Development of an Integrated Hydrological Model for Simulation of Surface Runoff and Stream Flow in Tims Branch Watershed, Savannah River Site, South Carolina – 16203

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ABSTRACT

This research is part of continued efforts to develop an integrated transport model to predict the distribution of tin within the overland flow in Tims Branch Watershed (TBW) at Savannah River Site (SRS), South Carolina. Tin was introduced into TBW during the application of an innovative mercury remediation technology implemented by the U.S. Department of Energy's Office of Environmental Management, which involved the injection of stannous (tin) chloride into mercury contaminated groundwater. Understanding the fate and transport of tin and its compounds is of primary importance due to their potential impact on the environment. In this study, we developed an overland hydrology model (MIKE SHE) capable of simulating surface hydrology throughout the TBW. The modeling application used historical precipitation, groundwater levels, geological data, and river discharges that were retrieved from government databases and input to the model. The model was developed to simulate spatiotemporal distribution of flow discharges, flow duration, and water levels in the TBW. The preliminary simulation results indicated that the model was capable of predicting flow depth and velocity within the study area during extreme climate events. The developed hydrology model will later on be coupled with transport model to simulate tin distribution within Tims Branch stream during seasonal storm events.

INTRODUCTION

As of today, the United States still undergoes the post-cold war nuclear activities. Facilities like the A/M area of the Savannah River Site (SRS) in South Carolina, which contained the main SRS administrative functions and manufacturing areas, are part of a long term cleanup strategy in the U.S. In the 1950's and 60's, SRS used millions of pounds of heavy metals, including mercury, and solvents such as trichloroethylene (TCE) to produce tritium, plutonium-239 and other radioisotopes to support national security, space exploration, and medicine. The A/M Area constitutes one of the largest groundwater contamination area in the country resulting from the production of fuel and target assemblies, research and development operations, and the disposal of waste and general debris. The principal contaminants in the A/M Area are solvents in the groundwater and vadose zone; however other contaminants such as uranium, nickel, and aluminum are also found in the subsurface, nearby streams, and infrastructure. Treatment of trace mercury in groundwater at A/M Area started in 2007 by addition of stannous (tin) chloride prior to air stripping in a pump and treat operation. As a result, mercury is removed as vapor and tin dioxide is precipitated and released into the receiving stream in the treated water. Tin in its elemental or oxide form is not very toxic to biota, but the organic form is toxic. Organotin compounds are persistent and not readily biodegradable. They are known to be toxic to aquatic ecosystems (Amouroux et al., 2000). Therefore, understanding the fate and transport of tin and its compounds is of primary importance due to their potential impact on the environment (Donard and Weber, 1985; Maguire et al., 1986). Tin methylation is of environmental concern because of its toxicity to humans and animals. Although precipitated tin is primarily deposited as sediment, remobilization may occur during episodic extreme events, such as storms or heavy rainfall. In these cases, sediment can be resuspended in the water column and deposited further downstream. It is therefore important to study the fate and transport of tin during such events, in particular its potential for methylation.

Numerical modeling has proven to be a cost effective tool in studying natural processes such as hydrology and fate and transport of contaminants. Numerical modeling can provide insight into how sediment may become resuspended, transported and redistributed in a waterbody during various extreme weather scenarios. It is possible to approximately determine the path of tin through the affected watershed using advanced watershed modeling software. MIKE SHE is an integrated surface water and groundwater software that can simulate the entire land phase of the hydrologic cycle, map the vulnerability of the aquifer, and delineate the floodplain for the watershed.

This main purpose of this paper is to develop an integrated surface water and groundwater model to predict the fate and transport of tin in Tims Branch. This paper describes the preliminary development of the hydrological model of Tim Branch using the MIKE SHE model.

STUDY AREA

Tims Branch Watershed (TBW) is a second order watershed located within SRS. This watershed is within 12-digit hydrologic unit code (HUC) 030601060504 and is contained within the larger Upper Three Runs watershed which is a sub basin of Lower Savannah River Basin (hydrologic units 03060106, 03060107, 03060109, 03060110) along the border of Georgia and South Carolina (Fig. 1a). TBW is in the Sand Hills and Upper Coastal Plain region of South Carolina. TBW is close to several cities, including Augusta, Georgia and Columbia, South Carolina. It is located 24 km southeast of Augusta, Georgia, and 16 km south of Aiken, South Carolina. It is also within a few hours of Atlanta, Savannah, Charleston, Greenville and Charlotte.

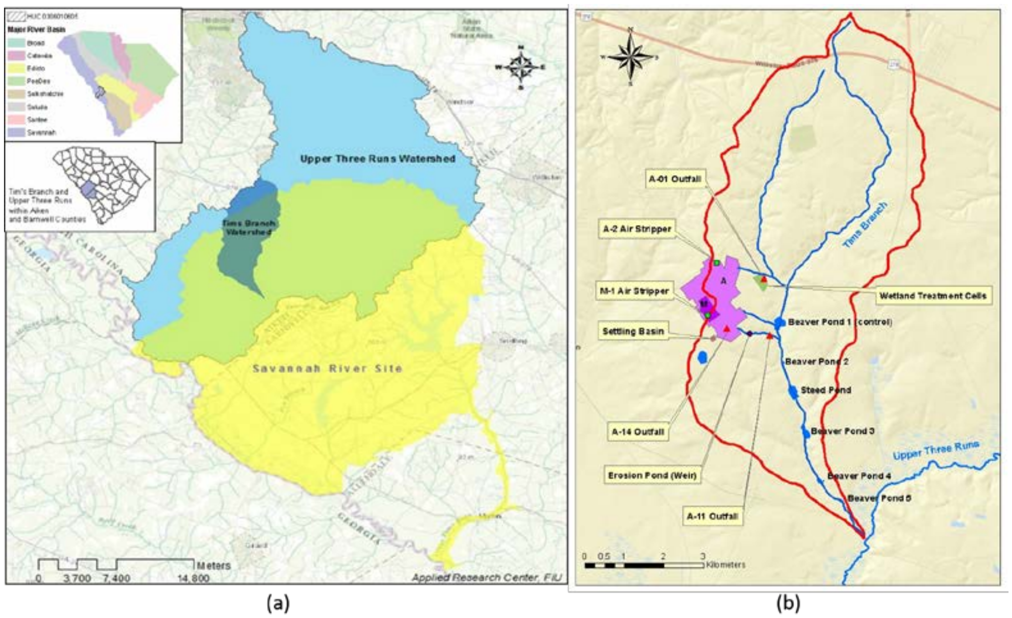


Fig. 1: (a) Tims Branch Watershed (TBW) location within Upper Three Run watershed, SC, (b) Beaver Ponds 1 – 5, Steed Pond and wetland treatment locations in TBW. Tims Branch receives water from A/M area and discharges into Upper Three Runs

Tims Branch stream is a small braided, marshy, second – order stream within SRS that starts at the northern portion of SRS and passes through Beaver Ponds 1 – 5 and Steed Pond, and eventually discharges into Upper Three Runs (Fig. 1b). Its drainage area is nearly 16 km^2 (Batson et al., 1996). The length of this stream from outfall A014 to Upper Three Runs is approximately 8 km. The average width of the stream varies between 2 – 3 m. Two major tributaries of Tims Branch are A014 and A011 outfalls which are approximately 230 m apart. They combine with the main stream of Tims Branch 1,400 m from the A014 outfall (Hayes, 1984). Flow in Tims Branch is strongly influenced by groundwater discharge (Mast and Turk, 1999). Because of the water table elevation and Tims Branch bed elevation, it is considered to be a losing stream (surface water discharges into the groundwater) near the A/M outfalls and a gaining stream (groundwater discharges into the stream) further south toward the confluence with Upper Three Runs (Looney et al., 2010; Varlik, 2013).

Tims Branch has constantly received wastewater from the A/M Area. A/M Area is located in the northwest portion of SRS and covers approximately 0.33 km^2 (Fig. 1b). Beginning in 1952, SRS produced nuclear materials. An important step in the production cycle was the manufacture of fuel and target assemblies in the M-Area for the nuclear reactors. The manufacturing processes in the M-Area consumed a large quantity of industrial cleaning solvents and water. Early practices included the discharge of spent solvents and water directly into the environment. The major production facilities used industrial cleaning processes and products such as trichloroethylene, tetrachloroethylene and trichloroethane, which were discarded to the M-Area Settling Basin via process sewer lines.

BACKGROUND

Hydrology of surface water is proven to be one of the key factors controlling erosion and deposition mechanisms in sediment transport process in streams and rivers. Therefore understanding the hydrology of a watershed is vital in determining environmental conditions and what may cause enhancing sediment erosion and deposition in this stream. Developing a conceptual model and numerical simulations provide an improved understanding of how an extreme rainfall or flooding episode may affect the fate and transport of sediment/contaminant in a watershed.

Very limited studies have addressed the hydrology of Tims Branch watershed in SRS. These studies are primarily based on experimental work and field data collections rather than numerical modeling approaches. Modeling hydrological processes and sediment transport mechanisms require a detailed understanding of soil and sediment characteristics, geologic formation, topography, climate, and hydraulic properties.

Most of previous hydrological modeling efforts were conducted in other areas of Savannah River and South Carolina. No particular hydrological model was found to specifically address the surface flow hydrology in SRS or Tims Branch. Conrads et al. (2006) have developed a three-dimensional model of Savannah River estuary to simulate changes in water levels and salinity conditions in the marsh by coupling 3D hydrodynamic river-estuary model and the marsh-succession empirical model. The coupled model however may not be applicable to SRS and Tims Branch because they only simulate water level in marsh areas. In addition, empirical modeling may not produce valid results when applied in other locations.

In a recent study, Feaster et al. (2012) investigated the relation between hydrological, geochemical, and ecological processes on mercury concentration in fish tissue. They applied two watershed hydrology models to the Mc Tier Creek watershed in South Carolina: a topography-based hydrological model, TOPMODEL (Beven and Kirkby, 1979; Wolock, 1993) to simulate surface flow hydrology, and a grid-based mercury model, GBMM (Dai T. et al., 2005) to simulate the fate and transport of mercury. Because TOPMODEL generates stream flow based on a variable-source-area concept, the model only reflects how rainfall moves through the watershed to become stream flow, so it is not feasible to apply it for an existing stream such as Tims Branch. In a similar study, Feaster et al. (2014), investigated the potential for scaling up the previous application of TOPMODEL for the Mc Tier Creek watershed (small scale) to Edisto River Basin (large scale) in South Carolina.

This study proposes the development of a comprehensive and integrated hydrology model using the MIKE software package created by the Danish Hydraulic Institute (DHI). The integrated hydrology model (MIKE SHE) analyses the effect of climate events on over land flow depth and velocity in the Tims Branch watershed. The model includes the main components of the hydrological cycle including precipitation, evapotranspiration, groundwater flow, and overland flow. The objective of this modeling attempt is to provide a spatiotemporal distribution of flow depth and velocity in Tims Branch under various extreme event scenarios.

METHODOLOGY

MIKE SHE is a fully integrated model for the 3D simulation and linkage of hydrologic systems including overland, subsurface, and river flows. It is a comprehensive deterministic, distributed and physically based modeling system capable of simulating all major hydrological processes in the land phase of the hydrological cycle.

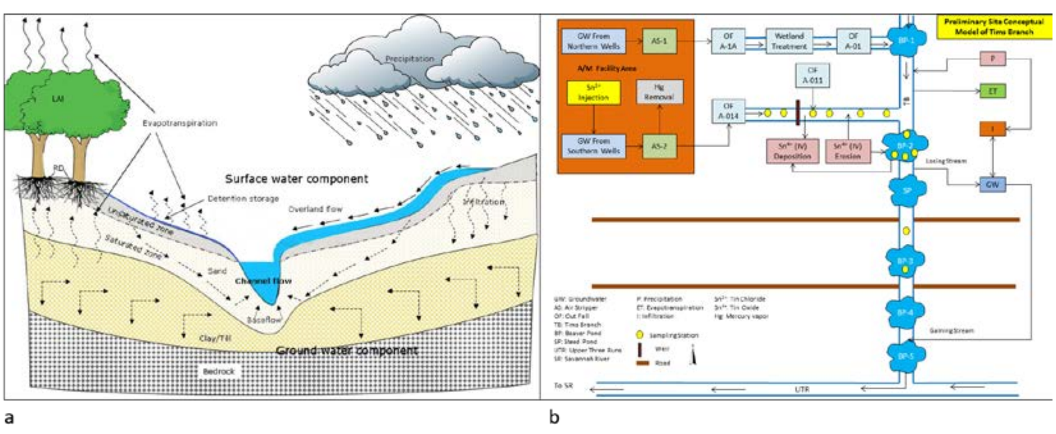
MIKE SHE is a GIS-based distributed model designed for applications in low-relief terrains (Graham and Butts, 2005). It is a spatially and temporally explicit, modularized modeling system. This model simulates the complete terrestrial water cycle by coupling with the flow routing model MIKE 11 (Sahoo et al., 2006), including saturated water movement in soils, 2-D water movement of overland flow, 1-D water movement in rivers/streams, unsaturated water movement and evapotranspiration (ET). It has been successfully applied at multiple scales, using spatially distributed and continuous climate data to simulate a broad range of integrated hydrologic, hydraulic, and transport problems. MIKE SHE couples partial differential equations that describe flow in the saturated and unsaturated zones with the overland and river flow. Different numerical solution schemes are then used to solve the different partial differential equations for each process.

Several studies have shown the ability of MIKE SHE (Refshaard et al., 1995) model to simulate overland flow in wide range of watershed such as agricultural, wetland, mountainous with flash flooding streams, or forested watershed in both US and around the world. Singh et al. (1999) successfully implemented MIKE SHE to simulate hydrological water balance in small watershed to develop an irrigation plan for agricultural purposes. They proposed MIKE SHE as a planning tool to manage irrigation in agricultural area in India. Thompson et al. (2004) coupled MIKE SHE with MIKE 11 (stream model) to evaluate evaporation from ditch surfaces of wetlands in Southeast England. Their modeling results indicate a successful coupling of the hydrology model (MIKE SHE) and the hydraulic model (MIKE 11). Sahoo et al. (2006) applied MIKE SHE to a tropical mountainous watershed in Hawaii to predict streamflow at short time intervals. They illustrated a systematic procedure for calibration and validation of the MIKE SHE model and presented preliminary results of the streamflow simulation. Although their results may consider to be preliminary, the MIKE SHE model shows potential for use as a tool to predict streamflow of a flashy flood-producing mountainous stream. Dai et al. (2010) evaluated the ability of MIKE SHE to simulate the hydrology of a forested watershed containing both uplands and wetlands on the Atlantic Coastal Plain of South Carolina. They argued that use of appropriate method of calibration and validation plays an important role in model capability to simulate flow in forested watershed. They promoted a calibration and validation method to improve the simulation results. Their results showed that calibrating MIKE SHE model using bi-criteria (streamflow and water table depth) approach can obtain optimum model input parameter rather than using single-criterion calibration approach.

In this study, a comprehensive modeling system was developed to evaluate the MIKE SHE application in Tims Branch watershed, South Carolina. Later, the developed overland flow model will be coupled with stream model (MIKE 11) to simulate flow within Tims Branch stream. In final step, the integrated overland and stream flow will be coupled with sediment transport model (ECO Lab) to simulate fate and transport of contaminant in the stream. The ultimate integrated model (MIKE SHE/MIKE 11/Eco Lab) will be used as a tool to estimate the spatiotemporal distribution of sediment/contaminant when an extreme atmospheric event happens.

Conceptual Model

A conceptual model describes the general physical framework of the relationship between physical processes that are part of an environment. Fig. 2a illustrates the general components involved in MIKE SHE watershed hydrology model. MIKE SHE includes the precipitation, infiltration, evapotranspiration, surface flow, and subsurface flow in both unsaturated and saturated zones. In addition, a data-driven site specific conceptual model was developed for contaminant transport in Tims Branch (Fig. 2b). The conceptual model developed for SRS was tended to address processes and features such as discharge points, groundwater/surface water interaction, geological formation, atmospheric characterization, infiltration, runoff, etc. This conceptual model includes location of outfalls, ponds, and other particular features in the area. Water mainly flows into Tims Branch from two outfall: A-01 and A-014. A-01 discharges water from wetland treatment facility at north of A/M area while A-014 located at discharges water from southern groundwater wells into Tims Branch.



a b

Fig. 2: a) Diagram representing hydrologic processes that are modeled in MIKE SHE, b) Data-driven conceptual model of Tims Branch representing the existing features, such as ponds, inflow, outflow, and sampling locations

Input Data

The MIKE-SHE model of flow in the overland, saturated and unsaturated zones requires a number of spatial and temporal parameters which was introduced to the model in the form of standard GIS data. Topography, land use/land cover, precipitation, geologic formation, etc. are basic input data that is required to set up MIKE SHE overland flow model. All data were prepared in Geographic Information System (GIS) application and exported as GIS shapefiles into MIKE model. The following explains the data preparation process.

Topography

The general topography of SRS includes upper and lower coastal plains. Lanier (1997) described the upper Coastal Plain as consisting of rounded hills with gradual slopes, areas of highly irregular terrain, and some elevations exceeding 200 m above sea level. The highest elevation at SRS is approximately 130 m above sea level, near Tims Branch and the northwest boundary of SRS. The land surface elevation at the boundary of the upper and lower Coastal Plains, located southeast of SRS, is usually less than 60 m above sea level. Upper Coastal Plain stream slopes range from 1.0 to 4 m/km (Lanier, 1997).

In MIKE SHE, topography defines the upper boundary of the model. The topography is used as top elevation in both Unsaturated Zone (UZ) and Saturated Zone (SZ) models. It also defines the drainage surface of Overland flow (OL). Therefore the accuracy of topography is the most important parameter in MIKE SHE model set up. LiDAR data with 3 m spatial resolution, acquired from the U.S. Geological Survey (USGS), was used to generate Digital Elevation Model (DEM) of the study area.

Climate Data

MIKE SHE requires climate data as precipitation, snowmelt, and evapotranspiration (ET) rates. SRS climate is categorized as humid subtropical with mean temperature of 18 °C and a mean annual precipitation of 1225 mm (Kilgo, 2005). SRS climate is heavily influenced by the Appalachian Mountains and Atlantic coast. As a result, the SRS rarely experiences snow or icing conditions. Precipitation is mainly in the rainfall form with little to no snowfall. Approximately 50 years of daily rainfall record was acquired from SRS database.

MIKE SHE estimates ET based on two methods: Kristensen and Jensen (1975) method which uses the Richards equation or Gravity flow method in unsaturated zone, or the Two-Layer UZ/ET model. The latter divides the unsaturated zone into a root zone where ET occurs and below the root zone, where ET does not occur (Yan and Smith, 1994). The Two-Layers UZ/ET model is suitable for areas where the water table is shallow such as South Carolina and SRS area (Dai et al., 2010). MIKE SHE also requires the value of reference ET (the rate of ET from a reference surface with an unlimited amount of water) that can be calculated in accordance with Food and Agriculture Organization (FAO) guidelines. Aadland et al. (1995) reported the value of 2.22 mm/day for reference ET at SRS which was used in our study.

Land Use

MIKE SHE uses the paved area (land use) and vegetation coverage (land cover) to calculate ponded water and the spatial and temporal distribution of ET. Paved run off coefficient can be defined as a function of paved area. Run off coefficient table can be found from water resources handbooks. It ranges from 0.05 for lawn sandy soil to 0.95 for heavy residential. In this study, the values of zero and 0.7 were assigned to paved and unpaved areas respectively. To calculate Actual ET, MIKE SHE requires vegetation properties, primarily, Leaf Area Index (LAI), and Root Depth (RD). MIKE SHE Vegetation Database defines the LAI and RD values for various vegetation. Table 1 shows the vegetation data for TBW which were defined based on land cover data depicted in Fig. 5. These data were used to spatially adjust the reference ET in the model simulation.

Table 1: Vegetation data for TBW

Vegetation ID	**LAI**	**RD (mm)**
Barren Land	1.31	4000
Cultivated Crops	3.62	1500
Deciduous Forest	5.5	2000
Developed Low Intensity	2.5	2000
Developed Medium Intensity	2.0	2000
Developed Open Space	3.0	2000
Emergent Herbaceous Wetland	6.34	2000
Evergreen Forest	5.5	1800
Hay/pasture	1.71	1500
Mixed Forest	5.5	2400
Open Water	0.0	0.0
Quarries	1.31	4000

transitional	1.31	4000
Urban/Recreational Grasses	2.0	2000
Woody Wetland	6.34	2000

Tims Branch watershed (TBW) is home to a variety of land uses and land covers. The A/M area operates within the TBW and occupies about 14% of the total watershed area. Fig. 3a maps the 2011 developed areas of the TBW, including roads and buildings, and illustrates the percent of impervious cover. Over 6 km of the total area of TBW has an imperviousness of 14% or less. This indicates that, overall, the watershed is mostly undeveloped or agricultural land. This conclusion is compatible with the land use data, which establishes that about 80% of the watershed is forested or agricultural (Table 2).

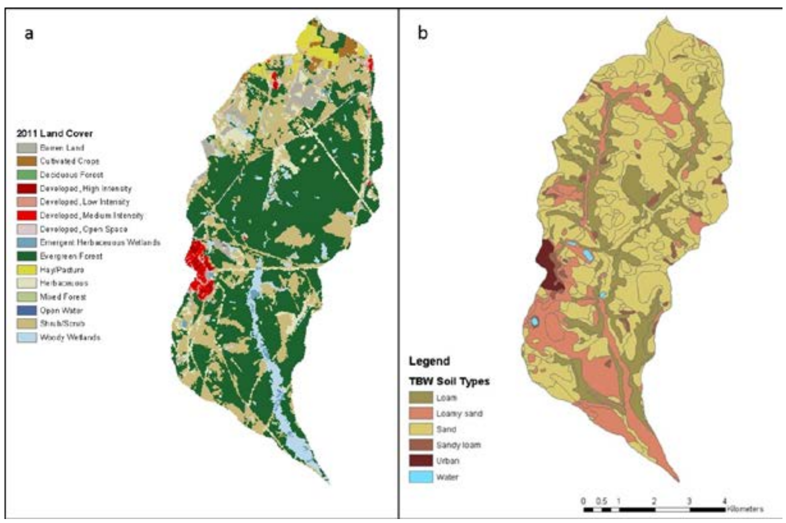


Fig. 3: a) 2011 geospatial distribution of land cover in TBW. Data derived from USDA National Land Cover Database (NLCD), b) TBW soil type classification based on five dominant soil type

Table 2: Land use classification and Manning's (M) MIKE SHE values

Land Use	**Area (m^2)**	**%**	**Manning's M (1/n)**
Agricultural	170,975	0.34	41
Barren Land	58,151	0.12	81
Forest	35,267,379	70.83	21
Rangeland	7,287,896	14.64	25
Urban/Built-up Land	6,816,222	13.69	90

Water	76,866	0.15	11
Wetland	115,658	0.23	23

Unsaturated Zone (UZ)

Flow in UZ is primarily vertical since the gravity plays the major role during the infiltration. Therefore, MIKE SHE calculates flow in one vertical dimension. In most application the assumption of 1-D flow direction is valid unless the land surface topography is very steep hill slope. Because of moderate topographic gradient in our study area, this assumption is valid.

The Two-Layer Water Balance model detailed in MIKE SHE reference guide was used to simulate the unsaturated flow for this study. The model divides the unsaturated zone into a root-zone where ET can occur, and a below-root-zone where ET does not occur (Yan and Smith, 1994). The model inputs include vegetation characteristics (LAI and RD) and the physical soil properties. The data for physical soil properties and vegetation characteristics were spatially distributed to simulate unsaturated flow in space and time. The van Genuchten (1980) water retention parameter is a simplified widely used approach for the prediction of soil water content as a function of pressure head.

Soil texture within TBW were identified by investigating soil map units on the basis of geologic formation, geomorphology, and soil parent material in SRS. Soil map units were delineated within the TBW watershed boundary according to the SRS soil coding and classifications described by Aadland et al. (1995). The dominant soil types were identified as sand, sandy loam, loam, and loamy sand (Fig. 3b).

Saturated Zone (SZ)

In MIKE SHE, the saturated zone is only one component of an integrated groundwater/surface water model. The saturated zone interacts with all of the other components, overland flow, unsaturated flow, channel flow, and evapotranspiration.

In this study, the 3-D finite difference method was used to simulate the saturated flow for this study. The inputs parameters include horizontal and vertical hydraulic conductivities, specific yield, and storage coefficient. Both the horizontal and vertical hydraulic conductivities used in this study were spatially distributed based on the distribution of soils.

The MIKE SHE Simulation

In this study, we developed a model to simulate the overland flow of the Tims Branch

Watershed. This model includes evapotranspiration, infiltration, unsaturated flow, saturated flow. The main inputs for the model were topography, soil, vegetation, precipitation and potential evapotranspiration (PET). At this stage, the model does not include stream flow. Therefore no drainage network data was added to the simulation. In this modeling effort, the study area () was divided into 66 m by 66 m cells. To simulate overland flow, the input data of initial water depth on the surface, surface detention storage, and Manning's number (M). We assumed initial surface water depth to be zero. MIKE SHE uses the surface detention storage parameter to limit the amount of water that can flow over the ground in the watershed. The surface depth of water must exceed the surface detention storage in order to flow overland, otherwise it becomes ponded water.

In MIKE SHE, the Manning M is the inverse of the traditional Manning's value (n) which varies between 0.01 and 0.1 which corresponds to M value between 10 and 100. The overland flow is significantly influenced by Manning M value. The higher the value, the faster overland flow occurs. The value of Manning M used in this work is shown in Table 2.

In this study the preliminary simulation was performed for the period of 2 months rainfall from 07/30/2014 to 09/30/2014. Future simulation will be performed for the period from 10/01/1993 to 09/30/1996 in which streamflow/discharge data were collected at USGS gage station downstream of Tims Branch. Calibration and validation of the hydrological model will be performed in the future modeling framework using the USGS observed streamflow data. The calibration of the model will be performed during the period of 10/01/1993 to 10/01/1995 and model validation will be performed during 10/01/1995 to 09/30/1996. The model will be also tested for various scenarios including extreme rainfall and episodic storm events.

PRELIMINARY RESULTS AND DISCUSSION

Simulation of overland flow for TBW was performed during high rainfall events. Fig. 4 indicates visual illustration of simulated results output of MIKESHE hydrology model. The overland flow was simulated under different rainfall conditions to understand the response of the watershed for annual and seasonal changes of rainfall as well as changes in the infiltration capacity of the soil.

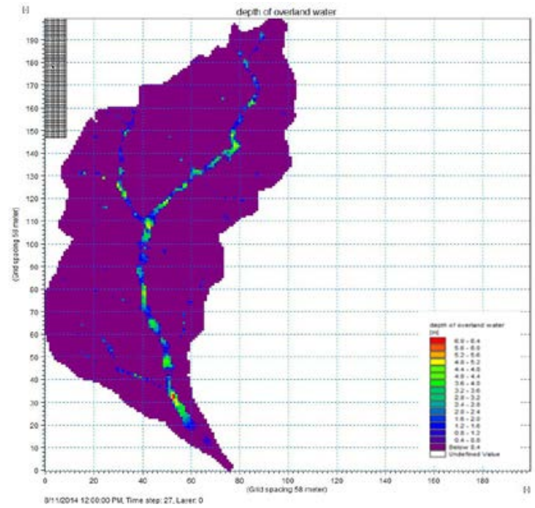


Fig. 4: Depth of overland flow during high rainfall day (31.5 mm), August 11, 2014

Fig. 4 is an illustration of the preliminary result of overland flow in the Tim Branch watershed for the high rainfall day (August 11, 2014). The measured rainfall data indicated that on August 11, 2014 approximately 31.5 mm of rainfall of water fell on the watershed. This high rainfall condition contributed to increases surface runoff/overland flow that contributes to higher streamflow. As it can be seen in the figure there is high discharge in the river system due to contribution of high depth of overland flow. Understanding the seasonal variability of rainfall and watershed response to the changes help to examine the response of the watershed as a function of climate variability, soil infiltration capacity, vegetation cover/land use and other hydrological conditions.

Another preliminary simulation was performed to provide series of preliminary results of overland flow during the year of 1993. Fig. 5 shows the time series graph of rainfall in 1993. The graph indicates two peak of high precipitation rate during the January and September with some rainfall events in July.

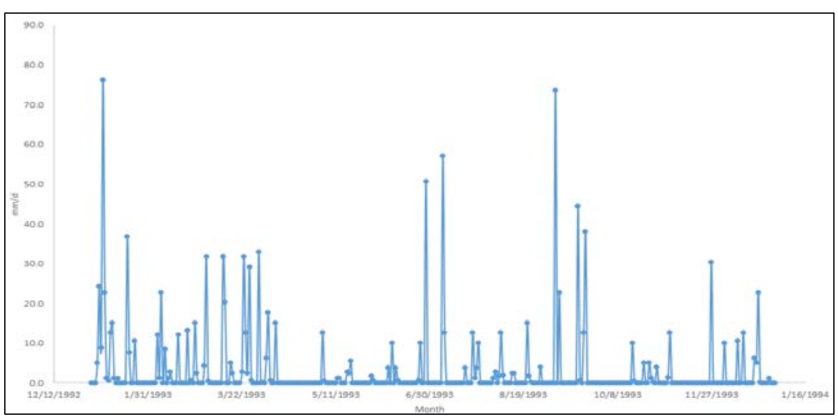


Fig. 5: Rainfall data for year of 1993

Fig. 6 shows the results of MIKE SHE simulation for one year from 1/1/1993 to 1/1/1994. This figure consists of snapshots of overland flow for the months of March, June, September, and December which represent spring, summer, fall and winter respectively.

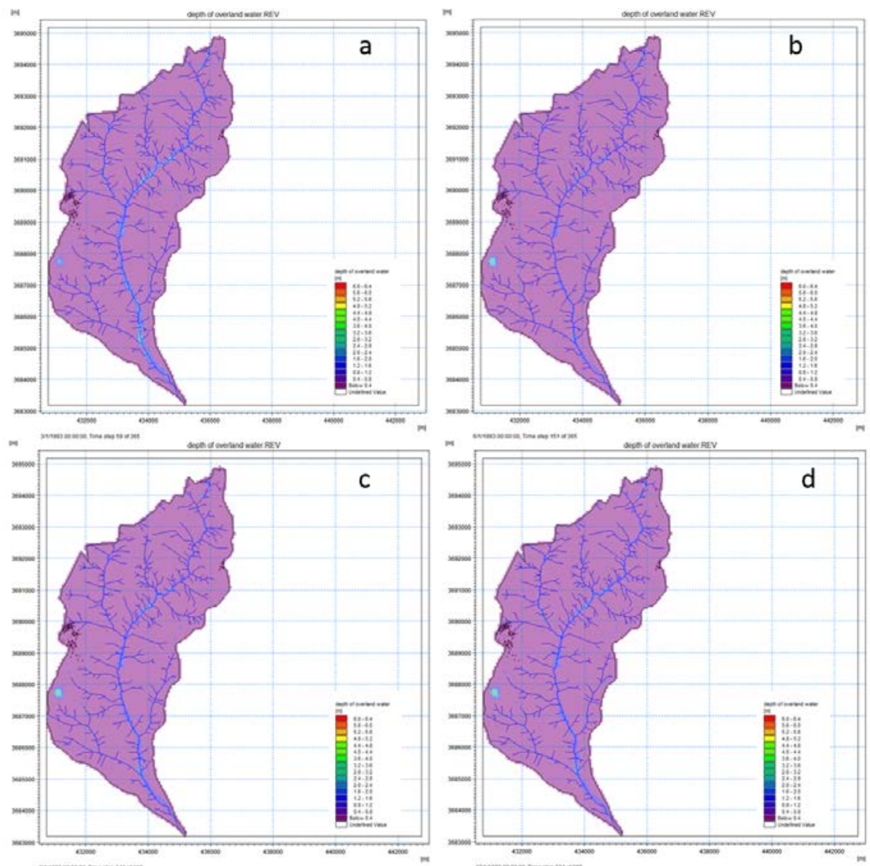


Fig. 6: MIKE SHE simulation results of seasonal overland depth of water for year 1993 indicating spring (a), summer (b), fall (c), and winter (d) overland flow simulation

Temporal variation of depth of overland flow during the rainfall in 1993 in two locations is shown in Fig. 7a. Point 1 is located in the vicinity of Steed Pond and Point 2 is located downstream of Tims Branch near the Upper Three Runs conjunction (Fig. 7b). The depth pattern in both locations exhibits similar behavior with higher depth of water during rain events and lower depth when low rainfall or no rainfall happens.

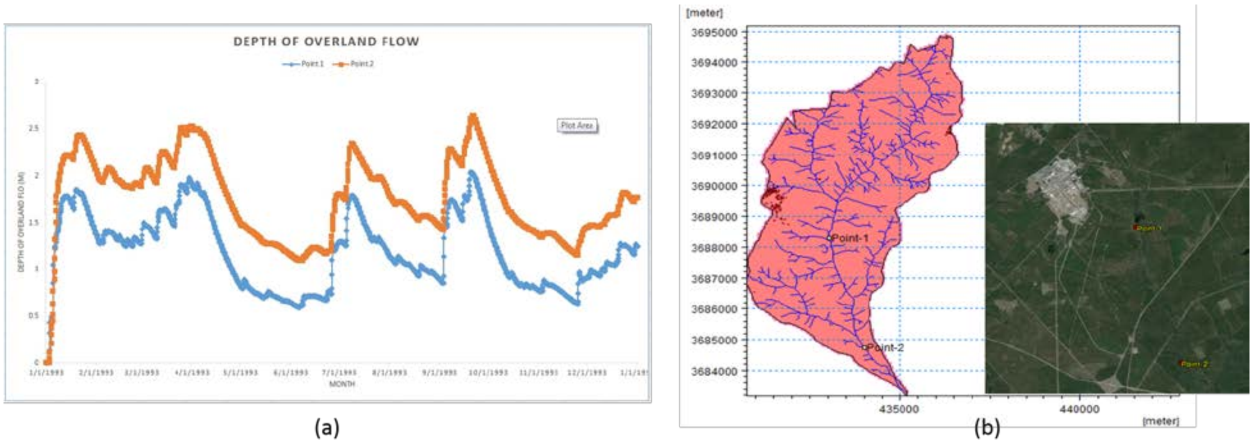


Fig. 7: (a) Depth of overland flow in Tims Branch at two locations, (b) Point 1 near Steed Pond and Point 2 close to Upper Three Runs conjunction

Depth of water seems to be lower at point 1 (Steed Pond) than Tim Branch downstream which is mostly due to the topographic gradient from north toward south of the study area, vegetation coverage and soil types.

The variation in the depth of overland flow in a watershed is highly depend on rainfall intensity and distribution. Comparing with the rainfall distribution as shown in Fig. 7a also indicates that variation in the depth of overland flow highly depend on the amount and distribution of rainfall in the watershed.

CONCLUSION

The main purpose of this study was to develop an overland hydrology model using MIKE SHE that was capable of simulating surface flow depth and velocity throughout the Tims Branch Watershed.

MIKE SHE, a comprehensive physically based distributed modeling system was adopted here to simulate the hydrology of a small watershed. While MIKE SHE requires large amount of input parameters and data, its application is not necessarily restricted due to data scarcity. The flexibility of MIKE SHE model offers the user the capability to simplify the model set up according to data availability.

The MIKE modeling package has several advantages over many hydrologic models for estimating watershed runoff: (1) it is a distributed model and most of the algorithms in describing the water movements are based on physical processes, (2) it is equipped with the built-in GIS user interface that can directly use geospatial databases for model inputs. Moreover, the model has a strong visualization utility that makes interpretation of modeling outputs much easier. The model developed in this study will be used as a tool to understand the dynamics of the different hydrological components of the Tims Branch Watershed. Preliminary model development has included the simulation of overland flow, which is one of the main components of the MIKE SHE modeling system in hydrological analysis due to the fact that a significant amount of water flows as overland flow/surface runoff that joins streams and waterbodies. Knowledge of the temporal and spatial distribution of overland flow helps to understand flow as a function of climate and catchment characteristics in the land phase of the hydrological cycle. The seasonal distribution of overland flow helps to understand the flooding and other extreme flow conditions in the watershed. In this study, seasonal (i.e., winter, spring, summer and fall) overland flow was simulated.

The results of simulation are preliminary as not all of the hydrological components have been incorporated, and tend to give a general understanding of the watershed as a function of precipitation and other catchment characteristics. While the results may be considered preliminary, the model shows potential for use with future refinements in input data.

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