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Effects of the resolution of soil dataset and precipitation dataset on SWAT2005 streamflow calibration parameters and simulation accuracy

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Abstract: The resultant calibration parameter values and simulation accuracy of hydrologic models such as the 2005 Soil and Water Assessment Tool (SWAT2005) depend on how well spatial input parameters describe the characteristics of the study area. The objectives of this study were to (1) investigate the effect of soils dataset resolution (State Soil Geographic Database and Soil Survey Geographic Database) on SWAT2005 streamflow simulation performance and calibration parameters using four precipitation datasets and (2) determine the best combination of soil and precipitation datasets for the Cobb Creek, Lake Creek, and Willow Creek subwatersheds within the Fort Cobb Reservoir Experimental watershed, Oklahoma. SWAT2005 was calibrated and validated for streamflow for the three subwatersheds using the State Soil Geographic Database and the Soil Survey Geographic Database for each of the four available precipitation datasets with different spatial resolutions. The four sources of rainfall data included the National Weather Service's network of Cooperative Observer Program weather stations, statewide Oklahoma Mesonet, USDA Agricultural Research Service's weather station network (MICRONET), and National Weather Service Next Generation Radar (NEXRAD) precipitation estimates. The model performance was assessed using the Nash-Sutcliffe efficiency coefficient and percent bias statistics. During both the calibration and validation periods, there were no significant differences in the model monthly performance statistics between the higher resolution Soil Survey Geographic Database and the lower resolution State Soil Geographic Database across subwatersheds, irrespective of the rainfall dataset used. However, the model performed better when the NEXRAD and MICRONET precipitation datasets were used. There were slight to large differences in the resultant calibration parameter values depending on the calibration parameter, the precipitation data used, and the subwatershed. Large differences in the simulated surface runoff and deep aquifer recharge due to soils dataset resolution could lead to significant differences in the simulated water quality components such as sediments and nutrients. This is important because significant differences in simulated sediments and/or nutrients could lead to significantly different outcomes in terms of the impacts of a given conservation practice for studies like the Conservation Effects Assessment Project. Due to the lack of measured data to validate the simulated water balance components, it was recommended to use both the fine and coarse resolution soil datasets in combination with the finer spatial resolution precipitation datasets and the simulated water balance components of interest reported as a range.

Key words: calibration parameters—precipitation dataset resolution—simulation accuracy—Soil and Water Assessment Tool (SWAT)—soil dataset resolution—streamflow

The level of uncertainty of input parameters associated with hydrologic modeling has a significant impact on the model simulation accuracy and the uncertainty of the resulting model outputs. In addition to the climate and land-use datasets, soil data is one of the basic inputs to 2005 Soil and Water Assessment Tool (SWAT2005) (Arnold et al. 1998; Arnold and Fohrer 2005), a distributed watershed-scale hydrologic model. Starks and Moriasi (2009) evaluated SWAT2005 in three subwatersheds located in the Fort Cobb Reservoir Experimental watershed, Oklahoma, and found that spatial precipitation dataset resolution affected both the SWAT2005 streamflow simulation performance and calibration parameter values. A detailed literature review on the impact of precipitation dataset resolution on streamflow simulations is given by Starks and Moriasi (2009) and hence is not given in this study. This study focuses on determining the impact of soil dataset resolution in the SWAT2005 streamflow simulations using the four precipitation datasets used by Starks and Moriasi (2009).

While measured soils data are preferred, the national soil datasets are the best alternative for watersheds where measured soils datasets are not available. In the United States, the USDA Natural Resources Conservation Service (NRCS) developed and distributed two digital soils databases, namely, State Soils Geographic (STATSGO) Database (USDA 1994) and Soil Survey Geographic (SSURGO) Database (USDA 1995), which are used to derive the soil input data for SWAT and other distributed hydrologic models. The STATSGO maps are compiled by the NRCS through generalizing more detailed soil survey maps, often county-level soil maps that are at the scale of SSURGO (USDA 1995). Compared with STATSGO (1:250,000), SSURGO (1:12,000 to 1:63,360) has a higher spatial resolution and provides more detailed information. Because of the higher spatial resolution, SSURGO soils datasets may contain more soil hydrologic groups than STATSGO datasets. Whereas it would seem intuitive to use the higher resolution SSURGO instead of STATSGO, SSURGO requires more resources (data preparation and computing time). In addition, studies conducted to date to determine the impact of using STATSGO or SSURGO datasets on model calibration parameters and simulation output and accuracy for streamflow, sediments, and nutrients, have yielded varied results (Mednick et al. 2008).

Gardiner and Meyer (2001) applied the geographical information system (GIS)–based Revised Universal Soil Loss Equation (RUSLE) to the 966 km^2 (373 mi^2) Upper Little Tennessee River Basin in North

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Carolina and found that STATSGO soil erodibility factors were on average 34% greater than the same factors taken from the SSURGO database. In most of the five subwatersheds within the 536 km^2 (207 mi^2) Leon Creek watershed, the uncalibrated SWAT water yield obtained using SSURGO soil data was higher compared with the water yield when STATSGO data were used in the model, but there were no definitive conclusions on whether the higher resolution datasets improved model output results (Peschel et al. 2003). Using the same uncalibrated SWAT model in the 541 km^2 (209 mi^2) Upper Sabinal River watershed in Texas, Peschel et al. (2006) found that SSURGO data produced a larger daily mean water yield than STATSGO, with evapotranspiration and surface runoff being found consistently lower for SSURGO across the watershed under the same hydrological conditions.

Levick et al. (2004) evaluated the Kinematic Runoff and Erosion Model (KINEROS2) (Woolhiser et al. 1990) at the 148 km^2 (57 mi^2) Walnut Gulch Experimental watershed and found that runoff simulated using STATSGO soils were generally higher than with SSURGO. In another study, Levick et al. (2006) used soil data inputs generated by the Automated Geospatial Watershed Assessment Tool (AGWA) to evaluate KINEROS2 in three 8 to 114 km^2 (3 to 44 mi^2) subwatersheds within the Walnut Gulch Experimental watershed. The KINEROS2 model simulated runoff volume and peak equally well using both SSURGO and STATSGO. Gowda and Mulla (2005) evaluated a field-scale water table management model (ADAPT) in the 39 km^2 (15 mi^2) High Island Creek, Minnesota. Statistical comparison of calibration results with measured streamflow, sediment, nitrate, and phosphorus data indicated excellent agreement for both SSURGO and STATSGO soil databases. Wang and Melesse (2006) assessed SWAT in the 515 km^2 (199 mi^2) upper portion of the Elm River watershed, North Dakota, and found that overall SSURGO yielded better stream discharge prediction than STATSGO, but STATSGO predicted the low stream flows more accurately.

Anderson et al. (2006) assessed the Sacramento Soil Moisture Accounting model (SAC–SMA) (Burnash 1995) in six basins ranging from 145 to 590 km^2 (56 to 228 mi^2) located within the Ohio River Forecasting Center covering Kentucky, Ohio, West Virginia, and Virginia. Overall, hydrologic simulation results revealed that SSURGO–based parameter estimates significantly improved flood prediction compared with the STATSGO–based parameter estimates. In another study using the gridded SAC–SMA model in 11 basins located in Arkansas and Oklahoma ranging from 37 to 2,485 km^2 (14 to 959 mi^2) in size, Zhang et al. (2006) found improvement in event flow simulation, peak flow values, and peak flow timing for most basins when SSURGO–based a priori parameters were used instead of STATSGO–based a priori parameters. Ghidey et al. (2007) calibrated and validated SWAT for streamflow in the Goodwater Creek Experimental subwatershed (70 km^2 [27 mi^2]), Missouri, with results showing that the performance of the model in simulating streamflow when using the STATSGO soil data was as good as using the SSURGO soil data. Geza and McCray (2008) evaluated SWAT in the Turkey Creek watershed (126 km^2 [49 mi^2]), Colorado, and determined that SSURGO predicted less stream sediment and nutrient loadings than STATSGO. When compared to mean daily measured streamflow, STATSGO performed better relative to SSURGO before calibration, but SSURGO provided better results after calibration—although both results were in the same satisfactory range. In a recent study using SWAT in the Cedar Creek watershed (707 km^2 [273 mi^2]), Indiana, Heathman et al. (2009) found no difference in the SWAT streamflow simulation performance when using SSURGO compared to STATSGO.

Based on the studies discussed above, the findings are far from unanimous and reveal no clear pattern of the impact of the soil dataset resolution on the simulation accuracy and output with respect to model type and component or scale of analysis. According to Mednick et al. (2008), a potentially confounding issue is the fact that some authors calibrate their STATSGO and SSURGO–based models separately before comparison (Gowda and Mulla 2005; Wang and Melessee 2006; Ghidey et al. 2007). Others avoid doing so for the express purpose of maintaining a clear signal of soil data resolution effects in their comparisons (Peschel et al. 2003; Peschel et al. 2006; Levick et al. 2006; Geza and McCray 2008). However, some studies using the same models calibrated and uncalibrated generally reported similar results (Peschel et al. 2006; Wang and Melessee 2006; Ghidey et al. 2007; Geza and McCray 2008). Mednick et al. (2008) concluded that a more likely cause for this lack of explanatory pattern is the small sample size within and across the different studies.

In spite of the varied study findings regarding the effect of SSURGO versus STATSGO soils datasets on model simulation accuracy and output for water quality models, there is a general agreement that it is important to use optimal soils and other GIS inputs for streamflow and water quality modeling studies. Therefore, the goals of this study were to (1) investigate the effect of soils dataset resolution (STATSGO and SSURGO) on SWAT2005 streamflow simulation performance and calibration parameters using four precipitation datasets and (2) determine the best combination of soil and precipitation datasets for the Cobb Creek, Lake Creek, and Willow Creek subwatersheds within the Fort Cobb Reservoir Experimental watershed (FCREW) in Oklahoma. The FCREW is one of 14 benchmark watersheds in the USDA's Conservation Effects Assessment Project–Watershed Assessment Studies (CEAP–WAS), which seeks to quantify the environmental benefits of conservation practices used by private landowners participating in selected USDA conservation programs (Mausbach and Derick 2004; Duriancik et al. 2008; Richardson et al. 2008).

Materials and Methods

Study Area. The FCREW is located in Caddo and Washita Counties, Oklahoma, (35°11'43"N, 98°29'05"W) (figure 1 and table 1) and is about 786 km^2 (303 mi^2) in size above the reservoir dam (Steiner et al. 2008). Surface and groundwater resources supply public, domestic, and irrigation water. Fort Cobb Reservoir is on the Oklahoma 303(d) list (list of water bodies that do not meet the water quality standards as given in the Clean Water Act) due to excessive sedimentation and the trophic state of the lake (Steiner et al. 2008). Four major streams feed the reservoir: Willow Creek, Lake Creek, Five Mile Creek, and Cobb Creek. The US Geologial Survey (USGS) stream gauges are located at the lower ends of Willow and Lake Creeks, and below the confluence of Cobb and Five Mile Creeks (referred to as Cobb Creek in this study) (figure 1). The drainage areas for the Cobb Creek, Lake Creek, and Willow Creek subwatersheds are 342 km^2 (132 mi^2), 154 km^2 (59 mi^2), and 75 km^2 (29

Figure 1
Location of reservoirs and weather and streamflow gauging stations, and stages of the channel bank instability in the Fort Cobb Reservoir Experimental watershed in Oklahoma. The rainfall datasets are the National Weather Service Next Generation Radar (NEXRAD), the USDA Agricultural Research Service's weather station network (MICRONET), the statewide Oklahoma Mesonet (MESONET), and National Weather Service's network of Cooperative Observer Program weather stations (COOP). Reservoir descriptions are in table 1.

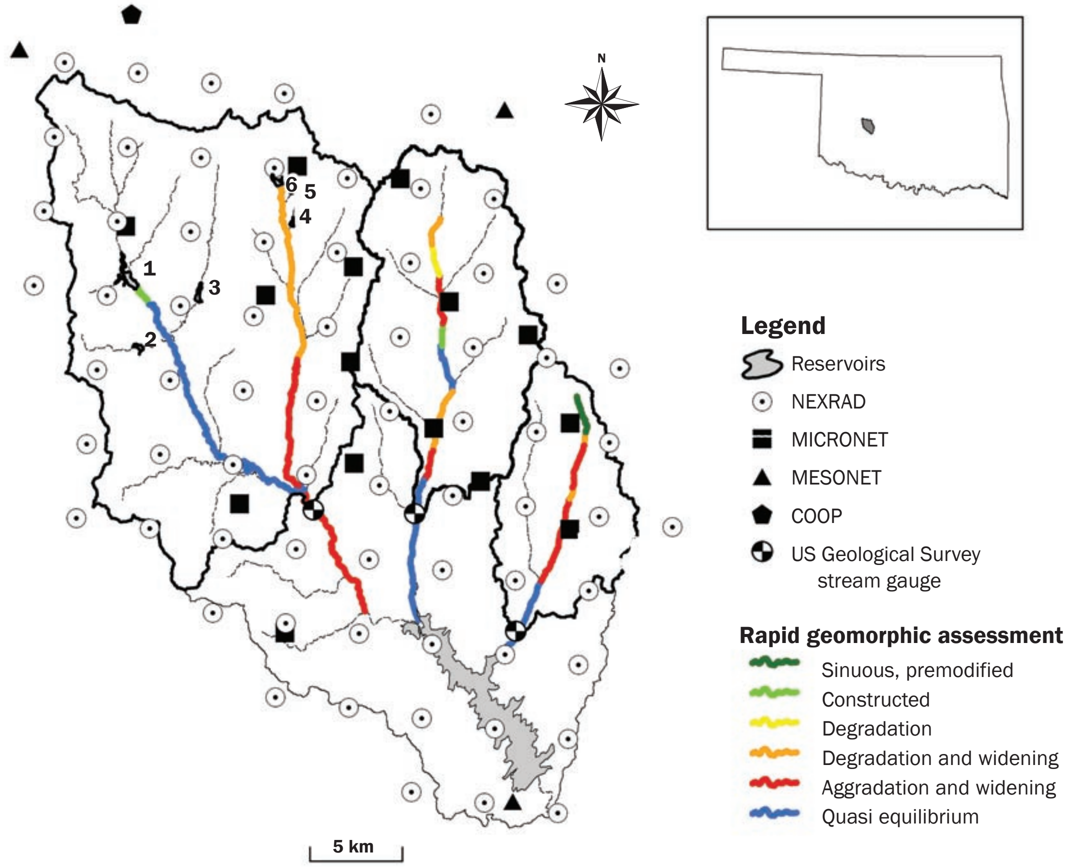


Table 1
Reservoir ID descriptions.

Reservoir ID	Year constructed	Surface area (ac)	Storage capacity permanent pool (ac ft)
1	1959	160	2,090
2	1957	59	480
3	1957	68	660
4	1956	11	110
5	1956	12	144
6	1957	66	587

mi^2), respectively. The land use in each of the subwatersheds is predominantly mixed cropland and grazing land. In Cobb Creek, the soils are predominantly silt-textured with some fine sandy loam soils. In Lake Creek, the most predominant soils are sandy loam and loamy fine sand, and in Willow Creek, the predominant soils are fine sandy loams (Starks et al. in review). A rapid geomorphic assessment study in 2006 (Simon and Klimetz 2008) indicated that unstable stream channels dominate the stream networks, making a significant but unknown contribution to suspended-sediment loadings (figure 1). In addition, the FCREW contains six USDA–funded flood retarding structures installed from 1956 through 1959 (table 1). A detailed description of FCREW and the past and current research activities within this watershed is given by Steiner et al. (2008).

Soil and Water Assessment Tool Overview. The SWAT model is a continuous-time physically based watershed-scale model developed to predict the impact of land management practices on water, sediment, and agricultural chemical yields in watersheds with varying soils, land use, and management conditions over time. The SWAT model has been successfully used to evaluate nonpoint source water resource problems for a large variety of water quality applications nationally and internationally and as a result it is under continuous development to meet the needs of its many users, while maintaining a user friendly framework (Gassman et al. 2007). The SWAT model requires specific information about weather, soil properties, topography, vegetation, ponds or reservoirs (if present), groundwater, the main channel, and land management practices to simulate

Table 2
Percentage of subwatershed area in a given land use/land cover category for Cobb Creek, Lake Creek, and Willow Creek.

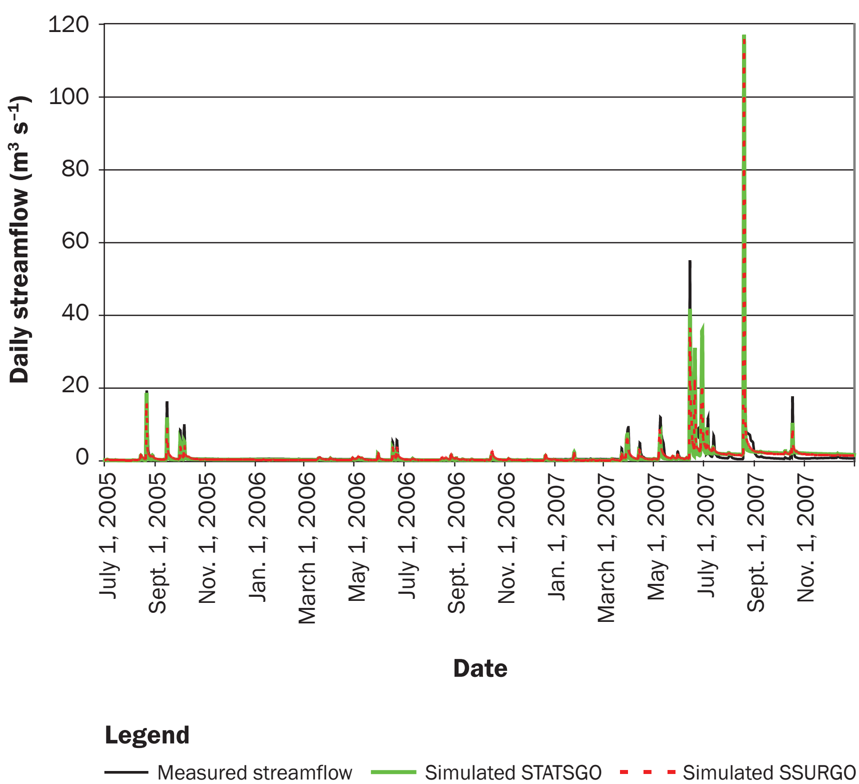
	Land use as percentage of total area (%)						
Subwatershed	Winter wheat	Pasture	Peanuts/cotton	Dryland summer crops	Forest	Water	Urban/roads
Cobb Creek	47.6	38.3	4.8	1.7	3.3	0.4	3.9
Lake Creek	38.5	37.9	9.3	4.7	5.2	0.1	4.3
Willow Creek	37.2	37.1	12.1	4.2	5.2	0.1	4.1

Table 3
Number of subbasins and hydrologic response units (HRUs) for the three subwatersheds as a function of the soil dataset resolution.

Subwatershed	Drainage area (km^2)	Subbasins	STATSGO HRUs	SSURGO HRUs
Cobb Creek	342	43	513	5,129
Lake Creek	154	24	311	1,129
Willow Creek	75	9	99	926

Notes: STATSGO = State Soil Geographic Database. SSURGO = Soil Survey Geographic Database.

Figure 2
Hydrograph for measured and simulated daily streamflow in Cobb Creek subwatershed using the USDA Agricultural Research Service's weather station network (MICRONET) rainfall dataset during the calibration period (July 2005 to December 2007).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

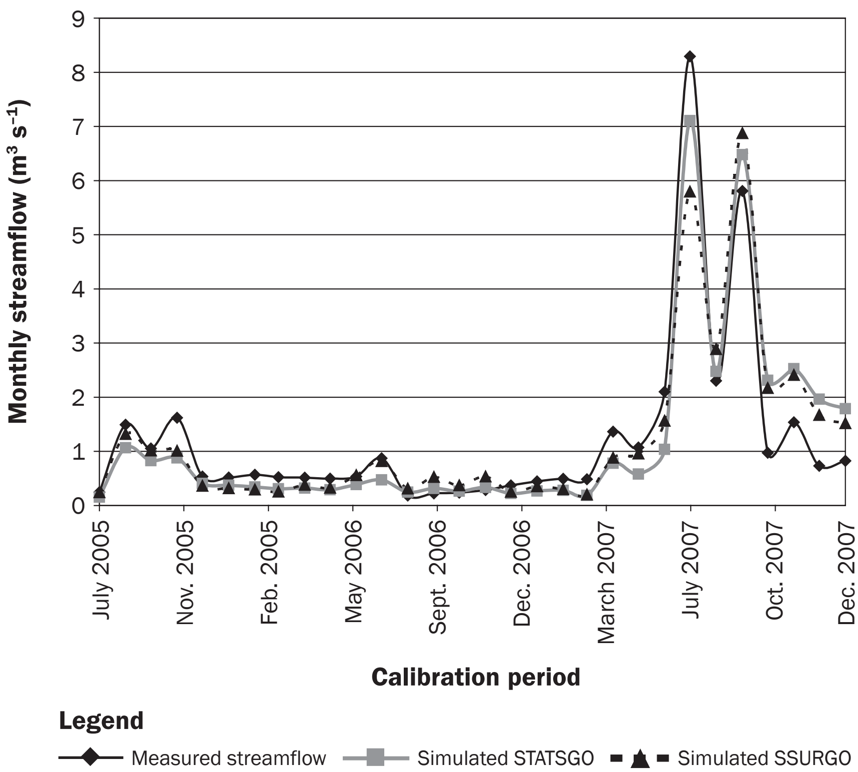
water quality and quantity (Neitsch et al. 2002a; 2002b). The model simulates a watershed by dividing it into subbasins, which are further subdivided into homogeneous hydrologic response units (HRUs). These HRUs are the product of a distinct combination of soils and land use. Components of SWAT include hydrology, weather, sedimentation and erosion, soil temperature, plant growth, nutrients, pesticides, and agricultural management (Neitsch et al. 2002a, 2002b).

Hydrologic processes simulated by SWAT include surface runoff, infiltration, evapotranspiration, lateral flow, tile drainage, percolation and deep seepage, consumptive use through pumping (if any), shallow aquifer contribution to streamflow for a nearby stream (baseflow), and recharge by seepage from surface water bodies (Neitsch et al. 2002a; 2002b). The SWAT model uses two methods to estimate surface runoff and infiltration: the Soil Conservation Service (SCS) curve number procedure (USDA SCS 1972) and the Green and Ampt infiltration method (Green and Ampt 1911). While the Green and Ampt method needs subdaily rainfall data, the SCS curve number is adjusted on a daily basis according to moisture conditions in the watershed. Evapotranspiration (ET) is calculated in the model (Arnold et al. 1998) by using either the Priestley-Taylor (Priestley and Taylor 1972), Penman–Monteith (Monteith 1965), or Hargreaves method (Hargreaves et al. 1985). The default Hargreaves method was used in this study. A detailed description of the algorithms used to simulate sedimentation and erosion, soil temperature, plant growth, nutrients, pesticides, and agricultural management is given in the SWAT Theoretical Documentation (Neitsch et al. 2002b).

The minimum weather inputs required by the SWAT model are maximum and minimum air temperature and precipitation. A detailed description of how these and other hydrologic components are computed in SWAT is given by Arnold et al. (1998) and/or the SWAT theoretical documentation (Neitsch et al. 2002b).

Figure 3

Hydrograph for measured and simulated monthly streamflow in Cobb Creek subwatershed using the USDA Agricultural Research Service's weather station network (MICRONET) rainfall dataset during the calibration period (July 2005 to December 2007).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

Weather and Streamflow Data. The SWAT model requires daily minimum and maximum temperature, relative humidity, solar radiation, and wind speed as inputs while measured streamflow data is used to calibrate and validate model streamflow simulation. Daily weather data were obtained from weather stations shown in figure 1 for the time period July 2005 through June 2008. Four sources of rainfall data were available for this study. These data were obtained from the National Weather Service's (NWS) network of Cooperative Observer Program (COOP) weather stations, the statewide Oklahoma Mesonet (McPherson et al. 2007) (herein designated as MESONET), a network of 15 USDA Agricultural Research Service meteorological stations deployed to measure air temperature, relative humidity, incoming solar radiation, rainfall, soil temperature, and volumetric soil water (Steiner et al. 2008) (herein referred to as MICRONET), and the NWS NEXRAD Stage III radar-based precipitation product (herein designated as NEXRAD) (figure 1). A detailed description of these four sources of precipitation data is given by Starks and Moriasi (2009).

Observed daily streamflow data were obtained from the three USGS stream gauges deployed in the FCREW (figure 1). The gauge on Cobb Creek was established in 1968 and has been continuously operated since that time. Stream gauges with stage recorders were established on Lake Creek in 2004 and on Willow Creek in 2005. The daily streamflow data were downloaded from the USGS Web site (USGS 2008). The length of the streamflow data record at the Lake Creek and Willow Creek sites in combination with the deployment date of the MICRONET in the FCREW limited the current study to the July 2005 through June 2008 time frame.

Other Soil and Water Assessment Tool Inputs. In addition to the weather data inputs, the SWAT model requires three GIS data layers, namely digital elevation model (DEM), soils, and land-use data. A 10 m (33 ft) DEM obtained from the USGS Seamless Data Distribution System (USGS 2007) was used in this study. The DEM is used to calculate subbasin parameters, such as slope and slope length, and to define the stream network. The resulting stream network was used to define the layout of the subbasins. The DEM also is used to obtain the stream network characteristics, such as channel slope, length, and width.

The map scale for SSURGO for the counties intersecting the three subwatersheds is 1:24,000. Therefore, the STATSGO (1:250,000) and SSURGO (1:24,000) soils datasets were used in this study. Herein, the SSURGO (1:24,000) soils dataset used in this study will simply be referred to as SSURGO and STATGO (1:250000) as STATSGO. The soils data required by SWAT and extracted from both soil databases include several physical and chemical characteristics. These data include soil hydrologic group, maximum rooting depth, soil profile depth, moist bulk density, available water capacity of the soil layer, saturated hydraulic conductivity, and soil texture data (percent clay, sand, silt, and rock fragment content) that are required in streamflow computations and others such as Universal Soil Loss Equation (USLE) soil erodibility K factor required to compute sediment yield. Chemical properties of soil such as the fraction of porosity (void space) from which anions are excluded, organic carbon content (percent soil weight), and initial concentrations of chemicals in the soil are also required in SWAT to determine transformation and transport of chemicals constituents. In addition to soil-related parameters, soil data resolution, when used in watershed models, affects other physical parameters such as slope and slope length.

Land use and land cover information were obtained from a 30 m (98 ft) Landsat 5 Thematic Mapper land cover study conducted in the area in 2005. The Landsat image was used to divide the land use into the following categories: pasture, wheat, peanuts and cotton, dry land summer crops, forest, and water. To model the effects of implementing no-till practices, winter wheat was subdivided into four equal subland uses. Using agricultural statistics data obtained from the Census of Agriculture and the National Agricultural Statistics Service for Caddo County, the peanuts and cotton category was subdivided into 60% peanuts, 40% cotton, and the dry land summer crop category was defined as grain sorghum, a typical

Table 4
Daily and monthly Nash-Sutcliffe efficiency (NSE) and percent bias (PBIAS [%]) statistics during the calibration period (July 2005 to December 2007) for a given precipitation/soil scenario for the Cobb Creek, Lake Creek, and Willow Creek subwatersheds.

	Daily		Monthly	
Sub watershed/ scenario	NSE	PBIAS (%)	NSE	PBIAS (%)
Cobb Creek NEXRAD STATSGO	0.81	–2.40	0.85	–2.30
Cobb Creek NEXRAD SSURGO	0.81	–2.10	0.83	–2.00
Lake Creek NEXRAD STATSGO	0.85	1.80	0.86	1.98
Lake Creek NEXRAD SSURGO	0.86	3.90	0.81	3.80
Willow Creek NEXRAD STATSGO	0.92	–1.20	0.89	–1.30
Willow Creek NEXRAD SSURGO	0.85	–0.70	0.92	–0.06
Cobb Creek MICRONET STATSGO	0.80	4.50	0.88	4.60
Cobb Creek MICRONET SSURGO	0.83	1.10	0.85	1.10
Lake Creek MICRONET STATSGO	0.96	–0.70	0.95	–0.80
Lake Creek MICRONET SSURGO	0.96	0.50	0.96	0.04
Willow Creek MICRONET STATSGO	0.94	5.10	0.95	5.40
Willow Creek MICRONET SSURGO	0.92	4.80	0.94	5.00
Cobb Creek MESONET STATSGO	0.68	5.10	0.81	5.00
Cobb Creek MESONET SSURGO	0.70	2.50	0.77	2.50
Lake Creek MESONET STATSGO	0.89	–4.30	0.90	–4.20
Lake Creek MESONET SSURGO	0.90	–2.50	0.88	–2.70
Willow Creek MESONET STATSGO	0.86	–2.20	0.85	–2.50
Willow Creek MESONET SSURGO	0.90	–1.90	0.83	–2.10
Cobb Creek COOP STATSGO	0.77	3.10	0.88	3.20
Cobb Creek COOP SSURGO	0.83	2.10	0.88	2.10
Lake Creek COOP STATSGO	0.76	–4.50	0.88	–4.40
Lake Creek COOP SSURGO	0.73	–4.10	0.83	–4.10
Willow Creek COOP STATSGO	0.65	4.00	0.70	3.80
Willow Creek COOP SSURGO	0.64	–5.30	0.70	–5.20

Notes: NEXRAD = National Weather Service Next Generation Radar. STATSGO = State Soil Geographic Database. SSURGO = Soil Survey Geographic Database. MICRONET = the USDA Agricultural Research Service's weather station network. MESONET = the statewide Oklahoma Mesonet. COOP = Cooperative Observer Program for the National Weather Service.

crop in the FCREW. Water was excluded. Table 2 gives detailed information on the percentage of subwatershed area for a given land use and land cover.

General crop management operations were taken from various crop guides, information provided by farmers, agronomists, animal scientists, and other farming specialists either in or familiar with the study area with an average stocking rate of 2 animal units ha^{-1} y^{-1} (0.81 animal units ac^{-1} yr^{-1}), where an animal unit is defined as a 454 kg (1,000 lb) cow or calf, or two 227 kg (500 lb) calves. Grassland management included a 180-day grazing operation, typical for the area. Both grassland and winter wheat grazing operations included daily consumed and trampled biomass and manure deposition. An auto-irrigation operation was applied only to the peanut and grain sorghum crops and was triggered when the plant-water stress factor reached 0.9 (Neitsch et al. 2002b).

Subbasin Delineation. In SWAT, the watershed is divided into subbasins and HRUs. The number of subbasins chosen depends on the size of the watershed and the amount of detail needed to meet project goals. The subbasin delineation should be detailed enough to capture significant variability. In this study, each subwatershed was manually divided into a series of subbasins with outlet points representing a USGS stream gauge, USDA Agricultural Research Service water sampling sites, or a reservoir on the stream channel. The number of subbasins was 43, 24, and 9 for Cobb Creek, Lake Creek, and Willow Creek, respectively. Each subbasin was further subdivided into HRUs, which are a function of uniform land cover and soil type. The multiple HRU method was used with threshold levels of 5% and 0% for land use and soils, respectively. The number of HRUs, for STATSGO and SSURGO soil datasets, for the respective subwatershed is given in table 3.

Model Calibration and Validation. Initial automatic sensitivity analysis conducted in this study indicated that the curve number (CN2), soil evaporation compensation coefficient (ESCO), aquifer percolation coefficient (RCH_DP), plant uptake compensation factor (EPCO), effective hydraulic conductivity in tributary channel alluvium (CH_K1), and surface runoff lag coefficient (SURLAG) were the most sensitive parameters in SWAT for this study. Although soil available water capacity (SOL_AWC) and soil saturated hydraulic conductivity (SOL_K [mm h^{-1}]) were also determined as sensitive, they were not calibrated to avoid introducing

Table 5
Calibration parameter values obtained for a project calibrated using a given precipitation/soil dataset scenario in the three subwatersheds located in the Fort Cobb Reservoir watershed in Oklahoma.

	Calibration parameter values					
Sub watershed/scenario	CN2	ESCO	RCH_DP	EPCO	CH_K1 (mm h^{-1})	SURLAG
Cobb Creek NEXRAD STATSGO	47 to 69	0.96	0.01	0.01	0.5	1
Cobb Creek NEXRAD SSURGO	35 to 73	0.60	0.01	0.01	0.5	1
Lake Creek NEXRAD STATSGO	52 to 76	0.65	0.01	0.10	0.5	4
Lake Creek NEXRAD SSURGO	35 to 77	0.25	0.30	0.30	300.0	4
Willow Creek NEXRAD STATSGO	48 to 70	0.20	0.53	0.30	0.5	4
Willow Creek NEXRAD SSURGO	35 to 66	0.70	0.70	0.10	150.0	1
Cobb Creek MICRONET STATSGO	44 to 64	0.90	0.05	0.01	0.5	1
Cobb Creek MICRONET SSURGO	35 to 68	0.20	0.03	0.01	0.5	1
Lake Creek MICRONET STATSGO	49 to 71	0.85	0.50	1.00	0.5	4
Lake Creek MICRONET SSURGO	35 to 72	0.40	0.65	1.00	150.0	4
Willow Creek MICRONET STATSGO	46 to 67	0.60	0.70	0.90	0.5	1
Willow Creek MICRONET SSURGO	35 to 65	0.60	0.90	0.80	300.0	4
Cobb Creek MESONET STATSGO	44 to 64	0.82	0.05	0.01	0.5	1
Cobb Creek MESONET SSURGO	35 to 65	0.30	0.30	0.01	0.5	1
Lake Creek MESONET STATSGO	49 to 71	0.10	0.60	1.00	0.5	6
Lake Creek MESONET SSURGO	35 to 72	0.01	0.99	1.00	200.0	4
Willow Creek MESONET STATSGO	46 to 67	0.01	0.95	1.00	0.5	1
Willow Creek MESONET SSURGO	35 to 65	0.01	1.00	1.00	300.0	4
Cobb Creek COOP STATSGO	47 to 69	0.86	0.01	0.01	0.5	1
Cobb Creek COOP SSURGO	35 to 69	0.25	0.10	0.01	0.5	1
Lake Creek COOP STATSGO	52 to 76	0.10	0.12	0.30	0.5	6
Lake Creek COOP SSURGO	35 to 77	0.85	0.60	1.00	150.0	6
Willow Creek COOP STATSGO	46 to 67	0.30	0.90	0.60	0.5	4
Willow Creek COOP SSURGO	35 to 69	0.01	1.00	1.00	300.0	4

Notes: CN2 = Curve number condition II. ESCO = soil evaporation compensation coefficient. RCH_DP = aquifer percolation coefficient. EPCO = plant uptake compensation factor. CH_K1 = effective hydraulic conductivity in tributary channel alluvium. SURLAG = surface runoff lag coefficient. NEXRAD = National Weather Service Next Generation Radar. STATSGO = State Soil Geographic Database. SSURGO = Soil Survey Geographic Database. MICRONET = the USDA Agricultural Research Service's weather station network. MESONET = the statewide Oklahoma Mesonet. COOP = Cooperative Observer Program for the National Weather Service.

Table 6
Percent of total subwatershed area containing respective soil hydrologic groups in Cobb Creek, Lake Creek, and Willow Creek subwatersheds.

	Hydrologic group (percent of area)			
Subwatershed/soils	A	B	C	D
Cobb Creek STATSGO	9	91	0	0
Cobb Creek SSURGO	5	68	24	3
Lake Creek STATSGO	16	84	0	0
Lake Creek SSURGO	14	68	18	0
Willow Creek STATSGO	39	61	0	0
Willow Creek SSURGO	9	67	24	0

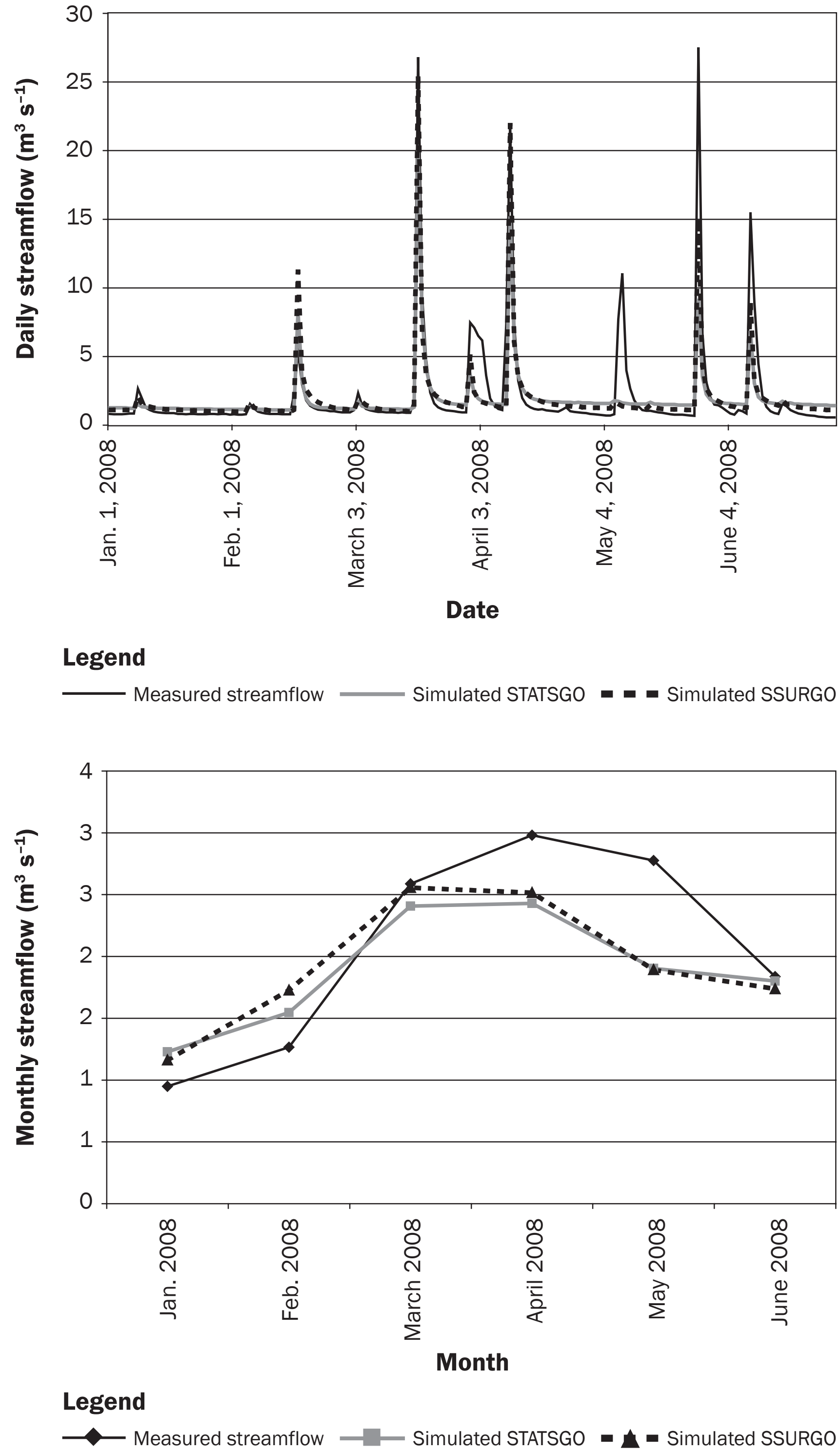
Notes: STATSGO = State Soil Geographic Database. SSURGO = Soil Survey Geographic Database.

biases on the soil datasets used. The CN2 is a function of the soil's permeability, antecedent soil moisture conditions, and land use, and varies from 30 to 100 inclusive. Surface runoff increases with an increase in CN2. The ESCO adjusts the depth distribution of soil evaporation to meet soil evaporative demand and varies between 0.01 and 1.0, inclusive. As the value of ESCO is reduced, the model is able to evaporate more water from deeper layers in the soil profile. The EPCO adjusts plant water uptake and varies between 0.01 and 1.00, inclusive. As EPCO approaches 0.0, the model limits uptake of water by the plant to the upper portions of the root zone. The RHC_DP describes the fraction of percolation from the root zone that recharges the deep aquifer and varies between 0.0 (no percolation) and 1.0 (all the water percolating from the root zone reaches the deep aquifer). The CH_K1 is the effective hydraulic conductivity (mm h^{-1}) of the channel alluvium and controls transmission losses from surface runoff as it flows through the tributary to the main channel in the subbasin. The SURLAG is the surface runoff lag coefficient and provides a storage factor in the model that allows runoff to reach a subbasin outlet when the time of concentration is greater than one day. As SURLAG decreases, the amount of water reaching the outlet decreases.

Manual streamflow calibration (July 2005 to December 2007) was accomplished by increasing or reducing the calibration parameter values, one parameter at a time, until the calibration objective functions described below were met; default values were used for the rest of the parameters. Although observed values are not available for each of the water balance components, the average annual values must be consistent with expected values for the region, as impacted by the individual land-use categories. This is a separate consistency or reality check with data to ensure that land use categories and overall water balance reflect local conditions (Donigian 2002). In this study, the calibrations were also constrained such that the simulated ET and biomass values were realistic and representative of the study area in order to minimize the potential for false positive outcomes (obtaining good statistics for the wrong reasons). The biomass values were obtained by calibrating the biomass-energy ratio (BIO_E) ([kg ha^{-1}]/[MJ m^{-2}]). The BIO_E is the amount of dry biomass produced per unit intercepted solar radiation in ambient CO_2 and varies between 10 and 90, inclusive. The greater the BIO_E, the greater the potential increase in total plant biomass on a given day (Neitsch et al. 2002b). According to Hanson (1991), the mean actual annual ET of this region during the study period was about 88%. A target range was set for ET values within 10% of the regions' mean annual ET. Ranges of total annual biomass production (in metric tons) were established using agricultural statistics, extension reports, scientific literature, and interviews with agronomic experts. Biomass production ranges in metric tons (US tons) used in this study were 1.8 to 2.7 t (2.0 to 3.0 tn) for cotton, 4.4 to 6.6 t (4.9 to 7.3 tn) for sorghum, 8.1 to 9.1 t (8.9 to 10.0 tn) for peanuts, 4 to 6 t (4.4 to 6.6 tn) for winter wheat, 3 to 7 t (3.3 to 7.7 tn)

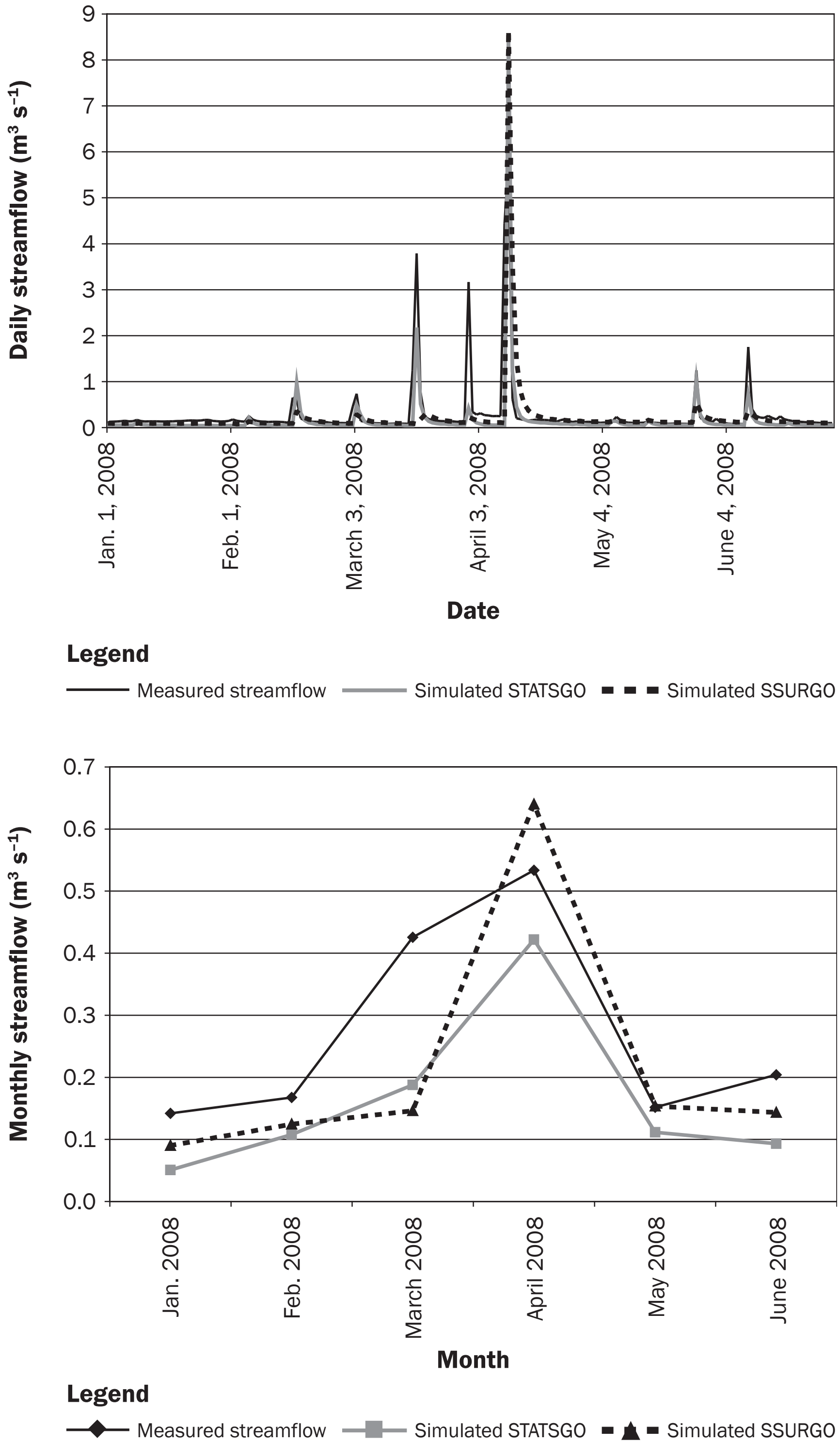
Figure 4

Hydrograph for measured and simulated (a) daily and (b) monthly streamflow in Cobb Creek subwatershed using the National Weather Service Next Generation Radar (NEXRAD) rainfall dataset during the validation period (January 2008 to June 2008).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

Figure 5
Hydrograph for measured and simulated (a) daily and (b) monthly streamflow in Willow Creek subwatershed using NEXRAD rainfall dataset during the validation period (January 2008 to June 2008).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

for pasture/grassland, and 5 to 10 t (5.5 to 11.0 tn) for forest. A wider range was given to the pasture/grass and forest categories due to large variation in species composition. The forest category is somewhat problematic because limited information is available for the study area. Actual biomass values could be very different from that indicated above. No other constraints were placed on the model during calibration.

Model validation is an extension of the calibration process. Its purpose is to assure that the calibrated model properly assesses all the variables and conditions that affect model results for a component of interest, in this case streamflow. In this study, validation was carried out by performing streamflow simulation using the calibration parameter values for a different simulation period (January 2008 to June 2008) and an independent dataset of the observed daily streamflow. The goodness of fit between measured and simulated values was assessed both on a monthly and daily time step to provide a reasonable measure of confidence in using the model. The short validation period was due to the fact that these were the only USGS daily streamflow data available at the outlet of the three subwatersheds. The daily discharge records were designated "approved" for the period of record by the USGS for the Cobb Creek and Willow Creek watersheds, but were designated "provisional" for Lake Creek from March through June. Subdaily records were obtained for the provisional data and used to verify the daily mean values reported by the USGS. It should be noted that provisional data is subject to change.

Model credibility is based on the ability of a single set of parameters to represent the entire range of observed data (calibration and validation). If a single parameter set can reasonably represent a wide range of events, then this is a form of validation. The monthly model performance statistics during the validation period was used to determine the model streamflow simulation accuracy.

Model Performance Evaluation Methods. Model performance, defined herein as the ability of a model to reproduce field observations during the calibration/validation period, is most often evaluated through both qualitative and quantitative measures, involving both graphical comparisons and statistical tests. Herein, monthly hydrographs are used to identify model bias and differences in the timing and magnitude of

Table 7

Daily and monthly Nash-Sutcliffe efficiency (NSE) and percent bias (PBIAS [%]) statistics during the validation period (January 2008 to June 2008) for a given precipitation/soil scenario for the Cobb Creek, Lake Creek, and Willow Creek subwatersheds. Bold values indicate cases when the model attained at least a satisfactory performance rating according to Moriasi et al. (2007).

	Daily		Monthly	
Sub watershed/scenario	NSE	PBIAS (%)	NSE	PBIAS (%)
Cobb Creek NEXRAD STATSGO	**0.65**	**8.90**	**0.65**	**8.70**
Cobb Creek NEXRAD SSURGO	**0.77**	**6.70**	**0.64**	**6.50**
Lake Creek NEXRAD STATSGO	**0.58**	36.30	0.28	36.30
Lake Creek NEXRAD SSURGO	0.47	46.10	–0.27	51.00
Willow Creek NEXRAD STATSGO	0.47	40.30	0.30	40.30
Willow Creek NEXRAD SSURGO	0.25	31.00	0.22	30.99
Cobb Creek MICRONET STATSGO	**0.63**	**–14.70**	0.40	**–14.80**
Cobb Creek MICRONET SSURGO	**0.69**	**–3.90**	**0.63**	**–4.00**
Lake Creek MICRONET STATSGO	**0.62**	**24.50**	0.46	**24.50**
Lake Creek MICRONET SSURGO	0.39	40.00	–0.01	40.00
Willow Creek MICRONET STATSGO	**0.61**	40.60	0.09	40.60
Willow Creek MICRONET SSURGO	0.36	54.30	–0.36	54.30
Cobb Creek MESONET STATSGO	0.38	**6.60**	0.02	**6.60**
Cobb Creek MESONET SSURGO	0.41	**15.90**	–0.10	**15.90**
Lake Creek MESONET STATSGO	0.28	55.10	–0.81	55.10
Lake Creek MESONET SSURGO	0.29	59.20	–0.83	59.20
Willow Creek MESONET STATSGO	0.39	61.80	–0.84	61.80
Willow Creek MESONET SSURGO	0.27	62.90	–0.83	62.90
Cobb Creek COOP STATSGO	0.39	–28.30	–0.04	–28.30
Cobb Creek COOP SSURGO	0.31	**–5.50**	0.48	**–5.50**
Lake Creek COOP STATSGO	0.17	**23.80**	0.18	**23.80**
Lake Creek COOP SSURGO	0.15	38.70	–0.25	38.70
Willow Creek COOP STATSGO	0.18	41.60	–0.56	41.40
Willow Creek COOP SSURGO	0.10	56.20	–1.10	56.20

Notes: NEXRAD = National Weather Service Next Generation Radar. STATSGO = State Soil Geographic Database. SSURGO = Soil Survey Geographic Database. MICRONET = the USDA Agricultural Research Service's weather station network. MESONET = the statewide Oklahoma Mesonet. COOP = Cooperative Observer Program for the National Weather Service.

peak flows for various precipitation and soil combination scenarios.

The statistical performance criteria used in this study are the Nash-Sutcliffe efficiency (NSE) (Nash and Sutcliffe 1970) and percent bias (PBIAS [%]) (Gupta et al. 1999). The NSE indicates how well the plot of observed versus simulated data fits the 1:1 line. The NSE ranges between $-\infty$ and 1.0 (1 inclusive) with an NSE of 1 being the optimal value. Although, there is no established performance rating for the commonly used statistics in watershed modeling, those recommended by Moriasi et al. (2007) were used in this study because they were developed in part due to the need for standardized model evaluation guidelines to support watershed modeling in CEAP–WAS for watersheds such as the FCREW. According to Moriasi et al. (2007), a model is considered calibrated if the NSE ≥ 0.65 on a monthly time step. During the validation period, NSE values $0.75 < \text{NSE} \leq 1.00$ are considered very good, $0.65 < \text{NSE} \leq 0.75$ are considered good, $0.50 < \text{NSE} \leq 0.65$ are considered satisfactory, and $\text{NSE} \leq 0.50$ are considered unsatisfactory (Moriasi et al. 2007). Values ≤ 0.0 indicate that the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance.

Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smaller than their observed counterparts (Gupta et al. 1999). The optimal value of PBIAS is 0.0, with low magnitude values indicating accurate model simulation. Positive values indicate model underestimation bias, and negative values indicate model overestimation bias. According to Moriasi et al. (2007), the model is considered calibrated if simulated streamflow is within 10% of the observed streamflow (i.e., $\text{PBIAS} \leq \pm 10\%$). During the validation period, Donigian et al. (1983) (adapted by Moriasi et al. 2007) consider $\text{PBIAS} < \pm 10\%$ very good, $\pm 10 \leq \text{PBIAS} < \pm 15$ good, $\pm 15 \leq \text{PBIAS} < \pm 25$ satisfactory, and $\text{PBIAS} \geq 25\%$ unsatisfactory.

Results and Discussion

Model Calibration and Validation. Figures 2 and 3 illustrate streamflow simulation performance on a daily and monthly time step for Cobb Creek subwatershed using the MICRONET precipitation data during the calibration period. These figures depict satisfactory calibration performance for this watershed. With the exception of the general daily and monthly differences, all the hydrographs for the 24 (3 subwatersheds, 2 soil datasets, 4 precipitation data types)

Table 8

Simulated average annual water budget for the three subwatersheds for a given precipitation/soil dataset scenario. Bold columns indicate the simulated water budget component values whose differences due to the soil dataset resolution, if large, could lead to significant differences in simulated sediments and/or nutrients, which could lead to substantially different applications and costs of conservation practices.

Subwatershed/scenario	Prec (mm)	ET (mm)	SurQ (mm)	GWQ (mm)	LatQ (mm)	TLoss (mm)	PLoss (mm)	TWY (mm)	Dp Rch (mm)
Cobb Creek NEXRAD STATSGO	723	598	**37**	52	10	0	3	97	**2**
Cobb Creek NEXRAD SSURGO	723	611	**31**	48	29	0	2	105	**2**
Cobb Creek MICRONET STATSGO	812	666	**34**	51	13	0	3	93	**5**
Cobb Creek MICRONET SSURGO	812	694	**43**	33	30	0	2	104	**4**
Cobb Creek MESONET STATSGO	874	722	**32**	52	15	0	2	96	**5**
Cobb Creek MESONET SSURGO	874	725	**22**	43	36	0	2	99	**19**
Cobb Creek COOP STATSGO	871	728	**36**	53	13	0	3	99	**0**
Cobb Creek COOP SSURGO	871	752	**22**	50	34	0	2	104	**6**
Lake Creek NEXRAD STATSGO	697	645	**33**	22	16	0	3	67	**1**
Lake Creek NEXRAD SSURGO	697	640	**39**	16	28	14	0	69	**11**
Lake Creek MICRONET STATSGO	787	680	**38**	12	19	0	4	65	**12**
Lake Creek MICRONET SSURGO	787	698	**41**	8	32	14	4	63	**15**
Lake Creek MESONET STATSGO	936	834	**31**	11	24	0	2	63	**16**
Lake Creek MESONET SSURGO	936	787	**51**	2	41	19	3	72	**40**
Lake Creek COOP STATSGO	871	816	**31**	20	20	0	3	67	**3**
Lake Creek COOP SSURGO	871	761	**43**	9	36	15	5	68	**36**
Willow Creek NEXRAD STATSGO	673	647	**15**	10	23	0	0	48	**11**
Willow Creek NEXRAD SSURGO	673	594	**29**	17	16	11	0	51	**41**
Willow Creek MICRONET STATSGO	750	686	**16**	8	26	0	0	50	**18**
Willow Creek MICRONET SSURGO	750	676	**20**	4	33	8	0	48	**15**
Willow Creek MESONET STATSGO	820	730	**19**	2	30	0	0	51	**31**
Willow Creek MESONET SSURGO	820	713	**25**	0	37	11	0	51	**42**
Willow Creek COOP STATSGO	871	789	**15**	4	31	0	0	50	**40**
Willow Creek COOP SSURGO	871	817	**16**	14	36	9	0	57	**14**

Notes: Prec = precipitation. ET = evapotranspiration. SurQ = surface runoff. GWQ = groundwater. LatQ = lateral flow. TLoss = transmission losses. PLoss = pond losses. TWY = total water yield (streamflow). Dp Rch = deep aquifer recharge. NEXRAD = National Weather Service Next Generation Radar. STATSGO = State Soil Geographic Database. SSURGO = Soil Survey Geographic Database. MICRONET = the USDA Agricultural Research Service's weather station network. MESONET = the statewide Oklahoma Mesonet. COOP = Cooperative Observer Program for the National Weather Service.

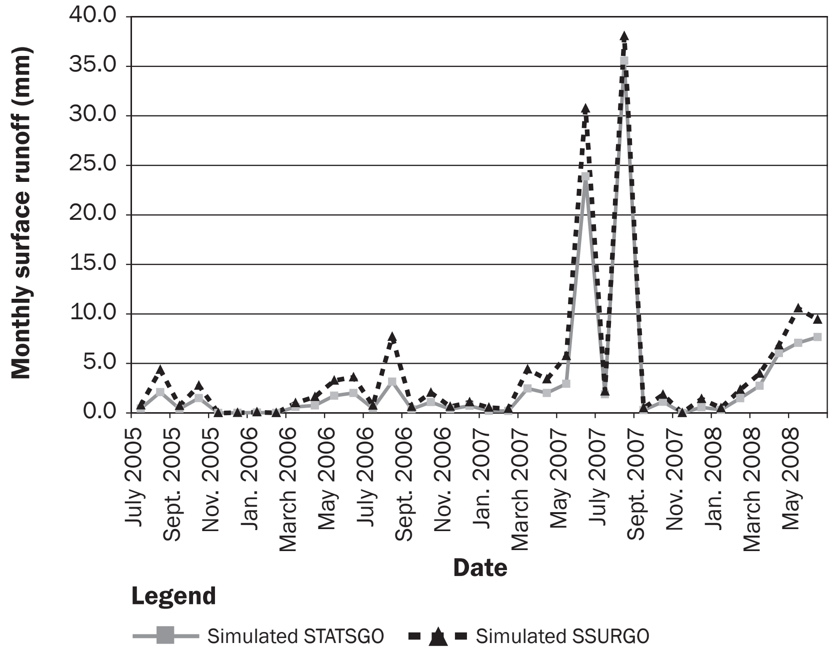
projects were satisfactory. Model streamflow calibration statistics are given in table 4. The general monthly graphical and statistical calibration criteria indicate that the model was well calibrated (Moriasi et al. 2007) for all the soil and precipitation dataset scenarios in the three subwatersheds. There were no large differences in the model performance statistics due to using the higher resolution SSURGO soil datasets compared to STATSGO across subwatersheds, irrespective of the rainfall dataset used. However, the NEXRAD and MICRONET precipitation, and STATSGO and SSURGO soils combination consistently yielded better statistics (e.g., $0.81 \leq$ NSE ≤ 0.96, monthly) compared with MESONET and COOP precipitation, and STATSGO and SSURGO soils combination ($0.70 \leq$ NSE ≤ 0.90, monthly) throughout the three subwatersheds (table 4).

The values for the calibration parameters are given in table 5. Unless stated, the following discussion of the differences in the values of the calibration parameter values is with regard to the soil data resolution only, irrespective of the precipitation dataset used. With the exception of Cobb Creek subwatershed, there were large variations in CH_K1 with regard to soil data resolution. With SSURGO soil datasets, higher apparent transmission losses were allowed in order to get simulated streamflow to fit measured streamflow in both Lake Creek and Willow Creek subwatersheds. The CN2 values' ranges were wider for the SSURGO than for the STATSGO soils datasets (table 5) primarily because the SSURGO soils datasets contain more soil hydrologic groups (table 6). There were small variations in SURLAG between STATSGO and SSURGO datasets across subwatersheds as a function of the precipitation dataset used to calibrate the model. However, in most cases the SURLAG value was higher in Lake Creek and Willow Creek subwatersheds than in Cobb Creek subwatershed because Lake Creek and Willow Creek are small-sized subwatersheds (table 3), and hence larger SURLAG values imply more surface runoff reaches the outlet. Little difference in deep recharge (RCH_DP) as a function of soil dataset resolution was observed in the Cobb Creek subwatershed. However, there were significant differences in RCH_DP values for the two soil datasets, with the higher spatial resolution SSURGO soil dataset yielding higher RCH_DP values than those calibrated using the STATSGO soil dataset in the Lake Creek and Willow Creek subwatersheds (table 5). This implies that in the Lake Creek and Willow Creek subwatersheds the RCH_DP values calibrated using the SSURGO soil dataset allowed more water to reach the deep aquifer than those calibrated using the STATSGO soil dataset. In most cases, large variations in ESCO as a function of the soil dataset used were observed within the subwatersheds. There were little or no differences in EPCO values across the three subwatersheds when NEXRAD, MICRONET, and MESONET precipitation datasets were used. However, in the Lake Creek and Willow Creek subwatersheds, use of the COOP precipitation dataset in conjunction with the SSURGO soils dataset resulted in significantly higher EPCO values than when the STATSGO soils dataset was used. This implies that plant water uptake was from lower portions of the root zone for the SSURGO soils datasets compared to the STATSGO soils datasets.

Figures 4 and 5 are the validation period streamflow hydrographs on a daily and monthly time step using the NEXRAD precipitation dataset for the Cobb Creek subwatershed and Willow Creek subwatershed, respectively. These figures were selected from the many project scenarios to illustrate the graphical model streamflow simulation performance. In general, there were no significant differences in model performance as a function of the soil data resolution. However, it can be inferred from figures 4 and 5 that the model fitted the measured streamflow data better in the Cobb Creek subwatershed than in the Willow Creek subwatershed. Table 7 presents the validation streamflow simulation statistics, with bold values indicating when the model attained at least a satisfactory performance rating according to Moriasi et al. (2007). Based on these results (table 7), the model did not perform as well during the short validation period as it did during the calibration period, especially on a monthly time step. A possible reason is the use of only six-month data available during the validation period, in which the model errors are magnified because of the few data points (six) used in the performance evaluation. It is recommended that a longer validation time be used for data that encompasses average, wet, and dry years, which cover a sufficient range of hydrologic events to activate all model constituent processes just like during calibration. The statistical results did not indicate any significant differences in streamflow simulation accuracy due to the differences in resolution of the soil database

Figure 6

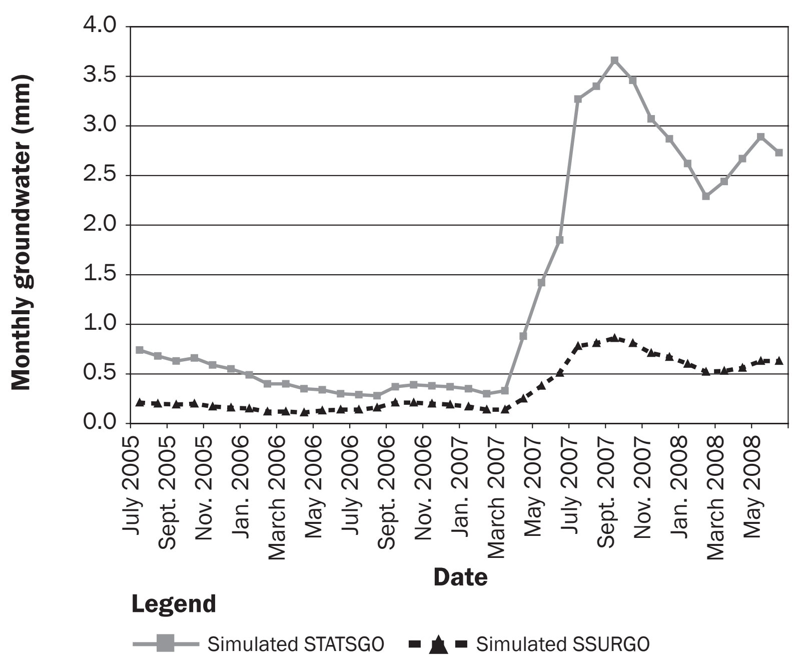
The SWAT2005 simulated monthly surface runoff using the National Weather Service's network of Cooperative Observer Program (COOP) precipitation data type for STATSGO and SSURGO soils datasets in Lake Creek subwatershed (July 2005 to June 2008).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

Figure 7

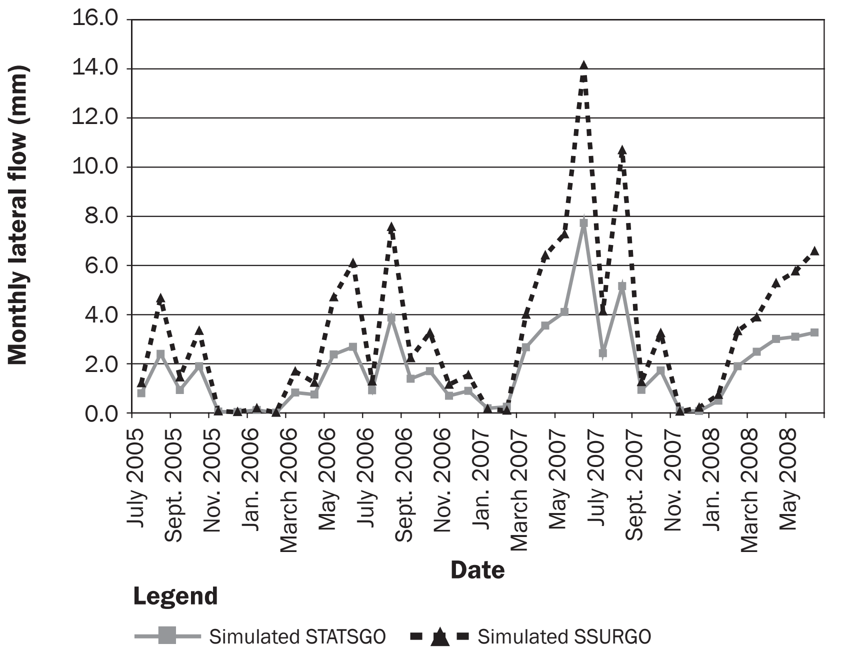
The SWAT2005 simulated monthly groundwater using the National Weather Service's network of Cooperative Observer Program (COOP) precipitation data type for STATSGO and SSURGO soils datasets in Lake Creek subwatershed (July 2005 to June 2008).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

Figure 8

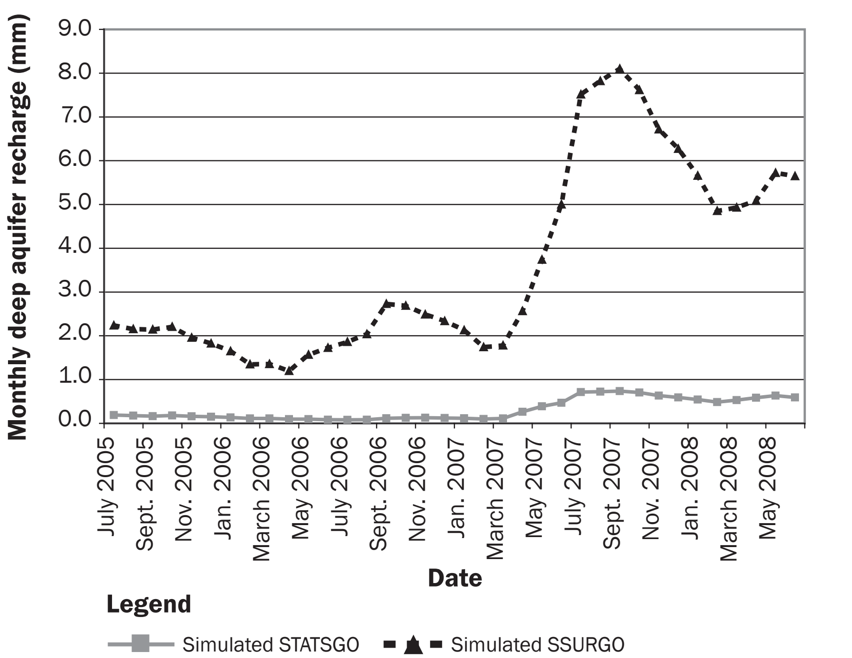
SWAT2005 simulated monthly lateral flow using the National Weather Service's network of Cooperative Observer Program (COOP) precipitation data type for STATSGO and SSURGO soils datasets in Lake Creek subwatershed (July 2005 to June 2008).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

Figure 9

SWAT2005 simulated monthly deep aquifer recharge using the National Weather Service's network of Cooperative Observer Program (COOP) precipitation data type for STATSGO and SSURGO soils datasets in Lake Creek subwatershed (July 2005 to June 2008).



Notes: STATSGO = the State Soil Geographic Database. SSURGO = the Soil Survey Geographic Database.

used. However, the model exhibited the best simulation accuracy (–0.04 ≤ NSE ≤ 0.65) (±4.00% ≤ PBIAS ≤ ±28.30%) in the largest size subwatershed (Cobb Creek), which had the largest discharges (figure 4), and the model exhibited the poorest simulation accuracy (–1.10 ≤ NSE ≤ 0.30) (±30.99% ≤ PBIAS ≤ ±62.90%) in the smallest subwatershed (Willow Creek), which had the smallest discharge (figure 5). It was also observed that the finer spatial resolution NEXRAD and MICRONET precipitation datasets resulted in better streamflow simulation accuracies (–0.36 ≤ NSE ≤ 0.65) (±4.00% ≤ PBIAS ≤ ±54.30%) compared with using the coarser spatial resolution MESONET and COOP precipitation datasets (–1.10 ≤ NSE ≤ 0.48) (±5.50% ≤ PBIAS ≤ ±62.90%) (table 7).

Effects of Soil Data Resolution and Precipitation Data Type on Simulated Water Balance Components. The simulated average annual water balance component values for the three subwatersheds for each of the precipitation and soil dataset combinations are given in table 8. Whereas there were no significant differences on model streamflow simulation accuracy in using the higher resolution SSURGO compared to the STATSGO soils database for a given precipitation dataset, the resultant calibration parameter values (table 5) led to some significant differences in water balance component values, depending on the precipitation dataset used and subwatershed (table 8). Figures 6, 7, 8, and 9 are graphical representations of simulated monthly surface runoff, groundwater, lateral flow, and deep aquifer recharge amounts using STATSGO and SSURGO soil datasets and COOP precipitation data type, respectively, in Lake Creek. These figures were selected from the many project scenarios to illustrate graphically the impact of soil resolution on simulated water balance components. These graphs show that there were some significant differences in the simulated monthly groundwater, lateral flow, and deep aquifer recharge especially during wet years (2007 and 2008). Although surface runoff does not seem to be significantly different from the visual assessment, it appeared that the SWAT2005 model always simulated higher surface runoff when using the SSURGO soils database than when using the STATSGO soils database to generate the soils inputs.

Surface runoff and deep aquifer recharge components have a direct impact on the simulated surface and groundwater quality components such as sediments and nutrients. Using the NEXRAD precipitation dataset, there were small differences in simulated surface runoff as a function of soil resolution, except in the Willow Creek subwatershed where the SSURGO soils dataset yielded 14 mm (0.55 in) more runoff than the STATSGO soil dataset. For the MICRONET precipitation dataset, there were small differences in simulated surface runoff as a function of soil resolution across the three subwatersheds. However, when using the coarse resolution MESONET and COOP precipitation datasets, there were greater differences in simulated surface runoff as a function of soil dataset resolution, except in the Willow Creek subwatershed where the SSURGO soil dataset yielded 6 mm (0.24 in) and 1 mm (0.04 in), respectively, more runoff than the STATSGO soil dataset. The greatest difference in simulated runoff amount as a function of soil dataset resolution occurred in the Lake Creek subwatershed using the MESONET precipitation data where the SSURGO soil dataset yielded 20 mm (0.79 in) more runoff than the STATSGO soil dataset.

Regarding deep aquifer recharge, there were generally smaller differences as a function of soil resolution using the higher spatial resolution NEXRAD and MICRONET precipitation datasets than using the coarser resolution MESONET and COOP precipitation datasets. The smallest difference in simulated deep aquifer recharge as a function of soil data resolution was in the Cobb Creek subwatershed using the NEXRAD precipitation dataset. The greatest difference in simulated deep aquifer recharge as a function of soil data resolution was in the Lake Creek subwatershed using the COOP precipitation dataset, where the SSURGO soil dataset yielded 33 mm (1.30 in) more deep aquifer recharge than the STATSGO soil dataset.

Large differences in the simulated surface runoff and deep aquifer recharge due to using the SSURGO or STATSGO soils datasets could lead to significant differences in the simulated water quality components, such as sediments and nutrients. Significant differences in simulated sediments and/or nutrients could lead to substantially different applications and costs of conservation practices. This is especially important because the current study is part of the CEAP–WAS whose objective is to quantify interactive effects of variable climate, dynamic land use, and land management, particularly conservation practices, on surface and subsurface water resources for Upper Washita River subwatersheds. A study by Gowda and Mulla (2005) yielded comparable findings. In a study to quantify the effect of using STATSGO and SSURGO soil databases on flow, sediment, nitrate, and phosphorus using the ADAPT model, Gowda and Mulla (2005) determined that although there were no statistical differences regarding calibration in using either soil database, evaluation of alternative management practices indicated that STATSGO–based simulated annual nitrate losses were consistently higher than when the SSURGO dataset was used in the simulations and vice versa for predicted phosphorus losses. That result led to an important issue in the development of the total maximum daily loads for impaired watersheds, where conflicting interests of stakeholders may lead them to choose a soil database that supports their interests.

Based on the results of this study, an important question to ask regarding implications for watershed modeling is, "which of the soils-precipitation datasets combination is the preferred one?" Since we did not have measured values for most of the water balance components, this was a difficult question to address in this study. Thus, our recommendation would be to use both soils datasets in combination with high resolution precipitation datasets and report the results as a range of outputs for the simulated water balance of interest. This recommendation is essential in order to avoid heated debate over which database should be selected in developing total maximum daily loads for impaired watersheds consisting of stakeholders with conflicting interests. It is also important to note that although one might argue that SSURGO gives more detailed soils information, use of SSURGO soils dataset might not be practical for large watersheds of the order of 5,000 km^2 (1,930 mi^2) because it would require a considerable amount of time on a modeler's part to set up a project with so many HRUs as a result of the more-detailed soils information.

Summary and Conclusions

The SWAT model, a daily continuous-time physically based watershed-scale model, was calibrated and validated for streamflow using discharges from the Cobb Creek, Lake Creek, and Willow Creek subwatersheds within the FCREW in Oklahoma. The model was calibrated and validated using STATSGO and SSURGO soil datasets for each of the four types of precipitation datasets that included the NEXRAD, MICRONET, MESONET, and COOP. The calibrated and validated model was used to (1) investigate the combined effect of the spatial resolution of soils and precipitation datasets on SWAT2005 streamflow simulation accuracy and calibration parameters and (2) to determine the soil-precipitation datasets combinations that result in the most representative streamflow calibration parameter values in the three subwatersheds. For the calibration period, the observed and predicted streamflow discharges were in good to very good agreement irrespective of the soil database used to derive soil input. However, the higher resolution NEXRAD and MICRONET precipitation datasets yielded slightly better model performance statistics than the MESONET and COOP precipitation datasets, regardless of the soil dataset used to generate the soil input. During the short validation period, the model did not perform as well as during the calibration period irrespective of the soil database used. However, model performance was better for the larger Cobb Creek subwatershed with the performance decreasing with decreasing size of the subwatershed. As in the calibration period, the higher resolution precipitation datasets yielded better model performance statistics. The differences between the streamflow calibration parameter values resulting from using the SSURGO and STATSGO datasets varied substantially depending on the parameter, the rainfall dataset used, and the subwatershed. Whereas there were no significant differences on model streamflow simulation accuracy in using the higher resolution SSURGO soils dataset compared with the STATSGO soils dataset for a given precipitation dataset, the respective resultant calibration parameter values led to some significant differences in the values of the simulated water balance components, depending on the precipitation dataset used and the study subwatershed. Generally, the coarser resolution MESONET and COOP precipitation datasets resulted in greater differences in simulated surface runoff and deep aquifer recharge values as a function of the soil dataset resolution compared with the higher spatial resolution NEXRAD and MICRONET precipitation datasets. Based on the results of this study, it is recommended that both SSURGO and STATSGO datasets be used in combination with the highest spatial resolution precipitation dataset obtainable. The resulting simulated water balance of interest should then be reported as a range.

Acknowledgements

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