Watershed description

The Shoal Creek watershed (22.5 km²) is located in the northwest corner of Fort Hood. The dominate soil types within the watershed include Brackett, Eckrant, Topsey and Slidell (Figure 1). Figure 2 is the soil map retrieved from Soil Survey Geographic (SSURGO) database.

Figure 1. Percentage of dominant soil map units (%) within Shoal Creek

Figure 2. Shoal Creek Soils (retrieved from: http://soildatamart.nrcs.usda.gov/Survey.aspx?County=TX099)
Historically the area was covered with tall grass prairies and small mountain ranges; however, the vegetation cover has been changed over the past five decades. Heavy artillery traffic from training activities has disturbed soils and largely denuded the land of vegetation. Therefore, intensive rainfall (Figure 3) poses severe erosion potential. The prairie areas received the maximum impacts from tracked and wheeled vehicular traffic. Over 63 km of eroding gullies were mapped within this area as of 2001. The Blackland Research and Extension Center (BREC) began collecting water quality and quantity data in this watershed from 1997. The average annual precipitation (1997-2005) for the area is 760 mm (Figure 3). Two BMPs implemented at Shoal Creek are contour ripping of the soil profile (approximately 27% of total area) and gully plugs placed within gully systems (Table 1 and Figure 4).

![Figure 3. Precipitation in Shoal Creek Watershed](image)

Table 1. Watershed treatment with monitored flow and sediment available

<table>
<thead>
<tr>
<th>Pre-BMP</th>
<th>Deep ripping</th>
<th>Gully plug</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>135 installed from 7/2002</td>
<td></td>
</tr>
</tbody>
</table>
APEX simulation

The APEX model is based on state-of-the-art technology taken from several mature and well tested models. The development history was reported by Gassman, et al. (2005). It was developed for use in whole farm/small watershed management. The model was constructed to evaluate various land management strategies considering sustainability, erosion (wind, sheet, and channel), economics, water supply and quality, soil quality, plant competition, weather and pests (Williams and Izaurralde, 2006). Management capabilities include irrigation, drainage, furrow diking, buffer strips, terraces, waterways, fertilization, manure management, lagoons, reservoirs, crop rotation and selection, pesticide application, grazing, and tillage. The model operates on a daily time step (some processes are simulated with hourly or less time steps) and is capable of simulating hundreds of years if necessary. Farms may be subdivided into fields, soil types, landscape positions, or any other desirable configuration.
**Constructing APEX subarea file**

Each subarea is homogenous in climate, soil, landuse (operation schedule), and topography. Therefore, the heterogeneity of the watershed is determined by the number of subareas.

Watershed delineation for Shoal Creek was conducted based on a 10 m DEM using the SWAT interface (AVSWATX). Originally, the watershed was delineated into 29 subbasins/subareas (1.4 -174.0 ha) (Figure 5). In general, the average upland slope is steeper in the upper watershed than in lower watershed. In this preliminary study, the watershed was further divided into 50 subareas manually based on the contour ripping placements (Figure 6). The 10 m DEM is not detailed enough to be used in the SWAT interface to identify all the gullies/channels. There are places where gully plugs were actually placed, but no channels were identified. With some of the gully plugs being as close as 10 m (Figure 4), at this stage it is not realistic to determine the drainage area and channel information for each gully plug based on the GIS data and GIS tool currently available. BREC is developing a new APEX GIS interface. We plan to use this interface and treat the gully plugs like small reservoirs with no permanent storage. Due to the limitation, only preliminary results are presented here.
Figure 5. Subbasin average upland slope in Shoal Creek watershed

Figure 6. Subareas in Shoal Creek watershed

**Modeling results**

*Model calibration and validation*

There were 25 daily storm events observed during the pre-BMP (1997-2001) period. The NRCS average moisture condition runoff curve number (CN2), the curve number retention parameter
index coefficient, the sediment routing travel time coefficient (parm(45)), and RUSLE C factor exponential residue coefficient (parm(46)) were calibrated in APEX using the first 13 events (Apr. 1997- Apr. 2000) of surface flow and sediment yield. They were adjusted until the $R^2$ values were $> 0.6$ and the percentage errors between the observed and predicted daily average values were $< 10\%$. The calibration process for the pre-BMP period resulted in a CN2 value of 89 and a curve number retention parameter index coefficient of 2.8. The calibration also resulted in a parm(45) value of 5.0 and a parm(46) value of 1.4, both within the APEX recommended ranges. The remaining 12 events (Jun. 00 - Feb. 01) were used to validate the model.

The observed and simulated average event values of surface flow and sediment yield at the watershed outlet are compared for both the calibration and validation periods in Table 2 and Figure 7. The $R^2$ values are $> 0.75$ for the calibration period and $> 0.50$ for the validation period. Daily event series of precipitation and observed vs. predicted outlet flow and sediment yield are plotted in Figure 8. APEX reasonably captured the daily event trend of observed flow and sediment yield. Although explicit standards for model evaluation were not established, Adeuya et al. (2005), Chung et al. (1999) and Ramanarayanan et al. (1997) used the criteria of $R^2 > 0.50$ to assess if the model results were satisfactory. APEX's performance can be judged acceptable for the event based comparisons of observed vs. predicted flow and sediment yield.

### Table 2. Observed and predicted surface flow and sediment yield summary statistics based on daily event values.

<table>
<thead>
<tr>
<th>Daily event</th>
<th>Observed Mean</th>
<th>Observed SD</th>
<th>Predicted Mean</th>
<th>Predicted SD</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calibration (13 events)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface flow (mm)</td>
<td>14.40</td>
<td>14.36</td>
<td>13.07</td>
<td>9.64</td>
<td>0.77</td>
</tr>
<tr>
<td>Sediment yield (Mg ha$^{-1}$)</td>
<td>1.09</td>
<td>1.09</td>
<td>1.20</td>
<td>1.19</td>
<td>0.76</td>
</tr>
<tr>
<td>Validation (12 events)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface flow (mm)</td>
<td>13.68</td>
<td>7.02</td>
<td>13.39</td>
<td>8.51</td>
<td>0.61</td>
</tr>
<tr>
<td>Sediment yield (Mg ha$^{-1}$)</td>
<td>0.89</td>
<td>0.64</td>
<td>0.59</td>
<td>0.39</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Figure 7. Regressions of simulated vs. observed event flow and sediment yield for calibration period (Apr. 1997 - Apr. 2000) and validation period (Jun. 00 - Feb. 01). RMSE (root mean squared error) = \sqrt{\frac{\sum_{i=1}^{n}(O_i - P_i)^2}{n}}$, where $O_i$ and $P_i$ are observed and predicted values on event $i$.

Figure 8. Daily precipitation, and observed vs. predicted event flow and sediment yield in Shoal Creek watershed outlet (Apr. 1997 – Feb. 2001).
BMP effectiveness

The gully plugs cannot be fully represented in APEX simulation at this stage because current GIS limitations. The BMP effectiveness was examined by running a continuous simulation of the calibrated model through 2005 without considering the presence of BMPs; therefore, the differences between predicted and observed values for the post-BMP period are the benefits of BMPs. As of 2005, there were 36 observed events for the post-BMP period. Comparing observed and simulated values showed that surface runoff was reduced by 344.8 mm (108%) and the sediment yield was reduced by 35.8 Mg ha\(^{-1}\) (395%) (Table 3). The contour ripping and gully plugs reduced average annual surface flow by 27% and sediment yield by 99%. The time series of observed (with BMPs) and predicted (with BMP condition) surface flow and sediment yield are plotted in Figure 9. During large rainfall events, the outlet surface flow and sediment yield were significantly reduced due to BMPs practices.

Table 3. Benefits of contour ripping and gully plugs in Shoal Creek watershed

<table>
<thead>
<tr>
<th>Period (11/01 – 03/05)</th>
<th>Surface flow</th>
<th>Sediment yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observed total for post-BMP</td>
<td>318.2 (mm)</td>
<td>9.05 (Mg ha(^{-1}))</td>
</tr>
<tr>
<td>Predicted total if without BMP</td>
<td>663.0 (mm)</td>
<td>44.85 (Mg ha(^{-1}))</td>
</tr>
<tr>
<td>Total reduction</td>
<td>108.3 (%)</td>
<td>395.4 (%)</td>
</tr>
<tr>
<td>Average annual reduction</td>
<td>27.1 (%)</td>
<td>98.8 (%)</td>
</tr>
</tbody>
</table>
The benefit of contour ripping alone was examined by running APEX with and without contour ripping. From 2001 to 2005, the contour ripping (approximately 27% of total area) reduced average annual surface flow by 8.5% and sediment yield by 8.2%.

REFERENCES


