CHAPTER 1

INTRODUCTION

1.1. PROBLEM STATEMENT

Erosion and sedimentation embody the processes of detachment, transport, and deposition of soil particles. Erosion and subsequent deposition can be major problems. Erosion reduces productivity of cropland and sediment degrades water quality and may carry soil absorbed polluting chemicals. Deposition in irrigation canals, stream channels and reservoirs reduce the capacity of the structure and requires costly removal (Foster *et al.*, 1980).

The processes controlling sediment detachment, transport and deposition are complex and interactive. This complexity results in the term "erosion process" in erosion models. The difficulty in the observation and measurement of the erosion processes during a runoff and erosion event due to small temporal and spatial scales makes necessary the use of an erosion model in the prediction of erosion and deposition in a watershed. The use of an erosion model and "after the fact" erosion observations are the best tools in resource management (Lane *et al.*, 1988).

Ideally, an erosion model should represent the essential mechanisms controlling erosion, and the model parameters should be directly related to measurable physical properties (Lane *et al.*, 1988). A two-dimensional (2-D) model is more appropriate than a one-dimensional (1-D) model when identifying those areas more sensitive to soil erosion (Hong and Mostaghimi, 1997).

Over the last two decades, the dramatic increase in computer power has led to significant developments in the way that hydrological research and operations are conducted. In this context, Geographical Information Systems (GIS) applications in environmental modeling have proliferated to take advantage of the spatial data representation capabilities, and GIS systems have been linked to process-based models (Gurnell and Montgomery, 1998). In hydrology, 2-D physical models are replacing simple 1-D representation of surface flow processes in catchment models. These add to the physical realism of existing models but at the same time require more field data collection to generate the necessary validation, calibration and parameterization data. It also needs better computational tools and techniques. The space, time and dimensional resolution at which such models may be applied has reached a stage where typical simulations can involve many thousands of grid cells, simulated for hundreds of thousands of time steps in anything up to three dimensions (Bates and Lane, 1998). In erosion models, 2-D studies enable the identification of vulnerable regions within a watershed, thus facilitating the improvement in the planning of soil conservation systems.

Digital Elevation Models (DEMs) have facilitated various hydrologic applications such as watershed hydrologic simulations, delineation of stream patterns, terrain catchment partitioning and erosion/deposition predictions. While GIS provides a rapidly expanding tool-kit that will allow hydrological scientists and engineers to address new questions, the development of such applications will inevitably raise a variety of interesting new problems (Gurnell and Montgomery, 1998). With the availability of high resolution DEMs, one such issues is the optimum resolution at which data is input in hydrological models.

In a raster map, spatial resolution increases as the size of grid cells decreases. There are some trade-offs when using a small resolution digital model versus using one with coarser resolution. Computational time, computer storage, level of accuracy and data manipulation are the most important factors that will determine the cell size selection. For a given area, a change to grid cells half the current size requires as much as four times the storage space, depending on the type of data and the storage techniques used (ESRI, 1994). The selection of the cell size will depend on the established objectives and the resources availability to model the watershed system.

It has been observed how the cell size in a DEM affects the landscape representation like slopes, slope lengths, and the extracted channel network in a basin (Zhang and Montgomery, 1994; Bruneau *et al.*, 1995; Yu, 1997; Wolock and McCabe, 2000). The change of these physical variables will translate into a change on hydrological model outputs. The cell size in distributed hydrological models will have a direct effect on the information content and the accuracy of the simulated output. In general, researchers agree in that the finer cell size gives more accurate results. However, there is no consensus in the selected cell size and the recommended one depends in each study on the used model, initial conditions and assumptions, magnitude of the rainfall event and watershed and objective of the study.

Investigation of the effect of the input DEM resolution on the prediction of erosion has been very limited until now. Studies of how a change of the grid cell size affects the upland erosion prediction are almost non-existent (Julien and Frenete, 1987; Kienzle, 1996; Molnar and Julien, 1998). These studies are limited to the application of the Universal Soil Loss Equation (USLE), which estimates average annual soil loss but fails to predict deposition. The USLE was originally developed for agricultural fields and its application to landscape scale erosion modeling is often inappropriate (Foster and Wischmeier, 1974; Moore and Wilson, 1992; Mitasova *et al.*, 1996).

The selection of the grid cell size affects empirical erosion models such as the USLE through a change of the landscape characteristics. Process-based erosion models will be affected by both the change in landscape representation and the change in the hydrological model. The effects of grid cell size on the prediction of erosion and deposition rates when using a 2-dimensional, physically-based hydrological model have not been investigated yet.

1.2. RESEARCH OBJECTIVES

The objectives of this proposed research are:

- Extended development of the CASC2D-SED upland erosion and sediment transport and implementation of a suitable channel sediment routing algorithm

- Coupling of the model time-series output grids with a GIS that will allow the geovisualization of sediment transport dynamics and the spatial erosion and deposition patterns.
- Investigation of the effects of grid resolution in the simulated values of gross erosion, sediment yield, spatial distribution of net erosion and sediment delivery ratios.

1.3. METHODOLOGY AND APPROACH

The 2-D physically-based computer model CASC2D-SED is a hydrological model able to simulate the erosion rates in a watershed in a grid basis. This model is used in this study to investigate the effects of the grid cell size on the prediction of the sediment production in a watershed.

Data are taken from the 20.5-km^2 Goodwin Creek watershed (MS). This extensively monitored watershed by the ARS National Sediment Laboratory (NSL) has been chosen because it has a complete database compiling precipitation, runoff, channel cross-section and sediment discharge.

The current CASC2D-SED version of upland sediment transport and deposition (Johnson, 1997) will be modified to include the transport of sediment by advection. To calibrate and validate the model, a channel sediment transport module will be implemented within CASC2D-SED. Eroded sediment in the overland will be simply routed in the channels by size fraction. While erosion is not going to be allowed in the channel, deposition may occur.

Coupling of the CASC2D-SED model output with GIS will aid in the testing phase of the model. Output grids time-series visualization of the simulation of the sediment transport dynamics and geovisualization of the net erosion spatial distribution patterns will be used as a form of model validation. The program Arc/Info[1] is going to be used for input data preparation, analysis and visualization of the time-series output grids. Results are to be presented for a given event and size fraction in a animated MPEG file.

Goodwin Creek will be resampled from 30-m to up to 330-m grid cell size to study the effects of spatial resolution on simulated erosion rates in a watershed. First, the gross erosion and sediment yield produced at the Goodwin Creek Watershed at a given resolution will be quantified for uniform impervious soils and uniform land use parameters using three different constant uniform rainfall intensities. Later, a real event will be simulated and the differences in hydrological and sediment outputs presented for different grid cell sizes.

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[1] Arc/Info® is a registered trademark of the Environmental Systems Research Institute