SWAT2005: Geo-referenced Tile Flow and Pothole Component Application to the South Fork of the Iowa River

USDA Grassland Soil & Water Research Lab

Agricultural Research Service

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Background

•The Natural Resources Conservation Service (NRCS) and Agricultural Research Service (ARS) are quantifying the benefits of the USDA conservation programs, under the Conservation Effects Assessment Program (CEAP). The South Fork of the Iowa River (78000 ha) is an ARS Benchmark Watershed that will support a watershed-scale assessment of environmental effects of conservation practices.

•The South Fork watershed is one of the more intensively managed agricultural areas in the Midwest. There are nearly 100 confined animal feeding operations in the watershed, most producing swine. Two major sub-basins, Tipton Creek (20000 ha) and the upper South Fork (25600 ha), contain most of the livestock.

•Approximately 80% of the watershed is tile drained. Subsurface drainage systems can be a significant source of pollutants.

•The SWAT2005 (Soil and Water Assessment Tool, version 2005) water quality model is being used to assess non-point source pollution within this watershed and to conduct agricultural management scenario comparison. The model's simulation accuracy will be evaluated with hydrologic and nutrient load data collected from the South Fork of the Iowa River watershed.

Objective 1: Evaluate Swat2005 model accuracy in simulating streamflow with the modified tile drain component and its impact on the SFW hydrologic yield

Objective 2: Demonstrate the importance of using calibration periods that represent the entire range of precipitation events.

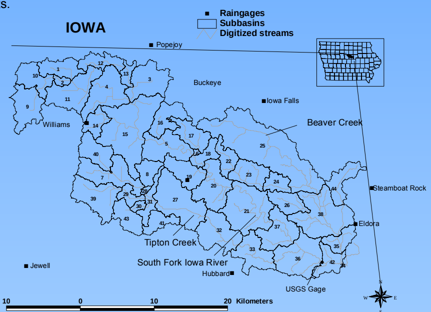


Figure 1. Distribution of rain and temperature gauges, USGS gauge and subbasins in the SFW.

Input Data

•AVSWAT-X: used to manage SSURGO data from Hardin, Hamilton, Franklin and Wright counties.

•The watershed was divided into 44 subbasins based on 30 m grid DEM.

•The measured discharge was from the USGS gauging station (site 05451210) near New Providence, IA.

•Daily precipitation totals where obtained from the NOAA and the NCDC from eight raingauge stations within and adjacent to the watershed (Fig. 1).

•Subsurface tile drains are present in nearly 80% of the watershed where there are intrinsically poorly drained soils. These tiles hasten the routing of water from the watershed.

•Two years of NASS crop-cover data (2002-2003) were overlaid to identify dominant crop rotations within the watershed (Table 1). The combination of land use and soil type resulted in 727 HRUs.

Table 1. Land use classification for the SFW.

Land Use	Percent of Watershed
Soybean/Corn-manure	23.6
Soybean/Corn-no manure	18.1
Corn/Soybean-manure	17.7
Corn/Soybean-no manure	14.0
Continuous Corn-manure	8.3
Urban	7.8
Pasture	4.1
Continuous Corn-no manure	4.1
Forest	1.9
Wetland	0.24
Water	0.23

Model Calibration

•Parameters adjusted for calibration are listed in Table 2; all others were kept at the default values suggested by the SWAT model. The Penman-Montieth PET method was used.

Table 2. Calibrated values of adjusted parameters for discharge calibration of the SWAT2005 model for the SFW.

Parameter	Description	Range	Calibrated Value
ESCO	Soil evaporation compensation factor	0.01 to 1.0	0.95
FFCB	Initial soil water storage expressed as a fraction of field capacity water content	0 to 1.0	0.8
Surlag	Surface runoff lag coefficient (days)	0 to 4	0.2
ICN	Based on the SCS runoff curve number procedure and a soil moisture accounting technique	0 or 1	1
CNcoeff*	Curve number coefficient	0.5 to 2.0	0.2
CN2	Initial SCS runoff curve number to moisture condition II	30 to 100	66-78
PHU	Potential heat unit (used for corn and soybeans)	1000 to 2000	1800

*Williams and LaSeuer, 1976

Tile Component

In an effort to simulate physical processes better, tile components were added to distribute water more accurately throughout the watershed. This component is important for its role in the water balance and for agricultural pollution transport. A depth to impermeable layer for the entire basin was developed to account for tile flow. The parameters added include:

Tile Components

➢**Tdrain** (hr): time to drain soil to field capacity;

➢**Gdrain** (hr): drain tile lag time; the amount of time between the transfer of water from the soil to the drain tile and the release of water from the drain tile to the reach;

➢**Ddrain** (mm): depth to the subsurface drain; and,

➢**Depimp** (mm): depth to impermeable boundary layer.

Basin Hydrologic Budget

➢SWAT2005 was calibrated to the South Fork watershed's average annual flow. The USGS gage station discharge data from 1995-2004 were used for the calibration.

➢The SFW data was simulated with and without the inclusion of the tile drainage system. Table 4 includes the hydrologic budget for the simulation without the tile flow component from 1995 to 2004.

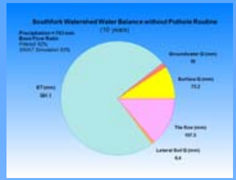
➢The presence of tile drains significantly impacts the SFW water yield. The water yield components (groundwater flow, tile flow, lateral flow, and surface runoff) listed in Table 4 clearly indicate that simulating the tile drainage system is critical to accurately represent the hydrologic balance of the watershed.

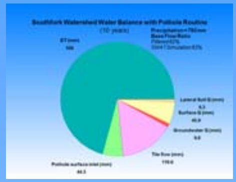
➢The mean annual water yield with and without tile flow, expressed as a percentage of precipitation, are significantly (α=0.05) different (25.1% and 16.9%, respectively) indicating the importance of including tile flow in water yield calculations for affected watersheds.

➢Without the tile drains present, the soil remains wetter; therefore more water is available for surface runoff. This reapportionment of water could impact management decisions regarding the reduction of pollutants such as excess nutrients and pesticides in the environment.

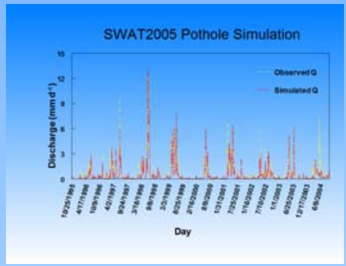
Table 4. The predicted hydrologic budget for the SFW from 1995 through 2004, including two calibration/validation scenarios and SWAT2005 simulations with and without the tile flow component.

Hydrologic Component	With tile flow (mm) 1995-2004	Without tile flow (mm) 1995-2004	Calibration (mm) 1995-1998	Validation (mm) 1999-2004	Calibration (mm) 1995-2000	Validation (mm) 2001-2004
Precipitation	768.0	768.0	786.3	757.4	770.0	748.4
Surface runoff	38.1	117.4	39.0	37.4	38.0	37.5
Lateral flow	7.1	0.40	6.3	6.6	6.7	6.0
Tile flow	136.4	0.0	157.5	118.0	151.2	110.9
Groundwater flow	10.8	11.7	10.0	10.3	10.3	9.4
Evapotranspiration	569.2	638.6	559.5	577.2	550.2	585.5
Potential ET	1190.6	1191.6	1113.7	1233.2	1150.4	1261.4





➢The inclusion of the pothole routine demonstrates that water is distributed more realistically. Water that is retained in the potholes is less available for surface runoff and becomes more available for subsurface flow, resulting in a higher base flow simulated value and an increase in NSE daily runoff value as shown below..



NSE value	Yearly	Monthly	Daily
With Pothole Routine	0.812	0.783	0.666
Without Pothole Routine	0.869	0.727	0.592

With greater detail added by the pothole routine, the daily NSE value increased. This indicates that the inclusion of potholes more adequately represents a physical process that impacts the water balance and pollutant transport.

Future Work

Pothole water balance fractionation.

Improve nitrate flow in runoff.

Best management practices development.

Autocalibration and sensitivity analysis enhancement.

Improve phosphorus routine.