seeds
Annual broomweed	0.19	0.19	0.12	0.25	0.25	0.00
Partridge pea	0.19	0.19	0.19	0.06	0.37	0.00
Texas doveweed	0.14	0.15	0.14	0.29	0.28	0.00
Sunflower	0.12	0.20	0.10	0.30	0.23	0.05
Duckweed	0.16	0.17	0.20	0.07	0.40	0.00
Texas bluebonnet	0.16	0.17	0.20	0.07	0.40	0.00
Dogweed	0.19	0.19	0.16	0.06	0.40	0.00

Appendix Table D.4 Allocation of biomass production in green-out months by plant part (proportion of total) for species included in the Karnes and Wilson EDYS models.

Species	Coarse Roots	Fine Roots	Trunks	Stems	Leaves	Seeds
Huisache	0.00	0.23	0.00	0.04	0.73	0.00
Pecan	0.00	0.24	0.00	0.05	0.71	0.00
Sugar hackberry	0.00	0.12	0.00	0.06	0.82	0.00
Texas persimmon	0.00	0.24	0.00	0.05	0.71	0.00
Mesquite	0.00	0.15	0.00	0.10	0.75	0.00
Post oak	0.00	0.15	0.00	0.06	0.79	0.00
Live oak	0.00	0.18	0.00	0.05	0.77	0.00
Guajillo	0.00	0.20	0.00	0.20	0.60	0.00
Blackbrush	0.00	0.20	0.00	0.20	0.60	0.00
Whitebrush	0.00	0.19	0.00	0.20	0.61	0.00
Prairie baccharis	0.00	0.19	0.00	0.20	0.61	0.00
Granjeno	0.00	0.21	0.00	0.19	0.60	0.00
Agarito	0.00	0.26	0.00	0.37	0.37	0.00
Rattlepod	0.00	0.19	0.00	0.30	0.51	0.00
Mustang grape	0.00	0.17	0.00	0.23	0.60	0.00
Prickly pear	0.10	0.15	0.05	0.69	0.01	0.00
Big bluestem	0.01	0.18	0.00	0.41	0.40	0.00
Purple threeawn	0.00	0.19	0.00	0.03	0.78	0.00
King Ranch bluestem	0.01	0.19	0.00	0.04	0.76	0.00
Silver bluestem	0.00	0.18	0.00	0.41	0.41	0.00
Sideoats grama	0.01	0.18	0.00	0.41	0.40	0.00
Hairy grama	0.00	0.14	0.00	0.03	0.83	0.00
Buffalograss	0.00	0.20	0.00	0.09	0.71	0.00
Sandbur	0.00	0.15	0.00	0.07	0.78	0.00
Hooded windmillgrass	0.00	0.18	0.00	0.03	0.79	0.00
Trichloris	0.00	0.19	0.00	0.40	0.41	0.00
Bermudagrass	0.01	0.19	0.00	0.03	0.77	0.00
Arizona cottontop	0.00	0.18	0.00	0.41	0.41	0.00
Virginia wildrye	0.00	0.17	0.00	0.41	0.42	0.00
Clubhead cutgrass	0.00	0.22	0.00	0.39	0.39	0.00
Kleingrass	0.00	0.18	0.00	0.41	0.41	0.00
Vine-mesquite	0.01	0.16	0.00	0.15	0.68	0.00
Switchgrass	0.00	0.18	0.00	0.41	0.41	0.00
Longtom	0.00	0.26	0.00	0.03	0.71	0.00
Thin paspalum	0.00	0.16	0.00	0.05	0.79	0.00
Little bluestem	0.01	0.18	0.00	0.40	0.41	0.00
Knotroot bristlegrass	0.01	0.19	0.00	0.05	0.75	0.00
Texas bristlegrass	0.00	0.15	0.00	0.05	0.80	0.00
Johnsongrass	0.01	0.17	0.00	0.41	0.41	0.00
Tall dropseed	0.00	0.18	0.00	0.41	0.41	0.00
Texas wintergrass	0.00	0.19	0.00	0.03	0.78	0.00
Milo	0.25	0.25	0.10	0.20	0.20	0.00
Wheat	0.25	0.25	0.10	0.20	0.20	0.00
Corn	0.25	0.25	0.10	0.20	0.20	0.00
Littletooth sedge	0.00	0.20	0.00	0.05	0.75	0.00
Flatsedge	0.00	0.26	0.00	0.20	0.54	0.00
Fimbry	0.00	0.26	0.00	0.20	0.54	0.00
Cattail	0.00	0.15	0.00	0.45	0.40	0.00
Ragweed	0.00	0.15	0.00	0.43	0.42	0.00
Old-mans beard	0.00	0.21	0.00	0.39	0.40	0.00
Bundleflower	0.00	0.14	0.00	0.43	0.43	0.00
Frogfruit	0.00	0.13	0.00	0.44	0.43	0.00
Prairie coneflower	0.00	0.18	0.00	0.41	0.41	0.00
Snoutbean	0.00	0.15	0.00	0.43	0.42	0.00
Ruellia	0.00	0.14	0.00	0.21	0.65	0.00
Bush sunflower	0.00	0.19	0.00	0.41	0.40	0.00
Texas verbena	0.00	0.15	0.00	0.43	0.42	0.00
Orange zexmenia	0.00	0.19	0.00	0.41	0.40	0.00
Giant ragweed	0.16	0.17	0.13	0.27	0.27	0.00

Appendix Table D.4 (Cont.)

Species	Coarse Roots	Fine Roots	Trunks	Stems	Leaves	Seeds
Broomweed	0.19	0.19	0.12	0.25	0.25	0.00
Partridge pea	0.19	0.19	0.19	0.06	0.37	0.00
Texas doveweed	0.14	0.15	0.14	0.29	0.28	0.00
Sunflower	0.16	0.17	0.13	0.27	0.27	0.00
Duckweed	0.16	0.17	0.20	0.07	0.40	0.00
Texas bluebonnet	0.16	0.17	0.20	0.07	0.40	0.00
Dogweed	0.19	0.19	0.16	0.06	0.40	0.00

General guidelines for greenout allocation:

Trees: coarse roots, trunks, and seeds = no allocation; fine roots and stems = 75% of new growth allocation; leaves = remainder of allocation

Shrubs, midgrasses, and perennial forbs: coarse roots, trunks, and seeds = no allocation; fine roots = 75% of new growth allocation; stems + leaves = remainder of allocation (exception = rhizomatous grasses, which have coarse roots = 10% of new growth allocation)

Shortgrasses: coarse roots, trunks, and seeds = no allocation; fine roots = 75% of new growth allocation; stems = 50% of new growth allocation; leaves = remainder of allocation (exceptions = rhizomatous grasses which have coarse roots = 10% of new growth allocation and stoloniferous grasses which have stems = 75% of new growth allocation)

Annuals = new growth allocations.

Appendix Table D.9 Root architecture, proportion of roots by maximum rooting depth, and maximum potential rooting depth (mm) for plant species included in the Karnes and Wilson Counties EDYS models.

Species	Percent by Maximum Rooting Depth												Maximum
	00-01	01-05	05-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	Rooting Depth
Huisache	4	11	14	18	15	12	10	6	4	3	2	1	12620
Pecan	2	9	14	20	15	5	6	6	2	6	8	7	6250
Sugar hackberry	2	9	14	20	15	5	6	6	2	6	8	7	6000
Texas persimmon	2	9	14	20	15	5	6	6	2	6	8	7	5300
Mesquite	14	14	15	15	11	9	7	5	4	3	2	1	53400
Post oak	2	8	9	18	15	11	11	6	5	5	5	5	5700
Live oak	4	14	15	21	12	8	8	7	4	4	2	1	22000
Guajillo	3	10	13	18	13	11	9	8	5	5	3	2	5000
Blackbrush	3	9	13	19	15	12	9	7	4	4	3	2	5250
Whitebrush	3	13	14	17	14	12	9	6	5	4	2	1	2230
Prairie baccharis	1	5	9	12	18	17	11	11	7	6	2	1	1900
Granjeno	4	13	14	17	14	12	10	6	4	3	2	1	6680
Agarito	3	10	12	19	13	12	10	9	5	4	2	1	3000
Rattlepod	2	5	9	15	17	16	13	8	7	5	2	1	1380
Mustang grape	5	12	15	17	13	11	9	7	5	3	2	1	3660
Prickly pear	2	9	12	19	13	20	11	6	4	2	1	1	840
Big bluestem	10	18	23	15	9	8	6	4	3	2	1	1	3050
Purple threeawn	4	7	10	15	18	15	14	8	5	2	1	1	1830
King Ranch bluestem	4	16	21	18	14	8	6	4	3	2	2	2	1200
Silver bluestem	10	22	20	20	10	6	3	3	2	2	1	1	2380
Sideoats grama	10	20	23	21	14	5	2	1	1	1	1	1	3960
Hairy grama	5	13	14	18	13	11	9	9	4	2	1	1	1070
Buffalograss	8	23	24	20	8	5	4	3	2	1	1	1	2160
Sandbur	4	12	12	20	13	10	9	9	5	3	2	1	350
Hooded windmillgrass	4	12	13	21	12	11	11	4	3	3	3	3	990
Trichloris	8	22	25	18	8	5	4	3	3	2	1	1	2300
Bermudagrass	5	14	17	15	12	10	8	6	5	4	3	1	900
Arizona cottontop	3	12	13	21	12	10	8	6	5	4	3	3	1000
Virginia wildrye	4	12	16	18	14	12	8	6	4	3	2	1	720
Clubhead cutgrass	5	19	17	11	11	11	10	4	3	3	3	3	750
Kleingrass	3	10	13	18	15	13	13	3	3	3	3	3	2280
Vine-mesquite	3	11	13	19	14	10	8	6	5	4	4	3	2020
Switchgrass	7	17	23	12	10	8	7	6	4	3	2	1	3350
Longtom	5	19	18	12	9	7	7	6	5	4	4	4	900
Thin paspalum	3	12	15	24	13	10	7	6	4	3	2	1	1660
Little bluestem	8	22	25	18	8	5	4	3	3	2	1	1	2440
Knotroot bristle	4	14	16	18	14	10	8	6	5	2	2	1	1020
Texas bristlegrass	3	13	14	21	12	11	9	6	4	3	2	2	930
Johnsongrass	3	12	17	18	14	10	9	7	5	3	1	1	2410
Tall dropseed	4	15	17	20	11	8	6	5	5	4	4	1	2130
Texas wintergrass	3	11	13	18	14	10	8	8	6	4	3	2	1950
Milo	2	6	9	18	17	14	12	9	7	3	2	1	1950
Wheat	2	5	7	15	16	15	13	10	8	5	3	1	3000
Corn	2	7	10	22	17	13	12	8	5	2	1	1	2400
Littletooth sedge	2	9	12	22	16	10	8	6	5	5	4	1	1310
Flatsedge	2	5	8	15	13	12	12	10	9	7	4	3	630
Fimbry	2	7	10	19	14	10	9	8	7	6	5	3	500
Cattail	3	12	13	18	10	9	8	8	7	6	4	2	1400
Ragweed	6	20	20	27	10	4	3	3	2	2	2	1	1830
Old-mans beard	3	9	13	24	16	9	7	6	4	3	3	3	1280
Bundleflower	3	9	14	23	12	5	4	5	9	7	6	3	2100
Frogfruit	2	6	8	14	12	11	14	11	11	5	4	2	690
Prairie coneflower	4	16	14	23	14	6	6	4	4	4	3	2	1830
Snoutbean	5	12	20	15	8	4	2	3	10	12	6	3	1350
Ruellia	1	4	7	19	20	17	11	7	6	4	3	1	1500
Bush sunflower	4	14	18	29	11	6	5	4	3	3	2	1	2620
Texas verbena	2	8	10	15	14	13	8	8	8	6	5	3	1520
Orange zexmenia	3	8	13	30	11	8	7	7	5	4	3	1	2640

Appendix Table D.9 (Cont.)

Species	Percent of Maximum Rooting Depth												Maximum
	00-01	01-05	05-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80-90	90-100	Rooting Depth
Giant ragweed	2	6	11	23	10	9	9	9	8	7	4	2	1970
Annual broomweed	4	17	9	17	12	14	8	7	4	3	3	2	1050
Partridge pea	2	8	10	15	14	10	8	11	8	6	5	3	850
Texas doveweed	3	13	8	16	13	14	10	7	5	4	4	3	320
Sunflower	6	24	6	9	12	16	10	7	2	3	3	2	3100
Duckweed	1	4	7	15	15	13	10	10	12	8	4	1	110
Texas bluebonnet	2	9	14	37	16	5	3	3	3	2	2	4	1040
Dogweed	3	6	8	15	11	12	12	11	9	6	4	3	760

Data Sources

Root Architecture

Huisache	mean of *Leucaena leucocephala* (Toky & Bisht 1992) and *Prosopis glandulosa*
Pecan, sugar hackberry, Texas persimmon	*Acer saccharum* (Dawson 1993)
Mesquite	mean of Heitschmidt et al. (1988) and Montana et al. (1995)
Post oak	*Quercus havardii* (Sears et al. 1986)
Live oak	mean of *Acer saccharum* (Dawson 1993), *Leucaena leucocephala* (Toky & Bisht 1992), *Nothofagus antarctica* and *N. pumila* (Schulze et al. 1996), *Populus fremontii* (McLendon 2008), *Prosopis glandulosa, Quercus havardii* (Sears et al. 1986)
Guajillo	*Larrea tridentata* (Wallace et al. 1980; Moorhead et al. 1989; Montana et al. 1995; Ogle et al. 2004)
Blackbrush	mean of *Flourensia cernua* (Wallace et al. 1980) and *Larrea tridentata* (Wallace et al. 1980; Moorhead et al. 1989; Montana et al. 1995; Ogle et al. 2004)
Whitebrush	mean of *Krameria parvifolia*, *Lycium andersonii*, *L. pallidum* (Wallace et al. 1980), and *Tetradymia spinosa* (Branson et al. 1976)
Prairie baccharis	*Pulchea sericea* (Gary 1963)
Granjeno	mean of *Flourensia cernua* (Wallace et al. 1980) and *Prosopis glandulosa*
Agarito	mean of *Ephedra nevadensis* (Wallace et al. 1980), *Larrea tridentata* (Wallace et al. 1980; Moorhead et al. 1989; Montana et al. 1995; Ogle et al. 2004), *Tetradymia spinosa* (Branson et al. 1976)
Rattlepod	mean of *Leucaena leucocephala* (Toky & Bisht 1992) and *Pulchea sericea* (Gary 1963)
Mustang grape	mean of 25 shrubs
Prickly pear	mean of *Opuntia acanthocarpa* (Nobel & Bobich 2002), *O. humifusa* (Sperry 1935), and *O. polyacantha* (Dougherty 1986)
Big bluestem	Sperry (1935), Weaver & Zink (1946), Weaver & Darland (1949), Coupland & Bradshaw (1953); Hopkins (1953), Weaver (1954)
Purple threeawn	modified from Weaver & Clements (1938)
King Ranch bluestem	Coyne & Bradford (1986)
Silver bluestem	mean of *Bouteloua curtipendula* and *Schizachyrium scoparium*
Sideoats grama	Weaver & Darland (1949), Hopkins (1953), Weaver (1954)
Hairy grama	mean of *Aristida purpurea* (Weaver & Clements 1938) and *Bouteloua gracilis* (Weaver & Clements 1938; Weaver 1947, 1958; Weaver & Zink 1947; Weaver & Darland 1949; Hopkins 1953; Lorenz & Rogler 1967; Redente et al. 1989; Lee & Lauenroth 1994; Gill et al. 1999)
Buffalograss	Weaver & Clements (1938), Weaver & Darland (1949), Hopkins (1953)
Sandbur	mean of *Aristida purpurea* (Weaver & Clements 1938) and *Sporobolus cryptandrus* (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Hooded windmill	mean of *Axonopus compressus* (Fiala & Herrera 1988) and *Sporobolus cryptandrus* (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)

Trichloris	*Schizachyrium scoparium*
Bermudagrass	mean of *Axonopus compressus* (Fiala & Herrera 1988), *Distichlis spicata* (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008), *Hilaria mutica* (Montana et al. 1995)
Arizona cottontop	mean of *Cenchrus ciliaris* (Chaieb et al. 1996), *Hilaria jamesii* (Moore & West 1973; Daddy 1985), *Sporobolus cryptandrus* (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Virginia wildrye	mean of *Agropyron trachycaulum* and *Poa compressa* (McLendon 2001)
Clubhead cutgrass	mean of *Axonopus compressus* (Fiala & Herrera 1988), *Paspalum notatum* (Hernandez & Fiala 1992)
Kleingrass	Hons et al. (1979)
Vine-mesquite	mean of *Boutleoua curtipendula* (Weaver & Darland 1949; Hopkins 1953; Weaver 1954; Pettit & Jaynes 1971), *Distichlis spicata* (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008), *Hilaria mutica* (Montana et al. 1995)
Switchgrass	Weaver & Darland (1949), Hopkins (1953), Pettit & Jaynes (1971)
Longtom	mean of *Distichlis spicata* (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008) and *Paspalum notatum* (Hernandez & Fiala 1992)
Thin paspalum	mean of *Andropogon gerardii* var. *paucipilus* (Weaver & Clements 1938), *Cenchrus ciliaris* (Chaieb et al. 1996), *Redfieldia flexuosa* (Weaver & Clements 1938), *Sporobolus cryptandrus* (Albertson 1937; Weaver & Darland 1949; Hopkins 1953), and *Schzachyrium scoparium*
Little bluestem	Sperry (1935), Weaver & Zink (1946), Weaver (1947, 1950, 1954, 1958), Weaver & Darland (1949), Coupland & Bradshaw (1953), Jurena & Archer (2003)
Knotroot bristlegrass	mean of *Bouteloua curtipendula* (Weaver & Darland 1949; Hopkins 1953; Weaver 1954; Pettit & Jayens 1971) and *Sporobolus airoides* (McLendon 2008)
Texas bristlegrass	mean of *Aristida purpurea* (Weaver & Clements 1938), *Axonopus compressus* (Fiala & Herrera 1988), *Digitaria commutata* (Chaieb et al. 1996), *Koeleria pyramidata* (Coupland & Bradshaw 1953), *Sporobolus cryptandrus* (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Johnsongrass	mean of *Panicum virgatum* (Weaver & Darland 1949; Hopkins 1953; Pettit & Jaynes 1971) and *Zea mays* (Weaver & Clements 1938)
Tall dropseed	mean of *Muhlenbergia cuspidata* (Sperry 1935), *Schizachyrium scoparium* (Sperry 1935; Weaver & Zink 1946; Weaver 1947, 1950, 1954, 1958; Weaver & Darland 1949; Coupland & Bradshaw 1953; Jurena & Archer 2003), *Sporobolus cryptandrus* (Albertson 1937; Weaver & Darland 1949; Hopkins 1953)
Texas wintergrass	mean of *Stipa comata* (Melgoza & Nowak 1991), *S. lagascae* (Chaieb et al. 1996), *S. spartea* (Sperry 1935; Coupland & Bradshaw 1953)

Milo	mean of *Triticum aestivum* and *Zea mays*
Wheat	Weaver et al. (1924), Weaver & Clements (1938)
Corn	Weaver & Clements (1938)

Littletooth sedge	mean of *Carex douglasii* (Manning et al. 1989) and *C. varia* (Sperry 1935)
Flatsedge	mean of *Carex nebrascensis* (Manning et al. 1989; Svejcar & Trent 1995; Kauffman et al. 2004) and *Scirpus validus* (Weaver & Clements 1938)
Fimbry	mean of *Carex douglasii* (Manning et al. 1989), *C. nebrascensis* (Manning et al. 1989; Svejcar & Trent 1995; Kauffman et al. 2004), *C. lasiocarpa, C. rostrata*, *C. trichocarpa* (Bernard & Fiala 1986), *C. varia* (Sperry 1935), *Juncus balticus* (Manning et al. 1989), *Scirpus validus* (Weaver & Clements 1938)
Cattail	mean of *Carex nebrascensis* (Manning et al. 1989), *Distichlis spicata* (Seliskar 1983; Dahlgren et al. 1997; McLendon 2008), *Lepidium latifolium* (Renz et al. 1997), *Paspalum notatum* (Hernandez & Fiala 1992), *Scirpus validus* (Weaver & Clements 1938), *Spartina pectinata* (Sperry 1935)

Ragweed	Sperry (1935)
Old-mans beard	mean of *Achillea millefolium* and *Solidago decumbens* (Holch et al. 1941)
Bundleflower	mean of *Oxytropis lambertii* (Weaver & Clements 1938), *Petalostemum purpureum*

	(Sperry 1935), and *Potentilla diversifolis* and *P. gracilis* (Holch et al. 1941)
Frogfruit	mean of *Potentilla gracilis* (Holch et al. 1941), *Pycanthemum tenuifolium* (Sperry 1935)
Prairie coneflower	*Ratibida pinnata* (Sperry 1935)
Snoutbean	*Petalostemum purpureum* (Sperry 1935)
Ruellia	*Ruellia humilis* (Sperry 1935)
Bush sunflower	*Helianthus scaberriums* (Sperry 1935)
Texas verbena	mean of *Aster multiflorus* (Sperry 1935), *A. oblongifolius* (Sperry 1935), *Erysimum asperum* (Holch et al. 1941), *Gallardia aristata* (Holch et al. 1941), *Geranium fremontii* (Holch et al. 1941), *Silphium integrifolium* (Sperry 1935)
Orange zexmenia	mean of *Helianthus scaberriums* and *Parthenium hispidum* (Sperry 1935)
Giant ragweed	mean of *Ambrosia psilostachya* and *Parthenium hispidum* (Sperry 1935)
Annual broomweed	mean of *Helianthus annuus* (Stone et al. 2001), *Grindelia squarrosa* (Holch et al. 1941)
Partridge pea	mean of *Erysimum asperum* (Holch et al. 1941), *Euphorbia corollata* (Sperry 1935)
Texas doveweed	mean of *Centaurea maculosa* (Marier et al. 1999), *Grindelia squarrosa* (Holch et al. 1941), *Helianthus annuus* (Stone et al. 2001)
Sunflower	Stone et al. (2001)
Duckweed	*Phacelia glandulosa* (Holch et al. 1941)
Texas bluebonnet	*Oxytropis lambertii* (Weaver & Clements 1938)
Dogweed	mean of *Aster multiflorus* (Sperry 1935), *A. oblongifolius* (Sperry 1935), *Eriogonum alatum* (Holch et al. 1941), and *Grindelia squarrosa* (Holch et al. 1941)

Maximum Potential Rooting Depth

Huisache	mean of *Chilopsis linearis* (Meinzer 1927), *Prosopis velutina* (Snyder & Williams 2003)
Pecan	mean of *Celtis laevigata* (Jackson et al. 1999), *Juglans nigra* (Canadell et al. 1996), *Ulmus americana* (Jackson et al. 1999), *Ulmus crassifolia* (Jackson et al. 1999)
Sugar hackberry	Jackson et al. (1999)
Texas persimmon	mean of *Malus pumila* (Weaver & Clements 1938), *Rhus glabra* (Weaver 1926)
Mesquite	Phillips (1963)
Post oak	mean of *Quercus durandii* (Jackson et al. 1999) and *Q. macrocarpa* (Biswell 1935)
Live oak	Jackson et al. (1999)
Guajillo	*Larrea tridentata* (Gile et al. 1998)
Blackbrush	mean of *Koeberlinia spinosa* (Gibbens & Lenz 2001), *Larrea tridentata* (Gile et al. 1998)
Whitebrush	mean of *Corylus americana* (Weaver 1919), *Fallugia paradoxa* (Foxx & Tierney 1986), *Lycium berlandieri* (Gibbens & Lenz 2001), *L. pallidum* (Yoder & Nowak 1999a)
Prairie baccharis	mean of *Baccharis glutinosa* (Gary 1963), *B. pilularis* (Wright 1928)
Granjeno	mean of *Arctostaphylos glandulosa* (Hellmers et al. 1955), *Celtis laevigata* (Jackson et al. 1999), *Flourensia cernua* (Gibbens & Lenz 2001), *Koeberlinia spinosa* (Gibbens & Lenz 2001), *Larrea tridentata* (Gile et al. 1998), *Lycium berlandieri* (Gibbens & Lenz 2001), *Sarcobatus vermiculatus* (Meinzer 1927)
Agarito	*Berberis repens* (Weaver 1919)
Rattlepod	mean of *Baccharis glutinosa* (Gary 1963), *Pulchea sericea* (Gary 1963), *Sesbania sesban* (Sekiya & Yano 2002)
Mustang grape	*Toxicodendron radicans* (Tolstead 1942)
Prickly pear	mean of *Opuntia imbricata* (Dittmer 1959), *O. polyacantha* (Tierney & Foxx 1987)
Big bluestem	Tomanek & Albertson (1957)
Purple threeawn	Albertson (1937)
King Ranch bluestem	Boyne & Bradford (1986)
Silver bluestem	mean of *Bouteloua curtipendula* (Tomanek & Albertson 1957), *Heteropogon contortus* (Cable 1980), *Schizachyrium scoparium* (Weaver & Fitzpatrick 1934), *Sporobolus asper* (Weaver & Albertson 1943)
Sideoats grama	Tomanek & Albertson (1957)
Hairy grama	Weaver (1926)

Buffalograss	Weaver & Clements (1938)
Sandbur	Dittmer (1959)
Hooded windmillgrass	mean of *Bouteloua hirsuta* (Weaver 1926), *Cenchrus incertus* (Dittmer 1959), *Digitaria californica* (Cable 1980), *Hilaria jamesii* (Weaver 1958), *Muhlenbergia torreyi* (Weaver 1958), *Scleropogon brevifolius* (Gibbens & Lenz 2001)
Trichloris	about 5% less than *Schizachyrium scoparium*
Bermudagrass	Garrot & Mancino (1994)
Arizona cottontop	Cable (1980)
Virginia wildrye	*Elymus canadensis* (Weaver 1958)
Clubhead cutgrass	mean of *Holcus lanatus* and *Nardus stricta* (Boggie et al. 1958)
Kleingrass	mean of *Eragrostis lehmanniana* (Gibbens & Lenz 2001) and *Panicum virgatum* (Weaver 1954)
Vine-mesquite	mean of *Distichlis spicata* (Shantz & Piemeisel 1940), *Hilaria mutica* (Cottle 1931), *Panicm virgatum* (Weaver 1954)
Switchgrass	Weaver (1954)
Longtom	mean of *Cynodon dactylon* (Garrot & Mancino 1994), *Distichlis spicata* (Shantz & Piemeisel 1940), and *Holcus lanatus* and *Nardus stricta* (Boggie et al. 1958)
Thin paspalum	mean of *Heteropogon contortus* (Cable 1980), *Muhlenbergia arenacea* (Gibbens & Lenz 2001), *Redfieldia flexuosa* (Weaver 1958), *Schizachyrium scoparium* (Weaver & Fitzpatrick 1934), *Sporobolus asper* (Weaver & Albertson 1943)
Little bluestem	Weaver & Fitzpatrick (1934)
Knotroot bristlegrass	mean of *Agrostis tenuis* (Boggie et al. 1958), *Dichanthelium scribnerianum* (Weaver 1954), *Muhlenbergia torreyi* (Weaver 1958), *Poa pratensis* (Weaver 1954)
Texas bristlegrass	mean of *Aristida purpurea* (Albertson 1937), *Bouteloua hirsuta* (Weaver 1926), *Cenchrus incertus* (Dittmer 1959), *Dichanthelium scribnerianum* (Weaver 1954), *Festuca ovina* (Boggie et al. 1958), *Koeleria pyramidata* (Wyatt et al. 1980), *Muhlenbergia porteri* (Gibbens & Lenz 2001), *Scleropogon brevifolius* (Gibbens & Lenz 2001)
Johnsongrass	mean of *Sorghastrum nutans* (Albertson 1937) and *Zea mays* (Weaver 1926)
Tall dropseed	Weaver & Albertson (1943)
Texas wintergrass	*Stipa comata* (Wyatt et al. 1980)

Milo	mean of *Pennisetum glaucum* (Payne et al. 1990) and *Zea mays* (Weaver 1926)
Wheat	Hamblin & Tennant (1987)
Corn	Weaver (1926)

Littletooth sedge	mean of *Carex filifolia* (Weaver 1920; Tolstead 1942), *C. geyerii* (Spence 1937), *C. varia* (Sperry 1935)
Flatsedge	mean of *Carex nebrascensis* (Chambers et al. 1999), *Juncus balticus* (Manning et al. 1989), *Scirpus validus* (Weaver & Clements 1938)
Fimbry	mean of *Juncus balticus* (Manning et al. 1989), *Scirpus validus* (Weaver & Clements 1938)
Cattail	mean of *Lepidium latifolium* (Renz et al. 1997), *Scirpus validus* (Weaver & Clements 1938), *Spartina pectinata* (Weaver 1958)

Ragweed	Weaver (1958)
Old-mans beard	mean of *Achillea millefolium* (Spence 1937), *Smilax rotundifolia* (Duncan 1935)
Bundleflower	*Desmanthus cooleyi* (Gibbens & Lenz 2001)
Frogfruit	mean of *Euphorbia albomarginata* (Gibbens & Lenz 2001), *Evolvulus nuttallianus* (Albertson 1937), *Hedyotis nigricans* (Albertson 1937)
Prairie coneflower	Hopkins (1951)
Snoutbean	mean of *Cassia bauhinioides* (Gibbens & Lenz 2001), *Desmanthus cooleyi* (Gibbens & Lenz 2001), *Hoffmanseggia drepanocarpa* (Gibbens & Lenz 2001), *Thermopsis rhombifolia* (Coupland & Johnson 1965), *Trifolium pretense* (Keim & Beadle 1927)
Ruellia	*Ruellia caroliniensis* (Sperry 1935)
Bush sunflower	mean of *Arnica pumila* (Holch et al. 1941), *Balsamorhiza sagittata* (Weaver 1958),

	Chrysopsis villosa (Weaver 1958), *Helianthus laetiflorus* (Weaver 1954), *Parthenium integrifolium* (Sperry 1935), *Veronica baldwinii* (Weaver 1919)
Texas verbena	*Verbena stricta* (Weaver 1958)
Orange zexmenia	mean of *Artemisia dracunculus* (Foxx & Tierney 1986), *Chrysopsis villosa* (Weaver 1958), *Helianthus laetiflorus* (Weaver 1954), *Machaeranthera pinnatifida* (Hopkins 1951), *Parthenium integrifolium* (Sperry 1935)
Giant ragweed	mean of *Ambrosia acanthicarpa* (Dittmer 1959), *A. artemisifolia* (Cole & Hatch 1941), *Helianthus annuus* (Schwarzbach et al. 2001), *Kochia scoparia* (Foxx & Tierney 1986)
Annual broomweed	mean of *Croton pottsii* (Gibbens & Lenz 2001), *C. texensis* (Dittmer 1959)
Partridge pea	*Cassia bauhinioides* (Gibbens & Lenz 2001)
Texas doveweed	Dittmer (1959)
Sunflower	Schwarzbach et al. (2001)
Duckweed	mean of *Mimulus bigelovii* and *Polygonum aviculare* (Forseth et al. 1984)
Texas bluebonnet	mean of *Cassia bauhinioides* (Gibbens & Lenz 2001), *Hoffmanseggia drepanocarpa* (Gibbens & Lenz 2001), *Medicago lupulina* (Cole & Hatch 1941), *Lupinus caudatus* (Foxx & Tierney 1986)
Dogweed	mean of *Aphanostephus ramoissimus* (Gibbens & Lenz 2001), *Centaurea solstitialis* (Sheley & Larson 1994), *Croton texensis* (Dittmer 1959), *Erodium botrys* (McKell et al. 1962), *Lepidium densiflorum* (Allen & Knight 1984), *Linum australe* (Gibbens & Lenz 2001), *Verbena utricifolia* (Cole & Hatch 1941)

Appendix Table D.11 Values for months when physiological reponses occur in plant species included in the Karnes and Wilson Counties EDYS models.

Species	Green-Out	Dormancy	Seed Set	Seed Germination
Huisache	2	12	4 -- 9	2 -- 9
Pecan	3	10	4 -- 9	3 -- 9
Sugar hackberry	3	10	4 -- 8	3 -- 9
Texas persimmon	1	12	3 -- 8	3 -- 9
Mesquite	3	11	4 -- 8	3 -- 9
Post oak	3	11	4 -- 8	3 -- 7
Live oak	3	2	4 -- 8	3 -- 7
Guajillo	1	12	6 -- 10	2 -- 10
Blackbrush	2	12	6 -- 10	2 -- 10
Whitebrush	2	11	6 -- 10	3 -- 10
Prairie baccharis	2	11	6 -- 10	2 -- 10
Granjeno	3	11	4 –- 8	2 -- 10
Agarito	1	12	4 -- 8	2 -- 10
Rattlepod	3	11	6 -- 7	2 -- 10
Mustang grape	2	12	6 -- 10	3 -- 9
Prickly pear	1	12	7 -- 8	2 -- 11
Big bluestem	3	11	8 -- 8	4 -- 8
Purple threeawn	3	11	8 -- 11	3 -- 9
King Ranch bluestem	3	11	7 -- 10	3 -- 10
Silver bluestem	3	11	5 –- 7	3 -- 9
Sideoats grama	3	11	6 -- 10	3 -- 9
Hairy grama	3	11	6 -- 10	3 -- 10
Buffalograss	3	11	5 -- 10	3 -- 9
Sandbur	3	11	7 –- 8	2 -- 10
Hooded windmillgrass	3	11	7 -- 8	3 -- 10
Trichloris	3	11	7 -- 8	3 -- 10
Bermudagrass	3	11	5 -- 7	3 -- 10
Arizona cottontop	3	11	5 -- 7	3 -- 9
Virginia wildrye	10	6	5 -- 7	10 -- 6
Clubhead cutgrass	3	12	5 -- 7	3 -- 10
Kleingrass	3	11	5 -- 7	3 -- 9
Vine-mesquite	3	12	5 -- 10	3 -- 10
Switchgrass	3	11	8 –- 9	4 -- 9
Longtom	3	11	8 -- 10	3 -- 10
Thin paspalum	3	11	8 –- 9	3 -- 10
Little bluestem	4	11	8 -- 10	4 -- 9
Knotroot bristlegrass	3	12	5 –- 8	3 -- 10
Texas bristlegrass	2	12	5 -- 8	2 -- 11
Johnsongrass	3	11	8 -- 11	3 -- 9
Tall dropseed	3	11	5 –- 8	3 -- 9
Texas wintergrass	10	6	5 -- 8	10 -- 5
Milo	3	11	5 -- 8	3 -- 9
Wheat	10	5	5 -- 8	10 -- 5
Corn	4	11	5 -- 8	4 -- 9
Littletooth sedge	3	12	5 -- 9	3 -- 10
Flatsedge	2	12	5 -- 9	3 -- 9
Fimbry	3	11	4 -- 8	3 -- 9
Cattail	3	12	6 -- 8	3 -- 10
Ragweed	3	11	3 -- 10	2 -- 10
Old-mans beard	3	12	6 -- 10	3 -- 10
Bundleflower	3	11	3 -- 10	3 -- 9
Frogfruit	3	11	3 -- 10	3 -- 9
Prairie coneflower	2	11	5 –- 9	3 -- 8
Snoutbean	3	11	4 -- 8	3 -- 9
Ruellia	2	12	4 -- 8	3 -- 10
Bush sunflower	3	11	4 -- 8	3 -- 9
Texas verbena	2	12	4 -- 8	2 -- 9
Orange zexmenia	3	1	4 -- 8	3 -- 9
Giant ragweed	3	11	3 -- 10	3 -- 9
Annual broomweed	3	11	3 -- 10	2 -- 9

Appendix Table D.11 (Cont.)

Species	Green-Out	Dormancy	Seed Set	Seed Germination
Partridge pea	3	11	6 –- 7	3 -- 9
Texas doveweed	3	11	4 -- 8	2 -- 9
Sunflower	3	11	6 -- 7	2 -- 10
Duckweed	2	11	6 -- 9	3 -- 10
Texas bluebonnet	1	5	4 -- 9	11 -- 4
Dogweed	3	11	4 -- 9	3 -- 9

Appendix Table D.13 Values for water use variables used in the Karnes and Wilson Counties EDYS models.

Species	Maintenance (mm/g bio/mo)	New Biomass Maintenance (mm/g biomass/mo)	Water to Production (kg/g)	Green-Out (g/g biomass)
Huisache	0.0000085	0.04	1.25	0.55
Pecan	0.0000085	0.04	0.90	0.55
Sugar hackberry	0.0000090	0.05	0.90	0.45
Texas persimmon	0.0000080	0.04	0.90	0.45
Mesquite	0.0000095	0.05	1.40	0.50
Post oak	0.0000080	0.04	0.90	0.45
Live oak	0.0000080	0.04	0.90	0.45
Guajillo	0.0000090	0.05	1.63	0.70
Blackbrush	0.0000090	0.05	1.63	0.70
Whitebrush	0.0000090	0.05	0.97	0.70
Baccharis	0.0000090	0.05	0.81	0.70
Granjeno	0.0000100	0.05	1.22	0.50
Agarito	0.0000090	0.05	1.47	0.65
Rattlepod	0.0000250	0.07	0.64	0.75
Mustang grape	0.0000090	0.05	0.90	0.70
Prickly pear	0.0000083	0.05	0.30	0.80
Big bluestem	0.0000280	0.05	0.83	0.80
Purple threeawn	0.0000150	0.04	0.74	0.65
KR bluestem	0.0000150	0.04	0.68	0.67
Silver bluestem	0.0000160	0.04	0.76	0.70
Sideoats grama	0.0000160	0.04	0.87	0.66
Hairy grama	0.0000160	0.04	0.60	0.65
Buffalograss	0.0000150	0.04	0.74	0.64
Sandbur	0.0003910	0.05	0.59	0.80
Hooded windmill	0.0003910	0.05	0.87	0.80
Trichloris	0.0003910	0.05	0.87	0.80
Bermudagrass	0.0000160	0.04	0.91	0.70
Arizona cottontop	0.0000160	0.04	0.63	0.70
Virginia wildrye	0.0000160	0.04	1.24	0.70
Clubhead cutgrass	0.0000160	0.04	0.29	0.70
Kleingrass	0.0000160	0.04	1.36	0.70
Vine-mesquite	0.0000150	0.04	0.90	0.64
Switchgrass	0.0000179	0.05	1.22	0.90
Longtom	0.0000017	0.06	0.50	0.65
Thin paspalum	0.0000017	0.06	0.76	0.65
Little bluestem	0.0000017	0.06	0.90	0.65
Knotroot bristle	0.0000120	0.04	0.90	0.70
Texas bristlegrass	0.0000120	0.04	0.61	0.70
Johnsongrass	0.0000175	0.06	0.89	0.64
Tall dropseed	0.0000120	0.04	0.71	0.70
Texas wintergrass	0.0000120	0.04	0.99	0.70
Milo	0.0000120	0.04	0.33	0.70
Wheat	0.0000120	0.04	0.76	0.70
Corn	0.0000120	0.04	0.37	0.70
Littletooth sedge	0.0000200	0.06	0.79	0.67
Flatsedge	0.0000200	0.06	0.73	0.67
Fimbry	0.0000250	0.08	0.81	0.82
Cattail	0.0000221	0.06	0.85	0.65
Ragweed	0.0000070	0.03	0.91	0.72
Old-mans beard	0.0000090	0.05	0.80	0.70
Bundleflower	0.0000070	0.03	0.67	0.72
Frogfruit	0.0000070	0.03	0.61	0.72
Prairie coneflower	0.0000190	0.06	0.69	0.67
Snoutbean	0.0000250	0.08	0.83	0.82
Ruellia	0.0000250	0.08	0.60	0.82
Bush sunflower	0.0000250	0.08	0.61	0.82
Texas verbena	0.0000250	0.08	0.79	0.82
Orange zexmenia	0.0000250	0.08	0.49	0.82

Appendix Table D.13 (Cont.)

Species	Maintenance (mm/g bio/mo)	New Biomass Maintenance (mm/g biomass/mo)	Water to Production (kg/g)	Green-Out (g/g biomass)
Giant ragweed	0.0000070	0.03	0.53	0.72
Annual broomweed	0.0000070	0.03	0.58	0.72
Partridge pea	0.0000250	0.07	0.76	0.75
Texas doveweed	0.0000250	0.08	0.56	0.82
Sunflower	0.0000200	0.07	0.55	0.70
Duckweed	0.0000070	0.03	0.38	0.72
Texas bluebonnet	0.0000200	0.07	0.64	0.70
Dogweed	0.0000070	0.03	0.50	0.72

Data Sources

Water to Production

Huisache: mean of *Cercidium microphylum* and *Prosopis velutina* (McGinnes & Arnold 1939)
Pecan, sugar hackberry, Texas persimmon, post oak, live oak: *Populus fremontii* (Anderson 1982)
Mesquite: Dwyer & DeGarmo (1970)

Guajillo and blackbrush: *Acacia greggii*, *Cercidium microphylum*, *Prosopis velutina* (McGinnes & Arnold 1939)
Whitebrush: mean of *Atriplex lentiformis* (Watson 1990), *Chrysothamnus nauseosus* (Donovan et al. 1996), *Sarcobatus vermiculatus* (Donovan et al. 1996), *Simmondsia chinensis* (McGinnes & Arnold 1939)
Baccharis: 0.9(*Populus fremontii*) = *Baccharis salicifolia* (Glenn et al. 1998)
Granjeno: mean of *Atriplex canescens* (Watson 1990), *Larrea tridentata* (Dwyer & DeGarmo 1970), *Populus fremontii* (Anderson 1982)
Agarito: *Larrea tridentata* (mean of Dwyer & DeGarmo 1970; Lane et al. 1984)
Rattlepod: mean of *Atriplex lentiformis* (Watson 1990), *Baccharis salicifolia* (Glenn et al. 1998), *Salix goodingii* (Glenn et al. 1998)
Mustang grape: *Populus fremontii* (Anderson 1982)

Prickly pear: *Opuntia basilaris* (Nobel 1976)

Big bluestem: Weaver (1941)
Purple threeawn: McLendon et al. (unpublished)
KR bluestem: Coyne & Bradford (1986)
Silver bluestem: McGinnes & Arnold (1939)
Sideoats grama: McGinnes & Arnold (1939)
Hairy grama: McGinnes & Arnold (1939)
Buffalograss: 90% of blue grama (Shantz & Piemeisel 1927)
Sandbur: *Cenchrus ciliaris*, mean of Khan (1971) and Kapinga (1982)
Hooded windmillgrass and trichloris: *Chloris gayana* (Kapinga 1982)
Bermudagrass: mean of McDonald & Hughes (1968) and Wiedenfeld (1988)
Arizona cottontop: McGinnes & Arnold (1939)
Virginia wildrye: *Leymus junceus*, mean of Hunt (1962), Power (1985), Frank & Berdahl (1999)
Clubhead cutgrass: *Phalaris aquatica* (Morison & Gifford 1984)
Kleingrass: mean of McCawley (1978) and Kapinga (1982)
Vine-mesquite: 90% of *Hilaria mutica* (Dwyer & DeGarmo 1970)
Switchgrass: mean of *Andropogon gerardii* (Weaver 1941), *Panicum antidotale* (Writht & Dobrenz 1970)
Longtom: *Paspalum vaginatum* (Biran et al. 1981)
Thin paspalum: mean of *Aristida purpurea* (McLendon et al., unpublished), *Bouteloua hirsuta* (McGinnes & Arnold), *Cenchrus ciliaris* (Kapinga 1982), *Eragrostis curvula* (Wiedenfield 1988), *Heteropogon contortus* (McGinnes & Arnold 1939), *Schizachyrium scoparium* (Weaver 1941), *Sporobolus airoides* (Benton & Wester 1998), *Sporobolus flexuous* (Dwyer & DeGarmo)

Little bluestem: mean of Weaver (1941) and McLendon et al. (unpublished)
Knotroot bristle: mean of *Spartina alterniflora* (Gallagher et al. 1980) and *Sporobolus wrightii* (Cox 1985)
Texas bristlegrass: mean of *Bothriochloa saccharoides* (McGinnes & Arnold), *Setaria italic* (Briggs & Shantz 1913), *Sporobolus flexuous* (Dwyer & DeGarmo 1970)
Johnsongrass: mean of *Andropogon gerardii* (Weaver 1941), *Chloris gayana* (Kapinga 1982), *Panicum antidotale* (Wright & Dobrenz), *Phragmites australis* (Mueller et al. 2005), *Sorghum bicolor* (Briggs & Shantz 1913)
Tall dropseed: *Sporobolus flexuosus* (Dwyer & DeGarmo 1970)
Texas wintergrass: *Stipa viridula* (Fairbourn 1982)

Milo: Briggs & Shantz (1913), Peng & Krieg (1992)
Wheat: Briggs & Shantz (1913)
Corn: Briggs & Shantz (1913)

Littletooth sedge: *Juncus roemerianus* (Giurgevich & Dunn 1978)
Flatsedge: *Phragmites australis* (Mueller et al. 2005)
Fimbry: *Phalaris arundinacea* (Mueller et al. 2005)
Cattail: mean of *Juncus roemerianus* (Giurgevich & Dunn 1978), *Paspalum vaginatum* (Biran et al. 1981), *Phalaris aquatica* (Morison & Gifford 1984), *Phragmites australis* (Mueller et al. 2005), *Spartina alterniflora* (Gallagher et al. 1980)

Ragweed: *Ambrosia artemisifolia* (Shantz & Piemeisel 1927)
Old-mans beard: mean of *Ambrosia artemisifolia* and *Iva xanthifolia* (Shantz & Piemeisel 1927)
Bundleflower: mean of *Lotus humistrautis* (McGinnes & Arnold 1939), *Melilotus alba* (Shantz & Piemeisel 1927)
Frogfruit: mean of *Amaranthus retroflexus* (Briggs & Shantz 1913), *Plantago insularis* (McGinnes & Arnold 1939), *Polygonum aviculare* (Shantz & Piemeisel 1927)
Priaire coneflower: mean of *Ambrosia artemisifolia, Grindelia squarrosa*, *Helianthus petiolaris, Polygonum aviculare* (Shantz & Piemeisel 1927)
Snoutbean: mean of *Glycine max* (Lawn 1982), *Lotus humistrautis* (McGinnes & Arnold 1939), *Pisum sativum* (Briggs & Shantz 1913)
Ruellia: mean of *Fagopyrum fagopyrum* (Briggs & Shantz 1913), *Iva xanthifolia* (Shantz & Piemeisel 1927), *Plantago insularis* (McGinnes & Arnold 1939), *Polygonum aviculare* (Shantz & Piemeisel 1927), *Solanum tuberosum* (Briggs & Shantz 1913)
Bush sunflower: mean of *Helianthus petiolaris* and *Polygonum aviculare* (Shantz & Piemeisel 1927)
Texas verbena: mean of *Chenopodium album* (Shantz & Piemeisel 1927), *Erodium cicutarium* (McGinnes & Arnold 1939)
Orange zexmenia: 0.8(bush sunflower)

Giant ragweed: mean of *Amaranthus retroflexus* (Briggs & Shantz 1913), *Helianthus annuus* (mean of 4 studies), *Iva xanthifolia* (Shantz & Piemeisel 1927), *Polygonum aviculare* (Shantz & Piemeisel 1927)
Annual broomweed: mean of *Fagopyrum fagopyrum* (Briggs & Shantz 1913), *Grindelia squarrosa* (Shantz & Piemeisel 1927)
Sunflower: mean of Shantz & Piemeisel (1927), Morison & Gifford (1984), Larcher (1995), Mueller et al. (2005)
Duckweed: mean of *Allenrolfea occidentalis* (Glenn et al. 1998), *Iva xanthifolia* (Shantz & Piemeisel 1927), *Phalaris aquatica* (Morison & Gifford 1984)
Partridge pea: mean of *Astragalus cicer* (Fairbourn 1982), *Lotus humistrautis* (McGinnes & Arnold 1939), *Pisum sativum* (Briggs & Shantz 1913)
Texas doveweed: mean of *Brassica napus* (Briggs & Shantz 1913), *Chenopodium album* (Shantz & Piemeisel 1927), *Fagopyrum fagopyrum* (Briggs & Shantz 1913),
Texas bluebonnet: mean of *Astragalus cicer* (Fairbourn 1982), *Lotus humistrautis* (McGinnes & Arnold 1939), *Trifolium pretense* (Mueller et al. 2005)
Dogweed: mean of *Boerhaavia torreyana* (McGinnes & Arnold 1939), *Pectocarya linearis* (McGinnes & Arnold 1939), *Salsola iberica* (Briggs & Shantz 1913)

Appendix Table D.14 Growth rate control factor values for plant species included in the Karnes and Wilson Counties EDYS models.

Species	Maximum Growth Rate (per mo)	Maximum Aboveground Biomass (g/m^2)	Maximum Old Biomass Drought Loss (per mo)
Huisache	1.10	5,000	0.10
Pecan	0.35	28,000	0.10
Sugar hackberry	0.50	14,000	0.10
Texas persimmon	0.30	3,600	0.05
Mesquite	0.90	6,400	0.05
Post oak	0.25	15,000	0.10
Live oak	0.40	29,000	0.10
Guajillo	0.28	2,100	0.20
Blackbrush	0.28	2,400	0.20
Whitebrush	1.00	2,600	0.30
Prairie baccharis	1.20	2,800	0.40
Granjeno	0.70	2,500	0.30
Agarito	0.25	1,200	0.10
Rattlepod	1.30	1,400	0.40
Mustang grape	1.00	2,000	0.40
Prickly pear	0.05	2,400	0.10
Big bluestem	3.00	800	0.30
Purple threeawn	2.50	300	0.20
King Ranch bluestem	2.50	800	0.20
Silver bluestem	2.75	600	0.25
Sideoats grama	2.75	600	0.25
Hairy grama	1.75	250	0.20
Buffalograss	1.71	350	0.20
Sandbur	2.50	150	0.20
Hooded windmillgrass	1.75	250	0.20
Trichloris	2.50	600	0.25
Bermudagrass	2.50	600	0.25
Arizona cottontop	2.50	500	0.25
Virginia wildrye	2.75	600	0.40
Clubhead cutgrass	2.00	250	0.70
Kleingrass	2.00	800	0.30
Vine-mesquite	2.75	400	0.30
Switchgrass	2.75	800	0.30
Longtom	2.75	500	0.50
Thin paspalum	2.25	400	0.25
Little bluestem	2.50	600	0.30
Knotroot bristlegrass	1.50	250	0.30
Texas bristlegrass	1.50	100	0.25
Johnsongrass	2.75	800	0.35
Tall dropseed	2.75	600	0.30
Texas wintergrass	2.00	300	0.25
Milo	4.00	1000	0.30
Wheat	2.00	350	0.30
Corn	3.00	1200	0.40
Littletooth sedge	1.75	250	0.30
Flatsedge	1.50	500	0.30
Fimbry	1.50	450	0.40
Cattail	1.00	800	0.50
Ragweed	2.80	600	0.20
Old-mans beard	1.00	400	0.40
Bundleflower	2.00	80	0.20
Frogfruit	2.40	60	0.30
Prairie coneflower	2.00	60	0.30
Snoutbean	2.00	80	0.20
Ruellia	2.00	50	0.20
Bush sunflower	2.49	300	0.20
Texas verbena	2.50	50	0.30
Orange zexmenia	1.35	200	0.15

Appendix Table D.14 (Cont.)

Species	Maximum Growth Rate (per mo)	Maximum Aboveground Biomass (g/m^2)	Maximum Old Biomass Drought Loss (per mo)
Giant ragweed	4.00	1000	0.50
Annual broomweed	3.00	300	0.15
Partridge pea	1.50	200	0.30
Texas doveweed	1.50	250	0.20
Sunfower	3.00	750	0.30
Duckweed	1.00	200	0.70
Texas bluebonnet	1.00	80	0.30
Dogweed	1.00	60	0.10

Maximum growth rate = maximum per month increase in standing crop photosynthetic tissue.
Maximum biomass = maximum aboveground biomass (g/m^2).
Maximum old biomass drought loss = maximum amount of current aboveground tissue that can be lost per month from drought.

Data Sources

Maximum Growth Rate

Purple threeawn	*Aristida glabrata* (McGinnies & Arnold 1939)
Silver bluestem	McGinnies & Arnold (1939)
Sideoats grama	McGinnies & Arnold (1939)
Hairy grama	McGinnies & Arnold (1939)
Buffalograss	*Hilaria belangeri* (McGinnies & Arnold 1939)
Arizona cottontop	modified from McGinnies & Arnold (1939)
Thin paspalum	*Heteropogon contortus* (McGinnies & Arnold 1939)

Maximum Aboveground Biomass

King Ranch bluestem	*Dichanthium annualtum* (Kapinga 1982)

Appendix Table D.15 Monthly growth rates (proportion of maximum potential growth rate; Appendix Table D.14) for plant species in the Karnes and Wilson Counties EDYS models.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Huisache	0.10	0.20	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Pecan	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.00	0.70	0.30	0.10	0.00
Sugar hackberry	0.00	0.00	0.60	0.90	1.00	1.00	1.00	1.00	0.70	0.30	0.10	0.00
Texas persimmon	0.20	0.40	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Mesquite	0.10	0.10	0.80	1.00	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Post oak	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.00	0.60	0.30	0.10	0.00
Live oak	0.30	0.40	0.80	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.40	0.30
Guajillo	0.05	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.10	0.05
Blackbrush	0.05	0.15	0.50	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Whitebrush	0.20	0.40	0.90	1.00	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.20
Prairie baccharis	0.10	0.40	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.60	0.30	0.10
Granjeno	0.05	0.10	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.30	0.05
Agarito	0.30	0.50	0.70	0.90	1.00	1.00	1.00	1.00	0.90	0.70	0.50	0.30
Rattlepod	0.05	0.20	0.40	0.70	1.00	1.00	1.00	1.00	0.90	0.70	0.40	0.05
Mustang grape	0.00	0.50	0.80	1.00	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.00
Prickly pear	0.10	0.10	0.50	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Big bluestem	0.00	0.10	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.60	0.30	0.05
Purple threeawn	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
King Ranch bluestem	0.10	0.20	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Silver bluestem	0.10	0.15	0.50	0.80	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Sideoats grama	0.20	0.30	0.40	0.70	0.90	1.00	1.00	0.80	0.50	0.40	0.30	0.20
Hairy grama	0.10	0.15	0.20	0.40	0.50	1.00	0.80	0.70	0.50	0.30	0.20	0.10
Buffalograss	0.05	0.10	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10
Sandbur	0.00	0.00	0.50	0.90	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.00
Hooded windmillgrass	0.00	0.01	0.40	0.80	0.90	1.00	1.00	0.90	0.70	0.50	0.20	0.00
Trichloris	0.10	0.10	0.50	0.70	1.00	1.00	1.00	0.90	0.70	0.50	0.20	0.10
Bermudagrass	0.10	0.20	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.10
Arizona cottontop	0.20	0.30	0.40	0.50	0.60	0.70	0.90	1.00	0.60	0.50	0.40	0.30
Virginia wildrye	0.50	0.80	1.00	1.00	0.80	0.40	0.10	0.10	0.30	0.40	0.50	0.50
Clubhead cutgrass	0.10	0.20	0.30	0.60	0.80	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Kleingrass	0.10	0.20	0.30	0.50	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20
Vine-mesquite	0.10	0.20	0.40	0.60	0.80	1.00	1.00	0.90	0.70	0.50	0.30	0.20
Switchgrass	0.10	0.20	0.40	0.70	0.90	1.00	1.00	1.00	0.80	0.50	0.30	0.10
Longtom	0.10	0.30	0.75	0.90	1.00	1.00	1.00	1.00	0.60	0.40	0.20	0.10
Thin paspalum	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Little bluestem	0.10	0.20	0.50	0.70	0.90	1.00	1.00	0.90	0.70	0.50	0.30	0.10
Knotroot bristlegrass	0.10	0.30	0.60	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Texas bristlegrass	0.20	0.40	0.60	0.80	1.00	1.00	0.80	0.70	0.60	0.50	0.40	0.30
Johnsongrass	0.00	0.00	0.50	0.80	1.00	1.00	1.00	1.00	0.70	0.30	0.00	0.00
Tall dropseed	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Texas wintergrass	1.00	1.00	1.00	1.00	0.70	0.40	0.10	0.05	0.10	0.30	0.60	0.90
Milo	0.00	0.10	0.90	1.00	1.00	1.00	1.00	0.80	0.50	0.20	0.00	0.00
Wheat	0.80	0.90	1.00	1.00	0.60	0.20	0.00	0.00	0.00	0.10	0.40	0.60
Corn	0.00	0.10	0.90	1.00	1.00	1.00	1.00	0.90	0.60	0.30	0.10	0.00
Littletooth sedge	0.10	0.25	0.50	0.90	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10
Flatsedge	0.10	0.20	0.60	0.80	1.00	1.00	0.80	0.60	0.40	0.30	0.20	0.10
Fimbry	0.10	0.20	0.60	0.80	1.00	1.00	0.80	0.60	0.40	0.30	0.20	0.10
Cattail	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.80	0.60	0.30	0.10	0.10
Ragweed	0.10	0.25	0.70	0.90	1.00	1.00	1.00	0.80	0.60	0.30	0.10	0.10
Old-mans beard	0.10	0.20	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.20
Bundleflower	0.10	0.20	0.50	0.70	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Frogfruit	0.10	0.20	0.50	0.70	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.10
Prairie coneflower	0.10	0.20	0.70	1.00	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10
Snoutbean	0.10	0.15	0.60	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Ruellia	0.10	0.20	0.70	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.20	0.10
Bush sunflower	0.05	0.20	0.50	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.30	0.10
Texas verbena	0.20	0.40	0.80	1.00	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30
Orange zexmenia	0.10	0.20	0.60	0.90	1.00	1.00	1.00	1.00	0.90	0.50	0.30	0.10

Appendix Table D.15 (Cont.)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Giant ragweed	0.10	0.20	0.50	0.90	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.00
Annual broomweed	0.10	0.20	0.40	0.80	1.00	1.00	0.90	0.70	0.50	0.30	0.10	0.00
Partridge pea	0.20	0.40	0.80	1.00	1.00	1.00	0.90	0.70	0.50	0.30	0.10	0.00
Texas doveweed	0.10	0.30	0.60	1.00	1.00	1.00	0.90	0.80	0.60	0.40	0.10	0.00
Sunflower	0.10	0.30	0.80	1.00	1.00	1.00	1.00	0.80	0.60	0.40	0.20	0.00
Duckweed	0.10	0.30	0.50	0.70	0.90	1.00	1.00	0.80	0.60	0.40	0.20	0.00
Texas bluebonnet	0.40	0.80	1.00	1.00	0.70	0.20	0.00	0.00	0.10	0.20	0.30	0.40
Dogweed	0.10	0.30	0.50	0.80	1.00	1.00	1.00	0.60	0.40	0.20	0.10	0.00

Data Sources

Purple threeawn	Modified from *Aristida divaricata* (McGinnies & Arnold 1939)
Silver bluestem	McGinnies & Arnold 1939
Sideoats grama	McGinnies & Arnold 1939
Hairy grama	McGinnies & Arnold 1939
Arizona cottontop	McGinnies & Arnold 1939

Appendix Table D.16 Plant part productivity rates (proportion of maximum photosynthetic rate) for plant species in the Karnes and Wilson Counties models.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Huisache	0.00	0.00	0.00	0.05	1.00	0.00
Pecan	0.00	0.00	0.00	0.00	1.00	0.00
Sugar hackberry	0.00	0.00	0.00	0.00	1.00	0.00
Texas persimmon	0.00	0.00	0.00	0.00	1.00	0.00
Mesquite	0.00	0.00	0.00	0.02	1.00	0.00
Post oak	0.00	0.00	0.00	0.00	1.00	0.00
Live oak	0.00	0.00	0.00	0.00	1.00	0.00
Guajillo	0.00	0.00	0.00	0.02	1.00	0.00
Blackbrush	0.00	0.00	0.00	0.00	1.00	0.00
Whitebrush	0.00	0.00	0.00	0.05	1.00	0.00
Prairie baccharis	0.00	0.00	0.00	0.00	1.00	0.00
Granjeno	0.00	0.00	0.00	0.00	1.00	0.00
Agarito	0.00	0.00	0.00	0.02	1.00	0.00
Rattlepod	0.00	0.00	0.00	0.05	1.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	1.00	0.00
Prickly pear	0.00	0.00	0.02	1.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.10	1.00	0.00
Purple threeawn	0.00	0.00	0.05	0.20	1.00	0.00
King Ranch bluestem	0.00	0.00	0.10	0.30	1.00	0.00
Silver bluestem	0.00	0.00	0.00	0.20	1.00	0.00
Sideoats grama	0.00	0.00	0.05	0.10	1.00	0.00
Hairy grama	0.00	0.00	0.10	0.20	1.00	0.00
Buffalograss	0.00	0.00	0.10	0.20	1.00	0.00
Sandbur	0.00	0.00	0.05	0.20	1.00	0.00
Hooded windmillgrass	0.00	0.00	0.10	0.20	1.00	0.00
Trichloris	0.00	0.00	0.01	0.20	1.00	0.00
Bermudagrass	0.00	0.00	0.10	0.20	1.00	0.00
Arizona cottontop	0.00	0.00	0.05	0.20	1.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.10	1.00	0.00
Clubhead cutgrass	0.00	0.00	0.00	0.20	1.00	0.00
Kleingrass	0.00	0.00	0.00	0.10	1.00	0.00
Vine-mesquite	0.00	0.00	0.10	0.20	1.00	0.00
Switchgrass	0.00	0.00	0.00	0.10	1.00	0.00
Longtom	0.00	0.00	0.03	0.20	1.00	0.00
Thin paspalum	0.00	0.00	0.05	0.20	1.00	0.00
Little bluestem	0.00	0.00	0.00	0.10	1.00	0.00
Knotroot bristlegrass	0.00	0.00	0.10	0.20	1.00	0.00
Texas bristlegrass	0.00	0.00	0.10	0.20	1.00	0.00
Johnsongrass	0.00	0.00	0.05	0.20	1.00	0.00
Tall dropseed	0.00	0.00	0.05	0.10	1.00	0.00
Texas wintergrass	0.00	0.00	0.10	0.20	1.00	0.00
Milo	0.00	0.00	0.00	0.20	1.00	0.00
Wheat	0.00	0.00	0.02	0.20	1.00	0.00
Corn	0.00	0.00	0.00	0.20	1.00	0.00
Littletooth sedge	0.00	0.00	0.05	0.20	1.00	0.00
Flatsedge	0.00	0.00	0.00	0.30	1.00	0.00
Fimbry	0.00	0.00	0.00	0.20	1.00	0.00
Cattail	0.00	0.00	0.00	0.10	1.00	0.00
Ragweed	0.00	0.00	0.00	0.10	1.00	0.00
Old-mans beard	0.00	0.00	0.10	0.20	1.00	0.00
Bundleflower	0.00	0.00	0.10	0.10	1.00	0.00
Frogfruit	0.00	0.00	0.05	0.05	1.00	0.00
Prairie coneflower	0.00	0.00	0.00	0.05	1.00	0.00
Snoutbean	0.00	0.00	0.05	0.10	1.00	0.00
Ruellia	0.00	0.00	0.05	0.10	1.00	0.00
Bush sunflower	0.00	0.00	0.05	0.10	1.00	0.00
Texas verbena	0.00	0.00	0.05	0.10	1.00	0.00
Orange zexmenia	0.00	0.00	0.00	0.10	1.00	0.00

Appendix Table D.16 (Cont.)

Species	Coarse Roots	Fine Roots	Trunks	Stems	Leaves	Seeds
Giant ragweed	0.00	0.00	0.00	0.20	1.00	0.00
Annual broomweed	0.00	0.00	0.00	0.10	1.00	0.00
Partridge pea	0.00	0.00	0.00	0.10	1.00	0.00
Texas doveweed	0.00	0.00	0.00	0.05	1.00	0.00
Sunflower	0.00	0.00	0.00	0.20	1.00	0.00
Duckweed	0.00	0.00	0.00	0.10	1.00	0.00
Texas bluebonnet	0.00	0.00	0.00	0.10	1.00	0.00
Dogweed	0.00	0.00	0.00	0.20	1.00	0.00

Appendix Table D.17 Green-out plant part productivity conversion rates (proportion of biomass weight converted to new production at green-out) for plant species in the Karnes and Wilson Counties models.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Huisache	0.02	0.00	0.01	0.05	1.00	0.00
Pecan	0.01	0.00	0.01	0.02	1.00	0.00
Sugar hackberry	0.01	0.00	0.01	0.03	1.00	0.00
Texas persimmon	0.01	0.00	0.01	0.02	1.00	0.00
Mesquite	0.02	0.00	0.01	0.05	1.00	0.00
Post oak	0.01	0.00	0.01	0.02	1.00	0.00
Live oak	0.01	0.00	0.01	0.02	1.00	0.00
Guajillo	0.02	0.00	0.02	0.05	1.00	0.00
Blackbrush	0.02	0.00	0.02	0.05	1.00	0.00
Whitebrush	0.04	0.00	0.04	0.10	1.00	0.00
Prairie baccharis	0.04	0.00	0.04	0.10	1.00	0.00
Granjeno	0.02	0.00	0.02	0.05	1.00	0.00
Agarito	0.02	0.00	0.02	0.05	1.00	0.00
Rattlepod	0.02	0.00	0.05	0.10	1.00	0.00
Mustang grape	0.01	0.00	0.02	0.10	1.00	0.00
Prickly pear	0.01	0.00	0.02	0.05	0.00	0.00
Big bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Purple threeawn	0.05	0.00	0.05	0.50	1.00	0.00
King Ranch bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Silver bluestem	0.05	0.00	0.10	0.50	1.00	0.00
Sideoats grama	0.10	0.00	0.10	0.50	1.00	0.00
Hairy grama	0.05	0.00	0.05	0.50	1.00	0.00
Buffalograss	0.05	0.00	0.05	0.50	1.00	0.00
Sandbur	0.05	0.00	0.05	0.50	1.00	0.00
Hooded windmillgrass	0.05	0.00	0.05	0.50	1.00	0.00
Trichloris	0.05	0.00	0.10	0.50	1.00	0.00
Bermudagrass	0.10	0.00	0.10	0.50	1.00	0.00
Arizona cottontop	0.05	0.00	0.10	0.50	1.00	0.00
Virginia wildrye	0.05	0.00	0.05	0.50	1.00	0.00
Clubhead cutgrass	0.05	0.00	0.05	0.50	1.00	0.00
Kleingrass	0.05	0.00	0.10	0.50	1.00	0.00
Vine-mesquite	0.10	0.00	0.10	0.50	1.00	0.00
Switchgrass	0.05	0.00	0.10	0.50	1.00	0.00
Longtom	0.05	0.00	0.10	0.50	1.00	0.00
Thin paspalum	0.05	0.00	0.05	0.50	1.00	0.00
Little bluestem	0.10	0.00	0.10	0.50	1.00	0.00
Knotroot bristlegrass	0.10	0.00	0.10	0.50	1.00	0.00
Texas bristlegrass	0.05	0.00	0.05	0.50	1.00	0.00
Johnsongrass	0.10	0.00	0.10	0.50	1.00	0.00
Tall dropseed	0.05	0.00	0.05	0.50	1.00	0.00
Texas wintergrass	0.05	0.00	0.05	0.50	1.00	0.00
Milo	0.00	0.00	0.10	0.50	1.00	0.00
Wheat	0.00	0.00	0.10	0.50	1.00	0.00
Corn	0.00	0.00	0.10	0.50	1.00	0.00
Littletooth sedge	0.05	0.00	0.05	0.50	1.00	0.00
Flatsedge	0.10	0.00	0.10	0.50	1.00	0.00
Fimbry	0.10	0.00	0.10	0.50	1.00	0.00
Cattail	0.30	0.00	0.20	0.30	1.00	0.00
Ragweed	0.10	0.00	0.10	0.40	1.00	0.00
Old-mans beard	0.10	0.00	0.10	0.40	1.00	0.00
Bundleflower	0.05	0.00	0.10	0.40	1.00	0.00
Frogfruit	0.05	0.00	0.10	0.30	1.00	0.00
Prairie coneflower	0.10	0.00	0.10	0.30	1.00	0.00
Snoutbean	0.10	0.00	0.20	0.30	1.00	0.00
Ruellia	0.10	0.00	0.10	0.30	1.00	0.00
Bush sunflower	0.10	0.00	0.20	0.40	1.00	0.00
Texas verbena	0.05	0.00	0.10	0.30	1.00	0.00
Orange zexmenia	0.10	0.00	0.10	0.40	1.00	0.00

Appendix Table D.17 (Cont.)

Species	Coarse Roots	Fine Roots	Trunks	Stems	Leaves	Seeds
Giant ragweed	0.00	0.00	0.20	0.50	1.00	0.00
Broomweed	0.00	0.00	0.10	0.20	1.00	0.00
Partridge pea	0.00	0.00	0.20	0.40	1.00	0.00
Texas doveweed	0.00	0.00	0.10	0.20	1.00	0.00
Sunflower	0.00	0.00	0.20	0.50	1.00	0.00
Duckweed	0.00	0.00	0.10	0.10	1.00	0.00
Texas bluebonnet	0.00	0.00	0.20	0.20	1.00	0.00
Dogweed	0.00	0.00	0.20	0.30	1.00	0.00

Appendix Table D.18 Physiological control constants for plant species in the Karnes and Wilson Counties models.

Species	Growing Season Max Root:Shoot Ratio	Growing Season Green-Out Shoot:Root Ratio	Max 1-month Seed Germination	Max First Month Seedling Growth
Huisache	1.70	0.23	0.73	20
Pecan	1.50	0.21	0.73	20
Sugar hackberry	0.56	0.11	0.80	15
Texas persimmon	1.50	0.21	0.70	9
Mesquite	0.68	0.13	0.75	15
Post oak	0.72	0.13	0.95	8
Live oak	0.92	0.16	0.95	8
Guajillo	1.30	0.20	0.96	20
Blackbrush	1.30	0.20	0.96	20
Whitebrush	1.22	0.19	0.96	20
Prairie baccharis	1.22	0.19	0.96	20
Granjeno	1.32	0.20	0.75	15
Agarito	1.94	0.25	0.48	20
Rattlepod	1.22	0.19	0.26	30
Mustang grape	1.00	0.33	0.96	20
Prickly pear	0.24	0.06	0.40	50
Big bluestem	1.72	0.23	0.54	20
Purple threeawn	2.00	0.25	0.90	40
King Ranch bluestem	2.00	0.25	0.70	30
Silver bluestem	2.00	0.25	0.90	30
Sideoats grama	1.92	0.24	0.66	30
Hairy grama	1.12	0.18	0.39	30
Buffalograss	2.40	0.27	0.62	30
Sandbur	1.40	0.21	0.44	15
Hooded windmillgrass	1.80	0.24	0.44	15
Trichloris	2.00	0.25	0.44	15
Bermudagrass	2.00	0.25	0.90	30
Arizona cottontop	1.80	0.24	0.90	30
Virginia wildrye	1.68	0.23	0.90	30
Clubhead cutgrass	3.00	0.30	0.90	30
Kleingrass	1.80	0.24	0.90	30
Vine-mesquite	1.52	0.22	0.62	30
Switchgrass	1.80	0.24	0.34	15
Longtom	5.00	0.36	0.53	30
Thin paspalum	1.52	0.22	0.53	30
Little bluestem	2.10	0.26	0.53	30
Knotroot bristlegrass	2.20	0.26	0.58	25
Texas bristlegrass	1.20	0.19	0.58	25
Johnsongrass	1.80	0.24	0.56	30
Tall dropseed	1.80	0.24	0.58	25
Texas wintergrass	2.00	0.25	0.58	25
Milo	2.00	0.25	0.58	25
Wheat	2.00	0.25	0.58	25
Corn	2.00	0.25	0.58	25
Littletooth sedge	2.40	0.27	0.35	30
Flatsedge	3.10	0.30	0.35	30
Fimbry	3.10	0.30	0.70	50
Cattail	4.00	0.34	0.65	20
Ragweed	1.40	0.21	0.50	20
Old-mans beard	2.60	0.28	0.96	20
Bundleflower	1.00	0.17	0.50	20
Frogfruit	1.00	0.17	0.50	20
Prairie coneflower	1.92	0.24	0.99	30
Snoutbean	1.40	0.21	0.70	50
Ruellia	1.20	0.19	0.70	50
Bush sunflower	2.00	0.25	0.70	50
Texas verbena	1.40	0.21	0.70	50
Orange zexmenia	2.00	0.25	0.70	50

Appendix Table D.18 (Cont.)

Species	Growing Season Max Root:Shoot Ratio	Growing Season Green-Out Root:Shoot Ratio	Max 1-month Seed Germination	Max First Month Seedling Growth
Giant ragweed	1.00	0.17	0.50	20
Broomweed	1.20	0.19	0.50	20
Partridge pea	1.20	0.19	0.26	30
Texas doveweed	0.80	0.14	0.70	50
Sunflower	1.00	0.17	0.60	30
Duckweed	1.00	0.17	0.50	20
Texas bluebonnet	1.00	0.17	0.60	30
Dogweed	1.20	0.19	0.60	30

Growing season max root:shoot ratio = twice the initial root:shoot ratio value (Appendix Table D.2). Examples of field root:shoot ratios include: *Quercus robur* 0.35 (Rodin & Bazilevich 1967); *Q. velutina* 0.54 (Nadelhoffer et al. 1985); *Larrea tridentata* 0.42 (Chew & Chew 1965), 1.08 (Wallace et al. 1974); *Bouteloua gracilis* 2.39 (Samuel & Hart 1992), 4.10 (Coupland & Johnson 1965), 6.90 (Vinton & Burke 1995); *Cynodon dactylon* 0.62 (Rodriguez et al. 2002), 1.60 (Hons et al. 1979), 2.90 (Beaty et al. 1975); *Distichlis spicata* 1.10 (Seliskar & Gallagher 2000); *Hilaria jamesii* 5.31 (Moore & West 1973); *Hilaria rigida* 0.57 (Robberecht et al. 1983); *Oryzopsis hymenoides* 2.62 (Orodho & Trlica 1990); *Paspalum notatum* 2.27 (Fiala et al. 1991), 2.50 (Beaty et al. 1975); *Schizachyrium scoparium* 2.76 (Cerligione et al. 1987); tallgrass prairie 0.90 Oklahoma (Sims & Singh 1978), 0.97 Missouri (Buyanovsky et al. 1987); Kansas midgrass prairie 1.76 (Sims & Singh 1978); shortgrass plains 1.87 Colorado (Sims & Singh 1978), 2.21 Texas (Sims & Singh 1978); *Carex nebrascensis* 5.62 (Manning et al. 1989); *Juncus roemerianus* 1.55 (Gallagher et al. 1977).

Growing season green-out shoot:root ratio = half the inverse of initial shoot:root ratio (Appendix Table D.2).

Appendix Table D.19 End of growing season dieback (proportion of tissue lost at onset of dormancy) for plant species in the Karnes and Wilson Counties models.

Species	Coarse Roots	Fine Roots	Trunk	Stems	Leaves	Seeds
Huisache	0.02	0.06	0.01	0.03	0.90	1.00
Pecan	0.01	0.05	0.01	0.04	0.99	1.00
Sugar hackberry	0.01	0.05	0.01	0.05	0.98	1.00
Texas persimmon	0.01	0.06	0.01	0.05	0.60	1.00
Mesquite	0.01	0.05	0.01	0.02	0.90	1.00
Post oak	0.01	0.05	0.01	0.02	1.00	1.00
Live oak	0.01	0.05	0.01	0.02	0.90	1.00
Guajillo	0.03	0.15	0.03	0.10	0.35	1.00
Blackbrush	0.03	0.15	0.02	0.10	0.40	1.00
Whitebrush	0.04	0.15	0.03	0.10	0.90	1.00
Prairie baccharis	0.04	0.17	0.06	0.15	0.85	1.00
Granjeno	0.03	0.15	0.02	0.05	0.80	1.00
Agarito	0.05	0.15	0.02	0.10	0.20	1.00
Rattlepod	0.08	0.15	0.10	0.20	0.95	1.00
Mustang grape	0.04	0.15	0.01	0.04	0.80	1.00
Prickly pear	0.05	0.15	0.02	0.05	0.05	1.00
Big bluestem	0.03	0.09	0.05	0.90	0.99	1.00
Purple threeawn	0.15	0.30	0.20	0.95	0.95	1.00
King Ranch bluestem	0.15	0.30	0.10	0.80	0.95	1.00
Silver bluestem	0.10	0.20	0.04	0.90	0.95	1.00
Sideoats grama	0.10	0.20	0.03	0.90	0.98	1.00
Hairy grama	0.15	0.30	0.15	0.95	0.90	1.00
Buffalograss	0.15	0.30	0.15	0.85	0.90	1.00
Sandbur	0.25	0.35	0.30	0.95	1.00	1.00
Hooded windmillgrass	0.15	0.30	0.08	0.95	0.95	1.00
Trichloris	0.10	0.20	0.04	0.90	0.95	1.00
Bermudagrass	0.18	0.30	0.15	0.70	0.90	1.00
Arizona cottontop	0.10	0.20	0.05	0.95	0.95	1.00
Virginia wildrye	0.12	0.25	0.10	0.95	0.99	1.00
Clubhead cutgrass	0.30	0.50	0.25	0.99	0.95	1.00
Kleingrass	0.18	0.40	0.15	0.95	0.95	1.00
Vine-mesquite	0.14	0.28	0.10	0.85	0.90	1.00
Switchgrass	0.10	0.20	0.05	0.90	0.95	1.00
Longtom	0.15	0.30	0.06	0.80	0.95	1.00
Thin paspalum	0.17	0.25	0.12	0.95	0.99	1.00
Little bluestem	0.10	0.20	0.04	0.90	0.98	1.00
Knotroot bristlegrass	0.18	0.30	0.15	0.90	0.90	1.00
Texas bristlegrass	0.25	0.50	0.25	0.98	0.99	1.00
Johnsongrass	0.10	0.30	0.10	0.95	0.95	1.00
Tall dropseed	0.14	0.25	0.05	0.95	0.97	1.00
Texas wintergrass	0.18	0.30	0.15	0.95	0.98	1.00
Milo	1.00	1.00	1.00	1.00	1.00	1.00
Wheat	1.00	1.00	1.00	1.00	1.00	1.00
Corn	1.00	1.00	1.00	1.00	1.00	1.00
Littletooth sedge	0.15	0.30	0.20	0.90	0.95	1.00
Flatsedge	0.15	0.30	0.15	0.98	0.95	1.00
Fimbry	0.15	0.30	0.20	0.95	0.95	1.00
Cattail	0.10	0.30	0.05	0.95	0.90	1.00
Ragweed	0.18	0.35	0.18	0.73	0.99	1.00
Old-mans beard	0.15	0.30	0.12	0.50	0.90	1.00
Bundleflower	0.05	0.15	0.08	0.60	0.95	1.00
Frogfruit	0.20	0.30	0.20	0.40	0.95	1.00
Prairie coneflower	0.15	0.30	0.20	0.70	0.95	1.00
Snoutbean	0.05	0.15	0.05	0.40	0.95	1.00
Ruellia	0.18	0.30	0.10	0.60	0.80	1.00
Bush sunflower	0.07	0.15	0.05	0.43	0.95	1.00
Texas verbena	0.25	0.50	0.30	0.90	0.90	1.00
Orange zexmenia	0.10	0.20	0.08	0.60	0.80	1.00

Appendix Table D.19 (Cont.)

Species	Coarse Roots	Fine Roots	Trunks	Stems	Leaves	Seeds
Giant ragweed	1.00	1.00	1.00	1.00	1.00	1.00
Annual broomweed	1.00	1.00	1.00	1.00	1.00	1.00
Partridge pea	1.00	1.00	1.00	1.00	1.00	1.00
Texas doveweed	1.00	1.00	1.00	1.00	1.00	1.00
Sunflower	1.00	1.00	1.00	1.00	1.00	1.00
Duckweed	1.00	1.00	1.00	1.00	1.00	1.00
Texas bluebonnet	1.00	1.00	1.00	1.00	1.00	1.00
Dogweed	1.00	1.00	1.00	1.00	1.00	1.00

Data Sources

Weaver & Zink (1946); Caldwell & Camp (1974); Peek et al. (2005).

Appendix Table D.20 Shading effect on species included in the Karnes and Wilson County models. Values are the proportional decrease in maximum potential production of the **shaded species** resulting from 100% cover of the **shading species.**

Shaded	Shading Species										
Species	huisac	pecan	hackbr	persim	msquit	postoak	liveoak	guajillo	blackbr	whitebr	bacchar
Huisache	0.00	0.05	0.02	0.01	0.01	0.02	0.05	0.00	0.00	0.01	0.01
Pecan	0.00	0.00	0.00	0.00	0.00	0.01	0.03	0.00	0.00	0.00	0.00
Hackberry	0.01	0.02	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00
TX persimmon	0.01	0.05	0.02	0.00	0.01	0.01	0.03	0.00	0.00	0.00	0.00
Mesquite	0.00	0.06	0.01	0.00	0.00	0.01	0.04	0.00	0.00	0.00	0.00
Post oak	0.00	0.03	0.01	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
Live oak	0.00	0.02	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Guajillo	0.05	0.05	0.04	0.03	0.04	0.04	0.06	0.00	0.01	0.03	0.03
Blackbrush	0.02	0.04	0.03	0.02	0.02	0.04	0.08	0.01	0.00	0.02	0.01
Whitebrush	0.02	0.03	0.02	0.01	0.01	0.02	0.03	0.00	0.00	0.00	0.01
Baccharis	0.02	0.03	0.02	0.01	0.02	0.02	0.03	0.00	0.00	0.01	0.00
Granjeno	0.01	0.02	0.01	0.01	0.01	0.02	0.03	0.00	0.00	0.01	0.01
Agarito	0.01	0.03	0.03	0.01	0.01	0.02	0.03	0.00	0.01	0.02	0.01
Rattlepod	0.04	0.04	0.04	0.01	0.04	0.04	0.04	0.00	0.00	0.02	0.01
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prickly pear	0.03	0.04	0.03	0.01	0.03	0.03	0.04	0.00	0.01	0.01	0.01
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
KR bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Buffalograss	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hooded windmill	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AZ cottontop	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clubhead cutgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Thin paspalum	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristle	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TX bristlegrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TX wintergrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wheat	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Littletooth sedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fimbry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Frogfruit	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coneflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Snoutbean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ruellia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Partridge pea	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Texas doveweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Appendix Table D.20 (Cont.)

Shaded	Shading Species										
Species	granjen	agarito	rattlep	msgrape	prkpear	bigblue	pthrawn	KRblust	silvrbl	sidoats	hrgrama
Huisache	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hackberry	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tx persimmon	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.01	0.01	0.00	0.07	0.00	0.06	0.00	0.00	0.01	0.01	0.00
Blackbrush	0.01	0.00	0.00	0.07	0.00	0.04	0.00	0.00	0.01	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baccharis	0.01	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.01	0.00	0.00	0.06	0.00	0.06	0.00	0.00	0.01	0.01	0.00
Rattlepod	0.01	0.00	0.00	0.08	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prickly pear	0.01	0.01	0.01	0.07	0.00	0.06	0.01	0.00	0.03	0.02	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02	0.01	0.00
KR bluestem	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.03	0.02	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.02	0.03	0.02	0.00
Buffalograss	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.01	0.02	0.01	0.00
Sandbur	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.02	0.04	0.03	0.00
Hooded windmill	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.01	0.02	0.02	0.00
Trichloris	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.00	0.02	0.01	0.00
AZ cottontop	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.01	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Clubhead cutgrass	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.02	0.03	0.03	0.00
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.01	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02	0.01	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.01	0.01	0.00
Thin paspalum	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.02	0.01	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Knotroot bristle	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.01	0.04	0.03	0.00
TX bristlegrass	0.00	0.00	0.00	0.00	0.00	0.09	0.02	0.02	0.04	0.03	0.00
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.01	0.00
TX wintergrass	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02	0.01	0.00
Milo	0.00	0.00	0.00	0.00	0.00	0.10	0.06	0.06	0.09	0.08	0.00
Wheat	0.00	0.00	0.00	0.00	0.00	0.10	0.07	0.07	0.09	0.08	0.00
Corn	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.08	0.07	0.00
Littletooth sedge	0.00	0.00	0.00	0.00	0.00	0.10	0.02	0.01	0.04	0.03	0.00
Flatsedge	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.03	0.02	0.00
Fimbry	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.03	0.02	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.01	0.00	0.00
Ragweed	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.03	0.02	0.00
Old-mans beard	0.00	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.01	0.01	0.00
Bundleflower	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.01	0.02	0.02	0.00
Frogfruit	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.01	0.02	0.02	0.00
Coneflower	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.01	0.03	0.02	0.00
Snoutbean	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.01	0.01	0.00
Ruellia	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.02	0.01	0.00
Bush sunflower	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.01	0.00
Texas verbena	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.01	0.01	0.00
Orange zexmenia	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.03	0.02	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.06	0.05	0.00
Partridge pea	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.04	0.03	0.00
Texas doveweed	0.00	0.00	0.00	0.00	0.00	0.10	0.01	0.00	0.05	0.04	0.00
Sunflower	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.01	0.01	0.00
Duckweed	0.00	0.00	0.00	0.00	0.00	0.09	0.00	0.00	0.04	0.03	0.00
Texas bluebonnet	0.00	0.00	0.00	0.00	0.00	0.10	0.04	0.02	0.06	0.03	0.00
Dogweed	0.00	0.00	0.00	0.00	0.00	0.10	0.03	0.01	0.06	0.05	0.00

Appendix Table D.20 (Cont.)

Shaded	Shading Species										
Species	buffalo	sandbur	hoodwd	trichlr	Bermuda	Arcott	Vwldry	cutgrass	Kleing	vinemq	switch
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tx persimmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Blackbrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.01	0.00	0.05
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prickly pear	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.02	0.00	0.05
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.00	0.04	0.00	0.05
KR bluestem	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.03	0.00	0.05
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Hairy grama	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.05	0.00	0.08
Buffalograss	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.04	0.00	0.08
Sandbur	0.00	0.00	0.00	0.07	0.00	0.03	0.03	0.00	0.06	0.00	0.10
Hooded windmill	0.00	0.00	0.00	0.02	0.00	0.02	0.02	0.00	0.05	0.00	0.08
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04
Bermudagrass	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.02	0.00	0.08
AZ cottontop	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.05
Virginia wildrye	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.03
Clubhead cutgrass	0.00	0.00	0.00	0.02	0.00	0.02	0.01	0.00	0.01	0.00	0.05
Kleingrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Vine-mesquite	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.02	0.00	0.04
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.05
Thin paspalum	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.03	0.00	0.06
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Knotroot bristle	0.00	0.00	0.00	0.02	0.00	0.00	0.02	0.00	0.04	0.00	0.06
Tx bristlegrass	0.00	0.00	0.00	0.03	0.00	0.02	0.02	0.00	0.05	0.00	0.10
Johnsongrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.07
Tall dropseed	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.01	0.00	0.08
TX wintergrass	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.02	0.00	0.08
Milo	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.04	0.00	0.10
Wheat	0.00	0.00	0.00	0.07	0.00	0.02	0.02	0.00	0.06	0.00	0.15
Corn	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02	0.00	0.09
Littletooth sedge	0.00	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.03	0.00	0.08
Flatsedge	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.02	0.00	0.08
Fimbry	0.00	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.02	0.00	0.08
Cattail	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08
Ragweed	0.00	0.00	0.00	0.02	0.00	0.01	0.01	0.00	0.02	0.00	0.08
Old-mans beard	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.07
Bundleflower	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03	0.00	0.09
Frogfruit	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.03	0.00	0.09
Coneflower	0.00	0.00	0.00	0.02	0.00	0.05	0.05	0.00	0.05	0.00	0.10
Snoutbean	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.02	0.00	0.07
Ruellia	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00	0.03	0.00	0.08
Bush sunflower	0.00	0.00	0.00	0.01	0.00	0.00	0.02	0.00	0.04	0.00	0.10
Texas verbena	0.00	0.00	0.00	0.01	0.00	0.02	0.01	0.00	0.02	0.00	0.07
Orange zexmenia	0.00	0.00	0.00	0.02	0.00	0.03	0.03	0.00	0.04	0.00	0.10
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Annual broomweed	0.00	0.00	0.00	0.05	0.00	0.02	0.01	0.00	0.05	0.00	0.10
Partridge pea	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00	0.03	0.00	0.06
Texas doveweed	0.00	0.00	0.00	0.04	0.00	0.02	0.01	0.00	0.04	0.00	0.10
Sunflower	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.01	0.00	0.06
Duckweed	0.00	0.00	0.00	0.03	0.00	0.02	0.02	0.00	0.03	0.00	0.09
Texas bluebonnet	0.00	0.00	0.00	0.03	0.00	0.02	0.02	0.00	0.03	0.00	0.09
Dogweed	0.00	0.00	0.00	0.05	0.00	0.05	0.04	0.00	0.05	0.00	0.10

Appendix Table D.20 (Cont.)

Shaded	Shading Species										
Species	longtom	thinpasp	littlblu	kntrbr	Txbrstl	Johnsgr	talldrop	Txwintr	milo	wheat	corn
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tx persimmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Blackbrush	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.01	0.03	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.06
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prickly pear	0.00	0.00	0.02	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.05
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.00	0.02	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.04
KR bluestem	0.00	0.01	0.03	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.05
Silver bluestem	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Sideoats grama	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03
Hairy grama	0.00	0.02	0.03	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.05
Buffalograss	0.00	0.02	0.02	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.05
Sandbur	0.00	0.04	0.06	0.00	0.00	0.06	0.04	0.00	0.00	0.00	0.07
Hooded windmill	0.00	0.02	0.05	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.05
Trichloris	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Bermudagrass	0.00	0.01	0.04	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.05
AZ cottontop	0.00	0.00	0.02	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.04
Virginia wildrye	0.00	0.00	0.02	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.05
Clubhead cutgrass	0.06	0.00	0.03	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.05
Kleingrass	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.04
Vine-mesquite	0.02	0.01	0.03	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.03
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
Longtom	0.00	0.00	0.04	0.00	0.00	0.03	0.01	0.00	0.00	0.00	0.03
Thin paspaplum	0.00	0.00	0.03	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.04
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Knotroot bristle	0.03	0.02	0.04	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.04
TX bristlegrass	0.01	0.03	0.06	0.00	0.00	0.06	0.02	0.00	0.00	0.00	0.04
Johnsongrass	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Tall dropseed	0.00	0.00	0.02	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.04
TX wintergrass	0.00	0.01	0.04	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.03
Milo	0.00	0.00	0.06	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.06
Wheat	0.02	0.04	0.08	0.00	0.00	0.09	0.04	0.00	0.03	0.00	0.06
Corn	0.00	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Littletooth sedge	0.02	0.02	0.05	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.04
Flatsedge	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02
Fimbry	0.00	0.00	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.02
Cattail	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.02
Ragweed	0.00	0.01	0.03	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.04
Old-mans beard	0.00	0.01	0.02	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.01
Bundleflower	0.00	0.03	0.04	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.02
Frogfruit	0.02	0.02	0.03	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.01
Coneflower	0.02	0.04	0.05	0.00	0.00	0.06	0.05	0.00	0.00	0.00	0.02
Snoutbean	0.00	0.02	0.03	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.02
Ruellia	0.00	0.01	0.04	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.02
Bush sunflower	0.00	0.00	0.02	0.00	0.00	0.04	0.03	0.00	0.00	0.00	0.05
Texas verbena	0.01	0.02	0.03	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.03
Orange zexmenia	0.00	0.03	0.05	0.00	0.00	0.07	0.03	0.00	0.00	0.00	0.05
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.04	0.07	0.00	0.00	0.08	0.03	0.00	0.00	0.00	0.04
Partridge pea	0.00	0.01	0.04	0.00	0.00	0.04	0.02	0.00	0.00	0.00	0.02
Texas doveweed	0.00	0.04	0.05	0.00	0.00	0.07	0.04	0.00	0.00	0.00	0.04
Sunflower	0.00	0.02	0.02	0.00	0.00	0.02	0.01	0.00	0.00	0.00	0.05
Duckweed	0.04	0.04	0.06	0.00	0.00	0.05	0.03	0.00	0.00	0.00	0.04
Texas bluebonnet	0.03	0.04	0.06	0.00	0.00	0.08	0.04	0.00	0.00	0.00	0.05
Dogweed	0.03	0.04	0.08	0.00	0.00	0.08	0.07	0.00	0.00	0.00	0.05

Appendix Table D.20 (Cont.)

Shaded	Shading Species										
Species	ltsedge	flatsdg	fimbry	cattail	ragweed	oldmans	bundlfl	frogfru	coneflr	snoutbn	ruellia
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tx persimmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baccharis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prickly pear	0.00	0.01	0.00	0.02	0.02	0.04	0.00	0.00	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Purple threeawn	0.00	0.03	0.03	0.04	0.03	0.03	0.00	0.00	0.00	0.01	0.00
KR bluestem	0.00	0.01	0.01	0.03	0.03	0.04	0.00	0.00	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hairy grama	0.00	0.03	0.03	0.04	0.04	0.04	0.00	0.00	0.00	0.01	0.00
Buffalograss	0.00	0.01	0.01	0.03	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Sandbur	0.00	0.04	0.04	0.04	0.05	0.04	0.00	0.00	0.00	0.02	0.00
Hooded windmill	0.00	0.03	0.03	0.04	0.04	0.04	0.00	0.00	0.00	0.02	0.00
Trichloris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bermudagrass	0.00	0.01	0.01	0.01	0.03	0.03	0.00	0.00	0.00	0.00	0.00
AZ cottontop	0.00	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Clubhead cutgrass	0.00	0.02	0.02	0.03	0.04	0.03	0.00	0.00	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Vine-mesquite	0.00	0.00	0.00	0.00	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Longtom	0.00	0.01	0.01	0.01	0.01	0.03	0.00	0.00	0.00	0.00	0.00
Thin paspalum	0.00	0.01	0.01	0.01	0.03	0.03	0.00	0.00	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Knotroot bristle	0.00	0.02	0.02	0.02	0.03	0.04	0.00	0.00	0.00	0.00	0.00
TX bristlegrass	0.00	0.04	0.04	0.04	0.06	0.05	0.00	0.00	0.00	0.02	0.00
Johnsongrass	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Tall dropseed	0.00	0.00	0.00	0.01	0.03	0.04	0.00	0.00	0.00	0.00	0.00
TX wintergrass	0.00	0.00	0.00	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
Milo	0.00	0.02	0.02	0.03	0.04	0.05	0.00	0.00	0.00	0.00	0.00
Wheat	0.00	0.03	0.03	0.04	0.09	0.10	0.00	0.00	0.00	0.02	0.00
Corn	0.00	0.00	0.00	0.01	0.04	0.05	0.00	0.00	0.00	0.00	0.00
Littletooth sedge	0.00	0.03	0.03	0.03	0.04	0.04	0.00	0.00	0.00	0.00	0.00
Flatsedge	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Fimbry	0.00	0.00	0.00	0.01	0.01	0.02	0.00	0.00	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Ragweed	0.00	0.00	0.00	0.01	0.00	0.04	0.00	0.00	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
Bundleflower	0.00	0.02	0.02	0.03	0.04	0.05	0.00	0.00	0.00	0.00	0.00
Frogfruit	0.00	0.01	0.01	0.01	0.03	0.05	0.00	0.00	0.00	0.00	0.00
Coneflower	0.00	0.02	0.02	0.02	0.05	0.08	0.00	0.00	0.00	0.04	0.00
Snoutbean	0.00	0.00	0.00	0.00	0.03	0.05	0.00	0.00	0.00	0.00	0.00
Ruellia	0.00	0.01	0.01	0.02	0.03	0.06	0.00	0.00	0.00	0.01	0.00
Bush sunflower	0.00	0.01	0.01	0.01	0.01	0.07	0.00	0.00	0.00	0.00	0.00
Texas verbena	0.00	0.00	0.00	0.01	0.02	0.06	0.00	0.00	0.00	0.00	0.00
Organge zexmenia	0.00	0.01	0.01	0.01	0.04	0.07	0.00	0.00	0.00	0.02	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.00	0.02	0.02	0.02	0.04	0.07	0.00	0.00	0.00	0.02	0.00
Partridge pea	0.00	0.00	0.00	0.01	0.03	0.05	0.00	0.00	0.00	0.01	0.00
Texas doveweed	0.00	0.02	0.02	0.02	0.04	0.06	0.00	0.00	0.00	0.02	0.00
Sunflower	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00
Duckweed	0.00	0.00	0.00	0.01	0.02	0.03	0.00	0.00	0.00	0.00	0.00
Texas bluebonnet	0.00	0.02	0.02	0.02	0.02	0.05	0.00	0.00	0.00	0.03	0.00
Dogweed	0.00	0.02	0.02	0.02	0.05	0.06	0.00	0.00	0.00	0.04	0.00

Appendix Table D.20 (Cont.)

Shaded	Shading Species									
Species	bshsun	verbna	zexmen	gtragwd	broom	parpea	dovewd	sunflwr	duckwd	bluebnt	dogwd
Huisache	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pecan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hackberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tx persimmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mesquite	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Post oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Live oak	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Guajillo	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Blackbrush	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Whitebrush	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Baccharis	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Granjeno	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Agarito	0.02	0.00	0.00	0.90	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Rattlepod	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Mustang grape	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Prickly pear	0.02	0.00	0.01	0.90	0.00	0.00	0.01	0.30	0.00	0.00	0.00
Big bluestem	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Purple threeawn	0.03	0.00	0.01	0.90	0.00	0.00	0.02	0.30	0.00	0.00	0.00
KR bluestem	0.01	0.00	0.00	0.90	0.00	0.00	0.01	0.20	0.00	0.00	0.00
Silver bluestem	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sideoats grama	0.01	0.00	0.00	0.70	0.00	0.00	0.01	0.20	0.00	0.00	0.00
Hairy grama	0.04	0.00	0.01	0.95	0.01	0.00	0.04	0.50	0.00	0.00	0.00
Buffalograss	0.01	0.00	0.00	0.90	0.00	0.00	0.05	0.30	0.00	0.00	0.00
Sandbur	0.02	0.00	0.01	0.95	0.01	0.00	0.05	0.60	0.00	0.00	0.00
Hooded windmill	0.02	0.00	0.00	0.95	0.01	0.00	0.05	0.60	0.00	0.00	0.00
Trichloris	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Bermudagrass	0.00	0.00	0.00	0.90	0.00	0.00	0.01	0.20	0.00	0.00	0.00
AZ cottontop	0.01	0.00	0.00	0.80	0.01	0.00	0.04	0.50	0.00	0.00	0.00
Virginia wildrye	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Clubhead cutgrass	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.40	0.00	0.00	0.00
Kleingrass	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Vine-mesquite	0.01	0.00	0.00	0.80	0.00	0.00	0.02	0.30	0.00	0.00	0.00
Switchgrass	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Longtom	0.01	0.00	0.00	0.70	0.00	0.00	0.01	0.30	0.00	0.00	0.00
Thin paspalum	0.03	0.00	0.01	0.80	0.01	0.00	0.04	0.60	0.00	0.00	0.00
Little bluestem	0.00	0.00	0.00	0.60	0.00	0.00	0.01	0.30	0.00	0.00	0.00
Knotroot bristle	0.01	0.00	0.00	0.80	0.02	0.00	0.03	0.50	0.00	0.00	0.00
TX bristlegrass	0.00	0.00	0.00	0.90	0.01	0.00	0.02	0.50	0.00	0.00	0.00
Johnsongrass	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Tall dropseed	0.01	0.00	0.00	0.70	0.00	0.00	0.01	0.40	0.00	0.00	0.00
TX wintergrass	0.01	0.00	0.00	0.80	0.01	0.00	0.03	0.60	0.00	0.00	0.00
Milo	0.02	0.00	0.00	0.90	0.00	0.00	0.01	0.40	0.00	0.00	0.00
Wheat	0.04	0.00	0.01	0.95	0.03	0.00	0.06	0.80	0.00	0.00	0.00
Corn	0.00	0.00	0.00	0.80	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Littletooth sedge	0.02	0.00	0.00	0.80	0.01	0.00	0.03	0.60	0.00	0.00	0.00
Flatsedge	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.40	0.00	0.00	0.00
Fimbry	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.50	0.00	0.00	0.00
Cattail	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Ragweed	0.03	0.00	0.00	0.90	0.00	0.00	0.02	0.40	0.00	0.00	0.00
Old-mans beard	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Bundleflower	0.02	0.00	0.00	0.90	0.01	0.00	0.03	0.50	0.00	0.00	0.00
Frogfruit	0.00	0.00	0.00	0.40	0.01	0.00	0.02	0.30	0.00	0.00	0.00
Coneflower	0.06	0.00	0.02	0.95	0.02	0.00	0.04	0.60	0.00	0.00	0.00
Snoutbean	0.01	0.00	0.00	0.80	0.01	0.00	0.03	0.50	0.00	0.00	0.00
Ruellia	0.03	0.00	0.00	0.80	0.01	0.00	0.02	0.40	0.00	0.00	0.00
Bush sunflower	0.00	0.00	0.00	0.90	0.00	0.00	0.00	0.30	0.00	0.00	0.00
Texas verbena	0.04	0.00	0.01	0.80	0.02	0.00	0.04	0.50	0.00	0.00	0.00
Orange zexmenia	0.06	0.00	0.00	0.95	0.01	0.00	0.03	0.50	0.00	0.00	0.00
Giant ragweed	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Annual broomweed	0.04	0.00	0.01	0.80	0.00	0.00	0.02	0.50	0.00	0.00	0.00
Partridge pea	0.02	0.00	0.00	0.70	0.00	0.00	0.01	0.20	0.00	0.00	0.00
Texas doveweed	0.02	0.00	0.00	0.90	0.01	0.00	0.00	0.50	0.00	0.00	0.00
Sunflower	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Duckweed	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.20	0.00	0.00	0.00
Texas bluebonnet	0.05	0.00	0.03	0.95	0.02	0.00	0.04	0.60	0.00	0.00	0.00
Dogweed	0.09	0.01	0.04	0.99	0.04	0.06	0.06	0.80	0.00	0.00	0.00

Appendix Table D.21 Cattle preference factors for plant parts, by species, in the Karnes and Wilson Counties models. Values are relative rankings (1 = highest, 30 = lowest). High rankings indicate the plant part and species are highly preferred by cattle.

Species	CRoots	FRoots	Trunk	Stems	Leaves	Seeds	SDStems	SDLvs	SdlgR	SdlgS	SeedBank
Huisache	35	35	35	35	10	21	36	28	10	10	35
Pecan	35	35	35	35	18	35	36	29	18	18	36
Sugar hackberry	35	35	35	35	11	20	35	28	11	11	35
Texas persimmon	35	35	35	35	20	20	35	30	20	20	36
Mesquite	35	35	35	35	24	6	35	29	23	23	34
Post oak	35	35	35	35	25	34	35	31	25	25	34
Live oak	35	35	35	35	27	34	35	32	26	26	34
Guajillo	35	35	35	34	6	18	35	20	6	6	35
Blackbrush	35	35	35	35	12	21	35	29	12	12	35
Whitebrush	35	35	35	34	17	18	30	28	17	17	35
Baccharis	35	35	35	34	23	35	35	30	23	23	36
Granjeno	35	35	35	34	16	16	31	29	16	16	36
Agarito	35	35	35	35	30	16	35	35	29	29	36
Rattlepod	35	35	35	34	26	36	35	30	25	25	36
Mustang grape	35	35	35	34	19	19	35	29	19	19	35
Prickly pear	35	35	35	7	37	7	35	35	7	7	35
Big bluestem	11	11	3	1	1	1	11	9	1	1	34
Purple threeawn	9	9	5	4	4	4	8	8	3	3	36
KR bluestem	10	10	4	3	3	3	9	9	2	2	35
Silver bluestem	10	10	3	2	2	2	9	9	1	1	35
Sideoats grama	10	10	3	1	1	1	9	9	1	1	34
Hairy grama	9	9	4	3	3	3	8	8	2	2	35
Buffalograss	8	8	2	1	1	1	2	2	1	1	35
Sandbur	10	10	7	6	6	6	9	9	5	5	37
Hooded windmill	9	9	5	4	4	4	8	8	3	3	36
Trichloris	10	10	4	2	2	2	9	9	1	1	36
Bermudagrass	4	3	3	1	1	1	3	3	1	1	35
AZ cottontop	10	10	3	1	1	1	9	9	1	1	36
Virginia wildrye	10	10	4	2	2	2	9	9	1	1	35
Club cutgrass	8	8	4	3	3	3	8	8	2	2	35
Kleingrass	10	10	4	2	2	2	9	9	1	1	35
Vine-mesquite	8	7	3	1	1	1	7	7	1	1	34
Switchgrass	10	10	4	1	1	1	9	9	1	1	35
Longtom	9	8	3	2	2	2	8	8	1	1	34
Thin paspalum	10	10	4	3	3	3	9	9	2	2	35
Little bluestem	10	10	4	2	2	2	9	9	1	1	35
Knotroot bristle	10	10	6	4	4	4	9	9	3	3	35
TX bristlegrass	9	9	4	3	3	3	8	8	2	2	35
Johnsongrass	6	9	3	1	1	1	10	9	1	1	6
Tall dropseed	10	10	4	2	2	2	9	9	1	1	35
TX wintergrass	6	6	3	2	2	2	4	4	1	1	36
Milo	10	10	9	3	2	2	11	9	1	1	3
Wheat	9	9	3	1	1	1	9	9	1	1	4
Corn	10	10	9	3	1	1	11	9	1	1	2
Littletooth sedge	9	9	6	5	5	5	9	9	4	4	35
Flatsedge	15	15	14	12	10	10	21	14	9	9	36
Fimbry	15	15	14	12	10	10	21	14	9	9	36
Cattail	17	17	22	20	16	30	35	29	14	14	37
Ragweed	30	30	30	26	24	24	31	30	23	23	34
Old-mans beard	16	16	15	14	14	14	16	16	13	13	36
Bundleflower	12	12	11	10	10	10	12	12	9	9	35
Frogfruit	14	14	12	11	11	11	13	13	10	10	35
Coneflower	16	16	15	14	14	14	15	15	13	13	34
Snoutbean	13	13	12	11	11	11	12	12	10	10	34
Ruellia	14	14	13	12	12	12	13	13	11	11	34
Bush sunflower	30	30	30	30	20	18	32	31	18	18	34
Texas verbena	18	18	17	15	15	15	17	17	14	14	35
Orange zexmenia	19	19	19	18	13	13	15	15	12	12	35

Appendix Table D.21 (Cont.)

Species	CRoots	FRoots	Trunk	Stems	Leaves	Seeds	SDStem	SDLvs	SdlgR	SdlgS	SeedBank
Giant ragweed	30	30	29	27	25	25	33	32	24	24	35
Broomweed	31	31	31	30	28	27	32	31	27	27	36
Partridge pea	13	13	10	8	8	8	12	12	7	7	34
Texas doveweed	31	31	32	31	26	26	31	30	25	25	34
Sunflower	29	28	29	28	22	20	29	27	21	21	10
Duckweed	15	15	15	13	13	13	15	15	12	12	34
TX bluebonnet	24	23	22	22	22	21	23	23	21	21	35
Dogweed	31	30	30	29	29	29	30	30	28	28	34

SDStems = standing dead stems; SDLvs = standing dead leaves; SdlgR = seedling roots; SdlgS = seedling shoots

Appendix Table D.22 Cattle competition factors for plant parts, by species, in the Karnes and Wilson Counties models. Values are relative rankings among competing herbivores for the respective plant material (1 = most competitive of the herbivores, 6 = least competitive).

Species	CRoots	FRoots	Trunk	Stems	Leaves	Seeds	SDStems	SDLvs	SdlgR	SdlgS	SeedBank
Huisache	6	6	6	4	4	4	4	4	6	6	6
Pecan	6	6	6	4	4	4	4	4	6	6	6
Sugar hackberry	6	6	6	4	4	4	4	4	6	6	6
Texas persimmon	6	6	6	4	4	4	4	4	6	6	6
Mesquite	6	6	6	4	4	4	4	4	6	6	6
Post oak	6	6	6	4	4	4	4	4	6	6	6
Live oak	6	6	6	4	4	4	4	4	6	6	6
Guajillo	6	6	6	5	5	5	5	5	6	6	6
Blackbrush	6	6	6	5	5	5	5	5	6	6	6
Whitebrush	6	6	6	5	5	5	5	5	6	6	6
Baccharis	6	6	6	5	5	5	5	5	6	6	6
Granjeno	6	6	6	5	5	5	5	5	6	6	6
Agarito	6	6	6	6	6	6	6	6	6	6	6
Rattlepod	6	6	6	5	5	5	5	5	6	6	6
Mustang grape	6	6	6	4	4	4	4	4	6	6	6
Prickly pear	6	6	6	6	6	5	6	6	6	6	6
Big bluestem	6	6	6	6	6	5	6	6	6	6	6
Purple threeawn	6	6	6	6	6	6	6	6	6	6	6
KR bluestem	6	6	6	6	6	6	6	6	6	6	6
Silver bluestem	6	6	6	6	6	5	6	6	6	6	6
Sideoats grama	6	6	6	6	6	5	6	6	6	6	6
Hairy grama	6	6	6	6	6	6	6	6	6	6	6
Buffalograss	6	6	6	6	6	6	6	6	6	6	6
Sandbur	6	6	6	6	6	6	6	6	6	6	6
Hooded windmill	6	6	6	6	6	6	6	6	6	6	6
Trichloris	6	6	6	6	6	5	6	6	6	6	6
Bermudagrass	6	6	6	6	6	6	6	6	6	6	6
AZ cottontop	6	6	6	6	6	5	6	6	6	6	6
Virginia wildrye	6	6	6	6	6	5	6	6	6	6	6
Club cutgrass	6	6	5	5	5	5	5	5	5	5	5
Kleingrass	6	6	6	6	6	5	6	6	6	6	6
Vine-mesquite	6	6	6	6	6	6	6	6	6	6	6
Switchgrass	6	6	6	6	6	5	6	6	6	6	6
Longtom	6	6	5	5	5	5	5	5	5	5	5
Thin paspalum	6	6	6	6	6	6	6	6	6	6	6
Little bluestem	6	6	6	6	6	5	6	6	6	6	6
Knotroot bristle	6	6	6	6	6	6	6	6	6	6	6
TX bristlegrass	6	6	6	6	6	6	6	6	6	6	6
Johnsongrass	6	6	6	6	6	6	6	6	6	6	6
Tall dropseed	6	6	6	6	6	6	6	6	6	6	6
TX wintergrass	6	6	6	6	6	6	6	6	6	6	6
Milo	6	6	6	6	6	6	6	6	6	6	6
Wheat	6	6	6	6	6	6	6	6	6	6	6
Corn	6	6	6	6	6	5	6	6	6	6	6
Littletooth sedge	6	6	6	6	6	6	6	6	6	6	6
Flatsedge	6	6	6	6	6	6	6	6	6	6	6
Fimbry	6	6	6	6	6	6	6	6	6	6	6
Cattail	6	6	5	5	5	5	5	5	5	5	5
Ragweed	6	6	6	6	6	6	6	6	6	6	6
Old-mans beard	6	6	6	6	5	5	6	5	6	6	6
Bundlefower	6	6	6	6	6	6	6	6	6	6	6
Frogfruit	6	6	6	6	6	6	6	6	6	6	6
Coneflower	6	6	6	6	6	6	6	6	6	6	6
Snoutbean	6	6	6	6	6	6	6	6	6	6	6
Ruellia	6	6	6	6	6	6	6	6	6	6	6
Bush sunflower	6	6	6	6	6	6	6	6	6	6	6
Texas verbena	6	6	6	6	6	6	6	6	6	6	6
Orange zexmenia	6	6	6	6	6	6	6	6	6	6	6
Giant ragweed	6	6	6	6	6	5	6	6	6	6	6
Broomweed	6	6	6	6	6	6	6	6	6	6	6
Partridge pea	6	6	6	6	6	6	6	6	6	6	6
Texas doveweed	6	6	6	6	6	6	6	6	6	6	6
Sunflower	6	6	6	6	5	5	6	5	6	6	6
Duckweed	6	6	5	5	5	5	5	5	5	5	5
TX bluebonnet	6	6	6	6	6	6	6	6	6	6	6
Dogweed	6	6	6	6	6	6	6	6	6	6	6

Appendix Table D.23 Accessability of plant parts, by species, for consumption by cattle in the Karnes and Wilson Counties models. Values are the percentage of standing crop biomass that could be accessed by cattle.

Species	CRoots	FRoots	Trunk	Stems	Leaves	Seeds	SDStems	SDLvs	SdlgR	SdlgS	SeedBank
Huisache	0	0	1	10	10	5	10	10	10	40	20
Pecan	0	0	1	1	1	0	1	1	5	75	50
Sugar hackberry	0	0	1	2	2	1	2	2	10	50	0
Texas persimmon	0	0	1	5	5	2	5	5	10	60	5
Mesquite	0	0	1	5	5	10	5	5	10	40	60
Post oak	0	0	1	1	1	0	1	1	10	70	50
Live oak	0	0	1	2	2	1	2	2	10	60	60
Guajillo	1	1	90	99	99	99	99	99	10	60	30
Blackbrush	1	1	90	95	90	90	95	80	10	50	10
Whitebrush	0	0	90	99	95	75	95	80	5	40	0
Baccharis	0	0	90	99	95	50	95	90	5	50	0
Granjeno	0	0	90	95	80	10	90	50	5	40	0
Agarito	0	0	95	99	95	90	99	90	5	30	1
Rattlepod	0	0	95	99	95	95	95	80	10	70	20
Mustang grape	0	0	90	10	5	1	5	3	5	60	5
Prickly pear	2	1	90	99	95	95	95	90	20	70	5
Big bluestem	1	1	40	90	90	95	90	90	10	50	0
Purple threeawn	1	1	20	90	85	90	90	80	5	30	0
KR bluestem	2	1	30	80	70	95	80	60	10	40	0
Silver bluestem	1	1	40	90	90	95	90	85	10	50	0
Sideoats grama	1	1	40	90	90	95	90	85	10	50	0
Hairy grama	1	1	10	90	80	90	90	75	5	20	0
Buffalograss	1	1	20	80	75	40	80	70	5	20	0
Sandbur	1	1	30	90	85	90	90	80	5	30	0
Hooded windmill	1	1	30	90	85	90	90	80	5	30	0
Trichloris	1	1	40	90	90	95	90	85	10	50	0
Bermudagrass	1	1	10	80	80	90	80	75	5	20	0
AZ cottontop	1	1	30	90	90	95	90	85	10	50	0
Virginia wildrye	1	1	40	90	90	95	90	85	10	50	0
Club cutgrass	2	2	20	75	70	90	75	65	10	20	0
Kleingrass	1	1	30	90	90	95	90	85	10	50	0
Vine-mesquite	2	1	10	80	75	80	75	70	5	20	0
Switchgrass	1	1	40	90	90	95	90	85	10	50	0
Longtom	3	2	10	80	75	90	80	70	10	30	0
Thin paspalum	1	1	20	90	90	95	90	85	10	30	0
Little bluestem	1	1	40	90	90	95	90	85	10	50	0
Knotroot bristle	1	1	10	80	75	90	80	70	5	20	0
TX bristlegrass	1	1	10	90	80	90	90	75	5	20	0
Johnsongrass	2	1	50	90	90	95	90	85	10	50	0
Tall dropseed	1	1	20	90	90	90	90	85	5	40	0
TX wintergrass	1	1	10	90	80	90	90	75	5	20	0
Milo	2	1	20	90	90	95	90	85	20	70	20
Wheat	1	1	10	90	85	90	90	80	10	50	5
Corn	2	1	30	90	90	95	90	85	30	80	70
Littletooth sedge	1	1	10	90	80	90	90	70	5	20	0
Flatsedge	1	1	20	90	90	95	90	85	10	40	0
Fimbry	1	1	20	90	90	95	90	85	10	40	0
Cattail	5	3	30	80	80	80	80	75	30	60	0
Ragweed	1	1	10	90	90	95	90	80	10	50	0
Old-mans beard	1	1	10	70	80	80	70	70	5	20	0
Bundleflower	1	1	10	70	60	70	70	50	5	10	0
Frogfruit	1	1	5	70	50	70	70	40	5	10	0
Coneflower	1	1	5	60	50	90	60	40	1	5	0
Snoutbean	1	1	10	75	60	80	75	50	5	10	1
Ruellia	1	1	1	60	40	60	60	30	1	5	0
Bush sunflower	1	1	20	85	80	90	85	70	5	20	0
Texas verbena	1	1	5	80	70	90	80	60	5	10	0
Orange zexmenia	1	1	20	85	80	90	85	70	5	20	0

Appendix Table D.23 (Cont.)

Species	CRoots	FRoots	Trunks	Stems	Leaves	Seeds	SDStem	SDLvs	SdlgR	SdlgS	SeedBank
Giant ragweed	1	1	20	90	90	80	90	80	10	50	0
Broomweed	1	1	5	80	80	85	80	70	10	40	0
Partridge pea	1	1	5	80	70	70	80	60	10	30	1
Texas doveweed	1	1	5	85	90	90	85	80	10	20	0
Sunflower	1	1	10	90	90	90	90	80	10	60	2
Duckweed	5	5	5	60	60	60	60	50	5	20	0
TX bluebonnet	1	1	2	60	40	70	60	60	5	20	1
Dogweed	1	1	1	80	60	90	80	50	1	10	0

SDStems = standing dead stems; SDLvs = standing dead leaves; SdlgR = seedling roots; SdlgS = seedling shoots.

APPENDIX E ANIMAL DATA

Appendix Table E.1 Estimation of cattle stocking rates (moderate level) for vegetation plot types in the Karnes and Wilson Counties EDYS models.

Range Type	Annual Forage (g/m^2)	Available Forage (g/m^2)	AU Forage Requirement (g/AUD)(365 d)	Stocking Rate (m^2/AU)	(ac/AU)
Blackland	266	133	5,840,000	43,910	10.85
Chalky ridge	137	68	5,840,000	85,883	21.22
Clay loam	326	163	5,840,000	35,828	8.85
Clayey bottomland	455	227	5,840,000	26,167	6.46
Deep sand	245	122	5,840,000	47,869	11.83
Deep sand savanna	242	121	5,840,000	48,264	11.93
Gravelly ridge	151	75	5,840,000	77,867	19.24
Gray sand loam	252	126	5,840,000	46,349	11.45
Hardland	305	152	5,840,000	38,421	9.49
Lakebed	294	147	5,840,000	39,728	9.82
Loamy bottomland	385	192	5,840,000	30,417	7.52
Loamy sand	277	138	5,840,000	42,319	10.46
Rolling blackland	249	124	5,840,000	47,098	11.64
Sandstone hills	168	84	5,840,000	69,524	17.18
Sandy	280	140	5,840,000	41,714	10.31
Sandy loam	308	154	5,840,000	37,922	9.37
Shallow	147	73	5,840,000	80,000	19.77
Shallow ridge	207	103	5,840,000	56,699	14.01
Sloping clay loam	175	87	5,840,000	67,011	16.56
Tight sandy loam	245	122	5,840,000	47,869	11.83
Very gravelly ridge	217	108	5,840,000	54,074	13.36
Improved pasture	505	252	5,840,000	23,175	5.73
Mean					12.22

Annual forage: (Appendix Table C.2)(0.7), where 0.7 is the adjustment for less than excellent range condition.
Available forage: (Annual forage)(0.5), where 0.5 is proper management harvest rate.
AU Forage Requirement = 16,000 g/AUD (Table 8.1)
Stocking rate: (AU Forage Requirement)/(Available Forage)