AN ANALYSIS OF THE INTENSITY OF PRECIPITATION, TOTAL SUSPENDED SOLID AND STAGE HEIGHT FOR STREAM GAUGING SITES 9 AND 11 WITHIN THE GOODWIN CREEK EXPERIMENTAL WATERSHED, NORTHERN MISSISSIPPI, FOR THE YEAR 2000

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Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
May, 2010

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ACKNOWLEDGMENTS

For some, a dissertation culminates as ones final achievement in their education, for others it is a stepping stone to future educational goals. For me it represents a personal goal composed of many hours of hard work, many late nights, and many hours away from my family, children and friends. For some, it is about working with others, meeting common goals and forging ahead as a team to reach one common goal of graduating. For me, being so far removed from the others in our collaborative, it was solitude. I did not learn until the last year of my dissertation that there were people out their willing to help me achieve my goal. As a result, in the last months of my dissertation, my life totally changed, I had an awaking.

Through this process or journey, there were many people who contributed to me reaching my goal of a successful dissertation. First and foremost, I would like to recognize a man I have never met, who owed me nothing, but was willing to work with me diligently, and in some cases all night and day, to help me complete my dissertation. I would like to recognize Dr. Gary Conti. If it were not for him, I would have never finished. I also would like to express my appreciation to my committee members: Dr. Steve Marks, Dr. Carlos Del Castillo, Dr. Jack Vitek, and Dr. Caroline Beller. They were a tremendous help in giving guidance and suggestions in formulating my idea into a research study, suggestions on how to make the study better and in reinforcing me in areas when I needed help.

Of course, there were many others who supported and encouraged me as I moved forward through this process. These include Mark Griffith and Dr. Koonley at the National Sediment Lab, who went back and searched every "old" discarded hard drive and through the warehouse of documents to find the data for my study, without their help it would not have been possible to obtain the information I needed. Thanks to the staff at OSU's NASA Education Project who helped make sure I had everything turned in on time and dotted my "T"s and crossed "I"s. I also want to recognize Talya Henderson, without her help and gentle reminders through the years; I would have forgotten to do a lot of things. I want to thank those who helped me in good times and bad; providing words of encouragement as I worked on this very long row to hoe. I would like to thank my mother, Barbara Witherspoon who always knew I could do it and who cheered me on through the entire process. I would also like to give a special thanks to my two daughters, Miranda and Katherine who always said they understood, though I missed quite a few special events in their lives. Last, I want to recognize and thank my wife, Chyrl. There are no words that can describe the love I feel for you. Without your help, time, support, ideas, a gentle push or two when and where it was needed, and someone to just talk to, I would have never finished this document. To all of these people in my life, I want to thank you and hope one day I can pay the debt forward to someone else.

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CHAPTER 1

INTRODUCTION

"The face of the water, in time, became a wonderful book, a book that was a dead language to the uneducated passenger, but which told its mind to me without reserve, delivering its most cherished secrets as clearly as if it uttered them with a voice. And it was not a book to be read once and thrown aside, for it had a new story to tell every day."

- Mark Twain (1901, p. 69)

Background

The Goodwin Creek Experimental Watershed (GCEW) was constructed by the U.S. Army Corps of Engineers in north-central Mississippi in the late 1970s as part of the "Streambank Erosion Control Evaluation and Demonstration Project" authorized by Section 32 of U.S. Public Law 93-251 (Alonso, 2000, p. 175). Goodwin Creek serves as a benchmark experimental watershed that drains 2,132 ha in the north-central part of the state of Mississippi. The effect of land use and management practices on erosion and transport of sediment and contaminants has been the major component of research conducted on the Goodwin Creek Experimental Watershed and is an important contributor to sediment research in the United States (Kuhnle, Bingner, Langendoen, Simon, Wilson, Alonso, Shields Jr., 2005).

Statement of Problem

According to Alonso (2000), sediments are the largest single pollutant of the surface waters of the United States. Poorly designed agricultural practice can cause a large increase in erosion, which pollute surface water, reduce soil fertility, and reduce the capacity of a channel to transfer flood waters.

Because of the current costs to test and measure water quality, most states are not in compliance with the Clean Water Act of 1972 for collecting, measuring, and reporting specific water pollutants such as total suspended solids. Throughout the calendar year water samples are collected for each major tributary and most minor streams, recorded, and sent to a lab for testing.

In the July 2008 *World Meteorological Organization Bulletin*, Muste, Kim, Fulford, (2008) state, “New demands on surface-water resources from an increasing world population and rising global living standards are requiring water managers to improve river flow measurements. Water managers are requiring flow instrumentation to measure those resources more accurately, in more detail and at lesser cost.” (p. 1). They further explain that within the past 20 years, “the availability of inexpensive computing power, electronics and improved batteries has led to the development of electronic velocity instruments for mapping river hydrodynamics that previously would have been impossible” (p. 1). Remarkable improvements have been made in the methods used to gather water quality measurements and the instrumentation used to take these measurements.

Though many states have begun using electronic instrumentation and computer simulated river modeling to provide estimations of many of these measurements; field sampling and lab analysis are still required to validate the electronic measurements taken (Blackmarr, 1995, p.23, 28, 130). According to Alonso (2000), measuring “sediment transportation rates in streams is labor intensive, very expensive, and often has questionable accuracy." (p. 176) As a result, a more accurate method needs to be developed to improve the results of the sampling techniques or computer estimations used to measure suspended sediments.

The focus of this study was to narrow the amount of field measurements taken by determining (1) if a significant correlation exists between the intensity of precipitation and total suspended solids and (2) if a significant correlation exists between the intensity of precipitation and the stage height of a stream, such as Goodwin Creek. If a correlation does exist, the results may be applied to understanding the relationship between the field sampling and the electronic data collection, as well as producing alternative methods of determining sediment loads within rivers and streams. The outcome of this study could be applied to future computer simulated river modeling and sediment modeling techniques by providing information about how the intensity of precipitation, sediments, and stage height are related.

Eisenbies, Aust, Burger, Adams (2007) determined that to model extreme floods, research studies must be better defined, and the effects that control the floods [stage height] must be better understood. "There is little information regarding the specific conditions that define the threshold between the 'standard' and so-called 'violent' watershed responses to rainfall" (p. 93). Eisenbies, et al. (2007) believe the variety of flooding may result from many factors, such as infiltration excess, saturation excess, delayed responses, preferential flow paths, or a combination of these different factors (p. 93).

Eisenbies et al. (2007, p. 93) also concluded a possible relationship may exist between high intensity rainfall spikes after a period of soil wetting and extreme flooding as a result of a sudden increase of water in the catchment area. Therefore, this study built on Eisenbies et al. research, of using paired gauging sites from a single watershed to determine if a relationship exists between the intensity of precipitation and the amounts of total suspended solids because of a cause and effect relationship between precipitation and sediments, and between precipitation and stage height.

EPA Background

In 1997, the EPA issued guidelines in response to concerns raised by state and local organizations as the TMDL program developed. To attain water quality standards, the directives include a number of recommendations intended to achieve a more nationally consistent approach to develop and implement TMDLs (U.S. EPA, 2003).

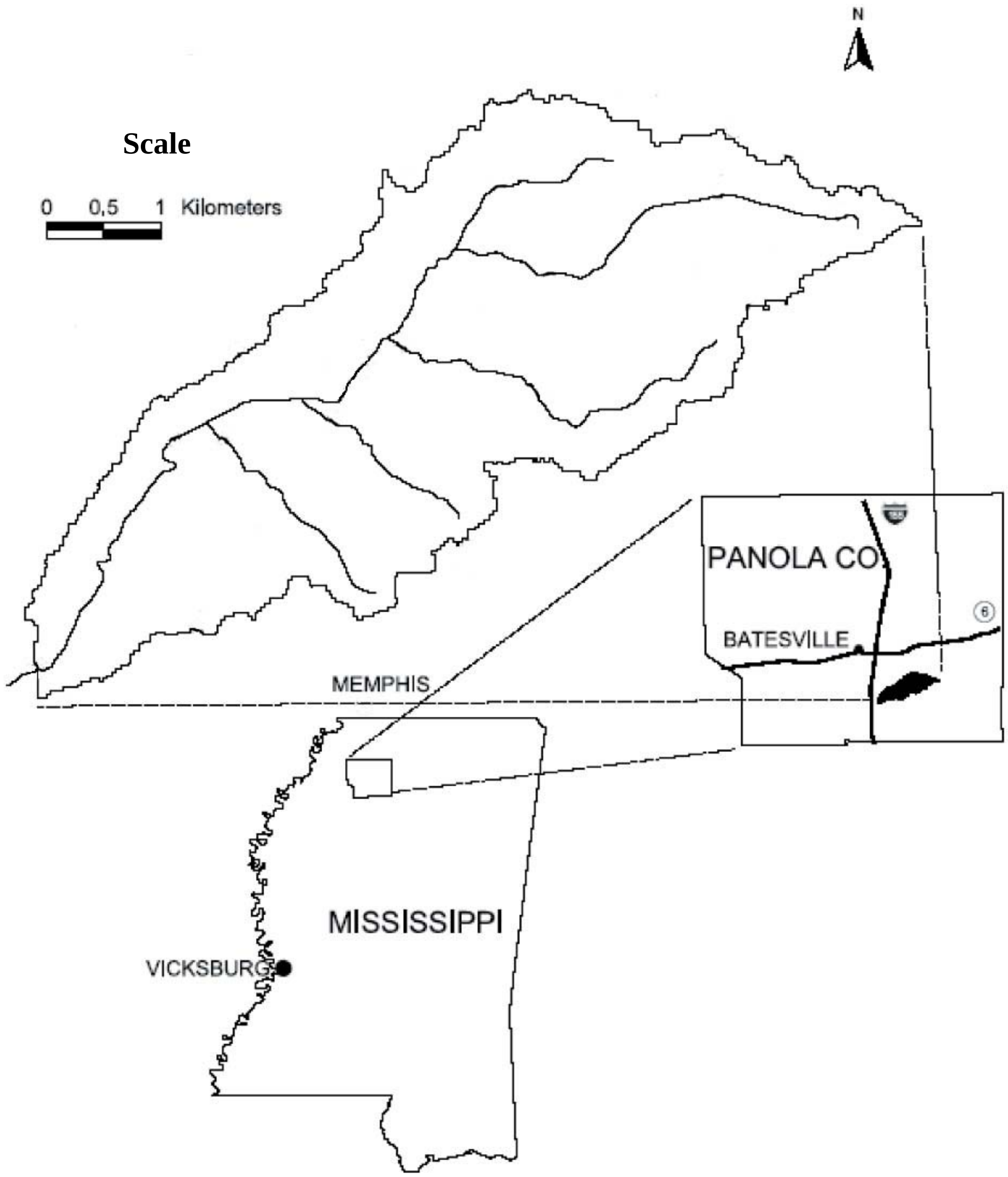
The 2010 EPA report *Watershed Assessment, Tracking, and Environmental Results* discusses the water quality of streams, lakes, and estuaries in 2010 in the nation (U.S. EPA, 2010, pp. 1-2). This report notes that tribes, territories, and other jurisdictions assessed approximately 5.6 million km of rivers and 107.9 million sq km of lakes; these reported figures are slightly more than the previous report in 2000.

Primary sources of pollution for streams and rivers include urban runoff, non-point source runoff, and land disposal of waste materials. The principle causes of the impairments include bacteria, oxygen depletion, and turbidity (U.S. EPA, 2010). Additional concerns currently contributing to impairments related to the Mississippi River and other U.S. waters include, but not limited to, the following: Alkalinity, Arsenic, Barium, Beryllium, Cadmium, Dissolved oxygen, Dissolved solids, Fecal Matter, Lead, Mercury, Organic and Inorganic Carbon, pH, Suspended sediment, Transparency, and Turbidity (USGS, 2010).

Description of Study Area

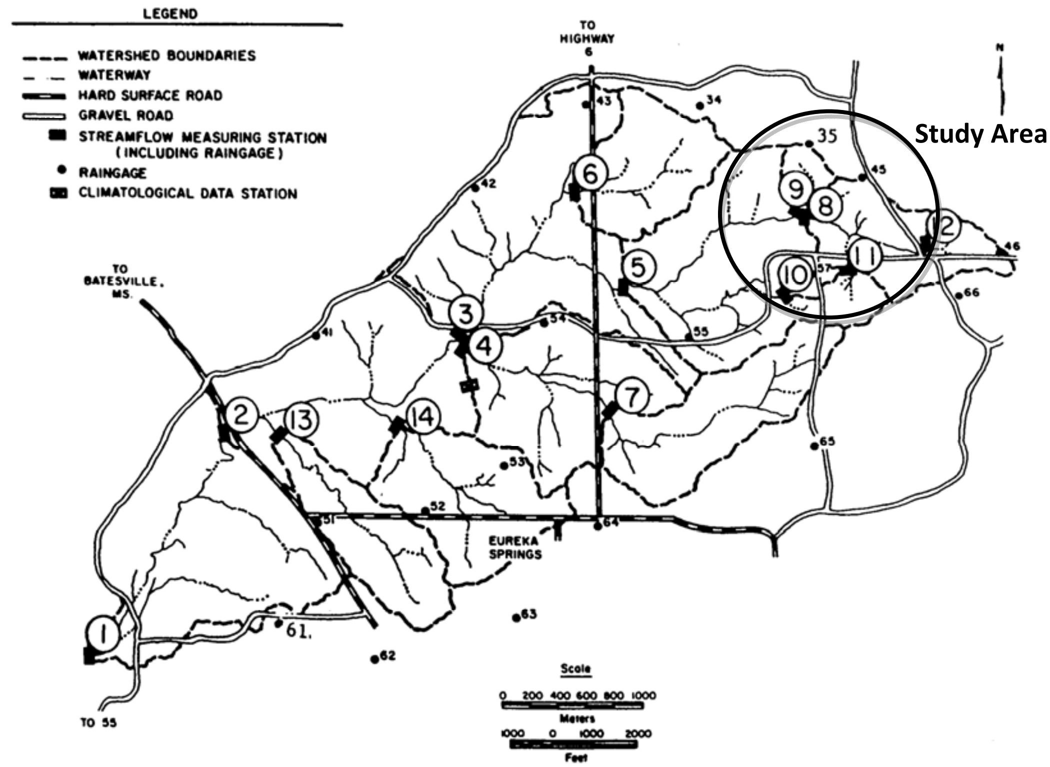
The Goodwin Creek Experimental Watershed is a controlled watershed located in Panola County located near Batesville, Mississippi consisting of approximately 21.3 km^2 of land (see Figure 1). The watershed is divided into 14 drainage areas (see Figure 2), from which gauging sites 9 and 11 were chosen for this study because of the location in the watershed. Eisenbies et al. (2007) believes that to offset limitations in water quality studies, researchers should use paired watersheds to provide a means to account for the issues associated with correlation [studies] using a single catchment area (p. 81). These two gauging sites are located in the extreme eastern part of the watershed and are the beginning of the entire drainage basin. No other gauging sites are higher or further away from the outlet of Goodwin Creek. These two drainage areas, for gauging sites 9 and 11, consist of two areas in close proximity of each other; however, they are different in makeup. Gauging site 9 consist of a drainage area that is extremely gullied whereas gauging site 11 drainage area is primarily pasture (see Figure 4).

Figure 1: Goodwin Creek Experimental Watershed, Panola County, Mississippi



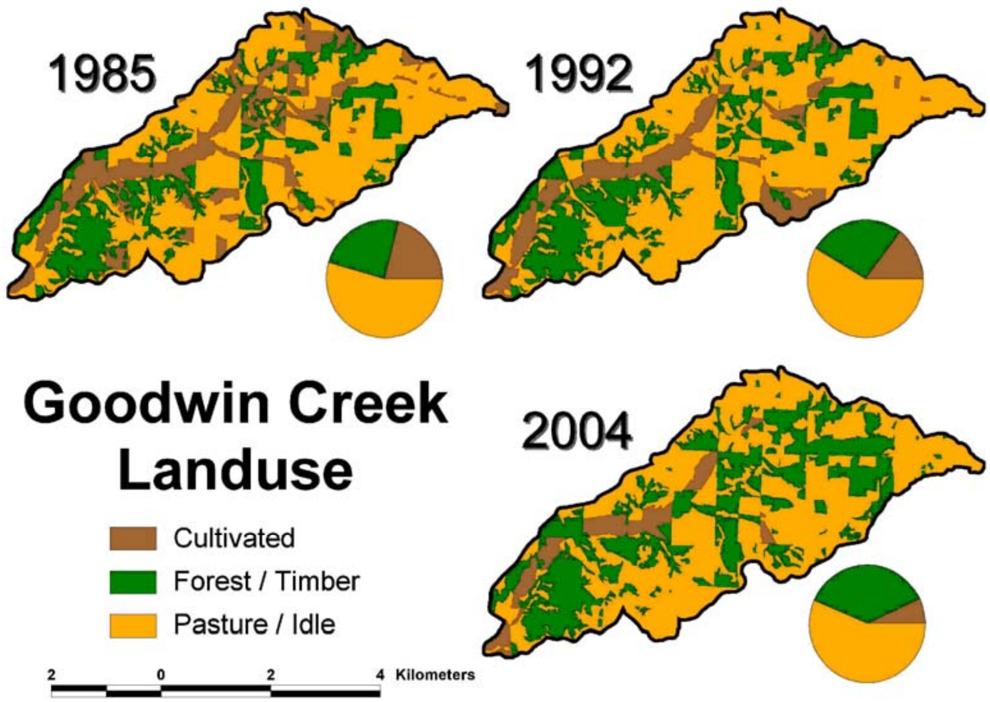
Note: Fox et al, 2007, p. 1560

Figure 2: Goodwin Creek Precipitation and Gauging Stations



Note: Blackmarr, 1995, p. 15

Figure 3: Land Use Change on Goodwin Creek



Note: Kuhnle et al, 2005, p. 3

Figure 4: Satellite Image of Goodwin Creek Experimental Watershed Gauging Sites 9 and 11

Note: Google Maps, 2010

Purpose of the Study

The propose of this study was to determine if a correlation exists between the intensity of precipitation and the total suspended solids data and between the intensity of precipitation and stage height for each rainfall. This study analyzed the intensity of precipitation (precipitation amounts in mm/ amount of time), total suspended solids data, and stage height data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging sites 9 and 11 (see Figure 2). All data used in this study were collected by National Sedimentation Laboratory from the controlled watershed at Goodwin Creek Experimental Watershed in 2000.

Hypotheses

Hypotheses were used to explore the relationships among the variables for which data were collected in this study. The following are the null hypotheses with the corresponding alternative hypotheses that were tested:

H_{01} No significant correlation exists between the intensity of precipitation and the total suspended solids data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging site 9.

H_{02} No significant correlation exists between the intensity of precipitation and the total suspended solids data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging site 11.

H_{03} No significant correlation exists between the intensity of precipitation and stage height for each rainfall in the Goodwin Creek Experimental Watershed at gauging sites 9.

H_{04} No significant correlation exists between the intensity of precipitation and stage height for each rainfall in the Goodwin Creek Experimental Watershed at gauging sites 11.

Hypothesis Statement

These hypotheses were assessed by collecting and analyzing precipitation data, total suspended solids data, and stage height data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging sites 9 and 11. Pearson's product-moment correlations were used to test four null hypotheses to determine if a correlation exists between the intensity of precipitation and total suspended solids at gauging sites 9 and 11 and determine if a correlation exists between the intensity of precipitation and stage height at gauging sites 9 and 11.

Conceptual Framework

This correlational research was designed to asses if a relationship exists between the intensity of precipitation data, total suspended solids data, and the stage height data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging sites 9 and 11 (see Figure 2). The study examined the relationship between the intensity of precipitation and total suspended solids data and between the intensity of precipitation and stage height for each rainfall.

The Goodwin Creek Experimental Watershed was a good location to use in this research study because of the meticulous procedures used by the National Sediment Lab to take field sediment samples while it is raining to insure the consistency of the instrument measurements used to make predictions, or fill in the gaps, when there are no instrument samples taken. To complete this calculation the National Sediment Lab use a computer model called the least squares method using field sediment samples.

Abbreviations

The following abbreviations are used in this study; most are commonly used in hydrologic studies related to sediment analysis.

ANN: Artificial Neural Network

EC: Electrical Conductivity

EPA: Environmental Protection Agency

ETR: Equal-transit-rate

GCEW: Goodwin Creek Experimental Watershed

GIS: Geographic Information Systems

NCDC: National Climate Data Center

NF: Neuro-fuzzy

NOAA: National Oceanic and Atmospheric Administration

PP: Particularly Phosphorous

PPM: Parts Per Million

PSD: Particle Size Distributions

SRC: Sediment Rating Curve

SSC: Suspended-Sediment Discharge

SST: Soil Suspension Turbidity

TMDLs: Total Maximum Daily Loads

TSS: Total Suspended Solids

USGS: United States Geological Survey

α and θ: Coefficient and exponent of the power law relating Q(A) - peak-discharge observed in data or simulations and A - drainage area of a basin

CHAPTER 2

REVIEW OF LITERATURE

"The face of the water…
… told its mind to me without reserve."
- Mark Twain, (1901, p. 69)

Selected Studies Conducted at Goodwin Creek

Over 100 research studies, papers, documents, and dissertations have been produced as a direct result of the Goodwin Creek Experimental Watershed over the past 20 years. In general, the majority of studies were conducted on sediment yield, sediment transportation, and the methods used to curtail the amounts of sedimentation within a stream. A small number of studies were conducted on precipitation and the amounts of sediment runoff, and only a few studies were based solely on precipitation.

Monitoring the water budget on a catchment requires an accurate representation of rainfall and its variability. Highly variable precipitation affects the capability to completely understand the amounts of rainfall reaching the surface from using either the actual rain gauge or remote sensing measurements. To further understand this process, Sieck, Steiner, Burges, Smith, Alonso (2003) conducted a study to understand the detailed observations of rainfall over Goodwin Creek and which type of instruments are better suited to measure rainfall amounts.

The research by Sieck et al., (2003) detailed observations of one major storm and was used to gain a better understanding of the uncertainty of measuring rainfall from using either a rain gauge or some type of remote sensing perspectives. These uncertainties are related to the rain gauge measurements, radar rainfall estimation, and the merging of information from various sources. As a result of their study, Siech et al. (2008) determined it is crucial to use only reliable rain gauge information, to have redundancy in rain gauge data, and to cluster at least three rain gauges within tens of meters (or less) of each other for storm analysis. This conclusion reflects that rain gauges are prone to malfunction, especially tipping-bucket gauges. Last, rain gauges should be buried if possible to minimize wind effects on the measurement.

Johnson, Smith, Anderson (1995) observed five rainfalls for the purpose of comparing them to observed flow records at six discharge gauge locations on Goodwin Creek. From the output, the peak flow, time to peak, volume of runoff, and hydrograph, variance parameters were summarized for three experimental models. From the results of the observed and hypothetical storm events simulated for the Goodwin Creek Watershed, the following conclusions were made:

1. In the case where an accurate spatial data representation of the watershed variability in soils and land use exist, a distributed model will simulate more closely the true shape, rate of rise, and volume of the stream flow runoff hydrograph than the lumped unit hydrograph method.

2. In the case where a sufficient sub-basin stream gage data are available for calibration purposes, the lumped unit hydrograph model can reproduce the observed hydrograph reasonably well.

3. The lumped models rely heavily on sub-basin stream gage data to adequately simulate the observed hydrograph. If accurate spatial data and sub-basin

stream gage data are both lacking, then both models, lumped and distributed, may produce questionable results.

4. Because the distributive model consistently produced more realistic results in terms of hydrograph shape and volume runoff, it offered more flexibility when performing sediment studies. (p. 1067)

The diagnostic framework that guided the research of Furey and Gupta (2007) was not specific to Goodwin Creek and could be applied to understanding space-time patterns in any basin. Their process consisted of five steps:

1. Identify and quantify a recurring space-time pattern in data.
2. Use data sets that complement the data in step 1 to show, qualitatively, how certain conditions and processes influence the pattern.
3. Develop theoretical expressions and/or run simulations to describe how the pattern depends on the conditions and physical processes examined in step 2
4. Test the results of step 3 against those in step 2.
5. Assess the test results from step 4 and repeat, if necessary, steps 2 - 5. (p. 2388)

They also observed in their study that α and θ changed between different events. Where α and θ are the coefficient and exponent of the power law relating Q (A) the peak-discharge observed in data or simulations and A the drainage area of a basin. This discovery showed for the first time that spatial power laws in peak-discharge were present in a real basin on an event-by-event basis. Using the estimated excess-rainfall time series and simulated basin-response functions, a stochastic equation was formulated that related expected discharge to the depth and duration of excess-rainfall and drainage area. Then using a maximum expected discharge equation Furey and Gupta (2007) were able to diagnose the observation that peak-discharge depends on drainage area during a single rainfall-runoff event. Furey and Gupta's (2007) research pointed out three limitations that should be addressed. First, they could not adequately explain why the concave relationship between α and excess-rainfall duration became more pronounced as the amounts of excess-rainfall depth increased. Second, a need exists to examine the impact of more realistic hill slope and network routing conditions on α. Third, a need exists to distinguish the dependence between excess-rainfall depth and the duration of the rainfall, followed by examining how these variables influences α. (p. 2398)

Kuhnle and Willis (1998) measured the transport rates of bed material at the Goodwin Creek Experimental Watershed and statistically analyzed the data to determine the mean rate of sediment transport. The bed material load of a stream is generally regarded as a deterministic quantity, and virtually all sediment transport measurements are averaged over space, or time. As a result, averages from most distributions are distributed according to the normal probability function. The number of measurements needed to obtain a defined level of accuracy can be calculated if the mean and standard deviation of the transport are known.

Numerous load relationships have been proposed to relate the rate of transport of the bed material to the fluid, sediment, and hydraulic properties of a channel system that are regarded to impact the rate of transport. Some developments of these relationships begin with considerations of the forces of the flow on sediment particles and the prediction of the amounts of bed materials through approximate equations of motion for fluid and, or sediment. According to Kuhnle and Willis (1998), "the complexity of the sediment/fluid interactions is so great that knowledge of the physics of transport processes is inadequate and resort must be made to empirical relationships to fill the gaps in knowledge" (p. 1109).

Kuhnle and Willis (1998) demonstrated that the sediment transport data from Goodwin Creek yielded information on the accuracy of the mean rate of transport calculated from the given number of sediment measurements of transport. This relationship shown in this study should be similar for mean sediment rates of transport on other steams. Therefore the application of this technique to other streams would require an estimate of the coefficient of variations of the sediment transport. Kuhnle and Willis concluded that when knowledge of the type of probability density function, that best describes the transport rates of sand and gravel for a stream, is lacking, then an estimate of the average cross-section measurements should be used.

Evans, Gibson, Rossell (2006) demonstrated that stream bank erosion contributes approximately 30 to 80% to total sediment loading in streams. Most researchers believe that stream bank erosion is a result of near bank velocity gradient and shear stress distribution resulting in the mass failure of the stream bank from gravity (Fox, Wilson, Simon, Langendoen, Akay, Fuchs, 2007). The research of Fox et al. on the Goodwin Creek Experimental Watershed, however demonstrates that groundwater seepage into a stream bed causes the bank erosion and failure to occur.

According to Blackmarr (1995), "numerous equations and procedures have been proposed in the literature for estimating the [rate of] sediment transport" (p.129). The ASCE Task Committee (1971) and Shulits and Hill (1968) are two excellent review articles describing several types of equations used for estimating rate of sediment transportation according to Blackmarr (1995). Each procedure varies in complexity from the relationship between the rates of sediment transport with only a flow parameter (Colby, 1964 as cited in Blackmarr) to extremely complex procedures that include state-of-the-art transport mechanics and alluvial channel hydraulics (Blackmarr, 1995). "It should be noted that no matter how complex a calculation procedure may be, the theory becomes inadequate at some point, and experimental data must be used to complete the procedure. Therefore, the calculation is no better than the data upon which it is based." (p.129)

The basic variable correlation, as described in the Colby study of 1964, seemed to perform just as well, if not better than, other methods used to estimate the rate of transport of sediments (Blackmarr, 1995). "This method presents the sediment transport rate as a function of depth, velocity, and particle size in a graphical correlation (p.129)." Blackmarr further states, although the basic variable may serve as good design tools, these variables give little information about how sediments are moved from one point to another. "The sediment transport rate is generally divided into two parts, one that moves in almost continuous contact with the bed and another that moves in suspension in the body of the flow." (Blackmarr, 1995, p.130) The suspended sediments within a stream occur because of the turbulent eddies that exchange sediments between the different flow levels in a stream. "A balance between the upward diffusion by turbulence and the downward settling by gravity defines the equilibrium concentration distribution for an assumed distribution of turbulent diffusivity" (Vanoni, 1946). Several different models have been developed to describe the turbulent diffusion of sediments with comparable results in the central flow region. (DeCoursey, 1981, as cited in Blackmarr, 1995)

Total Suspended Solids

James (2003) study reviews the best practices for measuring the amounts of suspended solids in a watershed. The initial methods of measuring total suspended solids were based on procedures used to measure wastewater particulates. Newer methods have been proposed, however, to separate wastewater measurements from the suspended sediments comprised of such things as sand, silt, rocks, pavement, atmospheric and natural dust, chemical precipitates, rust, trash, or plants. New guidelines from the EPA require states to clean up these run-off waters from U.S. cities at an established rate of 80%. These new guidelines are being met with stiff opposition. (James, 2003)

Two contemporary debates exist over the size and limitations of the particle size and method used to gather the samples (James, 2003). One group of individuals argues to continue the use the total suspended solids, whereas the opposing sector wants to use the total dissolved solids (TDS). The methodologies of both groups have brought to light the need by the EPA to develop an evaluation and verification process of the best management practices to assist in determining which method should be used. Though both methods are acceptable, the EPA found "that new and improved technique is needed to characterize storm water pollutants and determine the effectiveness of best management practices" (pp. 10-11). This review found:

1. Many of the current methods and techniques used by storm water programs for sample collection, management and analysis have significantly underestimated the concentration of total suspended solids and loadings of suspended sediments, the particle size distributions (PSD) of those sediments and overestimated the pollutants associated with the sediments.

2. New and improved techniques or methods for sample collection, management and analysis are needed to characterize all pollutants in storm water runoff. These methods must be standardized to ensure that study results can be compared.

3. During transition from use of total suspended solids to PSD to characterize storm water pollutants, it is essential that standard procedures be adopted for sample collection, management and analysis and all reports and studies fully document procedures and methods used. (p. 11)

The review of the practices discussed by James (2003) and the acceptance of the new particle-size distribution method present even greater challenges in determining which method should be used to measure suspended solids. James concluded that new and improved techniques are needed to characterize storm water pollutants and determine the effectiveness of best management practices.

Precipitation and Runoff

Typically, the amount of groundwater recharge may be accomplished in several ways. Part of the water that falls as precipitation, moves as surface runoff and goes into streams, part of the water evaporates, and some of the water is absorbed by plants and returned to the atmosphere as water vapor by transpiration. "Water that escapes runoff, evaporation, and transpiration, percolates slowly down through the soil and underlying strata, and part of it eventually reaches the zone of saturation" (Kansas Geological Survey, 2008, p. 1). "The quantity of water that [moves] by surface runoff depends upon several factors: the intensity of rainfall, the slope of the land, the type of soil, the type and amount of vegetation, and the season" (p. 1).

In general, a greater percentage of rainfall will enter the ground during a long gentle rain, than during a torrential downpour when a large percentage of runoff flows into lakes, ponds, and streams. The type of soil also affects the amount of runoff. In general, runoff is greater in places of tightly compacted, fine-grained soil than in places of loose sandy soil where absorption is more likely to occur. The velocity of surface runoff is reduced by the type of vegetation, dense forest, or land covering. A better chance to absorb precipitation into the ground occurs on open land or loosely-fitted grass lands (Kansas Geological Survey, 2008, p. 2).

Many climate prediction models disagree on how precipitation variables in North America are affected by changes in atmospheric conditions. In some regions of the United States, seasonal changes in weather may allow for quicker increases in detecting the frequency of extreme events if the hydrological event accelerates itself over time (Ziegler, Maurer, Sheffield, Nijssen, Wood, Lettenmaier, 2005). Karl and Knight (1998) found precipitation increases in the United States during the 20th century were most pronounced in spring and autumn, but they were also apparent in the summer. In these cases, Karl and Knight (1998) that suggest all four seasonal time series facilitated a quicker detection time rather than the annual time series because of a sharp decline in precipitation trends in the fall followed by increases in the trend in all other seasons. These initial results, using precipitation models, demonstrate the advantages of looking at seasonal trends versus annual data for detecting trends related to the hydrologic cycle over multiple years (Ziegler et al., 2005). It should be noted, however, that the changes in precipitation amounts are based on precipitation models and some field data, and are not solely based on field measurements.

In hydrology, the mechanisms involved in the catchment process of translating precipitation amounts into runoff have not been well defined, and modeling these processes is difficult. To represent these models accurately, the catchment process of rainfall, evaporation, and infiltration must be identified and correctly incorporated into the models. A sub-area of a larger catchment area, such as the Goodwin Creek

Watershed where in 2000 land use on the watershed was approximately 48% pasture, 32% forest, 12% cultivated and 9% idle, are most often considered homogeneous where a single input of average precipitation is applied over the entire area and individual process. Ideally, these measurements should have physical interpretation and be measurable in the field. According to McKerchar (1980), these measurements are rarely achieved and rely on numerical procedures to define at least one of the parameters within the study. "Despite these estimation difficulties, conceptual models have been extensively used in hydrology. Clarke (1973), as stated in McKerchar (1980), suggests three principal uses for conceptual models:

1. To forecast river flows, in operational or "real-time" situations, and in hypothetical or design situations.

2. To estimate records of flows that corresponds to long precipitation records.

3. To predict possible effects of proposed changes in the catchment on river flow characteristics." (pp. 172-173)

The physical importance of a trend in precipitation over a large area may have important effects on water resources, even one that has not been deemed statistically significant (McCabe and Wolock, 1997). The measurement of precipitation on a near-global basis has many scientific and public benefits. "These benefits include increased scientific understanding of the processes affecting global climate change, improved measurements of rainfall and hydrological processes, improvements in weather forecasting, and better definitions of severe storms, including the forecast of the storms' magnitude and a storm's ground track" (Flaming, 2002, p. 1). Furthermore, waiting for unequivocal proof of a change in the hydrological cycle before requiring policies to address the potential causes may turn out to be detrimental to the population of an area (McCabe & Wolock, 1997).

Erosion of Stream Banks

The composition of the stream bed acts as a filter allowing water to pass from one zone to another (Brunke and Gonser, 1997). Depending on the flow characteristics and particle loads, its composition and hydraulic properties may change, increasing or reducing the amount of flow.

Fox et al. (2007) demonstrated three types of interchanges occur between subsurface flow (ground water) and bank erosion: (1) intermittent low-flow seeps (flow rates typically less than 0.05 L per/min), (2) persistent high-flow seeps (average flow rate of 0.39 L per/min), and (3) buried seeps, which eroded unconsolidated bank material from previous bank failures. Low flow seeps act in conjunction with overland water flow and in-stream erosion to cause bank instability. High flow seeps result in the formation of headcuts and cause stream banks to collapse. Buried seeps originate from sloughed bank material from previous stream bank failures and result in the largest rate of erosion and sediment concentrations intrusions into the stream.

The interrelationship between the different types of seepage flow, overland flow, and in-stream erosion makes it difficult to generalize the role of bank instability. "In cases where perched water table conditions exist and persistent high flow seeps occur, the subsequent erosion and bank collapse… may be significant, especially in cases with buried seeps" (Fox et al., 2007, p. 1571). Though they measured seepage rates of erosion and sediment concentrations on Goodwin Creek, their study did not take into account bank sloughing by undercutting. During their 4 month study, at least three bank collapses were recorded as a result of seepage erosion undercutting the bank. At the end of their study, the question remained whether seepage erosion was significant in the total sediment load in the stream and watershed they were analyzing and acted independently, or was combined with overland flow erosion, in-stream erosion, and removal of negative pore-water pressures.

Correlation Models and Other Approaches to Predict Suspended Sediments

According to Deng, Lima, Jung (2008), "soil erosion has been recognized [internationally] as a serious environmental and soil degradation problem. It can reduce soil productivity and increase sediment and other pollution loads in receiving waters…. Estimation of soil erosion is, therefore, essential to issues of land and water management." (p. 54)

Mathematical models have been proven to be a cost-effective tool for improving the understanding of erosion processes and evaluating possible effects of land use changes on soil erosion and water quality. Deng et al. (2008) believe a sound mathematical model can provide an efficient and economic tool by which a large number of scenarios can be simulated and compared in a short time finding the best alternative for addressing the problem. "Consequently, a wide spectrum of models, ranging from simple empirical formulas to comprehensive distributed descriptions, has been proposed for the description and prediction of soil erosion and sediment transport. Some of the models show great promise and have been increasingly used" (p. 54).

Nadal-Romero, Regüés, Latron (2008) researched the relationships between precipitation, discharge, and suspended sediment transport in a small catchment within the badland area of the Araguás Catchment Watershed in Central Spanish Pyrenees. It sought to determine different "hysteretic loops for single floods and determine the relationships between the types of hysteresis and the hydrological and sediment responses" (p. 128).

To collect data for the Nadal-Romero et al. (2008) study, a gauging station similar to National Sediment Lab's Goodwin Creek was constructed at the outlet of the Rebullesa Stream to record discharge and suspended sediment concentration. The equipment used was also similar to the types of instruments used at Goodwin Creek. A total of 79 flood events were recorded between October 2005 and April 2007. A database was generated for each flood. This database contained variables related to rainfall depth, maximum rainfall intensity, precursor rainfall depths, storm-flow depth, storm-flow coefficient, baseflow at the start of the flood, peak flow, mean suspended sediment concentration, maximum suspended sediment concentration, and the amount of transported suspended sediment (p. 129).

To identify factors that might explain the measured hydrological and sedimentological responses, Nadal-Romero et al. (2008) used a Pearson correlation matrix. The linear correlation coefficients among rainfall, runoff-discharge, and sediment variables "determined the rapid sediment response were likely from the small size of the stream; in contrast, the arrival of clean water from the forested headwater area in the Araguás Catchment could act to reduce the suspended sediment concentration but not the total transport" (p. 135). From their study the research concluded the discharge characteristics and rainfall depth were the most relevant factors in controlling sediment concentration and yield. The succession of events presented shows that sediment availability was not the sole control for sediment load (p. 135).

The objective of Soler, Regüés, Latron, Gallart (2007) research was to analyze the hydrological and sediment transport functioning in the Ca l'Isard basin. They aimed to estimate the magnitude and frequency relationships of the 420 events observed over a 10-year period to assess the long-term validity of the sediment yield rates using several different variables, precipitation, runoff, peak discharge, and sediment load. Their second objective was to analyze whether the magnitude and frequency relationships obtained with precipitation could be transferred to the sediment transport ones (p. 165).

To collect their data, a gauging station, which was similar to National Sediment Labs at Goodwin Creek, was constructed at the outlet of the Ca l'Isard basin located within the Vallcebre basin at the headwaters of the Llobregat River in the southeastern Pre-Pyrenees. The equipment used was also similar to the types of instruments used at Goodwin Creek to record discharge and suspended sediment concentration.

In the Soler et al. (2007) study, when the 420 events were ranked and compared, the Spearman coefficients were significant; although some of them were rather low. The Spearman correlation produced a correlation coefficient between precipitation and sediment transport of $r = 0.21$ which was statistically significant ($p < 0.001$). Nevertheless, when just the events exceeding the 90^{th} percentile were compared, none of the variables were significantly correlated when suspended sediment concentration was used for selecting the events (Soler et al., 2007, p. 167). Even though two of the largest precipitation events for that area were included in their 10-year study, the results of study indicated that precipitation was an unreliable substitute for ranking sediment transport events (p. 170). At the present time, soil loss is currently computed and reported as a sediment transport rate of a mass (or volume) of sediment passing a given point at a given time. Sediment discharge is calculated based on the product of the rate of runoff (flow discharge) and the simulated sediment concentration in the flow (Soler et al., 2007).

According to Deng et al. (2008), to simplify these measurements, it is desirable to have a sediment discharge or transport rate-based model so the sediment discharge can be directly calculated. Once the sediment discharge amount becomes available, amounts of sediment-concentration can be easily determined from a simple equation $c = C/Q$, where C is the sediment discharge and Q is flow discharge because the relationship between the flow discharge Q and time are relatively easy and accurate (p. 55).

The goal of the Deng et al. (2008) research was to develop a new sediment transport rate-based model for simulating rainfall-induced soil erosion and accompanying sediment transport process. The specific objectives were:

1. to present a sediment transport rate-based mathematical model for the overland soil erosion based on the characteristics of rainfall-induced soil erosion
2. to propose an efficient method for numerical solution of the model equations
3. to test the efficacy of the mathematical model using laboratory data. (p. 55)

To test their module, Deng et al. (2008) concluded a series of soil flume experiments under constant rainfall to simulate the overland flow and sediment transport and to test the sediment transport rate-based model. The numerically simulated hydrographs, rate of sediment transport, and sediment concentration corresponded with the experimental measurements, demonstrating the laboratory proof-of-concept of the transport rate-based model (p. 62).

As a result of their study, Deng et al. (2008) developed a physically-based one-dimensional mathematical model for simulating overland flow and sediment transport under constant rainfall. The model was comprised of:

1. the kinematic wave overland flow equation

2. a generalized and transport rate based advective equation for overland sediment transport

3. a semi-Lagrangian algorithm for numerical solution of the sediment transport equation (p. 62)

A semi-Lagrangian method is a numerical solution technique for the partial differential equations describing the advection process (pollutant transport due to the mean wind fields). It accounts for the Lagrangian nature of the transport process but, at the same time, it allows to work on a fixed computational grid.

Udeigwe, Wang, Zhang (2007) evaluated the relationships between suspended solids in surface runoff and soil characteristics determined by simple laboratory tests. They believe these relationships could help in predicting the runoff of suspended solids from agricultural fields. Because particle loss in runoff influences nutrient loss, particularly phosphorous (*PP*), these relationships could aid calibrating indices of phosphorus loss to improve reliability. The objective of this study was to evaluate the relationships between the total suspended solid or *PP* losses in surface water runoff and selected soil characteristics using simple soil tests (p. 1311).

The runoff experiment was conducted on nine packed soil boxes following a protocol developed for the National Research Project for Simulated Rainfall-Surface Runoff Studies (National Phosphorus Research Project, 2001) and modifications made by Davis et al. (2005), as cited in Udeigwe et al. 2007. The simulation experiment over-packed soil boxes chosen for better controlled runoff conditions and was shown to yield similar and consistent relations between runoff characteristics and soil properties as field plots. De-ionized water was used as the source for the rainfall simulation; the boxes were irrigated to saturation and the excess water was allowed to drain 24 hours before the rainfall simulation began (Udeigwe et al., 2007, p. 1311).

Statistical analyses were performed using single and multiple linear regression analyses to establish a relationship between runoff and soil parameters. The nonlinear relationships were deducted using the Statistical Analysis Software (SAS) (Udeigwe et al., 2007, p. 1312). This study demonstrated interrelationships among major runoff parameters and the effects of selected soil properties, especially soil clay content, soil electrical conductivity (EC), and suspendability. All nine soil samples demonstrated highly significant and positive linear correlations between runoff total suspended solids and turbidity; between runoff, total suspended solids, and PP; and between runoff turbidity and PP. Runoff parameters were clearly affected by soil properties. The soil suspension turbidity (SST) was able to account for the integrated effect of soil clay content and electrolytic background on runoff total suspended solids. The good fit method of linear relationships between soil SST and runoff total suspended solids or PP suggests the SST test could be used to indirectly predict the potential loss of sediment and PP through surface runoff from these cultivated soils (p. 1316).

As a result of their study, Udeigwe et al. (2007) determined that the losses of sediment and nutrients from packed boxes are generally consistent with losses from field plots. They also determined the relationships derived in this study may represent a worst case scenario because the soil was bare and aggregate stability somewhat diminished compared to in situ soil. Their final conclusion was that future work is needed to validate the relationships for cultivated field soils and uncultivated soils such as pasture for which runoff loss of *P* is often dominated by dissolved phosphorus rather than particulate phosphorus (PP). Successful prediction of sediment and PP in runoff could improve *P* indices because the latter also contributes to the bio-available pool of P (p. 1316).

Marques, Bienes, Jiménez, Rodríguez (2007) believe that "the intensity and duration of simulated rainfall should be based on meteorological characteristics of the study area; but to predict the erosive potential of a rainfall its kinetic energy must be known" (p. 161). Their research area was located south of Madrid, Spain in an area composed traditional of agricultural land with sloping terrains where annual rainfall in the area is around 400 mm with a median amount of 315 mm distributed over 84 rainy days per year. The field experiments were conducted during the dry season on dry soil profiles (July through early September of 2004) and consisted of two simulated rainfalls applied over each plot with each simulation lasting 25 minutes. Runoff sub-samples were sampled every minute following the start of runoff, and runoff volumes were recorded and stored in bottles. Once in the lab, water was separated from sediment in the sub-samples. Water volume and sediment dry weight were recorded and the corresponding sediment concentration was subsequently calculated (p. 162).

The kinetic energy of the 15 minute simulated storm occurs independently only a few times a year within the study area, but it occurs more than 50 times a year from natural rainfall episodes. The runoff produced by this low-rainfall simulated event demonstrated that the presence of the vegetation effectively prevented runoff because of the plots with plant protection; runoff appeared to be stabilized (Marques et al., 2007, p. 163). Once the rainfall ceased, runoff cessation was much slower and was more progressive in the case of the soil with vegetation, which might explain the role played in flood control. In this study, soil loss was considered to be slight, because it was mostly suspended sediment in the runoff water (p. 164).

As a result of their study, Marques et al. (2007) demonstrated the erosive power of a single, light rainfall event of 20.75 mm with a kinetic energy of 13.5 joules is negligible when plots are covered with vegetation. This event, however, produces an average soil loss of 74 kg /ha when the soil is bare, and the runoff can vary from 3 to 10 mm. Even with slight soil losses, the frequency of events can play an important role in land degradation; moreover, the runoff magnitude can be serious with annual rainfall around 350 mm. They determined the consequences of light rainfall events should be revised depending on their frequency and amounts of precipitation per event (p. 164).

Factors Controlling and Tracing Suspended Sediment Sources

Zabaleta, Martínez, Uriarte, Antigüedad (2006) research demonstrated for the first time the results of field studies on suspended sediment yield and dynamics carried out in the central part of Basque Country in northeastern Spain. For their study they chose three areas with very different physical characteristics to determine an approximation of suspended sediment yields from different catchment types. Through their research they sought to determine the major factors that influence suspended sediment yield in each catchment and to identify the different hysteresis types for single floods and the relationship of those factors with runoff generated variables (p. 180).

To conduct their research, they collected the following data from each catchment: turbidity, discharge, and precipitation, because those three variables were continuously monitored at the gauging stations located at the outlet of each catchment from October 2003 onward (Zabaleta et al., 2007, p. 181). During the monitoring time, 76 events were recorded in Aixola, 18 in Añarbe, and 25 in Barrendiola. The precipitation events that caused the floods varied between 2.5 and 56.6 mm in Aixola, between 5.4 and 61.2 mm in Barrendiola, and between 16.8 and 147 mm in Añarbe (p. 183).

The discharge characteristics of these events totaled water volumes between 0.2 and 25.2 mm in Aixola, 0.2 and 33.6 mm in Barrendiola, and 0.2 and 131 mm in Añarbe. Suspended sediment characteristics also varied widely with the maximum suspended sediment concentration between 11 and 8816 mg/l in Aixola, 35 and 1614 mg/l in Barrendiola, and 17 and 1595 mg/l in Añarbe (Zabaleta et al., 2007, p. 184).

Through their statistical analysis they found in the Aixola catchment a strong correlation exists between precipitation, discharge, and suspended sediment variables, but no significant correlation between these and precursor conditions. In their opinion, "these results suggested a direct response of the catchment to rainfall events, in the discharge as well as in the sediments" (Zabaleta et al., 2007, p. 186).

In the Barrendiola catchment, total sediment yields of the event were well correlated with total precipitation; and the average suspended sediment concentration and maximum suspended sediment concentration were also correlated with maximum intensity of the precipitation. In this case, although suspended sediment yields were very well correlated with discharge variables, the suspended sediment concentration variables did not show any significant correlation with them. They also found in the Barrendiola catchment suspended sediment variables related to precipitation and discharge, but precipitation and discharge did not show a significant relationship to each other. Therefore, taking into account all the events of Añarbe, a very strong correlation occurred between precipitation, discharge and suspended sediment reflected in the optimum situation for suspended sediment transport in Añarbe (Zabaleta et al., 2007, pp. 186-187).

This study provides evidence in the differences between the three catchments studied in relation to discharge and sediment response to rainfall. It also demonstrates the importance of the catchment area and land uses in this kind of research. The correlation matrixes and factorial analysis demonstrated meaningful differences in the factors controlling sediment yield and suspended sediment concentration. In conclusion, Zabaleta et al. (2007) state that further work is being conducted to better understand the factors determining the different types of hysteresis in the Aixola catchment and the relationship with sediment sources (pp. 188-189).

The Kisi, Haktanir, Ardiclioglu, Ozturk, Yalcin, Uludag (2009) study focuses on the use of neuro-fuzzy (NF) computing techniques to attempt to predict the monthly amounts of suspended sediment and have been successfully applied in a number of diverse fields including water resources. Fuzzy logic also been successfully used in predicting the amounts of suspended sediment and runoff-induced sediment transport rates of bare soil (Kisi et al., 2009, p. 438). The main purpose of the Kisi et al. study was to analyze the performances of an adaptive NF computing technique for monthly suspended sediment estimation. The monthly stream flow and suspended sediment time series data belonging to two stations in Turkey were used (Kisi et al., 2009, p. 438).

Through their statistical analysis, the NF model predicted the total sediment load as 1,094,262 metric tons instead of the measured 1,219,456 metric tons, with an underestimation of 10%, while other fuzzy logic models computed the amount much lower, with underestimations between 26 and 83%. In general, the NF model can be considered to be relatively superior to the artificial neural network (ANN) and sediment rating curve (SRC) models (Kisi et al., 2009, p. 443).

Their research demonstrated the potential of an adaptive NF computing technique in monthly suspended sediment estimation. Based on the comparison results, the NF technique was found to perform better than the other models used in this study. The accuracy of the NF model in the estimation of total sediment load was also investigated and results were compared with those of the ANN and SRC models. Comparisons revealed the NF model had the best accuracy in the estimation of the total sediment load. Their final conclusion stated, "The estimation of monthly suspended sediment is very difficult, and there is room for much improvement" (Kisi et al., 2009, p. 444).

Adaptive Studies Focusing on Precipitation Intensity and Stage Height

The Wemple and Jones' (2002) study focused on continuous records of precipitation and runoff events using two automated procedure to measure precipitation and peak runoffs. Automatic systems were used to compare water table elevations to observed runoff patterns based on estimates of the response time (pp. 8 – 6). To obtain their results, the predicted and observed values were ranked and compared visually and using a correlation coefficients, then a "linear regression model were fit to matched peak runoff events to assess the relationships between each instrumented subcatchment and Watershed 3 (WS3)" (p. 8 – 8). The data produced by the regression models were then used to predict peak runoff in the subcatchments for a given peak period. An empirical model was then used, then compared to the observed time and predicted values at the instrumented culverts.

Their calculations of runoff were developed to estimate the amounts of precipitation needed to produce over saturation based on specified soil conditions. Average rates of rainfall varied from less than 1 to 5 mm/hr, with predictions of unsaturated zone response time ranging from 50 to 350 hours assuming very dry initial conditions, to 20 to 40 hours with very wet initial conditions. Similarly, predictions were made about the intensity of the precipitation. Saturated soil response time varied from 100 to 300 hours at low intensity (0.5 mm/hr) precipitation, but varied from 30 to 80 hours at high (5 mm/hr) precipitation rates. Comparisons of these predictions - to observed runoff amounts demonstrated, however, the sites exceed the peak times observed, which varied from 9 to 63.5 hours, on the instrumented segments (Wemple & Jones, 2002, p. 8 – 8).

The result of their study indicated the production of runoff from roads in steep forest lands is influenced by variable storm conditions and the characteristics of the subcatchments area. The timing of peak runoff from these subcatchments varied according to characteristics of the storm, including rates of precipitation [intensity] and the events preceding the conditions. Subcatchments with shorter response times had consistently higher peaks than those with longer response times. As the size of the peak increased within Watershed 3, runoff from the subcatchments became increasingly synchronized with the peak at the mouth of the watershed (Wemple & Jones, 2002, pp. 8 – 11 and 8 – 12).

According to Eisenbies et al. (2007), the "connection between forests and water resources is well established, but the relationships among controlling factors are only partly understood. Concern over the effects of forestry operations, particularly harvesting, on extreme flooding is a recurrent issue in forest and watershed management…. Because of to the complexity of the system and the cost of installing large-scale hydrologic studies, data are usually limited." (Eisenbies et al., 2007, p. 77) The objective of Eisenbies et al. study was to explore different approaches used in studying forested areas of the Appalachian region of the United States to find relevant forest hydrology concepts, the effects of forest land uses on flooding, and to evaluate the suitability of existing models and modeling approaches for assessing the effects of forest practices on flooding, and in particular extreme peak discharges (pp. 78-79)

McCulloch and Robinson (1993), as stated in Eisenbies et al. (2007), categorized watershed research studies into three groups: correlation studies, single catchment studies, and paired catchment studies. McCulloch and Robinson found the vast majority of hydrologic correlation studies utilized geologically similar watersheds that varied by vegetation or land use. They also found experimental replication was essential to the reliability of the study, but may suffer from variance inflation due to autocorrelation. They also believed the main limitation of correlation studies were the assumption that the treatment differences such as the responses to climate. Eisenbies et al. found the limitation of a correlation study is the post-treatment, which may fall outside the calibrated amounts for the study. To offset for these limitations, researchers should use paired watersheds to provide a means to account for the issues associated with correlation using a single catchment area. (Eisenbies et al., 2007, p. 81)

According to Boyle et al. (1998), as stated in Eisenbies et al. (2007), most hydrologic studies that evaluate land-use and flooding discharge, express the effects of flooding as an absolute or percentage as it relates to increases in flow volumes, peak discharge rates, or specific yield. Boyles believes these numbers are not helpful in evaluating flood risk, particularly from an economic basis. As stated in Eisenbies et al., Hicks et al. (2005) believes discharge may be a more precise method for describing flood heights. The maximum stage height achieved is always highly dependent on channel structure, such as in mountainous areas. Flooding at the mouths of streams can be considerably less severe than those realized in localized upper portions of a catchment.

Whereas the stage height on narrow streams may be more sensitive to the amounts of discharge, larger streams may be more at risk for erosion and changes in stream structure because of the kinetic energy associated with large volumes of water as stated in Miller, (1990) (Eisenbies et al., 2007, pp. 88-89).

Through their review of the literature, Eisenbies et al. determined that in order to model extreme floods, research studies must be better defined and the effects that control the floods must be better understood. "There is little information regarding the specific conditions that define the threshold between the 'standard' and so-called 'violent' watershed responses to rainfall" (Eisenbies et al., 2007, p. 93). The variety of flooding may be from many factors, e.g. infiltration excess, saturation excess, delayed responses, or preferential flow paths or a combination of these different factors. They also concluded a possible relationship may exist between high intensity rainfall spikes, after a period of soil wetting, and extreme flooding [stage heights] as a result of a sudden increase of water in the catchment area. Eisenbies et al. believe "mechanistic models that specifically incorporate preferential flow and forest roads are probably the best equipped to gain understanding of these floods and formulate hypotheses for field experiments" (Eisenbies et al., 2007, p. 93).

Summary of Literature

In general, the amount of stream flow recorded within a watershed represents a fraction of the precipitation accumulated in previous days, weeks, months or years. As well, the amounts of suspended sediments reported to the government, as required by the Clean Water Act, represents only a small amount of the total sediments washed into lakes, river and streams. Though electronic instrumentation and computer simulated river modeling is available for most hydrology measurements, field sampling and lab analysis are still required to validate the instrument measurements taken. According to Alonso, (2000, p. 176) simulation and prediction models "used to measure and predict sediment transportation rates in streams is labor intensive, very expensive, and often has questionable accuracy." As a result, a more accurate method is needed to improve the results of the sampling techniques or simulations models used to measure suspended sediments. If a correlation does exist between the intensity of precipitation and suspended solids and intensity of precipitation and stage height, the results may be applied to future simulation and prediction models, sediment gathering techniques, and to better understand the relationship between the field sampling and instrument measured data within a stream.

CHAPTER 3

METHODOLOGY

"The face of the water, in time, became a wonderful book, a book that was a dead language to the uneducated passenger..."

- Mark Twain, (1901, p. 69)

Design

This study utilized a correlation design study. This design typically involves analyzing data to determine the relationship between two or more variables or to make a prediction of how one variable predicts another (Gay, Mills, Airasain, 2006, p. 191). This relationship is expressed as the correlation coefficient. The correlation coefficient is expressed as a decimal ranging from -1.0 to +1.00. The correlation coefficient indicates the strength of the relationship which can be either; high, medium, or low and the direction of the relationship which can be either positive or negative (Gay et al. 2006, p. 191, 193). As the correlation coefficient moves closer to zero, the variables are less related to each other. Similarly, as the correlation coefficient gets closer to 1.00, the strength of the relationship between the variables increases. Correlation coefficients less than 0.50 are not considered reliably for prediction studies but can still be considered useful in a correlational study; these scores are highly dependent on the number of cases and the validity of the data used in the study (pp. 194-196). According to Gay et al. (2006), "to be 95% confident that a correlation represents a true relationship (not a chance one), with a sample of 12 participants you would need a correlation of at least 0.58. On the other hand, with a sample of 102 participants you would need a correlation of only 0.19 to conclude that the relationship is significant." (p. 196)

Correlational analysis are concerned with common variance; "common variance is the variation in one variable that is attributable to its tendency to vary with another variable. It indicates the extent to which variables vary in a systematic way." (Gay et al., 2006, p. 195) To calculate the common variance, the correlation coefficient is squared producing *r-squared* (r^2). This value can be expressed as a percent.

There is a need to further understand the relationship between the intensity of precipitation and total suspended solids in a stream and between the intensity of precipitation and stage height of a stream. To provide information in this area, a correlational analysis was conducted to investigate the relationship between the two data sets for this study. One data set consisted of information on the intensity of precipitation and the total suspended solids in the stream. The other data set consisted of information on the intensity of precipitation and the stage height of a stream during rainfall. Each data set contained data from two gauging stations. The sizes of the samples used in this study were 481 samples from gauging station 9 and 129 samples from gauging station 11. Thus, the correlational analysis for this study consisted of calculating two analyses for each gauging station.

Description of Study Area

The Goodwin Creek Experimental Watershed, a controlled watershed located in Panola County located near Batesville, Mississippi, consists of approximately 21.3 km^2

of land (see Figure 1). The Goodwin Creek Experimental Watershed was developed to conduct research using experimental methods to control the amounts of sediment in the stream. The watershed is divided into 14 stream drainage areas (see Figure 2) used to channel the stream across the concrete water gauging site sampling areas, which vary in size from 28 ha to 1,292 ha. From these 14 drainage areas, gauging sites 9 and 11 were chosen for this study because of the location in the watershed. These two gauging sites are located in the extreme eastern part of the watershed and are literally the beginning of the entire drainage basin. No other gauging sites are higher or further away from the outlet of Goodwin Creek. Elevation on the watershed varies from 71 m to 128 m above sea level with an average channel slope of 4 mm. The watershed is located in the bluff hills of the Yazoo River Basin of north-central Mississippi. The controlled experimental watershed was designed, organized, constructed, developed, and instrumented in the late 1970s and early 1980s to conduct extensive research on upstream erosion, stream erosion and sedimentation, topography and land usage, and measurements of watershed hydrology (Blackmarr, 1995, pp. 13 – 14).

Land use and management practices that influence the rate and amount of sediment delivered to Goodwin Creek through its associated streams vary from timbered areas to row crops. In 2000, land use on the watershed was approximately 48% pasture, 32% forest, 12% cultivated and 8% idle (see Figure 3). Incorporated in this study is gauging sites 9 and 11. Gauging site 9 covers an area of approximately 0.172 km^2 consisting of approximately 27% pasture, 27% forest, and 46% gullied land. Gauging site 11 covers an area of approximately 0.281 km^2 consisting of approximately 56%

pasture, 22% forest, and 22% gullied land (see Figure 4). In 2000, cultivated land in the watershed was planted primarily with cotton and soybeans.

All runoff from Goodwin Creek drains westerly into Long Creek, which in turn flows into the Yocona River, which is one of the main rivers of the Yazoo River Basin, located within a tributary of the Mississippi River. Rates of sediment yield are approximately 13.2 metric tons per hectare per year (13.2 t/ha/yr) and are among the highest in the nation in this region (Kuhnle, 2008, p. 497) with a mean daily runoff at the watersheds outlet of approximately 30,000 m^3 per day (Alonso, 2000, p. 1) at gauging site 1. Storm events produce runoff that quickly moves through the watershed, which return to pre-storm baselines within 1 to 3 days (Blackmarr, 1995, p. 124). At gauging site 9 approximately 617,425 ppm of suspended sediments moved over gauging site 9 (617 mg/m^3 year) during 948 mm of rain while at gauging site 11 approximately 1,225 ppm of suspended sediments moved over gauging site 11 (1.23 mg/m^3 year) during 406 mm of rainfall.

The soils on the watershed consist of two major types: the Collins-Falaya-Grenada-Calloway and the Loring-Grenada-Memphis. The Collins-Falaya-Grenada-Calloway soil is found on the terraces and flood plains. These soils are poorly to moderately well-drained and include much of the cultivated, pasture, and wooded areas of the watershed. The Loring-Grenada-Memphis soil layer exists on the ridges and hillsides. These soils are silty in texture and easily eroded when the vegetation cover is removed (USDA, 1995). Depth losses in the gullied areas range from 9.14 to 15.24 m (Blackmarr, 1995, p. 6).

In 2000 the climate on the watershed was humid with average daily maximum temperatures of about 27° C in the summer and 11° C in the winter. The annual rainfall over the Batesville, Mississippi and the Goodwin Creek Watershed in 2000 was approximately 1,356 mm with a daily average of 45 mm per day (NCDC, NOAA, 2010).

Samples

Selection of Study Year

The year 2000 was randomly selected from a set of 22 years of precipitation and total suspended sediment data for gauging sites 9 and 11 from 1982 - 2003. All data were obtained from the National Sedimentation Laboratory (NSL) -- Goodwin Creek Soil Conservation Department at Mississippi State University. Two sets of data were obtained for each gauging site. One set for each site, represented the amounts of precipitation for each gauging site for each calendar year. The other set, represented the amounts of total suspended solids for each gauging site for each calendar year. Thus, two sets of data represent the total amounts of precipitation at gauging site 9 (see Figure 5) and gauging site 11 (see Figure 6). Also, two sets of data represent the total amounts of sediment yields at gauging site 9 (see Figure 7) and gauging site 11 (see Figure 8). From the analysis of the data sets the year 2000 was not a typical year for precipitation and for total suspended solids.

For the year 2000, the average amount of precipitation at gauging site 9 was 1326.09 mm with a Std. Deviation of 324.56. The average amount of precipitation at gauging site 11 for the year 2000 was 1355.41 mm with a Std. Deviation of 363.08. From the analysis of the precipitation data sets from the years 1982 – 2003, the year 2000 had the least amount of precipitation for both gauging site 9 and 11. The highest amount of precipitation recorded for gauging site 9 was 1893.32 mm in 1991 and the lowest was 669.80 mm for the year 2000. The highest amount of precipitation recorded for gauging site 11 was 1947.67 mm in 1991 and the lowest was 580.64mm for the year 2000.

The average amount of total suspended solids, for the year 2000, at gauging site 9 was 3,530,116 ppm with a Std. Deviation of 3.38. The average amount of total suspended solids at gauging site 11 was 823,478 ppm with a Std. Deviation of 6.23. From the analysis of the suspended solids data sets from the years 1982 – 2003, the year 2000 was one of the lowest amounts of total suspended solids for both gauging site 9 and the lowest for gauging site 11. The highest amount of suspended solids recorded for gauging site 9 was 11,179,730 ppm in 2003 and the lowest was 16,488 ppm for the year 1995; with the year 2000 recording 2,697,806 ppm for the year. The highest amount of total suspended solids recorded for gauging site 11 was 2,682,968 ppm in 1984 and the lowest was 120,847 ppm for the year 2000.

Figure 5: 1982 – 2003 Total Amounts of Precipitation for Gauging Site 9

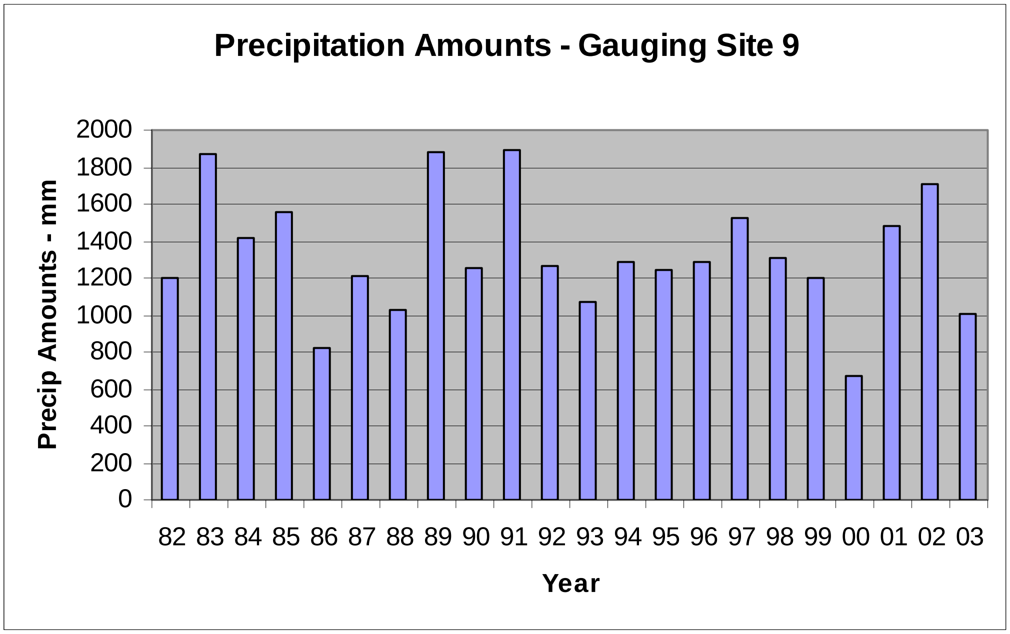


Figure 6: 1982 – 2003 Total Amounts of Precipitation for Gauging Site 11

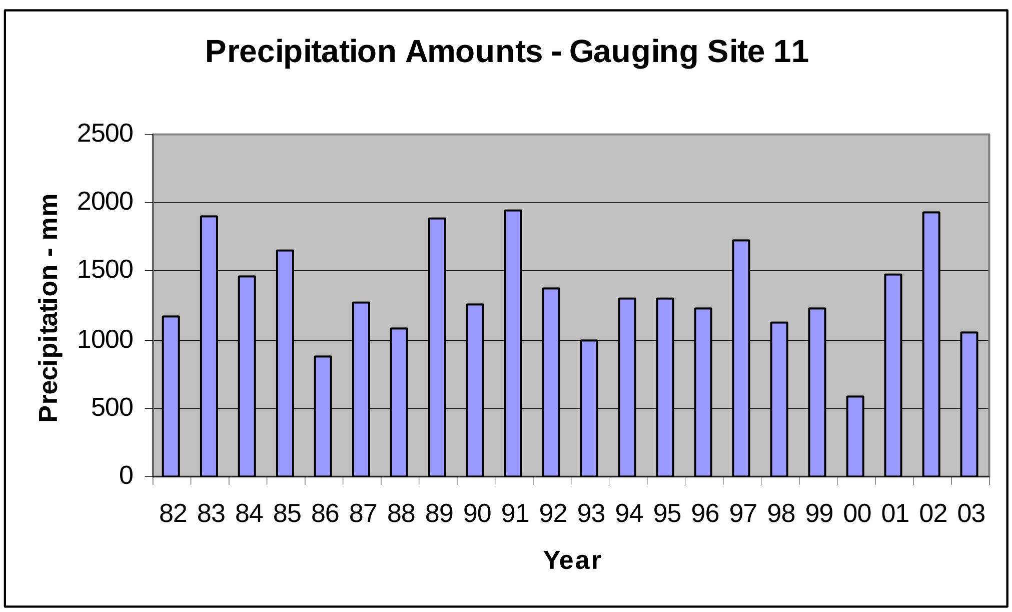


Figure 7: 1982 – 2003 Total Amounts of Suspended Sediment for Gauging Site 9

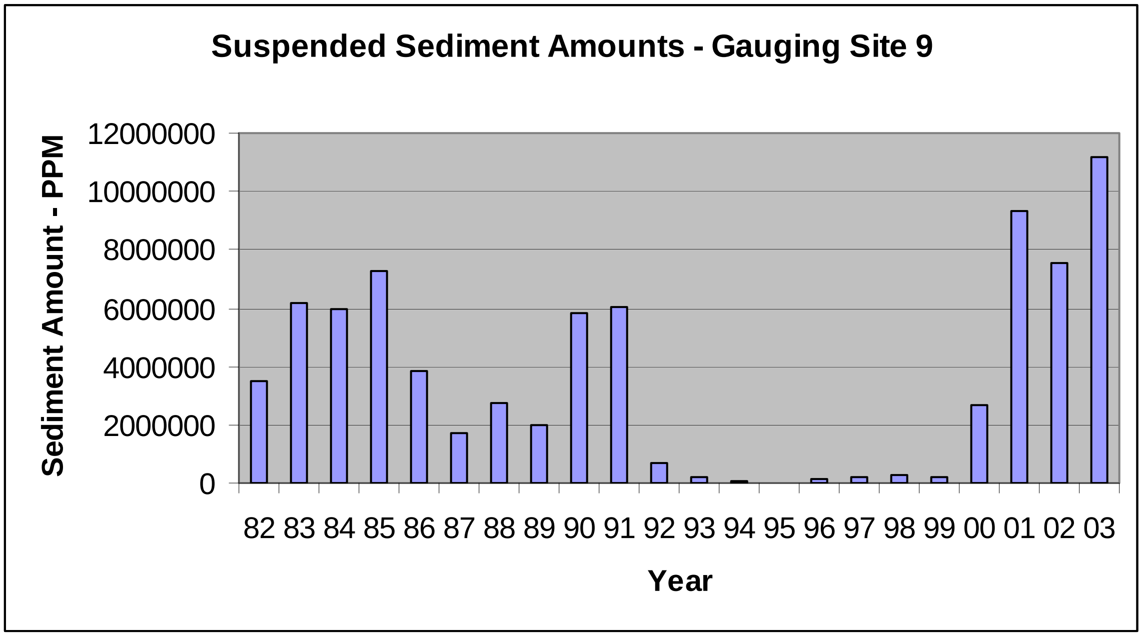
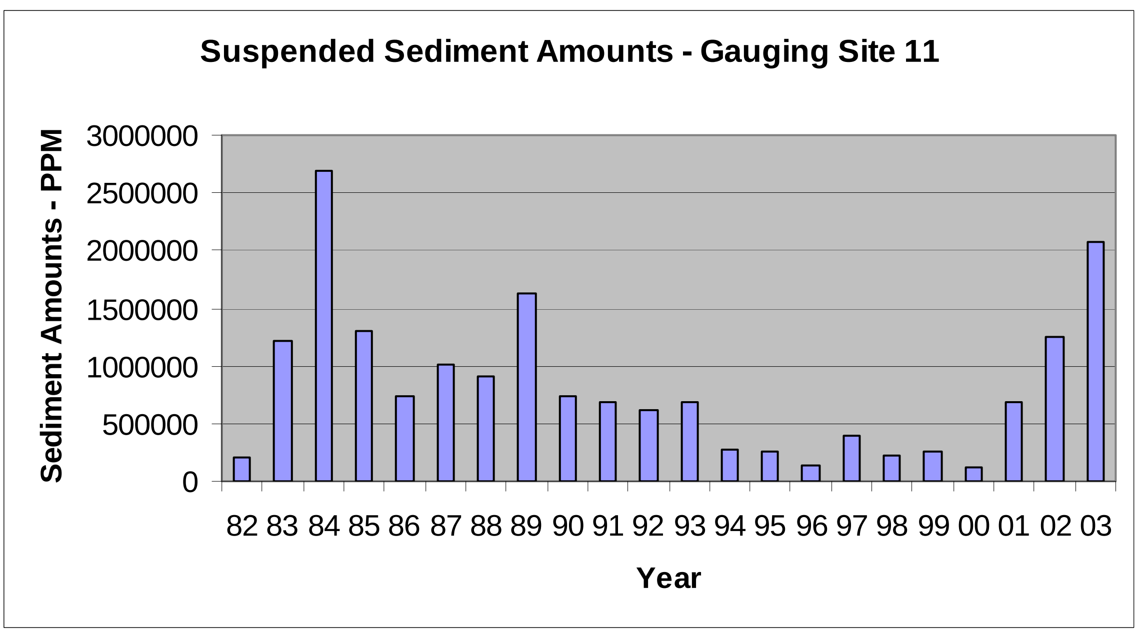


Figure 8: 1982 – 2003 Total Amounts of Suspended Sediment for Gauging Site 11



Raw Field Samples

To validate the automatic sediment samples, a sample of the raw field suspended solids sample data were obtained from the National Sedimentation Laboratory (NSL) -- Goodwin Creek Soil Conservation Department at Mississippi State University. The selection of data covered a period from 1982 through 1993. Each of the raw field samples were collected following the U.S. Department of Agriculture protocols, stored, and then analyzed in the Goodwin Creek Soil Conservation Lab to determine the amounts of total suspended solids at each stream gauging site and at each of the three major flume gates (Blackmarr, 1995, pp. 23, 28, 134). The sampling procedures used for the fine sediment follow closely the recommendations given in *Field Manual for Research in Agricultural Hydrology* Handbook No. 224 (Blackmarr, 1995, p.139). The raw sediment field samples (<0.062 mm) from gauging sites 9 and 11 were extracted from all the field sample measurements to compare with the collected instrument measured total suspended solids sediment samples.

Precipitation Data

The precipitation data for this study were downloaded from the National Sedimentation Laboratory (NSL) -- Goodwin Creek Soil Conservation Department website (http://ars.usda.gov/Business/docs.htm?docid=5120) for the year 2000 (USDS, 2009). The precipitation data set was collected every minute for each storm from spatially distributed standard recording precipitation gauges continuously monitoring the rainfall in the Goodwin Creek Watershed (see Figure 2). Precipitation station 35 is located in drainage area 9 and was used to measure rainfall for gauging site 9 for this study, and precipitation station 57 is located in drainage area 11 and was used to measure rainfall for gauging site 11. Each gauge is capable of an accuracy of 1/400 of 1 centimeter and is recorded on a digital data logger. "The Goodwin Creek rain gauge network consists of several types of instruments, including Belfort weighing gauges, Texas Instruments tipping bucket gauges, USDA Agricultural Research Service tipping bucket gauges, Australian Hydrologic Service tipping bucket gauges, and simple buried/pit collectors that have their rim at ground level" (Sieck et al., 2003, pp. 201-202). To ensure accuracy, proper data collection, and workability, field technicians regularly monitor and maintain the gauges. As a back-up, each rain gauge is equipped with a depth recording chart in case of power failure during storms (Blackmarr, 1995, p. 29).

Sediment and Stage Height Data

The sediment and stage height data for this study were downloaded from the National Sedimentation Laboratory (NSL) - Goodwin Creek Soil Conservation Department website (http://ars.usda.gov/Business/docs.htm?docid=5120) for the year 2000 (USDA, 2009). The sediment data were collected daily every time the stage height increased or decreased by 0.762 mm. The total suspended sediments (<0.062 mm) were collected from the 14 concrete flumed structures used to channel the in-stream flow into automatic pumping samplers. The samplers consist of equal-transitrate and Helley-Smith sampler. These samplers were used to measure the rates of transport of silt (<0.062 mm), sand (0.062 - 2.0 mm), and gravel-sized sediments (>2.0 mm) (Blackmarr, 1995, pp. 23-24), providing a total water-sediment sample for each calendar year.

Instrument measured and raw suspended sediment sampling measurements are taken to determine the concentration in parts per million (ppm). Raw field samples are used to validate the automatic instrument measurements and are returned to the National Sediment Lab for analysis (Blackmarr, 1995, pp. 23, 28, 130). The sample sediment concentrations were accumulated for each calendar year and appended to the database for the period of record, which was from 1982 to 2002. At the end of each calendar year, the sediment concentration equations were produced using the least squares method. These equations are then used to generate sediment concentration values for stage breakpoints when no suspended solids samples were taken because of failures in the electronic instruments. The types of sediment data were calculated and presented as a rate of runoff in cubic feet per second (cfs) and in inches per hour (in/hr), runoff interval (cfs-days), and accumulated runoff in cfs-days and in inches (Blackmarr, 1995, Appendix). The electronic instrument total suspended solids sampling data are tabulated and published at the end of each calendar year (Blackmarr, 1995).

In the Goodwin Creek study area, flows are highly variable, and sediment loads are usually transported during the most intense runoff. According to Blackmarr (1995), it is not unusual for only two or three extreme events to contribute half of the annual load of sediments in the watershed.

Validation of Data

Before correlating the precipitation data with the total suspended solid and with the stage height data sets, the total suspended sediment data was first validated. To validate the suspended sediment field data and the instrument measured sediment sample data, comparisons were made of approximately 1,500 total suspended solids samples for gauging site 9 and approximately 1,500 total suspended solids samples for gauging site 11. This process compared each of the raw suspended sediment field data measurements with the collected instrument measured suspended sediment sampling measurements. The two data sets were compared to each other to eliminate the instrument measured sample data that did not associate with a sample taken in the field at the exact same time and date.

From 1982 through 1993, 1,210 samples were taken for gauging site 9 and 1,037 samples for gauging site 11. The data sets showed a near-perfect correlation between the raw field data and instrument measured data. Very few exceptions occurred where the data did not match. Only 13 outliers out of 2,247 data points did not match between the raw field samples and the automatic instrument measurements (see Appendixes G – Q or see Table 1).

The analysis of the validation data for gauging site 9 examined 1,210 data points to determine if a correlation exists between the instrument measured sediment samples and the direct raw field samples. The Pearson's correlation produced a correlation coefficient of $r = 0.997$ which was statistically significant ($p < 0.001$). This indicates a positive association between the instrument measured sediment samples and the direct raw field samples. The coefficient indicated a positive correlation with only 1 chance in 1,000 that the results are caused by chance. Further, the squaring of the correlation coefficient, $r^2 = 0.994$, indicates that 99.4% of the variance in the instrument measured sediment samples can be explained by the direct raw field samples.

The analysis of the validation data for gauging site 11 examined 1,037 data points to determine if a correlation exists between the instrument measured sediment samples and the direct raw field samples. The Pearson's correlation produced a correlation coefficient of $r = 0.993$ which was statistically significant ($p < 0.001$). This indicates a positive association between the instrument measured sediment samples and the direct raw field samples. The coefficient indicated a positive correlation with only 1 chance in 1,000 that the results are caused by chance. Further, the squaring of the correlation coefficient, $r^2 = 0.986$, indicates that 98.6% of the variance in the instrument measured sediment samples can be explained by the direct raw field samples. Since the instrument measured sediment samples and the direct raw field samples were almost prefect, then the instrument measured sediment samples used in the study could be used with confidence that the calculations used to derive the suspended sediment sample data was correct.

Table 1: Comparisons of Raw Field Data and Instrument Measured Data Measurements Taken Each Year

Validation Sampling Year	Gauging Site 9	Gauging Site 11	Total Measurements Taken	Amount Matched	Amount Not Matched
1982	102	46	148	145	3
1983	267	338	605	604	1
1984	167	127	294	294	0
1985	331	131	462	461	1
1986	46	40	86	85	1
1987	147	97	244	242	2
1988	55	19	74	73	1
1989	9	36	45	45	0
1990	0	82	82	82	0
1991	9	17	26	25	1
1992	37	93	130	128	2
1993	40	11	51	50	1
Total Measurements Taken	1,210	1,037	2,247	2,234	13

Analysis of Data

The total suspended solids data for the year 2000 were complied into a table that analyzed the month, date, time, and amount of total suspended solids. Approximately 3,400 electronic data points were collected from gauging site 9, and approximately 2,000 electronic data points were collected from gauging site 11 (see Appendixes C and D). The total suspended solids data were grouped into dates with precipitation and dates without precipitation to make the analysis of the data easier. Only dates and times when sediment and precipitation samples were recorded were used in this study.

The precipitation data for the year 2000 were complied with the month, date, time, and amount for each rainfall. The precipitation data were aligned to calculate the length of time it rained, which was measured in minutes, and the amounts of rainfall, which was measured in hundredths of an inch (see Appendixes E and F). To obtain the accumulated precipitation amounts, both tables were compared to determine when it rained and when sediment amounts were both recorded. By reviewing the date and time when the sediment sample was taken, the amount of precipitation was then calculated. The precipitation calculation utilized the sediment sample time as an end marker. Then using the accumulated precipitation time and amounts, the accumulated values were tabulated from the preceding time to the end marker time; this process was repeated for all data (see Appendixes C and D). The end result of this process yielded 115 accumulated precipitation and suspended sediment data points for gauging site 11 and 418 accumulated precipitation and suspended sediment data points for gauging site 9. These data points were used in the statistical analysis.

The following is an example of how the accumulated precipitation amounts and sediment sample amounts were determined. For example, a sediment sample was collected on January 3 at 12:59 a.m. (see Table 2 and 3). To conduct this calculation, the date and time when the first sediment sample was taken (Jan 3 at 12:11 a.m.) was recorded. To know when to stop the precipitation tabulations, the next sediment sample was recorded (Jan 3 at 12:59). The accumulated amount of precipitation time (13 minutes) and the accumulated precipitation amount (0.13 inches) were tabulated between each sediment sample taken. Another example, a sediment sample was taken on Jan 3 at 13:03 p.m. and the next sediment sample was taken on Jan 3 at 13:13 p.m. The amount of precipitation time was tabulated at 2 minutes and the amount was tabulated at 0.03 inches.

To determine stage height for each rainfall, the amount of stream height was aligned with each precipitation occurrence for the year 2000. The stage height data were provided with the sediment data. The number of data points for stage height were 115 data points for gauging site 11 and 418 gauging site 9 (see Appendixes C and D).

Table 2: Example of Tabulated Precipitation Table

Month	Day	Time	Inches of Precip	Increase of Amounts	Accumulation of Precip (in)	Accumulation of Time (min)
1	3	12:11	0.25			
1	3	12:13	0.25			
1	3	12:16	0.27	0.02		
1	3	12:21	0.28	0.01		
1	3	12:36	0.28	0		
1	3	12:49	0.3	0.02		
1	3	12:52	0.31	0.01		
1	3	12:54	0.31	0		
1	3	12:55	0.33	0.02		
1	3	12:56	0.34	0.01		
1	3	12:57	0.36	0.02		
1	3	12:58	0.37	0.01		
1	3	12:59	0.38	0.01		
				Total	0.13	13
1	3	13:00	0.4	0.02		
1	3	13:01	0.43	0.03		
1	3	13:02	0.43	0		
				Total	0.05	3
1	3	13:03	0.44	0.01		
1	3	13:13	0.46	0.02		
				Total	0.03	2

Table 3: Example of Tabulated Suspended Sediment Table

Date of Sample	Time of Sediment Sample	Stage Height (ft)	Total Suspended Sediment(ppm)
1/3/2000	12:59	0.02	272
1/3/2000	13:02	0.05	485
1/3/2000	13:12	0.02	272
1/3/2000	13:17	0	0
1/3/2000	17:00	0.03	351

After the calculations were completed, the precipitation amounts were converted to intensity of precipitation. To calculate the intensity of precipitation, the precipitation value was divided by the amount of time in minutes to produce the intensity of precipitation for each rainfall. Once the intensity of precipitation was determined, all data were consolidated into two tables (see Table 4) with one table for gauging site 9 and with one table for gauging site 11. Each table consisted of the date, time, stage height, total suspended solids, and intensity of precipitation. These tables were stored in an Excel file. These files were used to analyze the data in SPSS to calculate the correlations to test the hypotheses for this study (see Appendixes A and B).

Table 4: Example of Combined Data for Analysis

Date of Sample	Time of Sediment Sample	Stage Height (cm)	Total Suspended Sediment (ppm)	Intensity of Precip (mm / min)
1/3/2000	12:59	0.61	272	0.25
1/3/2000	13:02	1.52	485	0.42
1/3/2000	13:12	0.61	272	0.38
1/3/2000	17:00	0.91	351	0.30
1/8/2000	21:39	1.22	421	0.60
1/8/2000	22:14	1.52	485	0.61
1/8/2000	22:20	0.61	272	0.51
1/8/2000	23:13	0.61	272	0.34
1/9/2000	1:49	0.61	272	0.38
1/9/2000	2:10	1.52	485	0.30
1/9/2000	2:18	0.61	272	0.51
1/9/2000	6:41	2.44	652	0.51

CHAPTER 4

RESULTS

"[It] told its mind to me without reserve, delivering its most cherished secrets as clearly as if it uttered them with a voice."

- Mark Twain (1901, p. 69)

Introduction

A statistical correlation was used to analyze the data for this study. Correlations are the assessment of the association between two variables (Kachigan, 1991, p. 117) and measure the central tendency and variability that describes the relationship between two variables with three general types of relationships: (1) positive correlations, (2) negative correlations, and (3) zero (no) correlations. By using a variety of techniques and types of correlational tests, a researcher can determine the degree of the relationship between two or more variables (Huck, Cormier, Bounds, 1974, p. 30). In addition to the types of relationships, correlations can also be described graphically in the form of scatter plots or lines; these graphs can be described as a straight line, nonlinear, or curvilinear. All of the graph descriptions can be either positive or negative (Kachigan, 1991, p. 120). Kachigan further states that the correlation coefficients are only appropriate for measuring the degree of relationships that are linearly related (Kachigan, 1991, p. 127).

The two most common types of correlation test are the Pearson product-moment correlation and the Spearman's rho. The Pearson product-moment correlation is a parametric statistic test that can be used to measure a correlation between continuous data sets and generally relates to an entire population. A Spearman's rho is a nonparametric statistic test and uses data arranged in rank order (Huck et al., 1974, p. 31; Gay et al., 2006, p. 198). Correlation results are often defined in a correlation matrix which represents how correlations interconnect to each other from of a list of variables that represent all the possible combinations of correlations between a certain numbers of variables (Huck et al., 1974, p. 33).

In a correlational relationship, the researcher has no control over the values of the variables within the study. Instead, the researcher observes how the two variables relate to each other (Kachigan, 1991, p. 118). When a correlation is interpreted, a high correlation does not necessarily indicate that a causal relationship exists between the two variables (Huck et al., 1974, p. 35). While a correlation "can determine the nature and degree of relationships between variables" (p. 30), correlation coefficients "do not provide sufficient information to infer causality" (p. 35).

The nature and size of the relationship in a correlation analysis is expressed by a correlation coefficient (Huck et al., 1974, p.31). The correlation coefficient (r) can vary in value from + 1.00 to - 1.00 and describes the linear relationship between the two sets of variables. A correlation coefficient of $r = +1.00$ signifies a perfect positive linear relationship, and a correlation coefficient of $r = -1.00$ signifies a perfect negative linear relationship (Kachigan, 1991, pp. 126 - 127). "Variables are either uncorrelated or have intermediate degrees of correlation" (p. 127). If no relationship exists between the respective values of the two variables, the correlation coefficient would be $r = 0$.

The most valuable and useful interpretation of the correlation coefficient is achieved by squaring the *r* value (Roscoe, 1975, p. 101). This method is used to describe or interpret the correlated variation between the variables. "That is, how much of the variation in one of the variables can be attributed to variation in the other, or vice versa" (Kachigan, 1991, p. 138). The interpretation of this value simply states the commonality between to two variables or common variance. "The square of the correlation coefficient, r^2, indicates the proportion of variance in one of the variables accounted for, 'explained', or predictable from the variance of scores of the other variable" (p. 138). This measure describes the amount of information in one variable that is accounted for by the information in the other variable. It is generally stated as a percent. When the squared value results in a low percentage, this indicates a small common variance between the two variables, and it leaves the difference of a higher percentage amount to describe the unexplained variance between the two variables (Gay et al., 2006, p. 195). On the other hand, when the squared value is high, it indicates a high degree of shared or common variance. Furthermore, it indicates that the variable may vary in a systematic way (p. 195).

In a correlation, the values for one variable set are just as likely to be paired randomly with the values in the other variable set as they are to form a pattern. In other words, a high value in one set can be just as likely paired with a lower value in the other set (Kachigan, 1991, p. 127). Because the variables are by nature random, the relationship expressed by the correlation is a measure of how these variables co-vary in the natural environment without external controls by the researcher (p. 118).

In addition to interpreting the correlation coefficient, the researcher must interpret the statistical significance of the analysis. Statistical significance refers to how likely the results were to happen by chance (Gay et al., 2006, p. 195). This indicator shows "the probability that there is or is not a significant, true relationship" (p. 195). The statistical significance of a correlation coefficient is the function of the sample size and is not related to the strength of the relationship between the two variables (Gay et al., 2006, p. 196; Roscoe, 1975, p. 101). "A significant correlation coefficient may suggest a cause-effect relationship but does not establish one" (Gay et al., 2006, p. 196).

Thus, correlational relationships indicate the pattern of association. "So whether we speak about predictive ability, or reduction in prediction errors, or common variance, it all comes down to the fact that the correlation coefficient is a summary description of the extent of systematic linear association between values on two random variables" (Kachigan, 1991, p. 138).

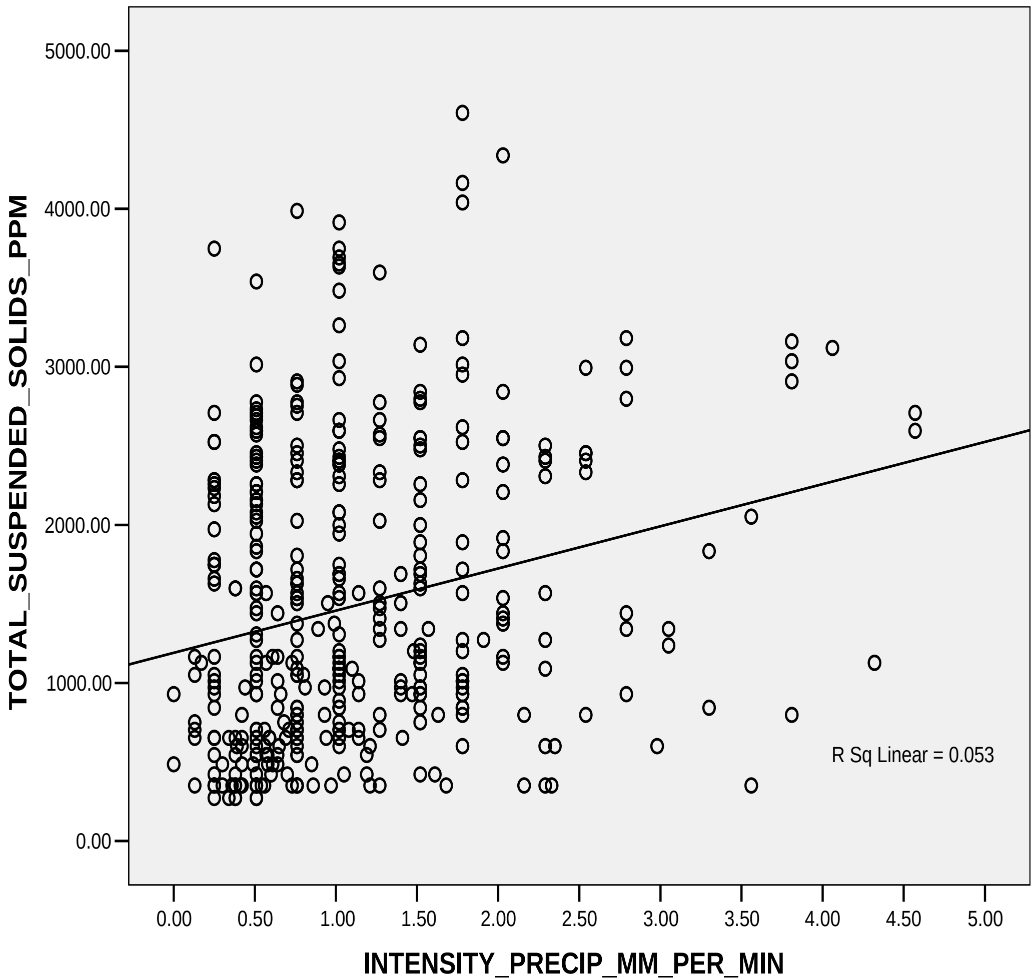
Analysis of Intensity of Precipitation and Total Suspended Sediments

Hypothesis 1 and Hypothesis 2 investigated the relationship between the intensity of precipitation and the total suspended solids data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging sites 9 and 11. Two separate Pearson correlations were conducted on this data because two gauging sites exist. Each analysis used a Pearson's correlation to investigate if a significant relationship exists between the amounts of total suspended solids and the intensity of precipitation for each gauging site.

Hypothesis 1 assessed the data for gauging site 9. It examined 418 data points to determine if a correlation exists between the intensity of precipitation and the amounts of total suspended solids. The Pearson's correlation produced a correlation coefficient of $r = 0.231$ which was statistically significant ($p < 0.001$). This indicates a positive association between the intensity of precipitation and the amounts of suspended solids produced up to 1.52 mm of intensity of precipitation. The interpretation for these values indicated increasing degrees of a positive correlation with a 1% chance in 1,000 that the results are caused by chance. Further, the squaring of the correlation coefficient, $r^2 = 0.05$, indicates that 5% of the variance in the total suspended solids can be explained by the intensity of the precipitation.

Figure 9 shows a positive correlation between intensity of precipitation and the amounts of suspended solids. The grouping of the data points demonstrates no significant difference between the two data sets. When the scatter plot was examined, no discernible pattern was observed. Therefore, the null hypothesis demonstrates that no significant correlation exists between the intensity of precipitation and the total suspended solids data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging site 9. The correlation coefficient indicates that this relationship is positive. Because the coefficient and the squaring of the coefficient are low, this demonstrates that there is no significant relationship between the variables. The outcome of this correlation determined that no matter how intensely it rained, it had very little effect on the amount of sediment produced in the drainage area for gauging site 9, even though it rained a total of 948 mm of rainfall in the year 2000.

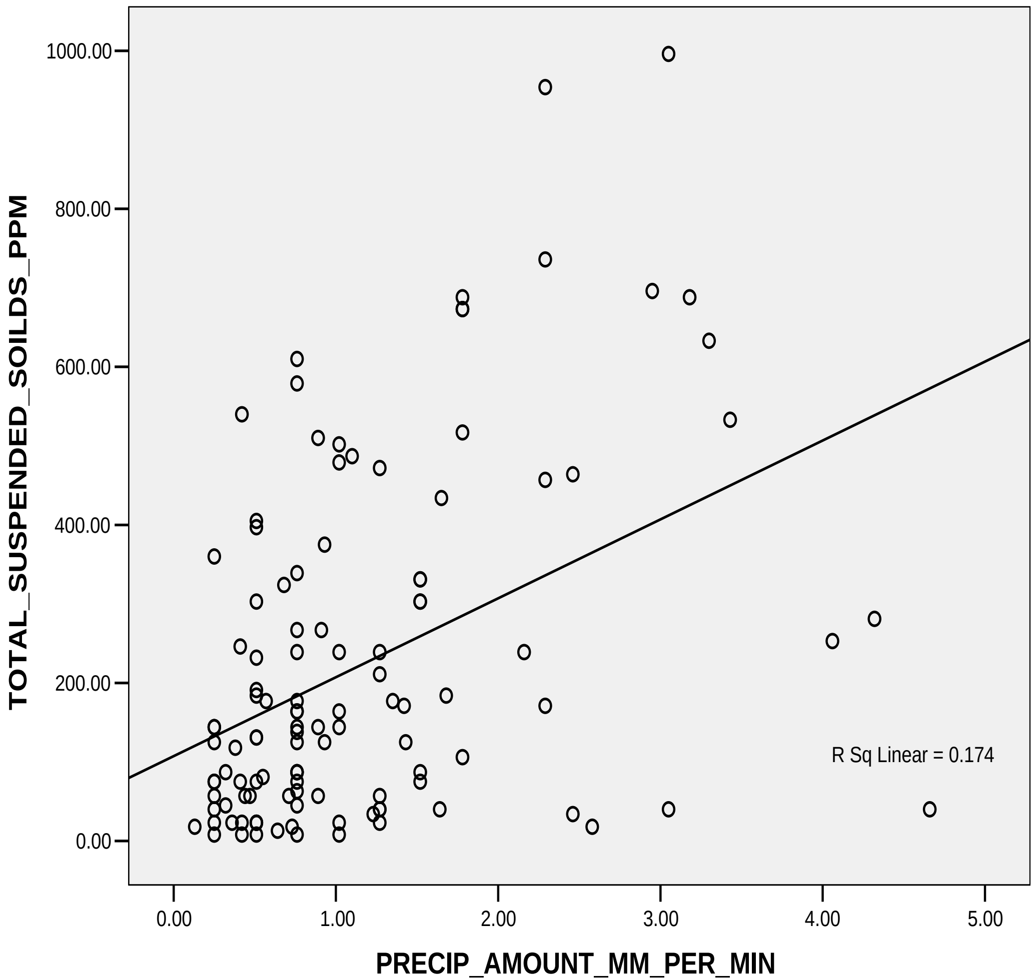
Figure 9: Scatter plot for the Intensity of Precipitation and the Amounts of Suspended Solids for Gauging Site 9



Hypothesis 2 assessed the data for gauging site 11. It examined 115 data points to determine if a correlation exists between the intensity of precipitation and the amounts of total suspended solids. The Pearson's correlation produced a correlation coefficient of $r = 0.417$ which was statistically significant ($p < 0.001$). This indicates a positive association between the intensity of precipitation and the amounts of suspended solids produced up to 1.0 mm of intensity of precipitation. The interpretation for these values indicated there is increasing degrees of a positive correlation with less than a 1% chance in 1,000 the results are caused by chance. Further, the squaring of the correlation coefficient, $r^2 = 0.17$, indicates that 17% of the variance in the total suspended solids can be explained by the intensity of the precipitation.

Figure 10 shows a positive correlation between intensity of precipitation and the amounts of suspended solids. The grouping of the data points demonstrates no significant difference between the two data sets. When the scatter plot was examined, no discernible pattern was observed. Therefore, the null hypothesis demonstrates that no significant correlation exists between the intensity of precipitation and the total suspended solids data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging site 11. The correlation coefficient indicates that this relationship is positive. Because the coefficient and the squaring of the coefficient are low, this demonstrates that there is no significant relationship between the variables. The outcome of this correlation determined that no matter how intensely it rained, it had very little effect on the amount of sediment produced in the drainage area for gauging site 11, even though it rained a total of 406 mm of rainfall in the year 2000.

Figure 10: Scatter plot for the Intensity of Precipitation and the Amounts of Suspended Solids for Gauging Site 11



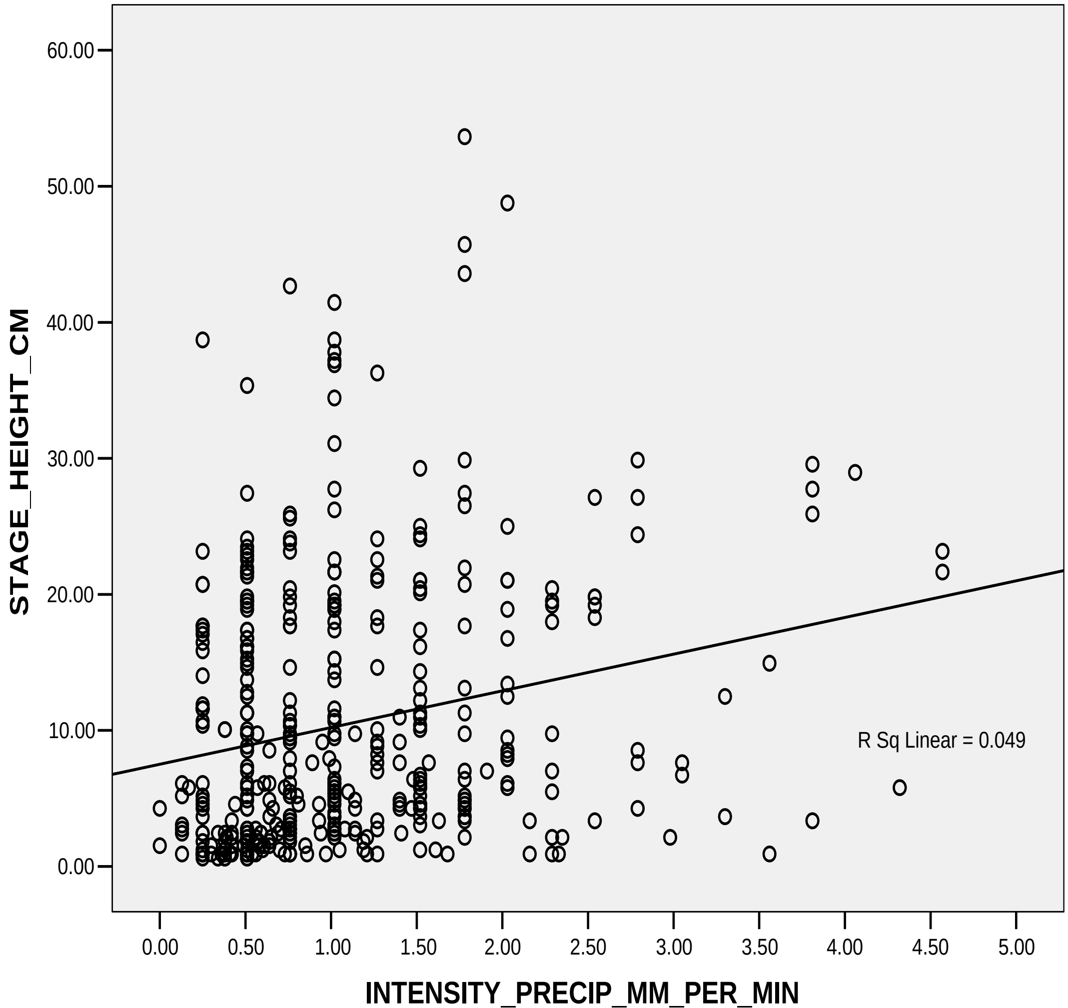
Analysis of Intensity of Precipitation and Stage Height

Hypothesis 3 and Hypothesis 4 investigated the relationship between the intensity of precipitation and the stage height data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging sites 9 and 11. Two separate Pearson correlations were conducted on this data because two gauging sites exist. Each analysis used a Pearson's correlation to investigate if a significant relationship exists between the amounts of stage height and the intensity of precipitation for each gauging site.

Hypothesis 3 assessed the data for gauging site 9. It examined 418 data points to determine if a correlation exists between the intensity of precipitation and the amounts of stage height. The Pearson's correlation produced a correlation coefficient of $r = 0.220$ which was statistically significant ($p < 0.001$). This indicates a positive association between the intensity of precipitation and the amounts of suspended solids produced up to 1.52 mm of stage height. The interpretation for these values indicated increasing degrees of a positive correlation with less than a 1% chance in 1,000 the results are from chance. Further, the squaring of the correlation coefficient, $r^2 = 0.05$, indicates that 5% of the variance in the stage height can be explained by the intensity of the precipitation.

Figure 11 shows a positive correlation between intensity of precipitation and stage height. The grouping of the data points demonstrates no significant difference between the two data sets. When the scatter plot was examined, no discernible pattern was observed. Therefore, the null hypothesis demonstrates that no significant correlation exists between the intensity of precipitation and stage height for each rainfall in the Goodwin Creek Experimental Watershed at gauging sites 9. The correlation coefficient indicates that this relationship is positive. Because the coefficient and the squaring of the coefficient are low, this demonstrates that there is no significant relationship between the variables. The outcome of this correlation determined that no matter how intensely it rained, it had very little effect on the stage height produced in the drainage area for gauging site 9, even though it rained a total of 948 mm of rainfall in the year 2000.

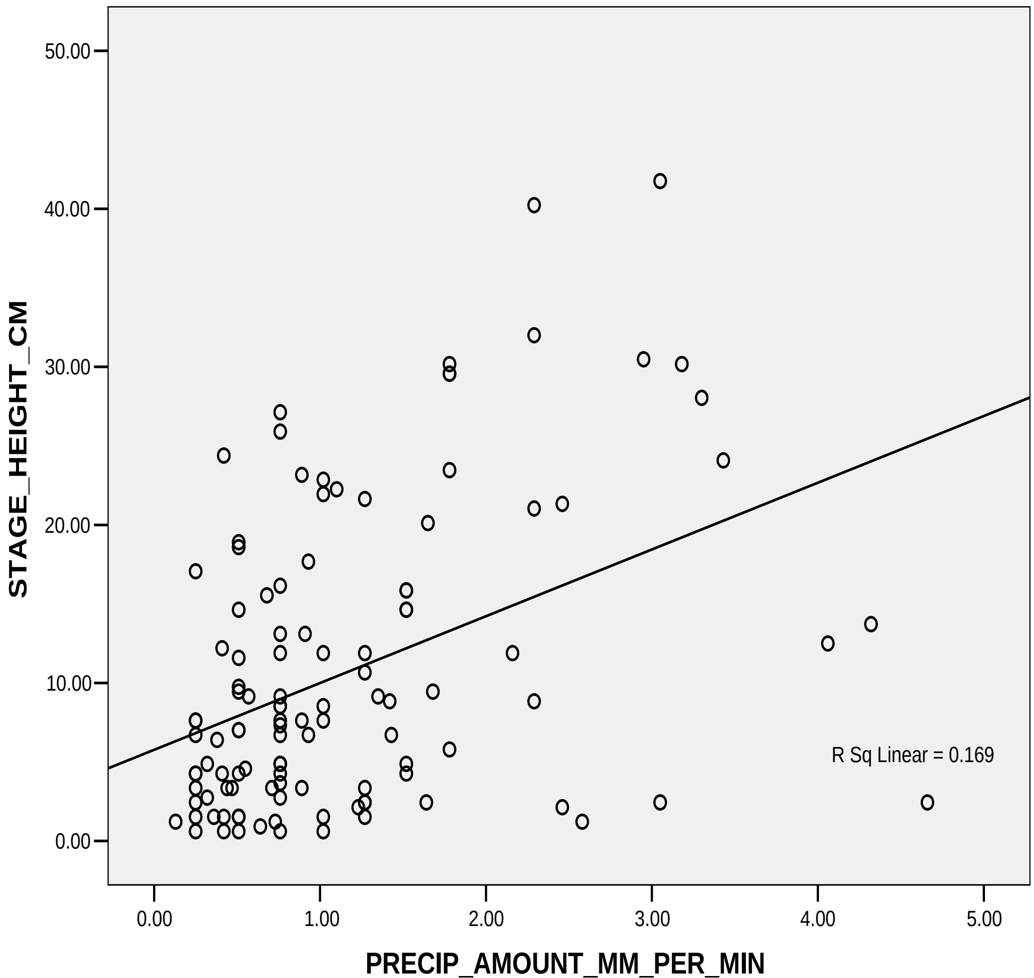
Figure 11: Scatter plot for the Intensity of Precipitation and the Amounts of Stage Height for Gauging Site 9



Hypothesis 4 assessed the data for gauging site 11. It examined 115 data points to determine if a correlation exists between the intensity of precipitation and the amounts of stage height. The Pearson's correlation produced a correlation coefficient of $r = 0.411$ which was statistically significant ($p < 0.001$). This indicates a positive association between the intensity of precipitation and the amounts of suspended solids produced up to 1.02 mm of stage height. The interpretation for these values indicated increasing degrees of a positive correlation exists with less than a 1% chance in 1,000 the results are caused by chance. Further, the squaring of the correlation coefficient, $r^2 = 0.17$, indicates that 17% of the variance in the stage height can be explained by the intensity of the precipitation.

Figure 12 shows a positive correlation between intensity of precipitation and stage height. The grouping of the data points demonstrates no significant difference between the two data sets. When the scatter plot was examined, no discernible pattern was observed. Therefore, the null hypothesis demonstrates that no significant correlation exists between the intensity of precipitation and stage height for each rainfall in the Goodwin Creek Experimental Watershed at gauging sites 11. The correlation coefficient indicates that this relationship is positive. Because the coefficient and the squaring of the coefficient are low, this demonstrates that there is no significant relationship between the variables. The outcome of this correlation determined that no matter how intensely it rained, it had very little effect on the stage height produced in the drainage area for gauging site 11, even though it rained a total of 406 mm of rainfall in the year 2000.

Figure 12: Scatter plot for the Intensity of Precipitation and the Amounts of Stage Height for Gauging Site 11



CHAPTER 5

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

"And it was not a book to be read once and thrown aside,
for it had a new story to tell every day."
- Mark Twain (1901, p. 69)

Summary of Study

Many studies have been completed over the past 10 years analyzing various variables affecting the watersheds around the world. These studies showed that suspended sediment is a major contributing factor to the water quality in most streams. The research demonstrated that precipitation, in some form, is the major contributing factor in the erosion of soil and the amount of suspended solids within a stream. These research studies analyzed such factors as types of ground cover, soil type, precipitation intensity, ground water intrusion, stream bank erosion, and bank failures or a combination of these different factors to explain the amounts of sediments in a stream (Blackmarr, 1995; Deng et al., 2008; Eisenbies et al., 2007; Fox et al., 2007; Kuhnle & Willis, 1998; Nadal-Romero et al., 2008; Soler et al., 2007; Wemple & Jones, 2003). According to James (2003), "Many of the current methods and techniques used by storm water programs for sample collection, management and analysis have significantly underestimated the concentration of total suspended solids….It is essential that standard procedures be adopted for sample collection, management and analysis" (p. 11).

In 1972, the EPA issued guidelines to obtain and maintain water quality standards in the United States. These describe in detail the primary sources of pollution within streams, lakes, estuaries, and rivers and the methods that could be implemented to remove these pollutants and aid states to obtain these water quality standards. Further reports from the EPA indicate that in 2010 the United States is still not in compliance with these standards. To assist in the understanding, analysis, and maintenance for controlling the amounts of suspended solids within the waterways, the Goodwin Creek Experimental Watershed was developed in the late 1970s, as part of the Streambank Erosion Control Evaluation and Demonstration Project. The Goodwin Creek project has been instrumental in developing methods and alternative approaches to decreasing and or eliminating the amounts of bank erosion and the amounts of suspended sediments within a stream.

The majority of the studies analyzing suspended solids used some type of a mathematical or computer model to analyze the amounts of suspended sediments based on the amounts of precipitation. Goodwin Creek utilizes a mathematical model, based on the instrument measured sediment samples taken and the least squares method hydrologic model, to calculate the amount of sediment when no data are available. Most of these studies measure precipitation, stage height, and rate of flow so they can determine or predict sediment yields in a stream. Deng et al. (2008) also used rate of transport to calculate the sediment amounts, whereas Marques et al. (2007) utilized kinetic energy in their model to obtain suspended sediment amounts. Very few studies measure precipitation intensity in computer models, but none measured suspended solids directly based on precipitation intensity. Even the most current computer modeling research has used precipitation and the intensity of precipitation in the computer modules to predict the amounts of sediment, but did not use field measurements (Hancock, 2009; Rai & Mathur, 2007).

Because Goodwin Creek is a controlled watershed, with control gates measuring the amounts of stage height, Hicks et al. (2005) believes the design of these structures might influence the measurements of the stage height. The controlled gauging stations at Goodwin Creek are similar to structures used in the Hicks et al. (2005) study where the maximum stage height achieved was highly dependent on the channel structure created by the Corp of Engineers. Miller (1990) argued that the maximum stage height achieved is always highly dependent on the channel structure and that stage height on narrow streams may be more sensitive to the amounts of discharge than to the structure to the channel. The unexplained variances in this research study could be explained by infiltration excess, saturation excess, delayed responses, preferential flow paths, soil covering, high intensity rainfall amounts, extreme water amounts from adjoining streams, or a combination of these different of these different factors (Blackmarr, 1995; Eisenbies et al., 2007; Fuery & Gupta, 2007; McKercher, 1980; Nadal-Romero et al., 2008; Sieck et al., 2003; Steiner & Smith, 2000).

McCulloch and Robinson's (1993) research demonstrated that land cover should have a profound effect on the amounts of sediments produced by precipitation; however, this was not the case in this study. Zabaleta et al. (2007) found a strong correlation between precipitation, discharge, and suspended sediment variables and argued that suspended sediment amounts are dictated by the amounts of precipitation. The result of the Zabaleta et al. study, however, produced almost the opposite effect as this study which yielded no significant difference between the intensity of precipitation and suspended solids.

Most prediction models use stage height and precipitation to determine or predict the amounts of suspended sediments and other water contaminates within a stream. These research studies analyzed the different variables controlling stage height and the complexity of the rise and fall of stream. Stage height ties together the amounts of precipitation and the movement of the sediments within a waterway or stream. It is also one of the key contributing forces in the erosive processes of a watershed. In contrast to the findings of this study, Wemple and Jones' (2002) demonstrated a strong correlation occurs between the intensity of precipitation and stage height. Boyle et al. (1998) found similar results and expressed the effects of flooding as an absolute or percentage as it relates to increases in flow volumes and rate of peak discharges.

The propose of this study was to analyze the intensity of precipitation data, total suspended solids data, and stage height data collected in 2000 from the Goodwin Creek Experimental Watershed at gauging sites 9 and 11 to determine the correlation between the intensity of precipitation and the total suspended solids data and between the intensity of precipitation and stage height for each rainfall. All data used in this study were collected from the controlled watershed at Goodwin Creek Experimental Watershed. This study employed a quantitative research methodology involving an experimental design using secondary data from the Goodwin Creek Experimental Watershed for the year 2000 from gauging sites 9 and 11.

Based on the intensity of precipitation data, total suspended solids data, and stage height data, Pearson product- moment correlations were used to test four hypotheses about the water quality from two gauging sites, site 9 and 11, within the Goodwin Creek Watershed in Mississippi. The first two hypotheses analyzed the relationship between the intensity of precipitation and the total suspended solids, and the second two hypotheses analyzed the relationship between the intensity of precipitation and stage height. Before the analysis began, the accuracy of the electronic sediment data were confirmed by a validation process. An almost a prefect correlation exists between the raw field data and the instrument measured data. Because the instrument measured sediment samples and the direct raw field samples are almost a prefect match, then the instrument measured sediment samples used in the study could be used with confidence that the calculations used to derive the suspended sediment sample data was correct.

This study was completed to further add to the insight of the research community addressing the relationship between the intensity of precipitation and the amounts of suspended sediments it produces. As well, this study was completed to describe how stream height is related to the intensity of precipitation. By completing the statistical analysis of the four hypotheses, the outcomes of this study have the potential to be applied to current and future hydrology models to aide in the prediction of the amounts of suspended sediments in a stream.

Summary of Findings

The year 2000 was randomly selected from a set of 22 years of precipitation and total suspended sediment data for gauging sites 9 and 11 from 1982 - 2003. All data were obtained from the National Sedimentation Laboratory (NSL) -- Goodwin Creek Soil

Conservation Department at Mississippi State University. Two sets of data were obtained for each gauging site. One set for each site represented the amounts of precipitation for each gauging site for each calendar year. The other set represented the amounts of total suspended solids for each gauging site for each calendar year. From the analysis of the data sets, the year 2000 was not a typical year for precipitation and for total suspended solids.

For the year 2000, the average amount of precipitation at gauging site 9 was 1326.09 mm with a Std. Deviation of 324.56. The average amount of precipitation at gauging site 11 for the year 2000 was 1355.41 mm with a Std. Deviation of 363.08. The average amount of total suspended solids, for the year 2000, at gauging site 9 was 3,530,116 ppm with a Std. Deviation of 3.38. The average amount of total suspended solids at gauging site 11 was 823,478 ppm with a Std. Deviation of 6.23.

Two hypotheses examined the relationship between the intensity of precipitation and suspended solids. Hypothesis 1 analyzed the data for gauging site 9. A Pearson product- moment correlation was applied to determine if a correlation exist between the intensity of precipitation and the amounts of suspended solids. The results of the study yielded no significant difference between the variables at the ($p < 0.001$) level. Hypothesis 2 analyzed the data for gauging site 11. A Pearson product- moment correlation was applied to determine if a correlation exist between the intensity of precipitation and the amounts of suspended solids. The results of the study yielded no significant difference between the variables at the ($p < 0.001$) level.

Two hypotheses examined the relationship between the intensity of precipitation and stage height. The results for Hypothesis 3 analyzed the data for gauging site 9. A Pearson product- moment correlation was applied to determine if a correlation exist between the intensity of precipitation and the amounts of suspended solids. The results of the study yielded no significant difference between the variables at the ($p < 0.001$) level. Hypothesis 4 analyzed the data for gauging site 11. A Pearson product- moment correlation was applied to determine if a correlation exist between the intensity of precipitation and the amounts of suspended solids. The results of the study yielded no significant difference between the variables at the ($p < 0.001$) level.

Conclusions

Based on the findings from this study the following conclusions can be drawn:

1. No significant difference exists between intensity of precipitation and the amount of suspended solids in a stream at gauging sites 9 and 11.
2. No significant difference exists between intensity of precipitation and the stage height of a stream at gauging sites 9 and 11.
3. At each gauging station, the relationship between intensity of precipitation and the amount of suspended solids in a stream and between intensity of precipitation and the stage height of a stream show a similar pattern at gauging sites 9 and 11.

Relationship between the Intensity of Precipitation and Suspended Sediments

The design of the study followed the suggestions of the research by Eisenbies et al. (2007) of using paired gauging sites from a single watershed to reduce the amount of error in the limitations of a correlation study. Measuring the correlation between intensity of precipitation and suspended solids, gauging station 9 consisted of an extremely gullied area, whereas gauging station 11 consisted primarily of pasture and produced no significant difference between the two variables.

This study demonstrated no significant difference exists between the intensity of precipitation and the amounts of suspended solids. Though the result of this study is counterintuitive to what should be occurring, based on previous studies, analyzing intensity of precipitation and suspended sediments produced no significant difference between the two variables. This study is important to the research community in that it will aide future researchers from attempting a similar study and producing similar results. The findings from this study strongly indicated that the amounts of sediment produced in a stream are not governed by the intensity of the precipitation, because 95% of the variance in the relationship in the intensity of precipitation and the amount of suspended sediments is explained by other outside factors. These variances may result from unexplained factors such as sediment infiltration, soil saturation excess, high intensity rainfall amounts and delayed responses to heavy precipitation amounts, extreme flooding, sporadic bank failures, or a combination of these different variables.

Relationship between the Intensity of Precipitation and Stage Height

The correlation between intensity of precipitation and stage height indicated no significant difference between the two variables. Though the Goodwin Creek Experimental Watershed was developed to measure, experiment, and control the amounts of sediments in the stream, the gauging sites where all of the measurements are collected use a very similar concrete structure to produce a channel for the stream to flow over. Therefore, the results of the amount of water as it rises and falls in the structure should be similar based on similar amounts of precipitation intensity. The results of this study produced almost no similarity between gauging site 9 which explained 5% of the variance, and gauging site 11 which explained 17% of the variance. The unexplained variance might be attributed to the structure of the stream or to the gauging concrete structure manipulating the stage height measurements. Similar to past research, this study showed varying amounts of stage heights in relation to the intensity of precipitation, however, produced yielded no significant difference between the variables.

Similar Patterns between Suspended Solids and Stage Height

This study produced a similar pattern of relationships between the intensity of precipitation and suspended solids, as well as stage height. When comparing sites 9 and 11 for suspended sediment and stage height, the correlation coefficients at each individual site produced very similar results. Gauging site 9 produced a correlation coefficient that explained about 5% of the variance for suspended solids and stage height. Gauging site 11 produced a correlation coefficient that explained about 17% of the variance for suspended solids and stage height. As well, the scatter plots almost mirrors gauging site 9 and 11 each for each correlation results.

Recommendations

This study demonstrated no significant difference between the intensity of precipitation and the amounts of total suspended solids, and to stage height. Intensity of precipitation can only explain between 5% and 17% of variance in the relationship between intensity of precipitation with suspended solids and with stage height. The variances that remain can be explained by other factors such as infiltration excess, saturation excess, delayed responses, preferential flow paths, unexplained sediment infiltration, soil saturation excess, high intensity rainfall and delayed responses to heavy precipitation amounts, extreme flooding, sporadic bank, or a combination of these different factors. These unexplained variances could also be explained by different types of ground cover, types of soils, slope, extreme water amounts from adjoining streams, or a combination of these different variables. As well, the unexplained variances could be a result of the small amount of data obtained from the year 2000, as compared to the other 22 years of data sets. Further studies will need to be completed on these contributing factors to better understand these unexplained variances and the effects they may have on determining sediment load within rivers and streams.

Further Research

The findings from this study (a) yielded no significant difference between the intensity of precipitation and suspended solids in a stream, (b) yielded no significant difference between the intensity of precipitation and stage height, (c) of the influence of local conditions at the gauging sites suggest that several future studies are needed to better understand the phenomenon of precipitation and the conditions of a stream.

This study highlighted that the intensity of the precipitation is only a minor factor in explaining the sediments in a stream and the stage height of a stream. Indeed, 83% to 95% of the variance in these relationships is explained by other factors. Past research indicates many factors that control the amounts of sedimentation in a stream. Rather than continuing research based on the intensity of precipitation, further research is warranted to identify the unexplained factors.

Though current research is being completed in precipitation and suspended sediments, further discussion needs to take place to better understand the relationship between precipitation and the amount of sediment produced. Such studies could examine the types of ground covering with different combinations of soil types. The type of ground covering may have caused the majority of variance in this study. Another method that could be utilized is the use of satellite imagery to examine the types of ground cover and possibly confirm the results of the study. Though this research study did not examine topography as a factor or use satellite imagery, this is one area where very little research is being completed and more is needed to examine the effects of topography on the type and amounts of sediments being produced by precipitation.

Future studies could expand on this research study. A similar study could vary the amounts of precipitation, ground cover, and a variety of soil types to determine how high values of intensity precipitation may affect the sediment yields. Further analysis could be conducted by modifying this research study to learn more about sediment infiltration and sporadic unexplained bank failures. Such a study could use the different controlled gauging sites at Goodwin Creek to attempt to control some of the unexplained variances. Another study could analyze extreme flooding and the effects it has on suspended sediments. The outcome of studies similar to these could possible explain the heavily gullied areas at gauging site 9 and the low amounts of sediments produced during rainfall.

The high amount of unexplained variances in this study may result from any or a combination of any of the following factors: sediment infiltration, high intensity rainfall, the influx of sediment through side streams, unexplained bank failures, stream branches, pools or extreme flooding. Though several studies have examined these factors and how they relate to suspended sediments, further discussion and research is needed to better understand how these factors affect sediment amounts. When analyzing high intensity rainfall, future researchers should take into consideration the outcomes of this study. This study demonstrated that no significant difference exists between the intensity of precipitation and suspended sediments, as well as between intensity of precipitation and stage height. Consequently, research should focus on the unexplained variances and less on the intensity of precipitation.

Computer Models

Based on the results of this study, it is recommended that the intensity of precipitation to predict sediment amounts in mathematical or computer models should either not be used or used with caution. This recommendation is based on the small amount of variance produced when analyzing the intensity of precipitation and suspended sediments. Contrary to the studies using computer models, this study was based on actual field measurement of sediment produced by the intensity of precipitation. In this study using the actual in field data yielded no significant difference, less than 5% and at the most 17% of variance, between the two variables, intensity of precipitation and sediment, suggests that the computer models could possibly be miscalculating the predicted amounts of suspended sediments.

Consequently, the intensity of precipitation should be used cautiously when building or modifying a computer model to predict sediment amounts. The findings from this study suggest that a new study is needed using a computer model and direct field samples. This study could be used to try and determine how the intensity of precipitation may or may not impact the results of using only a computer model to predict sediment amounts, as compared to incorporating field sampling. A similar study could also be used to develop or strengthen a computer model to predict the amounts of suspended sediments in a stream. Finally, a future research study is needed to determine if a computer model can be used to explain the large amount of unexplained variance when using the intensity of precipitation.

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APPPENDICES

The following tables are examples of the data collected and utilized in this research study. A full set of data can be obtained from the U.S. Department of Agriculture at http://ars.usda.gov/Business/docs.htm?docid=5120.

Table A: Examples of Combined Data for Analysis – Gauging Site 9

Date of Sample	Time of Sediment Sample	Stage Height (cm)	Total Suspended Sediment (ppm)	Intensity of Precip (mm/ min)
1/3/2000	1259	0.61	272	0.25
1/3/2000	1302	1.52	485	0.42
1/3/2000	1312	0.61	272	0.38
1/3/2000	1700	0.91	351	0.30
1/8/2000	2139	1.22	421	0.60
1/8/2000	2214	1.52	485	0.61
1/8/2000	2220	0.61	272	0.51
1/8/2000	2313	0.61	272	0.34
1/9/2000	149	0.61	272	0.38
1/9/2000	210	1.52	485	0.30
1/9/2000	218	0.61	272	0.51
1/9/2000	641	2.44	652	0.51
1/22/2000	1837	1.52	485	0.58
1/22/2000	2400	0.91	351	0.51
2/26/2000	1530	0.91	351	0.51
2/26/2000	1637	0.91	351	0.56
2/26/2000	1746	0.91	351	0.86
2/26/2000	1920	1.83	544	1.19
2/26/2000	1928	2.74	703	0.76
2/26/2000	1930	5.18	1051	0.25
2/26/2000	1942	9.75	1568	0.51
2/26/2000	1952	11.28	1718	0.51
3/9/2000	417	0.91	351	2.16
3/11/2000	137	0.91	351	0.41
3/11/2000	310	1.83	544	0.76
3/11/2000	440	2.44	652	1.02
3/15/2000	1047	1.22	421	1.05
3/15/2000	2247	2.74	703	1.14
3/15/2000	2353	3.05	751	0.13

3/15/2000	2400	3.05	751	1.02
3/16/2000	120	4.57	971	0.44
3/16/2000	417	5.79	1127	1.52
3/16/2000	507	5.18	1051	0.13
3/16/2000	600	5.49	1090	2.29
3/16/2000	839	9.14	1505	1.40
3/16/2000	919	9.14	1505	0.95
3/16/2000	950	10.97	1689	1.52

Table B: Examples of Combined Data for Analysis – Gauging Site 11

Date of Sample	Time of Sediment Sample	Stage Height (cm)	Total Suspended Sediment (ppm)	Intensity of Precip (mm/ min)
1/9/2000	120	2.74	45	0.76
1/9/2000	226	3.66	63	0.76
1/9/2000	239	7.32	138	0.76
1/22/2000	1346	4.57	81	0.55
1/22/2000	1429	6.40	118	0.38
1/22/2000	1534	7.62	144	0.89
1/22/2000	2257	2.44	40	4.66
1/29/2000	912	1.52	23	0.42
1/29/2000	1135	3.35	57	0.71
1/29/2000	1233	4.27	75	1.52
1/29/2000	1303	4.88	87	1.52
1/29/2000	1709	4.27	75	0.41
1/29/2000	2052	3.35	57	0.25
2/18/2000	1715	0.61	8	0.76
2/18/2000	1725	1.52	23	0.25
2/18/2000	1833	1.52	23	0.51
2/18/2000	1852	2.44	40	1.27
2/26/2000	1620	1.22	18	0.73
3/9/2000	424	0.61	8	1.02
3/9/2000	435	0.91	13	0.64
3/9/2000	550	4.27	75	0.76
3/9/2000	1003	1.52	23	0.51
3/10/2000	1647	0.61	8	0.25
3/10/2000	1729	1.52	23	1.27
3/10/2000	1759	2.44	40	1.27
3/10/2000	1818	9.75	191	0.51
3/10/2000	1847	8.53	164	0.76
3/10/2000	2046	4.27	75	0.25

3/10/2000	2326	2.44	40	0.25
3/10/2000	2400	2.74	45	0.32
3/11/2000	56	3.35	57	0.44
3/11/2000	102	4.27	75	0.25
3/11/2000	110	4.88	87	0.76
3/11/2000	127	6.71	125	0.25
3/11/2000	432	4.88	87	0.76
3/15/2000	803	2.44	40	3.05
3/15/2000	851	3.35	57	0.89
3/15/2000	901	7.01	131	0.51
3/15/2000	932	7.62	144	0.76
3/15/2000	946	8.53	164	0.76
3/15/2000	1950	4.27	75	0.51
3/15/2000	2000	4.88	87	0.32
3/15/2000	2400	6.71	125	0.76
3/16/2000	47	7.62	144	0.25

Table C: Examples of Tabulated Suspended Sediment Table - Gauging Site 9

Date of Sample	Time of Sediment Sample	Stage Height (ft)	Total Suspended Sediment (ppm)	Accumulation of Time (min)
1/3/2000	1259	0.02	272	13
1/3/2000	1302	0.05	485	3
1/3/2000	1312	0.02	272	2
1/3/2000	1317	0	0	
1/3/2000	1700	0.03	351	11
1/3/2000	1701	0.06	544	
1/3/2000	1704	0.03	351	
1/3/2000	1708	0	0	
1/3/2000	2400	0	0	6
1/3/2000		0.008	106	
			2381	35
1/8/2000	2139	0.04	421	14
1/8/2000	2152	0.01	0	2
1/8/2000	2214	0.05	485	3
1/8/2000	2220	0.02	272	2
1/8/2000	2226	0	0	
1/8/2000	2313	0.02	272	3

1/8/2000	2319	0	0	
1/8/2000	2400	0	0	
1/8/2000		0.019	203	
			1653	24
1/9/2000	149	0.02	272	2
1/9/2000	155	0	0	1
1/9/2000	208	0.02	272	
1/9/2000	210	0.05	485	5
1/9/2000	218	0.02	272	1
1/9/2000	323	0	0	3
1/9/2000	451	0.02	272	
1/9/2000	452	0.05	485	
1/9/2000	454	0.08	652	
1/9/2000	500	0.11	798	
1/9/2000	641	0.08	652	1
1/9/2000	812	0.05	485	
1/9/2000	1035	0.02	272	
1/9/2000	1935	0	0	
1/9/2000	2400	0	0	
1/9/2000		0.021	209	
			5126	13

Table D: Examples of Tabulated Suspended Sediment Table - Gauging Site 11

Date of Sample	Time of Sediment Sample	Stage Height (ft)	Total Suspended Sediment (ppm)	Accumulation of Time (min)
1/9/2000	118	0.03	13	
1/9/2000	119	0.06	29	
1/9/2000	120	0.09	45	4
1/9/2000	226	0.12	63	3
1/9/2000	228	0.15	81	
1/9/2000	229	0.18	99	1
1/9/2000	232	0.21	118	
1/9/2000	239	0.24	138	1
1/9/2000	244	0.27	157	
1/9/2000	249	0.29	171	

1/9/2000	305	0.27	157	
1/9/2000	324	0.24	138	
1/9/2000	402	0.21	118	1
1/9/2000	423	0.18	99	
1/9/2000	457	0.15	81	
1/9/2000	645	0.12	63	
1/9/2000	758	0.09	45	
1/9/2000	939	0.07	34	
1/9/2000	1228	0.04	18	
1/9/2000	2358	0.01	0	
1/9/2000	2400	0.01	0	
1/9/2000		0.068	34	
			1701	10
1/22/2000	1345	0.08	40	
1/22/2000	1346	0.15	81	17
1/22/2000	1422	0.18	99	
1/22/2000	1429	0.21	118	2
1/22/2000	1534	0.25	144	2
1/22/2000	1537	0.28	164	
1/22/2000	1539	0.3	177	
1/22/2000	1601	0.28	164	
1/22/2000	1647	0.25	144	
1/22/2000	1713	0.23	131	
1/22/2000	1752	0.2	112	
1/22/2000	1821	0.17	93	
1/22/2000	1920	0.14	75	
1/22/2000	2038	0.11	57	
1/22/2000	2257	0.08	40	3
1/22/2000	2400	0.09	45	
1/22/2000		0.095	50	
			1734	24

Table E: Examples of Tabulated Precipitation Table – Gauging Site 9

Date of Sample	Time of Sediment Sample	Inches of Precip	Increase in Amounts	Accumulation of Precip (in)	Accumulation of Time (min)
1/3/2000	1211	0.25			
1/3/2000	1213	0.25			

1/3/2000	1216	0.27	0.02		
1/3/2000	1221	0.28	0.01		
1/3/2000	1236	0.28	0		
1/3/2000	1249	0.3	0.02		
1/3/2000	1252	0.31	0.01		
1/3/2000	1254	0.31	0		
1/3/2000	1255	0.33	0.02		
1/3/2000	1256	0.34	0.01		
1/3/2000	1257	0.36	0.02		
1/3/2000	1258	0.37	0.01		
1/3/2000	1259	0.38	0.01		
				0.13	13
1/3/2000	1300	0.4	0.02		
1/3/2000	1301	0.43	0.03		
1/3/2000	1302	0.43	0		
				0.05	3
1/3/2000	1303	0.44	0.01		
1/3/2000	1313	0.46	0.02		
				0.03	2
1/3/2000	1320	0.47	0.01		
1/3/2000	1325	0.49	0.02		
1/3/2000	1335	0.5	0.01		
1/3/2000	1336	0.5	0		
1/3/2000	1337	0.52	0.02		
1/3/2000	1340	0.54	0.02		
1/3/2000	1341	0.55	0.01		
1/3/2000	1343	0.56	0.01		
1/3/2000	1402	0.56	0		
1/3/2000	1407	0.57	0.01		
1/3/2000	1703	0.58	0.01		
				0.12	11
1/3/2000	1714	0.6	0.02		
1/3/2000	1722	0.61	0.01		
1/3/2000	1723	0.62	0.01		
1/3/2000	1724	0.63	0.01		
1/3/2000	1725	0.64	0.01		
1/3/2000	1730	0.66	0.02		
				0.08	6
				0.41	35
1/8/2000	543	0.01			
1/8/2000	551	0.02	0.01		
1/8/2000	612	0.05	0.03		

1/8/2000	631	0.09	0.04		
1/8/2000	753	0.1	0.01		
1/8/2000	1024	0.18	0.08		
1/8/2000	1050	0.2	0.02		
1/8/2000	1108	0.2	0		
1/8/2000	1141	0.23	0.03		
1/8/2000	1703	0.25	0.02		
1/8/2000	1924	0.27	0.02		
1/8/2000	2008	0.3	0.03		
1/8/2000	2058	0.31	0.01		
1/8/2000	2138	0.34	0.03		
				0.33	14
1/8/2000	2144	0.4	0.06		
1/8/2000	2152	0.41	0.01		
				0.07	2
1/8/2000	2212	0.43	0.02		
1/8/2000	2213	0.46	0.03		
1/8/2000	2214	0.46	0		
				0.05	3
1/8/2000	2215	0.49	0.03		
1/8/2000	2220	0.5	0.01		
				0.04	2
1/8/2000	2310	0.51	0.01		

Table F: Examples of Tabulated Precipitation Table – Gauging Site 11

Date of Sample	Time of Sediment Sample	Inches of Precip	Increase in Amounts	Accumulation of Precip (in)	Accumulation of Time (min)
1/8/2000	2243	0.28			
1/8/2000	2250	0.3	0.02		
1/9/2000	52	0.28			
1/9/2000	100	0.33	0.05		
1/9/2000	115	0.34	0.01		
1/9/2000	120	0.37	0.03		
				0.09	3
1/9/2000	141	0.4	0.03		
1/9/2000	154	0.46	0.06		
1/9/2000	213	0.46	0		
				0.09	3
1/9/2000	230	0.46	0	0	0

1/9/2000	236	0.49	0.03	0.03	1
1/9/2000	358	0.49	0	0	0
				0.21	7
1/22/2000	800	0	0		
1/22/2000	840	0.01	0.01		
1/22/2000	907	0.03	0.02		
1/22/2000	919	0.03	0		
1/22/2000	944	0.05	0.02		
1/22/2000	1001	0.05	0		
1/22/2000	1019	0.07	0.02		
1/22/2000	1033	0.12	0.05		
1/22/2000	1105	0.2	0.08		
1/22/2000	1153	0.23	0.03		
1/22/2000	1211	0.23	0		
1/22/2000	1215	0.25	0.02		
1/22/2000	1226	0.28	0.03		
1/22/2000	1257	0.31	0.03		
1/22/2000	1316	0.34	0.03		
1/22/2000	1323	0.34	0		
1/22/2000	1335	0.36	0.02		
1/22/2000	1349	0.37	0.01		
				0.37	17
1/22/2000	1404	0.37	0		
1/22/2000	1436	0.4	0.03		
				0.03	2
1/22/2000	1449	0.41	0.01		
1/22/2000	1509	0.47	0.06		
				0.07	2
1/22/2000	2149	0.49	0.49		
1/22/2000	2152	0.5	0.01		
1/22/2000	2203	0.55	0.05		
				0.55	3
				1.02	24
1/28/2000	2045	0	0		
1/28/2000	2359	0.05	0.05		
1/28/2000	2400	0.05	0		
				0.05	3
				0.05	3

1/29/2000	1	0.05	0		
1/29/2000	54	0.07	0.02		
1/29/2000	256	0.07	0		
1/29/2000	341	0.07	0		
1/29/2000	402	0.1	0.03		
1/29/2000	428	0.12	0.02		
1/29/2000	503	0.15	0.03		
1/29/2000	756	0.09			
1/29/2000	829	0.15	0.06		
1/29/2000	851	0.15	0		
1/29/2000	912	0.17	0.02		
				0.18	11
1/29/2000	931	0.18	0.01		
1/29/2000	955	0.2	0.02		
1/29/2000	1018	0.25	0.05		
1/29/2000	1037	0.27	0.02		
1/29/2000	1125	0.31	0.04		
				0.14	5
1/29/2000	1146	0.36	0.05		
1/29/2000	1218	0.43	0.07		
				0.12	2
1/29/2000	1248	0.49	0.06	0.06	1

Table G: Examples of 1982 / 1983 Validation Sediment Samples –
Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	2	24	83	312	2500	2500	100.00%
9	2	24	83	336	1390	1390	100.00%
9	2	24	83	420	406	406	100.00%
9	2	24	83	506	202	202	100.00%
9	3	4	83	2036	1550	1550	100.00%
9	3	4	83	2058	732	732	100.00%
9	3	4	83	2206	552	552	100.00%
9	3	4	83	2230	3970	3970	100.00%
9	3	4	83	2253	1290	1290	100.00%
9	3	4	83	2316	1020	1020	100.00%
9	3	4	83	2338	1080	1080	100.00%
9	3	5	83	22	573	573	100.00%
9	3	5	83	456	1780	1780	100.00%

9	3	5	83	519	1620	1620	100.00%
9	3	5	83	650	3660	3660	100.00%
9	3	5	83	735	2180	2180	100.00%
9	3	5	83	758	1770	1770	100.00%
9	3	5	83	820	1500	1500	100.00%
9	3	5	83	842	1620	1620	100.00%
9	4	5	83	122	4600	4600	100.00%
9	4	5	83	208	5130	5130	100.00%
9	4	5	83	253	5870	5870	100.00%
9	4	5	83	316	2540	2540	100.00%
9	4	5	83	339	1470	1470	100.00%
9	4	5	83	423	1380	1380	100.00%
9	4	5	83	508	411	411	100.00%
9	4	5	83	554	589	589	100.00%
9	4	5	83	810	3570	3570	100.00%
9	4	5	83	832	1020	1020	100.00%
9	4	5	83	916	663	663	100.00%
9	4	5	83	1002	299	299	100.00%
11	2	1	83	110	606	606	100.00%
11	2	1	83	132	421	421	100.00%
11	2	1	83	154	489	489	100.00%
11	2	1	83	219	587	587	100.00%
11	2	1	83	240	499	499	100.00%
11	2	1	83	302	1640	1640	100.00%
11	2	1	83	324	224	224	100.00%
11	2	1	83	408	128	128	100.00%
11	2	1	83	452	101	101	100.00%
11	2	10	83	256	224	224	100.00%
11	2	10	83	318	201	201	100.00%
11	2	10	83	340	188	188	100.00%
11	2	10	83	402	181	181	100.00%
11	2	10	83	448	125	125	100.00%
11	2	10	83	532	107	107	100.00%
11	2	10	83	616	120	120	100.00%
11	2	10	83	700	103	103	100.00%
11	2	10	83	746	79	79	100.00%
11	2	10	83	830	79	79	100.00%
11	2	10	83	915	106	106	100.00%
11	2	10	83	938	68	68	100.00%
11	2	10	83	1000	88	88	100.00%
11	2	10	83	1022	61	61	100.00%
11	2	24	83	346	384	384	100.00%
11	2	24	83	408	190	190	100.00%

11	2	24	83	430	121	121	100.00%
11	3	4	83	2246	346	346	100.00%
11	3	4	83	2308	327	327	100.00%
11	3	4	83	2330	275	275	100.00%
11	3	4	83	2352	279	279	100.00%
11	3	5	83	15	238	238	100.00%
11	3	5	83	122	410	410	100.00%
11	3	5	83	524	155	155	100.00%
11	3	5	83	550	112	112	100.00%
11	3	5	83	656	1720	1720	100.00%
11	3	5	83	719	762	762	100.00%

Table H: Examples of 1983 / 1984 Validation Sediment Samples – Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	2	12	84	916	23000	23000	100.00%
9	2	12	84	938	14200	14200	100.00%
9	2	12	84	1001	8390	8390	100.00%
9	2	12	84	1006	6140	6140	100.00%
9	2	12	84	1024	6400	6400	100.00%
9	2	12	84	1109	4510	4510	100.00%
9	2	12	84	1112	3340	3340	100.00%
9	2	12	84	1155	2800	2800	100.00%
9	2	12	84	1217	2300	2300	100.00%
9	2	12	84	1240	2370	2370	100.00%
9	2	12	84	1325	3480	3480	100.00%
9	2	12	84	1348	6790	6790	100.00%
9	2	12	84	1411	9820	9820	100.00%
9	2	12	84	1433	9550	9550	100.00%
9	2	12	84	1457	6720	6720	100.00%
9	2	12	84	1519	5030	5030	100.00%
9	2	12	84	1604	2610	2610	100.00%
9	2	12	84	1627	2140	2140	100.00%
9	2	26	84	2011	7230	7230	100.00%
9	2	26	84	2033	3450	3450	100.00%
9	2	26	84	2205	1230	1230	100.00%
9	2	26	84	2228	1040	1040	100.00%
9	2	26	84	2251	910	910	100.00%
9	3	4	84	2254	1680	1680	100.00%

9	3	4	84	2314	1310	1310	100.00%
9	3	4	84	2337	972	972	100.00%
9	3	4	84	2359	1460	1460	100.00%
9	3	5	84	108	6200	6200	100.00%
9	3	5	84	130	3430	3430	100.00%
9	3	5	84	153	2060	2060	100.00%
9	3	5	84	239	1490	1490	100.00%
9	3	5	84	324	1170	1170	100.00%
9	3	5	84	347	1430	1430	100.00%
9	3	5	84	410	2670	2670	100.00%
9	3	5	84	432	2810	2810	100.00%
11	2	12	84	1417	2840	2840	100.00%
11	2	12	84	1439	4360	4360	100.00%
11	2	12	84	1524	2080	2080	100.00%
11	2	12	84	1546	1640	1640	100.00%
11	2	12	84	1609	1430	1430	100.00%
11	2	12	84	1631	1220	1220	100.00%
11	2	12	84	1653	1090	1090	100.00%
11	3	5	84	104	3720	3720	100.00%
11	3	5	84	126	4340	4340	100.00%
11	3	5	84	149	2410	2410	100.00%
11	3	5	84	210	1520	1520	100.00%
11	3	5	84	233	1210	1210	100.00%
11	3	5	84	255	1010	1010	100.00%
11	3	5	84	317	735	735	100.00%
11	3	5	84	338	640	640	100.00%
11	3	5	84	400	1200	1200	100.00%
11	3	5	84	422	1350	1350	100.00%
11	3	5	84	444	1440	1440	100.00%
11	3	5	84	506	1070	1070	100.00%
11	3	5	84	528	960	960	100.00%
11	3	5	84	550	716	716	100.00%
11	3	5	84	612	609	609	100.00%
11	3	5	84	634	640	640	100.00%
11	3	5	84	656	506	506	100.00%
11	3	27	84	2139	5130	5130	100.00%
11	3	27	84	2310	737	737	100.00%
11	4	2	84	1652	633	633	100.00%
11	4	2	84	1714	461	461	100.00%
11	4	21	84	2249	541	541	100.00%
11	4	21	84	2334	508	508	100.00%
11	5	2	84	532	837	837	100.00%
11	5	2	84	617	1130	1130	100.00%

11	5	2	84	702	1020	1020	100.00%
11	5	2	84	724	752	752	100.00%
11	5	2	84	832	449	449	100.00%
11	5	2	84	916	514	514	100.00%
11	5	2	84	939	507	507	100.00%
11	5	2	84	1001	565	565	100.00%
11	5	2	84	1024	447	447	100.00%
11	5	2	84	1046	326	326	100.00%
11	5	2	84	1109	262	262	100.00%
11	5	3	84	11	1640	1640	100.00%

Table I: Examples of 1984 / 1985 Validation Sediment Samples – Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	1	16	85	1417	2980	2980	100.00%
9	1	16	85	1423	3320	3320	100.00%
9	1	16	85	1429	3600	3600	100.00%
9	1	16	85	1435	3750	3750	100.00%
9	1	16	85	1441	3180	3180	100.00%
9	1	16	85	1446	3040	3040	100.00%
9	1	16	85	1458	2710	2710	100.00%
9	2	11	85	117	12700	12700	100.00%
9	2	11	85	128	12600	12600	100.00%
9	2	11	85	139	12300	12300	100.00%
9	2	11	85	151	7180	7180	100.00%
9	2	11	85	202	6540	6540	100.00%
9	2	11	85	213	4580	4580	100.00%
9	2	11	85	236	3590	3590	100.00%
9	2	11	85	247	2700	2700	100.00%
9	2	11	85	259	2610	2610	100.00%
9	2	11	85	310	2420	2420	100.00%
9	2	11	85	321	2000	2000	100.00%
9	2	11	85	344	2120	2120	100.00%
9	2	11	85	407	1950	1950	100.00%
9	2	11	85	418	1580	1580	100.00%
9	2	11	85	429	1580	1580	100.00%
9	2	11	85	452	1840	1840	100.00%
9	2	11	85	503	2050	2050	100.00%
9	2	11	85	514	1830	1830	100.00%

9	2	11	85	548	1230	1230	100.00%
9	2	11	85	600	1140	1140	100.00%
9	2	11	85	622	979	979	100.00%
9	2	23	85	1819	11400	11400	100.00%
9	2	23	85	1842	7320	7320	100.00%
9	2	23	85	1853	5740	5740	100.00%
9	2	23	85	1904	5010	5010	100.00%
9	2	23	85	1916	4780	4780	100.00%
9	2	23	85	1927	4340	4340	100.00%
9	2	23	85	1938	4670	4670	100.00%
9	2	23	85	1949	3300	3300	100.00%
9	2	23	85	2001	3120	3120	100.00%
11	1	30	85	1636	4860	4860	100.00%
11	1	30	85	1658	2360	2360	100.00%
11	1	30	85	1721	1600	1600	100.00%
11	1	30	85	1743	1220	1220	100.00%
11	1	30	85	1805	606	606	100.00%
11	2	11	85	201	3450	3450	100.00%
11	2	11	85	223	2500	2500	100.00%
11	2	11	85	245	2440	2440	100.00%
11	2	11	85	307	2710	2710	100.00%
11	2	11	85	329	1730	1730	100.00%
11	2	11	85	351	1420	1420	100.00%
11	2	11	85	414	1420	1420	100.00%
11	2	11	85	436	1960	1960	100.00%
11	2	11	85	458	1180	1180	100.00%
11	2	11	85	520	1110	1110	100.00%
11	2	11	85	604	434	434	100.00%
11	2	23	85	1906	3740	3740	100.00%
11	2	23	85	1917	3440	3440	100.00%
11	2	23	85	1928	3650	3650	100.00%
11	2	23	85	1939	3030	3030	100.00%
11	2	23	85	1950	2560	2560	100.00%
11	2	23	85	2001	2140	2140	100.00%
11	2	23	85	2023	1780	1780	100.00%
11	2	23	85	2034	1540	1540	100.00%
11	2	23	85	2046	1540	1540	100.00%
11	2	23	85	2057	1560	1560	100.00%
11	2	23	85	2203	1790	1790	100.00%
11	2	23	85	2214	1550	1550	100.00%
11	2	24	85	16	733	733	100.00%
11	2	24	85	50	615	615	100.00%
11	3	30	85	2229	3340	3340	100.00%

11	3	30	85	2240	2750	2750	100.00%
11	3	30	85	2251	2270	2270	100.00%
11	3	30	85	2303	1630	1630	100.00%
11	3	30	85	2314	1160	1160	100.00%
11	3	30	85	2325	996	996	100.00%
11	3	30	85	2336	820	820	100.00%
11	3	30	85	2347	583	583	100.00%
11	4	23	85	3	1520	1520	100.00%
11	4	23	85	14	2100	2100	100.00%
11	4	23	85	37	1540	1540	100.00%
11	4	23	85	48	1100	1100	100.00%

Table J: Examples of 1985 / 1986 Validation Sediment Samples –
Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	3	12	86	1412	3090	3090	100.00%
9	3	18	86	1633	8730	8730	100.00%
9	3	18	86	1650	9740	8730	89.63%
9	6	5	86	1549	3500	3500	100.00%
9	6	9	86	1423	2980	2980	100.00%
9	6	9	86	1434	2490	2490	100.00%
9	6	9	86	1443	1630	1630	100.00%
9	6	9	86	1454	1190	1190	100.00%
9	6	9	86	1506	860	860	100.00%
9	6	9	86	1516	706	706	100.00%
9	6	11	86	1009	3000	3000	100.00%
9	6	11	86	1026	6900	6900	100.00%
9	6	11	86	1038	2250	2250	100.00%
9	6	11	86	1049	1870	1870	100.00%
9	6	11	86	1106	1150	1150	100.00%
9	6	11	86	1123	724	724	100.00%
9	6	11	86	1140	484	484	100.00%
9	6	28	86	403	6890	6890	100.00%
9	6	28	86	409	7530	7530	100.00%
9	6	28	86	437	5910	5910	100.00%
9	6	28	86	448	2980	2980	100.00%
9	6	28	86	500	2250	2250	100.00%
9	6	28	86	511	1620	1620	100.00%
9	6	28	86	522	1120	1120	100.00%
9	6	28	86	534	794	794	100.00%

9	7	2	86	435	5400	5400	100.00%
9	7	2	86	440	6700	6700	100.00%
9	7	2	86	446	9970	9970	100.00%
9	7	2	86	452	7000	7000	100.00%
9	7	2	86	457	5000	5000	100.00%
9	7	2	86	503	3240	3240	100.00%
9	7	2	86	508	2330	2330	100.00%
9	7	2	86	514	1890	1890	100.00%
9	7	2	86	520	1490	1490	100.00%
9	7	2	86	525	1260	1260	100.00%
9	7	2	86	531	1140	1140	100.00%
9	7	2	86	537	955	955	100.00%
11	6	5	86	1336	2480	2480	100.00%
11	6	5	86	1347	1640	1640	100.00%
11	6	5	86	1359	1170	1170	100.00%
11	6	5	86	1410	3030	3030	100.00%
11	6	5	86	1421	2120	2120	100.00%
11	6	5	86	1433	1310	1310	100.00%
11	6	5	86	1444	977	977	100.00%
11	6	5	86	1519	881	881	100.00%
11	6	5	86	1530	626	626	100.00%
11	6	6	86	838	1140	1140	100.00%
11	6	6	86	849	808	808	100.00%
11	6	6	86	935	1000	1000	100.00%
11	6	6	86	946	801	801	100.00%
11	6	6	86	1118	483	483	100.00%
11	6	6	86	1207	299	299	100.00%
11	6	9	86	1530	500	500	100.00%
11	6	9	86	1553	340	340	100.00%
11	6	11	86	1041	1070	1070	100.00%
11	6	11	86	1053	866	866	100.00%
11	6	11	86	1116	809	809	100.00%
11	6	11	86	1127	447	447	100.00%
11	6	11	86	1139	345	345	100.00%
11	6	28	86	532	841	841	100.00%
11	6	28	86	555	887	887	100.00%
11	6	28	86	618	500	500	100.00%
11	8	27	86	1909	6760	6760	100.00%
11	8	27	86	1916	3570	3570	100.00%
11	8	27	86	1927	2330	2330	100.00%
11	8	27	86	2001	2010	2010	100.00%
11	8	27	86	2012	1580	1580	100.00%
11	9	5	86	1548	3130	3130	100.00%

11	9	5	86	1559	1680	1680	100.00%
11	9	5	86	1610	1310	1310	100.00%
11	9	5	86	1622	1100	1100	100.00%
11	9	5	86	1633	915	915	100.00%
11	11	17	85	905	761	761	100.00%
11	11	17	85	917	948	948	100.00%
11	11	17	85	928	926	926	100.00%
11	11	17	85	951	867	867	100.00%
11	11	17	85	1002	720	720	100.00%
11	11	17	85	1037	433	433	100.00%

Table K: Examples of 1986 / 1987 Validation Sediment Samples –
Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	1	12	87	1318	47	47	100.00%
9	1	18	87	905	962	962	100.00%
9	1	18	87	920	521	521	100.00%
9	1	18	87	925	444	444	100.00%
9	1	18	87	939	326	326	100.00%
9	1	18	87	1002	216	216	100.00%
9	1	18	87	1007	196	196	100.00%
9	1	18	87	1013	182	182	100.00%
9	1	18	87	1018	178	178	100.00%
9	1	20	87	1325	30	30	100.00%
9	1	27	87	1330	46	46	100.00%
9	2	2	87	1254	47	47	100.00%
9	2	9	87	1104	35	35	100.00%
9	2	15	87	1540	1950	1950	100.00%
9	2	15	87	1551	1860	1860	100.00%
9	2	15	87	1637	579	579	100.00%
9	2	15	87	1710	313	313	100.00%
9	2	15	87	1744	214	214	100.00%
9	2	22	87	907	918	918	100.00%
9	2	22	87	918	651	651	100.00%
9	2	22	87	929	460	460	100.00%
9	2	22	87	1002	233	233	100.00%
9	2	22	87	1037	156	156	100.00%
9	2	22	87	1111	145	145	100.00%

9	2	22	87	1122	142	142	100.00%
9	2	26	87	1245	463	463	100.00%
9	2	26	87	1256	479	479	100.00%
9	2	26	87	1308	623	623	100.00%
9	2	26	87	1319	868	868	100.00%
9	2	26	87	1630	284	284	100.00%
9	2	26	87	1704	238	238	100.00%
9	2	26	87	1749	195	195	100.00%
9	2	27	87	2105	3330	3330	100.00%
9	2	27	87	2201	660	660	100.00%
9	2	27	87	2235	588	588	100.00%
9	2	27	87	2246	1150	1150	100.00%
9	2	27	87	2257	1440	1440	100.00%
11	1	5	87	1037	48	48	100.00%
11	2	2	87	1302	42	42	100.00%
11	2	9	87	1119	25	25	100.00%
11	2	17	87	1312	30	30	100.00%
11	2	26	87	1254	1100	1100	100.00%
11	2	26	87	1305	1590	1590	100.00%
11	2	26	87	1642	256	256	100.00%
11	2	26	87	1825	183	183	100.00%
11	2	26	87	1858	218	218	100.00%
11	2	26	87	1922	235	235	100.00%
11	2	26	87	2030	317	317	100.00%
11	2	26	87	2105	449	449	100.00%
11	2	26	87	2140	306	306	100.00%
11	2	26	87	2214	171	171	100.00%
11	2	26	87	2323	181	181	100.00%
11	2	26	87	2350	260	260	100.00%
11	2	27	87	2114	1510	1510	100.00%
11	2	28	87	40	206	206	100.00%
11	2	28	87	114	146	146	100.00%
11	2	28	87	149	102	102	100.00%
11	3	2	87	1403	25	25	100.00%
11	3	9	87	948	19	19	100.00%
11	3	17	87	1854	1330	1330	100.00%
11	3	17	87	1917	1340	1340	100.00%
11	3	17	87	1928	1360	1360	100.00%
11	3	17	87	1940	935	935	100.00%
11	3	17	87	2037	566	566	100.00%
11	3	17	87	2145	1120	1120	100.00%
11	3	18	87	155	126	126	100.00%
11	3	18	87	1135	41	41	100.00%

11	3	19	87	1047	24	24	100.00%
11	3	31	87	948	53	53	100.00%
11	4	13	87	1913	1920	1920	100.00%
11	4	13	87	1924	2470	2470	100.00%
11	4	14	87	853	45	45	100.00%
11	11	7	86	1420	1560	1560	100.00%
11	11	7	86	1431	1230	1230	100.00%
11	11	7	86	1454	1080	1080	100.00%
11	11	7	86	1506	598	598	100.00%
11	11	8	86	420	5390	5390	100.00%
11	11	8	86	531	1690	1690	100.00%
11	11	8	86	542	1450	1450	100.00%

Table L: Examples of 1987 / 1988 Validation Sediment Samples –
Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	1	19	88	448	515	515	100.00%
9	1	19	88	413	800	800	100.00%
9	1	19	88	230	1270	1270	100.00%
9	1	19	88	145	1330	1330	100.00%
9	1	19	88	338	1340	1340	100.00%
9	1	19	88	110	1370	1370	100.00%
9	1	19	88	242	1500	1500	100.00%
9	1	19	88	253	1520	1520	100.00%
9	1	19	88	220	1550	1550	100.00%
9	1	19	88	208	1930	1930	100.00%
9	1	19	88	156	1940	1940	100.00%
9	1	19	88	36	2290	2290	100.00%
9	1	19	88	12	4090	4090	100.00%
9	1	19	88	1	4890	4890	100.00%
9	2	14	88	2247	600	600	100.00%
9	2	14	88	2224	868	868	100.00%
9	2	14	88	2201	1030	1030	100.00%
9	2	14	88	2115	1660	1660	100.00%
9	2	14	88	2041	2840	2840	100.00%
9	2	14	88	2029	3540	3540	100.00%
9	2	14	88	2018	5200	5200	100.00%
9	2	19	88	313	289	289	100.00%
9	2	19	88	250	355	355	100.00%

9	2	19	88	215	461	461	100.00%
9	2	19	88	141	749	749	100.00%
9	2	19	88	107	1230	1230	100.00%
9	2	19	88	55	1660	1660	100.00%
9	2	19	88	44	2150	2150	100.00%
9	3	3	88	401	535	535	100.00%
9	3	3	88	315	1040	1040	100.00%
9	3	3	88	241	1470	1470	100.00%
9	3	3	88	229	1990	1990	100.00%
9	3	3	88	206	6140	6140	100.00%
9	3	3	88	218	10800	10800	100.00%
9	3	8	88	2008	221	221	100.00%
9	3	8	88	1945	287	287	100.00%
9	3	8	88	1900	404	404	100.00%
11	2	14	88	2241	462	462	100.00%
11	2	14	88	2144	639	639	100.00%
11	2	14	88	1958	4320	4320	100.00%
11	2	14	88	2009	3420	3420	100.00%
11	3	3	88	202	45	45	100.00%
11	3	3	88	204	53	53	100.00%
11	3	3	88	238	52	52	100.00%
11	3	3	88	224	63	63	100.00%
11	3	3	88	227	61	61	100.00%
11	3	3	88	213	64	64	100.00%
11	3	3	88	218	76	76	100.00%
11	4	2	88	627	279		
11	4	2	88	601	312	312	100.00%
11	4	2	88	515	533	533	100.00%
11	4	2	88	259	2670	2670	100.00%
11	4	2	88	321	2730	2730	100.00%
11	11	16	87	1723	942	942	100.00%
11	11	16	87	1700	1330	1330	100.00%
11	11	16	87	1638	2420	2420	100.00%
11	11	16	87	1604	5540	5540	100.00%

Table M: Examples of 1988 / 1989 Validation Sediment Samples –
Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment	Direct Field Sediment Sample (ppm)	Percent of Error

					Sample (ppm)		
9	1	12	89	554	522	522	100.00%
9	1	12	89	542	837	837	100.00%
9	1	12	89	457	972	972	100.00%
9	1	12	89	422	1140	1140	100.00%
9	1	12	89	445	1300	1300	100.00%
9	11	26	88	553	963	963	100.00%
9	11	26	88	541	1080	1080	100.00%
9	11	26	88	529	1300	1300	100.00%
9	11	26	88	518	1420	1420	100.00%
11	1	7	89	2133	222	222	100.00%
11	1	7	89	2048	461	461	100.00%
11	2	14	89	1448	213	213	100.00%
11	2	14	89	1100	348	348	100.00%
11	2	14	89	906	440	440	100.00%
11	2	18	89	1059	1040	1040	100.00%
11	2	18	89	1122	844	844	100.00%
11	2	20	89	2352	187	187	100.00%
11	2	20	89	1941	754	754	100.00%
11	2	20	89	1507	2190	2190	100.00%
11	2	20	89	1832	1170	1170	100.00%
11	2	27	89	1314	179	179	100.00%
11	2	27	89	1120	257	257	100.00%
11	2	27	89	755	1100	1100	100.00%
11	2	27	89	430	1470	1470	100.00%
11	2	27	89	406	2610	2610	100.00%
11	3	4	89	2339	308	308	100.00%
11	3	5	89	237	262	262	100.00%
11	3	5	89	129	513	513	100.00%
11	3	5	89	152	426	426	100.00%
11	3	5	89	24	751	751	100.00%
11	3	30	89	2300	105	105	100.00%
11	3	30	89	2236	152	152	100.00%
11	3	30	89	2213	310	310	100.00%
11	4	4	89	257	320	320	100.00%
11	4	4	89	150	1900	1900	100.00%
11	5	5	89	738	600	600	100.00%

Table N: Examples of 1989 / 1990 Validation Sediment Samples – Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
11	1	4	90	31	1680	1680	100.00%
11	1	4	90	117	647	647	100.00%
11	1	4	90	140	539	539	100.00%
11	1	4	90	226	372	372	100.00%
11	1	4	90	311	268	268	100.00%
11	1	4	90	357	161	161	100.00%
11	1	20	90	240	1060	1060	100.00%
11	1	20	90	302	948	948	100.00%
11	1	20	90	325	869	869	100.00%
11	1	20	90	347	795	795	100.00%
11	1	20	90	432	504	504	100.00%
11	1	20	90	518	994	994	100.00%
11	1	20	90	605	232	232	100.00%
11	2	2	90	400	438	438	100.00%
11	2	2	90	442	292	292	100.00%
11	2	2	90	528	194	194	100.00%
11	2	3	90	252	410	410	100.00%
11	2	3	90	423	227	227	100.00%
11	2	3	90	1008	437	437	100.00%
11	2	9	90	2004	575	575	100.00%
11	2	9	90	2027	270	270	100.00%
11	2	9	90	2050	339	339	100.00%
11	2	9	90	2113	340	340	100.00%
11	2	9	90	2136	336	336	100.00%
11	2	9	90	2159	396	396	100.00%
11	2	10	90	139	206	206	100.00%
11	2	10	90	322	111	111	100.00%
11	2	22	90	225	313	313	100.00%
11	2	22	90	248	144	144	100.00%
11	2	22	90	311	110	110	100.00%
11	2	22	90	334	75	75	100.00%

Table O: Examples of 1990 / 1991 Validation Sediment Samples – Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	9	5	91	1704	2199	2199	100.00%
9	9	5	91	1716	1932	1932	100.00%
9	9	5	91	1727	853	853	100.00%
9	9	5	91	1739	536	536	100.00%
9	9	24	91	535	4296	4296	100.00%
9	9	24	91	610	1592	1592	100.00%
9	9	24	91	621	1190	1190	100.00%
9	9	24	91	633	717	717	100.00%
9	9	24	91	643	690	690	100.00%
11	12	3	90	154	3499	3499	100.00%
11	12	3	90	218	2282	2282	100.00%
11	12	3	90	241	1273	1273	100.00%
11	12	3	90	414	726	726	100.00%
11	12	3	90	437	532	532	100.00%
11	12	17	90	546	2719	2719	100.00%
11	12	17	90	606	1296	1296	100.00%
11	12	17	90	637	841	841	100.00%
11	12	17	90	655	617	617	100.00%
11	12	17	90	718	436	436	100.00%
11	12	17	90	741	306	306	100.00%
11	12	20	90	2329	592	592	100.00%
11	12	20	90	2352	457	457	100.00%
11	12	21	90	15	328	328	100.00%
11	12	21	90	101	133	133	100.00%
11	12	21	90	1704	721	721	100.00%
11	12	21	90	2030	237	237	100.00%
11	12	21	90	2209	151	208	137.75%

Table P: Examples of 1991 / 1992 Validation Sediment Samples –
Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	1	8	92	1117	808	808	100.00%
9	1	8	92	1128	613	613	100.00%
9	1	8	92	1227	103	103	100.00%
9	1	8	92	1242	83	89	107.23%
9	1	8	92	1302	130	130	100.00%
9	2	14	92	1654	1195	1195	100.00%
9	2	14	92	1706	1397	1397	100.00%
9	2	14	92	1718	922	922	100.00%
9	2	14	92	1804	170	170	100.00%
9	2	14	92	1838	122	122	100.00%
9	2	14	92	1947	197	197	100.00%
9	2	25	92	2037	461	461	100.00%
9	2	25	92	2048	427	427	100.00%
9	2	25	92	2123	178	178	100.00%
9	2	25	92	2134	142	142	100.00%
9	2	25	92	2157	75	75	100.00%
9	2	25	92	2220	73	73	100.00%
9	2	25	92	2232	56	56	100.00%
9	6	6	92	2020	3523	3523	100.00%
9	6	6	92	2032	2376	2376	100.00%
9	6	6	92	2043	1338	1338	100.00%
9	6	6	92	2055	914	914	100.00%
9	6	6	92	2106	491	491	100.00%
9	6	6	92	2118	348	348	100.00%
9	6	6	92	2129	219	219	100.00%
9	6	6	92	2141	125	125	100.00%
9	7	29	92	1754	2409	2409	100.00%
9	7	29	92	1806	1335	1335	100.00%
9	7	29	92	1817	725	725	100.00%
9	7	29	92	1829	420	420	100.00%
9	7	29	92	1841	270	270	100.00%
9	11	20	91	23	1778	1778	100.00%
9	11	20	91	121	749	749	100.00%
9	11	20	91	230	1039	1039	100.00%
9	11	20	91	241	1015	1015	100.00%
9	11	20	91	253	1280	1280	100.00%
9	11	20	91	305	853	853	100.00%
11	1	13	92	1506	343	343	100.00%

11	1	13	92	1517	272	272	100.00%
11	1	13	92	1529	191	191	100.00%
11	1	13	92	1540	156	156	100.00%
11	1	13	92	1552	126	126	100.00%
11	1	13	92	1603	102	102	100.00%
11	1	13	92	1617	83	83	100.00%
11	1	13	92	1628	63	63	100.00%
11	1	13	92	1649	63	63	100.00%
11	2	14	92	1658	736	736	100.00%
11	2	14	92	1709	671	671	100.00%
11	2	14	92	1721	392	392	100.00%
11	2	14	92	1732	349	349	100.00%
11	2	14	92	1744	244	244	100.00%
11	2	14	92	1841	128	128	100.00%
11	2	14	92	1926	73	73	100.00%
11	2	14	92	2001	89	89	100.00%
11	2	25	92	2039	296	296	100.00%
11	2	25	92	2051	351	351	100.00%
11	2	25	92	2102	203	203	100.00%
11	2	25	92	2114	194	194	100.00%
11	2	25	92	2125	162	162	100.00%
11	2	25	92	2137	133	133	100.00%
11	2	25	92	2148	135	135	100.00%
11	2	25	92	2200	85	85	100.00%
11	2	25	92	2212	88	88	100.00%
11	3	9	92	1329	2287	2287	100.00%
11	3	9	92	1513	300	300	100.00%
11	3	9	92	1610	140	140	100.00%
11	3	9	92	1708	82	82	100.00%
11	3	9	92	1914	210	210	100.00%
11	3	9	92	1926	185	185	100.00%
11	3	9	92	1937	785	785	100.00%
11	3	10	92	8	196	196	100.00%
11	3	10	92	157	150	150	100.00%
11	6	3	92	741	178	178	100.00%
11	6	3	92	827	219	219	100.00%
11	6	3	92	913	136	136	100.00%
11	6	6	92	2114	314	314	100.00%
11	6	6	92	2125	223	223	100.00%
11	6	6	92	2137	99	99	100.00%
11	6	10	92	2211	409	409	100.00%

Table Q: Examples of 1992 / 1993 Validation Sediment Samples – Automatic Samples / Field Samples

Gauging Site	Month	Day	Year	Time	Instrument Measured Sediment Sample (ppm)	Direct Field Sediment Sample (ppm)	Percent of Error
9	1	4	93	1809	63	63	100.00%
9	1	4	93	1700	85	85	100.00%
9	1	4	93	1602	168	168	100.00%
9	1	4	93	1551	192	192	100.00%
9	1	4	93	1539	304	304	100.00%
9	1	4	93	1528	423	423	100.00%
9	1	4	93	1516	644	644	100.00%
9	2	15	93	2243	78	78	100.00%
9	2	15	93	2134	84	84	100.00%
9	2	15	93	2037	108	108	100.00%
9	2	15	93	1940	208	208	100.00%
9	2	15	93	1928	223	223	100.00%
9	2	15	93	1917	289	289	100.00%
9	2	15	93	1854	294	294	100.00%
9	2	15	93	1905	321	321	100.00%
9	3	31	93	403	63	63	100.00%
9	3	31	93	340	75	75	100.00%
9	3	31	93	351	77	77	100.00%
9	3	31	93	329	107	107	100.00%
9	3	31	93	317	145	145	100.00%
9	3	31	93	306	266	266	100.00%
9	3	31	93	254	455	455	100.00%
9	3	31	93	242	790	790	100.00%
9	12	19	92	2046	212	212	100.00%
9	12	19	92	2035	230	230	100.00%
9	12	19	92	2241	232	232	100.00%
9	12	19	92	2023	321	321	100.00%
9	12	19	92	2109	387	387	100.00%
9	12	19	92	2012	475	475	100.00%
9	12	19	92	2000	620	620	100.00%
9	12	19	92	2144	278	700	251.80%
9	12	23	92	802	88	88	100.00%
9	12	23	92	900	89	89	100.00%
9	12	23	92	750	103	103	100.00%
9	12	23	92	1052	121	121	100.00%
9	12	23	92	652	134	134	100.00%
9	12	23	92	638	150	150	100.00%
9	12	23	92	626	180	180	100.00%
9	12	23	92	614	197	197	100.00%

9	12	23	92	1118	205	205	100.00%
11	12	23	92	1054	82	82	100.00%
11	12	23	92	1020	79	79	100.00%
11	12	23	92	728	86	86	100.00%
11	12	23	92	716	101	101	100.00%
11	12	23	92	826	106	106	100.00%
11	12	23	92	922	113	113	100.00%
11	12	23	92	652	128	128	100.00%
11	12	23	92	618	156	156	100.00%
11	12	23	92	606	193	193	100.00%
11	12	23	92	640	143	143	100.00%
11	12	23	92	704	126	126	100.00%
11	12	23	92	556	255	255	100.00%

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Figure 1: Goodwin Creek Experimental Watershed, Panola County, Mississippi
Fox et al, 2007, p. 1560

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Title: Measuring streambank erosion due to ground water seepage: correlation to bank pore water pressure, precipitation and stream stage

Author: Garey A. Fox,Glenn V. Wilson,Andrew Simon,Eddy J. Langendoen,Onur Akay,John W. Fuchs

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Figure 2: Goodwin Creek Precipitation and Gauging Stations
Blackmarr, 1995, p. 15

Email correspondence with Dr. Romkens 02-10-2011

Dr. Romkens,

I will certainly cite and credit the USDA-ARS-National Sediment Lab for its use. Thank you again for your help.

Sincerely,
Kelly Witherspoon

From: Romkens, Matt [mailto:Matt.Romkens@ARS.USDA.GOV]
Sent: Thursday, February 10, 2011 10:53 AM
To: Witherspoon, T Kelly (SSC-NASA)[Oklahoma State University]
Subject: RE: Permission to copy map from article

Dear Mr. Witherspoon,

Your request to make a copy of the map from the 1995 Goodwin Creek Blackmarr Report for use in your dissertation is granted. The Material is in the public domain as it was prepared from U.S. Government resources. I would appreciate if you would credit the USDA-ARS-NSL for this use.

M.J.M. Römkens, Lab. Director
USDA-ARS National Sedimentation Laboratory

phone: 662-232-2940; email: Matt.Romkens@ARS.USDA.GOV

From: Witherspoon, T Kelly (SSC-NASA)[Oklahoma State University]
Sent: Thursday, February 10, 2011 10:35 AM
To: Romkens, Matt
Subject: Permission to copy map from article

Dr. Romkens,

I am a graduate student at Oklahoma State University and I am writing to you to ask for permission to copy a map from the 1995 Goodwin Creek Blackmarr Report. The report is titled, "Documentation of Hydrologic, Geomorphic, and Sediment Transport Measurements on the Goodwin Creek Experimental Watershed, Northern Mississippi, for the Period 1982 – 1993." The map is the Goodwin Creek Precipitation and Sediment Gauging Stations located on page15. I would like to use this map in my dissertation which involved Goodwin Creek data for the year 2000. Thank you so much for your help.

Sincerely,
Kelly Witherspoon

Figure 3: Land Use Change on Goodwin Creek
Kuhnle et al, 2005, p. 3

Email correspondence with Dr. Kuhnle 02-01-2011

Yes sir,

I have cited you directly when I used your map in my dissertation and when I used it within the text. As well, you are cited in my reference section. Thank you for your help.

Sincerely,
Kelly Witherspoon

From: Kuhnle, Roger [mailto:Roger.Kuhnle@ARS.USDA.GOV]
Sent: Tuesday, February 01, 2011 7:26 AM
To: Witherspoon, T Kelly (SSC-NASA)[Oklahoma State University]
Subject: RE: Permission to copy map from article

Dear Mr. Witherspoon,

I have no problem with you using the map from the ASAE 2005 paper as long as you give complete information about where the map was originally published.

Roger

Roger A. Kuhnle, Ph. D.
Research Hydraulic Engineer
Watershed Physical Processes Research Unit
National Sedimentation Laboratory
USDA- Agricultural Research Service
Oxford, Mississippi 38655

phone: 662-232-2971; email: roger.kuhnle@ars.usda.gov

From: Witherspoon, T Kelly (SSC-NASA)[Oklahoma State University]
[mailto:t.k.witherspoon@nasa.gov]
Sent: Monday, January 31, 2011 4:46 PM
To: Kuhnle, Roger
Subject: Permission to copy map from article

Dr. Kuhnle,

I am a graduate student at Oklahoma State University and I am writing to you to ask for permission to copy a map you helped co-author for a paper prepared for the American Society of Agricultural Engineers Annual Meeting in 2005. The paper is titled, "Goodwin Creek Experimental Watershed – Assessment of Conservation and Environmental Effects." The map is the Landuse Change on Goodwin Creek for 1985, 1992 and 2004 located on page 3. I would like to use this map in my dissertation which involved Goodwin Creek data for the year 2000. Thank you so much for your help.

Sincerely,
Kelly Witherspoon

VITA

T. Kelly Witherspoon

Candidate for the Degree of

Doctor of Philosophy

Thesis: AN ANALYSIS OF THE INTENSITY OF PRECIPITATION, TOTAL SUSPENDED SOLID AND STAGE HEIGHT FOR STREAM GAUGING SITES 9 AND 11 WITHIN THE GOODWIN CREEK EXPERIMENTAL WATERSHED, NORTHERN MISSISSIPPI, FOR THE YEAR 2000

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Master of Science in Education at Stephen F. Austin State University, Nacogdoches, Texas in 1994.

Bachelor of Science in Education at Stephen F. Austin State University, Nacogdoches, Texas in 1990.

Experience:

July 2006 – Present	NASA Distance Learning Coordinator John C. Stennis Space Center, MS
April 2000 – July 2006	Aerospace Education Specialist John C. Stennis Space Center, MS

Certificates and Organizations:
Certified – Texas Teaching Certificate
Certified – Mississippi Teaching Certificate
Certified – GLOBE Master Trainer (June 2006)
GLOBE Trainer Certificate (June 2000 and September 2004)

Professional Affiliations:
ITEA – International Technology Education Association (2001- present)
NSTA – National Science Teachers Association (1999 – present)
NCTM – National Council of Teacher and Mathematics (1999 – present)
MSTA – Mississippi Science Teachers Association (2001 – present)
MECA – Mississippi Educational Computing Association (2005 – present)