Problems and Prospects of SWAT Model Application on an Arid/Semi-Arid Watershed in Arizona

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Introduction

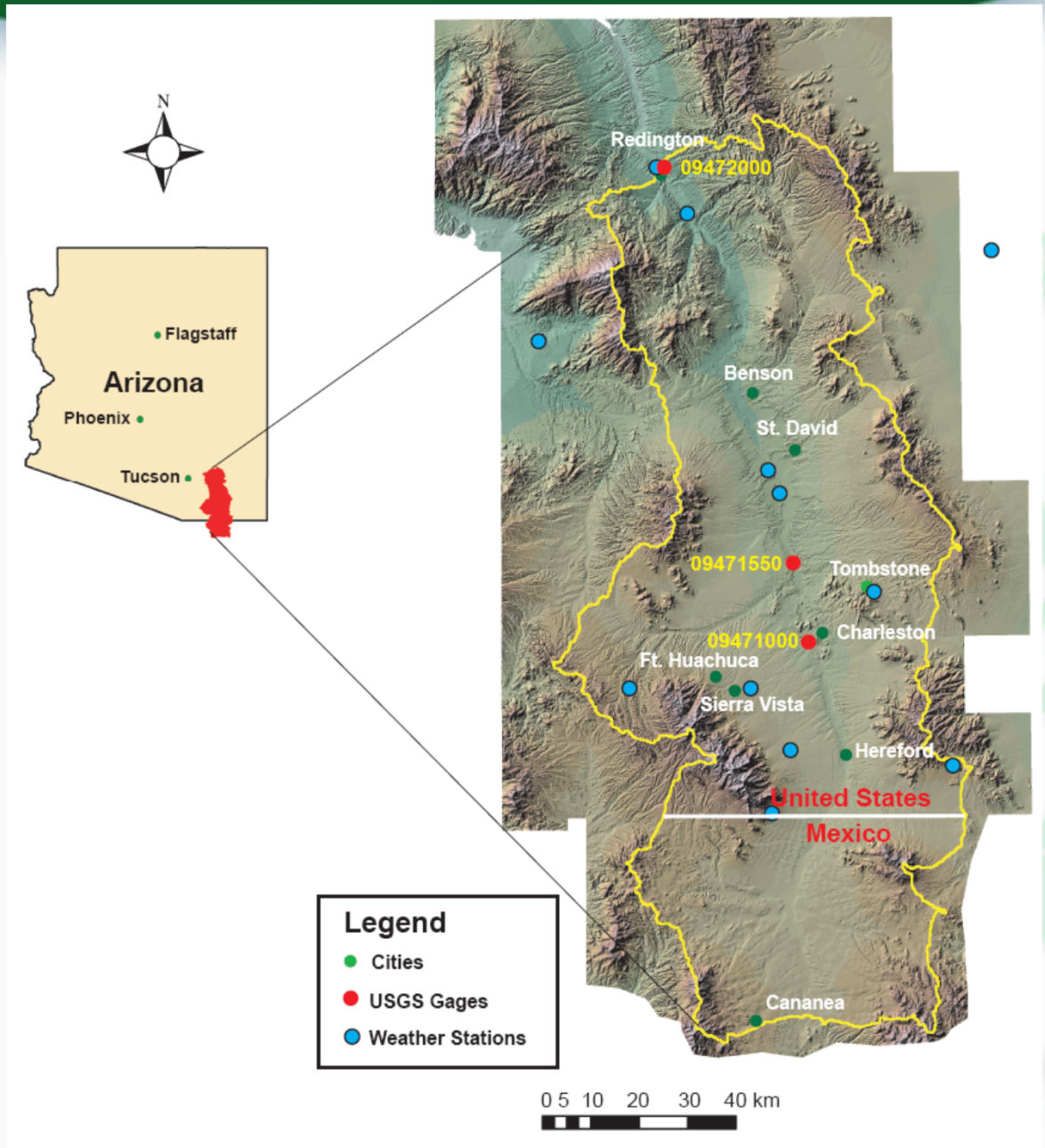
- **In arid/semi-arid regions, precipitation mainly occurs during two periods: long-duration, low-intensity rainfall in winter; and short-duration, high-intensity rainfall in summer.**
- **Watersheds in arid/semi-arid regions often release water almost immediately after a storm due to sparse vegetation, steep topography, complex soils and rapid land development changes.**

Challenges

- **In arid/semiarid areas, it has been a challenge to quantify water resources due to limited access and monitoring systems on the land, as well as limited capability of hydrological and water quality models to handle the unique hydrology of these regions.**

Objectives

- **To analyze the unique hydrology of a watershed located in the southwest U.S.**
- **To evaluate SWAT's applicability in this arid/semiarid watershed.**



Area

7,600 km²

Elevations

900 - 2900 m

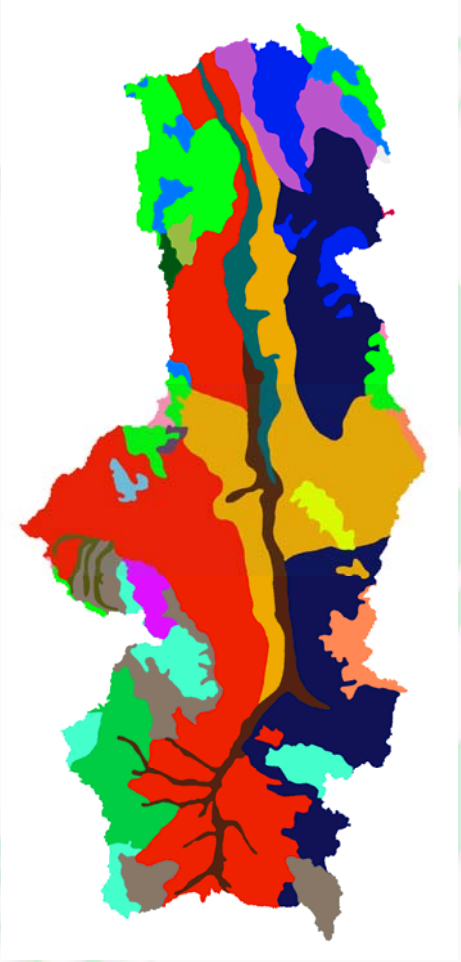
Annual Rainfall

300 - 750 mm

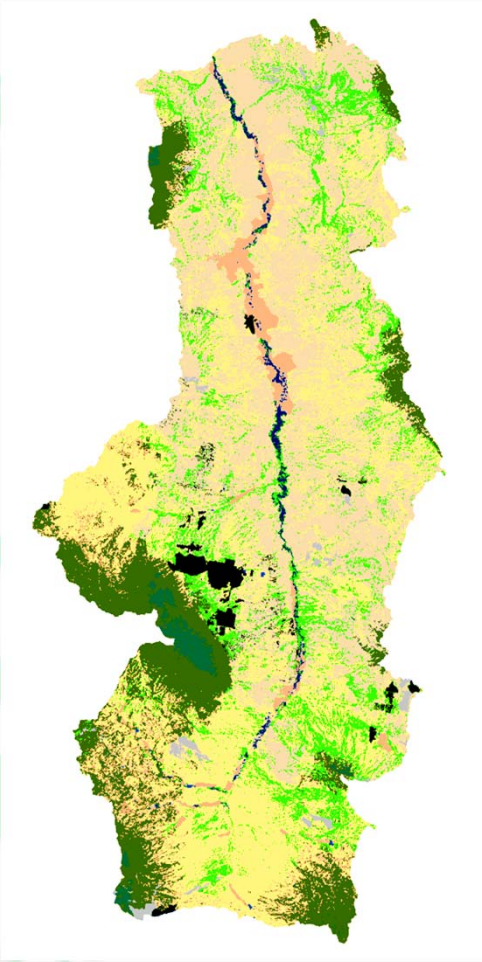
Location of the study area, USGS monitoring gages, weather stations and cities in the Upper San Pedro River Basin

Data Collection

DEM

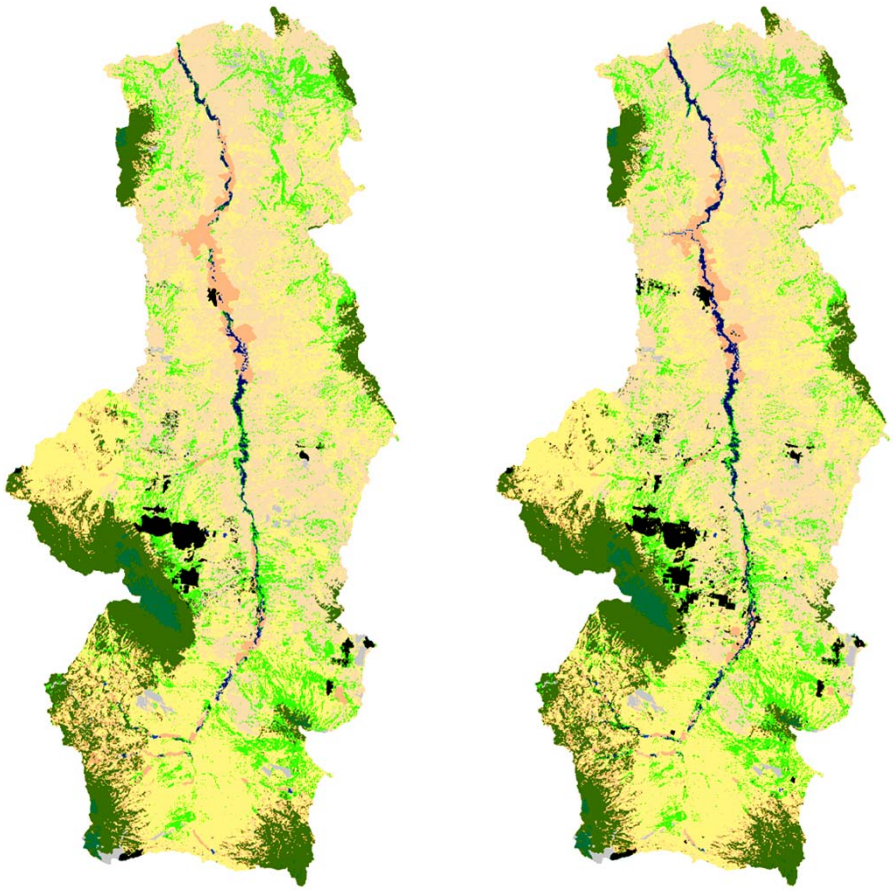


Soil (STATSGO)



LULC (NALC)

Land Use	1992	1997	97-92
	Hectare	Hectare	%
Mesquite	105394	103679	-1.63
Grassland	255939	258662	1.06
Desert scrub	238428	235062	-1.41
Agriculture	18162	14500	-20.16
Urban	12278	16573	34.98



1992 for calibration

1997 for validation

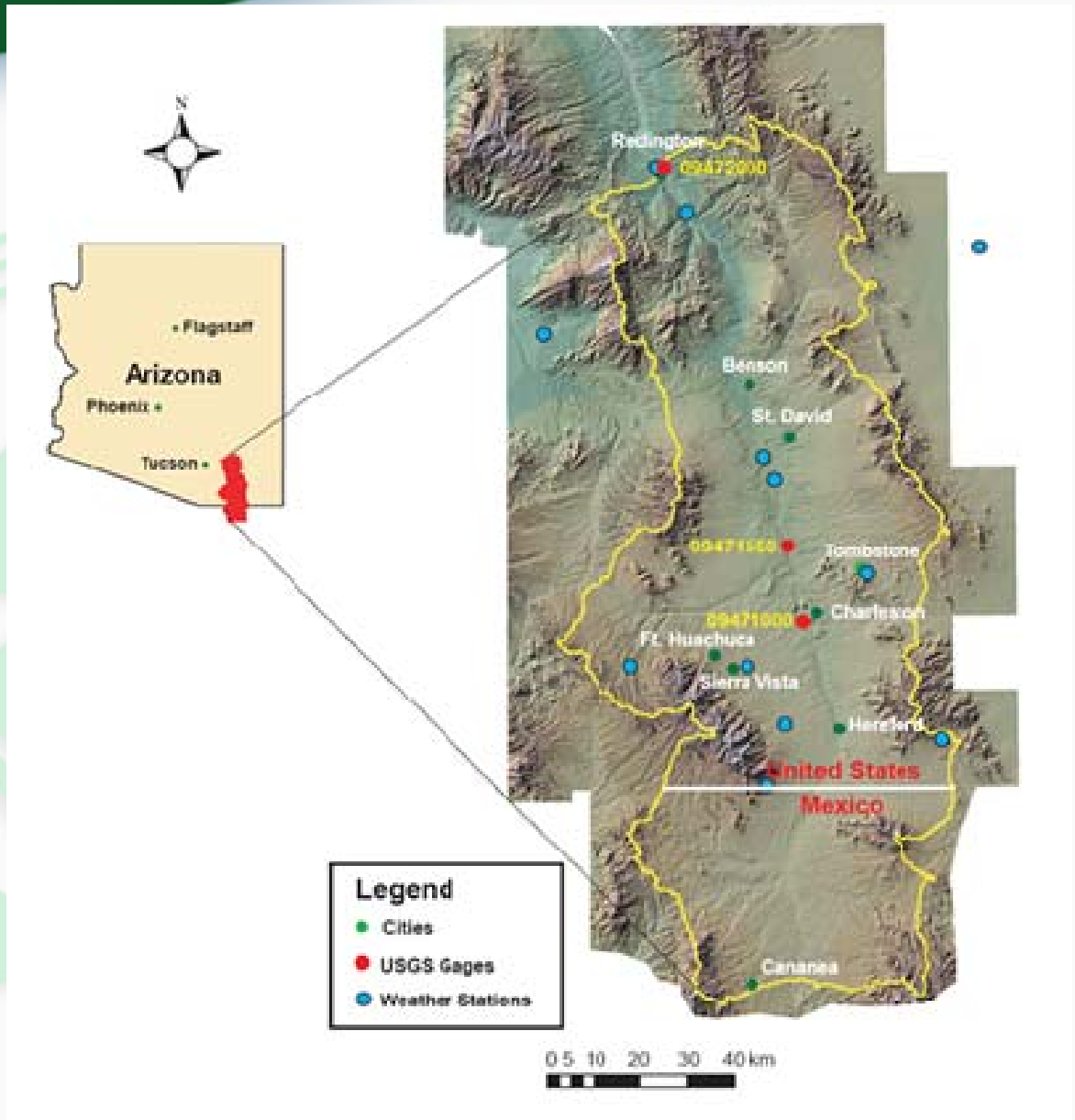
Legend

- Forest
- Oak Woodland
- Mesquite Woodland
- Grassland
- Desertscrub
- Riparian
- Agriculture
- Urban
- Water
- Barren

Land cover in the Upper San Pedro River Watershed

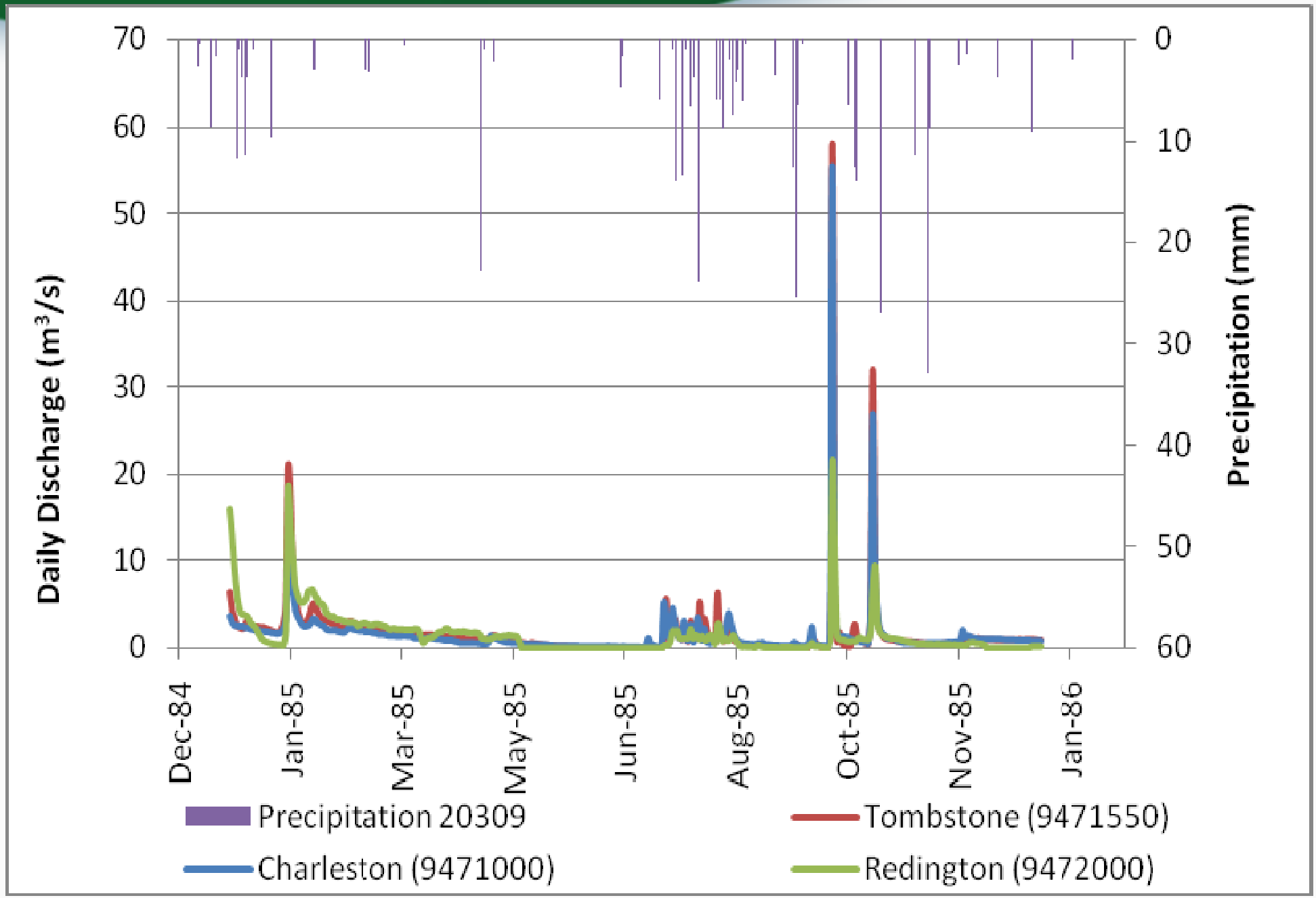
- **12 weather stations**
  (1960/01 – 2008/04)

- **3 USGS gage stations**
  Redington (10/85 - 09/95)
  Tombstone (10/96 – 09/05)
  Charleston (10/85 – 09/05)



Unique Hydrological Characteristics of the San Pedro River Watershed

- **In most channel locations, low or intermittent baseflow with ephemeral peak discharge occurred during sporadic storm events.**
- **Sections of the river can be classified as gaining or losing reaches, where streamflow is intermittent and associated with a mix of monsoon water sources and aquifer sources stored in the alluvial groundwater.**
- **Streamflow in losing portions is generally ephemeral.**
- **Streamflow in gaining portions is generally perennial.**


Daily Discharge (m³/s)
Precipitation (mm)
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Dec-84
Jan-85
Mar-85
May-85
Jun-85
Aug-85
Oct-85
Nov-85
Jan-86
Precipitation 20309
Tombstone (9471550)
Charleston (9471000)
Redington (9472000)

Redington Station

- **Although the Redington station is, hydrologically, a larger-order stream than the upstream gauges, its flow is characterized by the least amount of storm runoff and the lowest baseflow conditions.**
- **Larger-order streams typically have higher baseflow and steadier flow conditions; however, this phenomena is not observed in this semiarid stream system due to transmission losses and other factors such as increased ET.**

Tombstone Station

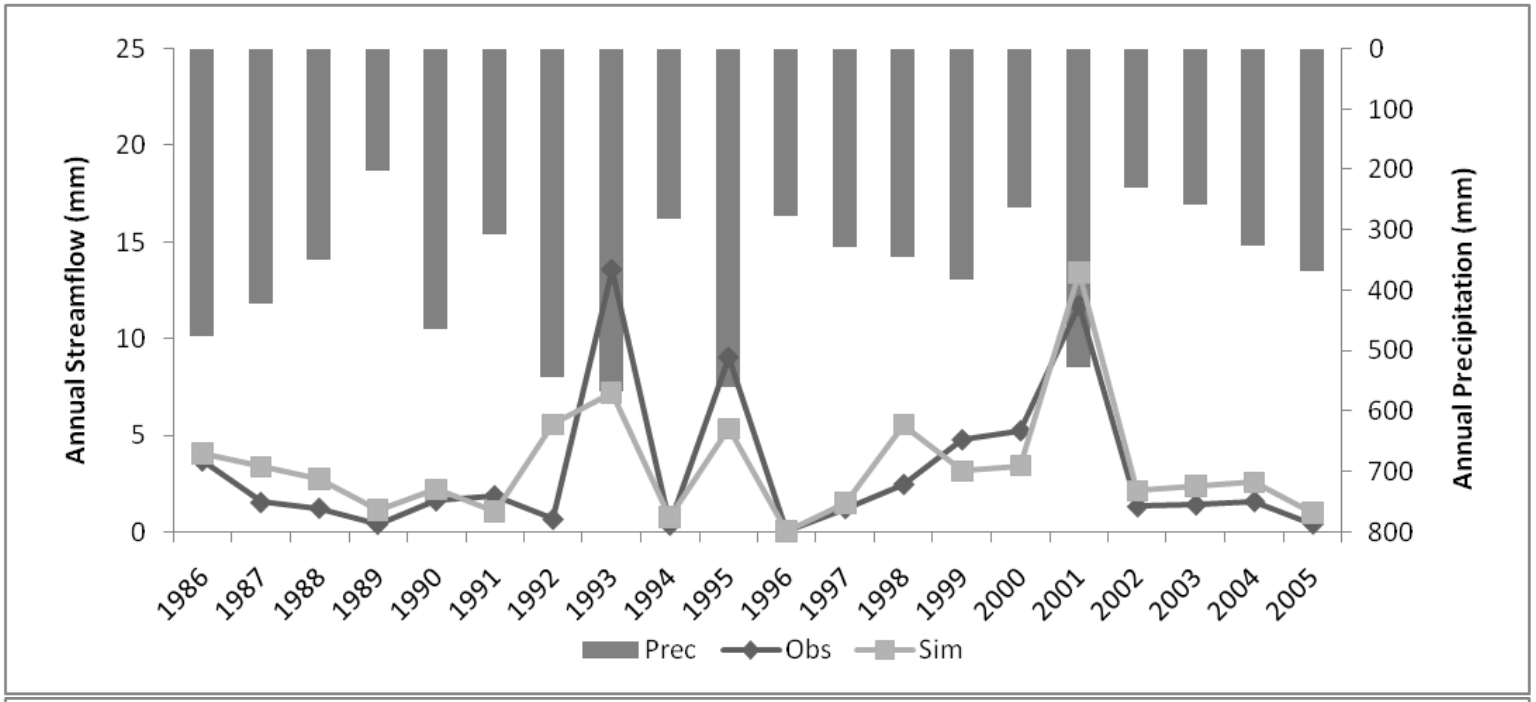
- **At the Tombstone gaging station, upstream groundwater flow to the stream's vicinity is less than the volume of water removed by ET during the growing season, meaning there is generally no base flow during summer time.**

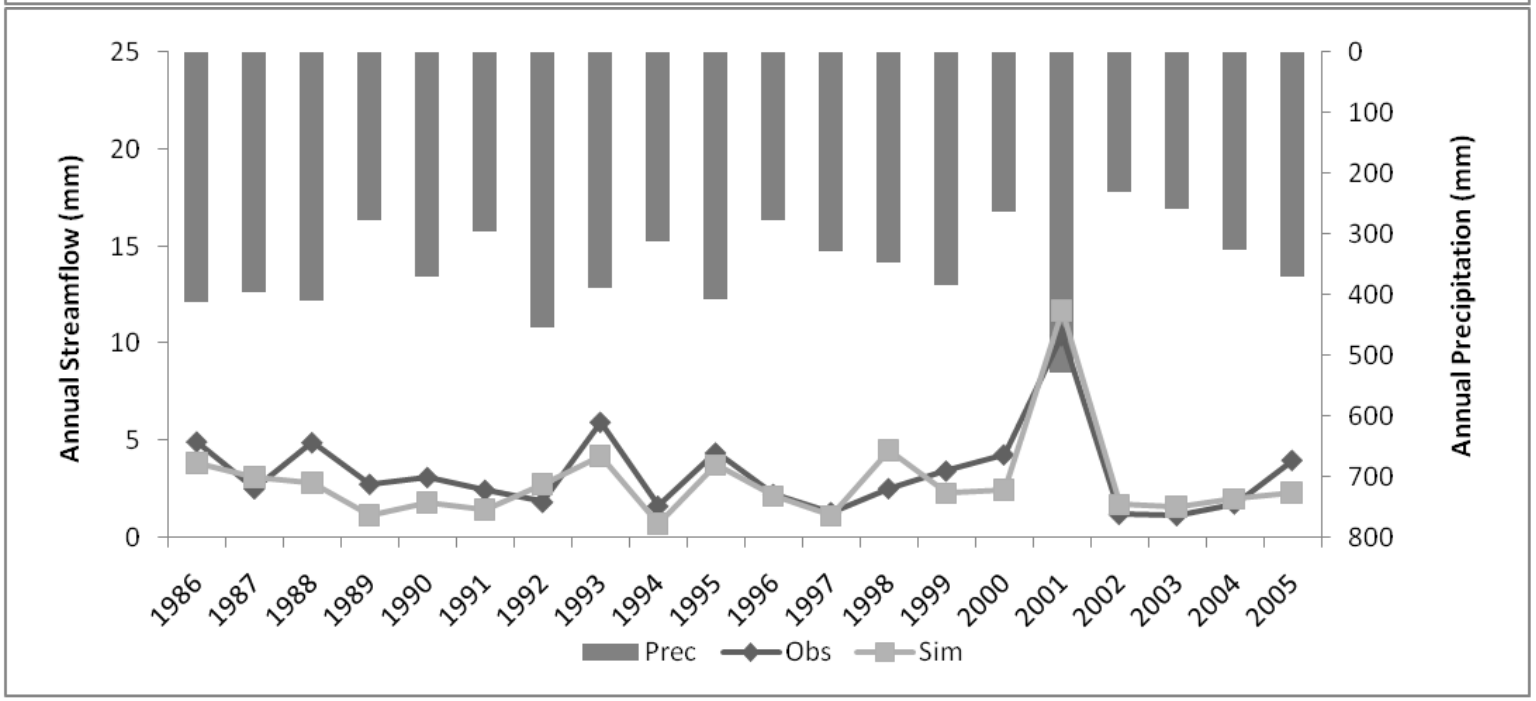
Soil and Water Assessment Tool

- **The SWAT model is a continuous, long-term, physically based, distributed model.**
- **SWAT assesses impacts of LULC and climate changes on hydrological components, sediment loading, and pollution transport in watersheds.**
- **In SWAT, a watershed is divided into subwatersheds or subbasins, with subbasins further divided into uniform hydrological response units (HRUs).**

Table 1 Top ranking sensitive parameters (in the order of ranking) and their description, default and calibrated values that were used in the model calibration/validation (*, the multiple sign, indicates that default parameter values are multiplied by the number shown).

Parameter	Default	Description	Calibrated Value
Adjf_latq	1	Adjust factor for lateral flow	0.02
λ	0.2	Initial Abstraction Ratio	0.05
CN2	30-92	SCS runoff curve number for moisture condition II	*0.58
ESCO	0.95	Soil evaporation compensation factor	0.05
Revapmn	1	Threshold water level in shallow aquifer for revap	0
SOL_AWC	0.01-0.19	Available water capacity of the soil layer	*1.4
Sol_K		Saturated hydraulic conductivity of first layer	
CH_K2	0	Effective hydraulic conductivity of channel	0.6
GW_Revap	0.02	Revaporation coefficient	0.2

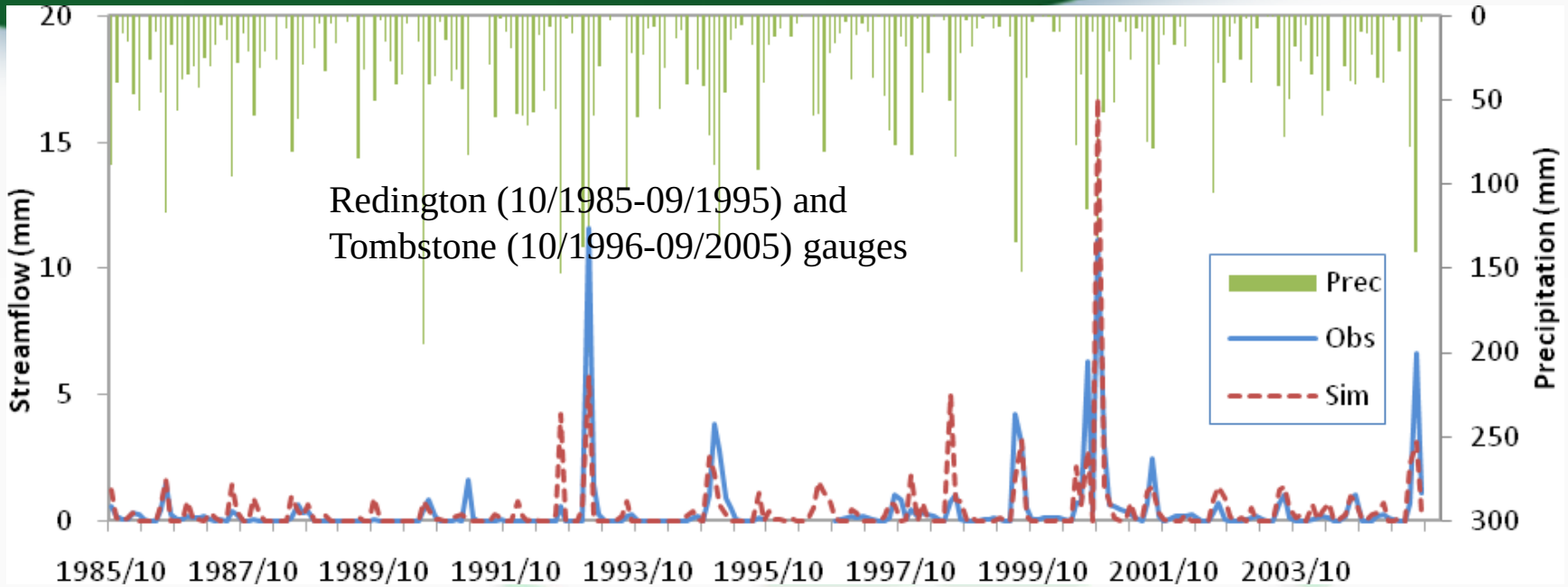


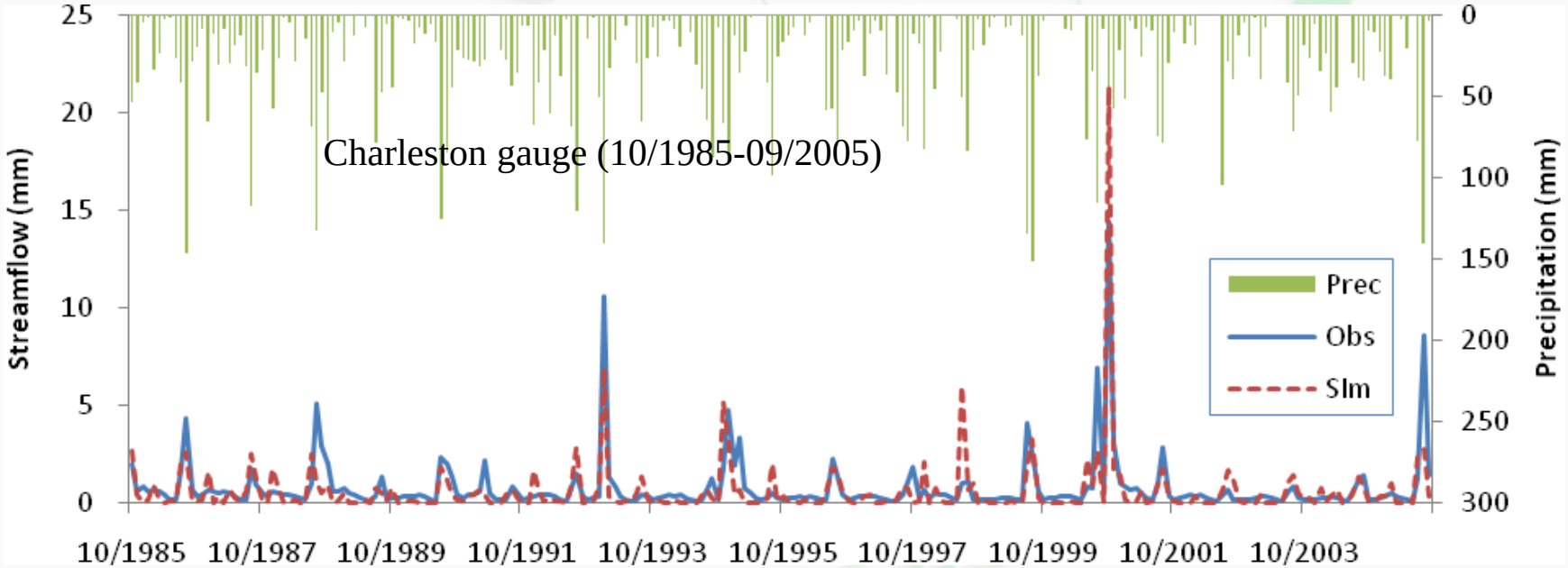


Annual (in water year) precipitation and simulated and observed streamflow

Upper: Redington (1986 – 1995) and Tombstone (1997 – 2005) gauges

Lower: Charleston gauge (1986 – 2005).





Monthly precipitation and simulated and observed streamflow

Table 2 Criteria for examining the accuracy of calibration and validation.

Index	Calibration (10/1985 - 09/1995)				Validation (10/1995 - 09/2005)			
	Redington		Charleston		Tombstone		Charleston	
	Annual	Monthly	Annual	Monthly	Annual	Monthly	Annual	Monthly
NS Coefficient	0.45	0.56	0.82	0.52	0.94	0.57	0.93	0.55
R^2	0.66	0.57	0.66	0.55	0.84	0.70	0.82	0.70
PBIAS	1.94	-1.29	25.46	24.63	-16.27	-9.23	1.38	3.00

Summary and Conclusions

- **Larger order streams (downstream gauge stations) did not have greater baseflow and steadier flow conditions due to transmission losses and factors such as increased ET. In fact, decreased runoff was observed in in the watershed's downstream gauge stations.**
- **SWAT model input parameters were modified to simulate the limited baseflow conditions, increased ET and transmission loss, and decreased runoff observed in downstream gauge stations in the watershed.**

Summary and Conclusions

- **Set up with calibrated parameters obtained through model sensitivity, calibration and validation analysis, the SWAT model generally reflects hydrological characteristics of this arid/semiarid watershed based on NS, R^2 and PBIAS values.**

Thank you!

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