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REPORT

"EFFECTS OF BRUSH MANAGEMENT ON WATER YIELD FROM RANGELANDS ON THE EDWARDS PLATEAU"

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EXECUTIVE SUMMARY

The volume of water pumped from the Edwards Aquifer has increased substantially in the past 50 years and maintaining an adequate volume of water in the Aquifer is an important Texas issue. The increased density and aerial coverage of ashe juniper on watersheds upstream of the aquifer recharge zone appear to have reduced recharge. Recent field research in Edwards and Uvalde counties indicates that brush control can increase water yields from these areas. This increased water yield could increase aquifer recharge. This report presents results from a TWDB-funded study by scientists at the Blackland Research Center who used a surface hydrology model, SWAT, to quantify water yield increases associated with replacing ashe juniper with grass on all land with a slope <10% in the Frio, Sabinal, Seco, Hondo, and Medina watersheds. The three tasks of this project were as follows:

- Calibrate and validate SWAT against measurements of evapotranspiration (ET) from a field-scale experiment in Seco Creek where all ashe juniper was removed from a watershed.
- Calibrate and validate simulated stream flow against measured stream flow above the recharge zone in Medina, Hondo, Seco, Sabinal, and Frio watersheds.
- Quantify water yield increases predicted by the model associated with replacing all brush on slopes < 10% with grass.

Results from this study showed the following:

- Simulated daily ET was similar to field-scale measured ET during the calibration and validation periods. The root mean square error between measured and simulated daily ET was 0.9 mm d^{-1}.
- Average annual measured and simulated stream flows were essentially equal in the Hondo and Seco Creek watersheds, and were within about 40% of each other in the other three watersheds.
- The amount of increased stream flow simulated when all brush was replaced with grasses on slopes < 10% was different in the three watersheds. In the Medina and Frio watersheds, where 85 to 100% of the land was treated, average annual stream flow approximately doubled in each year of the simulation. In the Seco Creek watershed, where only 15% of the land area was treated, there was consistent, but much smaller increase (ca. 20%) in average annual stream flow.

The increased water yield, per unit area of land for which brush was removed, simulated in this study (ca. 2000 m^3 ha^{-1} yr^{-1}) was greater than that measured on small plot areas by others and simulated for the North Concho River. Increases were greater in this study because we

assumed all brush was removed permanently, a moderate cover of herbaceous vegetation replaced this brush, and removal of brush on **all land** in a watershed with slopes < 10%.

These results have shown implementation of a brush removal program could increase water yields from watersheds above the Edwards Aquifer recharge zone. However, other important factors (e.g. sedimentation and wildlife) must be considered when implementing such a program, and **brush removal must be maintained by repeated treatment (e.g. fire) for these increased water yields to be sustained**.

INTRODUCTION

From the 1930's to the 1990's, water pumped from the Edwards Aquifer has increased by nearly 380% to about 0.6×10^{12} liters yr^{-1} (Brown et al. 1992). This change reflects increasing demands from a growing population and expansion of water uses. In recent years, the total volume of water leaving the aquifer annually by pumping and natural spring flow ($\approx 10^{12}$ liters) has occasionally exceeded annual recharge, which averages about 0.8×10^{12} liters, but varies from about 0.05×10^{12} to 3×10^{12} liters, depending upon precipitation (Brown et al. 1992). This 'mining' of the Edwards Aquifer potentially jeopardizes the livelihood of the region and the existence of five federally-protected species in the San Marcos and Comal Springs. Maintaining an adequate volume of water in the Aquifer is an important Texas issue. This was especially highlighted by the droughts of 1996 and 1998.

Early settlers on the Edwards Plateau found land that had a good cover of native grasses and forbs, fertile soil, wooded bottom lands, and abundant, spring-fed streams (Weniger 1984). *Juniperus ashei* (Buchh.), often termed mountain cedar or ashe juniper, and other woody brush and tree species occurred mainly on steep slopes and canyons (Taylor and Smeins 1994). However, reduced number and intensity of wildfires and heavy continuous grazing have contributed to an increase in density and aerial coverage of ashe juniper and decreased herbaceous plant growth (Taylor and Smeins 1994). This increased density and aerial coverage of ashe juniper appear to have reduced aquifer recharge due to reductions in runoff and percolation (Owens and Knight 1992; Thurow and Taylor 1995) and reduced spring and seep flow (Kelton 1975).

In 1982, there were 1.2, 0.9 and 0.4 million ha with light (1-10%), moderate (11-30%), and heavy (31-100%) crown canopy cover of ashe juniper, respectively, on the Edwards Plateau (Soil Conservation Service 1985). Natural Resource Conservation Service personnel estimate that in 1995, 0.6 million ha in the 13 county region that is in the catchment area of the Edwards Aquifer had a slope of < 10% and had a canopy cover of ashe juniper of > 20%. This area has potential for increasing water yields by replacing brush with grasses.

Recent field research in Edwards and Uvalde counties indicates that brush control and grazing management can increase water yields (Table 1). The amount of increased water yields depends upon site and environmental conditions. Field research (Table 1) was conducted on small areas, ranging from 1 to 15 ha, and involved a number of soil types, rainfall regimes, and research methods. The applicability of these results to other portions of the Edwards Plateau is unknown, and it would be too expensive to replicate field experimental studies on all the possible variations of climate, soil, slope, and land use. However, computer simulation models, which mathematically simulate important biotic and abiotic processes that operate over varying times scales, can be used to quantify increased water yields associated with replacing brush with grasses. These simulations can be made over many years for different soils, topography, etc. Because the models can simulate hydrologic processes over many years, they can incorporate climatic variations that can have a large impact on results from experiments that often are conducted only for a few years.

In July 1995, the TWDB funded TAES scientists at the Blackland Research Center to conduct research using a hydrology model to quantify increases in water yields from rangelands on the Edwards Plateau upon which brush was replaced with grasses. This report presents results from that study.

METHODS

Model Description, Inputs, and Algorithms

We used a surface hydrology model, SWAT (Arnold et al. 1993, 1994, 1998), to evaluate water yield increases associated with replacing ashe juniper with grass in five watersheds (Frio, Sabinal, Seco, Hondo, and Medina) (Fig. 1). We restricted our analyses to the portions of these watersheds that were above the Edwards Aquifer recharge zone.

SWAT is a distributed-parameter, continuous-time model that was developed to assist managers in assessing water supplies and non-point source pollution. It simulates the surface and near-surface hydrology from watersheds that vary from a few hectares to several thousand square kilometers. Watersheds are divided into sub basins (see, for example, Fig. 2 for sub basins in the Frio watershed). Inputs (e.g., soils, slope, land use/land cover, etc.) are defined for each sub basin and water is routed within and between sub basins. In this study, the number of sub basins in a watershed varied from about 10 to 25.

SWAT has been validated against measured stream flow for the Lower Colorado River watershed (Arnold and Srinivasan 1998), three Illinois watersheds (Arnold and Allen 1996), the Trinity River (Srinivasan et al. 1998), North Concho River (Upper Colorado River Authority 1998), and the upper portions of the Seco Creek watershed (Srinivasan and Arnold 1994). In most cases, simulated monthly stream flow was within 20% of measured.

Because of its importance to the water balance of these areas, precipitation interception by the vegetative canopy was included in SWAT in this study. Interception by ashe juniper was calculated as 100% of precipitation for precipitation amounts less than 9 mm d^{-1}, 90% for amounts between 9 and 16 mm d^{-1}, and 80% between 16 and 20 mm d^{-1} (Marsh and Marsh 1992). Rainfall above 20 mm d^{-1} had 20 mm intercepted. Grass interception was 100% for amounts below 0.4 mm d^{-1}, 90% for amounts between 0.4 and 0.8 mm d^{-1}, and 80% for amounts from 0.8 to 1.7 mm d^{-1} (Personal Communication, Tom Thurow 1997). Intercepted precipitation was evaporated at 65% of the potential evaporation rate.

Project Tasks and Methods

The three tasks of this project were as follows:

Task 1: Calibrate and validate SWAT against measurements of evapotranspiration (ET) from a field-scale experiment in Seco Creek (Dugas et al. 1998) where all ashe juniper was removed from a watershed.

Dugas et al. (1998) measured ET, precipitation, and runoff on two, adjacent 15 ha watersheds [termed treated (i.e., brush removed in the third year of a five year study) and untreated]. There were no differences in ET from the two watersheds during the pre-treatment period. A significant ET reduction was measured, however, from the watershed from which ashe juniper was removed.

For the current study, the model was changed by adding a litter layer under ashe juniper using the STATSCO default parameter values for a peat layer. Other model inputs were as follows:

1. Land use data were taken from field measurements (Dugas et al. 1998).
2. Baseflow was estimated from stream flow measurements at the Seco Creek gauge (Table 2).
3. Climate data (daily maximum and minimum temperatures, global radiation, and precipitation) were measured at the study site (Dugas et al. 1998). Daily global radiation was generated (Richardson 1982) for missing data.
4. Curve numbers (77 for brush and 80 for herbaceous) were estimated by P. Wright (Personal Communication 1998).

Muttiah et al. (1996) provides additional details on model inputs and methods.

The SWAT model was run using the above input data and daily measured and simulated ET were compared during the calibration and validation periods. SWAT ET was calibrated and validated in the following manner. For conditions with brush, ET was calibrated using measured data from both the treated and untreated watersheds for 1991 to 1992. For the conditions without brush, ET was calibrated using data from the treated watershed in 1994. The model was calibrated by adjusting soil parameters (available water capacity, depth, bulk density, and saturated hydraulic conductivity), maximum plant biomass, leaf area index, rooting depth, crack flow, and groundwater baseflow periods. Removal of ashe juniper, which was a large portion of the leaf area on the watershed (Hicks and Dugas 1998), was simulated by decreasing leaf area and increasing surface residue. ET was validated for both watersheds (i.e., with and without brush) with data from 1993 and 1995. In addition, we compared differences in simulated water yield (i.e., surface runoff + lateral subsurface flow in the soil layers + shallow groundwater baseflow) for existing conditions and without brush.

Task 2: Calibrate and validate the model against measured stream flow above the recharge zone in Medina, Hondo, Seco, Sabinal, and Frio watersheds.

These five watersheds (Fig. 1) were selected for this analyses because they contribute more than 65% of the recharge to the aquifer (Brown et al. 1992) and of the predominance of brush within them (Soil Conservation Service 1985).

For this task, model inputs were as follows:

1. Geographically-referenced data bases (e.g., soils, land use/land cover, elevation) were obtained from data we had for each watershed at a scale of 1:250,000 (Srinivasan et al. 1993), except for the Seco Creek watershed where inputs were available at a 1:24,000 scale (Unpublished Data, C. Baird 1998). Soils data were taken from the STATSCO data base (USDA-SCS 1992). Land use data were taken from a United States Geologic Survey (USGS) LUDA land use data base developed during the 1980s. Topographic data, used to define sub basin boundaries, were available at a 1:100,000 scale from a digital elevation data set. We used an existing GIS interface (Srinivasan and Arnold 1994) to extract the data from the data bases and to format SWAT inputs.
2. Baseflow period (the lag of ground water contribution to stream flow) was areally estimated from the Bureau of Economic Geology land resource units.
3. Curve numbers were the same as used in Task 1.
4. Weather data (maximum and minimum daily air temperatures and precipitation) were taken from the nearest National Weather Service station (Table 2). Daily global radiation was generated (Richardson 1982).
5. Stream height and width and streambed hydraulic conductivity were estimated by local experts (Personal Communication, Phil Wright and David Brown 1998).

The SWAT model was run for the lesser period of record for USGS measured stream flows or NWS weather data (Table 2). Thus, for example, SWAT runs were made for the Sabinal River from 1979 to 1989 because the NWS data were only available for this period even though USGS were available for longer.

SWAT input parameters such as interception rates, soil properties, and leaf area indices were set to values obtained from calibration (Task 1). The validation period for annual stream flows was the entire simulation period. Annual flows were obtained from monthly flows. Annual stream flow averages were calculated.

Task 3: Quantify water yield increases predicted by the model associated with replacing all brush on slopes < 10% with grass.

For the Medina, Frio, and Seco watersheds, we ran the model using the same inputs as for Task 2, except all land use/land cover classified as brush was changed to grass on areas with slopes < 10%. Model inputs associated with this vegetation change (e.g., leaf area) were changed based upon the 'without brush' calibration results from Task 1. An additional 4 years of simulation was added to the Medina watershed because we had NWS data and did not need USGS to simulate the effects of brush removal.

These three watersheds were selected because they represent large and small watersheds (Fig. 2 and Table 2), because they are on the east, center and western edge of the study area, and because there were marked differences in brush cover and slope, and, thus, amount of land upon which brush was simulated to be replaced with grasses. In the Medina watershed, 100% of the area within the watersheds had brush removed. Comparable figures for the Seco and Frio were 15 and 88%, respectively. In these watersheds, we compared annual average simulated stream flows with and without brush.

RESULTS

Task 1: Calibrate and validate SWAT against measurements of evapotranspiration (ET) from a field-scale experiment in Seco Creek (Dugas et al. 1998) where all ashe juniper was removed from a watershed.

Simulated daily ET was similar to measured ET during 1991 and 1992 (Fig. 3). There is slight under prediction by SWAT in drying conditions. During the validation period, the results for the untreated watershed were similar to those for the calibration period (results not shown) and there was a root mean square error for daily ET of 0.9 mm d^{-1} (Table 3). There was a small positive bias between simulated and measured daily ET for the combined treated and untreated watersheds during the calibration period (Fig. 4), and for the treated watershed during the calibration (Fig. 5) and validation (Fig. 6) periods. The slightly higher root mean square error in the treated watershed for the validation period (Table 3) is likely due to changing surface conditions (e.g. the fallen ashe juniper branches with leaf material attached to them in 1993 would have reduced measured ET, and the re-growth of young ashe juniper and other shrubs in 1995 (the third year after treatment) would have increased measured ET because of increased intercepted precipitation and leaf area). Overall, SWAT daily ET estimates were within 20% of measured ET.

Cumulative water yield from the treated and untreated watersheds simulated by SWAT in 1994 showed an increase of 90 mm yr^{-1} from the treated watershed (i.e., the one without brush) (Fig. 7). When expressed as the rate of water 'saved' per unit area of treated land, this is equivalent to 900 $\mathrm{m}^3\ \mathrm{ha}^{-1}\ \mathrm{yr}^{-1}$. This ET difference is similar to the 95 mm yr^{-1} ET difference shown by Thurow and Taylor (1995) and the 110 mm yr^{-1} difference (for the first two years after brush removal) shown by Dugas et al. (1998).

Task 2: Calibrate and validate the model against measured stream flow above the recharge zone in Medina, Hondo, Seco, Sabinal, and Frio watersheds.

Average annual measured and simulated stream flows were essentially equal in the Hondo and Seco Creek watersheds, and were within about 40% of each other in the other three watersheds (Table 4). Differences between averages increased with increasing stream flow, and measured and simulated stream flow increased with watershed area (Tables 2 and 4). The Upper Colorado River Authority (1998) also showed, prior to a model calibration procedure that involved reducing curve numbers, that stream flow simulated using SWAT in the North Concho River was greater than measured stream flow.

The root mean square errors (RMSEs) between average annual measured and simulated annual stream flow were relatively large, but were always less than or equal to average measured stream flow (Table 4). For the Medina watershed (Fig. 8), where the simulated stream flow tended to be only slightly greater than measured stream flow, the relatively large RMSE was primarily due to one year with a large difference and the small number of years in the comparison. In the Hondo and Seco Creek watersheds (Figs. 9 and 10), flows were much lower (Table 4) and there was little bias between the average annual flows, but there was a relatively large amount of scatter. This large scatter was likely due to either unrepresentative precipitation inputs or the lack of precision of land use/land cover and soil inputs relative to the heterogeneity of these values within this small watershed area (Table 2). In the Sabinal and Frio watersheds (Figs. 11 and 12), simulated flows tended to be greater than measured, although again the Sabinal results were quite good, except for one year that had a large difference between measured and simulated stream flow.

Task 3: Quantify water yield increases predicted by the model associated with replacing all brush on slopes < 10% with grass.

The amount of increased stream flow simulated when all brush was replaced with grasses reduction in leaf area) must be maintained for these increases to be sustained. Previous research has shown that, without this maintenance, water savings decrease rapidly over time as brush and other plants respond to the initial removal.

The study area of this research, i.e. the land upstream of the Edwards Aquifer recharge zone, has several unique characteristics (e.g. a soil dominated by a fractured limestone surface and relatively gentle slopes) that make it an ideal place to potentially increase water yields with brush removal. The water that is not evaporated by the brush has a high potential of either moving off the site as runoff or infiltrating beyond the root zone and thus potentially recharging the Aquifer as it passes over the recharge zone that is a short distance downstream. Other sites in Texas likely do not have these characteristics and thus these potential water yield increases may not be realized. Water yields may be considerably reduced if a lower percentage of brush is removed due to compensatory increased ET by brush that is not removed.

These results are based upon a computer simulation model and must be tempered by several factors, including errors in model inputs and processes. Additional controlled field experiments with replicated or paired watersheds that are reasonably large (> 100 ha) should be conducted to confirm the results of this study.

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Table 1. Water savings (per unit area of treated land) from land use changes, primarily removal of ashe juniper, at selected locations around and on the Edwards Plateau. Water savings at locations with a single asterisk are based on model simulations.

Location	**Reference**	**Land Use Change**	**Water Savings (m^3 ha^{-1} yr^{-1})**
Sonora	Thurow and Taylor (1995)	60% Juniper/40% grass to 100% grass	940
Annandale	Owens and Knight (1992)	Removal all Juniper	1250**
Seco Ck.	Dugas et al. (1998)	Removal all Juniper (1st year after treatment)	980
Seco Ck.	Wright (1996)	Remove 70% of Juniper (1st 14 months after treatment. Adjusted for reduced precipitation)	1125
N. Concho*	Upper Colo. R. Auth. (1998)	Remove all Brush (Mesquite and Juniper)	280
Medina*	This Study	Remove all Juniper	2400
Seco*	This Study	Remove all Juniper	1800
Frio*	This Study	Remove all Juniper	2600

**Calculated from ratio of average runoff to precipitation and from measured increase in runoff.

Table 2. United State Geologic Survey (USGS) and National Weather Service (NWS) stations used in analyses.

Water-shed	USGS Station Name	USGS Stn. #	USGS Period of Record	Drainage Area (km^2)	Elevation (m)	Nat. Weather Service Stn. Name and Period of Record
Medina	Medina R. @ Bandera	178880	1983-1989	1106	363	Medina (1966-1989)
Hondo	Hondo Ck. nr. Tarpley	200000	1961-1989	233	356	Tarpley (1961-1995)
Seco	Seco Ck. nr. Miller Ranch	201500	1961-1989	131	386	Tarpley (1961-1995)
Sabinal	Sabinal R. @ Sabinal	198500	1961-1989	549	269	Vanderpool (1979-1989)
Frio	Frio R. @ Concan	195000	1961-1989	991	367	Leakey (1961-1995)

Table 3. Mean measured and simulated daily evapotranspiration (ET in mm d^{-1}) and root mean square error between measured and simulated ET (RMSE in mm d^{-1}) in treated and untreated watersheds during calibration and validation periods at Seco Creek study site.

	Treated			**Untreated**		
Period	**Measured**	**Simulated**	**RMSE**	**Measured**	**Simulated**	**RMSE**
Calibration	1.5	1.8	0.6	1.9	1.9	0.8
Validation	1.7	1.9	1.0	1.8	1.9	0.9

Table 4. Average measured and simulated annual stream flow at stations above recharge zone in selected watersheds. The period of record for measurements is shown for each watershed. In the simulated column, values without parentheses represent SWAT simulated flows for all watersheds in their "as is" condition and should be compared with measured flows. Values in parentheses in simulated column are SWAT-predicted stream flows with brush removal on land with slope less than 10% for Medina, Seco, and Frio (see text). RMSE = root mean square error between annual average measured and simulated stream flows in the "as is" condition.

Watershed	**Measured ($m^3 s^{-1}$)**	**Simulated ($m^3 s^{-1}$)**	**RMSE ($m^3 s^{-1}$)**
Medina (1983-1989)	3.6	5.1 (14.2)	2.8
Hondo (1961-1989)	1.0	1.0	1.0
Seco (1961-1989)	0.54	0.53 (0.66)	0.5
Sabinal (1979-1989)	2.1	2.7	2.1
Frio (1961-1989)	3.3	4.6 (11.4)	2.8

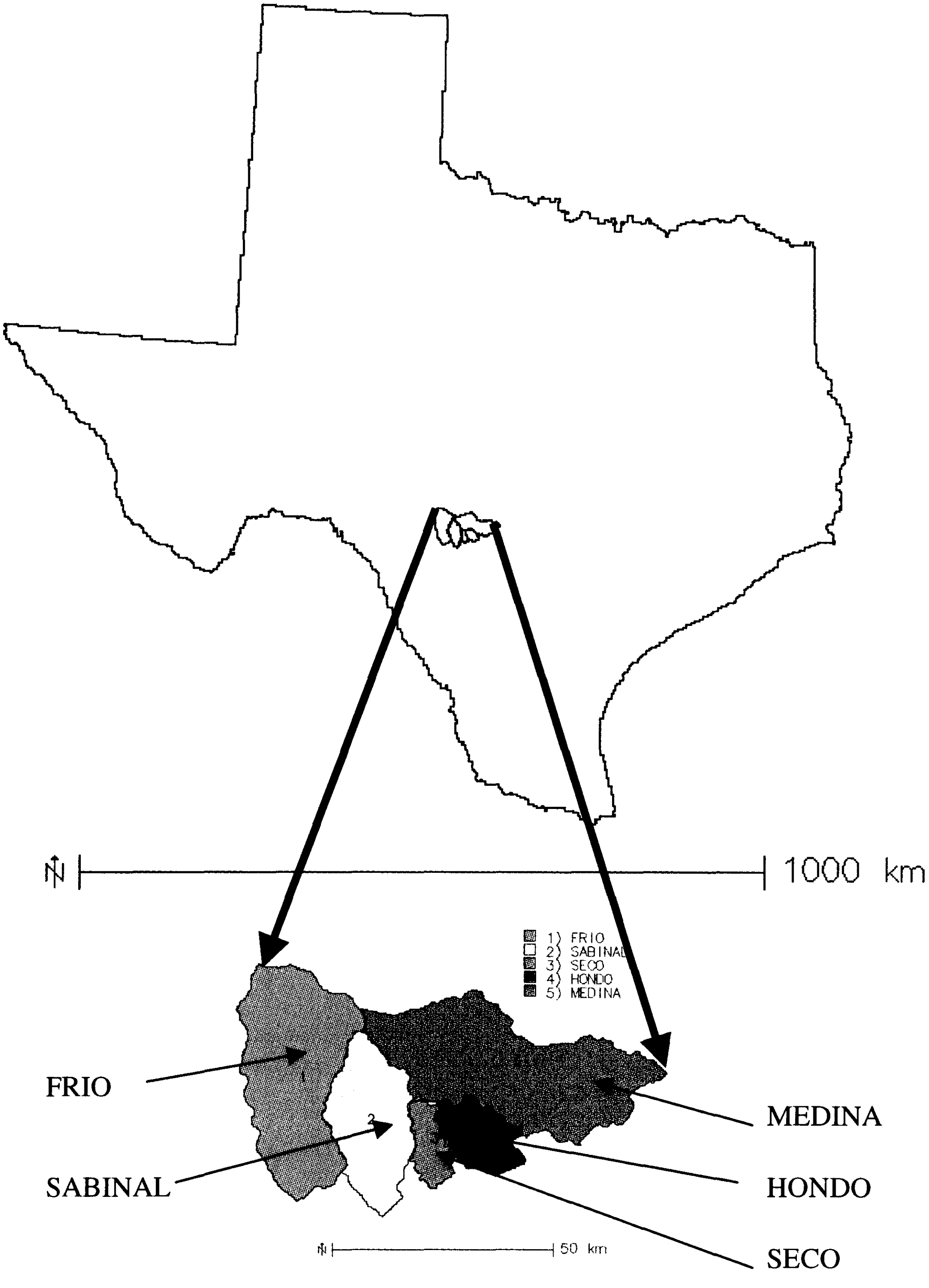

Figure 1. Watersheds for which simulations were made. Watersheds are from east to west, Medina, Hondo, Seco, Sabinal, and Frio.

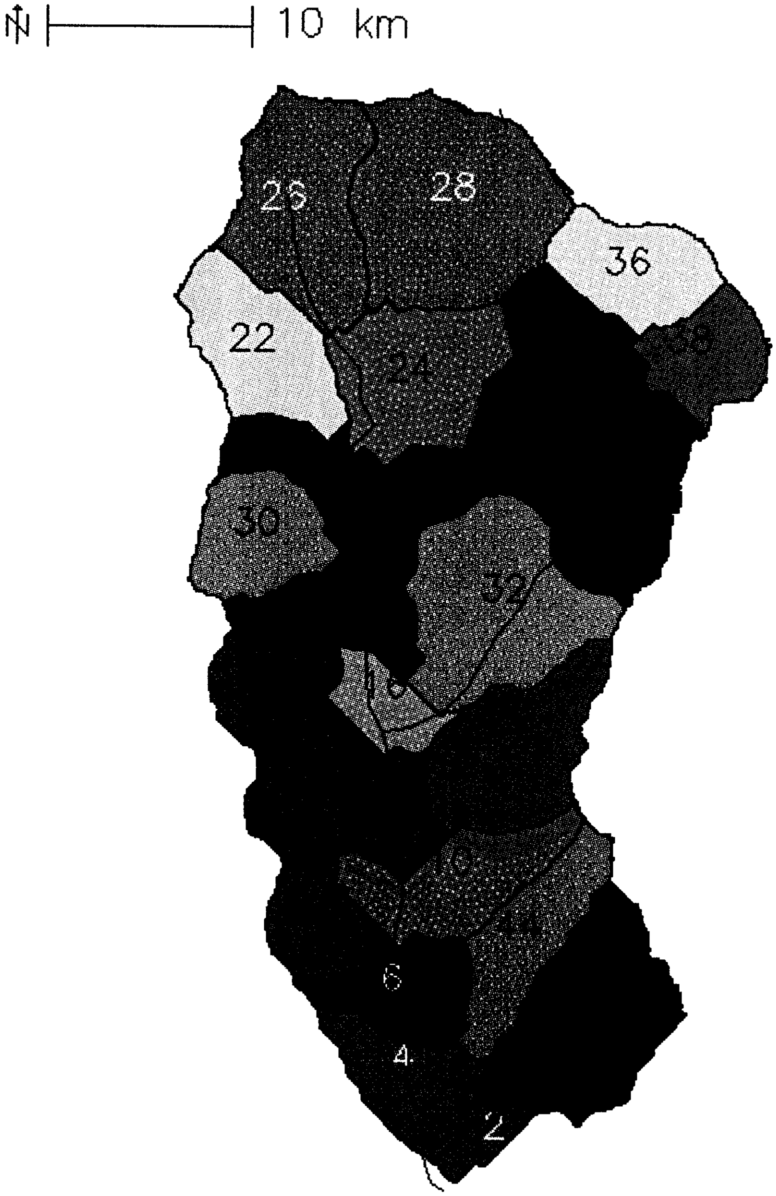

Figure 2. The SWAT sub-basins for Frio watershed.

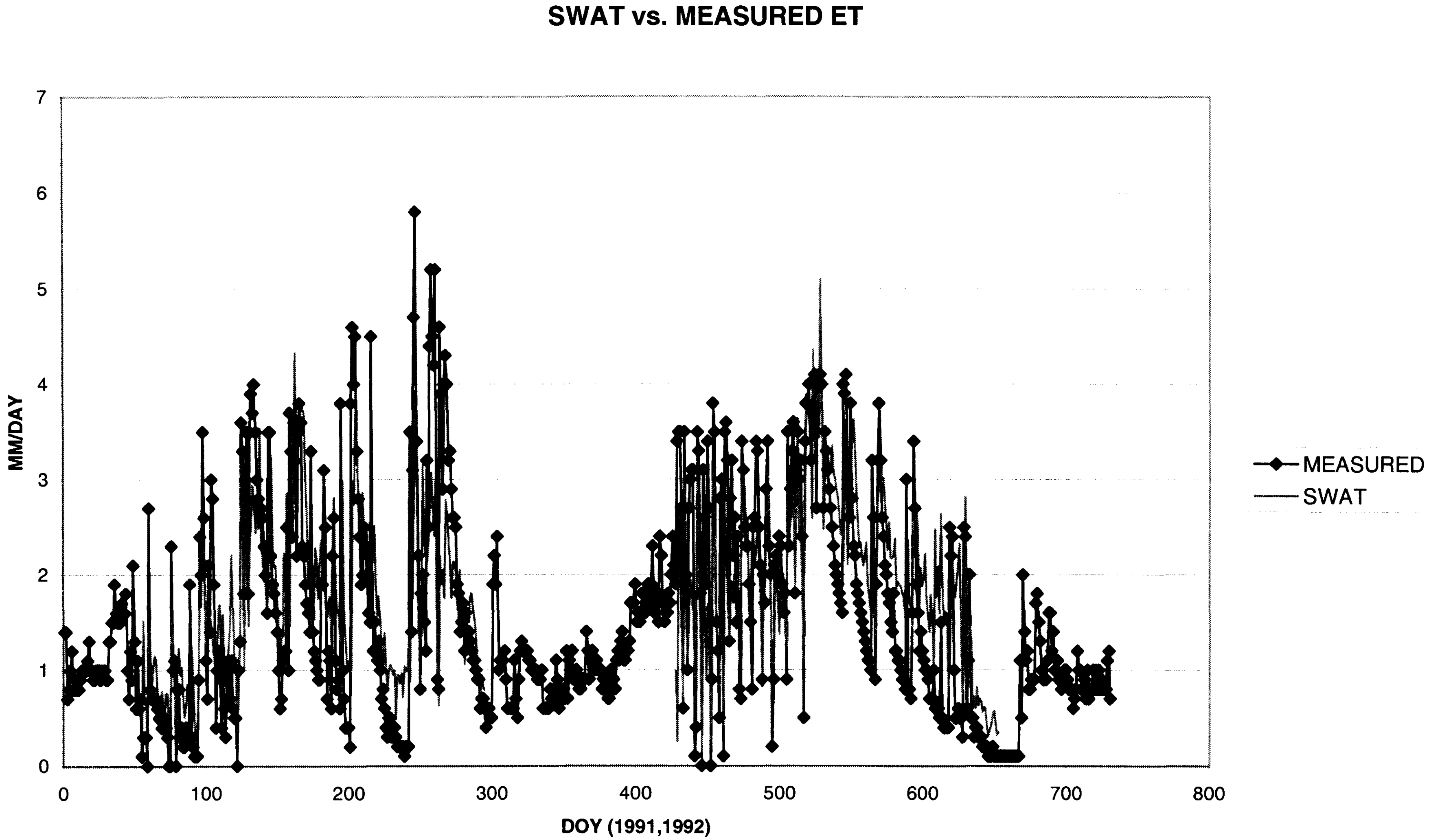

Figure 3. Daily evapotranspiration (ET) simulated by SWAT and measured at Seco Creek study site in 1991-1992. DOY = Day of year, starting January 1, 1991.

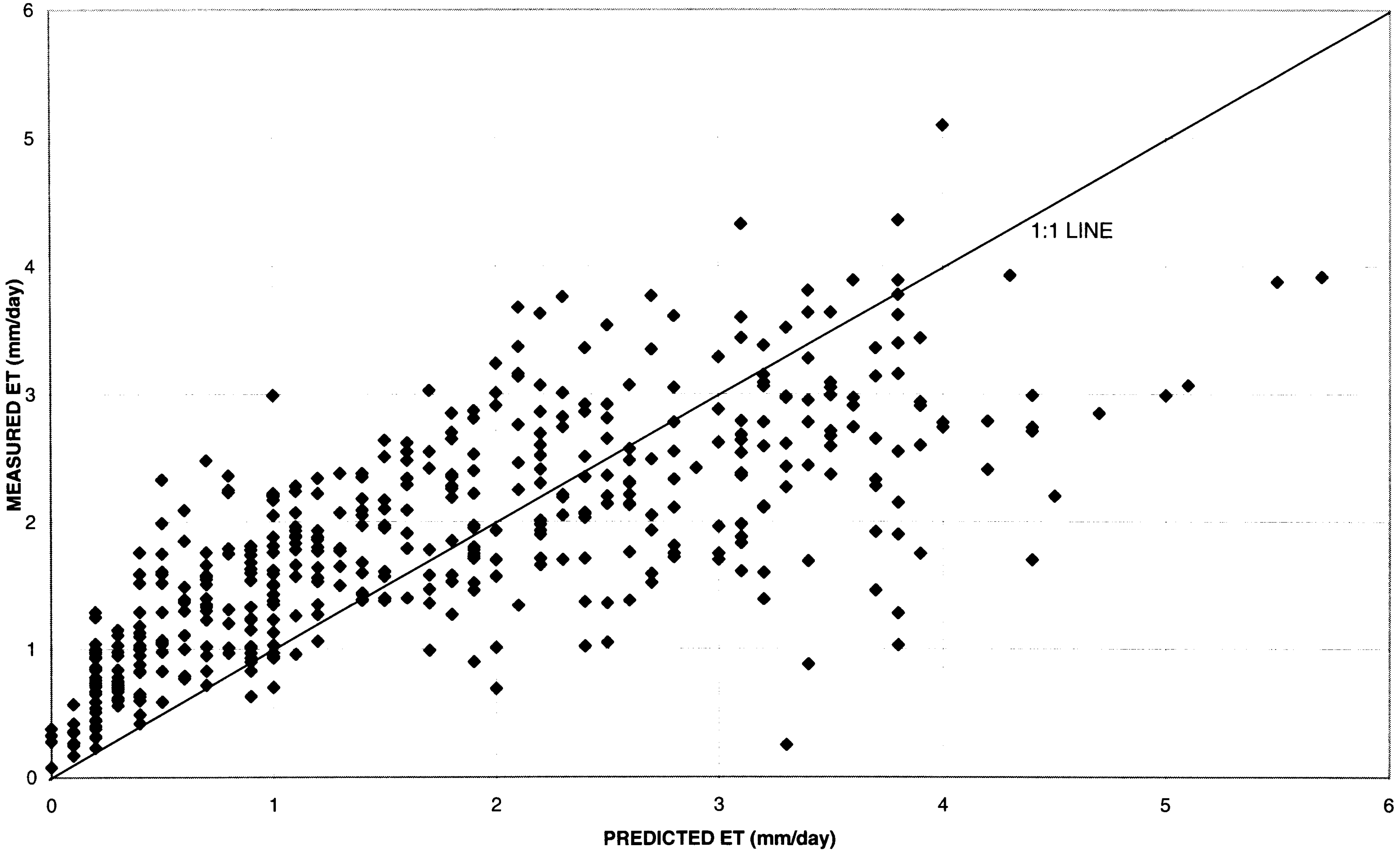

Figure 4. Measured versus simulated (predicted) daily ET from treated and untreated watersheds during calibration period 1991-1992.

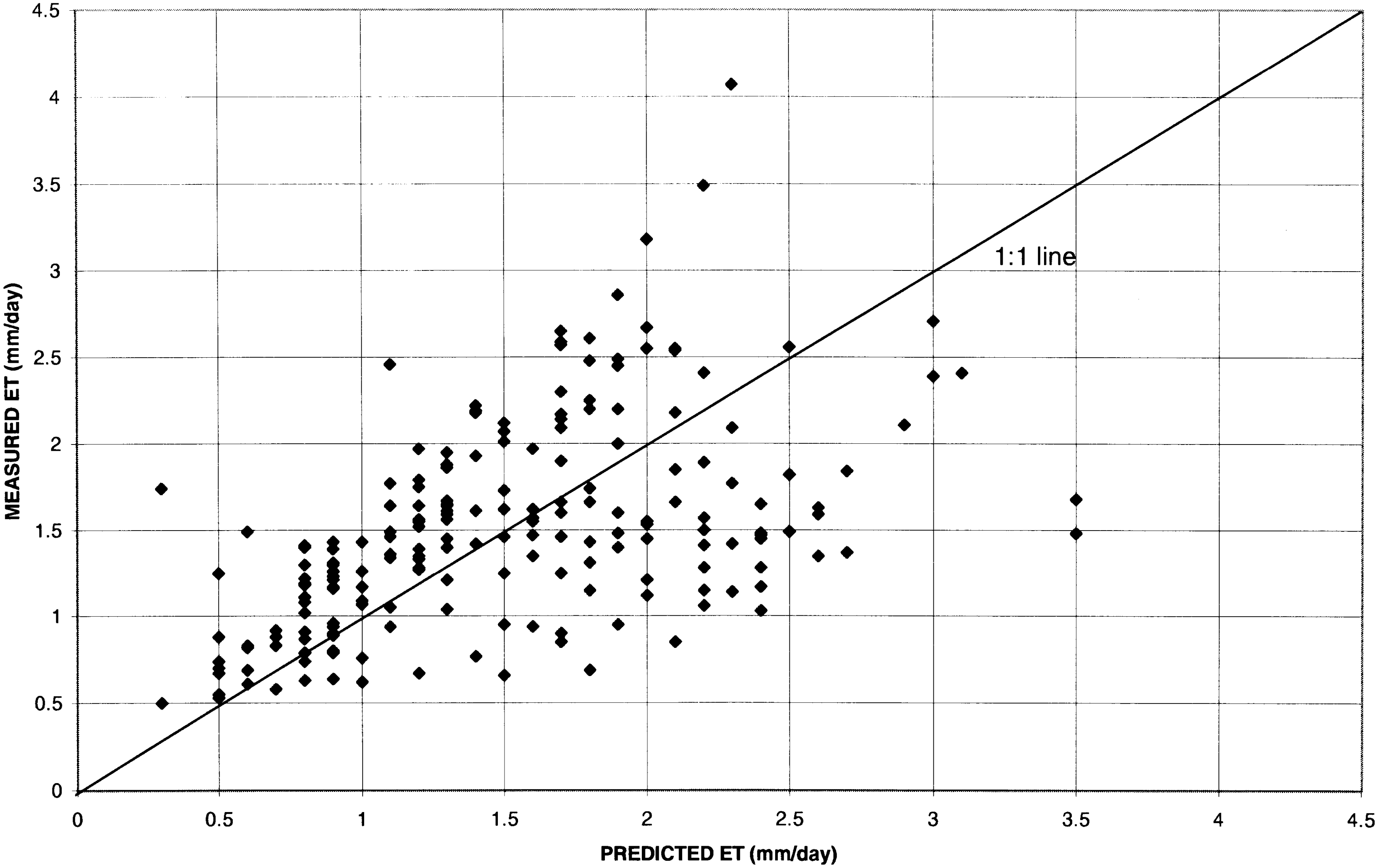

Figure 5. Measured versus simulated (predicted) daily ET from treated watershed during calibration period (1991-1992).

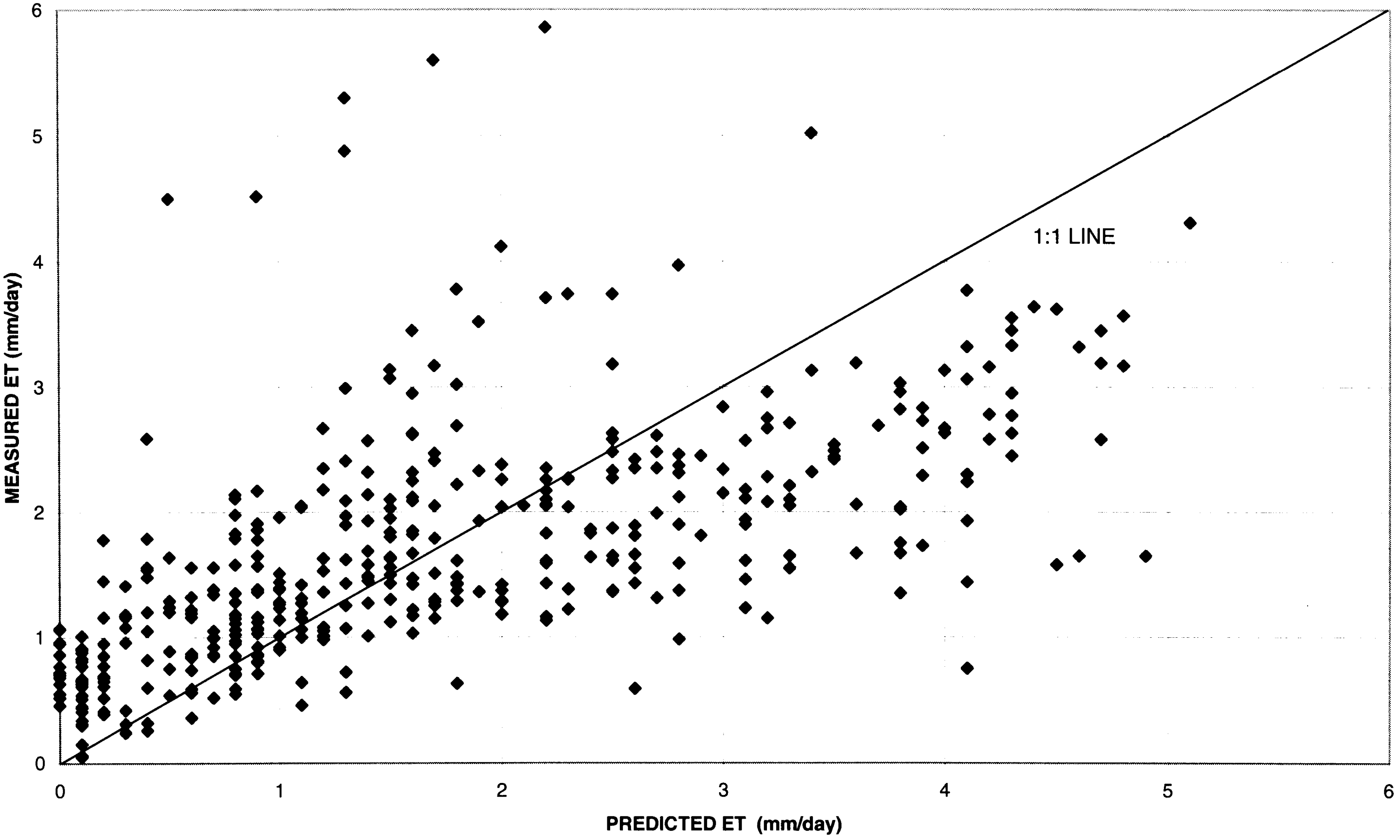

Figure 6. Measured versus simulated (predicted) daily ET for treated watershed during validation period (1994).

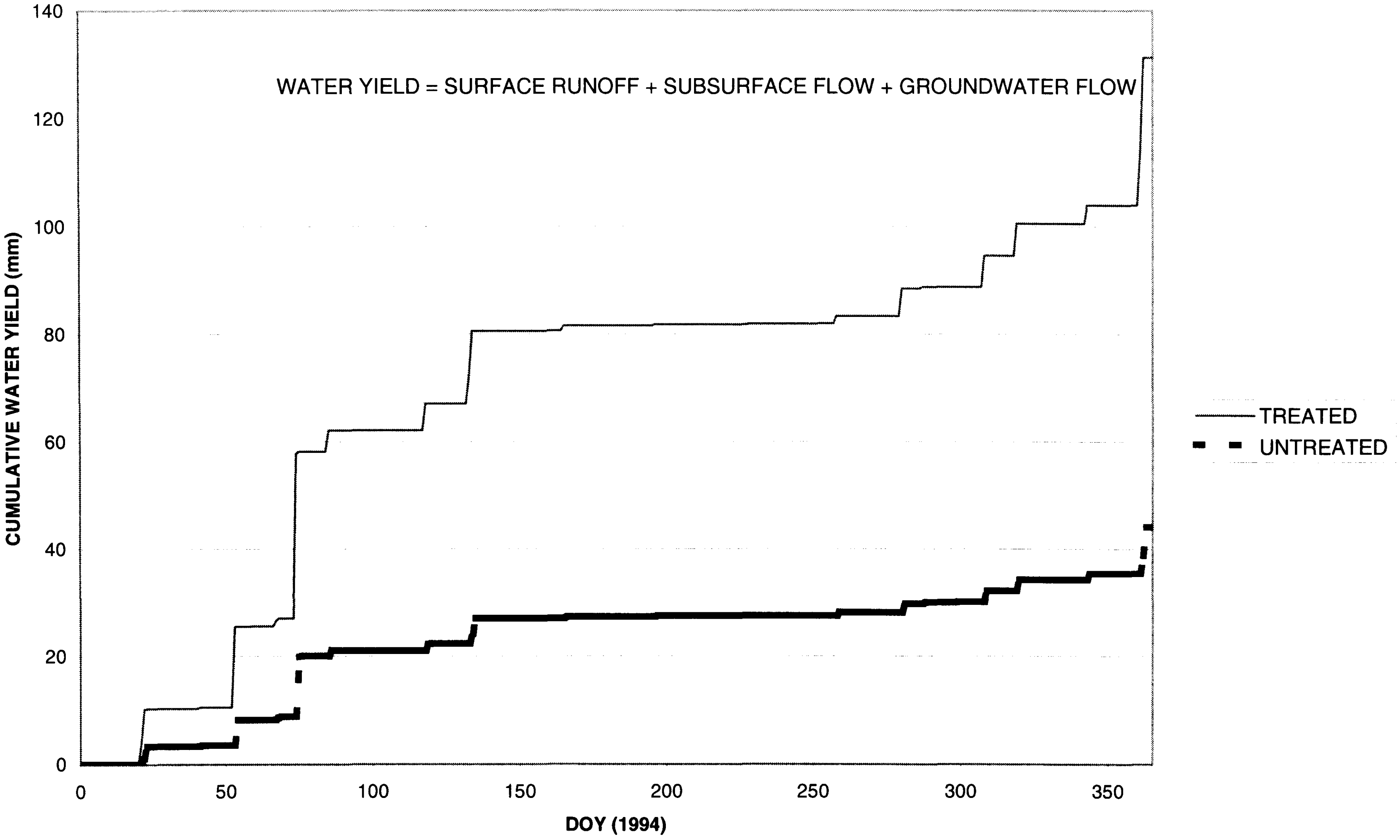

Figure 7. Simulated cumulative water yield for treated (removal of all ashe juniper on 15 ha.) and untreated (15 ha) watersheds at the Seco Creek study site in 1994. DOY = day of year.

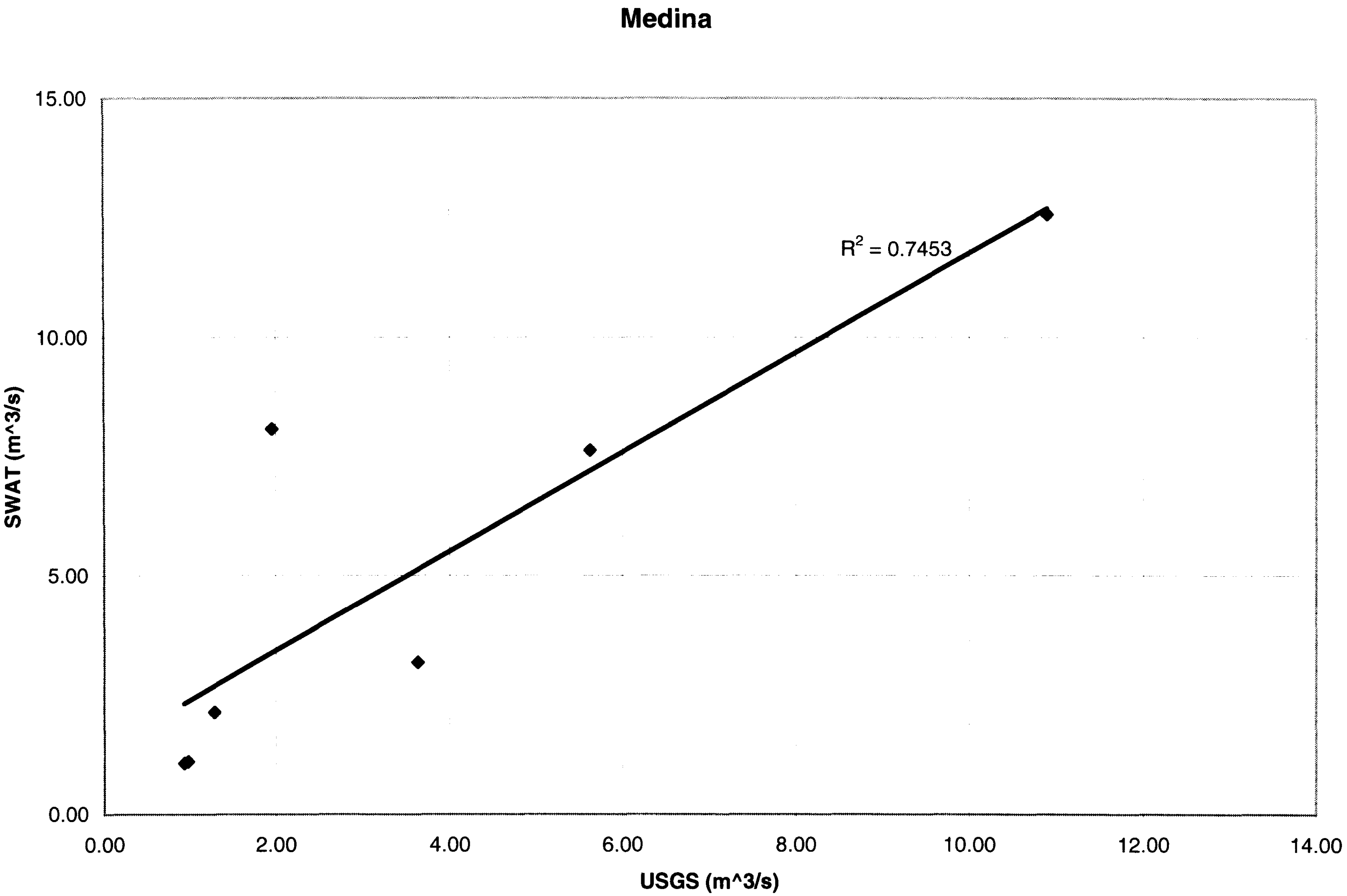

Figure 8. Simulated (SWAT) and measured (USGS) annual average stream flow for Medina river.

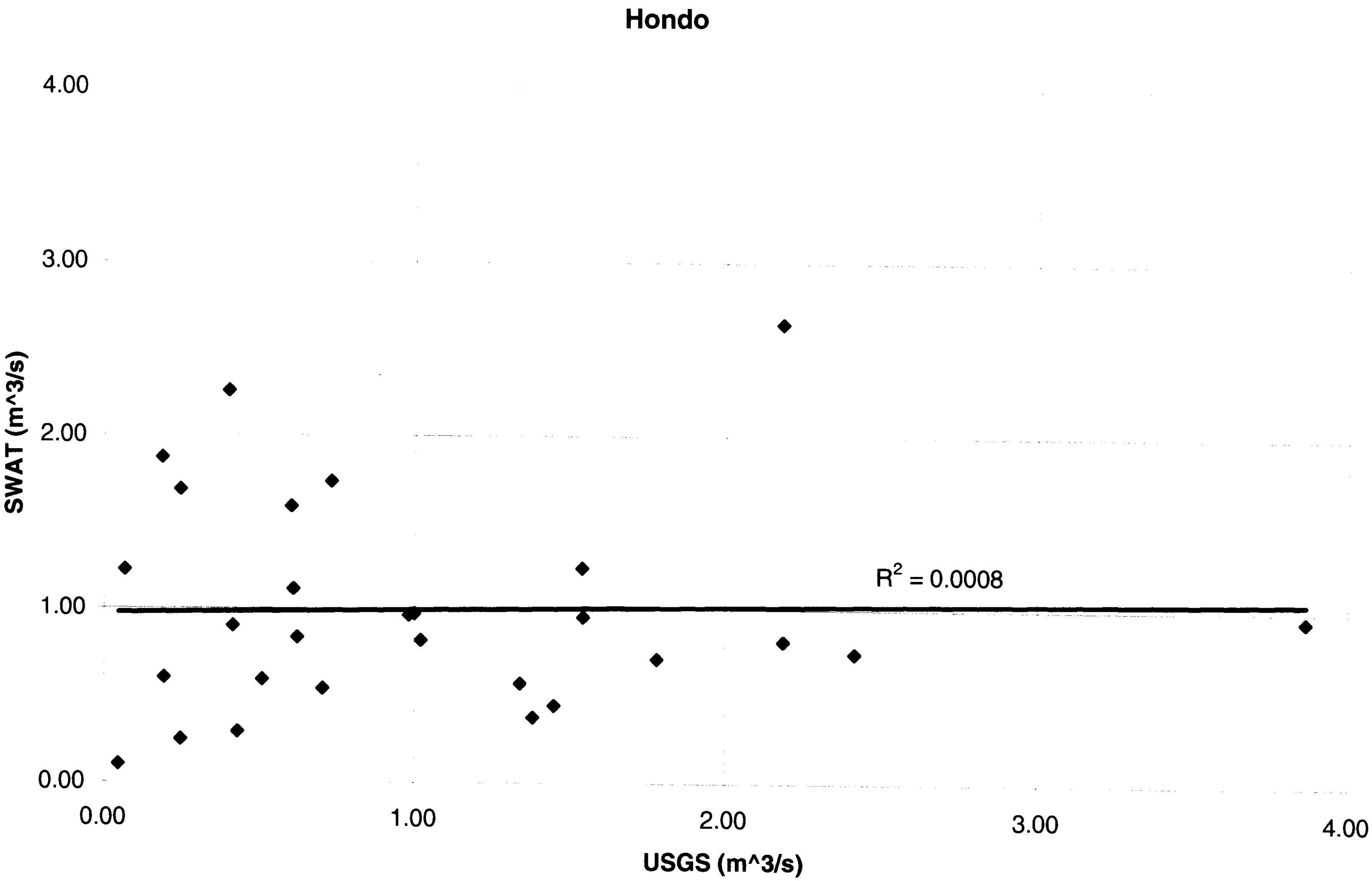

Figure 9. Simulated (SWAT) and measured (USGS) annual average stream flow for Hondo river.

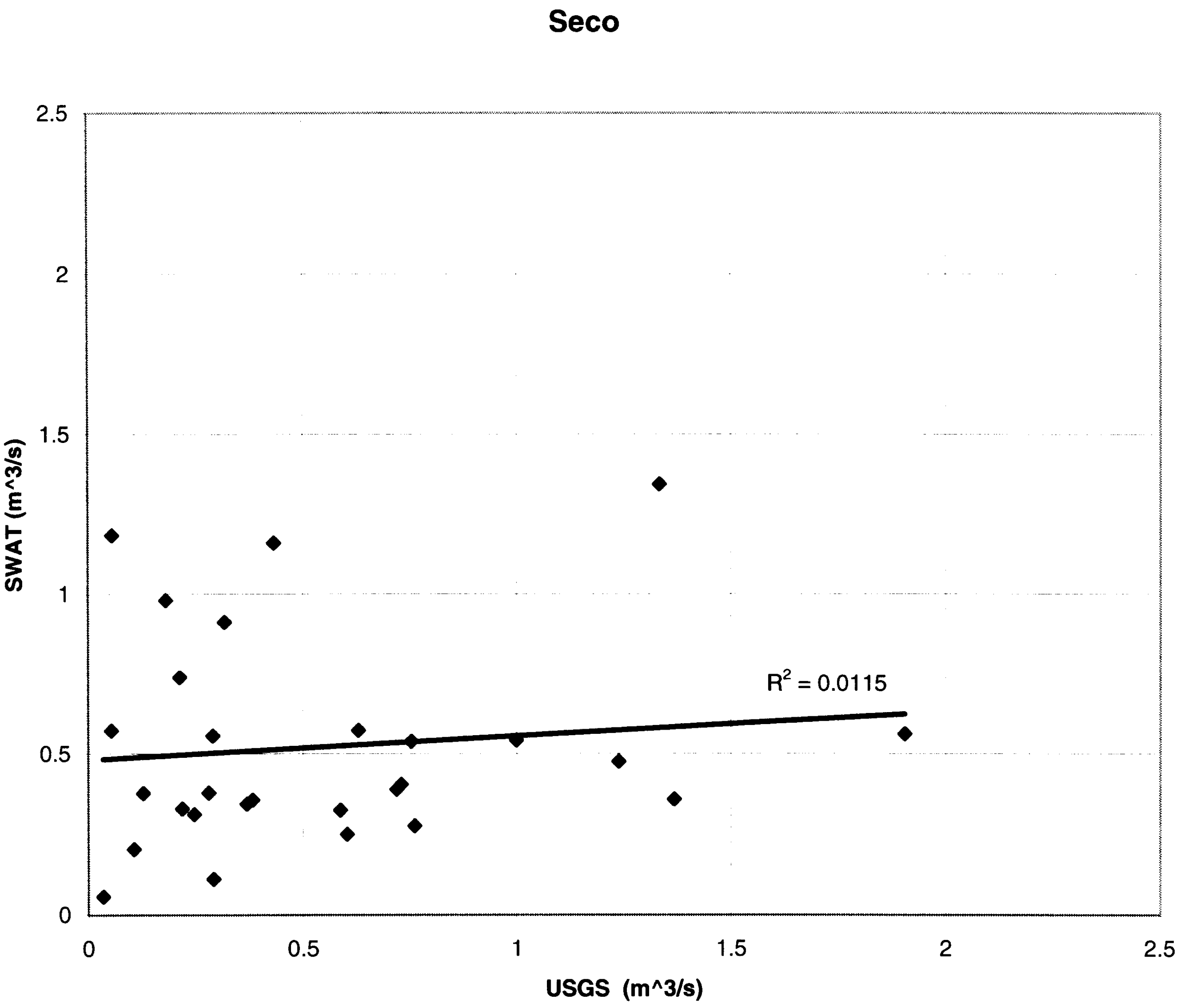

Figure 10. Simulated (SWAT) and measured (USGS) annual average stream flow for Seco Creek.

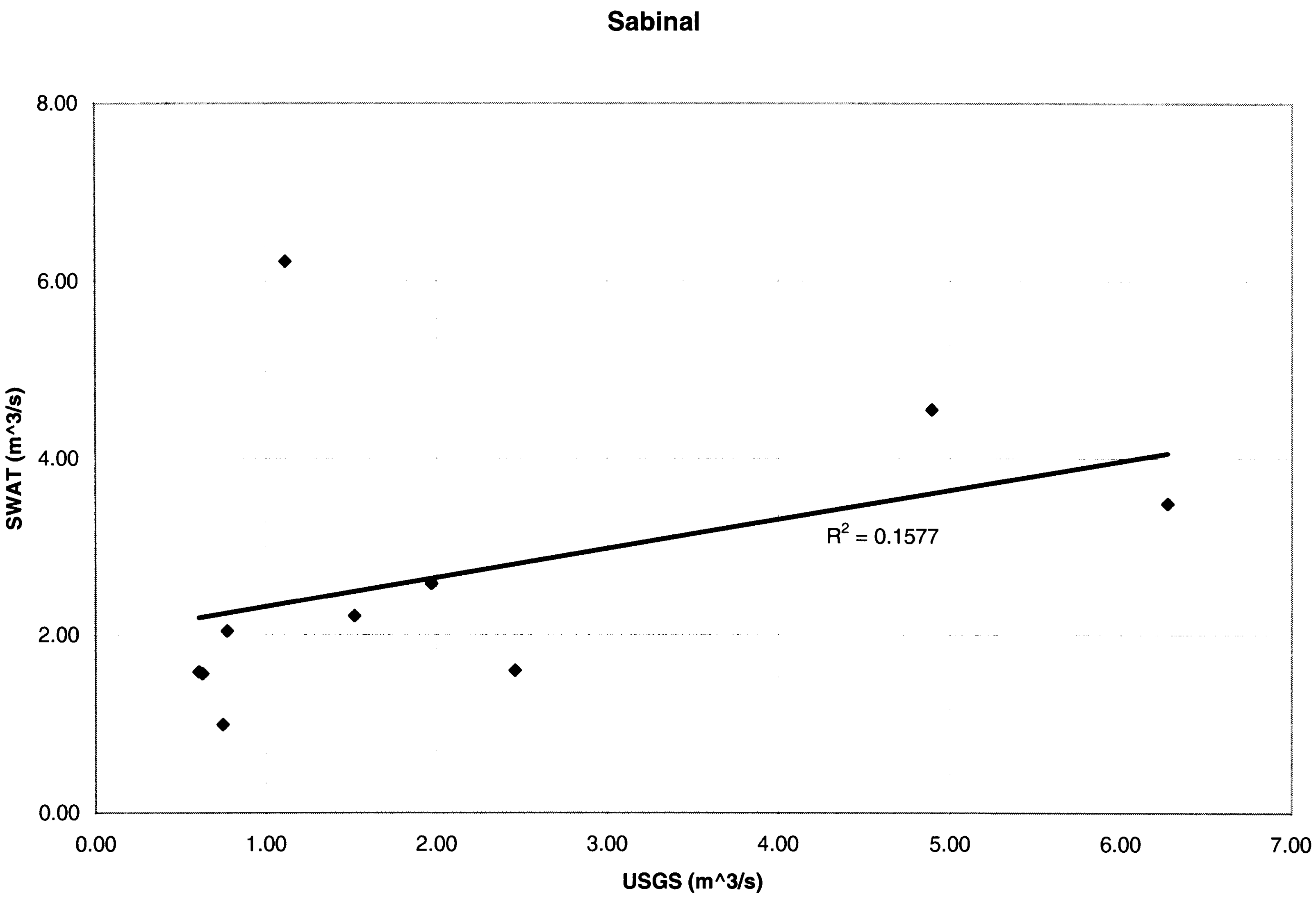

Figure 11. Simulated (SWAT) and measured (USGS) annual average stream flow for Sabinal river.

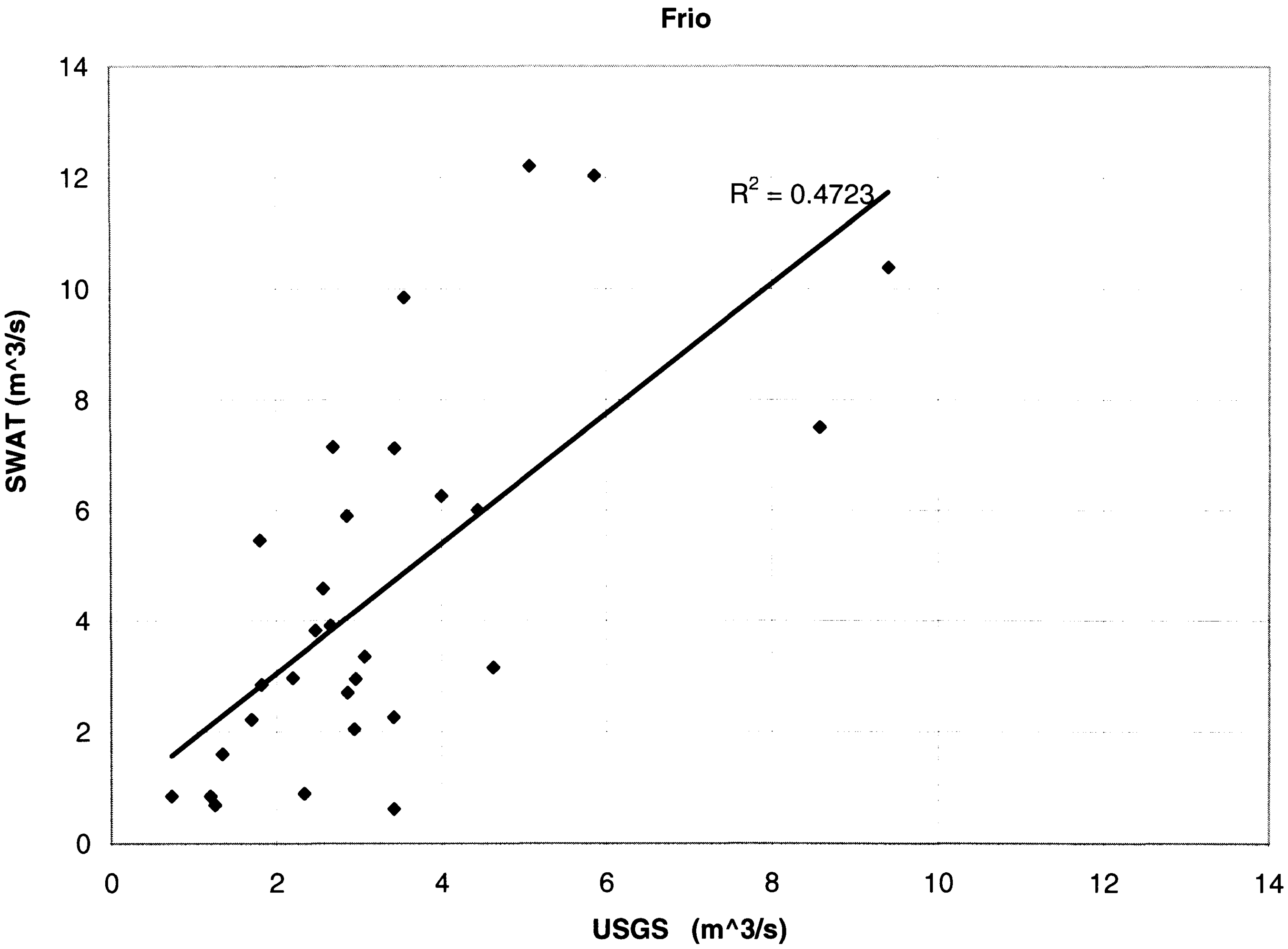

Figure 12. Simulated (SWAT) and measured (USGS) annual average stream flow for Frio river.

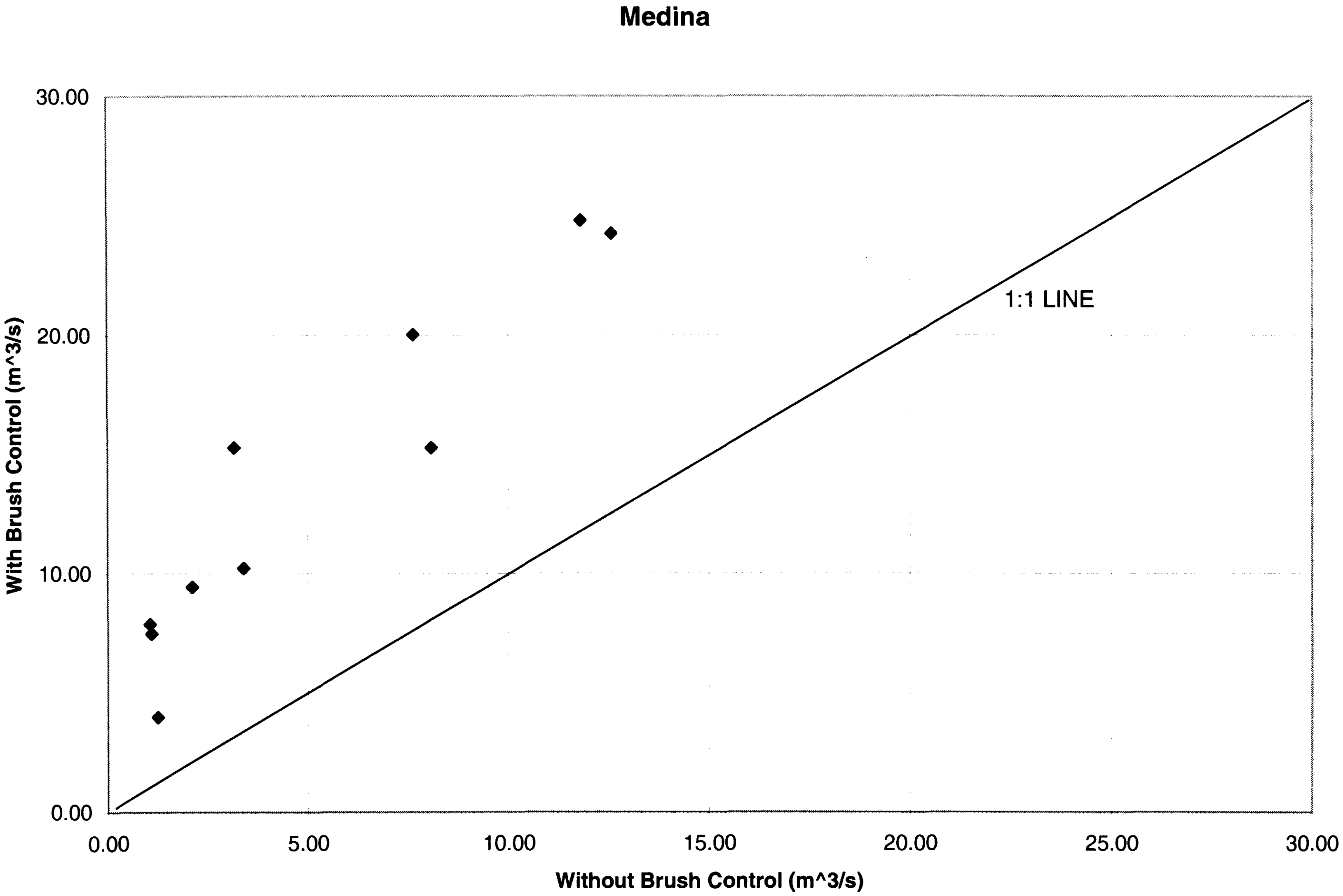

Figure 13. Simulated annual average stream flow in Medina river under existing conditions (without brush control) and with removal of all brush on lands less than 10% slope. Simulation period was 1980 to 1989.

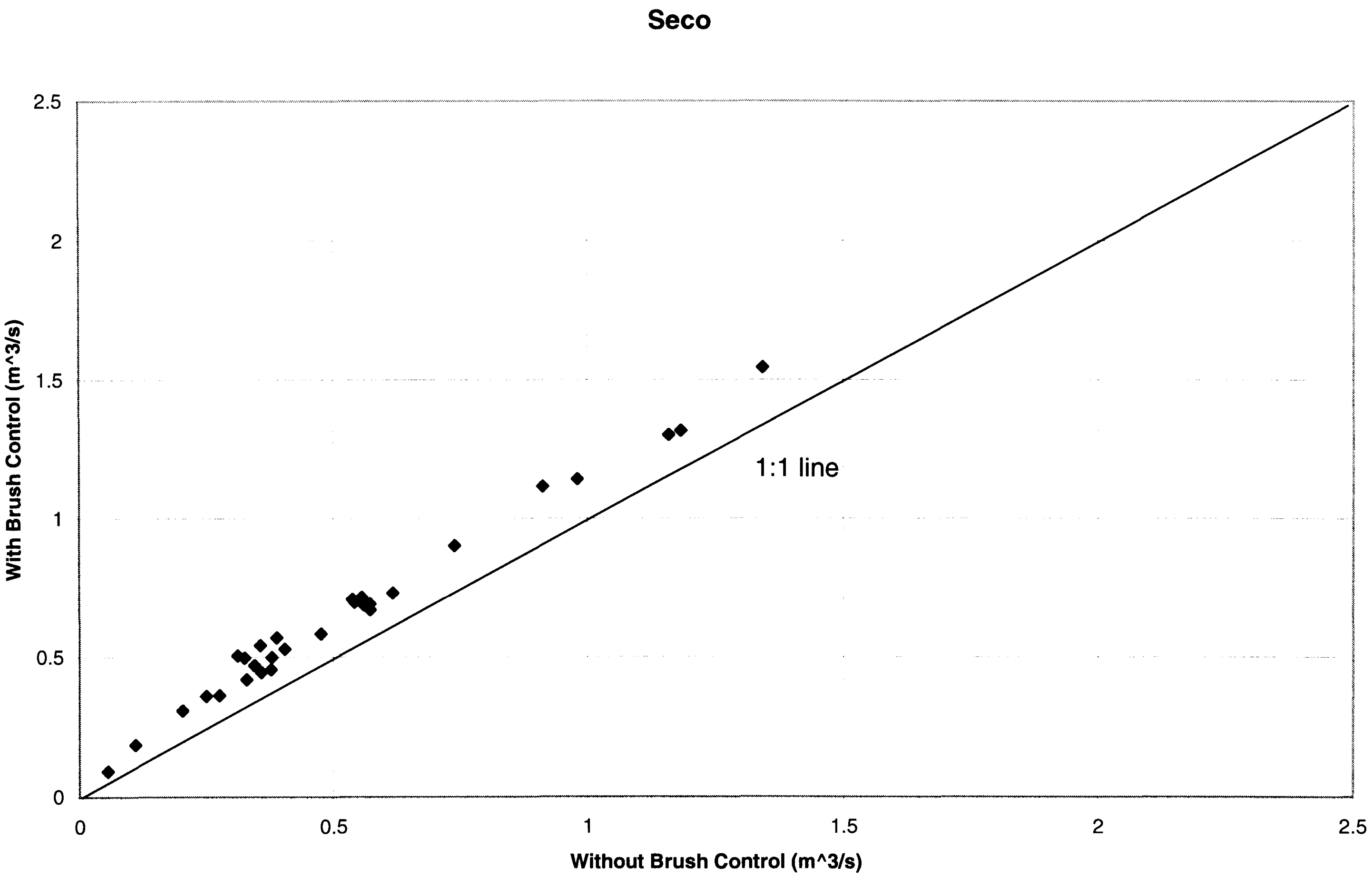

Figure 14. Simulated annual average stream flow in Seco Creek under existing conditions (without brush control) and with removal of all brush on lands less than 10% slope. Simulation period was from 1960 to 1989.

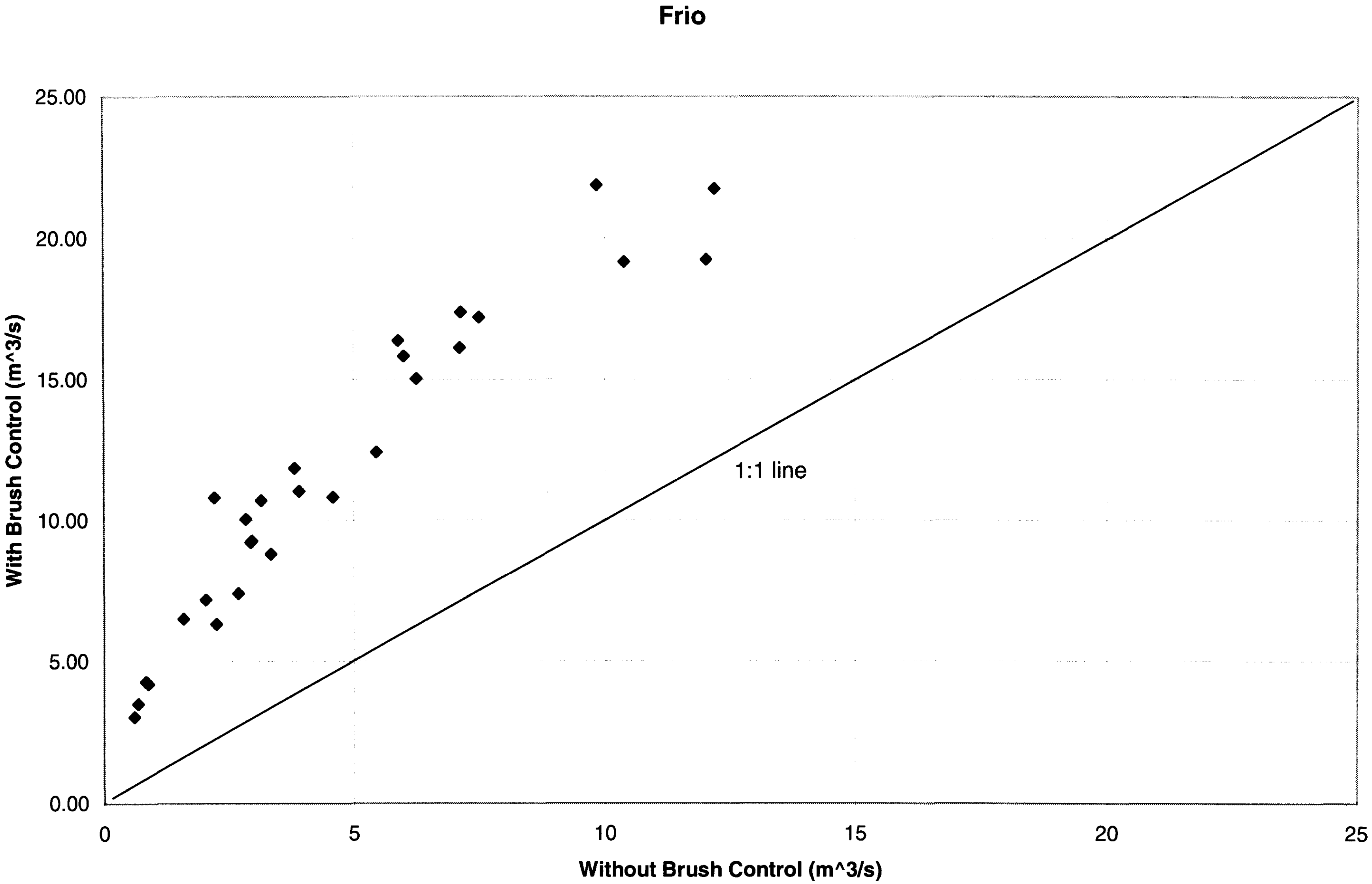

Figure 15. Simulated annual average stream flow in Frio under existing conditions (without brush control) and with removal of all brush on lands with less than 10% slope. Simulation from 1961- 1989.

ATTACHMENT 1
TEXAS WATER DEVELOPMENT BOARD

REVIEW COMMENTS ON THE DRAFT REPORT SUBMITTED BY
Texas Agricultural Experiment Station
Contract No. 95-483-134

1. Figure 5 is entitled "Same as Fig. 4, except for treated watershed in calibration period." The figure title should be self-explanatory and not dependent on another figure's title. Similarly, titles for Figures 6, 9, 10, 11,12, 14 and 15 should also stand alone and be fully self-explanatory.

2. Figure 7 's title or legend should indicate that the treated watershed has had all ashe juniper removed. Readers are forced to assume some level of partial removal, or forced to have to dig through the text to finally figure out what the term "treated" in this instance means. Please clarify.

3. Table 4 should also be more explanatory as a stand-alone.
   Board Staff suggests: "In the simulated column, values without parentheses represent simulated flows for all watersheds in their "as is" condition for comparative purposes against measured flows." and

   " In the simulated column, values in parentheses represent the simulated stream flow with replacement of all brush with grass on land with slope less than 10% for the Medina, Seco and Frio watersheds as explained in the text under 'Task 3'. "

4. Figures 13, 14 and 15 are based on the same data on which Table 4 is based, but the figures are very confusing as they currently exist. Please clarify.

5. The title for Figure 13 includes the term "annual average stream flow", but if this were the case, then only the datapoint pair of 5.1 and 14.2 would show on the figure, since this pair are values that are average for the entire time period 1983 to 1989. However, if one assumes that the title is incorrect and that the figure is intended to show all datapoint pairs for the time period, then the ten data points - or five datapoint pairs - shown on the figure still falls short of the logical number of data point pairs, since the time period of seven years infers that seven pairs of data points should show.

6. There is no legend or key and no color or other means to distinguish between the points representing "With brush control" from the points representing "Without brush control". Please include a legend or key to distinguish between the points. Similar comments apply to Figures 14 and 15.

7. Some datapoint pairs appear to be missing, but the quality of the figures are so poor that one cannot tell for sure.

8. The actual content should be improved by expanding the text somewhat to make it more explanatory, especially in the text of Task 2 in the paragraph beginning "SWAT was run for the entire period of record . . ." and in the text of Task 3 where the reasons for selecting Medina, Seco and Frio watersheds should be articulated more clearly.

9. Executive Summary, page 2, first paragraph, third sentence appears to be an incomplete sentence; should read: ". . . increase water yield from these . . . "watersheds""?